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TM 11-684

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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

UNIVERSITY OF VIRGINIA APR 2 7 '93 93 - 0179 ALDERMAN-GOV'T DOCUMENTS

PRINCIPLES AND APPLICATIONS OF MATHEMATICS FOR COMMUNICATIONS-ELECTRONICS

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CHANGE

HEADQUARTERS DEPARTMENT OF THE ARMY WASHINGTON, D. C., 24 July 1967

PRINCIPLES AND APPLICATIONS

OF MATHEMATICS FOR

COMMUNICATIONS-ELECTRONICS

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By Order of the Secretary of the Army:

HAROLD K. JOHNSON, General, United States Army, Chief of Staff.

Official: KENNETH G. WICKHAM, <u>Major General, United States Army,</u> The Adjutant General.

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For explanation of abbreviations used, see AR 320-50.

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TECHNICAL MANUAL)

No. 11-684

PRINCIPLES AND APPLICATIONS OF MATHEMATICS FOR

COMMUNICATIONS-ELECTRONICS

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PART I

MATHEMATICAL PRINCIPLES ESSENTIAL TO COMMUNICATIONS-ELECTRONICS

CHAPTER 1 INTRODUCTION

1. Purpose and Scope

a. Purpose. This manual provides the basic mathematics required by communications-electronics personnel.

b. Scope. This manual covers those principles and applications of arithmetic, algebra, logarithms, geometry, and trigonometry that are required for a practical understanding of electricity and electronics. The manual is divided into two parts:

- (1) Part I is a review of the mathematical principles essential to communications-electronics.
- (2) Part II covers the application of the

mathematical principles to common communications-electronics problems.

2. Mathematics and Electronics

Skill in the use of mathematics, particularly arithmetic, algebra, and trigonometry, is essential in the fields of electricity and electronics. Most of our basic ideas of electrical phenomena are based on mathematical reasoning and are stated in mathematical terms. Therefore, a thorough knowledge of mathematics and of the specific applications of mathematics to the field of electricity will serve as a foundation for the technical knowledge needed by communicationselectronics personnel.

3

CHAPTER 2 PERCENTAGE

3. General

a. Definition. Percentage is the process of computation in which the basis of comparison is a hundred. The term percent—from per, by, and centum, hundred—means by or on the hundred. Thus, 2 percent of a quantity means two parts of every hundred parts of the quantity.

b. Symbol. The symbol of percentage is %. Percent may also be indicated by a fraction or a decimal. Thus, $5\% = \frac{5}{100} = .05$. Figure 1 shows the relationship between fractions, decimals, and percentage.

c. Base, Rate, and Percentage.

- (1) The *base* is the number on which the percentage is computed.
- (2) The *rate* is the amount (in hundredths) of the base to be estimated.
- (3) The *percentage* is a part or proportion of a whole expressed as so many per hundred. Percentage is the portion of the base determined by the rate.

4. Conversion of Decimal to Percent

To change a decimal to percent, move the decimal point two places to the right and add the percent symbol.

Example: Chance .375 to percent. Move decimal point two places to right: 37.5 Add percent symbol: 37.5%

5. Conversion of Fraction to Percent

To convert a fraction to percent, divide the numerator by the denominator and convert to a decimal. Then, convert the decimal to percent (par. 4)

Example: Change fraction $\frac{5}{8}$ to percent.

Divide numerator by denominator: $5 \div 8 = .625$ Convert decimal to percent: 6.25 = 62.5%Thus, $\frac{5}{8} = 62.5\%$.

6. Conversion of Percent to Decimal

To change a percent to a decimal, omit the percent symbol and move the decimal point two places to the left.

Example 1:	Change 15% to a decimal.			
	Omit percent symbol: 15% be- comes 15			
	Move decimal point two places to the left: 15 becomes .15 Thus, $15\% = .15$.			
Engmals Q.				

Example 2: Change 110% to a decimal. Omit percent symbol: 110% becomes 110
Move the decimal point two places to the left: 110 becomes 1.10. Thus, 110% = 1.10.

7. Conversion of Percent to Fraction

To change a percent to a fraction, first change the percent to a decimal (par. 6) and then to a fraction. Reduce the fraction to its lowest terms.

Example 1: Change 25% to a fraction. Change to a decimal: 25% = .25Change to a fraction: $.25 = \frac{25}{100}$ Reduce fraction to lowest terms: $\frac{25}{100} = \frac{1}{4}$ Thus, $25\% = \frac{1}{4}$.

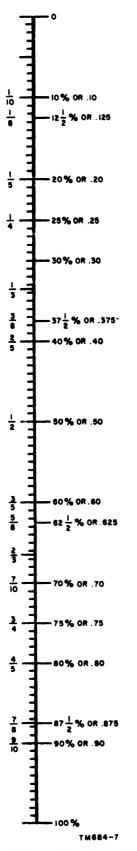


Figure 1. Relationship between fractions, decimals, and percentage.

Example 2: Change 37.5% to a fraction. Change to a decimal: 37.5% = .375 Change to a fraction: .375 = $\frac{375}{1000}$ Reduce fraction to lowest terms: $\frac{375}{1000} = \frac{3}{8}$ Thus, 37.5% = $\frac{3}{8}$.

8. Finding Percentage

a. General. To find the percent of a number, write the percent as a decimal and multiply the number by this decimal. In this case, the base and rate are given. The problem is to find the percentage.

Example 1: Find 5% of 140 (140 is the base, 5% is the rate, and the product is the percentage). 5% of 140 = .05 × 140 = 7 Example 2: Find 5.2% of 140. 5.2% of 140 = .052 × 140 = 7.28 Example 3: Find 150% of 36. 150% of 36 = 1.50 × 36 = 54 Example 4: Find $\frac{1}{2}$ % of 840.

$$\frac{1}{2}\% = .5\%$$

.5% of 840 = .005 × 840 = 4.20
Thus, $\frac{1}{2}\%$ of 840 = 4.20.

b. Application of Percentage. In communications-electronics, typical applications of percentage computation are used in determining tolerance values of resistors (par. 206) or in determining the efficiencies of motors and generators (par. 209).

9. Finding Rate

To find the percent one number is of another, write the problem as a fraction, change the fraction to a decimal, and write the decimal as a percent. In this case, the *percentage* and *base* are given. The problem is to find the *rate*.

Example 1: 3 is what percent of 8? (3 is the percentage, 8 is the base, and the quotient is the rate.)

$$\frac{3}{8} = .375$$

5



 $.375 = 37.5\% = 37\frac{1}{2}\%$ Therefore, 3 is $37\frac{1}{2}\%$ of 8. Example 2: What percent of 542 is 234? $\frac{234}{542} = .4317 + (round off)$.432 = 43.2%Therefore, 234 is 43.2% of 542. Example 3: 125 is what percent of 50? $\frac{125}{50} = 2.50$ 2.50 = 250%Therefore, 125 is 250% of 50.

10. Finding Base Numbers

To find a number when a percent of the number is known, first find 1% of the number, and then find 100% of the number. In this case, the *percentage* of the number and the *rate* are given. The problem is to find the *base*.

Example 1: 42 is 12% of what number? 12% (base number) = 42 1% (base number) = $\frac{42}{12} = 3.50$ 100% (base number) = 100 × 3.50 = 350 Therefore, the base number is 350. Example 2: 45 is 150% of what number? 150% (base number) = 45 1% (base number) = $\frac{45}{150} = .3$

100% (base number) =

$$100 \times .3 = 30$$

Therefore, the base number is 30

11. Expressing Accuracy of Measurements in Percent

a. Relative error is the accuracy of a measurement expressed in percent of the total measurement. In determining the relative error, it is first necessary to establish the *limit of error*.

b. The *limit of error* is the difference between the *true value* and the *measured value*. Assume that the reading on a scale, to the nearest tenth of an inch, is 2.2 inches. If the true value is 2.15 inches, the limit of error is the difference between 2.15 and 2.20, or .05 inch. c. Relative error is computed by solving the ratio $\frac{\text{LIMIT OF ERROR}}{\text{MEASURED VALUE}}$, and expressing the result as a percent. In the scale reading above, the relative error $=\frac{.05}{2.2}=2.27\%$, or 2.3%.

12. Review Problems—Percentage

a. Show each of the following in three forms —as a fraction or mixed number, as a decimal, and as a percent:

- (1) $\frac{3}{5}$ (2) 50% (3) .375 (4) $\frac{1}{4}$ (5) $62\frac{1}{2}\%$ (6) .6 (7) $\frac{3}{10}$ (8) 70% (9) 2.25 (10) $1\frac{7}{8}$ (11) .08 (12) $\frac{3}{50}$ (13) .18 (14) $\frac{1}{4}\%$ (15) .025 (16) .05 (17) $8\frac{1}{8}\%$ (18) $37\frac{1}{2}\%$ (19) 105% (20) 4% b. Evaluate the following:
 - (1) 250% of 60
 - (2) 125% of 40
 - (3) 200% of 2
 - (4) 225% of 400
- c. What percent of a number is—
 - (1) 1.5 times the number?



- (2) $2\frac{3}{4}$ times the number?
- (3) $\frac{3}{2}$ times the number?
- (4) $5\frac{1}{2}$ times the number?
- d. Find the following:

(1)
$$\frac{2}{5}$$
% of 410

(2)
$$\frac{3}{5}\%$$
 of 416,000

(3)
$$\frac{2}{5}$$
% of 85

(4) 5.2% of 85

- e. Solve the following problems:
 - (1) Find the relative error for a limit of error of .05 inch in measuring 24.2 inches.
 - (2) Find the relative error for a limit of error of 2 inches in measuring 200 yards.
- f. Find the number when-
 - (1) 12% of the number is 52
 - (2) 15% of the number is 375
 - (3) 32% of the number is 166.4
 - (4) 8% of the number is 16
 - (5) 84% of the number is 168



CHAPTER 3 RATIO AND PROPORTION

Section I. RATIO

13. Understanding Ratio

It is often desirable, for the purpose of comparison, to express one quantity in terms of another quantity of the same kind. One way to express this relationship is by means of a *ratio*. For example, if one resistor has a resistance of 800 ohms and another has a resistance of 100 ohms, the first resistor has 8 times as much resistance as the second. In other words, the ratio between the resistors is 8 to 1.

14. Expressing Ratio

Ratio can be expressed in four different ways For example, the ratio of 12 to 3 can be expressed as follows: 12 to 3, 12:3, 12 \div 3, or $\frac{12}{3}$. The numbers 12 and 3, which are the terms of the ratio, are called the *antecedent* and the *consequent*, respectively. The antecedent is the dividend or the numerator; the consequent is the divisor or denominator.

15. Obtaining Value of Ratio

Both terms of any ratio may be multiplied and divided by the same number without changing the value of the expression. In the ratio

Section II. PROPORTIONS

16. Understanding Proportion

A proportion is a statement of equality between two ratios. If the value of one ratio is equal to the value of another ratio, they are said to be in proportion. For example, the ratio 3:6 is equal to the ratio 4:8. Therefore, this can be written 3:6 :: 4:8 or 3:6 = 4:8. In any proportion, the first and last terms are called the *extremes*; the second and third terms are called the *means* (fig. 2). $\frac{12}{3}$, for example, the 12 is divided by 3, giving the value of 4. This means that the ratio 12:3 is equal to the ratio 4:1.

Example 1: What is the ratio of 6:2? $\frac{6}{2} = 3$, or 3:1 Example 2: What is the ratio of 7:3?

$$\frac{7}{3} = 2\frac{1}{3} \text{ or } 2\frac{1}{3}$$
:1

Example 5: Find the ratio of the areas (par.
26) of two squares the sides of which are 6 and 8 inches, respectively. The areas of similar figures are in the same ratios as the squares of their like dimensions.

$$8^{2}:6^{2} = 64:36$$

$$\frac{64}{36} = 1\frac{28}{36} = 1\frac{7}{9} \text{ or } 1\frac{7}{9}:1$$

Thus, the second square (8 inches on a side) is $1\frac{7}{9}$ times as large as the first square (6 inches on a side).

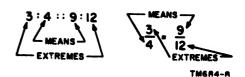


Figure 2. Terms of proportion.

17. Rules of Proportion

There are three rules of proportion that are used in determining an unknown quantity.



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They also can be used to prove that the proportion is true.

a. In any proportion, the product of the means equals the product of the extremes.

Example 1: 3:4 :: 9:12.

 $3 \times 12 = 36$ (product of extremes)

 $4 \times 9 = 36$ (product of means)

Example 2: $\frac{3}{4} = \frac{9}{12}$

Note. When the proportion is expressed in fractional form, the numerator of one fraction is multiplied by the denominator of the other fraction. This process is called *cross-multipli*cation.

 $3 \times 12 = 36$ (product of extremes)

 $4 \times 9 = 36$ (product of means)

b. In any proportion, the product of the means divided by either extreme gives the other extreme.

Example: 6:8::18:24. $8 \times 18 = 144$ (product of means) $144 \div 6 = 24$ (one extreme) $144 \div 24 = 6$ (other extreme)

c. In any proportion, the product of the extremes divided by either mean gives the other mean.

Example: 5:7::15:21 $5 \times 21 = 105$ (product of extremes) $105 \div 7 = 15$ (one mean) $105 \div 15 = 7$ (other mean)

18. Solving for Unknown Term

As demonstrated in paragraph 49, the unknown term of a proportion can be determined if the other three terms are known.

Example 1: In the proportion $\frac{5}{10} = \frac{10}{y}$, solve for y (the unkown quantity). Find the product of the means: $10 \times 10 = 100$ Find the product of the extremes: $5 \times y = 5y$ The products of the means and extremes are equal: 5y =100 Divide both sides by 5: 20 $\frac{3y}{3} = \frac{100}{3}$ y = 20Therefore, $\frac{5}{10} = \frac{10}{20}$

Example 2: In the proportion 6:12 :: 24:y, solve for y.

Write the proportion in fractional form: $\frac{6}{12} = \frac{24}{y}$ Cross-multiply. 6y = 288Divide both sides by 6. $\frac{48}{\frac{\psi y}{\psi}} = \frac{2\frac{\psi \psi}{\psi}}{\frac{\psi}{\psi}}$ y = 48Therefore, 6:12::24:48.

Example 3: In the proportion $\frac{z}{20} =$

$$\frac{5}{10}$$
, solve for z.
Cross-multiply.
 $10z = 100$
Divide both sides by 10:

$$\frac{10}{10}$$

 $\frac{10z}{10} = \frac{100}{10}$
 $z = 10$
Therefore, $\frac{10}{20} = \frac{5}{10}$.

19. Stating Ratios for Problems in Proportion

When setting up a proportion problem, be sure to state the ratios correctly. Analyze each problem carefully to determine whether the unknown quantity will be greater or lesser than the known term of the ratio in which it occurs. Arrange the terms of the ratio as shown below, and solve for the unknown quantity as explained in paragraph 18.



$\frac{\text{LESSER}}{\text{GREATER}} = \frac{\text{LESSER}}{\text{GREATER}}, \text{ or LESSER} : \text{GREATER} :: \text{LESSER} : \text{GREATER}$

Example: The weight of 15 feet of iron pipe is 8 pounds. What is the weight of 255 feet of the same pipe? Let the unknown quantity be represented by the letter y. Since ratios must express a relation between quantities of the same kind, one ratio must be between feet and feet and the other between pounds and pounds. Study the problems; 255 feet of pipe will weigh more than 15 feet of pipe. Arrange the first ratio in the order LES-SER to GREATER-15 feet: 255 feet, or $\frac{15}{255}$ Arrange the second ratio in the same order-LESSER to GREATER-8 pounds: pounds, or $\frac{8}{v}$. Write the proportion and solve. 15:255 = 8:y, or $\frac{15}{255} = \frac{8}{y}$ $15y = 255 \times 8$ 15y = 2040 $y = \frac{2040}{15}$ y = 136 pounds

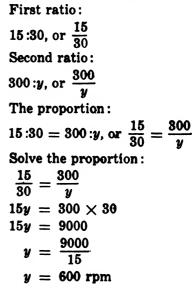
20. Inverse Proportion

a. The ratio 2:3 is the inverse of the ratio 3:2. In proportion, when a second ratio is equal to the inverse of the first ratio, the elements are said to be *inversely proportional*.

b. Two numbers are inversely proportional when one increases as the other decreases. In this case, their product is always the same. In problems dealing with pulleys, the speeds of different size pulleys connected by belts are inversely proportional to their diameters. A smaller pulley rotates faster than a larger pulley. Example 1: A pulley 30 inches in diameter 15 turning at a speed of 300 revolutions per minute. If this pulley is belted to a pulley 15 inches in diameter (fig. 3), determine the speed at which the smaller pulley is turning.

> Let the speed of the smaller pulley be represented by y. Study the problem; the first ratio will be between inches and the second will be between revolutions per minute (rpm). Also note that the second pulley is smaller than the first and must make more revolutions than the first. Therefore, the answer will be a number larger than 300.

Arrange the ratios in the order LESSER to GREATER.



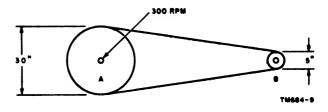


Figure S. Pulleys and inverse ratio.

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Example 2: A 24-inch pulley is fixed to a drive shaft that is turning at the rate of 400 rpm. This pulley is belted to a 6-inch pulley. Determine the speed of the smaller pulley in revolutions per minute. Driving pulley (400 rpm, 24

> inches in diameter). Driven pulley (y rpm, 6 inches

in diameter).

$$\frac{6}{24} = \frac{400}{y}$$

 $6y = 400 \times 24 = 9,600$
 $y = 1,600$ rpm

21. Problems Using Proportion

a. A steel plate $\frac{1}{2}$ inch thick, 12 inches wide, and 9 feet long weighs 183.6 pounds. What is the weight of a piece of steel plate of the same thickness and width if it is 16 feet 6 inches long?

b. If three men complete a certain job in 8 days, how many days would it take seven men

to complete the same job, considering that they will work at the same speed?

c. If 3 resistors cost 25 cents, find the cost of 60 resistors at the same rate?

d. If the upkeep on 62 trucks for a year is \$3,100, what would be the upkeep on 28 such trucks for 1 year at the same rate?

e. At a given temperature, the resistance of a wire increases with its length. If the resistance of a wire per 1,000 feet at 68°F is .248 ohm, what is the resistance of 1,500 feet; of 1,200 feet; of 1,850 feet; of 3,600 feet?

f. If 21-gage wire weighs 2.452 pounds per 1,000 feet, what is the weight of 1,150 feet; 1,540 feet; 1,680 feet; 349 yards?

g. The speeds of gears running together are inversely proportional to the number of teeth in the gears. A driving gear with 48 teeth meshes with a driven gear with 16 teeth. If the driving gear turns at the rate of 100 rpm, how many rpm are made by the driven gear?

h. A 36-tooth gear running at a speed of 280 rpm drives another gear with 64 teeth. What is the speed of the other gear?



CHAPTER 4 POWERS AND ROOTS

22. Powers

There are many times in mathematics when a number must be multiplied by itself a number of times, such as $4 \times 4 \times 4 \times 4 \times 4$. This is written as 4^5 and is described as 4 raised to the fifth power. A number multiplied by itself once is said to be raised to the second power (squared). Thus, 5×5 is written 5^2 . The number 2, written to the right and above the number 5, is the *exponent*; the number 5 is the *base*. The base number is a *factor* of a number written in exponential form because the product is evenly divisible by the base.

23. Roots

The root of a number is that number which, when multiplied by itself a given number of times, will equal the given number. The square root of 25 is 5, since 5×5 or 5^2 equals 25. The third root (cube root) of 216 is 6, since $6 \times 6 \times 6$ or 6^3 equals 216. The fourth root of 81 is 3, since $3 \times 3 \times 3 \times 3$ or 3^4 equals 81. Extraction of a root is generally indicated by placing, in front of the number, a radical sign ($\sqrt{-}$). A small figure is placed in the angle at the front of the sign to indicate the root to be taken. If the small figure is omitted, it is understood that the operation required is square root.

Thus,

 $\sqrt{25} = 5$ $\sqrt[3]{216} = 6$ $\sqrt[4]{81} = 3$

24. Finding Square Root of a Number

a. Finding Square Root by Mental Calculation. In some instances, the square root can be determined mentally from a knowledge of common multiplication. For example, $\sqrt{25}$ is 5, since 5×5 or $5^2 = 25$. Similarly, $\sqrt{144}$ is 12, since 12×12 or $12^2 = 144$. b. Finding Square Root by Arithmetical Process. In most cases, the square root of a number must be determined by a mathematical process. If the number is a perfect square, the square root will be an integral number; if the number is not a perfect square, the square root will be a continued decimal. To save time in calculation, a table of square roots of numbers from 1 to 100 is given in appendix III.

Example 1: Evaluate $\sqrt{3398.89}$.

Step 1.	Starting at the decimal point mark off the digits in pairs in
	both directions.
	$\sqrt{33}$ 98.89

Step 2. Place the decimal point for the answer directly above the decimal point that appears under the radical sign.

 $\sqrt{3398.89}$

Step 3. Determine by inspection the largest number that can be squared without exceeding the first pair of digits—33. The answer is 5, since the square of any number larger than 5 will be greater than 33. Place the 5 above the first pair of digits.

$$\sqrt{3398.89}$$

Step 4. Square 5 to obtain 25, and place it under 33. Substract 25 from 33 and obtain 8. Bring down the next pair of digits—98.

$$\frac{5}{\sqrt{33 \ 98.89}} \\
 \frac{25}{898}$$

Step 5.

Double the answer, 5, to obtain a trial divisor of 10. Divide the trial divisor into all but the last



digit of the modified remainer. It will go into 89 eight times. Place the 8 above the second pair of digits, and also place the 8 to the right of the trail divisor. Thus, the true divisor is 108. Multiply 108 by 8 and obtain 864. Subtract 864 from 898 to obtain 34. Bring down the next pair of digits—89.

$$5 \ \underline{8}.$$

$$\sqrt{33 \ 98.89}$$

$$\underline{2 \times 5 = 10[8]}$$

$$\underline{8} \times 108 = \frac{864}{8489}$$

Note. With each new successive digit in the answer:

1. Place the digit in the answer above the pair of digits involved.

2. Place the same digit to the right of the trial divisor to obtain the true divisor.

3. Multiply the digit by the true divisor. (Do not use the square boxes in actual problems.)

Step 6.

Double the answer, 58, to obtain a trial divisor of 116. Divide the trial divisor into all but the last digit of the remainder. It will go into 348 three times. Place the 3 above the third pair of digits, and also place the 3 to the right of the trial divisor. Thus, the true divisor is 1163. Multiply 1163 by 3 to obtain 3489. Subtract 3489 from 3489. There is no remainder. Therefore 3398.89 is a perfect square and its square root is 58.3.

$$5 8. [3]$$

$$\sqrt{33 98.89}$$

$$\frac{25}{898}$$

$$\frac{25}{898}$$

$$\frac{864}{3489}$$

$$\frac{3}{3} \times 1163 = 3489$$
Check the answer by squaring

The complete calculation is

 $58.3 - 58.3^2 = 3398.89.$

shown below:

Step 7.

 $5 \times 5 = 25$ $2 \times 5 = 10 \ 8 \ 898$ $8 \times 108 = 864$ $2 \times 58 = 1163 \ 3489$ $3 \times 1163 = 3489$

Example 2: Evaluate $\sqrt{786.808}$

- Step 1. Starting at the decimal point, mark off the digits in pairs in both directions.
 - $\sqrt{07 \ 86.80 \ 80}$

Note. The extreme left-hand group may have only one digit. However, there must be an even number of digits to the right of the decimal point. If necessary, add a zero.

Step 2. Place the decimal point for the answer directly above the decimal point that appears under the radical sign.

V07 86.80 80

Step 3. Determine the largest number that can be squared without exceeding the first digit—7. The answer is 2, since the square of any whole number larger than 2 will be greater than 7. Place the 2 above the 7.

$$\sqrt{07}$$
 36.80 80

Q

Step 4. Square 2 to obtain 4 and place it under 7. Subtract 4 from 7 to obtain 3. Bring down the next pair of digits—86.

$$\frac{2}{\sqrt{07 \ 86.80 \ 80}} \\
 \frac{4}{386}$$

Step 5.

Double the answer, 2, to obtain a trial divisor of 4. Divide the trial divisor into all but the last digit of the modified remainder. It will go into 38 nine times. Place the 9 above the second pair of digits, and also place the 9 to the right of the trial divisor. The true divisor is 49. Multiply 49 by 9 to obtain 441. However,

13



441 cannot be subtracted from 386, so the next lower digit must be tried. Substitute 8 for 9 in both the answer and the divisor and multiply 48 by 8 to obtain 384. Subtract 384 from 386 to obtain a remainder of 2. Bring down the next pair of digits— 80.

$$\begin{array}{r}
2 & 9. \\
\sqrt{07 & 86.80 & 80} \\
2 \times 2 = 4 & 9 & \frac{4}{386} \\
9 \times 49 = & 441 \\
& & \frac{2 & 8. \\
\sqrt{07 & 86.80 & 80} \\
& & \frac{4}{386} \\
8 \times 48 = & \frac{384}{280}
\end{array}$$

Step 6.

Double the answer, 28, to obtain a trial divisor of 56. Divide the trial divisor into all but the last digit of the remainder. Since it is not possible to divide 56 into 28, place a zero above the third pair of digits and bring down the next pair of digits—80.

Step 7. Multiply 280 by 2 to obtain a trial divisor of 560. Divide the trial divisor into all but the last digit of the remainder. It will go 5 times. Place the 5 above the fourth pair of digits, and also place the 5 to the right of the trial divisor. Thus, the true divisor is 5605. Multiply 5605 by 5 to obtain 28025. Subtract 28025 from 28080. There is a remainder of 55. Thus, the square root of 786.808 is 28.05, with a remainder of 55. A more exact answer can be obtained by adding pairs of zeros and continuing the square root process. $\begin{array}{r}
2 & 8. \ 0 & 5 \\
\sqrt{07 86.80 80} \\
\underline{4} \\
386 \\
\underline{384} \\
2 \times 280 = 560 \\
\overline{5} \\
28080 \\
\overline{5} \times 5605 = \underline{28025} \\
55 \\
\end{array}$

ſ

Check the answer by squaring 28.05 and adding the remainder $(28.05^2 + .0055)$. Place the extreme right digit of the remainder under the extreme right digit of the squared number. The complete calculation is shown below:

	2	8.	0	5
	$\sqrt{07}$	86.	80	80
$2 \times 2 = 4$ [8]	4			
8 × 48 =	- 3	86		
$\overline{2} \times 28 = 56$	3	84		
$2 \times 280 = 560[5]$	_	280	80	
$ 5 \times 5605 =$		260)25	
			55	

25. Review Problems—Square Root

- a. Solve the following:
 - (1) $\sqrt{441}$
 - (2) $\sqrt{1089}$
 - (3) $\sqrt{2500}$
 - (4) $\sqrt{8.40}$
 - (5) $\sqrt{2510.01}$
 - (6) $\sqrt{4901.4001}$
 - (7) $\sqrt{7482.25}$
 - (8) $\sqrt{5759.2921}$

b. Solve the following to nearest thousandth.

- (1) $\sqrt{5}$
- (2) $\sqrt{7}$
- **(3)** √11
- (4) $\sqrt{13}$
- (5) $\sqrt{15}$
- (6) $\sqrt{17}$

c. The current (in amperes) flowing through a resistor can be determined by taking the square root of the quotient obtained by dividing the value of power supplied to the resistor (in watts) by the value of the resistance (in





ohms). Thus, if a resistance of 300 ohms is absorbing 60 watts of power, it is drawing a current of $\sqrt{\frac{60}{300}}$ amperes. This equals about .447 ampere. In the same manner, find the value of current for each of the following values of power and resistance:

Power (watte)	Resistancs (ohms)	Current (amperes)		
(1) 25	1,000	?		
(2) 50	7,000	?		
(3) 40	500	?		
(4) 75	60	?		



CHAPTER 5

ALGEBRA

Section I. INTRODUCTION

26. General

a. Algebra is an extension of arithmetic. All of the four basic operations of arithmetic addition, subtraction, multiplication and division—apply also to algebra. Arithmetic deals only with particular numbers; algebra may also employ letters or symbols to represent numbers.

b. Algebra is often referred to as the shorthand language of mathematicians. The simplest example of the algebraic language is the formula, in which letters are used to represent words or numbers. For example, the area (A)of a rectangle can be determined by multiplying the length (l) by the width (w). Algebraically, this is stated as A = lw.

27. Algebraic Expressions and Terms

a. An algebraic expression is the representation of any quantity in algebraic signs and symbols; for example, 2x - 7. A numerical algebraic expression consists entirely of numerials and signs, such as $8 - (6 \times 2)$. A literal algebraic expression contains only letters and symbols, such as ax - ay.

b. Each algebraic expression contains two or more terms, separated by one of the signs of operation $(+, -, \div, \times)$. The expression 3x - 4xy - 2y, for example, contains three terms: 3x, 4xy, and 2y. If the terms have the same letters and exponents, such as $3a^2x$, $9a^2x$, and $12a^2x$, they are called *similar terms*. Terms that do not contain the same letters and exponents, such as $3ab^2$, $3a^2b$, and $3x^2y$, are *dissimilar terms*.

c. If an algebraic expression contains one term, such as 3abc or $5a^4x^2$, it is called a *mono-mial*; if it contains two terms, such as x - y,

it is called a *binomial*; and if it contains three terms, such as $5x^2 - 3xy - 2y^2$, it is called a *trinomial*. A more general rule of algebraic expressions states that any expression containing more than one term is called a *polynomial*.

28. Signs of Operation

In algebra, the conventional signs of operation $(+, -, \times \text{ and } \div)$ retain the same meaning as in arithmetic. In algebra, however, certain other signs may be used.

a. Multiplication may be indicated as follows:

Arithmetic	Algebra		
a imes b	ab		
$a \times b$	a . b		
$a \times b$	(a)(b)		

b. Division may be indicated as follows: Arithmetic Algebra

$x \div y$	$\frac{x}{x}$
æ y	y
$(a+b)\div(a-b)$	$\frac{a+b}{a+b}$

c. The arithmetical signs for both addition and subtraction are retained in algebra.

Arithmetic	Algebra		
4 + 5	4 + 5		
a - b	a — b		

29. Coefficients

Any factor of a product is known as a coefficient of the remaining factors. In the term $2\pi f$, 2 is the numerical coefficient of πf , f is the coefficient of 2π , and π is the coefficient of 2f. However, it is common practice to speak of the numerical part of the term as the coefficient. If a term contains no numerical coefficient, the number 1 is understood. Thus, *abc* is 1 *abc*, and *xyz* is 1 *xyz*.





30. Subscripts

In expression such as $R_1 = R_1 + R_2 + R_3$, the small numbers or letters written to the right and below the literal terms are called subscripts. Subscripts are used to designate different values of a variable quantity. They are read: R sub 1, R sub 2, etc.

Section II. POSITIVE AND NEGATIVE NUMBERS

32. Signed Numbers

Only positive numbers are used in arithmetical operations, but both *positive* and *negative* numbers may appear in algebraic expressions. The plus sign (+) is used to indicate a positive number and the minus sign (-) to indicate a negative number. If the sign is omitted, the number is understood to be positive. Positive and negative numbers are called *signed numbers*.

33. Need for Negative Numbers

The need for negative numbers may be seen from the succession of subtraction below:

6	6	6	6	6	6	6	6	6	6	
0	1	2	3	-4	5	6	-7	—8	9	
6	5	4	3	$\overline{2}$	ī	0	$-\overline{1}$	$-\overline{2}$	$-\frac{9}{3}$	

When the subtrahend is greater than the minuend, the difference becomes less than zero and the negative sign is placed before the difference. Thus, a negative number may be defined as a number less than zero.

34. Application of Positive and Negative Numbers

In technical work, many scales are calibrated above and below (or to the right and left of)

31. The Radical Sign

The radical sign ($\sqrt{}$) has the same meaning in algebra as in arithmetic (ch. 5). Thus, the expression $z = 2\sqrt{R^2 + x^2}$ states that z is equal to 2 times the square root of $R^2 + x^2$.

a center point designated 0 (zero). For example, the degrees of temperature indicated on a thermometer scale are measurements of distance taken on a scale in opposite directions from some point chosen to represent a reference or zero point. Temperature is always so many degrees above or below zero. In mathematics, it is convenient to indicate that a temperature is so many degrees above or below zero by prefixing the reading with a positive or negative sign. Thus, 45° above zero is $+45^{\circ}$ and 15° below zero is -15°. Similarly, in electronic and electrical measuring instruments, scales are often calibrated to read positive numbers on one side of a zero and negative numbers on the other.

35. Graphical Representation of Positive and Negative Numbers

a. Principle. Positive and negative numbers may be represented graphically as shown in figure 4. The zero is the reference point. This graph can be used to illustrate both addition and subtraction.

b. Addition. To add numbers graphically, start at the zero reference point and mark off the first number, going to the right if the number is positive, or to the left if the number is

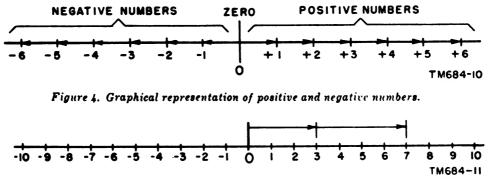


Figure 5. Graphical representation of addition of positive numbers.

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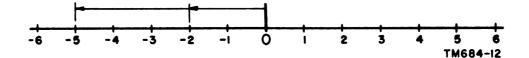


Figure 6. Graphical representation of addition of negative numbers (-1 and -5).

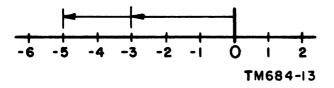


Figure 7. Graphical representation of addition of negative numbers (-3 and -2).

negative. From this new point, mark off the second number, again going to the right if the number is positive, or to the left if it is negative. The number of units between zero and the final point is the sum of the two numbers. This procedure can be continued for more than two numbers. Figure 5 shows graphical addition of positive numbers; figures 6 and 7 show graphical addition of negative numbers; and figure 8 shows the addition of a combination of a positive and a negative number. Figures 6 and 7 show that the order in which the negative numbers are taken does not affect the answer.

c. Subtraction. To subtract numbers graphically, change the sign of the subtrahend (number to be subtracted) and proceed as for addition. Figure 9 shows the subtraction of +3from +5 to obtain the difference of +2.

36. Absolute Value of a Number

The numerical value of a number, without regard to its sign, is called the *absolute value*

of the number. Thus, the absolute value of -3 or +3 is 3. This is written |3|.

37. Addition of Positive and Negative Numbers

a. Positive Numbers. To add two or more positive numbers, find the sum of their absolute values and prefix the sum with a plus sign. When there is no possibility of misunderstanding, the plus sign is usually omitted.

Example: Add
$$+4$$
, $+5$, and $+6$
+4 + (+5) + (+6) = +15 or
15

b. Negative Numbers. To add two or more negative numbers, find the sum of their absolute values and prefix the sum with a minus sign.

Example: Add
$$-4$$
, -5 , and -6
 $-4 + (-5) + (-6) = -15$

c. Positive and Negative Numbers. To add a positive and a negative number, find the difference between their absolute values and prefix the sum with the sign of the number that has the greater absolute value. This is called *algebraic addition*. When three or more positive and negative numbers are to be added, first find the sum of all positive numbers, and then the sum of all negative numbers. Add these sums algebraically as above.

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Example 1: Add +6 and -9. +6 + (-9) = -3

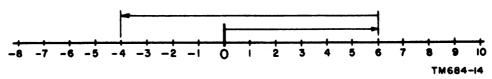


Figure 8. Graphical representation of addition of positive and negative numbers.

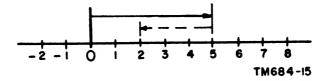


Figure 9. Graphical representation of subtraction of positive numbers.

Example 2: Add
$$+5$$
, -8 , $+12$, and -6 .
+5 + (+12) = +17
-8 + (-6) = -14
(+17) + (-14) = +3

38. Subtraction of Positive and Negative Numbers

To subtract positive and negative numbers, change the sign of the subtrahend and proceed as in addition (par. 37).

a. Positive Numbers.

Example 1: Subtract +2 from +5. +5 - (+2) = +5 -2 = +3or 3

Example 2: Subtract $+5a^2$ from $+6a^2$. $+6a^2 - (+5a^2) = +6a^2 - 5a^2$ $= +1a^2 = a^2$

b. Negative Numbers.

Example 1: Subtract
$$-3$$
 from -5 .
 $-5 - (-3) = -5 + 3 = -2$

Example 2: Subtract -4a from -2a. -2a - (-4a) = -2a + 4a =+2a or 2a

c. Positive and Negative Numbers.

- Example 1: Subtract -2 from +5. +5 - (-2) = +5 + 2 = +7or 7.
- Example 2: Subtract $-3x^2$ from $+5x^2$. $+5x^2 - (-3x^2) = +5x^2 + 3x^2$ $= +8x^2$ or $8x^2$
- 39. Multiplication of Positive and Negative Numbers

a. Numbers Having Like Signs. If the two numbers to be multiplied have the same signs, the product is positive.

Example 1: Multiply
$$+5$$
 by $+3$.
(+5)(+3) = +15 or 15

Example 2: Multiply -5 by -3. (-5) (3-3) = +15 or 15

b. Numbers Having Unlike Signs. If the two numbers to be multiplied have unlike signs, the product is negative.

Example 1: Multiply
$$-5$$
 by $+3$.
 $(-5)(+3) = -15$
Example 2: Multiply $+5$ by -3 .
 $(+5)(-3) = -15$

c. Several Positive and Negative Numbers. To multiply several positive and negative numbers, multiply the numbers in groups of two in the order in which they appear.

Example 1:
Multiply
$$(-5)(+3)(+7)(-2)(-4)$$
.
 $(-5)(+3)(+7)(-2)(-4)$
 $= (-15)(-14)(-4)$
 $= (+210)(-4)$
 $= -840$
Example 2:
Multiply $(+7)(+2)(-5)(-3)(-1)(-4)$
 $= (+7)(+2)(-5)(-3)(-1)(-4)$
 $= (+14)(+15)(-4)$
 $= (+210)(-4)$
 $= (+4)$
 $= (+210)(-4)$

40. Division of Positive and Negative Numbers

a. Numbers Having Like Signs. The quotient of two numbers that have the same signs is positive.

Example 1: Divide -15 by -5. $-15 \div -5 = +3 \text{ or } 3$ Example 2: Divide +24 by +6. $+24 \div +6 = +4 \text{ or } 4$

=

b. Numbers Having Unlike Signs. The quotient of two numbers that have opposite signs is negative.

Example 1: Divide 35 by -7. $+35 \div -7 = -5$ $-8988 \div 28 = -321$



41. Order of Signs

When only addition and subtraction signs appear in a series of terms, addition and subtraction procedures may be performed in any order. However, when multiplication and division signs appear in the same series with addition and subtraction signs, the multiplication and division must be performed first, and then the addition and subtraction.

Example 1:	Evaluate $15 + 5 - 3 + 4 - 8$.
Step 1.	Add the + terms: 15 + 5 + 4 = 24
Step 2.	Add the — terms: (3) + (8) =11
Step 3.	Add the + terms and — terms algebraically: 24 — 11 = 13.
Example 2:	Evaluate $9 \times 4 + 6 - 3 + 5 \times 2$.
Step 1.	Perform the multiplication first: $(9 \times 4) + 6 - 3 + (5 \times 2) =$ (36) + 6 - 3 + (10)
Step 2.	Add the + terms: 36 + 6 + 10 = 52
Step 3.	Add the + terms and the terms algebraically: 52 - 3 = 49
Example 5:	Evaluate $81 \div 9 - 3 + 6 - 15 + 4 \times 5$.
Step 1.	Perform the division: $(81 \div 9) - 3 + 6 - 15 + (4 \times 5) = (9) - 3 + 6 - 15 + (4 \times 5)$
Step 2.	Perform the multiplication: $9 - 3 + 6 - 15 + (4 \times 5) =$ 9 - 3 + 6 - 15 + (20)
Step 3.	Add the + terms: 9 + 6 + 20 = 35
Step 4.	Add the — terms: (3) + (15) =18
Step 5.	Add the \div terms and the — terms algebraically: 35 - 18 = 17.

42. Review Problems—Positive and Negative Numbers

- a. Add the following:
 - (1) 23 and -6
 - (2) 21 and 37
 - (3) ---54 and 33
 - (4) -43° and -96°
 - (5) 682 volts and --934 volts
- b. Subtract the following:
 - (1)—104 amperes from 147 amperes
 - (2) —37 volts from —45 volts
 - (3) .64cy from .0025cy
 - (4) $21.36ax^2$ from $-10.63ax^2$
 - (5) $-.986x^2y$ from $.824x^2y$
- c. Find the product of the following:

2

(1) -6.4 and 2.8 (2) 3 -6 and 4

$$(2)$$
 5, -0 , and -1

(3)
$$-\frac{1}{3}$$
, $-\frac{1}{7}$, and $-\frac{1}{5}$

- (5) ---.0025, 150, ---.10, and .075
- (6) -2, 5, 3, -1, and 4
- d. Divide:
 - (1) 36 by 4
 - (2) $-\frac{5}{7}$ by $\frac{3}{4}$

- (4) --750 by --3
- (5) $\frac{1}{3}$ ampere by $\frac{1}{2}$ ampere
- (6) —.3750 by 150
- e. Evaluate the following:
 - (1) 2 + 3 9
 - (2) $3 + 4 + 2 \times 5 3$
 - (3) $2 3 \times 9$
 - (4) $3 \times 4 + 2 \times 5 3$ (5) $5 + 3 \times 7 - 2 \times 11 + 7$
 - (6) $28 \div 14 8 + 16 + 3 \times 2$
 - (7) $46 18 + 3 \times 4 8 + 12$
 - (8) $5-3+6\times 4+40$
 - (9) $8 16 + 4 \times 3 10 \times 5$
 - (10) $15 \div 5 3 + 2 \times 10 2$

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43. Addition and Subtraction of Algebraic Expressions

a. General. Only similar algebraic terms those that are exactly alike in all respects other than numerical coefficients—may be added or subtracted. For example, the sum of $3x^2y$ and $5x^2y$ is $8x^2y$. Dissimilar terms cannot be added or subtracted directly, but the processes of addition or subtraction can be indicated by the use of plus or minus signs. For example, the sum of $4x^2y$ and $2xy^2$ is $4x^2y + 2xy^2$.

b. Procedure. To add or subtract algebraic expressions, arrange the terms so that like terms are in the same vertical column, and preferably in descending order of powers. Add or subtract the terms according to the rules of signed numbers (pars. 37 and 38).

Example 1: Add $x^3 - 3x^2 + 1$, $x^3 + x - 3$, and $x^2 + x + 1$. $x^3 - 3x^2 + 1$ $x^3 + x - 3$ $x^2 + x + 1$ $2x^3 - 2x^2 + 2x - 1$ Example 2: Subtract $x^3 + 3x^2 + x - 1$ from $x^4 + x^3 - x + 2$. $x^4 + x^3 - x + 2$. $(x^3 - 3x^2 - x + 1)$ Remove parentheses and change signs. $x^4 + x^3 - x + 2$ $-x^3 - 3x^2 - x + 1$ $x^4 - 3x^2 - 2x + 3$

44. Multiplication and Division of Monomials

a. Multiplication. In multiplying monomials, multiply the numerical coefficients and write this result as the coefficient of the product. After the coefficient, write each literal factor with an exponent equal to the sum of all the exponents of that letter in the original factors.

For example, $3a^{n} \cdot 2a^{m} = 6a^{n+m}$. Example 1: Multiply x^{2} by x^{3} . $x^{2} \cdot x^{3} = x^{2+3} = x^{5}$ Example 2: Multiply x, x^{3} , and x^{10} . $x^{1} \cdot x^{3} \cdot x^{10} = x^{1+3+10} = x^{14}$ Example 3: Multiply $x^{3}y^{6}$ by $3xy^{2}$. Step 1. Multiply the coefficients: $1 \cdot 3 = 3$

Step 2.	Multiply the two factors having the base x: $x^3 \cdot x = x^{3+1} = x^4$				
Step 3.	Multiply the two factors having the base y: $y^6 \cdot y^2 = y^{6+2} = y^6$				
Step 4.	The product is:				
Step 4.	$x^3y^6 \cdot 3xy^2 = 3x^4y^8$				
Example 4:	Multiply x^2y^4z and wx^2yz^5 . $x^2y^4z \cdot wx^3yz^5 = wx^{2+3}y^{4+1}z^{1+5}$ $x^{2+3} = x^5$ $y^{4+1} = y^5$ $z^{1+5} = z^6$				
	Therefore, $x^2y^4z \cdot wx^2yz^5 = wx^5y^5z^5$.				

b. Division. In dividing a monomial by a monomial, divide the numerical coefficient of the divisor and write the result as the coefficient of the divisor and write the result as the coefficient of the quotient. After the coefficient, write each literal factor with an exponent equal to its exponent in the dividend minus its exponent in the divisor. Thus, to divide $6a^n$ by $3a^m$ (n greater than m), $\frac{6a^n}{3a^m} = 2a^{n-m}$.

Example 1: Divide
$$x^{3}$$
 by x^{2} .
 $\frac{x^{3}}{x^{2}} = x^{3-2} = x^{1} =$

Example 2: Divide $5x^6yz^3$ by $6x^3z^2$.

$$\frac{5x^{4}yz^{3}}{6x^{3}z^{2}} = \frac{5}{6}x^{4-3}yz^{3-2}$$
$$= \frac{5}{6}x^{3}yz \text{ or } \frac{5x^{4}yz}{6}$$

x

- c. Removal of Parentheses and Brackets.
 - (1) In multiplying a quantity in parentheses by a given factor, multiply each term inside the parentheses by that factor and drop the parentheses. If the factor is a negative quantity, the sign of every term inside the parentheses is changed. For example, -5(a - b + c) = -5a + 5b - 5c.
 - (2) When an algebraic expression, such as 5x 4 [x 2(x 3)], has more than one grouping symbol (parentheses and brackets), remove the inside grouping symbol first and then successively remove the outer grouping symbols.

Example 1: Simplify
$$5x - 4 [x - 2(x - 3)]$$
.
 $5x - 4 [x - 2(x - 3)] = 5x - 4 [x - 2x + 6]$
 $= 5x - 4x + 8x - 24$
 $= 9x - 24$
 $= 3(3x - 8)$
Example 2: Simplify $4a - (6a - 2b + 2 [2a - b + 42] - (c + 2b))$.
 $4a - (6a - 2b + 2 [2a - b + 42] - (c + 2b))$.
 $= 4a - (6a - 2b + 4a - 2b + 84 - c - 2b)$
 $= 4a - (6a - 2b + 4a - 2b + 84 - c - 2b)$
 $= 4a - 6a + 2b - 4a + 2b - 84 + c + 2b$
 $= -6a + 6b + c - 84$
Example 3: Simplify $-\{-1 [-(x - y - z) + 29] - 39 + 2y - z\}$.
 $-\{-1 [-(x - y - z) + 29] - 39 + 2y - z\}$
 $= -\{+x - y - z - 29 - 39 + 2y - z\}$
 $= -x + y + z + 29 + 39 - 2y + z$
 $= -x - y + 2z + 68$

45. Raising Algebraic Functions to Powers

To raise an algebraic function to a power, multiply the exponents. Thus, $(a^{*})^{*} = a^{**}$.

Example 1: Simplify
$$(5^3)^4$$
.
 $(5^3)^4 = 5^{3.4} = 5^{12}$
Example 2: Simplify $(2ab)^3$.
 $(2ab)^3 = 2ab \cdot 2ab \cdot 2ab = 8a^3 b^3$
or $2^{1.3}a^{1.3}b^{1.3} = 8a^3b^3$
Example 3: Simplify $(ax^2)^3$.
 $(ax^2)^3 = a^{1.3}x^{2.3} = a^3x^4$
Example 4: Simplify $[(x^3)^4]^5$.
 $[(x^3)^4]^5 = [x^{3.4}]^5 = [x^{12}]^5 = x^{12.5} = x^6$
Example 5: Simplify $\left(\frac{2}{x^2}\right)^5$
 $\left(\frac{2}{x^2}\right)^5 = \frac{2^{1.5}}{x^{2.5}} = \frac{2^5}{x^{10}} = \frac{32}{x^{10}}$

46. Negative Exponents

The rule for dividing monomials (par. 44b) also holds when the exponents of the denominator is greater than the exponent of the numerator. For example, $a^3 \div a^5 = a^{2-5} = a^{-2}$; however, a quantity such as a^{-2} may be written as $\frac{1}{a^2}$.

Example: Multiply x^2 , x^{-1} , and $\frac{1}{x^{-3}}$. Step 1. Write down the factors of the multiplication:

$$x^2 \cdot x^{-1} \cdot \frac{1}{x^{-2}}$$

Step 2.Place all factors in the numerator: $x^2 \cdot x^{-1} \cdot x^4$ Step 3.Multiply the factors (add their exponents): $x^{2-1+3} = x^4$

47. Zero Exponents

The zero power of any quantity is equal to 1. For example $x^2 \cdot x^{-2} = x^6$ when the exponents are added. However, x^{-2} can also be written $\frac{1}{x^2}$; in this case, $x^2 \cdot x^{-2} = \frac{x^2}{x^2} = 1$.

Therefore, $x^0 = 1$. Any number (except zero) raised to the zero power is equal to 1.





Example: Solve $\frac{x^2y^2}{z} \cdot \frac{z^4}{xy} + \frac{x^2y^2}{z^3}$. $\frac{x^2y^3}{z} \cdot \frac{z^4}{xy} \div \frac{x^2y^2}{z^3} = \frac{x^2y^3z^4}{xyz} \div \frac{x^2y^2}{z^3} = \frac{x^2y^3z^4}{xyz} \cdot \frac{z^3}{x^2y^2}$ $= \frac{x^2y^3z^7}{x^3y^3z} = x^{3-3}y^{3-3}z^{7-1}$ $= x^{-1}y^0z^4 = x^{-1} \cdot 1 \cdot z^6 = \frac{z^6}{x}$

48. Multiplication of Polynomials

a. By a Monomial. To multiply a polynomial by a monomial, multiply each term in the polynomial separately by the monomial and add the products. Observe the rules for the multiplication of signed numbers (par. 39) and exponents (par. 44a).

Example 1: Multiply
$$3a + 2ab + 5c$$
 by 2b.
 $3a + 2ab + 5c$
 $2b$
 $\overline{6ab + 4ab^2 + 10bc}$
Example 2: Multiply $ad - ae + af$ by $3a^2$.
 $ad - ae + af$
 $3a^2$
 $\overline{3a^3d - 3a^3e + 3a^3f}$
Example 3: Multiply $3x^2y^2 - 2xy^3 + 5x^4y$ by
 $4x^3y$.
 $3x^2y^2 - 2xy^3 + 5x^4y$
 $4x^3y$
 $12x^4y^3 - 8x^4y^4 + 20x^7y^2$

b. By a Polynomial. To multiply a polynomial by another polynomial, multiply each term of one polynomial by each term of the other and add the products.

Example 1: Multiply
$$(a + b)$$
 by $(a + b)$.
 $a + b$
 $a + b$
 $a^2 + ab$
 $a^2 + ab$
 $a^2 + 2ab + b^2$
 $a^2 + 2ab + b^2$
Example 2: Multiply $2x + 3y$ by $2x + 3z$.
 $2x + 3y$
 $\frac{2x + 3z}{4x^2 + 6xy}$
 $\frac{4x^2 + 6xy + 6xz + 9yz}{4x^2 + 6xz + 9yz}$
Example 3: Multiply $5x^2 - 6xy + 3y^2$ by x
 $+y$.
 $5x^2 - 6x^2y + 3y^2$
 $\frac{x + y}{5x^3 - 6x^2y - 3xy^2 + 3y^3}$

49. Division of Polynomials

a. By a Monomial. To divide a polynomial by a monomial, divide each term of the polynomial by the monomial.

Example 1: Divide
$$3a^2 + 4ab + 5ac$$
 by a .

$$\frac{3a^2 + 4ab + 5ac}{a} = 3a + 4b + 5c$$
Example 2: Divide $7x^2 + 14xy - 21ax^2$ by $7x$.

$$\frac{7x^2 + 14xy - 21ax^2}{7x} = x + 2y - 3ax$$
Example 3: Divide $4r(s + t) - r^3(s + t)^2 + qr^2(s + t)^3$ by $r^2(s + t)$.

$$\frac{4r(s + t) - r^3(s + t)^2 + qr^2(s + t)^3}{r^2(s + t)}$$

$$= \frac{4r(s + t)}{r^2(s + t)} - \frac{r^3(s + t)^2}{r^2(s + t)} + \frac{qr^2(s + t)^3}{r^3(s + t)}$$

$$= \frac{4}{r} - r(s + t) + q(s + t)^2$$

b. By a Polynomial. To divide a polynomial by a polynomial, just arrange the dividend and the divisor according to descending powers of one variable, starting with the highest powers at the left. Then proceed as shown in the examples below. If there is a remainder, write it as the numerator of a fraction the denominator of which is the divisor.

Example 1:	Divide $ab + ac + db + dc$ by $a + d$.
Step 1.	Divide the first term of the divisor, a , into the first term of the dividend, ab . The quantity a is contained in the first term, ab , b times. Write b as the first term of the quotient. b a + d/ab + ac + db + dc
Step 2.	Multiply both terms of the divisor by b: $\frac{b}{a+d/ab+ac+db+dc}$ ab + db
Step 8.	Subtract the result from the original dividend: $\frac{b}{\frac{a+d}{ab+ac+db+dc}}$ $\frac{ab}{ac} + \frac{db}{dc}$

Step 4. Divide the first term of the divisor into the first term of the

remainder. It is contained in the first term, ac, c times. Write c as the second term of the quotient.

$$\frac{a+d}{ab} + \frac{ab}{ac} + \frac{ab}{ac} + \frac{ab}{ac} + \frac{ab}{ac} + \frac{ab}{ac}$$

Step 5.

$$\frac{b+c}{a+d/ab+ac+db+dc}$$

$$\frac{ab+db}{ac+dc}$$

$$\frac{ab+db}{ac+dc}$$

$$\frac{ac+dc}{ac+dc}$$

Step 6. Therefore, $\frac{ab + ac + db + dc}{a + d} = b + c.$

Example 2: Divide $x^2 + 2xy + y^2$ by x + y. $\frac{x^2 + 2xy + y^2}{x + y} =$ $\frac{x + y}{\frac{x + y}{x^2 + 2xy + y^2}}$ $\frac{x^2 + xy}{xy + y^2}$ Therefore, $\frac{x^2 + 2xy + y^2}{x + y} = x + y.$

Example 3: Divide $6a - ab - 27ac - 15b^2 + 7bc + 30c^2$ by 3a - 5b - 6c. $\frac{6a^2 - ab - 27ac - 15b^2 + 7bc + 30c^2}{3a - 5b - 6c} = \frac{2a + 3b - 5c}{2a + 3b - 5c}$ $\frac{3a - 5b - 6c}{6a^2 - ab - 27ac - 15b^2 + 7bc + 30c^2}$ $\frac{6a^2 - 10ab - 12ac}{2ac}$

$$\begin{array}{r} 9ab - 15ac - 15b^2 + 7bc + 30c^2 \\ \underline{9ab} - 15b^2 - 18bc \\ \hline - 15ac + 25bc + 30c^2 \\ - 15ac + 25bc + 30c^2 \end{array}$$

50. Review Problems—Fundamental Operations

- a. Add the following algebraic expressions:
 - (1) $2a^4 + 3a^2b^2 + 5b^4$, $a^4 5a^2b^2 2b^4$, and $3a^4 2a^2b^2 + b^4$.
 - (2) 3E 2RI 15ZI, 6RI + 24ZI, and -2E RI + 11ZI.
 - (3) 10w 4x + 3y + 6z, 2x 5w + y, 3z 2x y, and 6y 4w z + 5x.
- 24

b. Subtract the following algebraic expressions:

- (1) -7ax 2by + cz from 12ax + 15by 8cz.
- (2) 10w 3y 4z + 6x from 3x + 5y 2z 15w.
- (3) $8a^2 + 10ab 4b^2$ from $12a^2 24ab + 2b^2$.
- c. Simplify:
 - (1) 7a⁰
 - (2) $(5x + 9)^{\circ}$
 - (3) $(3x^2 + 7x + 1)^{\circ}$
- d. Perform the indicated operations:
 - (1) $f^6 \cdot f^4$
 - $(2) y^{a} \cdot y^{b}$
 - (3) $v^{x+1} \cdot v^{x-1}$
 - (4) $\frac{r^{10}}{r^5}$
 - (5) $(R^3)^m$
 - (6) $\frac{r^{m+5}}{r^4}$

- e. Express with positive exponents:
 - (1) $4x^{-4}$
 - (2) $r^{-3}x^{-4}$
 - (3) $(6a)^{-2b}$
 - (4) $I^{-2}R^{-1}$
 - (5) $2^{-3}a^2b^{-3}$
 - (6) $\frac{3EI^{-2}R^{-1}}{4}$
- f. Perform the indicated operations:
 - (1) $(5ab)(2a^2-3ab+7b^2)$
 - (2) $4a(a^2 + 3a + 1)$
 - (3) $(i^2 + 3i + 9)(i 3)$
 - (4) $(2x^2 + 3xy y^2)(x^2 + xy + y^2)$
 - (5) $(3x^2 2xy 5y^2)(3x^2 + 2xy 5y^2)$
 - (6) $[(x-1)a (x-1)c] \div [(x-1)ac]$
 - (7) $(3rL rR^2) \div rR$
 - (8) $(5a^4b 10a^6b^2 + 15a^3b^4) \div 5a^4b$
 - (9) $(1+2z^4+4z^2-z^3+7z)$ ÷
 - $(3+z^2-z)$
 - (10) $(100b^3 13b^2 3b) \div (3 + 25b)$

Section IV. FACTORING

51. Understanding Factoring

Factoring is the breaking up of an expression into the *factors* or *individual parts* of which it is composed. In other words, to factor an algebraic expression means to find two or more expressions which, when multiplied together, will result in the original expression. For example, since $3 \cdot 5 = 15$, 3 and 5 are the factors of 15; since $4 \cdot a \cdot b = 4ab$, 4, a, and b, are the factors of 4ab; since a(x + y) = ax + ay, a and (x + y) are the factors of $a\dot{x} + ay$.

52. Factors of Positive Integers

It is often difficult to determine at a glance the factors of which a number is composed. For example, consider the numerical expression 36. There are many different combinations of numbers that would result in an answer of 36; for example, the desired factors for 36 in a certain problem might $36 \cdot 1$, $18 \cdot 2$, $12 \cdot 3$, $9 \cdot 4$, $6 \cdot 6$, $2 \cdot 2 \cdot 9$, $4 \cdot 3 \cdot 3$, $2 \cdot 3 \cdot 6$, and so on.

53. Factors of a Monomial

Because the factors of a monomial are evident, usually a monomial is not separated into its prime factors. The factors of a^4b^2c are $a \cdot a \cdot a \cdot a \cdot b \cdot b \cdot c$, and the factors of $15a^2b^3$ are $3 \cdot 5 \cdot a \cdot a \cdot b \cdot b \cdot b$.

54. Square Root of a Monomial

The square root of an algebraic expression is one of its two equal factors. Thus, the square root of 49 is 7, the square root of 81 is 9, the square root of a^2 is a, and the square root of x^2y^2 is xy. As discussed in paragraph 31, the radical sign is used to indicate the square root of a number. Actually, every number has two square roots, one positive and one negative. If no sign precedes the radical, the positive or principal root is understood. For example, $\sqrt{9} = +3$. If a negative sign precedes the radical, however, the negative root is intended. Thus, $-\sqrt{9} = -3$. When dealing with literal terms, the values of the various factors often



are unknown. Therefore, when extracting the square root of a monomial, extract the square root of the numerical coefficient, divide the exponents of the literal terms by 2, and prefix the square root with the plus or minus (\pm) sign, which denotes that either the positive or negative root may be the correct one.

Example 1: $\sqrt{x^{16}y^4} = \pm x^8y^2$. Example 2: $\sqrt{49a^4b^2} = \pm 7a^2b$.

55. Cube Root of a Monomial

The cube root of a monomial is one of its three equal factors. The index 3 in the angle of the radical sign $(\sqrt[3]{})$ indicates cube root (par. 31). To extract the cube root of a monomial, extract the cube root of the numerical coefficient, divide the exponents of the literal terms by 3, and prefix the cube with the same sign as that of the monomial.

Example 1: $\sqrt[3]{a^{6}y^{3}} = a^{2}y$. Example 2: $\sqrt[3]{27x^{12}y^{6}z^{9}} = 3x^{4}y^{2}z^{3}$. Example 3: $\sqrt[3]{-64r^{21}s^{3}} = -4r^{7}s$.

56. Factors of a Polynomial

a. Common Monomial Factor. In an algebraic expression, the type of factor which can be recognized most easily is the monomial factor (single letter or number) which is common to each term in the expression. For instance, in the expression xa + xb + xc, the x is a factor common to each of the terms. Thus, the expression xa + xb + xc can be written x(a +b + c). This relationship is shown pictorially in figure 10. Since the area of a rectangle is equal to its base multiplied by its altitude (par. 136b), the area of the uppermost rectangle in figure 10 is x times a, or xa. The areas of the center and lower rectangles are xb and xc, respectively. The area of the large rectangle formed by the three small rectangles is equal to its base x times its altitude (a + b + c), or x(a + b + c). Since the area of the large

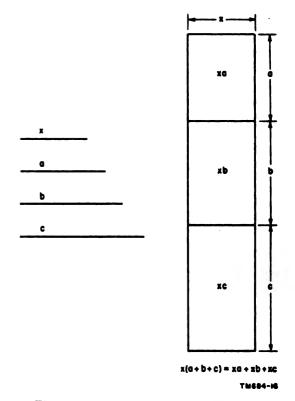


Figure 10. Common monomial factors.

rectangle is equal to the sum of the areas of the three smaller rectangles, then x(a + b + c)is equal to xa + xb + xc. This shows that the factor x can be removed from xa + xb + xcand the expression written x(a + b + c). Accuracy of factoring can be checked by multiplying the two factors together-the product should be the original expression. Thus, x(a +b + c) = xa + xb + xc. To factor a polynomial the terms of which have a common monomial factor, determine the largest factor common to all of the terms, divide the polynomial by this factor, and write the quotient in parentheses preceded by the monomial factor. The first factor contains all that is common to all of the terms; it may consist of more than one literal number and may be to a power higher than the first.

Example 1: Factor
$$x^3 - 7x^2 + 4x$$
.
 $x^3 - 7x^2 + 4x = x(x^2 - 7x + 4)$
Example 2: Factor $abx + aby - abz$.
 $abx + aby - abz = ab(x + y - z)$
Example 3: Factor $2az^2 - 4bz^2 + 6cz^2$.
 $2az^2 - 4bz^2 + 6cz^2 = 2z^2(a - 2^3 + 3^2)$

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b. Binomial Factors. Sometimes binomial factors are not immediately apparent, and an algebraic term may appear to have no common factors. For example, the expression am + bm+ an + bn may seem to have no factors in common. However, the first pair, am + bm, has a common factor, m, and the second pair, an + bn, has a common factor, n. Factoring out the common factors, the expression becomes m(a + b) + n(a + b). Since there are two terms containing a common factor (a + b), this factor can be removed to make the expression (a + b) (m + n). Thus, the factors are (a + b) and (m + n). This relationship is shown pictorially in figure 11. Starting with the upper left-hand rectangle and going clockwise, the areas of the four rectangles are an, am, bm, and bn. The area of the large rectangle formed by the four smaller rectangles is its base (m + n) times its altitude (a + b), or (m + n) (a + b). Since the area of the large rectangle is equal to the sum of the areas of the four smaller rectangles, then (m + n) (a + b)is equal to an + am + bm + bn. This shows that the expression am + bm + an + bn can be factored into (m + n) and (a + b). To check the factoring, multiply (a + b) by (m + n); the product is am + an + bm + bn. Since the addition of terms can be expressed in any order, the factoring is correct.

Example 1: Factor py - pz - qy + qz. py - pz - qy + qz = p(y - z) - q(y - z) = (p - q) (y - z)Example 2: Factor 4xa - 8zb - 6ya - 4xb + 8za + 6yb. 4xa - 8zb - 6ya - 4xb + 8za + 6yb = 4xa - 6ya + 8za - 4xb + 6yb - 8zb = 2a(2x - 3y + 4z) - 2b(2x - 3y + 4z) = (2a - 2b) (2x - 3y + 4z) = 2(a - b) (2x - 3y + 4z)Example 3: Factor da + db - dc - ea - eb + ec + fa + fb - fc.

$$aa + ab - ac - ea - eb + ec + fa + fb - fc$$

= $d(a + b - c) - e(a + b - c) + f(a + b - c)$
= $(d - e + f) (a + b - c)$

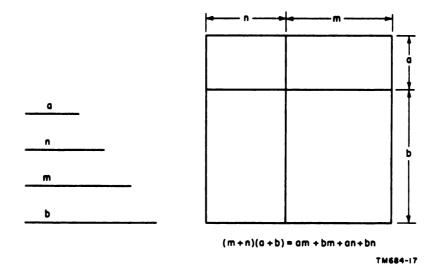
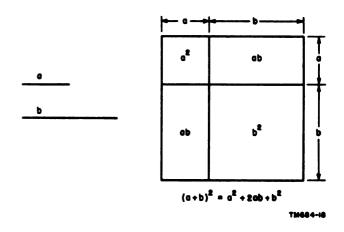


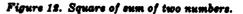
Figure 11. Binomial factors.



57. Factors of the Square of a Binomial

a. Square of Sum of Two Numbers. The square of the sum of two numbers is a special product that should be readily recognized to aid in factoring algebraic expressions. The square of the sum of two numbers equals the square of the first, plus twice the product of the first and second, plus the square of the second. To illustrate, $(a + b)^2 = a^2 + 2ab + b^2$. Conversely, the factors of $a^2 + 2ab + b^2$ are $(a + b^2) = a^2 + b^2 + b^2 + b^2$ b) (a + b) or $(a + b)^2$. This relationship is shown in figure 12. The areas of the four rectangles, as shown on the figure, are a^s, ab, ab, and b^2 . The area of the large rectangle formed by the four smaller rectangles is equal to its base (a + b) times its altitude (a + b). or $(a + b)^2$. Since the area of the large rectangle is equal to the sum of the areas of the four smaller rectangles, then $(a + b)^2$ is equal to $a^2 + ab + ab + b^3$, or $a^3 + 2ab + b^3$. This shows that the expression $a^2 + 2ab + b^2$ can be factored into (a + b) (a + b), or $(a + b)^2$. Figure 13 shows a similar relationship in which nine small rectangles form one large rectangle. In this case, the area of the large rectangle is $(a + 2b)^2$ and the sum of the areas of the nine smaller rectangles is $a^2 + 4ab + 4b^2$; consequently, (a + 2b) and (a + 2b) are factors of $a^2 + 4ab + 4b^2$. Thus, the factors of the square of one number, plus twice the product of the first and second number, plus the square of the sum of the second number are the square of the sum of the two numbers.





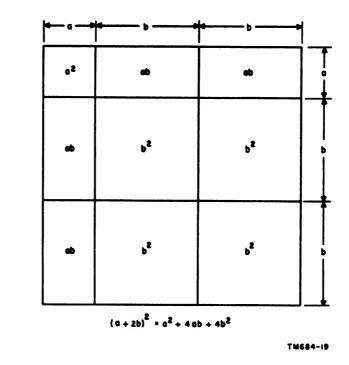


Figure 13. Factors of square of positive binomial.

Example:

Factor $4b^2 + 16db + 16d^2$.

 $4b^2 + 16db + 16d^2 = (2b + 4d) (2b + 4d)$ $= (2b + 4d)^2$ $= [2(b + 2d)]^{2}$ $= 2^{2} (b + 2d)^{2}$

To prove the factoring:

 $(2b + 4d)^2 = (2b)^2 + 2(2b) (4d) + (4d)^2$ $= 4b^2 + 16db + 16d^2$

Note that 4 (that is, 2^2) may be removed before factoring the rest of the expression—this often simplifies computation.

$$4(b^2 + 4bd + 4d^2) = 4(b + 2d)^2$$

- b2

b. Square of Difference of Two Numbers. The square of the difference of two numbers equals the square of the first, minus twice the product of the first and second, plus the square of the second. For example, $(a - b)^2 = a^2 - b^2 =$ $2ab + b^2$. The factors of $a^2 - 2ab + b^2$ are (a - b) (a - b) or $(a - b)^2$. This relationship is shown pictorially in figure 14. The area of the large rectangle formed by the four small rectangles is a^2 . The areas of the four smaller rectangles are shown on the illustration. The area of the upper left-hand rectangle is (a - bar) $b)^2$. It is also equal to the area of the large rectangle minus the areas of the other three rectangles, or $a^2 - b (a - b) - b (a - b) - b^2$. This can be further simplified as follows:

$$a^{2} - b (a - b) - b (a - b)$$

$$a^{2} - 2b (a - b) - b^{2}$$

$$a^{2} - 2ab + 2b^{2} - b^{2}$$

$$a^{2} - 2ab + b^{2}$$

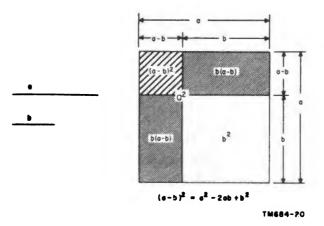


Figure 14. Square of difference of two numbers.

Therefore, $(a - b)^2 = a^2 - 2ab + b^2$, and $(a - b)^2 = a^2 - 2ab + b^2$. b) and (a - b) are factors of $a^2 - 2ab + b^2$. Thus, the factors of the square of one number, minus twice the product of the first and the second, plus the square of the second are the square of the difference of the two numbers.

Example:

Factor
$$9b^2 - 12bd + 4d^2$$
.
 $9b^2 - 12bd + 4d^2 = (3b - 2d) (3b - 2d)$
 $= (3b - 2d)^2$

To prove the factoring:

$$(3b-2d)^2 = (3b)^2 - 2 (3b) (2d) + (2d)^2 = 9b^2 - 12bd + 4d^2$$

58. Factors of Difference of Two Squares

The product of the sum and difference of two numbers is equal to the difference of their squares. Thus, $(a + b) (a - b) = a^2 - b^2$. To factor the difference of two squares, extract the square roots, then write the sum of the roots as one factor and the difference of the roots as the other factor. Thus, the factors of $a^2 - b^2$ are (a + b) (a - b).

Example:

Factor $4x^2 - 9y^2$. $4x^2 - 9y^2 = (2x + 3y) (2x - 3y)$

To prove the factoring:

(2x + 3y) (2x - 3y) $= (2x)^2 + (2x)(3y) - (2x)(3y) - (3y)^2$ $= 4x^2 - 9y^2$



59. Factors of Trinomials

a. Trinomials Such as $x^{s} + x(a + b) + ab$. The factors of a trinomial consisting of the square of the common term, the product of the common term and the algebraic sum of the unlike terms, and the product of the unlike terms are two binomials that have one term in common and the other term unlike. Thus, the factors of $x^{s} + x(a + b) + ab$ are (x + a)(x + b) where x is the common term, and a and b are the unlike terms. As proof, the product of (x + a)(x + b) is $x^{2} + xa + xb + xb + ab$. By factoring the two terms which have a common factor, x, the original trinomial $x^{2} + x(a + b) + ab$ is obtained.

Example: Factor
$$9r^2 + 6r(s + t) + 4st$$
.
 $9r^2 + 6r(s + t) + 4st = (3r + 2s)(3r + 2t)$
To prove the factoring:
 $(3r + 2s)(3r + 2t) = (3r)^2 + (3r)(2s) + (3r)(2t) + (2s)(2t)$
 $= 9r^2 + 6rs + 6rt + 4st$
 $= 9r^2 + 6r(s + t) + 4st$

b. Trinomials Such as $x^2 + 6x + 8$. To factor a trinomial of the form $x^2 + 6x + 8$, x^2 -6x + 8, $x^2 + 6x - 8$, or $x^2 - 6x - 8$, much of the work is done by trial and error. The problem is to find two factors of the final term which, when added together, will give the coefficient of the middle term. Taking the first of the trinomials above, the factors of 8 are $8 \cdot 1$ and $4 \cdot 2$. Since 4 + 2 = 6 and 8 + 1 = 9, the factors that will be used are 4 and 2. With regards to signs, if the sign of the final term is positive, the signs of the two factors are alike and will be the same as the sign of the middle term. Thus, the factors $x^2 + 6x + 8$ are (x + 4) and (x + 2), and the factors of $x^2 - 6x$ + 8 are (x - 4) and (x - 2). If the sign of the final term is negative, however, the signs containing the two terms of each binomial factor are unlike; the larger factor will take the sign of the middle term. For example, the factors of $x^2 + 2x - 8$ are (x + 4) and (x - 2), and the factors of $x^2 - 2x - 8$ are (x - 4)and (x+2).

Example 1: Factor
$$y^2 + 12y + 32$$
.
 $y^2 + 12y + 32 = (y+8)(y+4)$
Example 2: Factor $z^2 - 11z + 30$.
 $z^2 - 11z + 30 = (z-6)(z-5)$
Example 3: Factor $r^2 + 4r - 12$.
 $r^2 + 4r - 12 = (r+6)(r-2)$
Example 4: Factor $s^2 - s - 20$.
 $s^2 - s - 20 = (s-5)(s+4)$

c. Trinomials Such as $6a^2 - 11a - 10$. The procedure used to factor trinomials of this type

is an extension of the procedure described in b above and as shown in the example below.

Example:	Factor 6a ² — 11a — 10.
Step 1.	Find two numbers that, when multiplied together, form the left-hand term, $6a^2$. $(6a)(a) = 6a^2$ $(2a)(3a) = 6a^2$
Step 2	Find two numbers that, when multiplied together, form the right-hand term, -10 .

$$(10)(-1) = -10$$

 $(5)(-2) = -10$
 $(-10)(1) = -10$
 $(-5)(2) = -10$

Step 3. By trial and error, set up two binomial expressions containing factors from step 1 in the left-hand term and factors from step 2 in the right-hand term. The proper selection of factors should give the middle term of the trinomial when the binomials are multiplied.

$$(2a + 5) (3a - 2)$$
 (first trial)
 $6a^2 + 15a - 4a - 10 = 6a^2$

+ 11a - 10 (multiplying out)

The middle term obtained does not match the middle term of the given trinomial. The numerical value, is correct, but the sign is wrong. Make a second



trial with the signs in the binomials changed.

$$(2a - 5)(3a + 2)$$

 $6a^2 - 15a + 4a - 10 = 6a^2$
 $- 11a - 10$

Step 4.

Since the second trial results in the correct trinomial, the factors of $6a^2 - 11a - 10$ are (2a - 5)and (3a + 2).

> Note. The method of trial and error used above may not work in every case. Other arrangements of factors and signs must be tried until the correct results are obtained.

60. Factors of Two Cubes

a. Sum of Two Cubes. The factors of the sum of two cubes, such as $x^3 + y^3$, are (x + y) and $(x^2 - xy + y^2)$. In this case, the binomial is an expression of the sum of the primes times the sum of the squares of the primes minus the product of the primes. This is seen readily by dividing $x^3 + y^3$ by x + y.

Thus,

$$\frac{x^{2} - xy + y^{2}}{x + y/x^{3} + x^{2}y} + \frac{x^{3} + x^{2}y}{-x^{2}y} - \frac{x^{2}y - xy^{2}}{xy^{2} + y^{3}} + \frac{xy^{2} + y^{3}}{xy^{2} + y^{3}}$$

Example 1: Factor $z^3 + 8$. $z^3 + 8 = (z + 2)(z^2 - 2z + 4)$

To prove the factoring:

$$\frac{z^{2} - 2z + 4}{z + 2/z^{3} + 8}$$

$$\frac{z^{3} + 2z^{2}}{-2z^{2}}$$

$$\frac{-2z^{2} - 4z}{4z + 8}$$

$$4z + 8$$

Example 2:

Factor $r^3 + 125x^3$. $r^3 + 125x^3 = (r + 5x)(r^2 - 5rx + 25x^2)$

To prove the factoring:

$$\frac{r^2 - 5rx + 25x^2}{r + 5x/r^3 + 125x^3}$$

$$\frac{r^3 + 5r^2x}{-5r^2x}$$

$$\frac{-5r^2x - 25rx^2}{25rx^2 + 125x^3}$$

b. Difference of Two Cubes. The factors of the difference of two cubes, such as $x^3 - y^3$, are $(x - y)(x^2 + xy + y^2)$. These factors are an expression of the difference of the primes times the sum of the squares plus the product of the primes. As in the sum of two cubes, factoring can be proved by dividing the product by the binomial factor.

Example 1: Factor
$$a^3 - b^3$$
.
 $a^3 - b^3 = (a - b) (a^2 + ab + b^2)$

To prove the factoring:

$$\frac{a^{2} + ab + b^{2}}{\frac{a - b}{a^{3}} - \frac{a^{2}b}{a^{2}b}} \\ \frac{a^{3} - a^{2}b}{a^{2}b} \\ \frac{a^{2}b - ab^{2}}{ab^{2} - b^{3}} \\ \frac{ab^{2} - b^{3}}{ab^{2} - b^{3}}$$

Example 2: Factor $z^3 - 27$. $z^3 - 27 = (z - 3)(z^2 + 3z + 9)$

To prove the factoring:

$$\frac{z^{2} + 3z + 9}{z - 3/z^{3} - 27}$$

$$\frac{z^{3} - 3z^{2}}{3z^{2}}$$

$$\frac{3z^{2} - 9z}{9z - 27}$$

$$\frac{9z - 27}{9z - 27}$$



Example 3: Factor $64s^3 - 216t^3$. $64s^3 - 216t^3 = (4s - 6t)(16s^2 + 24st + 36t^2)$ To prove the factoring: $16s^2 + 24 st + 36t^2$ $4s - 6t/64s^3 - 216t^3$

$$\frac{-6t}{64s^{2} - 96s^{2}t} = 216t^{2}$$

$$\frac{64s^{2} - 96s^{2}t}{96s^{2}t} = \frac{96s^{2}t - 144st^{2}}{144st^{2} - 216t^{2}}$$

$$\frac{144st^{2} - 216t^{2}}{144st^{2} - 216t^{2}}$$

61. Review Problems—Factoring

a. Factor:

(1) 25 + 5 - 30

- (2) 8 + 4 32
- (3) 9 18 + 21
- (4) 7r 21r + 35r
- (5) 10x + 8y + 6z
- b. Find the values of the indicated powers:
 - (1) (7xy³)²
 - (2) $(-2w^{\sharp})^{2}$
 - (8) $(8a^2b^4)^2$
 - (4) $(9a^{2}x)^{2}$
- c. Find the value of each of the following:
 - (1) $\sqrt{5^2}$
 - (2) $\sqrt{4^3}$
 - (3) $\sqrt{a^2b^4}$
 - (4) $\sqrt{36y^2z^4}$

(5) $\sqrt{100a^2b^{10}}$ (6) $\sqrt{16a^2 \cdot 5^2}$

- (7) ∛<u>-27</u>
- (8) $\sqrt[4]{-x9}$
- $(9) \sqrt[3]{(-8)^2}$
- (10) $\sqrt[3]{125x^{12}y^{15}z^6}$
- d. Factor:
 - (1) 3x + 6
 - (2) $5a^2 + 15a$
 - (3) $10x^3 14x^2 2x$
 - (4) 6azy + 9bzx 12cz
 - (5) $m^2 + m^2 5mx$
 - (6) $3a^{5} 6a^{4}b 3a^{3}b^{3}$
 - (7) $7ry^3 14ry^3 + 21ry^3$
 - (8) $12x^2am + 14xa^2m + 16xam^2$
 - (9) $\pi r \frac{2}{1} + \pi r \frac{2}{2}$
 - (10) $\frac{1}{4}c^2d \frac{1}{8}c^2d^2 + \frac{1}{16}cd^2$

Section V. ALGEBRAIC FRACTIONS

62. General

Algebraic fractions play an important part in equations for electrical and electronic circuits. These fractions can be added, subtracted, multiplied, and divided in the same manner as arithmetical fractions.

63. Changing Signs of Fractions

a. The sign preceding a fraction is the sign of the fraction. It refers to the fraction as a whole and not to either the numerator or the denominator. In addition, the numerator and denominator each has a sign. For example, in the fraction $-\frac{3a}{5b}$, the sign of the fraction is minus, the sign of the numerator is plus, and the sign of the denominator is plus. Any two of the three signs can be changed without changing the value of the fraction.

Thus,
$$-\frac{3a}{5b} = \frac{-3a}{5b} = \frac{-3a}{-5b}$$

Therefore, the sign of the fraction is not changed if the signs of both the numerator and the denominator are changed. Also, the sign of the fraction must be changed if the sign of either the numerator or denominator, but not both, is changed.

b. If the numerator or denominator is a polynomial, the sign of each term should be changed, not just the first sign. For example,



 $-\frac{a-b}{c-d}=+\frac{-(a-b)}{c-d}=\frac{-a+b}{c-d}=\frac{b-a}{c-d}.$

c. If the numerator or denominator is in factored form, change only the sign of one of the factors, not both. Thus,

$$-\frac{(x-y)(x-2y)}{x+y} = \frac{(x+y)(x-2y)}{x+y} = \frac{(y-x)(x-2y)}{x+y}.$$

64. Changing Form of Algebraic Fractions

In algebra, as in arithmetic, any fraction can be changed to an equivalent fraction by multiplying or dividing both the numerator and denominator by the same term or number except zero. This will not change the value of the fraction. For example, to change the fraction $\frac{1}{2}$ to a fraction with 10 as its denominator, multiply both the numerator and the denominator by 2. Thus,

$$\frac{3}{5} = \frac{3 \cdot 2}{5 \cdot 2} = \frac{6}{10}.$$

Similarly, to change the fraction $\frac{x}{y}$ to a fraction with yz as its denominator, the denominator is changed to yz by multiplying by z; the numerator also is multiplied by z to become xz. Thus,

$$\frac{x}{y}=\frac{x\cdot z}{y\cdot z}=\frac{xz}{yz}.$$

Example 1: Change $\frac{4}{a-3}$ to a fraction with $a^2 - 9$ as its denominator.

$$\frac{4}{a-3} = \frac{4 \cdot (a+3)}{(a-3)(a+3)} = \frac{4(a+3)}{a^2-9}$$

Example 2: Change $\frac{4r-3}{6r}$ to a fraction with $18\pi r^2 s$ as its denominator. $\frac{4r-3}{6r} = \frac{(4r-3)\cdot 3\pi rs}{6r\cdot 3\pi rs} = \frac{3\pi rs(4r-3)}{18\pi r^2 s}$

65. Reducing Fractions to Lowest Terms

As in arithmetic, when the numerator and denominator of a fraction have no common factor other than 1, the fraction is said to be in its lowest terms. The fraction $\frac{3}{8}$, $\frac{a}{b}$, and $\frac{p+q}{p-q}$, therefore, are in their lowest terms since the numerator and denominator of each fraction have no other factor except 1. The fractions $\frac{6}{12}$ and $\frac{3a}{9a^2}$ are not in their lowest terms. The fraction $\frac{6}{12}$ can be reduced to its lowest term by dividing both the numerator and denominator by 6. Similarly, the fraction

 $\frac{5y}{15y^2}$ can be reduced to $\frac{1}{3y}$ by dividing the numerator and denominator by 5y. Thus, to reduce a fraction to its lowest terms, factor the numerator and denominator into prime factors and cancel the factors common to both (since they are equal to $\frac{1}{1}$).

Example 1: Reduce $\frac{6y}{8y^2}$ to lowest terms. $\frac{6y}{8y^2} = \frac{2y(3)}{2y(4y)} = \frac{3}{4y}$ Example 2: Reduce $\frac{xab^2}{xcb}$ to lowest terms.

$$\frac{xab^2}{xcb} = \frac{xb (ab)}{xb (c)} = \frac{ab}{c}$$

Example 3: Reduce $\frac{a^2 - b^2}{4a + 4b}$ to lowest terms. $\frac{a^2 - b^2}{4a + 4b} = \frac{(a + b) (a - b)}{4(a + b)} = \frac{a - b}{4}$ Example 4: Reduce $\frac{2a^2 + 4ab + 2b^2}{2a + 2b}$ to lowest terms. $\frac{2a^2 + 4ab + 2b^2}{2a + 2b} = \frac{2(a + b) (a + b)}{2(a + b)} = \frac{a + b}{1} = a + b$

66. Finding Lowest Common Denominator

The lowest common denominator (LCD) of two or more fractions is the smallest term or number that is divisible by each of the denominators. Inspect to find this term or number, divide the LCD by the denominator of each fraction, and multiply both the numerator and denominator by the quotient. For example, when changing the $-\text{ctions } \frac{2}{3}$ and $\frac{4}{5}$ to fractions which have an LCD, inspection shows that 15 is the smallest number which is divisible by both 3 and 5. Thus, the $-\text{ctions } \frac{2}{3}$ and $\frac{3}{5}$ become $\frac{10}{15}$ and $\frac{9}{15}$. Similarly, the LCD of $\frac{4xy}{3a^2}$ and $\frac{6z}{4ab}$ is $12a^2b$ because this is the smallest term that is divisible by both $3a^2$ and 4ab. Thus, the fraction $\frac{4xy}{3a^2}$ and $\frac{6z}{4ab}$ become $\frac{16xyb}{12a^2b}$ and $\frac{18za}{12a^2b}$, respectively. When fractions have factors with exponents in the denominators, the highest power of each distinct factor is used to form the LCD. For example, consider the problem of finding the LCD of fractions having the following denominators: x^3y^2z , $x^2y^3z^2$, y^4z^3 , x^2y^4 . The LCD is $x^2y^4z^3$ because x^3 , y^4 , and z^2 are the highest powers of x, y, and z in any one denominator.

Example: Change $\frac{3a}{a^2 - b^2}$ and $\frac{4b}{a^2 - ab - 2b^2}$ to equivalent fractions having an LCD.

Step 1. Factor each denominator into its prime factors:

$$\frac{3a}{a^2 - b^2} = \frac{3a}{(a+b) (a-b)}$$
$$\frac{4b}{a^2 - ab - 2b^2} = \frac{4b}{(a+b) (a-2b)}$$

Step 2. The lowest common multiple of the denominators is the LCD:

$$(a + b) (a - b) (a - 2b)$$

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Step 3. Divide the LCD by the denominators:

 $(a + b) (a - b) (a - 2b) \div (a + b) (a - b) = a - 2b$ $(a + b) (a - b) (a - 2b) \div (a + b) (a - 2b) = a - b$

Step 4. Change $\frac{3a}{(a+b)(a-b)}$ into a fraction having (a+b)

$$(a - b) (a - 2b) \text{ as its denominator:}$$

$$\frac{3a}{(a + b) (a - b)} = \frac{3a (a - 2b)}{(a + b) (a - b) (a - 2b)}$$

Step 5. Change
$$\frac{4b}{(a+b)(a-2b)}$$
 into a fraction having $(a+b)$
 $(a-b)(a-2b)$ as its denominator.
 $\frac{4b}{(a+b)(a-2b)} = \frac{4b(a-b)}{(a+b)(a-b)(a-2b)}$
Step 6. Therefore, $\frac{3a}{a^2-b^2} = \frac{3a(a-2b)}{(a+b)(a-b)(a-2b)}$
and $\frac{4b}{a^2-ab-b^2} = \frac{4b(a-b)}{(a+b)(a-b)(a-2b)}$

67. Addition and Subtraction of Algebraic Fractions

a. Addition. The addition of algebraic fractions is similar to the corresponding operation in arithmetic. To add two or more fractions having a common denominator, add the numerators and place the result over the common denominator. If the fractions have different denominators, convert them to fractions with an LCD. The sum of the fractions is equal to the algebraic sum of the numerators divided by the LCD. Simplify the numerator and reduce the result to its lowest terms. If possible, factor or combine for further simplification.

Example: Find the sum of
$$\frac{2x}{x+y}$$
 and $\frac{2y}{x-y}$.
The LCD is $(x+y)$ $(x-y)$. Therefore,
 $\frac{2x}{x+y} + \frac{2y}{x-y} = \frac{2x(x-y)}{(x+y)(x-y)} + \frac{2y(x+y)}{(x+y)(x-y)}$
 $= \frac{2x(x-y) + 2y(x+y)}{(x+y)(x-y)}$
 $= \frac{2x^2 - 2xy + 2xy + 2y^2}{(x+y)(x-y)}$
 $= \frac{2x^2 + 2y^2}{(x+y)(x-y)}$
 $= \frac{2(x^2 + 2y^2)}{x^2 - y^2}$

b. Subtraction. To subtract two fractions having a common denominator, subtract the numerator of the subtrahend from the numerator of the minuend and place the result over the common denominator. If the denominators are different, find the LCD and subtract, as shown below.

Example: Subtract $\frac{8}{x^2 + 6x - 16}$ from $\frac{9}{x^2 + 7x - 18}$. The LCD is (x - 2)(x + 8)(x + 9). Therefore, $\frac{9}{x^2 + 7x - 18} - \frac{8}{x^2 + 6x - 16}$ $= \frac{9(x + 8)}{(x - 2)(x + 8)(x + 9)} - \frac{8(x + 9)}{(x - 2)(x + 8)(x + 9)}$ $= \frac{9(x + 8) - 8(x + 9)}{(x - 2)(x + 8)(x + 9)}$ $= \frac{9x + 12 - 8x - 12}{(x - 2)(x + 8)(x + 9)}$ $= \frac{x}{(x - 2)(x + 8)(x + 9)}$



68. Multiplication and Division of Algebraic Fractions

a. Multiplication. The process of multiplication of algebraic fractions is the same as in arithmetic. The product of two or more fractions is the product of the numerators divided by the product of the denominators. The operation may be simplified by dividing common factors in the numerator and denominator by the same factor.

Example 1: Multiply
$$\frac{6a^2b}{7x}$$
 by $\frac{21x^2y}{24a^2b}$.
The first numerator and the second denominator are divisible by $6a^2b$; the first denominator and the second numerator are divisible by 7x. Therefore:
1 $3xy$
 $\frac{6a^2b}{7x} \cdot \frac{2ix^2y}{21a^2b} = \frac{3xy}{4}$
1 4
Example 2: Multiply $\frac{a^2 + 2ab + b^2}{a - b}$ by $\frac{a^2 - 2ab + b^2}{a + b}$
 $\frac{a^2 + 2ab + b^2}{a - b} \cdot \frac{a^2 - 2ab + b^2}{a + b} = \frac{(a + b)(a + b)}{a - b} \cdot \frac{(a - b)(a - b)}{a + b}$
 $= \frac{(a + b)(a - b)}{(a - b)(a - b)}$
 $= (a + b)(a - b)$
 $= a^2 - b^2$

b. Division. To divide algebraic fractions, multiply the dividend by the reciprocal of the divisor. Thus, to divide by x, multiply by the reciprocal of x, that is $\frac{1}{x}$. In other words, invert the divisor and proceed as in multiplication.

Example 1: Divide
$$\frac{2a+2b}{a-3}$$
 by $\frac{a^2-b^2}{2a-6}$.
 $\frac{2a+2b}{a-3} \div \frac{a^2-b^2}{2a-6} = \frac{2a+2b}{a-3} \div \frac{2a-6}{a^3-b^3}$
 $= \frac{2(a+b)}{a-b} \div \frac{2(a-b)}{(a+b)(a-b)}$
 $= \frac{2 \cdot 2}{a-b}$
 $= \frac{4}{a-b}$
Example 2: Divide $\frac{z^2-z-6}{z^2-25}$ by $\frac{z^2+z-12}{z^2-z-20}$.
 $\frac{z^2-z-6}{z^2-25} \div \frac{z^2+z-12}{z^2-z-20} = \frac{z^3-z-6}{z^3-25} \div \frac{z^2-z-20}{z^2+z-12}$
 $= \frac{1}{(a-5)(z+5)} \cdot \frac{(a-5)(z+4)}{(z+4)(a-5)}$
 $= \frac{z+2}{z+5}$

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69. Review Problems-Algebraic Fractions

a. Changing Signs of Fractions. Solve for the unknown.

(1)
$$\frac{4x+3}{6} - \frac{x-9}{4} = 5$$

(2) $\frac{x-2}{4} = \frac{1}{2}$
(3) $\frac{r+4}{3} - \frac{r-2}{5} = 2$
(4) $\frac{4x-3}{6x} - \frac{4x+5}{8x} = 2$
(5) $\frac{7t+2}{3} = 3$
(6) $\frac{x-4}{3} + \frac{2x-5}{6} = 8$
(7) $\frac{2r+3}{2} - \frac{3r+2}{4} = 2$
(8) $\frac{7x-4}{3} + \frac{x-5}{5} = \frac{1}{5}$

b. Equivalent Fractions. Supply missing terms.

(1)
$$\frac{4}{8} = \frac{1}{16}$$

(2) $\frac{1}{c} = \frac{?}{cx}$
(3) $\frac{3}{r-s} = \frac{?}{r^4-s^4}$
(4) $\frac{a-s}{1} = \frac{?}{3}$
(5) $\frac{I-6}{I-3} = \frac{?}{(I-3)(I-9)}$

(6) Change
$$\frac{4E^2}{R}$$
 into an equivalent fraction of which the denominator is $2I^2 R$.

(7) Change $\frac{1}{3\pi/c}$ into an equivalent fraction of which the denominator is $2l^2 R$.

c. Lowest Common Denominator. Reduce to equivalent fractions having an LCD.

(1)
$$\frac{1}{R}$$
, $\frac{1}{R^2}$, $\frac{1}{r}$
(2) $\frac{1}{a+1}$, $\frac{x}{a-1}$
(3) $\frac{b}{2x}$, $\frac{c}{3x}$
(4) $\frac{y}{2}$, $\frac{y}{2y+6}$
(5) $\frac{2}{c}$, $\frac{3}{c+1}$

(6)
$$\frac{i}{e-5}$$
, $\frac{i}{2e-10}$
(7) $\frac{y}{c^2-d^2}$, $\frac{z}{c-d}$

d. Addition and Subtraction of Fractions Perform the indicated operations.

(1)
$$\frac{1}{a} + \frac{4}{a} + \frac{7}{a}$$

(2) $\frac{s}{t} + \frac{s+4}{2t} + \frac{s+3}{4t}$
(3) $\frac{3a}{4x^2y} + \frac{5b}{6xy^2}$
(4) $\frac{2}{x^2-1} + \frac{4}{x^2-4}$
(5) $\frac{3c-2d}{4cd^2} + \frac{2c-3d}{3c^2d}$
(6) $\frac{(r+1)(r-3)}{r^2+2r-15} + \frac{(r-2)(r+5)}{r^2+2r-15}$
(7) $3y - \frac{1}{4}$
(8) $\frac{a+b}{a-b} - \frac{a-b}{a+b}$
(9) $\frac{32}{25q^2} - \frac{16}{5q}$
(10) $\frac{3t-2t}{4tr^2} - \frac{2t-3t}{3t^2r}$

e. Multiplication and Division of Fractions Perform the indicated operations.

(1)
$$\frac{9y^{2}}{16} \cdot \frac{2}{8}$$

(2) $\frac{a^{2}}{b^{4}} \cdot \frac{a^{6}}{b^{8}}$
(3) $\frac{3x^{2}}{49y^{2}z} \cdot \frac{7yz^{8}}{9xm}$
(4) $\left(\frac{1}{r} - \frac{1}{s}\right)\left(r - \frac{r^{4}}{s}\right)$
(5) $\frac{2x^{2} - 5xy - 3y^{2}}{x^{2} - 9y^{8}} \cdot \frac{3x + 9y}{10x^{2} + 5xy}$
(6) $\frac{a - b}{a^{2} + 2ab + b^{2}} \cdot \frac{a + b}{a^{2} - 2ab + b^{2}}$
 $\frac{a^{2} - b^{2}}{a^{3}}$
(7) $3z \div \frac{1}{5}$
(8) $\frac{5ba^{8}}{6cd} \div 5b$
(9) $\frac{12z^{2}t}{20uv} \div \frac{3st}{4u^{2}v}$
(10) $\left(e + 2 - \frac{3}{e}\right) \div \left(e + 1 - \frac{2}{e}\right)$

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70. General

Chapter 4 presents exponents and roots consisting only of whole numbers. However, to use exponents and radicals to solve many equations and formulas, a knowledge of additional operations is required.

71. Fractional Exponents

a. General. A fractional exponent is merely another way of expressing the root of a number. For example, the cube root of x usually is written $\sqrt[3]{x}$; however, it also can be written x^{i} . Similarly, $\sqrt{2}$ also can be written 2^{i} .

b. Application. Fractional exponents have a practical value in simplifying algebraic problems. They follow the same rules as exponents that consist of integers, and can be added, subtracted, multiplied, or divided in the same way; thus

$$a^{i} \cdot a^{j} = a^{i} + i = a^{1} = a$$
, and $a^{i} \cdot a^{j} \cdot a^{j} = a^{i} + i + i = a^{1} = a$.

In other words, a^{i} is one of two equal factors of a or the square root of a, and a^{i} is two of three equal factors of a or the square cube root of a; therefore, $a^{i} = \sqrt[3]{a}$ and $a^{j} = \sqrt[3]{a^{i}}$.

c. Changing from Radical Form to Exponential Form. To change a radical expression to exponential form, remove the radical sign and annex a fractional exponent to the radicand (number under the radical sign). The numerator of the fractional exponent is the power of the radicand, and the denominator is the index of the root.

Example 1: Change $\sqrt[4]{a^2}$ to exponential form and simplify.

$$\sqrt[4]{a^2} = (a^2)^{\frac{1}{4}}$$

Multiplying exponents and simplifying:
 $(a^2)^{\frac{1}{4}} = a^{2} \cdot \frac{1}{4} = a^{\frac{2}{4}} = a^{\frac{1}{2}} = \sqrt{a}$
Therefore, $\sqrt[4]{a^2} = \sqrt{a}$

Example 2: Change $\sqrt[3]{8a^2b^3}$ to exponential form and simplify.

$$\sqrt[3]{8a^{2}b^{3}} = \sqrt[3]{2^{3}a^{2}b^{3}} = (2^{3}a^{2}b^{3})^{\frac{1}{3}} = 2^{3 \cdot \frac{1}{3}} a^{3 \cdot \frac{1}{3}} b^{3 \cdot \frac{1}{3}} \\ = 2^{\frac{3}{2}a^{\frac{3}{2}}b^{\frac{3}{2}}} = 2^{1}a^{\frac{3}{2}}b^{1} = 2b (a^{2})^{\frac{1}{3}} = 2b \sqrt[3]{a^{2}}$$

d. Changing from Exponential Form to Radical Form. To change an expression with a fraction exponent to a radical form, make the base of the fractional exponent the radicand, the numerator of the exponent the power of the radicand, and the denominator of the exponent the index of the root.

Example 1: Change 4ⁱ to radical form.

$$4^{i} = \sqrt{4}$$

Example 2: Change 3ⁱ to radical form.
 $3^{i} = \sqrt[3]{3^{i}} = \sqrt[3]{9}$
Example 3: Change $(5a^{2}b)^{i}$ to radical form.
 $(5a^{2}b)^{i} = \sqrt[5]{(5a^{2}b)^{2}}$
 $= \sqrt[5]{25a^{4}b^{2}}$

72. Simplification of Radicals

a. Removing a Factor from the Radicand. The form in which a radical expression is written may be changed without altering its numerical value. Sometimes there is a question as to what actually is the simplest form for an expression. For instance, consider the simplification of an expression such as $\sqrt{1250}$: $\sqrt{1250} = \sqrt{2.5^4} = 5^2\sqrt{2} = 25\sqrt{2}$. The expression $25\sqrt{2}$ usually is accepted as being simpler than $\sqrt{1250}$. As a general rule, the fewer the factors under the radical sign, the simpler the expression. Thus, a radicand may be separated into two factors, one of which is the greater power whose root can be taken. The root of this factor may then be written as the coefficient of a radical of which the other factor is the radicand.

Example 1: Simplify
$$\sqrt{50}$$
.
 $\sqrt{50} = \sqrt{25.2}$
 $= \sqrt{25.2}$

38

=51/2

 $\sqrt{2}$

Example 2: Simplify $\sqrt[4]{32a^7b^4}$.

$$\sqrt[4]{82a^7b^3} = (2^{5}a^7b^3)^{\frac{1}{4}}$$
$$= 2^{\frac{5}{4}}a^{\frac{7}{4}}b^{\frac{3}{4}}$$
$$= 2^{\frac{4}{4}}2^{\frac{4}{4}}a^{\frac{4}{4}}b^{\frac{3}{4}}$$
$$= 2a\sqrt[4]{2a^3}b^{\frac{3}{4}}$$

b. Rationalizing Denominator. Rationalizing a denominator containing a radical means to eliminate the radical in the denominator. For example, to rationalize the expression $\frac{1}{\sqrt[3]{2}}$, first change the denominator into an expression having a fractional exponent; thus, $\frac{1}{\sqrt[3]{2}} = \frac{1}{2^{\frac{1}{2}}}$; then multiply the denominator by a number that will make its exponent equal to 1. This operation eliminates the radical sign below the line. In this case, 2ⁱ is such a factor; thus $2^{i} \cdot 2^{i} = 2^{i} = 2$. Such multiplication can be performed without changing the value of the fraction if the numerator also is multiplied by the same number; thus $\frac{1}{2i} \cdot \frac{2^{i}}{2i} = \frac{2^{i}}{2i+i} = \frac{2^{i}}{2}$. Finally, changing the numerator into radical form, $\frac{\sqrt[3]{2^2}}{2} = \frac{\sqrt[3]{4}}{2}$. Therefore, to rationalize a denominator, multiply both the numerator and the denominator by a number that will make the exponent in the denominator equal to 1; then simplify the radicand in the numerator. The examples below illustrate the method of rationalizing a few different types of denominators.

Example 1: Rationalize
$$\frac{1}{\frac{2}{3^{7}}}$$
.
 $\frac{1}{\frac{2}{3^{7}}} = \frac{1}{\frac{2}{3^{7}}} \cdot \frac{3^{\frac{5}{7}}}{3^{\frac{5}{7}}} = \frac{3^{\frac{5}{7}}}{3} = \frac{\sqrt{3^{5}}}{3}$

Example 2: Rationalize $\sqrt{\frac{1}{8}}$.

First simplify
$$\sqrt{8}$$
.
 $\sqrt{8} = \sqrt{4 \cdot 2} = \sqrt[3]{2} = 2 \cdot 2^{\frac{1}{2}}$
 $\frac{1}{\sqrt{8}} = \frac{1}{2 \cdot 2^{\frac{1}{2}}} = \frac{2^{\frac{1}{2}}}{2 \cdot 2^{\frac{1}{2}} \cdot 2^{\frac{1}{2}}} = \frac{\sqrt{2}}{4}$

Example 3: Rationalize $\frac{1}{\sqrt{7}}$.

Here the square root in the denominator is being multiplied by itself, making the number a perfect square.

$$\frac{1}{\sqrt{7}} = \frac{1}{\sqrt{7}} \cdot \frac{\sqrt{7}}{\sqrt{7}} = \frac{\sqrt{7}}{\sqrt{7}\sqrt{7}} = \frac{\sqrt{7}}{7}$$

c. Practical Application. The processes of the simplication of radicals and rationalization of denominators are useful when computing decimals. It is necessary to know, however, that $\sqrt{2} = 1.414$, $\sqrt{3} = 1.732$, etc. For example, consider the problem of evaluating $\frac{1}{\sqrt{2}}$. One way of evaluating this problem is to divide 1 by 1.414. This evaluation is a long-division problem of some length, however. A much more simple way is to rationalize—thus $\frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$, and dividing 1.414 by 2 gives the result, 0.707.

73. Addition and Subtraction of Radicals

As discussed in paragraph 27b, terms that are alike in all respects, except for their coefficients, are called similar terms. Similarly, radicals that have the same index and the same radicand and differ only in their coefficients are called similar radicals. For example, $-5\sqrt{3}$, $2\sqrt{3}$, and $\sqrt{3}$ are similar radicals. Similar radicals may be added or subtracted in the same way that similar terms are added and subtracted. However, if the radicands are not alike and cannot be reduced to a common radicand, they are dissimilar and addition and subtraction can only be indicated: thus to add or subtract radicals, reduce them to their simplest form, then combine similar radicals, and indicate the addition or subtraction of dissimilar radicals.



Example 1: Perform the indicated operations.

$$4\sqrt{6} - 5\sqrt{6} - \sqrt{6} + 10\sqrt{6} = 8\sqrt{6}$$

Example 2: Add.

$$\sqrt{48a} + \sqrt{\frac{a}{3}} + \sqrt{5a} = 4\sqrt{3a} + \frac{1}{3}\sqrt{3a} + \sqrt{3a}$$
$$= \frac{16}{3}\sqrt{3a}$$

$$\frac{16r^{2}}{16r^{2}} - r\sqrt[3]{4r} + \sqrt[3]{64r^{3}} = \sqrt[3]{(4r)^{3}} - r\sqrt[3]{4r} + \sqrt[3]{(4r)^{3}}$$

$$= (4r)^{\frac{1}{6}} - 4(4r)^{\frac{1}{2}} + (4r)^{\frac{3}{6}}$$

$$= \sqrt[3]{4r} - r\sqrt[3]{4r} + \sqrt[3]{4r}$$

$$= \sqrt[3]{4r} - r\sqrt[3]{4r} + \sqrt[3]{4r}$$

$$= \sqrt[3]{4r} (2 - r)$$

Example 4: Perform the indicated operations.

$$2\sqrt{6} + \sqrt[6]{\frac{2}{3}} - \sqrt[6]{36} = 2\sqrt{6} + \sqrt[6]{\frac{2}{3}} - \frac{3}{3} - \sqrt[6]{6.6}$$
$$= 2\sqrt{6} + \frac{9}{3}\sqrt{6} - \sqrt[6]{6^3}$$
$$= 2\sqrt{6} + 8\sqrt{6} - \sqrt{6}$$
$$- 4\sqrt{6}$$

74. Multiplication of Radicals

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a. Radicals With Same Indexes. Radicals can be multiplied and combined under the same radical sign even though they differ in value, provided the index of the radicals are the same. To multiply a radical expression when radicals are of the same order, first multiply the coefficients, then multiply the radicands, and then simplify, if possible. For example, $2\sqrt{3} \cdot 8\sqrt{5} = 6\sqrt{15}$. If the radicand is a perfect square, simplify the result by extracting the square root. Remember that there are two square roots, one positive and one negative; thus, $6\sqrt{3} \cdot 4\sqrt{3} = 24\sqrt{9} = 24(\pm$ $3) = \pm 72$. When polynomial expressions, either or both of which involve radicals, are to be multiplied, proceed in the same manner as with literal polynominal expressions (par. 48). For example, $(\sqrt{3} + 2\sqrt{5}) \times (\sqrt{3} - 2\sqrt{5}) =$

$$\frac{\sqrt{8} + 2\sqrt{5}}{\sqrt{3} - 2\sqrt{5}} \\
\frac{\sqrt{9} + 2\sqrt{15}}{\sqrt{9} + 2\sqrt{15}} \\
\frac{-2\sqrt{15} - 4\sqrt{25}}{\sqrt{9}} \\
= \pm 3 - 4(\pm 5) \\
= \pm 3 \pm 20 \\
= 3 \pm 20 \text{ or } -3 \pm 20 \\
= \pm 17 \text{ or } \pm 23$$

Example 1: Multiply 2
$$\sqrt[3]{3a}$$
, 5 $\sqrt[3]{4a}$, and 3 $\sqrt[3]{18a}$.
2 $\sqrt[3]{3a} \cdot 5 \sqrt[3]{4a} \cdot 3 \sqrt[3]{18a} = 2 \cdot 5 \cdot 3 \cdot \sqrt[3]{3a} \cdot \sqrt[3]{4a} \cdot \sqrt[3]{18a}$
= $30 \sqrt[3]{216a^3}$
= $30 \cdot 6a$
= $180a$
Example 2: Multiply $\sqrt[3]{8t^3}$ and $\sqrt[4]{4t^3s}$.
 $\sqrt[4]{8t^3} \cdot \sqrt[4]{4t^3s} = \sqrt[4]{32t^3s}$
= $\sqrt[4]{2^4 \cdot 2 \cdot t^4 \cdot t \cdot s}$
= $2t \sqrt[4]{2ts}$

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b. Radicals With Different Indexes. To multiply radicals when the indexes are different, first express them as radicals with a common index (or common fractional exponent) and proceed as in *a* above. The common index is the lowest common multiple of the indexes of the original radicals.

Example 1: Multiply
$$\sqrt{2} \cdot \sqrt[3]{4}$$
.
 $\sqrt{2} \cdot \sqrt[3]{4} = \sqrt{2} \cdot \sqrt[3]{2^{\frac{3}{4}}}$
 $= 2^{\frac{1}{2}} \cdot 2^{\frac{2}{5}}$
 $= 2^{\frac{5}{6}} \cdot 2^{\frac{4}{5}}$
 $= 2^{\frac{6}{5}} \cdot 2^{\frac{1}{5}}$
 $= 2 \cdot 2^{\frac{1}{5}} \text{ or } 2 \sqrt[3]{2}$

Example 2: Multiply
$$\sqrt[3]{4x} \cdot \sqrt[4]{8x^3}$$
.
 $\sqrt[3]{4x} \cdot \sqrt[4]{8x^3} = \frac{14}{(4x)^4} \cdot \frac{19}{(8x^3)^3}$
 $= \frac{12}{(2^3x)^4} \cdot (2^3x^3)^3$
 $= \frac{12}{2^5} \cdot 2^5 \cdot x^4 \cdot x^5$
 $= \frac{12}{2^{17}} \cdot x^{13}$
 $= \frac{14}{2^{12}} \cdot 2^5 \cdot x^{12} \cdot x$
 $= 2x \cdot \frac{19}{2^5} \cdot x$
 $= 2x \cdot \frac{19}{2^5} \cdot x$

75. Division of Radicals

a. Monomial Radical Expressions. The division of radicals is essentially the opposite of multiplication. When radicals are of the same order, the division of two radicals may be expressed under one radical sign—for example, $\frac{\sqrt{4}}{\sqrt{2}} = \sqrt{\frac{4}{2}} = \sqrt{2}$. When radicals are of different orders, they must be expressed as

radicals having the same index or be changed to fractional exponents.

Example 1: Divide
$$\sqrt{15}$$
 by $\sqrt{5}$.
 $\frac{\sqrt{15}}{\sqrt{5}} = \sqrt{\frac{5}{15}} = \sqrt{3}$

Example 2: Divide $\sqrt[3]{x^{\frac{5}{y}}}$ by $\sqrt[3]{y^{7}}$. $\frac{\sqrt[3]{x^{\frac{5}{y}}}}{\sqrt[3]{y^{7}}} = \sqrt[3]{\frac{x^{\frac{5}{y}}}{y^{7}}}$ $= \sqrt[3]{\frac{x^{\frac{5}{y}}}{y^{\frac{5}{y}}}}$

$$= \frac{x}{y^2} \sqrt[3]{x^2}$$

Example 3: Divide $\sqrt{35}$ by $\sqrt{15}$.

$$\frac{\sqrt{35}}{\sqrt{15}} = \sqrt{\frac{35}{15}}$$
$$= \sqrt{\frac{7}{3}}$$
$$= \frac{1}{3}\sqrt{21}$$

Example 4: Divide
$$\sqrt{4ab} \sqrt[3]{2ab}$$
 by $\sqrt[6]{4a^5b^3}$.
 $\sqrt{4ab} \sqrt[3]{2ab}}{\sqrt{4a^5b^3}} = \sqrt[6]{(4ab)^3 \sqrt{(2ab)^3}}}{\sqrt{4a^5b^3}}$
 $= \sqrt[6]{(4ab)^3 \sqrt{(2ab)^3}}$
 $= \sqrt[6]{(4ab)^3 \sqrt{(2ab)^$

b. Binomial Expressions With Radical in Divisor. When the divisor is a binomial in which one or more of the terms contains a square root, division is performed by first rationalizing the divisor. Multiply the numerator and denominator of the fraction by the denominator with the sign between the terms changed; then simplify the numerator and the denominator.

Example 1: Divide 3 by
$$4 + \sqrt{6}$$
.

$$\frac{3}{4 + \sqrt{6}} = \frac{3}{4 + \sqrt{6}} \cdot \frac{4 - \sqrt{6}}{4 - \sqrt{6}}$$

$$= \frac{3(4 - \sqrt{6})}{16 - 6}$$

$$= \frac{3}{10} (4 - \sqrt{6})$$



Example 2: Divide
$$\sqrt{1+x} - \sqrt{1-x}$$
 by $\sqrt{1+x} + \sqrt{1-x}$.
 $\sqrt{\frac{1+x}{\sqrt{1+x}} + \sqrt{1-x}} \frac{\sqrt{1+x} - \sqrt{1-x}}{\sqrt{1+x} + \sqrt{1-x}} \frac{\sqrt{1+x} - \sqrt{1-x}}{\sqrt{1+x} - \sqrt{1-x}}$
 $= \frac{(1+x) - 2\sqrt{1-x^2} + (1-x)}{(1+x) - (1-x)}$
 $= \frac{2 - 2\sqrt{1-x^2}}{2x}$
 $= \frac{1 - \sqrt{1-x^2}}{x}$

- 76. Review Problems—Exponents and Radicals
 - a. Simplify.
 - (1) $2^{\frac{1}{2}}(2^{\frac{1}{2}})$
 - (2) $(8^{\frac{1}{3}})^{\frac{1}{3}}$
 - (3) $\sqrt{50}$
 - (4) $\sqrt[3]{\frac{1}{16}}$
 - (5) $\sqrt{18x-9}$
 - (6) $\sqrt[n]{\frac{6x^{2n}}{y^n}}$
 - (7) $(x^{10}y^5)^{\frac{1}{5}}$
 - (8) $(d^{6}e^{4})^{\frac{3}{4}}$ (9) $\left(\frac{64r^{4}}{s^{3}}\right)^{\frac{1}{3}}$
 - (10) (a⁹b³)²
 - b. Express with radical signs.
 - (1) $4^{\frac{1}{3}}$
 - (2) $a^{\frac{3}{2}}b^{\frac{2}{3}}$
 - (3) $\frac{1}{6^3}$
 - (4) $(8f)^{\frac{1}{2}}$
 - (5) 5 x.5
 - (6) $a^{\frac{3}{4}}c^{1\cdot 5}$
 - (7) $6r^{\frac{1}{3}}$
 - (8) $(8 a^2 b^3)^{\frac{1}{3}}$
 - (9) $({}^{2}r_{1} + {}^{3}r_{2})^{\frac{1}{2}}$

(10)
$$3(x^4y^2)^2$$

- c. Express with fractional exponents.
 - (1) **∜**a[∎]
 - (2) $\sqrt[3]{5x}$
 - (3) $6x \sqrt[3]{d^2}$
 - $(4) \sqrt[5]{z^2}$
 - (5) $\sqrt[4]{3a^3b^5}$
 - (6) $y^3 \sqrt[4]{a^3}$
 - (7) 8 <u>∛3e</u>
 - (8) $9 \sqrt[5]{g^4}$
 - (9) $3b \sqrt[6]{cd^2}$
 - (10) $\sqrt[3]{(x-y)^2}$

d. Simplify by removing suitable factors from radicand.

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- (1) $\sqrt{12}$
- (2) $\sqrt{63}$
- (3) $\sqrt{63x^2}$
- (4) $2\sqrt{72a^2b^4}$
- (5) $\sqrt{60b^2d^2}$
- $(6) \sqrt{8I^2R}$
- (7) $3\sqrt{63p^3z^2}$
- (8) $2dr^2 \sqrt{108dr^4s^3}$
- (9) $5a \sqrt{81a^2b}$
- (10) $16w^2x \sqrt{98w^4x^2y^2z}$

e. Rationalize denominators.

$$(1)\frac{1}{\sqrt{50}}$$

$$(2)\frac{1}{\sqrt{4x}}$$

$$(3)\frac{2a}{\sqrt{3a}}$$

$$(4)\frac{1}{\sqrt[3]{x}}$$

$$(5)\frac{1}{\sqrt[4]{3ax^2}}$$

(6)
$$\frac{1}{\sqrt[3]{3}-2x}$$

(7) $\frac{a+b}{\sqrt[3]{a^{2}}}$
(8) $\frac{a}{\sqrt[3]{a^{2}bc}}$
(9) $\frac{1}{\sqrt[3]{(s+1)^{2}}}$
(10) $\frac{i+3}{\sqrt[4]{(i+3)^{2}}}$
(10) $\frac{i+3}{\sqrt[4]{(i+3)^{2}}}$
(1) $6\sqrt{4}-3\sqrt{4}+2\sqrt{4}$
(2) $6\sqrt{45}-2\sqrt{20}$
(3) $x-\sqrt{\frac{3x^{2}}{4}}$
(4) $\frac{a}{2}+\sqrt{\frac{9a^{2}}{2}}$
(5) $r\sqrt{rst}+rt\sqrt{\frac{5}{rt}}$
(6) $\sqrt{\frac{x+y}{x-y}}-\sqrt{\frac{x-y}{x+y}}$
(7) $\sqrt{5}+3\sqrt{x}+5\sqrt{x}$
(8) $7\sqrt{a}-4\sqrt{5}-2\sqrt{5}$
(9) $4\sqrt{x-y}+3\sqrt{x+y}-8\sqrt{x-y}$
(10) $3\sqrt{125a^{3}b^{3}}+b\sqrt{20a^{3}}-\sqrt{500a^{3}b^{3}}$
g. Find product and simplify.
(1) $3\sqrt{5} \cdot 4\sqrt{2}$
(2) $2\sqrt[3]{9} \cdot 3\sqrt[3]{3}$

(3)
$$4\sqrt[3]{a^{5}b^{4}} \cdot 2\sqrt[3]{ab^{3}}$$

(4) $\sqrt{4z^{3}} \cdot z\sqrt{3z^{3}}$
(5) $\sqrt[3]{4x^{2}y^{3}} \cdot \sqrt[3]{2x^{3}y^{3}} \cdot \sqrt[3]{4xy^{3}}$
(6) $2\sqrt[3]{2pq^{2}r} \cdot \sqrt[3]{4pq^{3}r^{4}} \cdot 3\sqrt[3]{8pq^{2}r^{4}}$
(7) $(\sqrt{a} + \sqrt{b} + \sqrt{c})^{2}$
(8) $a\sqrt{x}(a\sqrt{ax} + x\sqrt{ax} + \sqrt{ax})$
(9) $\sqrt{9} - \sqrt{17} \cdot \sqrt{9} + \sqrt{17}$
(10) $\sqrt[3]{x^{3}y^{6}} \sqrt{256a^{5}}$
h. Divide and simplify.
(1) $\frac{\sqrt{12}}{\sqrt{8}}$
(2) $\frac{\sqrt[3]{625y}}{\sqrt[3]{5y}}$
(3) $\frac{\sqrt[3]{16x^{3}}}{\sqrt{5y}}$
(4) $\frac{3zy}{\sqrt{zy}}$
(5) $\frac{2}{\sqrt{6-2}}$
(6) $\frac{\sqrt{30a}\sqrt[4]{24a^{2}}}{\sqrt{5a}} \sqrt[3]{72a}}$
(7) $\frac{\sqrt{2} + \sqrt{c}}{\sqrt{c} + 2\sqrt{2}}$
(8) $\frac{4\sqrt{3} - 3\sqrt{2}}{\sqrt{6}} \div \frac{\sqrt{10}}{4\sqrt{3} + 3\sqrt{2}}$
(9) $\frac{\sqrt{e^{3} + f^{2} + f}}{\sqrt{e^{2} + f^{2} - f}}$
(10) $\frac{2b + \sqrt{1 - 4b^{2}}}{2b - \sqrt{1 - 4b^{2}}}$

Section VII. IMAGINARY AND COMPLEX NUMBERS

77. Imaginary Numbers

a. Indicated Square Root of Negative Numbers.

(1) In the study of roots to this point, only the roots of positive numbers have been considered. Sometimes a negative expression will appear under the radical. Such an expression originally was given the designation *imaginary number* to distinguish it from real numbers. In electricity and electronics, however, so-called imaginary numbers are used for real physical calculations—the reactance of a large capacitor or inductor must be calculated by using this type of number.

(2) In multiplication, when a real number is multiplied by itself the result is always positive. For example, +5 ⋅ +5 = 25, and -5 ⋅ -5 = 25. Therefore, any number raised to a power having an even exponent will be positive because like signs are being multiplied. However, this is not true for the interpretation of an expression such as √-9. Any negative number can be regarded as the product of a positive number of the same absolute value and -1, and the square root of a negative

number can be written as the square root of a positive number times $\sqrt{-1}$; thus, $\sqrt{-9} = \sqrt{9} \sqrt{-1} = 3\sqrt{-1}$, with $\sqrt{-1}$ being the imaginary number. Most mathematics texts represent the imaginary number $\sqrt{-1}$ by the letter *i*. However, the letter *I* or *i* means current in electrical formulas; therefore, the letter *j*, commonly called the operator *j*, is used in electronics.

Example 1:
$$\sqrt{-36} = \sqrt{(-1)36} = \sqrt{-1} \cdot \sqrt{36} = \sqrt{-1} \cdot 6 = j6$$

Example 2: $\sqrt{-2^2} = \sqrt{(-1)2^2} = \sqrt{-1} \cdot \sqrt{2^2} = \sqrt{-1} \cdot 2 = j2$
Example 3: $-\sqrt{-9a^2} = -\sqrt{(-1)9a^2} = -\sqrt{-1} \cdot \sqrt{9a^2} = -\sqrt{-1} \cdot 3a = -j3a$

b. Powers of Operator j. Imaginary numbers follow the fundamental laws of addition, subtraction, multiplication, and division. They also can be raised to a power; thus, $j^3 = j^2 \cdot j = -1(j) = -j$, and $j^4 = j^2 \cdot j^2 = -1(-1) = 1$. The values of the powers of j are obtained as follows:

 $j^{2} = j \cdot j = \sqrt{-1} \cdot \sqrt{-1} = -1;$ $j^{3} = j \cdot j \cdot j = \sqrt{-1} \cdot \sqrt{-1} \cdot \sqrt{-1} = -1\sqrt{-1} = -j; \text{ and }$ $j^{4} = j \cdot j \cdot j \cdot j = \sqrt{-1} \cdot \sqrt{-1} \cdot \sqrt{-1} \cdot \sqrt{-1} = -1 \cdot -1 = 1; \text{ but }$

 $j^{i} = j \cdot j \cdot j \cdot j \cdot j = j^{i} \cdot j = j^{i} = \sqrt{-1}$, and the whole cycle starts over again. Therefore, j^{i} can be eliminated as many times as it is contained in an expression, reducing the quantity to j, j^{2} , or j^{3} and getting its value from the following:

$$j = j = \sqrt{-1}$$

$$j^{2} = -1$$

$$j^{3} = -j$$

$$j^{4} = 1$$
Example 1: Simplify j^{13} .
$$j^{13} = j^{12} \cdot j = j = \sqrt{-1}$$
Example 2: Simplify j^{27} .
$$j^{37} = j^{24} \cdot j^{3} = j^{3} = -j = -\sqrt{-1}$$

c. Addition and Subtraction of Imaginary Numbers. These numbers may be added or subtracted in the same manner that any algebraic expression is added or subtracted (par. 44). First change the expression to the j form; then treat the j as any other letter in an algebraic expression.

Example 1: Add
$$\sqrt{-25}$$
, $\sqrt{-36}$, and $\sqrt{-9}$.
 $\sqrt{-25} + \sqrt{-36} + \sqrt{-9} = j5 + j6 + j3 = j14$
Example 2: Add $6\sqrt{-2} + 5\sqrt{-8} + 8\sqrt{-18}$.
 $6\sqrt{-2} + 5\sqrt{-8} + 8\sqrt{-18} = j^4\sqrt{2} + j^5\sqrt{8} + j^6\sqrt{18}$
 $= j^6\sqrt{2} + j(5 \cdot 2)\sqrt{2} + j(8 \cdot 3)\sqrt{2}$
 $= (j^6 + j^{10} + j^{24})\sqrt{2}$
 $= j^{40}\sqrt{2}$
Example 3: Subtract $\sqrt{-64}$ from $\sqrt{-36}$.
 $\sqrt{-36} - \sqrt{-64} = j^6 - j^8 = -j^2$
Example 4: Subtract $4\sqrt{-8}$ from $6\sqrt{-18}$.
 $6\sqrt{-18} - 4\sqrt{-8} = j(6 \cdot 3)\sqrt{2} - j(4 \cdot 2)\sqrt{2}$
 $= (j^{13} - j^8)\sqrt{2}$
 $= j^{10}\sqrt{2}$

d. Multiplication of Simple Imaginary Numbers. When multiplying two imaginary numbers, remember that $j^2 = -1$, $j^2 = -j$, and $j^4 = 1$ (b above); then, proceed as with any problem in multiplication (par. 45).

Example 1: Multiply
$$\sqrt{-16}$$
 and $\sqrt{-4}$.
 $\sqrt{-16} \cdot \sqrt{-4} = j^4 \cdot j^2 = j^2 8 = (-1)8 = -8$
Example 2: Multiply $\sqrt{-81}$, $\sqrt{-25}$, and $\sqrt{-49}$.
 $\sqrt{-81} \cdot \sqrt{-25} \cdot \sqrt{-49} = j^9 \cdot j^4 \cdot j^7 = j^3 815 = (-j)815 = -j815$

e. Division of Single Imaginary Numbers. In the division of two simple imaginary numbers, when both the dividend and divisor contain operator j, divide both by j and proceed as with ordinary integers. If a j remains in the denominator, the denominator must be rationalized because the j represents a radical expression. To rationalize, multiply both the numerator and denominator by the imaginary number.

Example 1: Divide
$$\sqrt{-100}$$
 by $\sqrt{-16}$.
 $\frac{\sqrt{-100}}{\sqrt{-16}} = \frac{\frac{1}{2}}{\frac{2}{2}} = 2\frac{1}{4}$

Example 2: Divide 12 by $\sqrt{-6}$.

$$\frac{12}{\sqrt{-6}} = \frac{12}{j\sqrt{6}} = \frac{12 \cdot j\sqrt{6}}{j\sqrt{6} \cdot j\sqrt{6}} = \frac{j12\sqrt{6}}{j^26} = \frac{j2\sqrt{6}}{-1} = -j2\sqrt{6}$$

Example 3: Divide $\sqrt{-3}$ by $\sqrt{-4}$.

$$\frac{\sqrt{-3}}{\sqrt{-4}} = \frac{\frac{1}{\sqrt{3}}}{\frac{\sqrt{2}}{1}} = \frac{\sqrt{3}}{2} \text{ or } \frac{1}{2}\sqrt{3}$$

Example 4: Divide 6 by j.

$$\frac{6}{j} = \frac{6}{j} \cdot \frac{j}{j} = \frac{j6}{j2} = \frac{j6}{-1} = -j6$$

78. Complex Numbers

a. Operations With Complex Numbers. A complex number is a real number united to an imaginary number by a plus or minus sign; thus, 10 - j5, x + jy, and R + jx are complex numbers. Complex numbers are of great importance in alternating-current electricity in which many problems would be difficult to solve without their use. A complex number expressed in the form x + jy may be considered a bi-

nomial; thus, the addition, subtraction, multiplication, and division of complex numbers are reduced to the corresponding operations with binomials in which one term is real and the other imaginary.

b. Addition and Subtraction of Complex Numbers. To add or subtract complex numbers, first combine the real parts, then combine the imaginary parts, and write the results as a binomial with the appropriate sign separating the real and imaginary terms.

Example 1: Add
$$3 + j5$$
 and $5 - j$.
 $(3 + j5) + (5 - j) = 3 + j5 + 5 - j$
 $= 8 + j4$



Example 2: Add
$$6 + \sqrt{-25}$$
 and $8\sqrt{-16}$.
 $(6 + \sqrt{-25}) + (8\sqrt{-16}) = 6 + j5 + (8 \cdot j4)$
 $= 6 + j5 + j32$
 $= 6 + j37$
Example 3: Add $8 + \sqrt{-12}$ and $9 + \sqrt{-75}$.
 $(8 + \sqrt{-12}) + (9 + \sqrt{-75}) = 8 + j2\sqrt{8} + 9 + j5\sqrt{8}$
 $= 17 + j7\sqrt{3}$
Example 4: Subtract 7 - j6 from 3 - j2.
 $(3 - j2) - (7 - j6) = 3 - j2 - 7 + j6$
 $= -4 + j4$
Example 5: Subtract 2 - $8\sqrt{-4}$ from 10 + $\sqrt{-4}$.
 $(10 + \sqrt{-4}) - (2 - 3\sqrt{-4}) = (10 + j2) - (2 - j6)$
 $= 10 + j2 - 2 + j6$
 $= 8 + j8 \text{ or } 8(1 + j)$
Example 6: Subtract 3 + $7\sqrt{-24}$ from 5 + $8\sqrt{-6}$.
 $(5 + 8\sqrt{-6}) - (3 + 7\sqrt{-24}) = 5 + j8\sqrt{6} - [8 + j(7 \cdot 2)\sqrt{6}]$
 $= 5 + j3\sqrt{6} - 3 - j14\sqrt{6}$

c. Multiplication of Complex Numbers. As in addition and subtraction, when complex numbers are multiplied they are treated as ordinary binomials. Remember, however, that $j^2 = -1$.

 $= 2 - j 11 \sqrt{6}$

Example 1: Multiply 3 — j6 by 4 + j2. 3 - j6 4 + j2 12 - j24 $+j6 - j^{2}12$ = j12 - j18 - (-1) (12) = 12 - j18 + 12 = 24 - j18

Example 2: Multiply 8
$$-\sqrt{-5}$$
 by $-2 + \sqrt{-6}$.
8 $- j\sqrt{5}$
 $-2 + j\sqrt{6}$
 $-16 + j2\sqrt{5} + j8\sqrt{6} - j^2\sqrt{30} = -16 + j2\sqrt{5} + j8\sqrt{6} - (-1)\sqrt{30}$
 $= -16 + j2\sqrt{5} + j8\sqrt{6} + \sqrt{30}$
 $= -16 + \sqrt{30} + j(2\sqrt{5} + 8\sqrt{6})$

d. Divisio of Complex Numbers. When dividing complex numbers, the denominator of the expression in its fractional form must first be rationalized (par. 74). To obtain a real number as a divisor, multiply both the numerator and denominator by the complex number of the denominator with its sign changed (called the *conjugate* of the complex number). In carrying out the multiplication, the radical expression is eliminated. Since $j^2 = -1$, the sign of the coefficient of j^2 is changed; the complex number thus becomes a real number to combine with the other real number in the denominator.

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Example 1: Divide
$$3 + j4$$
 by $1 + j$.

$$\frac{3 + j4}{1 + j} = \frac{3 + j4}{1 + j} \cdot \frac{1 - j}{1 - j}$$

$$= \frac{3 + j - j^{2}4}{1 - j^{2}}$$

$$= \frac{3 + j - (1 - 1)4}{1 - (-1)}$$

$$= \frac{3 + j + 4}{2}$$

$$= \frac{7}{2} + j\frac{1}{2}$$

Example 2: Divide 6 by $3 + \sqrt{-2}$.

$$\frac{6}{3+\sqrt{-2}} = \frac{6}{3+j\sqrt{2}} \cdot \frac{3-j\sqrt{2}}{3-j\sqrt{2}}$$
$$= \frac{6(3-j\sqrt{2})}{(3+j\sqrt{2})(3-j\sqrt{2})}$$
$$= \frac{18-j6\sqrt{2}}{9-j^{2}2}$$
$$= \frac{18-j6\sqrt{2}}{11}$$

79. Review Problems—Imaginary and Complex Numbers

- a. Simplify the radical, using operator j.
 - (1) $\sqrt{-75}$
 - (2) **___23**

$$(3) - \sqrt{-64ax^6}$$

(4)
$$-\sqrt{-100x^{4}y^{4}}$$

(5)
$$\sqrt{-\frac{1}{6}}$$

(6)
$$\sqrt[3]{-128x^{1}y^{1}}$$

b. Add.

- (1) -47 + j17 and 63 + j92
- (2) 27 j11 and 14 j11
- (3) 123 j114 and -62 j187
- (4) 44 + j17 and -j7
- (5) 6 + j10 and j1
- (6) 14 + j15 and -16 j62
- c. Subtract.
 - (1) -69 + j432 from 710 + j61
 - (2) 14 j121 from 73 j7
 - (3) 84 j62 from 62 j47
 - (4) -74 j20 from 81 j81
 - (5) -87 j7 from 82 + j16

(6)
$$-9 + j$$
 from $-j7$

d. Multiply.

- (1) $4 + \sqrt{-81}$ by $2 + \sqrt{-49}$ (2) $2 + 2\sqrt{-2}$ by $3 + 3\sqrt{-3}$ (3) 2 - j3 by 2 + j3(4) $(2 - j3)^2$ (5) $(j^4 + j^2 2 + j^2 3 + j4)^2$ (6) 4 - j7 by 8 + j2(7) f + jg by f + jg(8) I + jE by I - jE(9) 8 - j13 by 11 - j12(10) $5 + \sqrt{-16}$ by $7 - \sqrt{-81}$ e. Divide. (1) 1 by 3 + j2(2) 6 + j by j(3) 2 + j3 by 3 - j4
 - (4) $4 + \sqrt{-9}$ by $2 \sqrt{-1}$
 - (5) x + jy by x jy
 - (6) 10 by 1 + j2
 - (7) 3 by 1 j
 - (8) $3 + \sqrt{-25}$ by $4 \sqrt{-4}$
 - (9) 6 j2 by 4 j7
 - (10) I + jE by I jE

80. General

An equation is a statement of equality between two expressions. For example, x + y =12, 3x + 5 = 20, and $3 \cdot 9 = 27$ are equations; therefore, all expressions separated by the equality sign are equations, whether the expressions are algebraic or arithmetical. The expression to the left of the equality sign is called the *left-hand member* of the equality sign is called the *left-hand member* of the equality sign is called the right-hand member. Finding the values of the unknown quantities of an algebraic equation is known as solving the equation, and the answer is called the solution. If only one unknown is involved, the solution is also called the root.

81. Solving Simple Equations

a. Adding Same Quantity to Both Members of Equation. Equal quantities may be added to both sides of an equation without changing the equality.

Example 1: Solve the equation x - 4 =7 for x. x - 4 = 7x - 4 + 4 = 7 + 4x = 11

Example 2: Solve the equation x - 7 = 14

$$x - 7 = 14$$

$$x - 7 + 7 = 14 + 7$$

$$x = 21$$

b. Subtracting Same Quantity From Both Members of Equation. Equal quantities may be subtracted from both sides of an equation.

Example 1: Solve the equation x + 2 = 5for x. x + 2 = 5

$$x + 2 = 0
 x + 2 - 2 = 5 - 2
 x = 3$$

Example 2: Solve the equation x + 5 = 12for x.

c. Multiplying Both Members of Equation by Same Quantity. Both sides of an equation can be multiplied by the same quantity. Example 1: Solve the equation $\frac{x}{8} = 5$ for x.

$$\frac{x}{3} = 5$$
$$\frac{x}{3} \cdot \frac{4}{1} = 5 \cdot 3$$
$$x = 15$$

Example 2: Solve the equation $\frac{z}{2} + \frac{z}{6} =$

4 for z. Multiply both sides of the equation by 9.

$$\begin{pmatrix} z \\ \overline{\sharp} \\ \overline{\sharp} \\ 1 \end{pmatrix} + \begin{pmatrix} z \\ \overline{\sharp} \\ \overline{\sharp} \\ 1 \end{pmatrix} = 4 \cdot 9 3z + z = 36 4z = 36 z = 9$$

d. Dividing Both Members of Equation by Same Quantity. Both sides of an equation may be divided by the same quantity.

Example 1: Solve the equation 3x = 12 for x.

$$3x = 12$$
$$\frac{3x}{3} = \frac{12}{3}$$
$$x = 4$$

Example 2: Solve the equation PV = RT for T.

$$PV = RT$$

$$\frac{PV}{R} = \frac{KT}{K}$$

$$T = \frac{PV}{R}$$

82. Solving More Difficult Equations

a. Transposition. The process of adding to or subtracting from both members of an equation (par. 81a and b) can be shortened by shifting a term or terms from one side of the equation to the other and changing the signs. This operation is called transposition.

Example 1: Solve the equation 6x + 4 = x - 16 for x

$$\begin{array}{r}
16107 \ x.\\
6x + 4 = x - 16\\
6x - x = -16 - 4\\
5x = -20\\
x = -4
\end{array}$$



Example 2: Solve the equation
$$5a - 7 = 2a + 2$$
 for a.
 $5a - 7 = 2a + 2$
 $5a - 2a = 2 + 7$
 $3a = 9$
 $a = 3$

b. Equations With Fractions. In solving a fractional equation, first find the LCD and multiply both members of the equation, term by term; then perform the operations in paragraph 81 or a above.

Example 1: Solve the equation $\frac{x}{2} + \frac{x}{3} = 10$ for x. $\frac{x}{2} + \frac{x}{3} = 10$ $\frac{3x + 2x}{6} = 10$ $\frac{5x}{6} = \frac{10}{1}$ 5x = 60

x = 12

Example 2: Solve the equation $\frac{x-1}{2} = 3$ + x for x. $\frac{x-1}{2} = 3 + x$ $\frac{x-1}{2} = \frac{3+x}{1}$ 1(x-1) = 2(3+x)x-1 = 6 + 2xx-2x = 6 + 1-x = 7x = -7

Example 3: Solve the equation
$$\frac{2}{x-2}$$
 +
 $\frac{2}{x+4} = \frac{4}{x-3}$ for x.
 $\frac{2}{x-2} + \frac{2}{x+4} = \frac{4}{x-3}$
 $\frac{2(x+4) + 2(x-2)}{(x-2)(x+4)} = \frac{4}{x-3}$
 $\frac{2x+8+2x-4}{(x-2)(x+4)} = \frac{4}{x-3}$
 $\frac{4x+4}{(x-2)(x+4)} = \frac{4}{x-3}$
 $(4x+4)(x-3) = 4(x-2)(x+4)$
 $4x^2 - 8x - 12 = 4(x^2 + 2x - 8)$
 $4x^2 - 8x - 12 = 4x^2 + 8x - 32$
 $4x^2 - 8x - 8x = -32 + 12$
 $-16x = -20$
 $16x = 20$
 $x = \frac{20}{16} = \frac{5}{4} = 1\frac{1}{4}$
 $x = 1\frac{1}{4}$

83. Written Equations

Many practical problems are stated in words and must be translated into symbols before the rules of algebra can be applied. There are no specific rules for the translation of a written problem into an equation of numbers, signs, and symbols. The following general suggestions may be helpful in developing equations:

a. From the worded statement of the problem, select the unknown quantity (or one of the unknown quantities) and represent it by a letter, such as x. Write the expression, stating exactly what x represents and the units in which it is measured.

b. If there is more than one unknown quantity in the problem, try to represent each unknown in terms of the first unknown.

Example 1: In simple problems, an equation may be written by an almost direct translation into algebraic symbols; thus, Seven times a certain voltage diminished by 3

	Ē		3
gives the same r	esult as the	voltage increa	sed by 75,
=			+ 75 .
Solving the equa	tion:		
7E - 3 = E	7 + 75		
7E - E = 7	5 + 3		
6E = 7	8		
E = 1	3		

Check:
$$7(13) - 3 = 13 + 75$$

 $91 - 3 = 13 + 75$
 $88 = 88$

Example 2: A triangle has a perimeter of 30 inches. The longest side is 7 inches longer than the shortest side, and the third side is 5 inches longer than the shortest side. Find the length of the three sides.

Let x = length of shortest side. x + 7 = length of longest side. x + 5 = length of third side. x + (x + 5) + (x + 7) = 30Solving the equation: x + x + 5 + x + 7 = 30 3x + 12 = 30 3x = 30 - 12 3x = 18 x = 6 = shortest side. 6 + 5 = 11 = third side. 6 + 7 = 13 = longest side.

84. Simultaneous Equations

a. Definition. Simultaneous equations are two or more equations satisfied by the same sets of values of the unknown quantities. They are used to solve a problem with two or more unknown quantities.

b. Example. Assume that the sum of two numbers is 17, and that three times the first number less two times the second number is equal to 6. What are the numbers? In setting up equations for this problem, let x equal the first number and y equal the second number. The first equation is x + y = 17, and the second equation is 3x - 2y = 6. This problem can be solved in three ways: by substitution, by addition, or by subtraction. All three methods are explained below.

(1) Substitution.

```
x + y = 17 \text{ or } x = 17 - y
Substitute x = 17 - y in the second
equation:
3x - 2y = 6
3(17 - y) - 2y = 6
Remove the parentheses:
51 - 3y - 2y = 6
Transpose:
-5y = 6 - 51
-5y = -45
5y = 45
y = 9
```

Substitute y = 9 in the first equation and solve for x: x + y = 17 or x + 9 = 17Transpose: x = 17 - 9x = 8(2) Addition.

x + y = 17

$$3x-2y=6$$

Before adding, change the y in the first equation to 2y so that the y terms drop out when added; thus, the first equation must be multiplied by 2.

$$2x + 2y = 34$$
$$3x - 2x = 6$$
$$5x = 40$$
$$x = 8$$

Substitute x = 8 in the first equation and solve for y:

$$x + y = 17 \text{ or } 8 + y = 17$$

 $y = 17 - 8$
 $y - 9$

(3) Subtraction.

Before subtracting, multiply the first equation by 3 so that the x terms drop out when subtracted.

$$3x + 3y = 51$$

$$3x-2y=6$$

Subtract the second equation from the first equation:

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$$3x + 3y = 51$$

$$-3x + 2y = -6$$

$$5y = 45$$

$$y = 9$$

Substitute y = 9 in the first equation and solve for x: Refer to (1) and (2) above.

c. Additional Examples. If the coefficients of the unknowns differ (for example, 3x and x and 2y and 4y), multiply one or both equations to establish equal coefficients for one of the unknowns (x or y).

Example 1: Solve for x and y if 3x + 2y = 7 and x + 4y = 9.

$$3x + 2y = 7$$
$$x + 4y = 9$$

Multiply the first equation by 2 so that 2y will become 4y:

$$6x + 4y = 14$$
$$x + 4y = 9$$

Subtract the second equation from the first equation:

$$6x + 4y = 14$$

$$-x - 4x = -9$$

$$5x = 5$$

$$x - 1$$

Solve for y by substituting x = 1 in either equation.

Example 2: Solve for x and y if 2x + 3y = 24 and 3x - 4y = 2.

$$2x + 3y = 24$$
$$3x - 4y = 2$$

Multiply the first equation by 4 to change 3y to 12y; multiply the second equation by 3 to change 4y to 12y; then add the two equations:

$$8x + 12y = 96$$

$$9x - 12x = 6$$

$$17x = 102$$

$$x = 6$$

Solve for y by substituting x = 6 in either equation.

85. Solving Formulas

a. The Formula. A formula is a rule or law that states a scientific relationship. It can be

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expressed in an equation by using letters, symbols, and constant terms. For example, a formula in electricity (par. 184) states that the voltage across any part of a circuit is equal to the product of the current and resistance of that part of the circuit. In formula form, this is expressed as E = IR, where E is the voltage or difference in potential expressed in volts, I is the current expressed in amperes, and R is the resistance expressed in ohms.

b. Solving the Formula. To solve a formula, perform the same operations on both members of an equation until the desired unknown can be isolated in one member of the equation. If the numerical values for some variables are given, substitute in the formula and solve for the unknown as in any other equation.

Example 1: Solve the formula
$$T = \frac{12(D-d)}{l}$$
 for D.
 $T = \frac{12(D-d)}{l}$ for D.
 $T = \frac{12D-12d}{l}$
Multiply both sides by l:
 $Tl = 12D - 12d$
Transpose and change signs:
 $12D = Tl + 12d$
Divide both sides by 12:
 $\frac{12D}{12} = \frac{Tl}{12} + \frac{12d}{12}$
 $D = \frac{Tl}{12} + d$
Example 2: Given the formula for elect

Example 2: Given the formula for electrical power, $P = I^2 R$, find the value of P in watts when I =15.4 amperes and R = 25.7 ohms. $P = I^2 R$ Substituting the given numerical

Substituting the given numerical values for I and R:

$$P = (15.4)^{2} \times 25.7$$

= 237.16 × 25.7
= 6,095 watts

Example 3: Given the formula for the total resistance of two resistors in parallel,

$$R_r = rac{R_1 R_2}{R_1 + R_2}$$
, solve for R_r in ohms when



 $R_1 = 40$ ohms and $R_2 = 60$ ohms.

$$R_{T}=\frac{R_1R_2}{R_1+R_2}$$

Substitute the given numerical values for R_1 and R_2 :

$$R_{r} = \frac{40 \times 60}{40 + 60} \\ = \frac{2,400}{100} \\ = 24 \text{ ohms}$$

86. Review Problems—Equations

a. Solve for the unknown quantity in each of the following:

- (1) y + 12 = 15
- (2) $\frac{n}{8} = \frac{1}{4}$
- (3) 0.63s = 53.55
- $(4) \quad 47x 17 = 235 37x$
- (5) (10m + 6) (11 15m) = 14m + 6m
- (6) x + y = 33x + 2y = 1
- (7) a 3b = 0
- 5a 4b = 11
- (8) 7x 5y = 15x + y = 19

(9)
$$4m - 2n = 2$$

 $3m + n = 14$

(10) 3r - 9s = 156r - 7s = 41

b. Solve the following formulas for the quantity indicated:

(1) Fd = Wh for d

(2)
$$v^2 = v_0^2 + 2gh$$
 for g

(3)
$$F = \frac{w}{y} a \text{ for } a$$

(4)
$$H = \frac{D^2 N}{2.534} \text{ for } N$$

(5)
$$F = \frac{22.5 Bll}{10^5} \text{ for } l$$

c. Solve the following linear equations for the unknown quantity:

- (1) 7(2x-6)-8=10x+10
- (2) 10(x-2) 10(2-x) = 4x 40
- (3) 9.8a 9.4 = 6.8a + .6

$$(4) \ 2x + 3 + \frac{11x - 11}{3} = 22$$

$$(5) \ 3R + (2R - 4) = 6R - 10(R - 2)$$

$$(6) \ \frac{5Z}{4} + 2Z = \frac{3 + Z}{3} - 7Z$$

$$(7) \ -(5x + 15) = 5x + 21 - \frac{5(2 - x)}{2}$$

$$(8) \ \frac{11y - 13}{25} + \frac{17y + 4}{21} + \frac{19y + 3}{7} = .$$

$$28 \frac{1}{7} + \frac{5y - 25\frac{1}{3}}{4}$$

$$(9) \ \frac{4X_L}{5} - 6X_L + 2 = \frac{X_L}{4}$$

$$(10) \ (x - 1)(x + 1) + x(1 - x) = 4x(2x + 1) - 8x(x - 2)$$

d. Solve the following sets of simultaneous linear equations:

(1) 5x - 2y = 103x - y = 7(2) 6a + 15b = 696a - 6b = 14(3) x - 3y = -172x+6y=50(4) 6x - 8y = 203x + 2y = -14(5) -4x + y = 138x - 5y = -29(6) $2I + \frac{2Z-22}{3} = 30$ $\frac{3I-15}{4}+6Z=108$ $(7) \frac{2}{x} + y = 1$ $\frac{1}{x}+2y=1\frac{1}{4}$ (8) $\frac{a}{3} + \frac{b}{4} = 1$ $\frac{a}{5} + \frac{b}{2} = -\frac{4}{5}$ (9) $\frac{5}{r} + \frac{2}{n} = -1$ $\frac{3}{x} + \frac{1}{y} = 1$ (10) Solve for r and s: $(a-b)r + (a+b)s = a^2 - b^2$ (a+b)r - (a-b)s = 2ab

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- e. Solve the following problems:
 - (1) Three times a voltage (E) diminished by 2 is equal to that voltage. What is the voltage?
 - (2) The sum of two resistances in series is R ohms. One resistance is 20 ohms. Give the algebraic expression for the other.
 - (3) If a certain voltage (E) is tripled and the result is diminished by 220 volts, the remainder is equal to the original voltage. What is the voltage?
 - (4) When two resistors are connected in series, the total resistance (R) is the sum of the two resistances. If one resistor is 25 ohms and the total resist-

ance is 100 ohms, what is the value of the other resistor?

- (5) The current (1) from a battery is divided among three circuits. The first circuit draws 20 milliamperes more than the second circuit, and the second circuit draws 20 milliamperes more than the third circuit. If the total current drawn is 240 milliamperes, what is the current in each circuit?
- (6) Solving by the formula $I = \frac{E}{R}$, how

Nmuch current (I) does an electric circuit having a resistance (R) of 20 ohms take if the voltage (E) is 110 volts?

Section IX. QUADRATIC EQUATIONS

87. General

A quadratic equation is one which can be reduced to the form $ax^2 + bx + c = 0$ where a, b, and c are known and x is the unknown quantity. In other words, a quadratic equation contains the square of the unknown quantity, such as x^2 , but no higher power. For example, $3x^2 + 5x - 2 = 0$ and $x^2 - 4x + 3 = 0$ are quadratic equations. The form $ax^2 + bx + c = 0$ is called the general quadratic equation.

88. Pure Quadratic Equations

A pure quadratic equation is obtained from the general quadratic equation when b is equal to zero and the middle term (bx) does not appear. The equation then becomes $ax^2 + c = 0$. The pure quadratic equation has two roots that are equal in absolute value but have opposite signs. As discussed in paragraph 49, all numbers have two square roots. The equation $x^2 - 36 = 0$ is a pure quadratic equation since there are two numbers which, when substituted for x, will satisfy the equation. Thus $(+6)^2 - 36 = 0$ since 36 - 36 = 0; also, $(-6)^2 - 36 = 0$ since 36 - 36 = 0. Therefore, $x = \pm 6$.

Example: Solve the equation $x^2 - 5 = 20$ for x. $x^2 - 5 = 20$ $x^2 = 25$ $x = \pm 5$

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$$(\pm 5)^2 - 5 = 20$$

 $25 - 5 = 20$
 $20 = 20$

89. Solution by Factoring

a. Quadratic equations are found in many applications of even the simplest nature. For example, suppose that a sheet of metal is to be cut so that it has an area of 30 square inches, and that the length of the piece will be 1 inch longer than the width. With x representing the unknown width and x + 1 the unknown length, x(x + 1) equals the area; therefore, the equation that must be satisfied is x(x + 1) = 30. By performing the indicated multiplication and subtracting 30 from each side, the equation now can be written in the form of a quadratic equation, as $x^2 + x - 30 = 0$.

b. To solve this equation, factor the left-hand side into the equivalent equation: (x - 5)(x + 6) = 0. The product of two factors is zero if either of the factors is zero (par. 53). Thus, each factor is set equal to zero and solved for the unknown. The equation is satisfied if x - 5 = 0 or x = 5. Note that the equation also is satisfied if x + 6 = 0. This illustrates an important fact concerning quadratic equations: Every quadratic equation has two solutions. Only one solution, however, may be appropriate when quadratic equations are used to solve

actual problems. The quadratic equation only gives two *possible* solutions—the *actual* solution must be determined by referring to the facts in the original problem.

P-					
Example 1:		equation	$x^2 - 2x =$		
	0 for <i>x</i> .				
	$x^2 - 2x = 0$				
	Factoring:				
	x(x-x)	2) =: 0			
	x = 0				
	or <i>x</i> —	-2 = 0			
		x = 2			
	•		roots of the		
	equation a	$x^2 - 2x =$: 0.		
Example 2:	Solve the	equation	$2x^2 - 3x - 3$		
	5 = 0 for	x .			
	$2x^2 - 3$	x - 5 = 0)		
	Factoring:				
	(2x -	5) $(x + 1)$) = 0		
	80	x +	1 = 0		
	and		x = -1		
	or	2x -	5 = 0		
		2	x = 5		
	and	;	$x=\frac{r}{2} \text{ or } 2\frac{1}{2}$		
		1			
	Thus, -1 and $2\frac{1}{2}$ are the roots				
	of the equation $2x^2 - 3x - 5 = 0$.				

90. Solution by Completing the Square

In solving quadratic equations, the method of factoring described in paragraph 89 usually is best if the factors are immediately apparent by inspection. When the values of the unknown are not whole numbers or rational fractions, a quadratic equation can be solved more easily by the method of *completing the square*. This method also is used to derive the quadratic formula (par. 91). For example, to solve the equation $2x^2 - x - 2 = 0$ by completing the square, proceed as follows:

a. Transpose all terms involving x to the left-hand side of the equation and all other terms to the right-hand side. The equation is now in the form $2x^2 - x = 2$, or $x^2 - \frac{1}{2}x = 1$. When using this method, the coefficient of the squared term must be unity (one).

b. Add a number to both sides of the equation so that the left-hand side will be a perfect trinomial square. To determine this number, divide the coefficient of the middle term $(-\frac{1}{2})$ by 2 and square the resulting number.

$$x^{2} - \frac{1}{2}x = 1$$
$$x^{2} - \frac{1}{2}x + \frac{1}{16} = 1 + \frac{1}{16}$$

c. Replace the trinomial square on the lefthand side of the equation with the square of a binomial.

$$(x-\frac{1}{4})^2=\frac{17}{16}$$

d. Extract the square root of both sides of the equation.

$$x - \frac{1}{4} = \frac{\pm\sqrt{17}}{4}$$

Thus, $x = \frac{1 \pm \sqrt{17}}{4}$

91. The General Quadratic Equation

a. General. Another method of solving quadratic equations consists of substitution in a formula derived from the general quadratic equation (b below). The general quadratic equation is in the form $ax^2 + bx + c = 0$, and any quadratic equation can be written in this form (par. 87). Thus, in the equation $2r^2 + 5r - 3 = 0$, a = 2, b = 5, and c = -3. Similarly, in the equation $9x^2 - 25 = 0$, a = 9, b = 0, and c = -25.

b. Deriving Formula for Solving any Quadratic Equation. Since the general quadratic equation, $ax^2 + bx + c = 0$, represents any quadratic equation, the roots of this equation will represent the roots of any quadratic equation; then, if the general quadratic equation is solved for the unknown values, the roots obtained will serve as a formula for finding the roots of any quadratic equation. The formula is derived from the general form by the method of completing the square; thus, given the general equation $ax^2 + bx + c = 0$, proceed as follows:

(1) Divide through by the coefficient a.

$$x^2+\frac{bx}{a}+\frac{c}{a}=0$$

(2) Subtract the term $\frac{c}{a}$ from both sides of the equation.

$$x^2+\frac{bx}{a}=-\frac{c}{a}$$

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This operation prepares the equation for the addition of a quantity to both sides of the equation that will make the left-hand side a perfect square. This quantity is obtained by dividing the coefficient of the x term by 2, and squaring the quotient. Since the coefficient of the x term is $\frac{b}{a}$, the quantity to be added to both sides of the equation is $(\frac{b}{2a})^2$, or $\frac{b^2}{4a^2}$.

(3) Add $\frac{b^2}{4a^2}$ to both sides of the equation.

$$x^2 + \frac{bx}{a} + \frac{b^2}{4a^2} = \frac{b^2}{4a^2} - \frac{b^2}{a}$$

(4) Factor the left-hand side of the equation, and add the fraction on the righthand side.

$$(x+\frac{b}{2a})^2=\frac{b^2-4ac}{4a^2}$$

(5) Take the square root of both sides of the equation.

$$x+\frac{b}{2a}=\pm\frac{\sqrt{b^2-4aa}}{2a}$$

(6) Subtract $\frac{b}{2a}$ from both sides of the equation.

$$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

(7) Collect the terms on the right-hand side of the equation.

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

This equation is known as the quadratic formula. The two roots of any quadratic equation can be obtained by substituting in the formula the particular values of a, b, and c.

92. Solution by the Quadratic Formula

In practical problems, pure quadratic equations (par. 88) are seldom found, and solution by factoring (par. 89) can be used only occasionally. However, any quadratic equation can be solved by the method of completing the square (par. 90)—the method used to derive the quadratic formula (par. 91). This method is unnecessary, however, when the values for a, b, and c for any quadratic equation can be substituted in the formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Example 1: Solve the equation $2x^2 - 6x + 3$ = 0 by using the quadratic formula.

$$2x^{2} - 6x + 3 = 0$$

$$a = 2; b = -6; c = 3$$

Substituting in the formula:

$$x = \frac{-b \pm \sqrt{b^{2} - 4ac}}{2a}$$

$$x = \frac{-(-6) \pm \sqrt{36 - (4)(2)(3)}}{4}$$

$$= \frac{6 \pm \sqrt{12}}{4}$$

$$= \frac{3 \pm \sqrt{3}}{2}$$

Thus, $x = \frac{3 \pm \sqrt{3}}{2}$ or $x = \frac{3 - \sqrt{3}}{2}$.
Check: $x = \frac{3 \pm \sqrt{3}}{2}$

$$x = \frac{3 \pm \sqrt{3}}{2} = 2.366$$

Substituting in the equation :

ubstituting in the equation:

$$2(2.366)^{2} - 6(2.366) + 8 = 0$$

 $11.20 - 14.20 + 3 = 0$
 $14.20 - 14.20 = 0$

$$x = \frac{3 - \sqrt{3}}{2}$$
$$x = \frac{3 - 1.732}{2} = .634$$

Substituting in the equation: $2(.634)^2 - 6(.634) + 3 = 0$ 2(.40) - 3.80 + 3 = 03.80 - 3.80 = 0





Example 2: Solve the equation $8x^2 + 5x - 2 = 0$ by using the quadratic formula.

$$8x^{2} + 5x - 2 = 0$$

 $a = 3; b = 5; c = -2$
Substituting in the formula:

$$x = \frac{-b \pm \sqrt{b^{2} - 4ac}}{2a}$$

 $x = \frac{-5 \pm \sqrt{25 - (4)(3)(-2)}}{(2)(3)}$
 $= \frac{-5 \pm 7}{6}$
Thus, $x = \frac{1}{2}$ or $x = -2$.

Thus, $x = \frac{1}{3}$ or $x = -\frac{1}{3}$

Check: $x = \frac{1}{3}$

Substituting in the equation:

$$3\left(\frac{1}{3}\right)^{2} + 5\left(\frac{1}{3}\right) - 2 = 0$$
$$\frac{3}{9} + \frac{5}{3} - 2 = 0$$
$$\frac{1}{3} + \frac{5}{3} - 2 = 0$$
$$\frac{1}{3} + \frac{5}{3} - 2 = 0$$
$$\frac{1}{3} + \frac{5}{3} - \frac{6}{3} = 0$$
$$\frac{6}{3} - \frac{6}{3} = 0$$

Substituting in the equation:

$$3(-2)^{2} + 5(-2) - 2 = 0$$

 $12 - 10 - 2 = 0$
 $12 - 12 = 0$

93. Character of the Roots

a. The values for unknowns that are not

whole numbers or rational fractions are called irrational roots. A rational number is a number which can be expressed as the ratio of two integers. For example, 9, $\frac{7}{3}$, $\frac{1}{8}$, and $\sqrt{16}$ are rational numbers. Any whole number is rational since it is the quotient of itself and unity; thus, $9 = \frac{9}{1}$. Numbers such as $\frac{7}{3}$ and $\frac{1}{8}$ are often referred to as rational fractions. A radical is rational if it can be expressed as the quotient of two whole numbers. Thus $\sqrt{16}$ is rational since $\sqrt{16} = 4 = \frac{4}{1}$. A number such as $\sqrt{3}$ which cannot be written as the ratio of two whole numbers is called irrational. Rational and irrational numbers, taken together, make up the system of real numbers. Any number, such as $3 + \sqrt{3}$, which contains a radical sign that cannot be removed also is considered irrational. Roots of quadratic equations are real if a minus sign does not occur under a radical. For example, x = 5 is a real root—roots such as x = $\frac{3+\sqrt{8}}{2}$ or $x = \frac{3-\sqrt{8}}{2}$ are real, but irrational.

b. One important fact to be remembered when using the quadratic formula is that the expression under the radical sign, $b^2 - 4ac$, must be regarded as a whole before the square root can be taken. The quantity $b^2 - 4ac$ is called the *discriminant* of the quadratic equation. Many things can be learned about a quadratic equation merely by inspecting the discriminant. If the value of the discriminant is positive, real roots will be obtained when the equation is solved. These roots are either rational or irrational—rational when the discriminant is a perfect square, irrational when it is not. The roots are equal only when the value of $b^2 - 4ac$ is zero. When $b^2 - 4ac$ is negative, the square root will be that of a negative number and the roots will be imaginary.

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c. In summary, a quadratic equation always has two solutions. The solutions will be:

Real and equal______if $b^2 - 4ac$ equals 0. Unequal but real_____if $b^2 - 4 ac$ is positive. Real and rational_____if $b^2 - 4ac$ is a perfect square. Imaginary______if $b^2 - 4ac$ is negative.

94. Review Problems—Quadratic Equations

a. Solve by factoring.

- (1) $2x^2 + 3x = 0$
- (2) (x-4)x = 0
- (3) $(x+3)\frac{x}{3}=0$
- $(4) \quad \frac{1}{2}x^2 + \frac{1}{2}x = 0$
- (5) $2x^2 128 = 0$
- (6) $\frac{1}{3}x^2 2 = 1$
- (7) $3x^2 25 = 2$
- (8) 3x(x-2) + 2x(3-x) = 16
- (9) $x^2 x 42 = 0$
- (10) $x^2 13x + 12 = 0$
- b. Solve by completing the square.

(1)
$$x^2 + 3x - 1 = 0$$

- (2) $y^2 + 6y 10 = 0$
- (3) $E^2 4E + 1 = 0$

- (4) $2E^2 + 8E 8 = 0$ (5) $8H^2 - 8H = 5$ (6) $5L^2 - 5 = 2L^2 - 10L$
- (7) $14r^2 28r 42 = 0$
- (8) $\frac{1}{v^2} \frac{4}{v} = 2$
- (9) $y^2 5 = 2y$
- (10) $8x^2 8x = 8$
- c. Solve by using the quadratic formula.
 - (1) $a^2 + 2a + 1 = 0$
 - (2) $12y^2 6 + y = 0$
 - $(3) \ 0 = 1 + 5E + 3E^2$
 - $(4) \ 6I^2 + I 12 = 0$
 - (5) $2c^2 + 4c 6 = 0$
 - (6) $15R^2 = 22R + 5$
 - $(7) \ \frac{Z-2}{Z} = 1-Z$

(8)
$$\frac{3}{r-2} = 1 + \frac{2}{r+3}$$

(9)
$$\frac{3x+2}{2x+4} = \frac{x+2}{2x}$$

(10)
$$0 = 6 - \frac{b-2}{b+2} + \frac{b-1}{b+1}$$

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CHAPTER 6

GRAPHS

Section I. BASIC CHARACTERISTICS OF GRAPHS

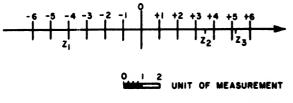
95. General

A graph is a pictorial representation of the relation between two or more quantities. In many instances, problems are more clearly understood when solved graphically than when solved by other methods. Numerical data taken from an experiment or calculations derived from a formula require interpretation, and a curve on a graph depicting such data will provide a picture that shows at a glance how one factor or function depends on another.

96. The Number Line

a. In figure 15, on a straight line of indeterminate length, a point 0 has been chosen from which to measure distances. The point 0 is called the origin. A unit of measurement also has been chosen, and positive and negative integers have been marked off and labeled. The usual choice for a positive direction is shown by the arrow. On the number line, Z_1 corresponds to -4, Z_2 corresponds to $3\frac{1}{2}$, and Z_3 corresponds to 5.2.

b. Consider a number x as corresponding to a point a distance of x units from 0. If x is positive, the point will be in the direction of the arrow from 0; if x is negative, the point will be in the opposite direction from 0. The relative size of two numbers is indicated graphically by the relative positions on the number



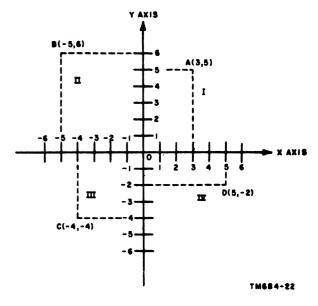
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line of points corresponding to the two numbers. For example, if x is greater than w, the point corresponding to x will be to the right of the point corresponding to w; if x is less than w, the point corresponding to x will be to the left of the point corresponding to w. The number of units from the origin to the point representing a certain number, regardless of direction, is the absolute value (par. 35) of the number.

97. Rectangular Coordinates

a. In the preceding paragraph, a relationship was given between numbers and points on a straight line. A similar relationship can be established between a pair of numbers and a point on a plane. In figure 16, two number lines are drawn perpendicular to each other at their origins for form a set of axes. The horizontal axis is commonly called the x axis;





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the vertical axis is commonly called the y axis. Any point on the plane can be located with reference to the two axes: It must lie a certain number of units to the left (negative) or to the right (positive) of the y axis; and it must lie a certain number of units above (positive) or below (negative) the x-axis. To locate a point with reference to the set of axes, it is necessary only to know the x value and the yvalue of the point. These two values are known as the coordinates of the point. The x value, called the abscissa, is written first; the y value, called the ordinate, follows. The two numbers are separated by a comma and are usually inclosed in parentheses. Thus, in figure 16, the correct notation for the coordinates at point A is (3,5), because the x value is 3 and the y value 5.

b. The axes divide the graph into four sections, or quadrants, identified by the Roman numerals I, II, III, and IV in figure 16. The signs of the abscissa and the ordinate in each of the quadrants are given in the chart below.

Quadrant	Abecisea	Ordinate	
I	+	+	
п	-	+	
III	—	-	
IV	+	-	
IV	+		

98. Plotting Points

The procedure for locating points by their coordinates is called *plotting* the points. To plot the point D (5, -2) in figure 16, for example, erect a perpendicular on the x axis five units to the right of the y axis; then erect a perpendicular to the y axis two units below the

Section II. GRAPHING EQUATIONS

100. Graphing Linear Equations

a. General. An equation in the first degree in two unknowns is called a *linear equation* since its graph is a straight line. For example, x + y = 5, 2x + y = 12, and x - 6y = 6 are linear equations. An equation is said to be of the first degree in two unknowns if only the first power of either unknown is involved and x axis; the point of intersection of these two perpendiculars is the point D (5,-2).

99. Review Problems—Plotting Points

a. Plot each of the following points and state the quadrant, if any, in which each lies:

- (1) (4,2)
 (2) (4,-2)
 (3) (-1,3)
 (4) (6,-1)
 (5) (3,0)
- (6) (0,---3)
- (7) (-15,-27)
- $(8) (3\frac{1}{2}, 4\frac{1}{3})$
- (9) (5.6,--6.5)

b. Plot the points in the following chart and connect them by straight segments in the order of increasing values of x:

x	3	2	-1	0	1 .	2	3	4
¥	18	8	2	0	2	8	18	32

c. Plot the points in the following chart and sketch a smooth curve passing through them in the order of increasing values of x:

x	3	2	1	0	1	2	8
¥		8	5	8	7	7	17

d. If y = 2x - 3, plot the points for which x = 4, 2, 1, 0, -1, -2, and -4 after finding the corresponding values of y.

e. Draw the triangle of which the vertices are (-2,6), (3,2), and (0,-3).

f. Draw the quadrilateral of which the vertices, connected in the order given, are (1,3), (-3,4), (-2,-5), and (3,-2).

if neither of the unknowns appears in a denominator.

- b. Plotting Graphs of Linear Equations.
 - (1) The first step in plotting the graph of a linear equation (or of any other equation or formula) is to set up a table of values for both unknowns that will satisfy the equation. In the equa-



tion x + y = 5, for example, it is apparent that there are a number of values for x and y that will satisfy the equation. For any number assigned to x, there is a corresponding number for y which will satisfy the equation. Consider that 4 and -4 will be the maximum plus and minus values for x. Using the values 4, 3, 2, 1, 0, -1, -2, -3, and -4 for x, the equation is solved for y at each value of x. These are arranged in tabular form as shown on figure 17.

(2) Each of these pairs of values gives a point on a graph. Consider each of the corresponding points as coordinates—the value of x the abscissa and the value of y the ordinate. The line joining these points (fig. 17) is the graph of the equation x + y = 5. Note that the coordinates for any two points are sufficient to determine its graph. Therefore, plotting the coordinates for any two points is sufficient to determine the graph of a first degree equation. Plotting a third point. however, will serve as a check, for if the three points are not on the same straight line, one of them is in error.



a. When two *independent* linear equations contain the same two related unknowns, there will be an unlimited number of solutions for each equation. However, there can be only one set of values that will satisfy both equations. Determining the one set of values is known as the simultaneous solution of the two independent equations.

b. Graphically, the two equations can be solved simultaneously by plotting them on the same graph and locating their point of intersection (if there is one). For example, consider the graphical solution of the equations 3x - 2y= 0 and 3x + 2y = 6. Selecting 6 and -6 as the maximum plus and minus values for x and using x = 4 as a checkpoint, the coordinates for both equations are determined. For the equation 3x - 2y = 0, these coordinates are (6.9), (4,6), and (-6,-9); for the equation 3x +2y = 6, (6,--6), (4,--3), and (--6,12). These coordinates are plotted on an axis and a line is drawn joining the plotted points of each equation (fig. 18). The graphs of the two independent linear equation cross at point P, where x = 1 and y = 1.5. To check the graphical solution of the equations, substitute these values for x and y in the original equations. Since they satisfy both equation, the graphical solution is correct.

c. If two dependent equations are plotted on a graph, their lines will coincide. For example, the equations x + y = 4 and 2x + 2y = 8

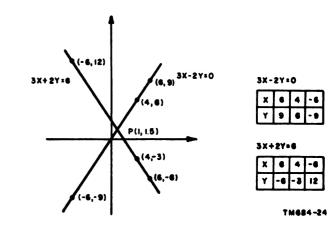


Figure 18. Graphical solution of simultaneous linear equations.

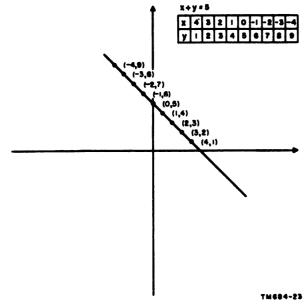


Figure 17. Graph of linear equation.





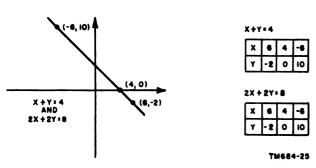


Figure 19. Graph of dependent simultaneous linear equations.

are dependent, since they can be reduced to identical forms. Selecting the same plus and minus values for x and the same checkpoint as in b above, the coordinates for both equations are found to be (6,-2), (4,0), and (-6,10). Plotted on a graph, both equations form a single line (fig. 19).

d. Simultaneous equations that have no common solution are called *inconsistent*. No solution is possible for the equations x + y = 3and x + y = 5, because there are no values for x and y which, when added together to make 3, will also equal 5. Using 6 and -6 as maximum plus and minus values for x, and using x = 4as a checkpoint, the coordinates for equation x + y = 3 are found to be (6, -3), (4, -1),and (-6,9); the coordinates for x + y = 5are (6, -1), (4, 1), and (-6, 11). Plotted on a graph, these equations form parallel lines (fig. 20).

102. Graphing Quadratic Equations

a. The Dependent Variable. In graphing a quadratic equation, only two values, or points, for plotting the equation can be obtained by finding the roots of the equation (par. 88). These values do not give a complete picture of the equation. To get a continuous graph, a dependent variable is introduced. This variable, usually identified by the letter y, gets its name from the fact that it depends on another quantity for its value. For example, in the equation $y = x^2 - 6x + 5$, the value of y depends on the value of x; therefore, y is a dependent variable. The quantity on which y depends is called the independent variable. A more accurate designation for the dependent variable is f(x), meaning function of x. Using

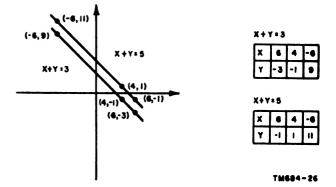


Figure 20. Graph of inconsistent simultaneous linear equations.

this designation, the equation given above would be written $f(x) = x^2 - 6x + 5$. If the independent variable in the equation were z, the equation would be written $f(z) = z^2 - 6z + 5$.

b. Graphical Solution of Quadratic Equations. In the original equation f(x) = $x^2 - 6x + 5$, different values are substituted for the unknown to find the corresponding values of the function; thus if x equals -1, the equation becomes $f(-1) = (-1)^2 - 6(-1) + 6(-1)^2 - 6(-1) + 6(-1)^2 - 6(-1) + 6(-1)^2 - 6(-1)^$ 5 = 12; if x equals zero, the equation becomes f(0) = 0 - 0 + 5 = 5; if x equals 1, the equations becomes $f(1) = (1)^2 - 6(1) + 5 = 0$, etc. Compile a table of enough values to make it possible to plot the equation, as shown in figure 21. The graph of the function crosses the xaxis at two points, 1 and 5, which give a graphical solution of the equation $x^2 - 6x + 5 = 0$. The equation also may be solved by factoring, as follows:

$$(x-1) (x-5) = 0$$

 $x-1=0$ and $x-5=0$
 $x=1$ and $x=5$

Thus, the solutions or the roots of the equation are obtained when f(x) = 0. These roots represent the points where the graph of $f(x) = x^2 - 6x + 5$ crosses the x-axis.

c. Properties of Functions. In addition to the original equation, $f(x) = x^2 - 6x + 5$, consider three equations that differ in one respect —their constant terms are not the same. For example:

$$f(x) = x^{2} - 6x + 8$$

$$f(x) = x^{2} - 6x + 9$$

$$f(x) = x^{2} - 6x + 12$$

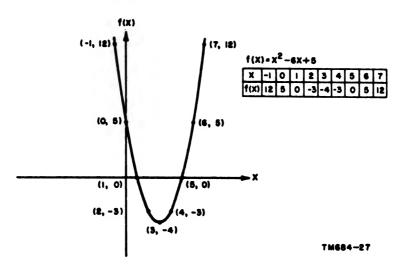


Figure \$1. Graph of function of quadratic equation.

The graphs of the four corresponding functions have interesting properties and can be studied more advantageously when plotted on the same graph, as shown in figure 22.

> (1) The function of $x^2 - 6x + 5$ crosses the horizontal or x-axis at two points, 1 and 5. These points indicate that the roots of the equation are x = 1and x = 5. To compare this information with the discussion on quadratic equations in chapter 5, the discriminant of the equation must be investigated. The discriminate of $x^2 - 6x + 5$ is $(b^2 - 4ac) =$ $(36 - 4 \cdot 1 \cdot 5) = 36 - 20 = 16.$ Referring to the summary of the character of roots in paragraph 93, the roots are real and rational. To prove this, substitute the value of the discriminant in the quadratic formula.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-(-6) \pm \sqrt{16}}{2}$$

$$x = \frac{6+4}{2} = 5 \text{ or } \frac{6-4}{2} = 1$$

Thus, the discriminant is a perfect square and the roots are real and rational.

(2) The function of $x^2 - ox + 8$ crosses the horizontal axis at 2 and 4, indicating that the roots are x = 2 and x = 4. Calculating the discriminant, $(b^2 - 4ac) = (36 - 4 \cdot 2 \cdot 2) =$ 36 - 32 = 4. Thus, the discriminant is a perfect square and will give real and rational roots.

- (3) The function of $x^2 6x + 9$ touches the x-axis at only one point, 3. Thus, both roots of the equation are x = 3. Calculating the discriminant, $(b^2 - 4ac) = (36 - 4 \cdot 9) = 0$, which indicates that the roots are real and equal. Check the graph of this equation (fig. 22); it will be seen that the curve just touches the x-axis at one point. Thus, the root x = 3 must be counted twice and may be called a double root.
- (4) The equation f(x) x² 6x + 12 has a discriminant equal to (36 - 4 · 12) or -12. Solving for the roots of this equation,

$$x = \frac{6 \pm \sqrt{-12}}{2} = 3 \pm \sqrt{-3}.$$

This is imaginary, but the meaning becomes apparent when the graph of the function of the equation is inspected. The plot does not cross the x-axis and, therefore, both roots must be imaginary.

- d. Minimum Value of a Quadratic.
 - (1) The minimum value of a quadratic function will occur at $x = \frac{-b}{2a}$ when

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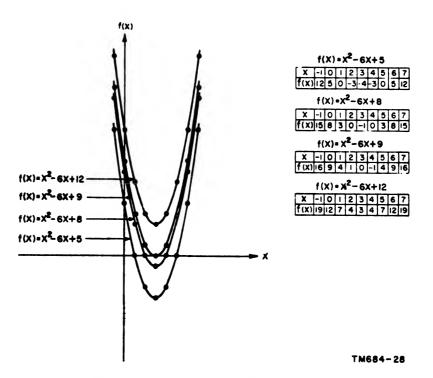


Figure 22. Properties of functions.

the general quadratic equation $ax^2 + bx + c = y$ (par. 91) defines the coefficients a and b. This relation can be checked by calculating the value of x at which the minimum value of the function $x^2 - 6x + 5$ occurs and comparing this calculated value with the plot of the equation (fig. 21 or 22). Thus,

$$x = \frac{-b}{2a} = -\frac{(-6)}{2(1)} = \frac{6}{2} = 3,$$

and the minimum value of the function $x^2 - 6x + 5$ occurs at x = 3. Checking the graph verifies this statement. The minimum value of the functions $x^2 - 6x + 8$, $x^2 - 6x + 9$, and $x^2 - 6x + 12$ also occurs at x = 3.

(2) To find the value of the function at the minimum point, substitute for x. The minimum occurs at $x = \frac{-b}{2a}$; therefore, substitute $\frac{-b}{2a}$ for x in the function of the general quadratic equation.

$$f(x) = ax^{2} + bx^{2} + c$$

$$= a\left(\frac{-b}{2a}\right)^{2} + b\left(\frac{-b}{2a}\right) + c$$

$$= \frac{b^{2}}{4a} - \frac{b^{2}}{2a} + c = \frac{b^{2}}{4a} - \frac{2b^{2}}{4a} + c$$

$$= \frac{-b^{2}}{4a} + c$$

Thus, to find the value of the function $f(x) = x^2 - 6x + 5$ at the minimum point:

$$f(x) = \frac{-b^2}{4a} + c = \frac{-36}{4} + 5 = -9 + 5 = -4$$

This method can be used to find the minimum value of the function if the value of x at which the minimum occurs is not known. However if it is known that the minimum value occurs at x = 3, merely substitute this value for x in the original equation.

$$f(x) = x^{2} - 6x + 5$$

= 9 - 6 \cdot 3 + 5
= 14 - 18
$$f(x)\min = -4$$

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(3) Note that in all cases where the word minimum is used, the word maximum is applicable if the equation y = f(x)is such that its graph has a maximum instead of a minimum. If the equation were $f(x) = 3 + 6x - x^2$, the minus sign preceding the term x^2 would indicate that the curve has a maximum.

e. Practical Application. The methods of analysis presented in c and d above can be used for some very important relationships in applied electricity and electronics. It may be used, for example, to find the load resistance of a circuit in terms of the circuit components necessary to obtain maximum power transfer (par. 216).

103. Review Problems—Graphs

a. Plot the graphs of the following linear equations:

(1)
$$2x - 5 = y$$

(2) $5 - 2x = y$

(2)
$$5 - 2x =$$

- (3) y = 5x
- (4) 8x + 2y = 18
- (5) 5x 5y = 20
- (6) 8x + y + 14 = 0

b. Plot the graphs of the following sets of simultaneous equations:

- (1) 2x + 3y = 123x - y = 7(2) x + y = 95x + y = 17(3) x + 5y = 223x - 2y = -2(4) 3x - 2y = 0x - 5y = 13(5) 6x + 2y = 124y + 2y = 10
- (6) x 2y = 0y = 1 + x

c. Find the roots of the following quadratic equations to the nearest tenth by plotting their graphs:

- (1) $y^2 2y 2 = 0$
- (2) $x^2 1 + x = 0$
- (3) $9 t^2$
- (4) $x^2 2x + 2 = 0$
- (5) $x^2 5x + 3 = 0$
- (6) $10 3x x^2 = 0$

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104. General

The technique of using powers of 10 can greatly simplify mathematical calculations. A number containing many zeros to the right or to the left of the decimal point can be dealt with much more readily when put in the form of powers of 10. For example, .0000037 \times .000021 can be handled more easily when put in the form $3.7 \times 10^{-6} \times 2.1 \times 10^{-6}$.

105. Table of Powers of 10

The table below gives some of the values of the powers of 10. In a whole number, the exponent is positive and equals the number of zeros following the 1; in decimals, the exponent is negative and equals one more than the number of zeros immediately following the decimal point.

Number	Power of 10	Number	Power of 10
.000001	106	1	100
.00001	10-5	10	101
.0001	10-4	100	102
.001	10-3	1,000	103
.01	10-2	10,000	104
.1	10-1	100,000	105
		1,000,000	106

106. Expressing Numbers in Scientific Notation

Any number written as the product of an integral power of 10 and a number between 1 and 10 is said to be expressed in *scientific notation*.

Example 1: $81,000,000 = 8.1 \times 10,000,000 = 8.1 \times 10^7$

Example 2: $600,000,000 = 6 \times 100,000,000$ = 6×10^8

Example 3: .000,000,000,9 = $9 \times .000,000,-000,1 = 9 \times 10^{-10}$

107. Addition and Subtraction of Numbers in Scientific Notation

Numbers expressed in scientific notation can only be added or subtracted if the powers of 10 are the same. For example, 3×10^5 can be added to 2×10^5 to get 5×10^5 ; however, 3×10^8 cannot be added to 2×10^5 because the powers of 10 are not the same. The number 3×10^8 can be changed to 30×10^5 , however, and it can then be added to 2×10^5 to obtain 32×10^5 . The answers to problems solved by using scientific notation can be left in the exponential form. In the examples below, however, the answers are converted to the decimal form to aid in understanding this technique.

Example 1: Add
$$450,000$$
 and $763,000$.
 $450,000 + 763,000 = 4$

$$+763,000 = 45 \times 10^4 + 76.3 \times 10^4$$

= 121.3 × 10⁴

Example 2: Add .000,068,25 and .000,007,54. .000,068,25 + .000,007,54 = $6825 \times 10^{-8} + 754 \times 10^{-8}$ = 7579×10^{-8} = .000,075,79 Example 3: Subtract .000,004,33 from .000,05. .000,05 - .000,004,33 = $5000 \times 10^{-8} - 433 \times 10^{-8}$ = 4567×10^{-8}

= .000,045,67

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108. Multiplication of Numbers in Scientific Notation

The general rules covering the multiplication of radicals (par. 74) also apply in the multiplication of numbers that are expressed in scientific notation.

> Example 1: Multiply 100,000 by 1,000. $100,000 \times 1,000 = 10^{5} \times 10^{3} = 10^{5+3} = 10^{8} = 100,000,000$ Example 2: Multiply 25,000 by 5,000. $25,000 \times 5,000 = 2.5 \times 10^{4} \times 5 \times 10^{8} = 2.5 \times 5 \times 10^{4+3}$ $= 12.5 \times 10^{7}$ = 125,000,000Example 3: Multiply 1,800, .000015, 300, and .0048. $1,800 \times .000015 \times 300 \times .0048$ $= 1.3 \times 10^{3} \times 1.5 \times 10^{-5} \times 3 \times 10^{2} \times 4.8 \times 10^{-5}$ $= 1.8 \times 1.5 \times 3 \times 4.8 \times 10^{3-5+2-3}$ $= 38.88 \times 10^{-3}$ = .03888

109. Division of Numbers in Scientific Notation

The general rules covering the division of radicals (par. 75) also apply in the division of numbers that are expressed in scientific notation.

Example 1: Divide 75,000 by .0005.

$$\frac{75,000}{.0005} = \frac{75 \times 10^3}{5 \times 10^{-4}} = \frac{75}{5} \times 10^{3+4} = 15 \times 10^7 = 150,000,000$$
Example 2: Divide 14,400,000 by 1,200,000.

$$\frac{14,400,000}{1,200,000} = \frac{144 \times 10^8}{12 \times 10^6} = \frac{144}{12} = 12$$
Example 3: Divide 98,100 by .0025, 180, and 1,090,000.

$$\frac{98,100}{.0025 \times 180 \times 1,090,000}$$

$$= \frac{9.81 \times 10^4}{2.5 \times 1.8 \times 10^2 \times 1.09 \times 10^6}$$

$$= \frac{9.81 \times 10^4}{2.5 \times 1.8 \times 10^9 \times 10^{-3+2+6}}$$

$$= \frac{9.81 \times 10^4}{4.905 \times 10^6}$$

$$= 2 \times 10^{-1}$$

$$= .2$$

110. Finding the Power or Root of a Number in Scientific Notation

The general rules covering powers and roots (pars. 71 and 72) also apply to numbers expressed in scientific notation.

Example 1: Find the square root of 144,000,000

$$\sqrt[2]{144,000,000} = \sqrt[3]{144 \times 10^6}$$

 $= 12 \times 10^3$
 $= 12,000$

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Example 2: Find the cube root of .000,008. $\sqrt[3]{.000.008} = \sqrt[3]{8 \times 10^{-4}}$ $= 2 \times 10^{-3}$ = .02 Example 3: Square 15,000. $(15,000)^2 = (15 \times 10^3)^2$ $= 225 \times 10^{6}$ = 225,000,000Example 4: Find the square root of (160,000)³. $\sqrt[3]{160.000^3} = (160,000)^{3/2}$ $= (16 \times 10^4)^{3/2}$ $= 64 \times 10^6$ = 64.000.000Example 5: Find the square root of $\frac{86,900}{3,560,000}$. $\sqrt{\frac{86,900}{3,560,000}} = \sqrt{\frac{8.69 \times 10^4}{3.56 \times 10^6}}$ $=\sqrt{2.44\times10^{-2}}$ $= 1.56 \times 10^{-1}$ = .156

111. Review Problems-Powers of 10

In the following problems, leave the answer in powers of ten:

a. Convert the following numbers to powers of 10 and add:

- (1) 1,245,000 + 368,000
- (2) 79,000 + 421,000
- (3) .000,007,66 + .000,054

b. Convert the following numbers to powers of 10 and subtract:

- (1) 333,400 22,500
- (2) .000,068 .000,049
- (3) .000,004,89 .000,000,398

c. Convert the following numbers to powers of 10 and multiply:

(1) $446,000 \times 200$

(2) 7,700 \times .003,2

(3) .000,096 imes .000,33

(4) $.003,66 \times 4,000,000$

d. Convert the following numbers to powers of 10 and divide:

- (1) $668,000 \div 4,000$
- (2) $88.445,000 \div .000,55$
- (3) $.000,963 \div .000,009$
- (4) $.006,93 \div 21$

e. Convert the following numbers to powers of 10 and perform the indicated operations:

- (1) $\sqrt[3]{64,000,000}$
- (2) $\sqrt[3]{.000,169}$
- (3) .0033
- (4) $27,000^{2/3}$

LOGARITHMS

112. General

Many lengthy mathematical operations may be accomplished more easily through the use of logarithms. With logarithms (also called logs), multiplication of numbers is reduced to a simple process of addition, division becomes a process of subtraction, raising a number to a power becomes simple multiplication, and extraction of roots is done by simple division.

113. Definition

The logarithm of a given number is the power to which another number (called the base) must be raised to equal the given number. The word "logarithm" has the same meaning as the word "exponent."

Example: Find the logarithm of 1,000 to the base 10.

From the definition, the logarithm of a number (1,000) is the power (x) to which another number called the base (10)must be raised to equal the given number (1,000).

Thus, $10^{2} = 1,000$. Since $10^{3} = 1,000$, then:

 $10^{z} = 10^{s}$ and by inspection:

$$x = 3$$

Therefore, the logarithm of 1,000 to the base 10 equals 3 or $\log_{10} 1,000 = 3$.

114. Types of Logarithms

a. Common Logarithms. Common logarithms use the number 10 as a base. They are so universally used that the 10 usually is omitted; the answer in paragraph 113 could be log 1,000 = 3. Some values of common logarithms are included in the table below. The common logarithm of any number between

these values consists of the logarithm of the smaller number plus a decimal. For example, the log of a number between 100 and 1,000, such as 157, consists of the log of the smaller number (10) plus a decimal. The log of 157 is 2.1959.

log 1	= 0	log .001	= -1
log 10	= 1		= -2
log 100	= 2		= -3
log 1,000 log 10,000	= 3 = 4	log .0001	<u> </u>

b. Natural Logarithms. Natural logarithms are based upon the irrational number e, and are written both as log, and ln. Natural logarithms are used in special applications and as such are not explained further in this text.

115. Parts of Logarithms

a. Logarithms are divided into two parts, the integral and the decimal. The integral part is known as the *characteristic*, and the decimal part is called the *mantissa*.

(1) The characteristic of any number is one less than the number of digits to the left of the decimal point. Thus, the characteristic for the number 3 is 1 ---1 or zero, since there is one number to the left of the decimal point. The characteristic for 30, with two numbers to the left of the decimal point, is 2 - 1 or 1. Similarly, the characteristic for 300 is 2, and the characteristic for 3,000 is 3. The characteristic of the log of a decimal is negative and is based upon the position of the first rational number to the right of the decimal point. If there are no numbers to the left of the decimal point. the characteristic is negative. In the number .327, for example, the first

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rational number is in the first decimal place and the characteristic is -1; in the number .03, the first rational number is in the second decimal place and the characteristic is -2. Similarly, the characteristic for .003 is -3, and the characteristic for .0003 is -4.

(2) The mantissa is always the same for a given sequence of integers, regardless of where the decimal point appears among them. Thus, the mantissa is the same for 1570, 157, 15.7, 1.57, .157, and .0157, and the logs of these numbers differ only in respect to their characteristics. Their logarithms, respectively, are 3.1959, 2.1959, 1.1959, 0.1959, -1.1959 and -2.1959.

b. The mantissa is always positive—even when the characteristic is negative. This fact poses a problem of notation, and also complicates the addition and subtraction of logarithms.

- (1) In the notation of logarithms, to say that log .157 is -1.1959 is not strictly true, for what we mean to say is -1plus .1959. To overcome this problem, the minus sign is generally written above the characteristic, and is made long enough to cover the entire negative portion of the logarithm. More properly, therefore, log .157 is written $\overline{1}.1959$.
- (2) In the addition and subtraction of logarithms, the complication can be removed by expressing the negative characteristic in a positive manner; more precisely, by adding a large enough number to the characteristic and by subtracting the same number from the entire logarithm. Thus, the log of .157 is written 9.1959-10, and the log of .0157 is written 8.1959—10.

116. Finding a Logarithm

A table of common logarithms is given in appendix III. Note, however, that the table contains only the mantissas of logarithms. The characteristic must be obtained, in each instance, by following the rules given in paragraph 115a(1).

Example 1: Find the logarithm of 333.

Determine the characteristic of 333. The characteristic is 3-1, or 2.

Determine the mantissa of 333. In the table of common logarithms, look down the N column for the number 33. The mantissa for 333 is in this horizontal row in the column headed by the number 3. The mantissa is .5224.

Log 333 = 2.5224.

Example 2: Find the logarithm of .127.

- Determine the characteristic of .127. The characteristic is —1 or 9. _____ 10.
 - Determine the mantissa of .127. In the table of common logarithms, look down the N column for 12. The mantissa for 127 is in this horizontal row in the column headed by the number 7. The mantissa is .1038.

Log .127 = 9.1038 - 10.

117. Logarithmic Interpolation

The table of common logarithms given in appendix III is adequate if the given number has three or less integers. If it has four or more integers, however, it is necessary to interpolate—that is, to find the proportional part of the difference between the logarithms shown in the table.

Example 1: Find the logarithm of 2.369.

Step 1. The characteristic of 2.369 is 0. Since the mantissa for this number cannot be found in the table, it is necessary to interpolate. Look for the mantissas of the numbers next lower and higher than 2369. The mantissa of the number 2360 is .3729 and the mantissa of the number 2370 is .3747. Since 2369 lies between 2360 and 2370, the mantissa of

2369 must lie between .3729 and .3747. This may be written: log 2360 = .3729 log 2369 = .3729 + x log 2370 = .3747

- Step 2. Set up the proportions. The difference between 2369 and 2360 is 9. The difference between 2370 and 2360 is 10. Therefore, the desired mantissa is $\frac{9}{10}$ of the difference between these two. Let the difference between the mantissa of 2369 and 2360 equal x. The difference between .3747 and .3729 is .0018. The proportion is $\frac{x}{.0018}$.
- Step 3. Solve the problem.

$$\frac{9}{10} = \frac{x}{.0018} \\ 10x = .0162 \\ x = .0016$$

- Step 4. Since the value of x is .0016, the mantissa of 2369 is .3729 + .0016 or .3745. Therefore, log 2.369 = 0.3745.
- Example 2: Find the logarithm of .017234.

log 17200 = .2355log 17234 = .2355 + xlog 17300 = .2380

Step 2. Let the difference between the mantissas of 17234 and 17200 equal x. The equation is as follows:

$$\frac{34}{100} = \frac{x}{.0025}$$

100x = .0850
x = .00085 = .0009

Step 3. Since the value of x is .0009, the mantissa of 17234 is .2355 + .0009 or .2364. Therefore, log .017234 = 8.2364-10.

118. Reading Antilogarithms

The process of finding the antilogarithm (also called antilog), consists of determining the number from which the logarithm was derived. This process is essentially the reverse of finding the logarithm (par. 116). Consequently, the location of the decimal point is determined from the characteristic, and the numerical value of the number is determined from the mantissa.

Example 1: Find the antilog of 1.8954.

- Step 1. Since the characteristic of the logarithm is 1, there will be two digits to the left of the decimal point in the number.
- Step 2. Look in the table for the mantissa, .8954. The number given for .8954 is 786.
- Step 3. Count off two digits from the left and insert the decimal point. The antilog of 1.8954 is 78.6.
- Example 2: Find the antilog of 7.0828-10.
- Step 1. Since the characteristic of the logarithm is -3, the first significant figure will be in the third decimal place.
- Step 2. Look for the mantissa .0828 in the table. The number given for .0828 is 121.
- Step 3. Add two zeros to the right of the decimal point and before the first significant figure. Thus, the antilog of 7.0828-10 is .0021.

119. Antilogarithmic Interpolation

If the mantissa of a logarithm does not appear in the table, it is necessary to interpolate.

Example 1: Find the antilog of 2.7654.

- Step 1. Since the characteristic of the logarithm is 2, there will be three digits to the left of the decimal point in the number.
- Step 2. The mantissa in the table lower than .7654 is .7649. The num-

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	as a mantissa is 583.
Step 4.	Set up the proportions. The dif- ference between .7654 and .7649 is .0005; the difference between .7657 and .7649 is .0008. The proportional difference is $\frac{.0005}{.0008}$
	or $\frac{5}{8}$. The difference between
	583 and 582 is 1. This can be written: antilog $.7649 = 582$
	antilog $.7654 = 582 + x$ antilog $.7657 = 583$
Step 5.	Let x equal the difference be- tween the number represented by the mantissa .7654 and the number 582. The equation is as follows: $\frac{5}{8} = \frac{x}{1}$ $8x = 5$ $x = .625$
Step 6.	The number is $582 + .625$. Since there are three digits to the left of the decimal point, the antilog of 2.7654 is 582.625.
Example 2:	Find the antilog of 6.7166—10.
Step 1.	Since the characteristic of the logarithm is —4, the first ra- tional number will be in the fourth decimal place.
Step 2.	The mantissa in the table lower than .8166 is .8162; the number with .8162 as a mnatissa is 655.
Step 3.	The mantissa in the table higher than .8166 is .8169; the number with .8169 as a mantissa is 656.
Step 4.	The difference between .8162 and .8166 is .0004; the difference between .8169 and .8162 is .0007. The proportional dif-
	ference is $\frac{.0004}{.0007}$ or $\frac{4}{7}$. The dif-
	ference between 656 and 655 is 1. This may be written:
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ber with .7649 as a mantissa is

The mantissa higher than .7654 is .7657. The number with .7657 antilog .8162 = 655antilog .8166 = 655 + xantilog .8169 = 656

Let x equal the difference be-Step 5. tween the number represented by the mantissa .8166 and the number 655. The equation is as follows:

$$\frac{4}{7} = \frac{x}{1}$$
$$7x = 4$$
$$x = .57$$

Step 6.

The number is 655 + .57. Since the first rational figure is in the fourth decimal place, the antilog of 6.7166-10 is .00065557.

120. Addition and Subtraction of Logarithms

Logarithms are added and subtracted arithmetically. Since every mantissa is positive (par. 115b), however, every negative characteristic should be expressed as a posiitve (par. 115b).

Example 1: Add the logarithms 3.7493 and **2.4**036. .

$$3.7493 \\ + 2.4036 \\ - 6.1529$$

Example 2: Add the logarithms 3.4287 and 6.3982.

$$\begin{array}{r}
 3.4287 \\
 + 4.3982 \\
 \hline
 7.8269 \\
 -10
 \end{array}$$

Example 3: Add the logarithms 8.9324-10, 7.2812-10, 5.4138-10, and

9.9918-10. 8.9324-10 7.2812-10 5.4138-10 9.9918-10 31.6192-40 _(30 ----30) 1.6192-10

Example 4: Subtract the logarithm 9.1245 from the logarithm 6.3058.

> To subtract a larger logarithm from a smaller logarithm, add 10 or a multiple of 10 to the smaller logarithm, and subtract the same number from the loga-

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rithm by writing that number with a minus sign to the right of the logarithm. The number chosen for this purpose should be the least that will cause the smaller logarithm to exceed the larger.

$$\begin{array}{r} 16.3058 - 10 \\ - 9.1245 \\ \hline 7.1813 - 10 \\ \end{array}$$

Example 5: Subtract the logarithm 3.7980-10 from 2.8686. When subtracting a negative logarithm from a positive logarithm, where that part of the characteristic of the negative logarithm to the left of the mantissa is larger than the characteristic of the positive logarithm, add 10 or a multiple of 10 to the characteristic of the positive logarithm, and subtract that same amount from the right of the positive logarithm. 12.8686-10 3.7980-10 9.0706

121. Multiplication by Use of Logarithms

The logarithm of the product of two numbers is equal to the sum of the logarithms of the numbers. Thus, $\log (2 \times 6) = \log 2 + \log 6$; and $\log (12 \times 8) = \log 12 + \log 8$.

Example 1: Multiply 68.2 by 40.8 by using logarithms. $\log (68.2 \times 40.8) = \log 68.2 +$ log 40.8. $\log 68.2 = 1.8338$ $\log 40.8 = 1.6107$ $\log (68.2 \times 40.8) = 3.4445$ antilog .4440 = 278antilog .4445 = 278 + xantilog .4455 = 279 $=\frac{x}{1}$ 15 15x = 5x = .33antilog .4445 = 2783 $68.2 \times 40.8 = 2,783$ Example 2: Find the product of 2.11 and 41.3 by using logarithms.

$$\log (2.11 \times 41.3) = \log 2.11$$

$$\log 41.3.$$

$$\log 2.11 = 0.3243$$

$$\log 41.3 = 1.6160$$

$$\log (2.11 \times 41.3) = 1.9403$$

antilog .9400 = 871
antilog .9403 = 871 + x
antilog .9405 = 872

$$\frac{3}{5} = \frac{x}{1}$$

$$5x = 3$$

$$x = .6$$

antilog 1.9403 = 87.16
2.11 \times 41.3 = 87.16

122. Division by Use of Logarithms

The logarithm of the quotient of two numbers is equal to the difference between the logarithms of the numbers. Thus, $\log (75 \div 83) = \log 75 - \log 83$, and $\log (8 \div 2) = \log 8$ $-\log 2$.

Example 1: Divide 785 by 329 by using logarithms. $\log (785 \div 329) = \log 785$ log 329. $\log 785 = 2.8949$ $\log 329 = 2.5172$ $\log (785 \div 329) = 0.3777$ antilog .3766 = 238antilog .3777 = 238 + xantilog .3784 = 23911 = 18 ī 18x = 11x = .611antilog 0.3777 = 2.386 $785 \div 329 = 2.386$ **Example 2:** Find the value of $\frac{3}{7}$ by using logarithms. $\log \frac{3}{7} = \log 3 - \log 7.$ $\log 3 = 0.4771$ $\log 7 = 0.8451$

> Since the logarithm of 7 is greater than the logarithm of 3, it is necessary to add 10. _____ --10 to the logarithm of 3 before subtracting the logarithm of 7.

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$$\log 3 = 10.4771-10$$

$$\log (3 \div 7) = 9.6320-10$$
antilog .6314 = 428
antilog .6320 = 428 + x
antilog .6325 = 429
$$\frac{6}{11} = \frac{x}{1}$$
11x = 6
x = .55
antilog 9.6320-10 = .42855
3 \div 7 = .42855

123. Finding the Power of a Number by Logarithms

The logarithm of a number raised to a power is equal to the logarithm of the number multiplied by the power.

```
Example 1: Evaluate (18.7)<sup>3</sup>.
             \log (18.7)^3 = 3 \log 18.7
                          = 3 \times 1.2718
                          = 3.8154
          antilog .8149 = 653
          antilog .8154 = 653 + x
          antilog .8156 = 654
                       \frac{5}{7} = \frac{x}{1}
                      7x = 5
                       x = .7
          antilog 3.8154 = 6537
                 (18.7)^3 = 6,537
Example 2: Evaluate (.03625)4.
             \log (.03625)^4 = 4 \log .03625
             log 3620
                          = .5587
                          = .5587 + x
             log 3625
                           = .5599
             log 3630
                        \frac{5}{10} = \frac{x}{.0012}
                         x = .0006
             \log (.03625)^4 = 4 (8.5593 - 10)
                            = 34.2372-40
                                30.0000-30
               (Subtract)
                            = 4.2372-10
             antilog .2355 = 172
             antilog .2372 = 172 + x
             antilog .2380 = 173
                        \frac{17}{25} = \frac{x}{1}
                       25x = 17
                          x = .68 = .7
```

```
antilog 4.2372-10 = .000001727

(.03625)<sup>4</sup> = .000001727

Example 3: Evaluate (2.13)<sup>3</sup>.

log (2.13)<sup>3</sup> = \frac{3}{5} log 2.13

= \frac{3}{5} \times 0.3284

= 0.2189

antilog .2175 = 165

antilog .2189 = 165 + x

antilog .2201 = 166

\frac{14}{26} = \frac{x}{1}

26x = 14

x = .5

antilog 0.2189 = 1.655

(2.13)<sup>3</sup> = 1.655
```

124. Finding the Root of a Number by Logarithms

The logarithm of the root of a number is equal to the logarithm of the number divided by the root.

Example 1: Evaluate $\sqrt[4]{34987}$. $\log \sqrt[4]{34987} = \frac{\log 34987}{4}$ $\log 34900 = .5428$ $\log 34987 = .5428 + x$ $\log 35000 = .5441$ 87 x $\frac{87}{100} = \frac{x}{.0013}$ 100x = .1131x = .0011 $=\frac{4.5439}{4}$ = 1.135975 = 1.1360antilog .1335 = 136antilog .1360 = 136 + xantilog .1367 = 137 $\frac{25}{32} = \frac{x}{1}$ 32x = 25x = .78antilog 1.1360 = 13.678 $\sqrt[4]{34987} = 13.678$ Example 2: Evaluate $\sqrt[3]{76.24}$. $\log \sqrt[3]{76.24} = \frac{\log 76.24}{2}$ $\log 7620 = .8820$ $\log 7624 = .8820 + x$ $\log 7630 = .8825$ $\frac{4}{10} = \frac{x}{.0005}$

$$10x = .0020$$

 $x = .0002$
 $= \frac{1.8822}{3}$
 $= 0.6274$
antilog $0.6274 = 4.24$
 $\sqrt[3]{76.24} = 4.24$
 $\sqrt[3]{76.24} = 4.24$
Example 3: Evaluate $\sqrt[3]{.0073573}$.
 $\log \sqrt[3]{.0073573} = \frac{\log .0073573}{3}$
 $\log 73500 = .8663$
 $\log 73573 = .8663 + x$
 $\log 73600 = .8669$
 $\frac{73}{100} = \frac{x}{.0006}$
 $100x = .0438$
 $x = .0004$
 $= \frac{7.8667-10}{3}$

The quotient of 7.8667-10 divided by 3 is $2.6222-3\frac{1}{2}$. By adding 20.0000-20 to 7.8667-10, the sum, 27.8667-30, can be divided by 3 and the quotient will be a workable logarithm.

log .0073573	=	7.8667—10
add		20.0000-20
		27.8667-30

$$\frac{27.8667-30}{3} = 9.2889-10$$
antilog .2878 = 194
antilog .2889 = 194 + x
antilog .2800 = 195

$$\frac{11}{22} = \frac{x}{1}$$

$$22x = 11$$

$$x = .5$$
ntilog 9.2889-10 = .1945
 $\sqrt[3]{.0073573} = .1945$

125. Cologarithms

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The cologarithms of a number is the logarithm of the reciprocal of the number. For example, colog $N = \log \frac{1}{24}$. However,

$$\log \frac{1}{N} = \log 1 - \log N$$
$$= 0 - \log N$$
$$\log \frac{1}{N} = -\log N$$

Therefore, colog $N = \log \frac{1}{N} = -\log N$. Thus the cologarithm of a number is the logarithm of the number subtracted from the logarithm of 1 (0.0000 or, to avoid a negative mantissa, 10.0000-10).

Example 1: Evaluate the cologarithm of 373.

colog 373 = log $\frac{1}{373}$ log 1 = 10.0000-10 log 373 = $\frac{2.5717}{7.4283-10}$ Example 2: Evaluate $\frac{2.37}{3.61}$. log $\frac{2.37}{3.61}$ = log 2.37 - log 3.61 = log 2.37 + colog 3.61 log 1 = 10.0000-10 log 3.61 = $\frac{0.5575}{9.4425-10}$ log 2.37 = $\frac{0.3747}{9.8172-10}$ antilog 9.8172-10 = .65643

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126. Computation by Logarithms

In performing logarithmic computations, follow the principles given in paragraphs 117 through 125. When negative quantities are involved (in multiplication and division), disregard the minus sign when making logarithmic calculations. After calculating the antilog, the sign is determined in accordance with the algebraic law of signs for multiplication and division.

Example 1: Evaluate
$$\sqrt[4]{(94.7)^{\frac{3}{2}}(.00789)}{(3.71)^{\frac{3}{2}}(.345)}$$
.
log (94.7)² = 2 log 94.7
= 2 × 1.9763
= 3.9526
log (00789) = 7.8971-10
log (94.7)² + log (.00789) = 7.8971-10 = 1.8497
log (3.71)² = 8 log 8.71
= 3 × 0.5694
= 1.7082
log (3.71)³ + log (.345) = 11.2460-10 = 1.2460
log (94.7)² (.00789) = 1.8497
log (3.71)³ (.345) = $\frac{0.6037}{3}$
log $\sqrt[4]{(94.7)^{\frac{3}{2}}(.00789)}$ = $\frac{0.6037}{3}$
= .2012
antilog .2012 = 1.5892
Example 2: Evaluate $\sqrt[4]{(6.484)^{\frac{3}{2}} \cdot \sqrt{7.667}}$.
log (6.484)² = 2 log 6.484
= 2 × 0.8118
= 1.6236
log $\sqrt[3]{7.567} = \frac{\log 7.667}{3}$
= $\frac{0.8846}{3}$
= 0.2949
log (6.484)² + log $\sqrt[3]{7.667} = 1.6236 + .2949$
= 1.9185
log (12.85)² = 2 log 12.35
= 2 × 1.0917
= 2.1834
log $\sqrt[3]{3007} = \frac{\log 3007}{3}$
= $\frac{3.4782}{3}$
log (6.484)² $\sqrt[3]{7.667} = 11.9185-10$
log (12.85)² $\sqrt[3]{3007} = \frac{3.8428}{3}$
log (12.85)² $\sqrt[3]{3007} = \frac{3.8428}{3.8428}$
log (12.85)² $\sqrt[3]{3007} = \frac{3.8428}{3.8428}$
log (12.85)² $\sqrt[3]{3007} = \frac{3.8428}{3.8757-10}$

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$$\log \sqrt[4]{\frac{(6.484)^2 \sqrt[3]{7.667}}{(12.35)^2 \sqrt[3]{3007}}} = \frac{38.5757-40}{4}$$

= 9.6439-10
antilog 9.6439-10 = .4405

127. Review Problems—Logarithms

a. Find the logarithms of the following numbers to the base 10:

- (1) 785
- (2) 3.57
- (3) .0345
- (4) .000476
- (5) 49.6
- (6) 273.5
- (7) 760.1
- (8) 7.234
- (9) .009875
- (10) .00005254

b. Find the antilogs of the following logarithms:

- (1) 4.8457
- (2) 2.4330
- (3) 9.5453-10
- (4) 6.8299-10
- (5) 0.6010
- (6) 2.5690
- (7) 5.4343-10
- (8) 5.6994
- (9) 0.2018
- (10) 4.5372-10

c. Using logarithms, find the products of the following to four significant figures:

- (1) 6.93×23.7
- (2) 186×215
- (3) 64.3×21.4
- (4) $.089 \times .076$
- (5) 135×42.3

d. Using logarithms, find the quotients of the following to four significant figures:

- (1) $148 \div 297$
- (2) $\frac{251}{648}$

- (3) $14.9 \div 37.4$
- (4) $47.38 \div 63.29$
- (5) $\frac{1.06}{4.35}$
- e. Using logarithms, evaluate the following:
 - (1) (.0293)4
 - (2) (1.756)7
 - (3) (7.953)[‡]
 - (4) (69.37) 7
 - (5) (27.98)²
 - (6) ∛.01325
 - (7) $\sqrt[4]{815}$
 - **(8)** √7698
 - (9) $\sqrt[5]{8.942}$
 - **(10) √**.000079911
- f. Using logarithms, compute the following:
 - (1) $\frac{3.8 \times 2.6}{4.3}$ (2) $\sqrt[3]{\frac{.541 \times 47.3}{.0157}}$
 - (3) $\frac{44.1 \times 1.82}{10.27 \times .32}$
 - (4) $\frac{85.21 \times \sqrt[3]{4651}}{\sqrt{46.82} \times 6.230}$
 - (5) $\left(\frac{31.21}{40.70}\right)^3$
 - (6) $\sqrt[3]{\frac{(57.20)^2}{(31.42)^3}}$
 - (7) $\sqrt{\frac{.08152 \times 1.953}{95.27}}$

(8)
$$\sqrt{\frac{.8531}{9.327}} \times \sqrt[3]{\frac{518.2}{61.52}}$$

(9) $\frac{48.19 \times \sqrt{56.02}}{431.6 \times \sqrt[3]{46.25} \times \sqrt{16.34}}$

(10)
$$\sqrt{\frac{.008150 \times .08532}{.01234 \times \sqrt[3]{.09156}}}$$

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CHAPTER 9 PLANE GEOMETRY

128. Introduction

Plane geometry is that part of geometry which deals with plane figures. In electronics, as in many other fields, it is necessary to know how to deal with areas of common plane figures. This chapter presents the formulas for finding the areas of triangles, quadrilaterals (plane figures having four sides and four angles), and circles. No effort has been made to cover the entire field of geometry. Only those principles and proofs are presented that are of value in practical work.

129. Definitions

a. Lines. A line has length, but no width or thickness. What is drawn on paper and called a line has thickness and breadth because of the material used to draw it—however, this mark only *represents* the actual line.

b. Angles. An angle, such as ABC in A, figure 23, is formed by the intersection of two lines. An angle, therefore, is the measure of the difference in direction of two straight lines that meet. The lines which form the angle, AB or BC, are called the sides of the angle, and the point of meeting, B, the vertex. The symbol \angle is used to indicate angles. Angles usually are measured in degrees. A complete circle or rotation consists of 360 degrees. The symbol ° is used to indicate degrees; it is written to the right and slightly above the number. For example, 30 degrees is written 30°. Each degree consists of 60 minutes, and each minute is further broken down into 60 seconds. The symbol' is used to indicate minutes: the symbol " indicates seconds. For example, 20 minutes is written 20'; 15 seconds is written 15".

When one straight line is perpendicular to another straight line, the angle formed is a right angle (90°) (B, fig. 23).

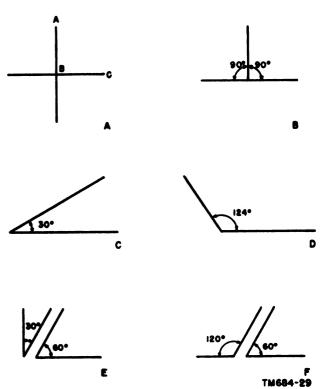


Figure 23. Angles.

- (2) Two right angles, added together, form a *straight angle*. A straight angle, therefore, is an angle of 180°.
- (3) Any angle less than a right angle is an acute angle (C, fig. 23).
- (4) Any angle greater than a right angle and less than 180° is an obtuse angle (D, fig. 23).
- (5) Two angles whose sum is one right angle are called *complementary angles* (E, fig. 23).
- (6) Two angles whose sum is a straight angle are called supplementary angles (F, fig. 23).

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130. Basic Principles of Geometric Construction

a. Reproducing Angles. To draw an angle equal to a given angle BAC (fig. 24)—

- (1) Draw a line, A'C'.
- (2) With A as the center, use a compass to strike an arc that cuts the sides of the given angle at X and Y. Using the same radius, strike a similar arc, X'Y', on the line, A'C'.
- (3) Measure the opening of the given angle by setting one point of the compass at Y and the other at X. With the compass at this distance and with Y' as the center, strike an arc as shown in figure 24. This will cut the first arc at point X'.
- (4) Draw a line, A'B', through X'. The new angle, B'A'C', is the same size as angle BAC.

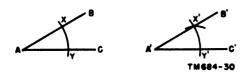


Figure 24. Reproducing an angle.

b. Finding the Midpoint of a Straight Line Segment. To find the midpoint of any straight line segment, such as AB in figure 25—

- (1) Use a radius greater than half the length of AB. Using point A as the center, draw arcs CD and C'D'. With point B as the center, and using the same radius, draw arcs EF and E'F'.
- (2) Draw a straight line to connect the points where the arcs intersect. Point X, where this line intersects AB, is the midpoint of straight line segment AB.

c. Constructing a Perpendicular. To construct a perpendicular to a straight line at a given point—

- (1) On the straight line, such as AB in figure 26, mark point P at which the perpendicular is to be constructed.
- (2) Set a compass for a radius less than the shorter of the two segments, AP

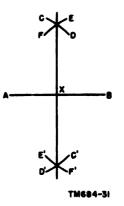


Figure 25. Bisecting a straight line segment.

or PB. With P as a center, draw arcs, cutting line AB at points X and Y.

- (3) Set the compass for a radius greater than PX. With X as a center, draw an arc above point P (fig. 26). Keep the compass at the same setting and, with Y as a center, draw another arc intersecting the one drawn with X as a center. (The two arcs may be drawn to intersect below point P instead of above.)
- (4) Draw a straight line from the point where the two arcs intersect to point P. The line is perpendicular to AB.
- (5) To construct the perpendicular bisector of a straight line segment, first find the midpoint of the line segment (b above), and construct the perpendicular at that point.



Figure 26. Constructing a perpendicular to a straight line at a point or the line.

d. Constructing a Perpendicular to a Straight Line from a Point Not on the Line. To draw a perpendicular to a straight line from a point outside the line, such as point P in figure 27—

(1) With point P as the center, draw an arc cutting line AB at points X and Y.

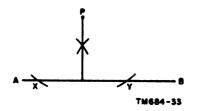


Figure 27. Constructing a perpendicular to a straight line from a point not on the line.

- (2) Using a radius greater than one-half the distance between X and Y and, with points X and Y as centers, draw arcs that intersect.
- (3) Draw a straight line from point P, through the point where the two arcs intersect, to line AB. The line is perpendicular to AB.
- e. Finding the Center of a Circle.
 - (1) Draw any two chords, such as AB and AC in figure 28.
 - (2) Construct the perpendicular bisector of each chord (c above). Point X, where the two perpendicular bisectors meet, is the center of the circle.

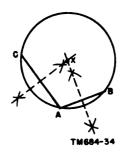


Figure 28. Finding the center of a circle.

f. Bisecting an Angle. Any angle, such as angle CAB in figure 29, can be divided into two equal angles. An angle, thus divided, is said to be bisected. To bisect an angle—

- (1) Using A as a center, draw an arc cutting the sides of angle CAB at X and Y.
- (2) With X and Y as centers, draw intersecting arcs.
- (3) Draw a straight line from A through the point where the arcs intersect. The line divides angles CAB into two

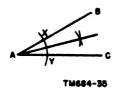


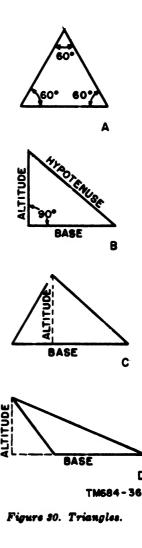
Figure 29. Bisecting an angle.

equal angles and is called the bisector of angle CAB.

131. Triangles

a. General. A triangle is a plane figure bounded by three straight lines. There are several different kinds of triangles.

- (1) An equilateral triangle (A, fig. 30) has three equal sides and three equal angles; each angle equals 60°.
- (2) An isosceles triangle has two equal





sides and two equal angles. The equal angles are opposite the equal sides.

- (3) A right triangle (B, fig. 30) has one right angle.
- (4) An oblique triangle (C and D, fig. 30) is one that does not contain a right angle. Thus, all except right triangles are oblique triangles.

b. Base. The base of a triangle is the side on which the triangle is supposed to stand. However, any side of a triangle may be used as the base.

c. Altitude. The altitude is the perpendicular line distance from the vertex of the triangle to the base or the base extended. In B, figure 30, the altitude of a right triangle is shown, in C, figure 30, the altitude of an acute triangle, and in D, figure 30, the altitude of an obtuse triangle. Note that in an obtuse triangle, it is necessary to extend the base of the triangle to find the altitude.

d. Area. The area of a triangle is the entire surface within the perimeter.

e. Hypotenuse. The side opposite the right angle of any right triangle is the hypotenuse (B, fig. 30).

132. Law of Angles of Any Triangle

The sum of the angles of any triangle is equal to 180° . When given any two of three angles of a triangle, the third angle can be found by subtracting the sum of the given angles from 180°

Example 1:

If two angles of a triangle are 90° and 45° , what is the size of the third angle?

 $90^{\circ} + 45^{\circ} = 135^{\circ}$ $180^{\circ} - 135^{\circ} = 45^{\circ}$

Therefore, the third angle is 45°.

Example 2:

Angle A of triangle ABC is 100°; angle B is 30°. What is the size of angle C?

$$\angle A + \angle B + \angle C = 180^{\circ}$$

$$\angle A = 100^{\circ}$$

$$\angle B = 30^{\circ}$$

$$\angle A + \angle B = 130^{\circ}$$

$$\angle C = 180^{\circ} - 130^{\circ}$$

$$\angle C = 50^{\circ}$$

133. Law of Right Triangles

a. The Pythagorean Theorem. This theorem, which applies to any right triangle, states that the square of the hypotenuse is equal to the sum of the squares of the other two sides. The Pythagorean theorem is of prime importance in trigonometry (ch. 10) since the value of one side of a right triangle can be found if the other two sides are known. Thus, in figure 31:

$$c^{2} = a^{2} + b^{2}$$
 or $25 = 16 + 9$
 $a^{2} = c^{2} - b^{2}$ or $16 = 25 - 9$
 $b^{2} = c^{2} - a^{2}$ or $9 = 25 - 16$

Example 1: Find the hypotenuse of a right triangle if the sides are 3 and 4 inches long, respectively.

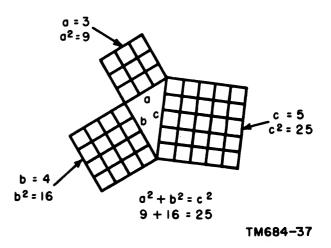


Figure 31. The Pythagorean theorem.

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 $c^{s} = a^{2} + b^{s}$ $c^{s} = 9 + 16$ $c^{s} = 25$ $c = \sqrt{25}$ c = 5 inches

Example 2: The nypotenuse of a right triangle is 13 inches long and one side is 5 inches long. Find the length of the other side.

> $c^{2} = a^{2} + b^{2}$ $13^{2} = 5^{2} + b^{2}$ $b^{2} = 169 - 25$ $b^{2} = 144$ $b = \sqrt{144}$ b = 12 inches

Example 3: Given the right triangle ABC (fig. 31), find c if a = 7 and

b = 6.		9. 2 2
$c^2 = a^2 + b^2$	٦	√85.00 00
$c^{2} = 49 + 36$		81
$c^{1} = 85$	182	400
		364
$c = \sqrt{85}$	1842	3600
c = 9.22-		3684

Example 4: Given the right triangle ABC (fig. 31), find b if a = 9 and

c = 12.		7.93
$b^2 = c^2 - a^2$	١	63.00 00
$b^2 = 144 - 81$		<u>49</u>
$b^2 = 63$	149	1400
		1341
$b = \sqrt{63}$	1583	5900
b = 7.93 +		<u>4749</u>

Example 5: Given the right triangle ABC (fig. 31), find a if b = 6 and

c = 13.]	l 1.5 3
$a^{2} = c^{2} - b^{2}$	$\sqrt{0}$	33.00 00
a ² = 169 - 36	21	33
a² = 133	225	$\frac{21}{1200}$
$a = \sqrt{133}$	2303	$\frac{1125}{7500}$
a = 11.53 +	2010	<u>6909</u>

b. Special Right Triangles. The two right triangles in examples 1 and 2 of a above are special right triangles with sides that have whole numbers. These triangles are called the 3-4-5 right triangle and the 5-12-13 right triangle, although their sides may also be multiples of these numbers. For example, a triangle having sides of 6, 8, and 10 inches is also a 3-4-5 right triangle, because its sides are multiples of 3, 4, and 5. When determining the unknown side of a right triangle, the process is greatly simplified if the triangle is a 3-4-5 or 5-12-13 right triangle. In these cases, the unknown side can often be determined by inspection.

Example 1: The hypotenuse of a right triangle is 15 inches long, and one side is 12 inches long. Find the other side.

> Since 15 and 12 can be divided by 3 to give 5 and 4, the triangle is a 3-4-5 right triangle. The third side, therefore, is equal to 3 times 3, or



9 inches. The answer can be checked by the Pythagorean theorem.

Example 2: The two sides of a triangle are 10 and 24 feet long. Find the length of the hypotenuse.

Dividing 10 and 24 by 2 gives 5 and 12, the two sides of a 5-12-13 right triangle. Therefore, the hypotenuse is 2 times 13, or 26 inches.

134. Area of Any Triangle

The area of any triangle is equal to one-half the product of its base and altitude. The formula for finding the area is $A = \frac{bh}{2}$ where b is the base of the triangle and k is the altitude.

Example 1:

What is the area of a triangle with a base of 15 inches and an altitude of 1 inches?

$$A = \frac{bk}{2}$$
$$= \frac{15 \times 10}{2}$$
$$= \frac{150}{2}$$

= 75 square inches

Example 2:

Find the area of a right triangle if the base measures 7 feet and the hypotenuse 25 feet.

$$c^{2} - b^{2} = e^{2}$$

$$e^{2} = 25^{2} - 7^{2} = 625 - 49$$

$$a^{2} = 576$$

$$a = \sqrt{576} = 24 \text{ feet altitude}$$

$$A = \frac{bh}{2}$$

$$= \frac{7 \times 24}{2} = \frac{168}{2}$$

$$= 84 \text{ square feet}$$

135. Quadrilaterals

A quadrilateral is a plane figure bounded by four straight lines.

a. A parallelogram (A, fig. 32) is a quadrilateral having both pairs of opposite sides parallel.

b. A rectangle (B, fig. 32) is a parallelogram that has four right angles.

c. A square (C, fig. 32) is a rectangle, all four sides of which are equal.

d. A trapezoid (D, fig. 32) is a quadrilateral with two sides (called bases) parallel and unequal.

136. Area of Any Parallelogram

The area of any parallelogram is equal to the product of the base by the altitude. The formula for finding the area is A = bh where b is the base and h is the height or altitude.

Example 1: Find the area of a square, each side of which is 15 inches.

$$A = bh$$

= 15 × 15
= 225 square inches

Example 2: What is the area of a rectangle with a base of 12 inches and an altitude of 7 inches?

$$A = bh$$

= 12 × 7
= 84 square inches •

137. Area of Trapezoid

The area of a trapezoid is determined by multiplying one-half the sum of the bases by the altitude of the trapezoid.

Thus,
$$A = \left(\frac{B+b}{2}\right)h$$
.

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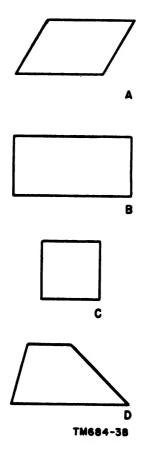


Figure 32. Quadrilaterals.

Example: Find the area of a trapezoid the bases of which are 16 and 10 inches long and the altitude is 8 inches.

$$A = \left(\frac{B+b}{2}\right)h$$
$$= \left(\frac{16+10}{2}\right)8$$
$$= \frac{26}{2} \times \frac{4}{8}$$
$$= 104 \text{ square inches}$$

138. Circles

a. General. A circle is a plane figure bounded by a closed curve, every point of which is equidistant from the center.

b. Circumference. The circumference is the curved line that bounds a circle (A, fig. 33).

c. Chord. A chord is a straight line drawn through a circle and terminated at its intersections with the circumference (B, fig. 33).

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d. Diameter. The diameter of a circle is a chord that passes through the center of the circle (A, fig. 33).

e. Radius. The radius of a circle is a straight line from the center to a point on the circumference (A, fig. 33). All radii of the same circle are of equal length, one-half of the diameter.

f. Arc. An arc is any part of the circumference of a circle.

g. Segment. A segment is that area of a circle bounded by a chord and the arc subtended by that chord (C, fig. 33).

k. Sector. A sector is the area between an arc and two radii drawn to the ends of the arc (C, fig. 33).

i. Tangent. A tangent is a straight line that touches the circumference of a circle at only one point and is perpendicular to the radius drawn to the point of contact (B, fig. 33). This

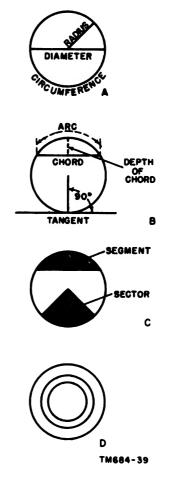


Figure 33. Circles.



point is called the *point of tangency* or the *point* of contact.

j. Concentric Circles. Concentric circles are circles having a common center (D, fig. 33).

k. $Pi(\pi)$. The Greek letter π is used to represent the relationship of the circumference of any circle to its diameter. Roughly, it equals . More approximately, it equals 3.1416. In

many applications, it is rounded off to 3.14.

139. Circumference of Any Circle

The circumference of any circle is π times the diameter; therefore, $C = \pi D$.

- Example 1: Find the circumference of a circle if the diameter is 64 inches. $C = \pi D$ $= 3.14 \times 6.5$ = 20.42 inches
- Example 2: Find the diameter of a circular tank having a circumference of 311 inches.

When the circumference of a circle is given, the diameter is calculated by dividing the cir-

cumference by
$$\pi - D = \frac{\sigma}{\pi}$$

$$D = \frac{C}{\pi}$$
$$= \frac{31.5}{3.1416}$$
$$= 10.03 \text{ inches}$$

140. Area of Any Circle

a. The area of any circle is equal to π multiplied by the radius squared; therefore, $a = \pi r^2$.

Example 1: Find the area of a circle having a diameter of 5 feet 6 inches.

$$A = \pi r^{2}$$

= $\pi \left(\frac{5.5}{2}\right)^{2}$
= $\pi (2.75)^{2}$
= 3.14×7.56
= 23.76 square feet

Example 2: What is the diameter of a circle the area of which is 78.54 square rods?

$$A = \pi r^{4} \text{ and } r = \frac{D}{2}$$

$$A = \pi \left(\frac{D}{2}\right)^{2}$$

$$A = \frac{\pi D^{2}}{4}$$
Transposing:
$$D^{2} = \frac{4A}{\pi}$$

$$D = \sqrt{\frac{4A}{\pi}}$$

$$D = \sqrt{\frac{4A}{\pi}}$$
Substituting and solv

ving for D:

 $D = \sqrt[2]{\frac{78.54}{3.1416}}$ $D = \sqrt[4]{25}$ $D = 2 \times 5$ D = 10 rods

b. The area of any circle also is equal to onehalf the product of the circumference and the radius.

If the diameter of a circle is 10 Example: inches, and the circumference of the circle is 31.416 inches, what is the area of the circle? $A = \frac{1}{2}Cr$ $r = \frac{1}{2}D$ or r = 5 $A = \frac{1}{4}(31.416 \times 5)$ _ 157.08 = 78.54 square inches

141. Area of Ring

A ring is the area between the circumferences of two concentric circles. The area of a ring may be found by subtracting the area of the small circle from the area of the large circle. If R is the radius of the large circle and r is the radius of the small circle, a simplified formula for the area of the ring can be developed as follows:

Area of ring = area of large circle — area of small circle

$$= \pi R^2 - \pi r^2$$
$$= \pi (R^2 - r^2)$$

By factoring $(R^2 - r^2)$ into (R + r) (R - r), the formula also can be written:

$$A = \pi (R+r) (R-r)$$

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Example: Find the area of a ring having an inside diameter of 8 inches and an outside diameter of 12 inches.

$$A = \pi (R + r) (R - r)$$

= 3.14(6 + 4)(6 - 4)
= 3.14 × 10 × 2
= 62.8 square inches

142. Review Problems—Plane Geometry

a. Find the area of a rectangle having a base of 12 inches and an altitude of 8 inches.

b. What is the area of a square, each side of which is 6 inches?

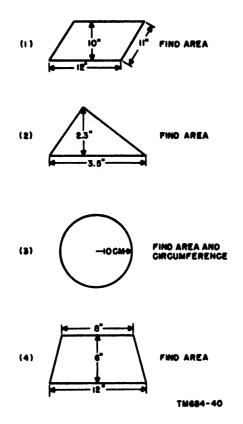
c. Find the area of a triangle of which the altitude is 5 inches and the base is 10 inches.

d. Find the area of a triangle having an altitude of 15 inches and a base of 2 inches.

e. What is the hypotenuse of a right triangle the sides of which are 12 and 8 inches?

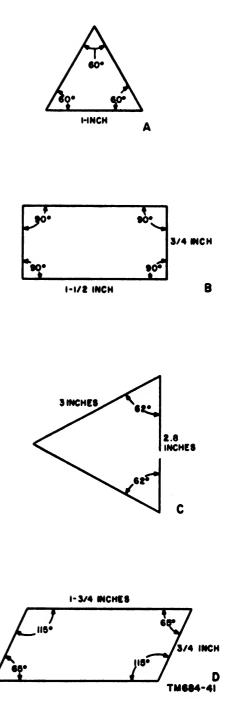
f. Find the third side of a right triangle if ons side is 7 inches and the hypotenuse is 9 inches.

g. Identify the following figures, give the formulas, and solve for the required quantity.





A. What are the perimeters of the following figures?



i. Find the area of the largest circle that can be cut from a square piece of sheet metal with sides of 10 inches.

j. If the height of an antenna is 80 feet, how far from its top is an object on the ground 60 feet from the base of the pole?



k. How many square feet of lumber are needed to build 10 boxes 18 inches by 16 inches by 9 inches?

l. A metal plate is in the shape of an equilateral triangle. If the altitude is 14 inches, what is the perimeter?

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CHAPTER 10 TRIGONOMETRY

Section I. BASIC TRIGONOMETRIC THEORY

143. Introduction

a. Definition. Trigonometry deals with the relationships between the sides and angles of triangles. It uses the theories of basic mathematics—the numbers of arithmetic, the equations of algebra, and the theorems of geometry —to aid in the measurement of the sides and angles of triangles.

b. Application. The ability to use angles and their trigonometric relationships in electrical calculations is especially important in the study of alternating current (ac). Most effects of ac circuit components can be studied or described only in terms of the part of a cycle by which a current lags behind a corresponding voltage, or vice versa. A large percentage of the problems relating to the analysis of ac circuits and communication networks involves the solution of the right triangle in some form. Certain facts about right triangles are familiar (ch 9) -namely, that the square of the hypotenuse is equal to the sum of the squares of the other two sides $(c^2 = a^2 + b^2)$, that the sum of the acute angles of a right triangle is 90°, and that the sum of the interior angles of any triangle is 180°. However, it would be impossible to solve certain problems with only this information. After learning other relationships between the sides and angles of triangles, it will be found that trigonometry is an easy and accurate method of solving many problems in ac electricity (ch 15).

144. Trigonometric Functions

a. General. Trigonometry is based on the six trigonometric functions involved in the study of the right angle. If the value of one quantity depends on the value of a second quantity, the first quantity is said to be a function of the second. The six trigonometric functions —sine (sin), cosine (cos), tangent (tan), co-

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tangent (cot), secant (sec), and cosecant (csc) —are derived from the ratios of the sides of a right triangle to each other.

b. The Right Triangle. Figure 34 shows a right triangle, with the angles labeled A, B, and C; C is the right angle. The sides of the triangle are labeled a, b, and c, with the side opposite each angle given the same letter as the angle. The following are the trigonometric ratios of the sides of a triangle:

$$sin = \frac{opposite side}{hypotenuse}$$

$$cos = \frac{adjacent side}{hypotenuse}$$

$$tan = \frac{opposite side}{adjacent side}$$

$$cot = \frac{adjacent side}{opposite side}$$

$$sec = \frac{hypotenuse}{adjacent side}$$

$$csc = \frac{hypotenuse}{opposite side}$$

c. Angle A. Refer again to figure 34. Using the acute angle A, a is the opposite side, b is the adjacent side, and c, which is the side opposite the right angle, is the hypotenuse. Therefore,

$$\sin A = \frac{a}{c}$$
$$\cos A = \frac{b}{c}$$
$$\tan A = \frac{a}{b}$$
$$\cot A = \frac{b}{a}$$
$$\sec A = \frac{c}{b}$$
$$\csc A = \frac{c}{a}$$



d. Angle B. Using the acute angle B in figure 34, b is the opposite side, a is the adjacent side, and c is the hypotenuse. Therefore,

$$\sin B = \frac{b}{c}$$

$$\cos B = \frac{a}{c}$$

$$\tan B = \frac{b}{a}$$

$$\cot B = \frac{a}{b}$$

$$\sec B = \frac{c}{a}$$

$$\csc B = \frac{c}{b}$$

e. Angle C. Right angle C is the angle which establishes the relationship between the other sides and other angles and thus may be called a constant. Although it is possible to obtain functions for angle C, they are not covered here because they are not needed in solving problems of this type.

Example:

Determine the values of the trigonometric functions of a right triangle with sides as follows: a = 3, b = 4, c = 5 (fig. 35).

Functions of angle A:

sin	A	= -	a c	=	$\frac{3}{5}$
C08	A	= ·	b c	=	4 5
tan	A	= -	a b	=	<u>3</u>
cot	A	= -	b a	=	4 3
sec	A	= ·	c b	=	<u>5</u> 4
CSC	A	= ·	c a	=	$\frac{5}{3}$

Functions of angle B:

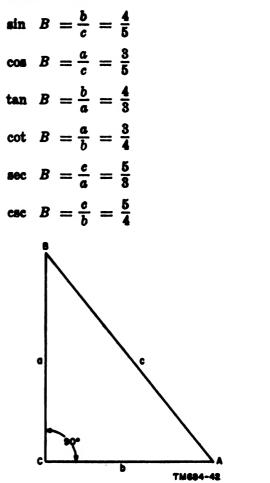


Figure 34. Trigonometric functions of the right triangle.

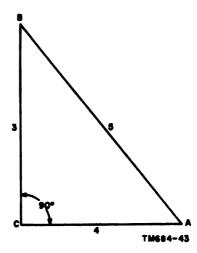


Figure 85. Right triangle with sides known.

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145. Reciprocal Relations of Trigonometric Functions

From the definitions of the six trigonometric functions (par. 144), the reciprocal relations (listed below) can be determined. The cosecant, secant, and cotangent should always be thought of as the reciprocals of the sine, cosine, and tangent, respectively.

sin	A	=	a c	=	$\frac{1}{c}$	H	$\frac{1}{\csc A}$
COS	A	=	b c	=	$\frac{1}{c}$	=	$\frac{1}{\sec A}$
tan	A	=	<u>а</u> b	=	$\frac{1}{b}a$	=	$\frac{1}{\cot A}$
CSC	A	=	c a	=	1 a c	=	$\frac{1}{\sin A}$
80C	A	=	c b	Ξ	$\frac{1}{b}$	=	$\frac{1}{\cos A}$
cot	A	=	ba	=	$\frac{1}{a}$	=	$\frac{1}{\tan A}$

146. Functions of Complementary Angles

a. The function of an acute angle is equal to the cofunction of its complementary angle. Apply the definitions of the trigonometric functions (par. 144) to angles A and B to obtain the following relations:

$$\sin B = \frac{b}{c} = \cos A$$
$$\tan B = \frac{b}{a} = \cot A$$
$$\sec B = \frac{c}{x} = \csc A$$
$$\cos B = \frac{a}{c} = \sin A$$
$$\cot B = \frac{a}{b} = \tan A$$
$$\csc B = \frac{c}{b} = \sec A$$

b. With angle B equal to $90^{\circ} - A$, these relations may be written:

 $\sin (90^\circ - A) = \cos A$ $\tan (90^\circ - A) = \cot A$ $\sec (90^\circ - A) = \csc A$ $\cos (90^\circ - A) = \sin A$ $\cot (90^\circ - A) = \tan A$ $\csc (90^\circ - A) = \sec A$

147. Solving for Unknown Functions

If one trigonometric function of a right triangle is known, the other trigonometric functions can be determined. This is done by using the Pythagorean theorem (par. 133).

Example 1: Given the right triangle ABC (fig. 23): side a is 4; side C is 9. Since sin $A = \frac{4}{9}$, find the other trigonometric functions of angle A. $\sin A = \frac{a}{c}$; also, $\sin A = \frac{4}{9}$. Therefore, a = 4, c = 98.06 $b^2 = c^2 - a^2$ $\sqrt{65.0000}$ $b^2 = 81 - 16$ 64 10000 1606 $b^2 = 65$ 9636 $b = \sqrt{65}$ b = 8.06



$$\sin A = \frac{4}{9} \qquad \cot A = \frac{8.06}{4} \\ \cos A = \frac{8.06}{9} \qquad \sec A = \frac{9}{8.06} \\ \tan A = \frac{4}{8.06} \qquad \csc A = \frac{9}{4}$$

Example 2: Given the right triangle ABC (fig. 23): side A is $\sqrt{3}$; side b is 7. Since $\tan A = \frac{\sqrt{3}}{7}$ or $\frac{1}{7}\sqrt{3}$, find the other trigonometric functions of angle A. Tan $A = \frac{a}{b}$; also, tan $A = \frac{1}{7}\sqrt{3} = \frac{\sqrt{3}}{7}$. Therefore, $a = \sqrt{3}, b = 7$ $c^{2} = a^{2} + b^{2}$ $c^2 = 3 + 49$ $c^2 = 52$ $c = \sqrt{52}$ $c = \sqrt{4} \cdot \sqrt{13}$ $c = 2\sqrt{13}$ $\sin A = \frac{\sqrt{3}}{2\sqrt{13}}$ $\cot A = \frac{7}{\sqrt{3}}$ $\sec A = \frac{2\sqrt{13}}{7}$ $\cos A = \frac{7}{2\sqrt{13}}$ $\csc A = \frac{2\sqrt{13}}{\sqrt{3}}$ $\tan A = \frac{\sqrt{3}}{7}$

148. Solving for Sides and Trigonometric Functions When One Side and One Function Are Given

When one side and one function of an angle of a right triangle are given, the two other sides and the remaining trigonometric functions of the given angle can be found. These are determined by use of the Pythagorean theorem.

> Example 1: Given the right triangle ABC (fig. 34): if the hypotenuse is 30 inches and sec A = 5, solve for sides a and b and the trigonometric functions of angle A.

Sec
$$A = \frac{c}{b}$$
; also, sec $A = \frac{30}{b}$; but sec $A = 5$ or $\frac{5}{1}$
Therefore, $\frac{30}{b} = \frac{5}{1}$
 $5b = 30$
 $b = 6$ inches
 $a^2 = c^2 - b^2$
 $a^2 = 900 - 36$
 $a^2 = 864$
 $a = \sqrt{144} \sqrt{6}$
 $a = 12 \sqrt{6}$ inches, $b = 6$ inches, $c = 30$ inches

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$$\sin A = \frac{12\sqrt{6}}{30} = \frac{12}{30}\sqrt{6} = \frac{2}{5}\sqrt{6}$$

$$\cos A = \frac{\sqrt{6}}{30} = \frac{1}{5}$$

$$\tan A = \frac{12\sqrt{6}}{6} = 2\sqrt{6}$$

$$\cot A = \frac{6}{12\sqrt{6}} = \frac{1}{2\sqrt{6}} \cdot \frac{\sqrt{6}}{\sqrt{6}} = \frac{\sqrt{6}}{(2)(6)} = \frac{\sqrt{6}}{12} = \frac{1}{12}\sqrt{6}$$

$$\sec A = \frac{30}{6} = 5$$

$$\csc A = \frac{30}{12\sqrt{6}} = \frac{5}{2\sqrt{6}} \cdot \frac{\sqrt{6}}{\sqrt{6}} = \frac{5\sqrt{6}}{(2)(6)} = \frac{5\sqrt{6}}{12} = \frac{5}{12}\sqrt{6}$$

Example 2: Given the right triangle ABC (fig. 34): solve for sides b and c and the trigonometric functions of angle A when side a

> is 21.2 inches and sin $A = \frac{4}{7}$. Sin $A = \frac{a}{c}$; also, sin $a = \frac{21.2}{c}$, but sin $A = \frac{4}{7}$. Therefore, $\frac{21.2}{c} = \frac{4}{7}$ 4c = 148.4 c = 37.1 inches $b^2 = c^2 - a^2$ $b^3 = 1376.41 - 449.44$ $b^3 = 926.97$ $b = \sqrt{926.97}$ b = 30.4 inches, a = 21.2 inches, c = 37.1 inches $\sin A = \frac{21.2}{37.1} = \frac{4}{7}$ $\cot A = \frac{30.4}{21.2} = \frac{7.6}{5.3}$ $\cos A = \frac{30.4}{37.1}$ $\sec A = \frac{37.1}{30.4}$ $\tan A = \frac{21.2}{30.4} = \frac{5.3}{7.6}$ $\csc A = \frac{37.1}{21.2} = \frac{7}{4}$

149. Constructing an Acute Angle of Right Triangle When One Trigonometric Function Is Known

When the trigonometric function of an acute angle is given, the angle may be constructed geometrically. Use the definition given for the given function.

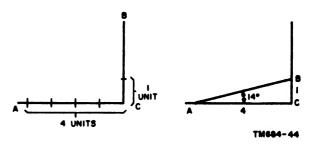
Example: Construct the acute angle A of right triangle ABC if $\tan A = \frac{1}{2}$.

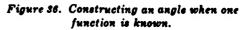
Step 1.Let a = 1 unit and b = 4 units.Step 2.Erect perpendicular lines AC
and BC. Use cross-sectional
paper if available.

Step 8. Measure off 1 unit along *BC* and 4 units along *AC* (A, fig. 36).

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Step 4.Join A and B, thus forming the
right triangle ABC (B, fig. 86).Step 5.Tan $A = \frac{1}{4}$; therefore, A is the
required angle. Measuring angle
A with a protractor shows it to







be an angle of approximately 14°.

150. Common Trigonometric Functions

a. General. There are two special-case right triangles that are commonly used in solving mathematical problems. These are the right isosceles triangle (par. 131a) with equal acute angles of 45° (fig. 37) and the right triangle with acute angles of 30° and 60° . The functions of these angles are tabulated in appendix III.

b. Trigonometric Functions of 45° . Draw the right triangle ABC (fig. 37) with angle A equal to 45° . Because the acute angles of a right triangle are complementary, angle A plus angle B equals 90°. Thus, angle B is also 45° . Since sides opposite equal angles are equal, side a is equal to side b.

Let a = 1 and b = 1. $c^2 = a^2 + b^2$ $c^2 = 1 + 1$ $c^2 = 2$ $c = \sqrt{2}$ sin $45^\circ = \frac{1}{\sqrt{2}} \cdot \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1}{2}\sqrt{2}$ $\cos 45^\circ = \frac{1}{\sqrt{2}} \cdot \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1}{2}\sqrt{2}$ $\tan 45^\circ = \frac{1}{1} = 1$ $\cot 45^\circ = \frac{1}{1} = 1$ $\sec 45^\circ = \frac{\sqrt{2}}{1} = \sqrt{2}$ $\csc 45^\circ = \frac{\sqrt{2}}{1} = \sqrt{2}$

c. Trigonometric Functions of 30° and 60° . Draw the equilateral triangle ABX (fig. 38). The angles of any equilateral triangle are 60° and the sides are equal (par. 131a). Drop a perpendicular BC to the center of the base AX. Right angles ACB and BCX are formed by the perpendicular and the base. The angles ABC and XBC are 30° angles. Since the sides of the equilateral triangle are equal, the perpendicular bisecting the base makes the base AC of the right triangle ABC one-half the length of the base AX of the equilateral triangle. Thus, the side opposite the right angle in a right triangle

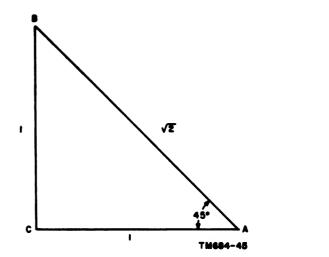


Figure 37. Right isosceles triangle—trigonometric functions of 45°.

is twice the length of the side opposite the 30° angle.

Let
$$b = 1$$
 and $c = 2$.
 $a^2 = c^2 - b^2$
 $a^2 = 4 - 1$
 $a^2 = 3$
 $a = \sqrt{3}$
sin $60^\circ = \frac{\sqrt{3}}{2} = \frac{1}{2}\sqrt{3}$
cos $60^\circ = \frac{1}{2}$
tan $60^\circ = \frac{\sqrt{3}}{1} = \sqrt{3}$
cot $60^\circ = \frac{1}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{\sqrt{3}}{3} = \frac{1}{3}\sqrt{3}$
sec $60^\circ = \frac{2}{1} = 2$
csc $60^\circ = \frac{2}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{2\sqrt{3}}{3} = \frac{2}{3}\sqrt{3}$
ain $30^\circ = \frac{1}{2}$
cos $80^\circ = \frac{\sqrt{3}}{2} = \frac{1}{2}\sqrt{3}$
tan $80^\circ = \frac{1}{\sqrt{3}} = \frac{1}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{\sqrt{3}}{3} = \frac{1}{3}\sqrt{3}$
cot $80^\circ = \frac{\sqrt{3}}{1} = \sqrt{3}$
sec $30^\circ = \frac{2}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{2\sqrt{3}}{3} = \frac{2}{3}\sqrt{3}$
cot $80^\circ = \frac{\sqrt{3}}{1} = \sqrt{3}$
sec $30^\circ = \frac{2}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{2\sqrt{3}}{3} = \frac{2}{3}\sqrt{3}$

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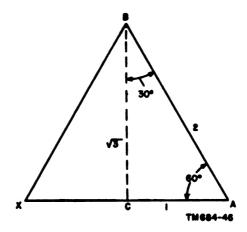


Figure 38. Equilatoral right triangle—trigonometric functions of a right triangle with angles of 30° and 80°

151. Solving for Sides of 45°-45°-90° or 30°-60°-90° Triangles When One Side Is Given

In special cases, right triangles can be solved when only one side is given. These are the $45^{\circ}-45^{\circ}-90^{\circ}$ isosceles triangle and the $30^{\circ}-60^{\circ}-90^{\circ}$ triangle.

Example 1: Solve for the unknown sides of right triangle ABC if angle $A = 60^{\circ}$ and b = 4 inches. Tan 60° = $\frac{a}{b} = \frac{a}{4}$; however, tan 60° = $\sqrt{3}$. Therefore, $\frac{a}{4} = \frac{\sqrt{8}}{1}$ $a = 4\sqrt{8}$ inches Cos 60° = $\frac{b}{c} = \frac{4}{c}$; however, cos 60° = $\frac{1}{2}$. Therefore, $\frac{4}{2} = \frac{1}{2}$ c = 8 inches Thus, $a = 4\sqrt{3}$ inches, b = 4 inches, c = 8 inches. Example 2: Solve for the unknown sides of right triangle ABC if angle $A = 45^{\circ}$ and c = 6 inches. Sin 45° = $\frac{a}{c} = \frac{a}{6}$; however, sin 45° = $\frac{\sqrt{2}}{2}$. Therefore; $\frac{a}{6} = \frac{\sqrt{2}}{2}$ $2a = 6\sqrt{2}$ $a = 8\sqrt{2}$ $\cos 45^\circ = \frac{b}{c} = \frac{b}{6}$; however, $\cos 45^\circ = \frac{\sqrt{2}}{2}$. Therefore, $\frac{b}{6} = \frac{\sqrt{2}}{2}$ $2b = 6\sqrt{2}$ $b = 3\sqrt{2}$ inches Thus, $a = 8\sqrt{2}$ inches, $b = 8\sqrt{2}$ inches, c = 6 inches.

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152. Calculations Involving Angles

a. Addition. To add angles, arrange the degrees, minutes, and seconds in separate columns and add each column separately. If the sum of the seconds column is 60 or more, subtract 60 or a multiple of 60 from that column, and add 1 minute or the same multiple of 1 minute to the minutes column. If the sum of the minutes column is 60 or more, subtract 60 from that column and add 1° to the degree column.

> Example 1: Add 20° 40' 25", 8° 35' 5", and 30° 58' 51". 20° 40' 25" 8° 35' 5" 80° 58' 51" 58° 133' 81" Subtract 60" from 81" and add 1' to 133'. 58° 133' 81" + 1' ---60" 58° 134' 21" Subtract 120' from 134' and add 2° to 58°. 58° 134' 21" 60° 14' 21" Example 2: Add 15° 44' 36" and 12° 38' 35". 15° 44' 36" 12° 38' 35" $\overline{27^{\circ} 82' 71''} = 27^{\circ} 83' 11'' = 28^{\circ} 23' 11''$

b. Subtraction. To subtract angles, arrange the degrees, minutes, and seconds in separate columns with the larger angle on top. Then, subtract the individual columns. If the upper number in a column is too small to allow subtraction, one unit must be taken away from the preceding column and 60 units added to the insufficient number to make subtraction possible.

```
Example 1: Subtract 14° 51' 30" from 86° 45' 10".
              86° 45' 10"
            -14° 51' 30"
            Subtraction cannot be performed in either the seconds or
            minutes columns. Subtract 1' from 45' leaving 44', and add
            60" to 10" for a total of 70".
              86° 44' 70"
            -14° 51' 30"
            Subtraction still cannot be performed in the minutes col-
            umn. Subtract 1° from 86°, leaving 85°, and add 60' to 44'
            for a total of 104'.
              85° 104' 70"
            <u>-14°</u> 51′ 30″
              71° 53' 40"
Example 2: Subtract 10° 35' 42" from 19° 20' 20".
              19° 20' 20"
             -10° 35′ 42″
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c. Multiplication. To multiply an angle by a given number, multiply each column by the number. If the answer in the seconds or minutes column is greater than 60, reduce as in the addition of angles (a above).

> Example 1: Multiply 15° 21' 40" by 3. 15° 21' 40" $\frac{8}{45^{\circ} 63' 120"} = 45^{\circ} 65' 0" = 46^{\circ} 5'$ Example 2: Multiply 12° 14' 36" by 5. 12° 14' 36" $\frac{5}{60^{\circ} 70' 180"} = 60^{\circ} 78' = 61^{\circ} 13'$

d. Division. To divide an angle by a given number, divide each column by the number (beginning with the degrees column). Change the remainder in degrees, if any, into minutes and add it to the minutes column; then, perform division on the numbers in the minutes column. Change the remainder in minutes, if any, to seconds and add it to the seconds column; then, perform division on the numbers in the seconds column.

Example 1: Divide 71° 22' 21" by 8.

$$\begin{array}{r}
23^{\circ} & 47' & 27'' \\
\sqrt[3]{71^{\circ}} & 22' & 21'' \\
\hline
\frac{69}{2^{\circ}} &= 120' \\
\hline
\frac{141'}{1'} &= \frac{60''}{81''} \\
\hline
\underline{81''} \\
\end{array}$$
Example 2: Divide 166° 17' 36" by 6

$$\frac{27^{\circ}}{\sqrt[4]{166^{\circ}}} \frac{42'}{17'} \frac{56''}{36''}$$

$$\frac{162^{\circ}}{4^{\circ}} = \frac{240'}{257'}$$

$$\frac{252'}{5'} = \frac{800''}{336''}$$

$$\frac{336''}{336''}$$

153. Review Problems—Basic Trigonometry

Note. In the following problems, angle C is the right angle and equals 90°.

a. Find the third side of each of the following right triangles ABC, if two sides are:

(1) a = 5, b = 7(2) b = 18, c = 19(3) a = 17, c = 43(4) a = 3b(5) $a = 2m, c = m^{2} + 1$

b. Given the right triangle ABC, solve for the trigonometric functions of angle A in each of the following cases:

(1) sin $A = \frac{4}{7}$ (2) tan $A = \frac{2}{3}$ (3) cos $A = \frac{\sqrt{3}}{2}$ (4) csc A = 2.4(5) cot $A = \frac{1}{y}$ (6) sec $A = 2\frac{2}{3}$

c. Solve each of the right triangles (ABC) for the two unknown sides:

(1) sin $A = \frac{1}{2}$, a = 17(2) tan $A = \frac{3}{4}$, b = 12



(8) $\cos A = \frac{4}{5}, c = 20$	d. Solve each of the following right triangles (ABC) for the unknown sides:
(4) csc $A = \frac{15}{7}, c = 37.5$	(1) $A = 80^{\circ}, a = 10$ (2) $B = 45^{\circ}, b = 7$
(5) cot $A = \frac{3}{5}$, $a = 10$	(8) $A = 60^{\circ}, c = 8$
(6) sec $A = \frac{9}{4}, b = 18.4$	(4) $B = 30^{\circ}, a = 9$ (5) $B = 60^{\circ}, c = 25$

Section II. NATURAL TRIGONOMETRIC FUNCTIONS

154. Tables and Their Uses

For convenience in computing, trigonometric functions are arranged in tables similar to the tables of logarithms. The ratios themselves are called *natural* sines, cosines, tangents, cotangents, etc. The tables in appendix III give the sines and cosines, the tangents and cotangents, and the secants and cosecants of the angles from 0° to 90° . Angles less than 45° are read down the page; the degrees are at the top of the page and the minutes are on the left. Angles greater than 45° are read up the page; the degrees are at the bottom of the page and the minutes are on the right. As with logarithms, it is necessary to interpolate to find the function of an angle which does not reduce to an integral number of minutes. When working with the sine and tangent, which are increasing in size from 0° to 90° , it is necessary to add in interpolation. When working with the cosine and cotangent, which are decreasing in size from 0° to 90° , it is necessary to subtract.

155. Finding the Function of an Angle From the Table

To find the function of an angle from the table, proceed much the same as with the table of logarithms. This is illustrated by the following examples:

a. When an Angle Is Given in the Table.

Example 1: Find the cosine of 44° 27'

- Step 1. Turn to the table of sines and cosines.
- Step 2. Locate the 44° column at the top of the page.
- Step 3. Locate the 27' at the left of the page.
- Step 4. Read .71386 in the column headed Cosin.
- Step 5. $\cos 44^{\circ} 27' = .71386$.

Example 2: Fine the tangent of 86° 18'.

- Step 1. Turn to the table of tangents and cotangents.
- Step 2. Locate the 86° column at the bottom of the page.
- Step 3. Locate the 18' at the right of the page.
- Step 4. Read 15.4638 in the column headed Tang.
- Step 5. Tan 86° 18' = 15.4638.

b. When an Angle Is Not Given in the Table.

Example 1: Find the sine of 32° 46' 36".

 $\sin 32^{\circ} 46' = .54122$ $\sin 32^{\circ} 46' 36'' = .54122 + 7'$ $\sin 32^{\circ} 47' = .54146$



sin 82° 46' 86" 82' 47' $\frac{-32^{\circ} \ 46'}{1'} = \ 60''$ 86" ratio = $\frac{36}{60} = \frac{6}{10} = \frac{8}{5}$.54146 - .54122 = .00024ratio = $\frac{x}{.00024}$ $\frac{8}{5} = \frac{x}{.00024}$ 5x = .00072x = .000144 $\sin 82^{\circ} 46' 36'' = .54122 + .000144 = .54136$ Example 2: Find the tangent of 56° 43' 27". $\tan 56^{\circ} 43' = 1.52332$ $\tan 56^{\circ} 43' 27'' = 1.52332 + x$ $\tan 56^{\circ} 44' = 1.52429$ $\frac{27}{60}$ or $\frac{9}{20} = \frac{x}{.00097}$ 20x = .00878x = .000436 or .00044 $\tan 56^{\circ} 43' 27'' = 1.52332 + .00044 = 1.52376$

156. Finding an Angle When the Trigonometric Function Is Given

The procedure for using the table to find an angle corresponding to a function is similar to that of logarithms. This is illustrated in the examples in a and b below.

a. When the Function Is Given in the Table.

Example:	Find the value of angle A if sine $A = .27284$.	
Step 1.	Find .27284 in the Sine column of the Sines and Cosines table.	
Step 2.	Reading 15° at the top of the column and 50' in the minutes column on the left, angle $A = 15^{\circ}$ 50'.	

b. When the Function Is Not Given in the Table.

Example 1: Find the value of angle A when sine A = .78112.

$$.78098 = \sin 51^{\circ} 21'$$

$$.78112 = \sin 51^{\circ} 21' + x$$

$$.78116 = \sin 51^{\circ} 22'$$

$$.78112 .78116$$

$$-..78098 .-.78098$$

$$..00014 ..00018$$
ratio = $\frac{.00014}{.00018} = \frac{14}{18} = \frac{7}{9}$

$$51^{\circ} 22' - 51^{\circ} 21' = 1' = 60''$$
ratio = $\frac{x}{60}$

$$\frac{7}{9} = \frac{x}{60}$$

$$9x = 420$$

$$x = 47$$
angle $A = 51^{\circ} 21' 47''$

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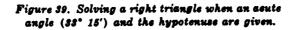
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Examp. 'ind the value of angle A when $\cot A = .33820$. .33848 = $\cot 71^{\circ} 18'$.33820 = $\cot 71^{\circ} 18' + x$.33816 = $\cot 71^{\circ} 19'$ $\frac{28}{32}$ or $\frac{7}{8} = \frac{x}{60}$ 8x = 420 x = 53angle $A = 71^{\circ} 18' 53''$

157. Solving a Right Triangle When an Acute Angle and the Hypotenuse Are Given

To solve for the unknowns in a right triangle when an acute angle and the hypotenuse are given. proceed as in a and b below. In both examples, angle C is the right angle; therefore, angle $C = 30^{\circ}$.

> Example 1: Find the unknown sides a and b, and the value of angle Bin right triangle ABC (fig. 39) if angle A is 33° 15' and the hypotenuse, c is 9 inches. $\angle A + \angle B + \angle C = 180^{\circ}$ $\angle B = 180^{\circ} - \angle A - \angle C$ $\angle B = 180^{\circ} - 33^{\circ} 15' - 90^{\circ}$ $\angle B = 56^{\circ} 45'$ $\sin A = \frac{a}{c}$ $\sin 33^{\circ} 15' = \frac{a}{9}$ $a = 9 \sin 33^{\circ} 15'$ $a = 9 \times .54829 = 4.93461$ a = 4.93461 $\cos A = \frac{b}{c}$ $\cos 33^{\circ} 15' = \frac{b}{9}$ $b = 9 \cos 33^{\circ} 15'$ $b = 9 \times .83629$ b = 7.52661Therefore, $\angle A = 33^{\circ} 15'$ a = 4.93461 inches $\angle B = 56^{\circ} 45'$ b = 7.52661 inches $\angle C = 90^{\circ}$ c = 9 inches C = 9 INCHES ٥ 33 . 15 C b TM684-47

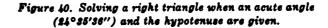


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Example 2: Solve for the unknown sides a and b, and the value of angle B in right triangle ABC (fig. 40) if angle A is 24° 35' 36" and the hypotenuse, c, is 12 inches.

```
\angle B = 180^\circ - \angle A - \angle C
 \angle B = 180^{\circ} - 24^{\circ} 35' 36'' - 90^{\circ}
\angle B = 65^{\circ} 24' 24''
\sin A = \frac{a}{c}
\sin 24^{\circ} 35' 36'' = \frac{a}{12}
                a = 12 \sin 24^{\circ} 35' 36''
                           \sin 24^{\circ} 35' = .41602
                           \sin 24^{\circ} 35' 36'' = .41602 + x
                           \sin 24^{\circ} 36' = .41628
                                     \frac{36}{60} or \frac{3}{5} = \frac{x}{.00026}
                                            5x = .00078
                                              x = .00016
                           \sin 24^{\circ} 35' 36'' = .41602 + .00016 = .41618
                 a = 12 \times .41618
                 a = 4.99416
\cos A = \frac{b}{c}
\cos 24^{\circ} 35' 36'' = \frac{b}{12}
                   b = 12 \cos 24^{\circ} 35' 36''
                              cos 24° 35' = .90936
                              \cos 24^{\circ} 35' 36'' = .90936 - x
                              \cos 24^{\circ} 36' = .90924
                                        \frac{36}{60} or \frac{3}{5} = \frac{x}{.00012}
                                               5x = .00036
                                                 x = .00007
                              \cos 24^\circ 35' 36'' = .90936 - .00007 = .90929
                   b = 12 \times .90929
                   b = 10.91148
 Therefore, \angle A = 24^{\circ} 35' 36''
                                                     a = 4.99416 inches
                 \angle B = 65^{\circ} 24' 24''
                                                    b = 10.91148 inches
                 \angle C = 90^{\circ}
                                                     c = 12 inches
                                    C=
               a
                                    24" 35' 36'
                c
                                    b
                                                 TM684-48
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158. Solving a Right Triangle When an Acute Angle and the Adjacent Side Are Given

Example:

To solve a right triangle when an acute angle and the adjacent side are given, proceed as shown in the example below. Angle C is the right angle.

Find the unknown sides a and c and the value of angle B in the right tri-

angle ABC (fig. 41) if angle A is 37° 42' 42" and the side adjacent to angle A is 8 inches. $\angle B = 180^{\circ} - 90^{\circ} - 37^{\circ} 42' 42''$ $\angle B = 52^{\circ} 17' 18''$ $\cos A = \frac{b}{c}$ $\cos 37^{\circ} 42' 42'' = \frac{8}{c}$ $c (\cos 37^{\circ} 42' 42'') = 8$ cos 37° 42' = .79122 $\cos 37^{\circ} 42' 42'' = .79122 - x$ cos 37° 43' = .79105 $\frac{42}{60}$ or $\frac{7}{10} = \frac{x}{.00017}$ 10x = .00119x = .00012 $\cos 37^{\circ} 42' 42'' = .79122 - .00012 = .79110$.79110c = 8 $c = \frac{8}{.79110}$ c = 10.11 $\tan A = \frac{a}{b}$ $\tan 37^{\circ} 42' 42'' = \frac{a}{8}$ $a = 8 \tan 37^{\circ} 42' 42''$ = .77289 tan 37° 42' $\tan 37^{\circ} 42' 42'' = .77289 + x$ $\tan 37^{\circ} 43' = .77335$ $\frac{42}{60}$ or $\frac{7}{10} = \frac{x}{.00046}$ 10x = .00322x = .00032 $\tan 37^{\circ} 42' 42'' = .77289 + .00032 = .77321$ $a = 8 \times .77321$ a = 6.18568 $\angle A = 37^{\circ} 42' 42''$ Therefore, a = 6.18568 inches $\angle B = 52^{\circ} \cdot 17' \, 18''$ b = 8 inches $\angle C = 90^{\circ}$ c = 10.11 inches

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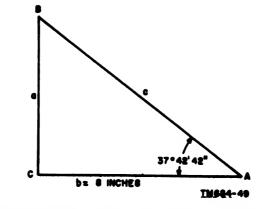


Figure 41. Solving a right triangle when an soute angle and the adjacent side are given.

159. Solving a Right Triangle When Hypotenuse and One Side Are Given

Given the hypotenuse and one other side of a right triangle, solve for the unknown angles and side as illustrated in the example below.

Example:	wple: Find the unknown angles A and B , and side c of right triangle ABC (fig. 42) if the hypotenuse is 12 inches and the side opposite angle A is 8 inches.	
	$b^{\mathbf{s}} = c^{\mathbf{s}} - a^{\mathbf{s}}$	
	$b^{2} = 12^{2} - 8^{2}$	
	$b^{s} = 144 - 64$	
	$b^s = 80$	
	$b = \sqrt{80}$	
	b = 8.94	
	$\sin A = \frac{a}{c}$	
	$\sin A = \frac{8}{12} = \frac{2}{3}$	
	$\sin A = .666667$	
	$.66653 = \sin 41^{\circ} 48'$	
	$.66667 = \sin 41^{\circ} 48' + x$	
	$.66675 = \sin 41^{\circ} 49'$	
	$\frac{14}{22}=\frac{x}{60}$	
	22x = 840	
	$x = \frac{840}{22} = 38$	
	.666667 = sin 41° 48' 38"	
	angle $A = 41^{\circ} 48' 38''$	
	$\angle B = 180^\circ - \angle C - \angle A$	
	$\angle B = 180^{\circ} - 90^{\circ} - 41^{\circ} 48' 38''$	
	$\angle B = 48^{\circ} 11' 22''$	
	Therefore, $\angle A = 41^{\circ} 48' 38''$ $a = 8$ inches	
	$\angle B = 48^{\circ} 11' 22'' \qquad b = 8.94$ inches	
	$\angle C = 90^{\circ}$ $c = 12$ inches	

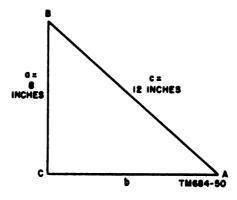


Figure 42. Solving a right triangle, when the hypotenuse and one side are given.

160. Solving a Right Triangle When Two Sides Are Given

When two sides of a right triangle are given, solve for the unknown angles and the hypotenuse as shown in the example below.

Example:	Find the unknown angles A and B and side c in right triangle ABC (fig. 43) if side a is 8 inches and side b is 10 inches.
	$c^2 = a^2 + b^2$
	$c^2 = 64 + 100$
	$c^2 = 164$
	$c = \sqrt{164}$
	c = 12.8
	$\tan A = \frac{a}{b}$
	$\tan A = \frac{8}{10}$
	$\tan A = .80000$
	$.79972 = \tan 38^{\circ} 39'$
	$.80000 = \tan 38^{\circ} 39' + x$
	$.80020 = \tan 38^{\circ} 40'$
	$\frac{28}{48}$ or $\frac{7}{12} = \frac{x}{60}$
	12x = 420
	x = 35
	$.80000 = \tan 38^{\circ} 39' 35''$
	angle $A = 38^{\circ} 39' 35''$
	$\angle B = 180^\circ - \angle C - \angle A$
	$\angle B = 180^{\circ} - 90^{\circ} - 38^{\circ} 39' 35''$
	$\angle B = 51^{\circ} 20' 25''$
	Therefore, $\angle A = 38^{\circ} 39' 35''$ $a = 8$ inches
	$\angle B = 51^{\circ} \ 20' \ 25'' \qquad b = 10 \text{ inches}$
	$\angle C = 90^{\circ}$ $c = 12.8$ inches

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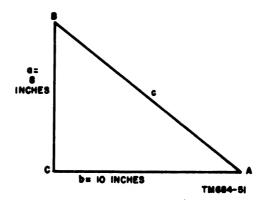


Figure 48. Solving a right triangle when two sides are given.

161. Solving a 30°-60°-90° Triangle When One Side Is Given

In a $30^{\circ}-60^{\circ}-90^{\circ}$ triangle, the side opposite the 30° angle is equal to one-half the hypotenuse. Refer to paragraph 150c for the derivation of the trigonometric functions. Solve for the unknown sides as shown in the example below.

Example: Find the unknown sides b and c of $30^{\circ}-60^{\circ}-90^{\circ}$ triangle ABC (fig. 44) if the side opposite the 60° angle is 6 inches.

$$\sin 60^\circ = \frac{\sqrt{3}}{2}; \text{ also, } \sin 60^\circ = \frac{a}{c} = \frac{6}{c}$$
$$\frac{\sqrt{3}}{2} = \frac{6}{c}$$
$$\sqrt{3c} = 12$$
$$c = \frac{12}{\sqrt{3}}$$

Eliminate $\sqrt{3}$ in the denominator by multiplying $\frac{12}{\sqrt{3}}$ by $\frac{\sqrt{3}}{\sqrt{3}}$:

$$c = \frac{12}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{12\sqrt{3}}{\sqrt{9}} = \frac{12\sqrt{3}}{3} = 4\sqrt{3}$$

$$c = 4\sqrt{3} = 4 \times 1.7321 = 6.9284$$

$$\tan 60^{\circ} = \frac{\sqrt{3}}{1}; \text{ also, } \tan 60^{\circ} = \frac{a}{b} = \frac{6}{b}$$

$$\frac{\sqrt{3}}{1} = \frac{6}{b}$$

$$\sqrt{3b} = 6$$

$$b = \frac{6}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{6\sqrt{3}}{\sqrt{9}} = \frac{6\sqrt{3}}{3} = 2\sqrt{3}$$

$$b = 2\sqrt{3} = 2 \times 1.7321 = 3.4642$$
Therefore, $a = 6$ inches
 $b = 3.4642$ inches
 $c = 6.9284$ inches

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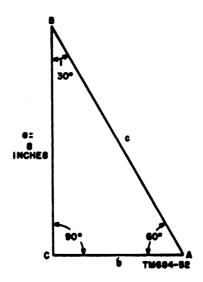


Figure 11. Solving a 30°-60°-90° triangle when one side is given.

162. Solving a 45°-45°-90° Triangle When One Side Is Given

In a 45°-45°-90° triangle, the sides opposite the equal angles are equal. Refer to paragraph 150b for the derivation of the trigonometric functions. Solve for the unknown sides as shown in the example below.

Example: Find the unknown sides a, b, and c of $45^{\circ}-45^{\circ}-90^{\circ}$ triangle ABC (fig. 45) if the side opposite acute angle A is 5 inches.

$$\sin 45^{\circ} = \frac{1}{\sqrt{2}}; \text{ also, } \sin A = \frac{a}{c} = \frac{5}{c}$$

$$\frac{1}{\sqrt{2}} = \frac{5}{c}$$

$$c = 5\sqrt{2}$$

$$c = 5 \times 1.4142 = 7.0710$$

$$\tan 45^{\circ} = \frac{1}{1}; \text{ also, } \tan A = \frac{a}{b} = \frac{5}{b}$$

$$\frac{1}{1} = \frac{5}{b}$$

$$[b = 5]$$
Therefore, $a = 5$ inches
 $b = 5$ inches
 $c = 7.071$ inches

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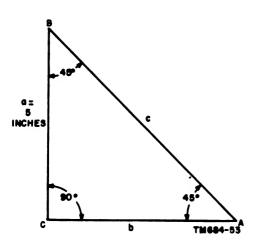


Figure 45. Solving a 45°-45°-90° triangle when one side is given.

163. Angles of Elevation and Depression

When an object is higher than the observer's eye, the angle between the horizontal and the line of sight to the object is called the angle of elevation (A, fig. 46). When an object is lower than the observer's eye, the angle between the line of sight to the object and the horizontal is called the angle of depression (B, fig. 46).

Example:

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A television antenna mast is 450 feet high (fig. 47). Find to the nearest second the angle of elevation to its top at a point 200 feet from the base of the mast.

$$\tan A = \frac{a}{b}$$

$$\tan A = \frac{450}{200}$$

$$\tan A = 2.2500$$

$$2.2496 = \tan 66^{\circ} 2'$$

$$2.2500 = \tan 66^{\circ} 2' + x$$

$$2.2513 = \tan 66^{\circ} 3'$$

$$\frac{4}{17} = \frac{x}{60}$$

$$17x = 240$$

$$x = 14$$

$$2.2500 = \tan 66^{\circ} 2' 14''$$

$$A = 66^{\circ} 2' 14''$$

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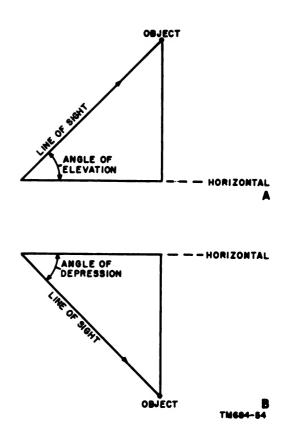


Figure 16. Angles of elevation and depression.

164. Review Problems—Natural Trigonometric **Functions**

a. Find the sine, cosine, tangent, and cotangent of the following angles:

(1) 1° 30' (2) 15° 25' (3) 32° 10' (4) 36° 39' (5) 44° 59' (6) 44° 59' 45" (7) 35° 12' 15" (8) 54° 27' 32" (9) 48° 25' 37" (10) 67° 33' 42"

b. Solve for the values of the following angles in degrees, minutes and seconds:

- (1) $\sin A = .25737$
- (2) cot A = .43279



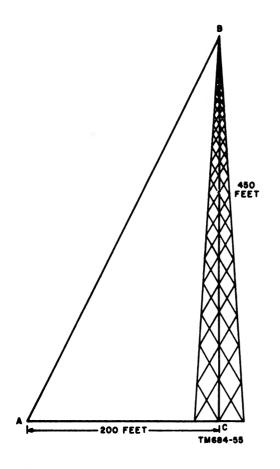


Figure 47. Finding the angle of elevation to top of an antenna mast.

- (3) $\cos A = .94000$
- (4) $\tan A = .47237$
- (5) $\cot A = 1.17529$
- (6) $\cos A = .36243$
- (7) $\sin A = .37778$
- (8) $\tan A = .67676$
- (9) $\tan A = 1.29000$
- (10) $\cot A = .79553$
- c. Solve for the following (angle $C = 90^{\circ}$):
 - (1) Angle A in right triangle ABC when a = 19 and c = 27.
 - (2) Side a in right triangle ABC when $A = 37^{\circ} 15'$ and c = 17.
 - (3) Side c in right triangle ABC when $A = 42^{\circ} 37' 15''$ and a = 22.
 - (4) Side B in right triangle ABC when $A = 37^{\circ} 45' 42''$ and c = 25.

- (5) Side c in right triangle ABC when $A = 14^{\circ} 35'$ and b = 12.
- (6) Angle A in right triangle ABC when b = 7 and c = 12.
- (7) Side a in right triangle ABC when $A = 47^{\circ} 22' 52''$ and b = 31.
- (8) Side b in right triangle ABC when $A = 56^{\circ} 31' 25''$ and a = 25.
- (9) Angle A in right triangle ABC when a = 17 and b = 23.
- (10) Side b in right triangle ABC when $A = 7^{\circ} 32' 54''$ and a = 17.
- (11) Side c in right triangle ABC when a = 15 and b = 27.
- (12) Angle A in right triangle ABC when a = 15 and b = 27.
- d. Solve the following problems:
 - (1) Over a distance of 300 feet, the angle of elevation of a road is 8° 24' 80". What is the rise in feet?
 - (2) The angle of elevation to the top of an antenna mast is 34° 17' 50". If the distance from the transit to the center of the mast is 110 feet, how high is the mast? The transit is 5 feet high.
 - (3) If a ladder 15 feet long just touches the top of a wall and subtends an angle of 35° 24' 16" with the ground, how far is the lower end of the ladder from the wall and how high is the wall?
 - (4) A captive balloon is anchored by 950 feet of cable. A man observes that the angle of elevation from his point of observation to the bottom of the balloon is 16° 47' 12". How far is he from the balloon anchor?
 - (5) An excavation is 33 feet wide. The angle of depression from the top of one side to the bottom of the other side is 19° 34' 24". How deep is the excavation?
 - (6) The angle of elevation from a given

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point to the top of a tower is $17^{\circ} 87'$ 15". Moving back 40 feet in a direct line, the angle of elevation from this point to the top of the tower is 15° 35' 20". Find the height of the tower.

- (7) To determine the height of a tower, two sights are taken on a straight line perpendicular to the tower. If the distance between the points of observation is 60 feet and the angles of elevation are 32° 30' 15" and 28° 15' 30", respectively, what is the height of the tower?
- (8) From a point in an open field a man sights on two mileposts along the side of a highway. The angles formed by an imaginary line perpendicular to the highway and the sights on the mileposts are 33° 20' and 39° 17' 30". How far is the man from the closest point on the highway?
- 165. Solving Oblique Triangles

An oblique triangle is one in which one of the angles is a right angle. The formulas in this section are used primarily to solve oblique triangles, but may also be used to solve right triangles. In the solution of triangles by trigonometric laws, the four following cases arise:

s. When any side and any two angles are given.

b. When any two sides and the angle opposite one of them are given.

(9) An airplane is flying between two towns at an altitude of 5,000 feet. Measured with respect to the horizontal, at a given moment, the angle to the outskirts of one town is 50° 26' 14", while the angle to the outskirts of the other town is 64° 44' 12". How far apart, in a direct line, are the two towns?

- (10) A radio antenna on top of a building is 10 feet high. The angle of elevation to the base of the pole is 37° 17' 20"; the angle of elevation to the top of the antenna is 40° 80' 15". How high is the building?
- (11) In a 45°-45°-90° right triangle the hypotenuse is 2 inches long. Find the length of the other two sides.
- (12) In a 30°-60°-90° right triangle the hypotenuse is 6 inches long. Find the length of the other two sides.

Section III. TRIGONOMETRIC LAWS

c. When any two sides and the angle included between them are given.

d. When the three sides are given.

166. Law of Sines

In any triangle, the sides are proportional to the sines of the opposite angles.

Thus,
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$
.

a. Two Angles and One Side Given.

Example: Solve for the unknowns in oblique triangle ABC (fig. 48) when angle $A = 35^{\circ}$ 47' 36", angle $B = 68^{\circ}$ 42' 27", and the side opposite angle A is 15 inches.

$$\angle C = 180^{\circ} - \angle A - \angle B$$

$$\angle C = 180^{\circ} - 35^{\circ} 47' 36'' - 68^{\circ} 42' 27''$$

$$\angle C = 75^{\circ} 29' 57''$$

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

$$b \sin A = a \sin B$$

$$b = \frac{a \sin B}{\sin A}$$

$$b = \frac{15 \sin 68^{\circ} 42' 27''}{\sin 85^{\circ} 47' 86''}$$

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sin 68° 42′ = .98169 $\sin 68^{\circ} 42' 27'' = .98169 + x$ $\sin 68^{\circ} 43' = .98180$ $\frac{27}{60}$ or $\frac{9}{20} = \frac{x}{.00011}$ 20x = .00099x = .000049 = .00005 $\sin 68^{\circ} 42' 27'' = .98169 + .00005 = .98174$ $\sin 35^{\circ} 47' = .58472$ $\sin 35^{\circ} 47' 36'' = .58472 + x$ $\sin 35^{\circ} 48' = .58496$ $\frac{36}{60}$ or $\frac{8}{5} = \frac{x}{.00024}$ 5x = .00072x = .00014 $\sin 35^{\circ} 47' 36'' = .58472 + .00014 = .58486$ $b = \frac{15 \times .93174}{.58486}$ $b = \frac{13.97610}{.58486}$ b = 23.89C $\frac{a}{\sin A} = \frac{c}{\sin C}$ $c \sin A = a \sin C$ $c = \frac{a \sin C}{\sin A}$ $c = \frac{15 \sin 75^{\circ} 29' 57''}{\sin 35^{\circ} 47' 36''}$ $\sin 75^{\circ} 29' = .96807$ $\sin 75^{\circ} 29' 57'' = .96807 + x$ $\sin 75^{\circ} 30' = .96815$ $\frac{57}{60}$ or $\frac{19}{20} = \frac{x}{.00008}$ 20x = .00152x = .000076 = .00008 $\sin 75^{\circ} 29' 57'' = .96807 + .00008 = .96815$ $c = \frac{15 \times .96815}{.58486}$ $c = \frac{14.52225}{59400}$.58486 c = 24.83Therefore, $\angle A = 35^{\circ} 47' 36''$ a = 15 inches. $\angle B = 68^{\circ} 42' 27''$ b = 23.89 inches $\angle C = 75^{\circ} 29' 57''$ c = 24.83 inches

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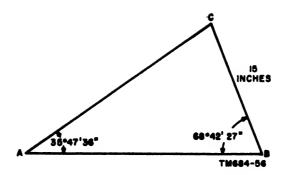


Figure 48. Solving an oblique triangle by the law of since when two angles and a side are given.

b. Two Sides and One Angle Given.

Example: Find the unknowns in oblique triangle ABC (fig. 49) when angle $A = 53^{\circ} 35' 40''$, the side opposite angle A is 10 inches, and the side opposite angle B is 12 inches.

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$
 $a \sin B = b \sin A$
 $\sin B = \frac{b \sin A}{a}$
 $\sin B = \frac{12 \sin 58^{\circ} 35' 40''}{10}$
 $\sin 58^{\circ} 35' 40'' = .80472$
 $\sin 58^{\circ} 35' 40'' = .80472 + x$
 $\sin 58^{\circ} 36' = .80489$
 $\frac{40}{60} \text{ or } \frac{2}{3} = \frac{x}{.00017}$
 $8x = .00084$
 $x = .00011$
 $\sin 58^{\circ} 35' 40'' = .80472 + .00011 = .80488$
 6
 $\sin B = \frac{12 \times .80483}{10}$
 5
 $\sin B = \frac{4.82898}{5}$
 $\sin B = \frac{4.82898}{5}$
 $\sin B = .965796 = .96580$
 $.96678 = \sin 74^{\circ} 58' + x$
 $.96680 = \sin 74^{\circ} 58' + x$
 $.96685 = \sin 74^{\circ} 59'$
 $\frac{2}{7} = \frac{x}{60}$
 $7x = 120$
 $x = 17$
 $.96580 = \sin 74^{\circ} 58' 17''$
 $\angle B = 74^{\circ} 58' 17''$

AGO MEA

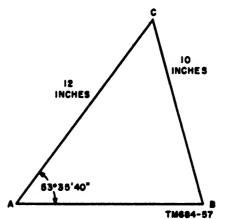


Figure 19. Solving an oblique triangle by the law of since when two sides and an angle are given.

167. Law of Cosines

In any triangle, the square of any side equals the sum of the squares of the other two sides minus twice the product of these two sides times the cosine of the angle between them.

Thus, $a^2 = b^2 + c^2 - 2bc \cos A$ $b^2 = a^2 + c^2 - 2ac \cos B$ $c^2 = a^2 + b^2 - 2ab \cos C$

AGO MAA



Example: Find the unknowns in oblique triangle ABG (fig. 50) when angle $C = 56^{\circ} 45' 24''$, the side opposite angle A is 6 inches, and the side opposite angle B is 8 inches.

```
c^{\mathbf{i}} = a^{\mathbf{i}} + b^{\mathbf{i}} - 2ab \cos C
       c^{2} = 6^{2} + 8^{2} - 2(6)(8) \cos 56^{\circ} 45' 24''
       c^2 = 36 + 64 - 96 \cos 56^\circ 45' 24''
       c^{2} = 100 - 96 \cos 56^{\circ} 45' 24''
              cos 56° 45' = .54829
              \cos 56^{\circ} 45' 24'' = .54829 - x
              cos 56° 46' = .54805
                       \frac{24}{60} or \frac{2}{5} = \frac{x}{.00024}
                              5x = .00048
                               x = .000096 or .00010
              \cos 56^{\circ} 45' 24'' = .54829 - .00010 = .54819
       c^{2} = 100 - 96(.54819)
       c^{2} = 100 - 52.62624
       c^{2} = 47.87876
       c = \sqrt{47.87876}
      c = 6.882
  \frac{a}{\sin A} = \frac{c}{\sin C}
c \sin A = a \sin C
  \sin A = \frac{a \sin C}{c}
  \sin A = \frac{6 \sin 56^{\circ} 45' 24''}{1000}
                      6.882
              sin 56° 45'
                                 = .83629
              \sin 56^{\circ} 45' 24'' = .83629 + x
              \sin 56^{\circ} 46' = .83645
                       \frac{24}{60} or \frac{2}{5} = \frac{x}{.00016}
                              5x = .00082
                                x = .000064 = .00006
              \sin 56^{\circ} 45' 24'' = .83629 + .00006 = .83635
  6.882
  \sin A = \frac{5.01810}{2}
  \sin A = .72916
              .72897 = \sin 46^{\circ} 48'
              .72916 = \sin 46^{\circ} 48' + x
              .72917 = sin 46^{\circ} 49'
                   \frac{19}{20} = \frac{x}{60}
                 20x = 1140
                    x = 57
              .72917 = sin 46° 48' 57"
     ∠A = 46° 48' 57"
     \angle B = 180^\circ - \angle C - \angle A
```



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Figure 50. Solving an oblique triangle by the law of cosines when an angle and two sides are given.

168. Law of Tangents

The law of tangents is expressed by the formula $\frac{a-b}{a+b} = \frac{\tan \frac{1}{2}(A-B)}{\tan \frac{1}{2}(A+B)}$, where a and b are any two sides and A and B are the angles opposite these sides.

Example: Find the unknowns in oblique triangle ABC (fig. 51) when two sides of the triangle are 9 and 11 inches, respectively, and angle C, the angle included between these two sides, is $40^{\circ} 40' 40''$.

$$\begin{array}{l} \langle A + \langle B + \langle C = 180^{\circ} \\ \langle A + \langle B + 40^{\circ} 40' 40'' = 180^{\circ} \\ \langle A + \langle B = 180^{\circ} - 40^{\circ} 40' 40'' \\ \langle A + \langle B = 189^{\circ} 19' 20'' \\ \frac{1}{2}(A + B) = \frac{139^{\circ} 19' 20''}{2} \\ \frac{1}{2}(A + B) = 69^{\circ} 39' 40'' \\ \frac{a - b}{a + b} = \frac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)} \\ \frac{11 - 9}{a + b} = \frac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)} \\ \frac{11 - 9}{11 + 9} \text{ or } \frac{2}{20} = \frac{\tan \frac{1}{2}(A - B)}{\tan 69^{\circ} 39' 40''} \\ 20 \tan \frac{1}{2}(A - B) = 2 \tan 69^{\circ} 39' 40'' \\ 10 \tan \frac{1}{2}(A - B) = \tan 69^{\circ} 39' 40'' \\ 10 \tan \frac{1}{2}(A - B) = \frac{\tan 69^{\circ} 39' 40''}{10} \\ \tan 69^{\circ} 39' 40'' = 2.69612 \\ \tan 69^{\circ} 39' 40' = 2.69853 \\ \frac{40}{60} \text{ or } \frac{2}{3} = \frac{x}{.00241} \\ 3x = .00482 \\ x = .00161 \\ \tan 69^{\circ} 39' 40'' = 2.69612 + .00161 = 2.69773 \\ \end{array}$$

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$$\tan \frac{1}{4}(A - B) = \frac{2.69773}{10}$$

$$\tan \frac{1}{4}(A - B) = .26977$$

$$\frac{.26951}{.26977} = \tan 15^{\circ} 5' + x$$

$$.26982 = \tan 15^{\circ} 6'$$

$$\frac{26}{31} = \frac{x}{60}$$

$$31x = 1560$$

$$x = 50$$

$$.26977 = \tan 15^{\circ} 5' 50''$$

$$\frac{1}{4}(A + B) = \frac{1}{4}A + \frac{1}{4}B = 69^{\circ} 39' 40''$$

$$\frac{1}{4}(A - B) = \frac{1}{4}A - \frac{1}{4}B = \frac{15^{\circ}}{5'} \frac{5' 50''}{50''}$$

$$(add) \quad A = \frac{54^{\circ}}{44' 90''}$$

$$(A - B) = \frac{1}{4}A - \frac{1}{4}B = \frac{15^{\circ}}{5'} \frac{5' 50''}{50''}$$

$$\frac{1}{4}(A + B) = \frac{1}{4}A + \frac{1}{4}B = 69^{\circ} 38' 100''$$

$$\frac{1}{4}(A - B) = \frac{1}{4}A - \frac{1}{4}B = \frac{15^{\circ}}{5'} \frac{5' 50''}{50''}$$

$$(add) \quad A = \frac{54^{\circ}}{38' 50''}$$

$$\frac{2}{4}B = 54^{\circ} 33' 50''$$

$$\frac{a}{\sin A} = \frac{c}{\sin c}$$

$$c = \frac{a \sin C}{\sin A}$$

$$c = \frac{11 \sin 40^{\circ} 40' 40''}{ain 84^{\circ} 45' 30''}$$

$$\sin 40^{\circ} 40' = .65166$$

$$\sin 40^{\circ} 40' 40'' = .65166 + x$$

$$\sin 40^{\circ} 40' 40'' = .95166 + .00015 = .65181$$

$$\sin 84^{\circ} 45' 30'' = .99580$$

$$\sin 84^{\circ} 45' 30'' = .99580 + .00002$$

$$\sin 84^{\circ} 45' 30'' = .99580 + .00002 = .99582$$

$$c = \frac{11 \sin 40^{\circ} 40' 40''}{.99582}$$

$$c = \frac{7.18991}{.99582}$$

$$c = 7.2$$

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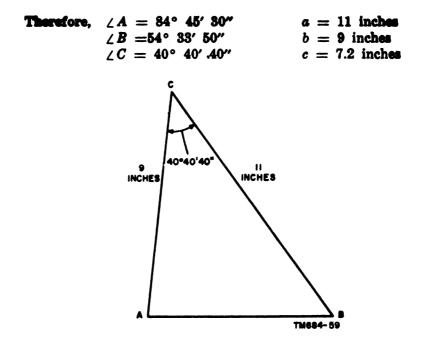


Figure 51. Solving an oblique triangle by the law of tangents when an angle and two sides are given.

169. Finding an Angle When Three Sides Are Given

The following formulas are used to find the angles of a triangle when three sides of the triangle are given:

$$\sin \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}}$$
$$\sin \frac{1}{2}B = \sqrt{\frac{(s-a)(s-c)}{ac}}$$
$$\sin \frac{1}{2}C = \sqrt{\frac{(s-a)(s-b)}{ab}}$$

In these formulas, a, b, and c are the sides of the triangle, and $s = \frac{1}{2}(a + b + c)$.

Example: Find the angles of an oblique triangle if a = 5 inches, b = 8 inches, and c = 11 inches.

$$s = \frac{1}{2}(a + b + c)$$

$$s = \frac{1}{2}(5 + 8 + 11)$$

$$s = \frac{1}{2}(24)$$

$$s = 12$$

$$\sin \frac{1}{2}A = \sqrt{\frac{(s - b)(s - c)}{bc}}$$

$$\sin \frac{1}{2}A = \sqrt{\frac{(12 - 8)(12 - 11)}{(8)(11)}}$$

$$\sin \frac{1}{2}A = \sqrt{\frac{(4)(1)}{88}}$$

$$\sin \frac{1}{2}A = \sqrt{\frac{4}{88}} = \sqrt{\frac{1}{22}}$$

$$\sin \frac{1}{4}A = \sqrt{.0454545}$$

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$$\sin \frac{1}{4}A = .21319$$

$$.21303 = \sin 12^{\circ} 18'$$

$$.21319 = \sin 12^{\circ} 18' + x$$

$$.21331 = \sin 12^{\circ} 19'$$

$$\frac{16}{28} \text{ or } \frac{4}{7} = \frac{x}{60}$$

$$7x = 240$$

$$x = 34$$

$$.21319 = \sin 12^{\circ} 18' 34''$$

$$\frac{1}{4}A = 12^{\circ} 18' 34''$$

$$\angle A = 24^{\circ} 36' 68'' \text{ or } 24^{\circ} 37' 8''$$

$$\sin \frac{1}{2}B = \sqrt{\frac{(x - a)(s - c)}{ac}}$$

$$\sin \frac{1}{2}B = \sqrt{\frac{(12 - 5)(12 - 11)}{(5)(11)}}$$

$$\sin \frac{1}{2}B = \sqrt{\frac{(7)(1)}{55}}$$

$$\sin \frac{1}{2}B = \sqrt{\frac{7}{55}}$$

$$\sin \frac{1}{2}B = \sqrt{\frac{7}{55}}$$

$$\sin \frac{1}{2}B = \sqrt{\frac{1272727}{55}}$$

$$\sin \frac{1}{2}B = \sqrt{.1272727}$$

$$\sin \frac{1}{2}B = \frac{.35675}{.35675} = \sin 20^{\circ} 54' + x$$

$$.35701 = \sin 20^{\circ} 54' + x$$

$$.35701 = \sin 20^{\circ} 54' + x$$

$$.35701 = \sin 20^{\circ} 54' + x$$

$$.35675 = \sin 20^{\circ} 54' 2''$$

$$\frac{1}{2}B = 20^{\circ} 54' 2''$$

$$\angle B = 40^{\circ} 108' 4'' \text{ or } 41^{\circ} 48' 4''$$

$$\angle C = 180^{\circ} - \angle A - \angle B$$

$$\angle C = 180^{\circ} - 24^{\circ} 37' 8'' - 41^{\circ} 48' 4''$$

$$\angle C = 180^{\circ} - 66^{\circ} 25' 12''$$

$$\angle B = 41^{\circ} 48' 4''$$

$$\angle C = 113^{\circ} 34' 48''$$
Therefore, $\angle A = 24^{\circ} 37' 8''$

$$\angle B = 41^{\circ} 48' 4''$$

$$\angle C = 113^{\circ} 34' 48''$$

170. Finding the Area of a Triangle When Two Sides and the Included Angle Are Given

The formula for finding the area of a triangle when two sides and the included angle are given is $S = \frac{1}{2} ab \sin C$ where S is the area of the triangle, a and b are the given sides, and C is the included angle.

> Example: Find the area of oblique triangle ABC (fig. 52) when two sides are 7 and 8 inches, respectively, and the included angle is 50° 50' 50". $S = \frac{1}{2}ab \sin C$ $S = \frac{1}{2} \times 7 \times 8 \times \sin 50^{\circ} 50' 50"$ $\sin 50^{\circ} 50' = .77531$ $\sin 50^{\circ} 50' 50'' = .77531 + x$

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sin 50° 51' = .77550

$$\frac{50}{60}$$
 or $\frac{5}{6} = \frac{x}{.00019}$
 $6x = .00095$
 $x = .00016$
sin 50° 50' 50'' = .77531 + .00016 = .77547
 $S = \frac{1}{4} \times 7 \times 8 \times .77547 = 21.71316$
 $S = 21.71316$ square inches

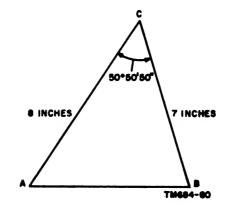


Figure 52. Solving for the area of an oblique triangle when two sides and the included angle are given.

171. Finding the Area of a Triangle When Two Angles and a Side Are Given

The formula for finding the area of a triangle when two angles and a side are given is $S = \frac{a^2 \sin B \sin C}{2 \sin A}$ where S is the area of the triangle, B and C are the given angles, and a is the given side.

Example: Find the area of oblique triangle ABC (fig. 53) when the two angles are 38° 42' 48" and 68° 52' 42" and the side is 10 inches.

$$\begin{array}{l} \angle A = 180^{\circ} - \angle B - \angle C \\ \angle A = 180^{\circ} - 38^{\circ} 42' 48'' - 68^{\circ} 52' 42'' \\ \angle A = 180^{\circ} - 107^{\circ} 35' 30'' \\ \angle A = 72^{\circ} 24' 30'' \\ S = \frac{a^{4} \sin B \sin C}{2 \sin A} \\ S = \frac{10^{4} \sin 38^{\circ} 42' 48'' \sin 68^{\circ} 52' 42''}{2 \sin 72^{\circ} 24' 30''} \\ \sin 38^{\circ} 42' = .62524 \\ \sin 38^{\circ} 42' 48'' = .62524 + x \\ \sin 38^{\circ} 43' = .62547 \\ \frac{48}{60} \text{ or } \frac{4}{5} = \frac{x}{.00023} \\ 5x = .00092 \\ x = .00018 \\ \sin 38^{\circ} 42' 48'' = .62524 + .00018 = .62542 \\ \sin 68^{\circ} 52' = .93274 \\ \sin 68^{\circ} 52' 42'' = .93274 + x \end{array}$$

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sin 68° 53' = .98285 $\frac{42}{60}$ or $\frac{7}{10} = \frac{x}{.00011}$ 10x = .00077x = .000077 or .00008 $\sin 68^{\circ} 53' 42'' = .98274 + .00008 = .93282$ $\sin 72^{\circ} 24' = .95819$ $\sin 72^{\circ} 24' 30'' = .95319 + x$ $\sin 72^{\circ} 25' = .95328$ $\frac{30}{60}$ or $\frac{1}{2} = \frac{x}{.00009}$ 2x = .00009x = .000045 or .00005 $\sin 72^{\circ} 24' 30'' = .95319 + .00005 = .95324$ $S = \frac{100 \times .62542 \times .93282}{.93282}$ $2 \times .95324$ $S = \frac{50 \times .62542 \times .98282}{0.0004}$.95324 $S = \log 50 + \log .62542 + \log .93282 - \log .95324$ $\log 50 = 1.6990$ $\log .62500 = 9.7959 - 10$ $\log .62542 = 9.7959 - 10 + x$ $\log .62600 = 9.7966 - 10$ 42 x $\frac{42}{100} = \frac{2}{.0007}$ 100x = .0294x = .000294 or .0008 $\log .62542 = 9.7959 - 10 + .0008 = 9.7962 - 10$ $\log .98200 = 9.9694 - 10$ $\log .93282 = 9.9694 - 10 + x$ $\log .93300 = 9.9699 - 10$ 82 X $\frac{1}{100} = \frac{1}{.0005}$ 100x = .0410x = .00041 or .0004 $\log .93282 = 9.9694 - 10 + .0004 = 9.9698 - 10$ $\log .95300 = 9.9791 - 10$ $\log .95324 = 9.9791 - 10 + x$ $\log .95400 = 9.9795 - 10$ 24 x $\frac{1}{100} = \frac{1}{.0004}$ 100x = .0096x = .000096 or .0001 $\log .95324 = 9.9791 - 10 + .0001 = 9.9792 - 10$ S = 1.6990 + 9.7962 - 10 + 9.9698 - 10 - 9.9792 - 101.6990 9.7962-10 + 9.9698-10 21.4650-20 - 9.9792-10 11.4858-10 or 1.4858

antilog 1.4857 = 80.6
antilog 1.4858 = 80.6 +
$$x$$

antilog 1.4871 = 80.7
 $\frac{1}{14} = \frac{x}{.1}$
 $14x = .1$
 $x = .007$
antilog 1.4858 = 80.6 + .007 = 80.607
 $S = 30.607$ aquare inches

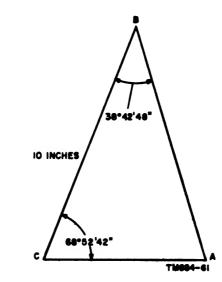


Figure 53. Solving for the area of an oblique triangle when two angles and a side are given.

172. Finding the Area of Triangle When Three Sides Are Given

To find the area of triangle when three sides are given, use the formula $S = \sqrt{s(s - a)(s - b)(s - c)}$ where a, b, and c are the sides of the triangle and $s = \frac{1}{2}(a + b + c)$.

Example: Find the area of an oblique triangle when the sides are 8, 11, and 15 inches, respectively.

$$s = \frac{1}{2}(a + b + c)$$

$$s = \frac{1}{2}(8 + 11 + 15)$$

$$s = \frac{1}{2}(34)$$

$$s = 17$$

$$S = \sqrt{s(s - a)(s - b)(s - c)}$$

$$S = \sqrt{17(17 - 8)(17 - 11)(17 - 15)}$$

$$S = \sqrt{17(9)(6)(2)}$$

$$S = \sqrt{1836}$$

$$S = 42.84 \text{ square inches}$$

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173. Review Problems-Trigonometric Laws

a. In an oblique triangle ABC, angle $A = 42^{\circ} 15' 12''$, angle $B = 75^{\circ} 28' 10''$, and side b measures 21 inches. Solve the triangle for angle C and side a.

b. In an oblique triangle ABC, angle $C = 52^{\circ} 30^{\circ}$, side b = 45 inches, and side c = 38 inches. Solve for angle B.

c. In an oblique triangle ABC, sides a, b, and c opposite angles A, B, and C have lengths of 9, 16, and 21 inches, respectively. Find the three angles of the triangle.

d. In an oblique triangle where a and b are any two sides and A and B are the angles opposite these sides, angle $C = 57^{\circ} 20' 45''$, a = 9.78 inches, and b = 6.47 inches. Find angles A and B.

e. The three sides of a triangle are 40, 37, and 13 inches, respectively. Find the area of the triangle.

f. Two sides of an oblique triangle measure 12 and 18 feet, respectively. The angle between the two sides is 115° . Find the area of the triangle.

g. In a triangle ABC, angle $A = 30^{\circ}$ and angle $B = 60^{\circ}$. The side opposite angle C = 16 inches. Find the area of the triangle.

h. In an oblique triangle ABC, angle $C = 62^{\circ}$ 50'. The side opposite angle A measures 9.65 inches, and the side opposite angle B measures 17.85 inches. Find angles A and B and the length of the side opposite angle C.



RADIANS

174. Angular Measurement Using Radians

s. Definition. A radian is a unit of angular measurement equal to that angle which, when its vertex is upon the center of a circle, intercepts an arc that is equal in length to the radius of the circle. Thus, in figure 54, central angle AOB is equal to 1 radian because arc AB is equal to radius OA.

- (1) The system that makes use of the radian is called the *natural system* of angular measurement because it has no arbitrary unit, such as the degree, but is founded upon the observation that the absolute size of any angle is the ratio of its arc to the radius of that arc. Where the arc and radius are equal, the ratio is 1, and this unit is the radian.
- (2) The natural system of angular measurement—also called the circular system and the radian system—is used

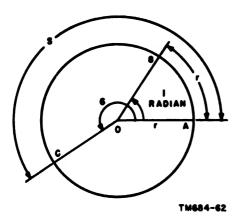


Figure 54. The radian or circular system of measurement.

extensively in electrical formulas (part II).

b. Finding Any Angle. To find any angle, such as angle AOC in figure 54, when the length of arc AB is known, determine the number of times that radius r will go into arc length ABC, thus determining the number of radians in the angle.

Thus,

Angle =
$$\frac{\text{arc}}{\text{radius}}$$

or, if angle AOC is denoted by the Greek letter θ (Theta) and arc ABC by s,

$$\theta = \frac{\theta}{r}$$
 radians

Example: A circle has a radius of 6 inches. Find the angle subtended at the center of the circle by an arc 9 inches in length.

$$\theta = \frac{s}{r}$$
$$= \frac{9}{6}$$
$$= 1.5 \text{ radians}$$

c. Finding Length of Arc. To find the length of an arc intercepted by a central angle when the radius of the circle and the number of radians in the angle are known, use the formula in b above in the form—

$$s = r\theta$$

Example: A circle has a radius of 5 feet. How long is the arc intercepted by a central angle of 1.5 radians?

$$s = r\theta$$

= 5 × 1.5
= 7.5 feet

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175. The Relation Between Degrees and Radians

a. General. It is often necessary to convert an angle from degrees to radians or from radians to degrees. If the angle is one complete revolution, the arc is one complete circumference of a circle; thus, it is 2π times the radius. Therefore, the angle is equal to $2\pi r$ divided by r—that is, 2π radians ($\pi = 3.1416$).

Therefore,
1 revolution =
$$2\pi$$
 radians
also 1 revolution = 360°
Thus,
2 π radians = 360°
1 radian = $\frac{360^{\circ}}{2\pi} = \frac{180^{\circ}}{\pi} = 57.29578^{\circ}$
and since $360^{\circ} = 2\pi$ radians
 $1^{\circ} = \frac{2\pi}{360} = \frac{\pi}{180} = 0.017453$ radians

To change radians to degrees, accurate to seconds, use figures accurate to at least five decimal places.

b. Changing Degrees to Radians and Radians to Degrees.

Example 1: Change 2.74 radians to degrees, minutes, and seconds.

$$1 \text{ radian} = 57.29578^{\circ}$$

$$2.74 \text{ radians} = 2.74(57.29578)$$

$$= 156.99044^{\circ}$$

$$1^{\circ} = 60'$$

$$.99044^{\circ} = .99044(60)'$$

$$= 59.4264'$$

$$.4264' = .4264(60)''$$

$$= 25.5'''$$

$$2.74 \text{ radians} = 156^{\circ} 59' 25.5''$$

Example 2: Change 57° 15' 18" to radians.

Step 1. Change the minutes and seconds to decimals of a degree:

$$1' = 60''$$

$$18'' = \frac{18}{60}$$

$$= .3'$$

$$15.3' = \frac{15.3}{60}$$

$$= .255^{\circ}$$

$$57^{\circ} 15' 18'' = 57.255^{\circ}$$

Step 2. Change to radians:

 $1^{\circ} = .017453$ radian $57.255^{\circ} = 57.255(.017453)$ = .99927 radian

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c. Expressing Angles in Radians as Multiples of π . It is often convenient to express angles in radians as multiples of π . Since $360^\circ = 2\pi$ radians, $90^\circ = \frac{1}{2}\pi$ radians, $40^\circ = \frac{1}{2}\pi$ radians, etc. It is necessary only to multiply the degrees by $\frac{\pi}{180}$ to change to radians.

Example: Express 135° in radians as a multiple of π . 135° = 135 $\left(\frac{\pi}{180}\right)$ = $\frac{3}{4\pi}$ radians

176. Review Problems—Radians

a. Find the angle θ for the following arc lengths and radii:

- (1) r = 5 inches, s = 2 inches.
- (2) r = 3 feet, s = 12 feet.
- (3) r = .8 miles, s = 6.4 miles.
- (4) r = 27 meters, s = 75 meters

b. Find the arc lengths for the following angles and radii:

- (1) $\theta = 5$ radians, r = 7 inches
- (2) $\theta = 8$ radians, r = 2.2 feet
- (3) $\theta = 2.1$ radians, r = 9 miles
- (4) $\theta = .03$ radians, r = .066 inch
- c. Express the following angles in radians:
 (1) 30°
 - (2) 263° 12'
 - (3) 158° 33'
 - (4) 336° 24' 22"
- d. Express the following angles in degrees:
 - (1) ° radians
 - (2) 25 radians
 - (3) 3.45 radians
 - (4) 3π radians
- e. Express the following angles as multiples of π :
 - (1) 30°
 - (2) 60°
 - (3) 225°
 - (4) 720°

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CHAPTER 12

VECTORS

177. Plane Vectors

a. A line segment used to represent a quantity that has direction as well as magnitude is called a vector. The length of a vector is proportionate to the magnitude, and the arrow, or head, of the vector indicates the direction of the quantity represented.

b. The quantity represented by a vector is called a vector quantity. This is the directed magnitude itself. Electrical quantities, such as current and voltage, are vector quantities in ac circuits (par. 194).

Example: An airplane is flying northeast at 120 miles per hour. Its speed is represented on figure 55 by line OA. The direction in which the airplane is traveling is represented by the direction of the line.

178. Vector Notation

Because a vector quantity has direction as well as magnitude, the methods of denoting a vector are different from the methods of de-

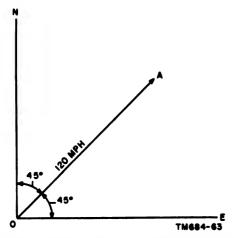


Figure 55. The velocity of an airplane described by a vector.

noting a scaler quantity. A vector may be denoted by two letters, the first indicating the origin, or initial point, and the other indicating the head or terminal point. For example, a vector may be represented by the letters AB, indicating that the quantity went from A to B. A small arrow sometimes is placed over the

letters for emphasis; for example, \overrightarrow{AB} . Another method of notation is A/θ , where A represents the magnitude of the quantity, and $/\theta$ represents the angle the vector makes with some reference line. For example, if line OE in figure 55 were used as the reference line, vector OAcould be represented by the notation $120/45^\circ$, where 120 represents the magnitude of the quantity, and $/45^\circ$ represents the direction with respect to line OE. With respect to line ON, vector OA, would be represented by the notation $120/-45^\circ$.

179. Addition of Vectors, Parallelogram Method

The addition of vectors by the parallelogram method is shown in figure 56. To add vector OA to OC, draw a vector OC with its initial point located at the initial point of vector OA, and complete the parallelogram with these vectors forming two sides. The diagonal vector OB, with its initial point at the same initial point of OA and OC and its terminal point at the opposite vertex of the parallelogram, is the sum of OA and OC. Thus, two vectors (OA and OC) acting simultaneously on a point or object may be replaced by a single vector called the resultant (OB). The resultant vector will pro-

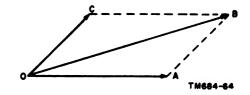
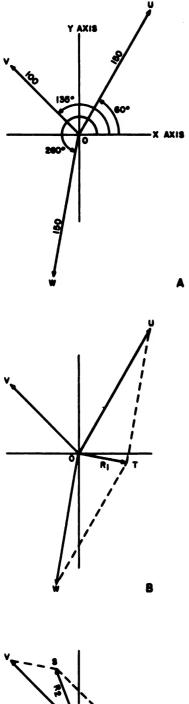


Figure 56. Adding vectors, parallelogram method.

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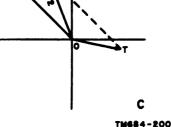


Figure 57. Resolution of three vectors.

duce the same effect on the object as the joint action of the two vectors.

180. Addition of More Than Two Vectors

a. In determining the resultant (par. 179) of vectors when more than two quantities are represented, proceed as follows:

- (1) Find the resultant of two of the vector quantities,
- (2) Determine the final resultant between the third quantity and the resultant obtained from (1), above.

b. Assume three forces U, V, and W are acting on point O as shown in A, figure 57. Force U exerts 150 pounds at an angle of 60° , V exerts 100 pounds at an angle of 135° , and W exerts 150 pounds at an angle of 260° . Find the resultant of forces on point O.

- (1) The resultant of any two vectors, such as U and W, are determined graphically by the line R_1 (B, fig. 57). To solve this problem first draw the vectors to scale at the designated angles; then construct the parallelogram OUTW with adjacent sides WT and UT. The resultant R_1 of OW and OU will be the diagonal OT.
- (2) Combine the resultant R_1 with force V, then construct another parallelogram to scale as in (1), above. The final resultant R_2 is similarly determined by the line SO (C, fig. 57).

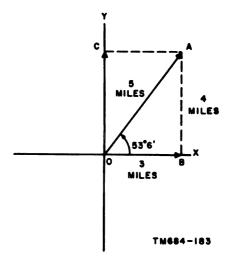


Figure 58. Horizontal and vertical components of vector.

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This, then, is the resolution of all three forces U, V, and W acting on point O.

181. Components of a Vector

a. A vector may be resolved into components along any two specified directions. If the directions of the components are chosen so that they are at right angles to each other, the components are called *rectangular components*.

b. By placing the initial point of a vector at the origin of the X and Y axes, the rectangular components are readily obtained either graphically or by computation. In figure 58, a vector with a magnitude of 5 and a direction of 58° 6' is shown broken down into a horizontal component of 8 and a vertical component of 4. This is done by using the sine and cosine function as follows:

$$\sin 53^{\circ} 6' = \frac{BA}{5}$$

$$.79968 = \frac{BA}{5}$$

$$BA = 5 \times .79968$$

$$= 4 \text{ (approx)}$$

$$\cos 53^{\circ} 6' = \frac{OB}{5}$$

$$.60042 = \frac{OB}{5}$$

$$OB = 5 \times .60042$$

$$= 3 \text{ (approx)}$$



PART N

APPLICATIONS OF MATHEMATICAL PRINCIPLES TO COMMON COMMUNICATIONS-ELECTRONICS PROBLEMS

CHAPTER 13 INTRODUCTION

182. Series Circuits

In a series circuit, electrical energy is supplied to a number of devices in series; that is the same current passes through each device in completing its path to the source of supply. Figure 59 shows a resistance, an inductor, and a capacitor connected in series with a voltage source.

a. The current is the same in all parts of a series circuit.

b. The total voltage drop (E_t) in a series circuit is equal to the sum of the voltage drops across individual loads:

 $E_1 = E_1 + E_2 + E_3 + \ldots$

c. The total resistance (R_t) of a series circuit is equal to the sum of all individual resistance:

$$R_1 = R_1 + R_2 + R_3 + \ldots$$

d. The total inductance L_i of a series circuit is equal to the sum of the individual inductances:

$$L_t = L_1 + L_2 + L_3 + \ldots$$

e. The reciprocal of the total capacitance (C_i) is equal to the sum of the reciprocals of the separate capacitances. The total capacitance is also less than the capacitance of any one of the capacitors, and is expressed as follows:

$$\frac{1}{C_{i}} = \frac{1}{C_{1}} + \frac{1}{C_{2}} + \frac{1}{C_{3}} + \cdots$$

If only two capacitances are in series, a simplified formula can be derived by combining fractions over an LCD, and taking the reciprocal:

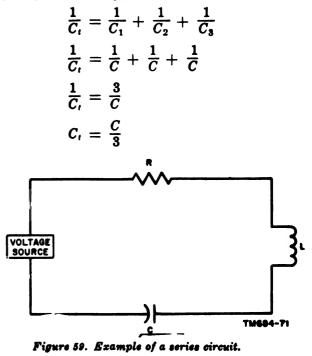
$$\frac{1}{C_t}=\frac{1}{C_1}+\frac{1}{C_2}$$

$$\frac{1}{C_{t}} = \frac{C_{2}}{C_{1}C_{2}} + \frac{C_{1}}{C_{1}C_{2}}$$
$$\frac{1}{C_{t}} = \frac{C_{1} + C_{2}}{C_{1}C_{2}}$$
$$C_{t} = \frac{C_{1}C_{2}}{C_{1} + C_{2}}$$

If two or more capacitors of equal value are placed in series, the total capacitance is equal to the value of one capacitor (c) divided by the number of capacitors used (n):

$$C_t = \frac{C}{n}$$

This equation can be derived as follows (assuming 3 equal-value capacitors):



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183. Parallel Circuits

Figure 60 is an example of a simple parallel circuit, with two resistors connected in parallel across a generator. As indicated by the arrows, the current from the generator separates into two parts, each resistor receiving a part of the total current. The larger fraction of current flows through the branch of less resistance, and the smaller fraction of current flows through the branch of greater resistance. The two parts of the current join again upon leaving the resistors.

a. The total current (I_t) in a parallel circuit is the sum of the currents in the separate branches:

$$I_1 = I_1 + I_2 + I_3 + \dots \dots$$

b. The voltage (E) across each branch of a parallel circuit is the same:

$$E_1 = E_2 = E_3 \ldots \ldots$$

c. The reciprocal of the total resistance (R_t) of all resistors in a parallel circuit is equal to the sum of the reciprocals of the separate resistance. The total resistance is also less than the resistance of any one of the resistors, and is expressed as follows:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

If only two resistors are in parallel, a simplified formula can be derived for the total resistance as for total capacitance in a series circuit (par. 182e):

$$R_{\prime}=\frac{R_1R_2}{R_1+R_2}$$

If two or more resistors of the same value are placed in parallel, the total resistance is equal to the value of one resistor (R) divided by the number of resistors used (n), as for capacitances, in series (par. 182e):

$$R_{\prime}=\frac{R}{n}$$

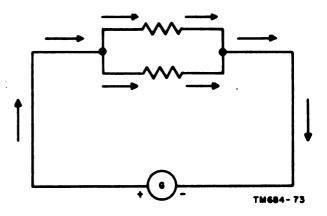


Figure 60. Example of a parallel circuit.

d. The reciprocal of the total inductance (L_t) in a parallel circuit is equal to the sum of the reciprocals of the separate inductances, as with resistances (c above):

$$\frac{1}{L_i} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots$$

The rules covering the calculation of resistances in parallel (c above) also apply to inductances in parallel.

e. The total capacitance in a parallel circuit is equal to the sum of the individual capacitances, as for resistances and inductances in series (par. 182c and d):

$$C_{t} = C_{1} + C_{2} + C_{3} + \dots$$

The rules covering the calculation of resistances and inductances in series also apply to capacitances in parallel.

184. Series-Parallel Circuit

A series-parallel circuit is simply a combination of a series circuit and a parallel circuit. The rules covering series circuits (par. 182) apply to the series portion of the circuit, and the rules covering parallel circuits (par. 183) apply to the parallel portion of the circuit. The examples given in chapters 14 through 18 more clearly illustrate the various types of circuits.



CHAPTER 14 PROBLEMS IN DC ELECTRICITY

185. General

In circuits using constant-value dc electricity, only the effects of the resistance in the circuit are significant, because inductance and capacitance depend on varying current or voltage. Consequently, the examples given in this chapter involve only resistances.

186. Ohm's Law

a. An important relationship between current (I), voltage (E), and resistance (R) in a circuit is given by Ohm's law which states that the current in an electrical circuit varies directly as the voltage and inversely as the resistance. Expressed in a formula, the relationship is:

$$I = \frac{E}{R}$$

The formula may also appear in the following forms:

$$E = IR$$

 $R = rac{E}{I}$

b. The following example illustrates Ohm's law:

Example: Solve the following problem: A voltmeter (voltage measuring device) connected directly

187. Solving Series Circuits

The following example illustrates the method of using Ohm's law and the principles of series circuits (par. 182) to solve series dc circuits.

Example: Solve the following problem:

Resistors R_1 , R_2 , and R_3 are connected in series across a 110-volt generator (fig. 62). If resistor $R_1 = 6.5$ ohms, resistor $R_2 = 10.3$ ohms, and resistor $R_3 = 7.6$ ohms, what is the total current in the circuit? What is the voltage drop across each resistance?

across a resistance reads 65 volts (fig. 61). An ammeter (current measuring device) connected in series reads 5.3 amperes. What is the value of the resistance in ohms?

$$E = 65, I = 5.8, R = ?$$

 $R = \frac{E}{I}$
 $R = \frac{65}{5.8}$
 $= 12.26 \text{ or } 12.3 \text{ ohms.}$

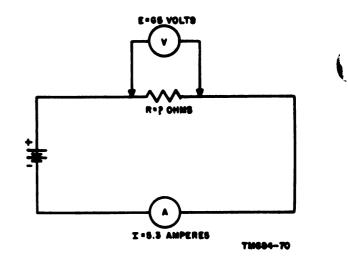


Figure 61. Simple circuit with unknown resistance.





Step 1.	Find the total resistance in the circuit. $R_t = R_1 + R_2 + R_3$ = 6.5 + 10.3 + 7.6 = 24.4 ohms total resistance
Step 2.	Find the total current in the circuit. E = IR 110 = I(24.4) 24.4I = 110 I = 4.508 amperes total current
Step 3.	Find the voltage drop across R_1 . E = IR = 4.508(6.5) $= 29.302$ volts across R_1
Step 4.	Find the voltage drop across R_2 . E = IR = 4.508(10.3) $= 46.432$ volts across R_2
Step 5.	Find the voltage drop across R_s . E = IR = 4.508(7.6) $= 34.261$ volts across R_s
Check:	34.261 + 46.432 + 29.303 = 109.996 or 110 volts.
	RI

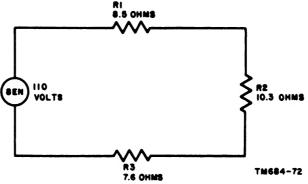


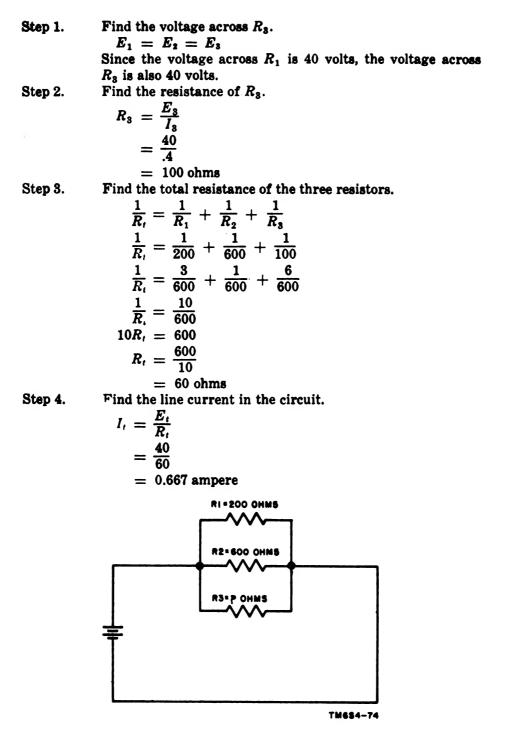
Figure 62. Series circuit with unknown current,

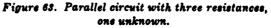
188. Solving Parallel Circuits

The following example illustrates the method of using Ohms' law and the principles of parallel circuits (par. 183) to solve parallel dc circuits.

Example: Solve the following problem: In figure 63, a resistor of 200 ohms (R_1) , a resistor of 600 ohms (R_2) , and an unknown resistor (R_3) are connected in parallel across a source of emf. The voltage across R_1 is 40 volts. The current through the resistor of unknown value (R_3) is 0.40 ampere. Find (a) the value of R_3 , (b) the total resistance of the circuit, and (c) the total current, in the circuit.







189. Solving Series-Parallel Circuits

A simple series-parallel circuit, with series-connected resistors R_2 and R_3 connected in paralbel with resistor R_4 and the combination connected in series with resistors R_1 and R_3 , is shown in A, figure 64. The following example uses B through D, figure 64, to illustrate the method of solving series-parallel dc circuits.

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- **Example:** .Find the current through each resistance and the voltage drop across each resistance in A, figure 64.
- Step 1. Since R_2 and R_3 are in series, their total resistance is the sum (B, fig. 64) of the two resistances.

$$R_{2,3} = R_2 + R_3 \\ = 5 + 15 \\ = 20 \text{ ohms}$$

Step 2. $R_{2,3}$ is in parallel with R_4 . Find the total resistance of the combination (C, fig. 64).

$$\frac{1}{R_{2,3,4}} = \frac{1}{R_{2,3}} + \frac{1}{R_4}$$
$$\frac{1}{R_{2,3,4}} = \frac{1}{20} + \frac{1}{30}$$
$$\frac{1}{R_{2,3,4}} = \frac{3}{60} + \frac{2}{60}$$
$$\frac{1}{R_{2,3,4}} = \frac{5}{60}$$
$$5R_{2,3,4} = 60$$
$$R_{2,3,4} = \frac{60}{5}$$
$$R_{2,3,4} = 12 \text{ ohms}$$

Step 3. $R_{1,R_{2,3,4}}$ and R_{3} are in series. Their total resistance is the sum (D, fig. 64) of the resistances.

$$R_{1,2,3,4,5} = R_1 + R_{2,3,4} + R_5$$

= 3 + 12 + 10
= 25 ohms

Step 4. Find the total current sent through these resistances by a voltage of 100 volts.

$$I_t = \frac{E_t}{R_t} = \frac{100}{25}$$

= 4 amperes

Step 5. Find the voltage drop across $R_{2,3,4}$. $E_{2,3,4} = IR_{2,3,4}$

$$K_{2,3,4} = IK_{2,3,4}$$

= 4 × 12

= 48 volts

Step 6. Analyze the parallel circuit.

The voltage across R_4 is 48 volts. Find the current.

$$I_4 = \frac{E_4}{R_4}$$
$$= \frac{48}{30}$$

The voltage across R_2 and R_3 also is 48 volts, and the resistance $R_{2,3}$ is 20 ohms. Find the current.

$$I_{2.3} = \frac{E_{2.3}}{R_{2.3}} = \frac{48}{20} = 2.4 \text{ amperes } (I_2 = I_3)$$

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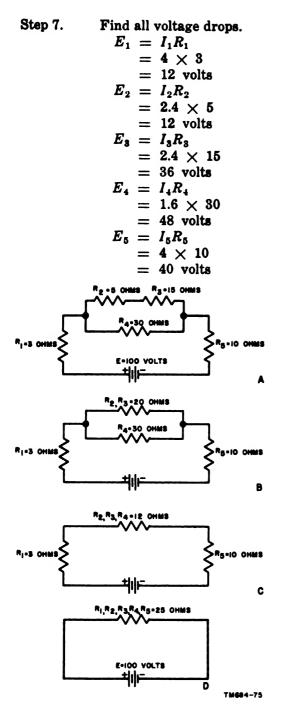


Figure 64. Solving a series-parallel circuit.

190. Solving More Complex Electrical Problems by Using Kirchhoff's Laws

a. General. The more complex seriesparallel problems are often more readily solved by using Kirchhoff's laws. A full treatment of the electrical phenomena embodied in Kirchhoff's laws is not within the scope of this manual. For a complete treatment of electrical theory on this subject, see TM 11-661. The basic principles of Kirchhoff's laws are as follows:

- (1) The algebraic sum of the currents at any junction of conductors is zero.
- (2) The algebraic sum of the electromotive forces and voltage drops around a closed circuit is zero.

b. Understanding Kirchhoff's Laws. The first of Kirchhoff's laws simply means that there is just as much current flowing away from a point as there is flowing to it. The second law simply means that the voltage source is equal to the sum of the voltage drops around any closed circuit. For example, starting at point X (fig. 65) and going around the circuit clockwise, the following equation is obtained:

$$\mathbf{E} - \mathbf{I}\mathbf{R}_1 - \mathbf{I}\mathbf{R}_2 - \mathbf{I}\mathbf{R}_3 = \mathbf{0}$$

Substituting the values of resistance as indicated in the figure, the equation becomes:

$$37 - 13I - 9I - 11I = 0$$

Collecting like terms and solving for I gives: 37 - 33I = 0

$$33I = 37$$

$$I = 1.121$$
 amperes

To prove that this is correct, use Ohm's law as follows:

$$E_1 = IR_1 = 1.121 \times 13 = 14.58 \text{ volts}$$

$$E_2 = IR_2 = 1.121 \times 9 = 10.09 \text{ volts}$$

$$E_3 = IR_3 = 1.121 \times 11 = 12.33 \text{ volts}$$

$$E_t = IR_t = 1.121 \times 33 = 37.00 \text{ volts}$$

Thus, the sum of the voltage drops equals the applied voltage and the second law is verified.

c. Solving Series-Parallel Circuits Using Kirchhoff's Laws. Problems involving seriesparallel circuits are readily solved by using Kirchhoff's laws and simultaneous equations (par. 84). The example below illustrates such a problem.

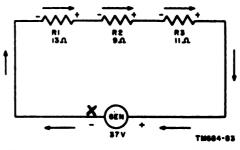


Figure 65. Example of Kirchhoff's second law.

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- **Example:** Solve for the current in each branch of the circuit shown in figure 66.
- Step 1. Assume a direction for the current flow in each branch, as shown in the figure. (It will be shown that the direction assumed does not affect the accuracy of the result.) According to Kirchhoff's first law, the current I_1 flowing through the 6-ohm resistor plus the current I_2 flowing through the 7- and 8-ohm resistors equals the current $I_1 + I_2$ flowing through the remainder of the circuit, which includes the 5-ohm resistor.
- Step 2. Considering the first part of the circuit, from point B through the generator and around the circuit back to point B through the 6-ohm resistor, the application of Kirchhoff's second law yields the following equation:

Step 3. Considering the path from point B through the generator and through points A, X, and Y back to B, the application of Kirchhoff's second law yields the following equation:

Step 4. Using the methods of solving simultaneous equations described in paragraph 116, solve for I_1 by multiplying equation 1 by 4 and subtracting equation 2 from the new equation :

$$40 - 44I_1 - 20I_2 = 0$$

$$10 - 5I_1 - 20I_2 = 0$$

$$30 - 39I_1 = 0$$

$$- 39I_1 = -30$$

$$I_1 = 0.769 \text{ ampere}$$

Step 5. Solve for I_2 by substituting the value of I_1 in either equation 1 or equation 2, or by eliminating I_1 in solving the simultaneous equations. Substituting I_1 in equation 2 yields the following:

$$10 - 5(0.769) - 20I_2 = 0$$

$$10 - 3.845 - 20I_2 = 0$$

$$- 20I_2 = -6.155$$

$$I_2 = 0.308 \text{ ampere}$$

Step 6. The current in the left-hand side of the circuit is $I_1 + I_2$ or 1.077 amperes.

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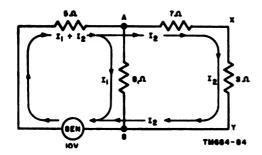


Figure 66. Solving series-parallel circuits, using Kirchhoff's laws.

d. Direction of Current Flow. If the direction of current flow is assumed incorrectly, the computed value for the current will have a negative sign; however, the magnitude of the current will be the same. Therefore, to correct the error, simply reverse the assumed direction of current flow on the diagram.

e. Facts to Remember When Working Problems. The solution of problems involving series-parallel circuits by the above method normally is relatively simple. The important facts to remember when working such problems are:

- (1) Assume any direction of current flow in the beginning.
- (2) Take any path around any portion of the circuit, as long as the path is a complete circuit.
- (3) Observe the polarities of the circuit, both voltage sources and voltage drops.
- (4) Be sure to have as many equations as there are unknowns.

191. Dc Power

In dc circuits, the amount of power absorbed by a resistor or the resistance of a circuit is easily determined by Joule's law:

$P = I^2 R$, where:

- P = power absorbed in watts
- I = total current in amperes

R =total resistance of the circuit in ohms

Since the voltage drop (E) across a resistor (R) is equal to IR, the formula above may also be written: $P = IR \times I = EI$.

Example 1: Find the power consumed in a 50-ohm resistor when a current of 5 amperes flows through it.

$$P = I^2 R$$

= 5² × 50
= 1,250 watts

Example 2: Find the power delivered by a 12-volt battery when the current drain is 6 amperes.

P = EI= 12 × 6 = 72 watts

192. Review Problems—Dc Electricity

a. (1) The resistance of a tungsten lamp is 20 ohms when the lamp is cold. What current will the lamp draw the instant it is placed across a 110-volt line? (2) When the lamp is glowing at full brilliancy, its resistance rises to 84 ohms. What is the final steady current of the lamp?

b. An adjustable resistor has a minimum setting of 14 ohms and a maximum setting of 50 ohms. (1) What ranges of resistance can be covered with two of these resistors connected in series? (2) What ranges of resistance can be covered with two of these resistors connected in parallel?

c. When a 6,500-ohm resistance is connected into the plate circuit of a radio tube, the plate current is 34 milliamperes. (1) What is the voltage drop across the 6,500-ohm resistance? (2) How much power is consumed by the resistor?

d. Three resistors of 20 ohms, 30 ohms, and 50 ohms, respectively, are connected in series. The current through R_1 (20 ohms) is 0.8 ampere. (1) What is the current through R_3 (50 ohms)? (2) What is the voltage across R_2 (30 ohms)? (3) What is the total voltage drop across the three resistors?

e. A divided circuit has three branches of 5, 10, and 20 ohms resistance, respectively. (1) What is the joint conductance of the three branches? (Conductance is the reciprocal of resistance.) (2) What is the joint resistance? (3) A current of 20 amperes flows in the 5Į



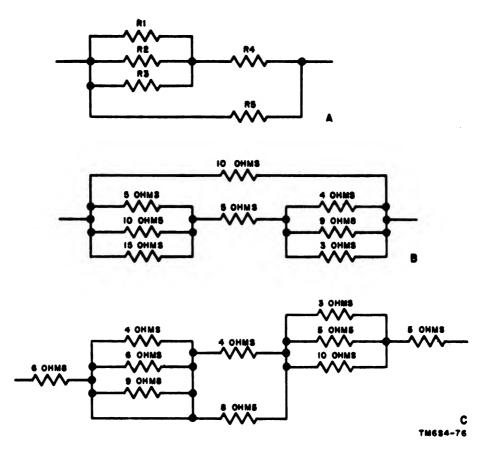
ohm branch; find the current in each of the other branches. (4) Find the combined current.

f. A parallel circuit has branches with resistances of 1, 3, 10, 20, and 50 ohms, respectively. (1) What is the conductance of each branch? (2) What is the conductance of the combination? (3) What is the resistance of the combination?

g. Three resistors R_1 (36 ohms), R_2 (42 ohms) and R_3 are connected in series with a generator. An ammeter inserted in the circuit

between R_1 and R_2 reads 2.4 amperes, and a voltmeter across R_3 reads 41 volts. (1) What is the resistance of R_3 ? (2) What is the voltage across R_1 ? (3) What is the voltage across R_2 ? (4) What is the voltage across the generator?

h. Find the total resistance of: (1) circuit A when $R_1 = 6$ ohms, $R_2 = 9$ ohms, $R_3 = 17$ ohms, $R_4 = 5$ ohms, $R_5 = 11$ ohms; (2) circuit a when $R_1 = 12$ ohms, $R_2 = 25$ ohms, $R_3 = 19$ ohms, $R_4 = 8$ ohms, $R_5 = 12$ ohms. (3) circuit B; (4) circuit C.



i. A 10-ohm resistor is connected in series with a 15-ohm resistor. (1) What voltage must be placed across the two resistors to send a current of 5 amperes through it? (2) What would the voltage be across each resistor?

j. (1) What voltage is required to force a current of 10 amperes through a parallel combination of three branches having resistances of 15.3 ohms, 1.3 ohms, and 10.5 ohms, re-

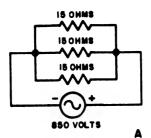
spectively? (2) What will the current be in each branch? (3) What is the voltage drop across each branch?

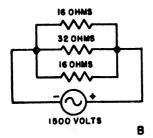
k. A generator has an output voltage of 110 volts. (1) What current is flowing in a wire of 0.02 ohm connected across the terminals? (2) What current will flow if an incandescent lamp of 484 ohms is also connected across the generator?

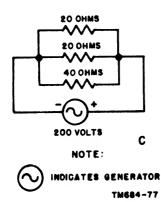
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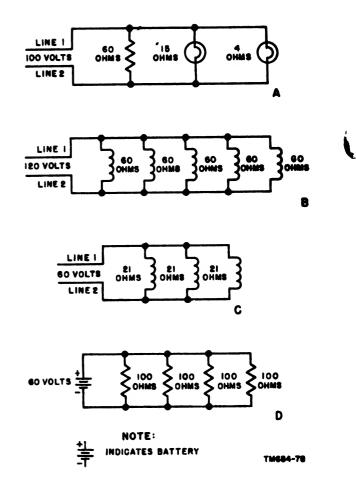
I. Find the total resistance of each of the parallel circuits A, B, and C.

m. Find the total resistance of each of the parallel circuits A, B, C, and D.







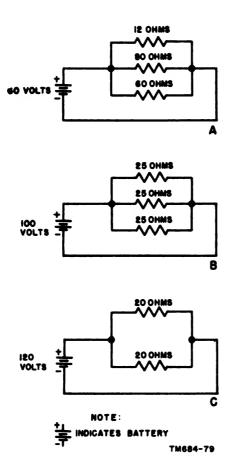


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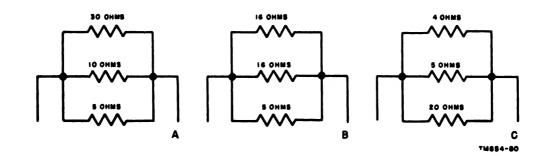
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n. Find the total resistance of each of the parallel circuits A, B, and C.



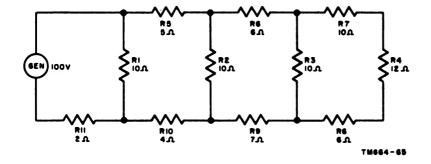
o. Find the total resistance of each of the parallel circuits A, B, and C.



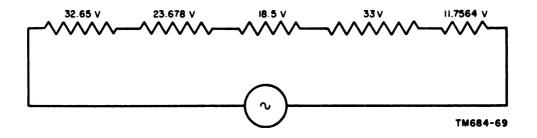
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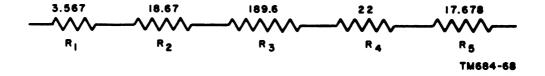
p. Find the current through each resistor in the circuit below.



q. Find the total resistance in the circuit below when a current of .5 amperes flows through it.



r. Find the current through the resistors in the circuit below when 115 volts is applied across the circuit.



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CHAPTER 15 PROBLEMS IN AC ELECTRICITY

193. General

In circuits using ac electricity¹, the current is affected by inductance and capacitance as well as resistance. In addition, certain combinations of these loads will produce unusual effects, such as resonance (par. 202), not experienced in dc circuits. These phenomena are used extensively in electrical and electronic circuits. Consequently, problems in ac electricity are more complex than corresponding problems in dc electricity.

194. Application of Vectors and Trigonometry in Solving Ac Circuit Problems

a. As discussed in chapter 12, a vector is a line whose length and direction represent accurately a given quantity; the quantity thus represented is a vector quantity. Because the magnitude of ac currents and voltages varies from instant to instant, the magnitude is a function of time, and the current and voltage can be expressed as vectors: The length of the vector represents the magnitude of the current or voltage, and the direction represents its relationship in time to another vector (b below).

b. When a circuit contains inductance or capacitance, the current in the circuit is not in phase with the voltage that produces it. In other words, the instant the voltage is zero, the current that it produces has a value other than zero, or when the voltage is at its maximum, the current has a value different from its maximum value. The current is said to *lead* the voltage if the current reaches its maximum *before* the voltage maximum occurs; the current is said to *lag* the voltage if the current

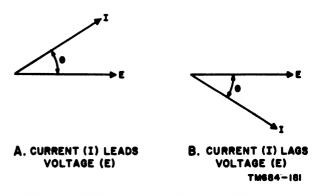


Figure 67. Vector representation of leading and lagging current.

reaches its maximum *after* the voltage maximum occurs. The relationship between current and voltage can be represented by vectors, with one vector representing current, another voltage, and with the angle between them indicating the amount of lag or lead. Figure 67 shows a vector representation of leading and lagging current. The angle is called the phase angle.

c. The voltage drop across a resistor also may be represented by a vector having the same direction as the vector representing the current flowing through the resistor. In other words, the voltage across the resistor and the current flowing through it are in phase.

d. The voltage drop across a capacitor may be represented by a vector making an angle of 90° with the vector representing the current flowing through the capacitor. In a purely capacitive circuit, the current will lead the applied voltage by an angle of 90° .

e. The voltage drop across an inductor may be represented by a vector making an angle of 90° with the vector representing the current flowing through the inductance. In a purely inductive circuit, the current will lag the applied voltage by an angle of 90° .



¹ This chapter is limited to the application of mathematics to single-phase, sinusoidal ac. The electrical phenomena of this type of ac are treated briefly. See TM 11-681 for a complete treatment of single-phase, sinusoidal ac.

f. In a circuit that contains inductance, capacitance, and resistance, the current will lead or lag the applied voltage by a phase angle of less than 90° .

g. The example below illustrates the use of vectors in the solution of a typical ac circuit problem. Paragraphs 199 through 201 give a more detailed coverage of problems of this type.

Example: In a series circuit (fig. 68), the voltage drop across the capacitor (E_c) is 10 volts, the voltage drop across the inductance (E_L) is 50 volts, and the voltage drop across the resistance (E_R) is 30 volts. Determine the magnitude of the applied voltage. By what phase angle (A) does the current lead or lag the applied voltage in the circuit?

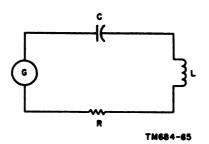


Figure 68. An ac series circuit containing inductance, capacitance, and resistance.

- Step 1. The vector diagram for this circuit is shown in figure 69. In a series circuit, the same current flows through each element. Draw the vector representing the current (I) in a horizontal position. The angles of all vectors representing voltage drops are given with respect to the current.
- Step 2. Draw the vector E_L , representing the voltage drop across the inductance, at an angle of 90° with the vector I.
- Step 3. Draw the vector E_c , representing the voltage drop across the capacitor, at a angle of -90° with the vector *I*.

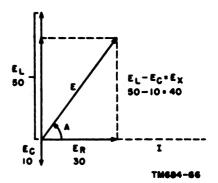


Figure 69. A vector diagram of an ac series circuit containing inductance, capacitance, and resistance.

- Step 4. The vector E_R , representing the voltage drop across the resistor, has the same direction as the vector I.
- Step 5. The vector sum of these voltage drops is equal to the applied voltage.

Along the horizontal:

 $E_L = 0, E_c = 0, E_R = 30$ Along the vertical:

$$E_L = 50, E_C = -10, E_R = 0$$

Step 6. Adding the horizontal and vertical voltage drops, respectively:

Step 7.

$$E_L + E_c + E_R = 0 + 0 + 30$$

= 30
$$E_L + E_c + E_R = 50 + (-10) + 0 = 40$$

Because the vectors form a right triangle, with the applied voltage E as the hypotenuse and E_R and E_X as the sides (fig. 69), the law of right triangles (par. 133) can be used to solve for one of the quantities when the other two are known. From this law, the relationship between E, E_R , and E_X is expressed by the formula

$$E = \sqrt{E_R^2 + E_X^2}.$$

$$E = \sqrt{E_R^2 + E_X^2}.$$

$$= \sqrt{(30)^2 + (40)^2}.$$

$$= \sqrt{900 + 1600}.$$

$$= \sqrt{2500}.$$

$$= 50 \text{ volts}.$$

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Step 8. The formula for determining angle A which the vector representing the applied voltage makes with the vector I (fig.

69) is
$$\tan A = \frac{E_X}{E_R}$$
.
 $\tan A = \frac{E_X}{E_R}$
 $= \frac{40}{30} \text{ or } \frac{4}{3}$
 $= 1.33333$
 $A = 53^{\circ} 7' 48''$

Step 9.

The circuit is predominately inductive; therefore, the current lags the applied voltage by a phase angle of 53° 7′ 48″.

195. Ohm's Law Applied to Ac Circuits

Because of the effects of inductance and capacitance in ac circuits, Ohm's law (par. 186) must be modified to take these added effects into consideration.

a. If the circuit contains a combination of resistance and inductive reactance (par. 196) or capacitive reactance (par. 197), or both, the overall effect is called impedance (par. 198), and Ohm's law is modified to read:

$$I = \frac{E}{Z}$$

where I is the current in amperes, E the ac voltage in volts, and Z the impedance in ohms. This formula may also be written:

$$E = IZ$$
$$Z = \frac{E}{I}$$

b. If the circuit contains reactances only, the formulas become:

$$I = \frac{E}{X}$$
$$E = IX$$
$$X = \frac{E}{I}$$

where X is the total reactance (par. 198a) of the circuit in ohms.

c. If the circuit contains resistance only, the formula is the same as in a dc circuit (par. 186).

d. The application of these formulas in solving ac circuit problems is covered in paragraphs 196 through 208.

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196. Inductive Reactance

Inductance enables an electric circuit to build up a voltage by electromagnetic induction whenever the current strength changes. The induced voltage always opposes the applied voltage and thus retards the change in the current. *Inductive reactance* is the effect of inductance expressed in *ohms*. The formula for finding inductive reactance is:

$$X_L = 2\pi f L$$

where X_L is the inductive reactance in ohms, L is the inductance in henrys, and f is the frequency in cps.

Example 1: Determine the inductive reactance of a coil if the ac in the circuit has a frequency of 100 cps, and the inductance of the coil is 0.036 henry.

$$X_{L} = 2\pi f L = 2 \times 3.14 \times 100 \times .036 = 628 \times .036 = 22.608 ohms$$

Example 2: If a coil with an inductance of 0.2 henry and negligible resistance is connected across the terminals of a 220-volt, 60-cycle ac generator, how much current will flow through the coil?

Step 1. Find the inductive reactance of the coil.

$$X_{L} = 2\pi fL = 2 \times 3.14 \times 60 \times .2 = 376.8 \times .2 = 75.36 \text{ ohms}$$

Step 2. Find the amount of current that will flow through the coil.

$$I = \frac{E}{X_L}$$
$$= \frac{220}{75.36}$$
$$= 2.92 \text{ amperes}$$

197. Capacitive Reactance

Capacitance enables a capacitor to retain an electric charge which opposes any changes in the voltage of the circuit in which the capacitor is connected. *Capacitive reactance* is the effect of the capacitance expressed in *ohms*.



The formula for finding capacitive reactance is:

$$X_{c'}=\frac{1}{2\pi fC}$$

where X_c is the capacitive reactance, C is the capacitance expressed in farads, and f is the frequency in cycles per second.

Example: A 110-volt, 60-cycle ac generator is connected in series with a 1-microfarad (10⁻⁶ farad) capacitance. What is the capacitive reactance of the circuit?

$$X_{c} = \frac{1}{2\pi fC}$$

= $\frac{1}{2 \times 8.14 \times 60 \times 10^{-4}}$
= $\frac{10^{6}}{6.28 \times 60}$
= $\frac{1,000,000}{376.8}$
= 2,653 ohms

198. Impedance

a. The impedance of a circuit is the circuit's total opposition to the flow of current. In a dc circuit, the opposition consists of resistance alone. In an ac circuit, the opposition consists of resistance and reactance (X). Inductive and capacitive reactances can be combined, but because their effects in the circuit are exactly opposite—inductive reactance causes the current to lag the voltage by 90° and capacitive reactance causes the voltage by 90°—they are combined by subtraction:

 $X = X_L - X_C$ or $X = X_C - X_L$ (subtracting the smaller from the larger)

b. Resistance and reactance cannot be added directly, but they can be considered as two vectors acting at right angles to each other. Thus, the relation between resistance, reactance, and impedance may be illustrated by a right triangle (fig. 70). Since these quantities may be related to the sides of a right triangle, the formula for finding the impedance of a circuit is:

$$Z^2 = R^2 + X^2$$
 or $Z = \sqrt{R^2 + X^2}$

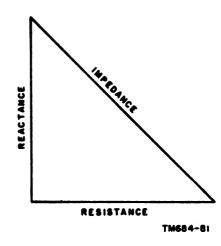


Figure 70. The resistance-reactance-impedance triangle.

where Z is the impedance in ohms, R is the resistance in ohms, and X is the reactance in ohms.

Example 1: A 110-volt, 60-cycle ac gener-

ator is connected in series with a 1-microfarad capacitance and a 1,000-ohm resistance. The capacitive reactance of the circuit is 2,650 ohms. What is the impedance of the circuit?

$$Z = \sqrt{R^2 + XC^2}$$

= $\sqrt{(1000)^2 + (2650)^2}$
= $\sqrt{(10^3)^2 + (2.65 \times 10^3)^2}$
= $\sqrt{10^4 + 7.023 \times 10^4}$
= $\sqrt{8.023 \times 10^4}$
= 2.83×10^3

= 2,830 ohms

Example 2: A 300-volt, variable-frequency ac generator is connected in series with an inductive reactance of 300 ohms, a capacitive reactance of 100 ohms, and a resistance of 100 ohms. What is the impedance of the circuit?

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

= $\sqrt{(100)^2 + (300 - 100)^2}$
= $\sqrt{(100)^2 + (200)^3}$
= $\sqrt{(10^2)^2 + (2 \times 10^2)^2}$
= $\sqrt{10^4 + 4 \times 10^4}$
= $\sqrt{5 \times 10^4}$
= 2.236×10^2
= 223.6 ohms

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199. Solving Ac Circuits Having Resistance and Inductance

c. Series Circuits. The following examples illustrate the method of solving series ac circuits having resistance and inductance (called series RL circuits) by using the principles described in paragraphs 198 through 198.

- Example 1: An ac circuit with a resistance of 1,000 ohms and an inductance of 5 henrys is connected in series with a generator (fig. 71). The voltage drop across the resistance is 51.5 volts, and the voltage drop across the inductance is 97 volts. Find the applied voltage in the circuit. If the impedance of the circuit is 2,132 ohms, what is the phase angle by which the current lags the applied voltage?
- Step 1. The vector diagram for this circuit is shown in figure 77. In an ac series circuit, the same current flows through all parts of the circuit—in this case, 0.051 ampere. Draw the vector E_R to represent the voltage drop across the resistance. Draw the vector E_L to represent the voltage drop across the inductance.
- Step 2. The vector sum of these voltage drops is equal to the applied voltage. Adding the horizontal and vertical voltage drops, respectively:

 $E_L + E_R = 0 + 51.5 = 51.5$ $E_L + E_R = 97 + 0 = 97$

Step 3.

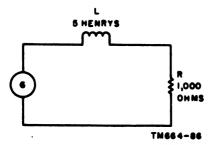
Find the applied voltage as follows:

$$E^2 = E_L + E_R^2$$

 $= (97)^2 + (51.5)^2$
 $= 9409 + 2652.25$
 $= 12061.25$
 $E = \sqrt{12061.25}$
 $= 109.8 \text{ or approx 110 volts}$

Step 4. Find the phase angle by which the current lags the applied voltage.

$$\cos A = \frac{R}{Z} \text{ (for series circuit)}$$
$$= \frac{1000}{2132}$$
$$= 0.46904$$
$$A = 62^{\circ} 1' 19''$$



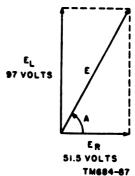


Figure 71. An ac series eircuit containing inductance and resistance.

Figure 72. Ac series circuit containing inductance and resistance, vector diagram.

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- Step 5. Therefore, the current lags the applied voltage by a phase angle of 62° 1′ 19″.
- **Example 2:** A 110-volt, 60-cycle ac generator is connected in a series circuit to a load consisting of an inductance of 3 henrys and a resistance of 10,000 ohms (A, fig. 73).

Step 1. Find the inductive reactance of the circuit.

- $X_L = 2 \pi f L$
 - $= 2 \times 3.14 \times 60 \times 3$
 - $= 6.28 \times 180$
 - = 1130.4
 - = 1,180 ohms (approx)
- **Step 2.** Find the impedance of the circuit.
 - $Z = \sqrt{R^2 + X_L^2}$
 - $= \sqrt{(10,000)^2 + (1180)^2}$
 - $=\sqrt{100,000,000+1,276,900}$
 - $=\sqrt{101,276,900}$
 - = 10,063.64
 - = 10,064 ohms (approx)
- Step 3. Find the effective current in the circuit. (The effective value is the equivalent heating value of an alternating current as compared to a direct current. It is also called the root-mean-square (rms) value.)

$$I = \frac{E}{Z}$$
$$= \frac{110}{10,065}$$
$$= 0.0109 \text{ ampere}$$

- Step 4. In a series circuit, the same current flows through all parts of the circuit. Therefore, the current through both the inductance and the resistance is 0.0109 ampere.
- Step 5. Find the voltage drop across the inductance.
 - $E_L = IX_L$ = 0.0109 × 1180 = 12.817
 - = 12 volts (approx)
- Step 6. Find the voltage drop across the resistance.
 - $E_R = IR$
 - $= 0.0109 \times 10,000$
 - = 109 volts
- Step 7.
 - rep 7. Find the total voltage in the circuit. In an ac series circuit, voltage drops are added vectorially (B, fig. 73).

$$E_{t}^{2} = E_{L}^{2} + E_{R}^{2}$$

$$= (12)^{2} + (109)^{2}$$

$$= 144 + 11,881$$

$$= 12,025$$

$$E_{t} = \sqrt{12,025}$$

$$= 109.6$$

$$= 110 \text{ volts (approx)}$$

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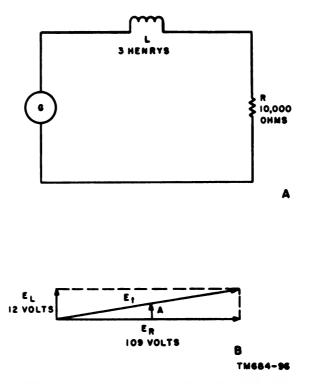


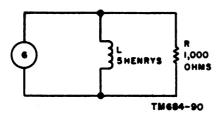
Figure 75. Ac series circuit having inductance and resistance, schematic and vector diagrams.

Step 8. Find the phase angle by which the current lags the applied voltage.

$$\cos A = \frac{R}{Z} \\
= \frac{10,000}{10,065} \\
= 0.99354 \\
A = 6^{\circ} 31'$$

b. Parallel Circuits. The following examples illustrate the method of solving parallel RL circuits by using the principles described in paragraphs 193 through 198.

- Example 1: An ac circuit has an inductance and resistance connected in parallel (fig. 74). The current flowing through the inductance is 0.0584 ampere, and the current flowing through the resistance is 0.11 ampere. What is the total current in the circuit? If the impedance of the circuit is 884 ohms, what is the phase angle by which the line current lags the applied voltage?
- Step 1. The vector diagram for this circuit is shown in figure 75. In a parallel circuit the voltage drop across each inductance or resistance is the same—in this circuit, 110 volts. Draw the vector I_R to represent the current through the resistor. Draw the vector I_L to represent the current through the inductance.



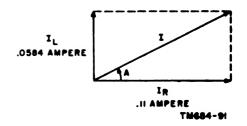


Figure 74. An ac parallel circuit containing inductance and resistance.

Figure 75. Ac parallel circuit containing inductance and resistance, vector diagram.

Step 2.The horizontal and vertical currents, respectively are: $I_R = 0.11$ ampere $I_L = 0.0584$ ampereStep 3.Find the total current as follows: $I^2 = I_L^2 + I_R^2$ $= (0.0584)^2 + (0.11)^2$ = 0.0034 + .0121= 0.0155 $I = \sqrt{0.0155}$ = 0.1245 ampereStep 4.

applied voltage.

$$\cos A = \frac{Z}{R} \text{ (for parallel circuit)}$$

$$= \frac{884}{1,000}$$

$$= 0.88400$$

$$A = 27^{\circ} 52' 43''$$

- Step 5. Thus, the line current lags the applied voltage by a phase angle of 27° 52′ 43″.
- Example 2: A 110-volt, 60-cycle ac generator is connected in a parallel circuit to a load consisting of an inductance of 3 henrys and a resistance of 10,000 ohms (A, fig. 76).

Step 1. Find the inductive reactance of the circuit.

- $X_{L} = 2\pi fL \\ = 2 \times 3.14 \times 60 \times 3 \\ = 6.28 \times 180 \\ = 1130.4$
 - = 1130 ohms (approx)

Step 2. Find the impedance of the circuit.

$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}} = \frac{10,000 \times 1130}{\sqrt{(10,000)^2 + (1130)^2}} = \frac{10^4 \times 1.13 \times 10^8}{\sqrt{(10^4)^2 + (1.13 \times 10^3)^2}} = \frac{1.13 \times 10^7}{\sqrt{10^8 + 1.277 \times 10^4}}$$

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$$= \frac{1.13 \times 10^7}{\sqrt{100 \times 10^4 + 1.277 \times 10^4}}$$

$$= \frac{1.13 \times 10^7}{\sqrt{101.277 \times 10^4}}$$

$$= \frac{1.13 \times 10^7}{10.07 \times 10^3}$$

$$= .1123 \times 10^4$$

$$= .1123 \times 10^4$$

$$= .1123 \cos(3)$$
Step 3. Find the line current in the circuit.
$$I = \frac{E}{Z}$$

$$= \frac{110}{1123}$$

$$= 0.09795 \text{ ampere}$$
Step 4. Find the current flowing through the inductance.
$$I_L = \frac{E}{X_L}$$

$$= \frac{110}{1130}$$

$$= .09734$$

$$= 0.0973 \text{ ampere (approx)}$$
Step 5. Find the current flowing through the resistance.
$$I_R = \frac{E}{R}$$

$$= \frac{110}{10,000}$$

$$= 0.0011 \text{ ampere}$$
Step 6. Find the total current in the circuit. In an ac parallel circuit, the currents through the separate parts of the circuit are added vectorially (B, fig. 76).
$$I_r^3 = I_r^3 + I_R^3$$

$$= (0.097)^2 + (0.011)^3$$

$$= (9.7 \times 10^{-1})^2 + (1.1 \times 10^{-2})^2$$

$$= 94.09 \times 10^{-4} + 1.21 \times 10^{-4}$$

$$= 9.8 \times 10^{-4}$$

$$I_r = \sqrt{95.3 \times 10^{-4}}$$

$$= 9.8 \times 10^{-2}$$

$$= .098 \text{ ampere (approx)}$$
Step 7. In a parallel circuit, the voltage drop across one element would be the same as the voltage drop across another element in parallel with it. Thus, the voltage drop across both the inductance and the resistance is 110 volts.
Step 8. Find the phase angle by which the line current lags the applied voltage.
$$\cos A = \frac{Z}{R}$$

$$cos A = \frac{2}{R} = \frac{1123}{10,000} = 0.11230$$
$$A = 83^{\circ} 33' 52''$$

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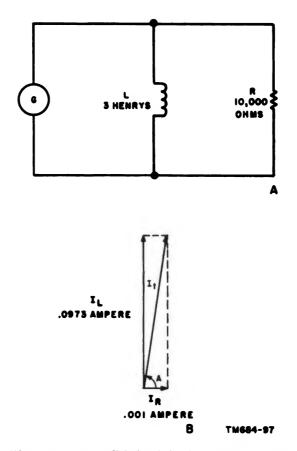


Figure 76. As parallel circuit having inductance and resistance, schematic and vector diagrams.

200. Solving Ac Circuits Having Resistance and Capacitance

a. Series Circuits. The following examples illustrate the method of solving series ac circuits having resistance and capacitance (called series RC circuits) by using the principles described in paragraphs 198 through 198.

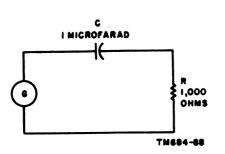
- Example 1: An ac generator in a series circuit is connected to a load consisting of a capacitance and a resistance (fig. 77). The voltage drop across the capacitance is 103 volts, and the voltage drop across the resistance is 39 volts. What is the applied voltage in the circuit? If the impedance of the circuit is 2,840 ohms, what is the phase angle by which the current leads the applied voltage?
- Step 1. The vector diagram for this circuit is shown in figure 78. In a series circuit, the same current flows through all parts of the circuit—in this case, 0.039 ampere. Draw the vector E_R to represent the voltage drop across the resistance. Draw the vector E_c to represent the voltage drop across the capacitance.
- Step 2. The vector sum of these voltage drops is equal to the applied voltage. Adding the horizontal and vertical voltage drops, respectively:

$$E_c + E_R = 0 + 39 = 39$$

 $E_c + E_R = 103 + 0 = 103$

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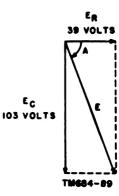


Figure 77. An ac series circuit containing capacitance and resistance.

Figure 78. Ac series circuit containing capacitance and resistance, vector diagram.

- Step 3. Find the applied voltage as follows:
 - $E^{2} = E_{c}^{2} + E_{R}^{3}$ $= (108)^{2} + (89)^{2}$ $= (1.08 \times 10^{2})^{2} + (8.9 \times 10)^{2}$ $= 1.061 \times 10^{4} + 15.2 \times 10^{2}$ $= 106.1 \times 10^{2} + 15.2 \times 10^{2}$ $= 121.3 \times 10^{2}$ $E = \sqrt{121.3 \times 10^{2}}$ $= 11.01 \times 10$

$$- 110.1$$
 volta

Step 4. Find the phase angle by which the current leads the applied voltage.

$$\cos A = \frac{R}{Z}$$
$$= \frac{1000}{2840}$$
$$= 0.35211$$
$$= 69^{\circ} 24'$$

- Step 5. Thus, the current leads the applied voltage by a phase angle of 69° 24'.
- Example 2: A 110-volt, 60-cycle ac generator is connected in a series circuit to a load consisting of a 2-microfarad capacitor and a 10,000-ohm resistor (A, fig. 79).
- Step 1. Find the capacitive reactance of the circuit.

$$X_{c} = \frac{1}{2 \pi fC}$$

$$= \frac{1}{2 \times 3.14 \times 60 \times 2 \times 10^{-6}}$$

$$= \frac{1}{753.6 \times 10^{-6}}$$

$$= \frac{1}{7.536 \times 10^{-4}}$$

$$= \frac{10^{4}}{7.536}$$

$$= \frac{10,000}{7.536}$$

$$= 1,327 \text{ ohms (approx)}$$

Step 2. Find the impedance of the circuit.

$$Z = \sqrt{R^{2} + X_{c}^{2}}$$

= $\sqrt{(10,000)^{2} + (1327)^{2}}$
= $\sqrt{(10^{4})^{2} + (1.327 \times 10^{2})^{2}}$
= $\sqrt{10^{3} + 1.761 \times 10^{4}}$
= $\sqrt{100 \times 10^{4} + 1.761 \times 10^{4}}$
= $\sqrt{101.761 \times 10^{4}}$
= 10.088×10^{3}
= $10,088$ ohms (approx)

Step 3. Find the current in the circuit.

$$I = \frac{E}{Z}$$

= $\frac{110}{10,088}$
= 0.0109 ampere (approx)

- Step 4. In a series circuit, the same current flows through all parts of the circuit; therefore, the current through both the capacitance and the resistance is 0.0109 ampere.
- Step 5. Find the voltage drop across the capacitance.

$$E_c = IX_c$$

= 0.0109 × 1327
= 14.46
= 14 volts

- Step 6. Find the voltage drop across the resistance.
 - $E_R = IR$ = 0.0109 × 10,000 = 109 volts
- Step 7. Find the total voltage in the circuit (B, fig. 79).

$$E_{i}^{2} = E_{R}^{2} + E_{c}^{2}$$

$$= (109)^{2} + (14)^{2}$$

$$= (1.09 \times 10^{2})^{2} + (1.4 \times 10)^{2}$$

$$= 1.1881 \times 10^{4} + 1.96 \times 10^{2}$$

$$= 118.81 \times 10^{2} + 1.96 \times 10^{2}$$

$$= 120.77 \times 10^{2}$$

$$E = \sqrt{120.77 \times 10^{2}}$$

$$= 10.99 \times 10$$

$$= 109.9 \text{ or } 110 \text{ volts}$$

Step 8. Find the phase angle by which the current leads the applied voltage.

$$\cos A = \frac{R}{Z} \\ = \frac{10,000}{10,088} \\ = 0.991178 \\ = 0.99118 \\ A = 7^{\circ} 37'$$

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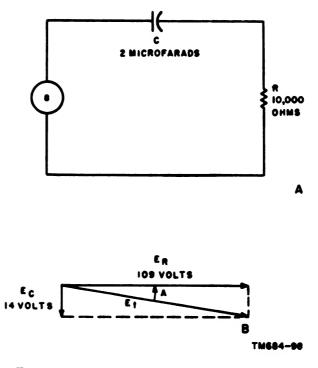
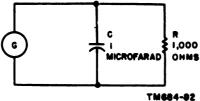


Figure 79. Ac series circuit having capacitance and resistance, schematic and vector diagrams.

b. Parallel Circuits. The following examples illustrate the method of solving parallel RC circuits by using the principles described in paragraphs 193 through 198.

- Example 1: An ac circuit has a capacitance and resistance connected in parallel (fig. 80). The current flowing through the capacitance is 0.0415 ampere, and the current flowing through the resistance is 0.11 ampere. What is the total current in the circuit? If the impedance of the circuit is 938 ohms, what is the phase angle by which the current leads the applied voltage?
- Step 1. The vector diagram for this circuit is shown in figure 81. In a parallel circuit, the voltage drop across each capacitance or resistance is the same—in this case, 110 volts. Draw the vector I_R to represent the current through the resistor. Draw the vector I_c to represent the current through the capacitance.





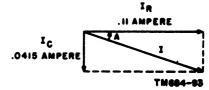


Figure 81. As parallel circuit containing capacitance and resistance, vector diagram.

Figure 80. An ac parallel circuit containing capacitance and resistance.

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Step 2. The vector sum of the currents through the separate parts of the circuit will be equal to the total current. Adding the horizontal and vertical currents, respectively:

$$I_0 + I_R = 0 + .11 = .11$$

 $I_c + I_R = .0415 + 0 = .0415$

Step 3. Find the total current as follows:

 $I^{2} = I_{c}^{2} + I_{z}^{2}$ $= (.0145)^{2} + (.11)^{2}$ $= (1.45 \times 10^{-2})^{2} + (11 \times 10^{-2})^{2}$ $= 2.1 \times 10^{-4} + 121 \times 10^{-4}$ $= 123.1 \times 10^{-4}$ $I = \sqrt{123.1 \times 10^{-4}}$ $= 11.1 \times 10^{-2}$ = .111 ampere

Step 4. Find the phase angle by which the current leads the applied voltage.

$$\cos A = \frac{Z}{R} \\ = \frac{938}{1,000} \\ = .98800 \\ A = 20^{\circ} 17' 6''$$

- Step 5. Thus, the current leads the applied voltage by a phase angle of 20° 17' 6".
- Example 2: A 110-volt, 60-cycle ac generator is connected to a load consisting of a 2-microfarad capacitance and a 10,000-ohm resistance in parallel (A, fig. 82).
- Step 1. Find the capacitance reactance of the circuit.

$$X_{\sigma} = \frac{1}{2 + fC}$$

= $\frac{1}{2 \times 3.14 \times 60 \times 2 \times 10^{-4}}$
= $\frac{1}{7.536 \times 10^{-4}}$
= $\frac{10^{4}}{7.536}$
= 1,327 ohms
Find the impedance of the circuit.

Step 2.

$$Z = \frac{.RX_{o}}{\sqrt{R^{2} + X_{c}^{2}}}$$

$$= \frac{10,000 \times 1327}{\sqrt{(10,000)^{2} + (1327)^{2}}}$$

$$= \frac{10^{4} \times 1.327 \times 10^{3}}{\sqrt{(10^{4})^{2} + (1.327 \times 10^{3})^{2}}}$$

$$= \frac{1.327 \times 10^{7}}{\sqrt{10^{4} + 1.76 \times 10^{4}}}$$

$$= \frac{1.327 \times 10^{7}}{\sqrt{100 \times 10^{4} + 1.76 \times 10^{4}}}$$

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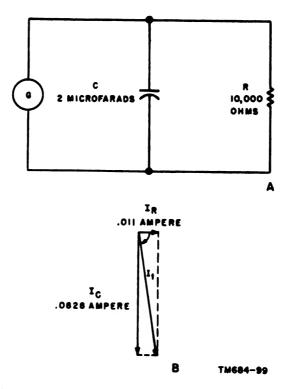


Figure 82. Ac parallel circuit having resistance and capacitance, schematic and vector diagrams.

	$=\frac{1.327\times10^{7}}{\sqrt{101.76\times10^{6}}}$
	$=\frac{1.327\times10^{7}}{10.088\times10^{3}}$
	$= .1315 \times 10^{4}$
	= .1315 ohms (approx)
Step 3.	Find the current flowing through the capacitance.
	$I_c = \frac{E}{X_c}$
	$T_c = \overline{X_c}$
	$=\frac{110}{1327}$
	- 1327
	= 0.08289
	= 0.0829 ampere
Step 4.	Find the current flowing through the resistance.
	$I_{R} = \frac{E}{R}$
	$r_R = R$
	$=\frac{110}{10,000}$
	_ ,
	= 0.011 ampere
Step 5.	Find the total current in the circuit.
	$I_{1^{2}} = I_{k^{2}} + I_{c^{2}}$
	$= (.011)^2 + (.0829)^2$
	$= (1.1 \times 10^{-2})^2 + (8.29 \times 10^{-2})^2$
	$= 1.21 \times 10^{-4} + 68.72 \times 10^{-4}$
	$= 69.93 \times 10^{-4}$

$$I_t = \sqrt{69.98 \times 10^{-4}} \\ = 8.86 \times 10^{-8} \\ = .0836 \text{ ampere (approx)}$$

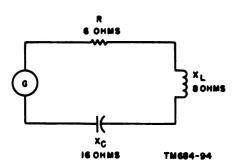
- Step 6. In a parallel circuit, the voltage drop across each capacitance or resistance in parallel is the same. Thus, the voltage drop across both the capacitance and the resistance is 110 volts.
- Step 7. Find the phase angle by which the current leads the applied voltage.

$$\cos A = \frac{Z}{R} \\ = \frac{1815}{10,000} \\ = 0.18150 \\ A = 82^{\circ} 26' 87''$$

201. Solving Ac Circuits Having Resistance, Inductance, and Capacitance

a. Series Circuits. The following examples illustrate the method of solving series ac circuits having resistnace, inductance, and capacitance (called series RLC circuits) by using the principles described in paragraphs 193 through 198.

- Example 1: A 300-volt, 60-cycle ac generator is connected in series with a 6-ohm resistance, an 8-ohm inductive reactance, and a 16-ohm capacitive reactance (fig. 83). Find (1) the resultant reactive voltage, (2) the current flowing in the circuit, and (3) the voltage drops across the resistance, the inductance, and the capacitance. (4) Check the solution by vectorially adding E_L , E_C , and E_R . The result should equal the applied voltage. (5) Find the phase angle by which the current leads or lags the applied voltage.
- Step 1. The vector diagram for this circuit is shown in figure 84. Since E_c and E_L are 180° out of phase, their vector sum



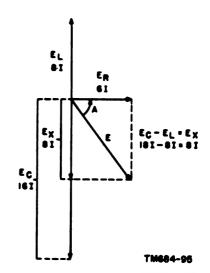
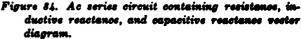


Figure 53. An ac series circuit containing resistance, inductive reactance, and capacitance reactance.



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is the difference between the two. E_c is greater than E_L ; thus, the resultant reactive voltage, E_x , is 16I - 8I = 8I.

Step 2. Find the current flowing in the circuit.

$$E^{2} = E_{R}^{2} + EX^{2}$$

$$E^{2} = (IR)^{2} + (IX)^{2}$$

$$(300)^{2} = (6I)^{2} + (8I)^{2}$$

$$(3 \times 10^{2})^{2} = (6I)^{2} + (8I)^{2}$$

$$9 \times 10^{4} = 36I^{2} + 64I^{2}$$

$$9 \times 10^{4} = 100I^{2}$$

$$9 \times 10^{4} = 10^{2}I^{2}$$

$$\sqrt{9 \times 10^{4}} = \sqrt{10^{2}I^{2}}$$

$$3 \times 10^{2} = 10I$$

$$300 = 10I$$

$$I = 30 \text{ amperes}$$

Step 3. Find the voltage drop across the resistance.

- $E_R = IR$ = 30 × 6 = 180 volts
- Step 4. Find the voltage drop across the inductance.

$$E_L = IX_L$$

= 30 × 8
= 240 volts

- **Step 5.** Find the voltage drop across the capacitance.
 - $E_c = IX_c$ = 30 × 16 = 480 volts
- Step 6. Find the resultant reactive voltage.
 - $E_X = E_c E_L$ = 480 - 240 = 240 volts
- Step 7. Vectorially add the voltages in the circuit. The result should equal the applied voltage.
 - $E^{2} = E_{R}^{2} + E_{X}^{2}$ $= (180)^{2} + (240)^{2}$ $= (1.8 \times 10^{2})^{2} + (2.4 \times 10^{2})^{2}$ $= 3.24 \times 10^{4} + 5.76 \times 10^{4}$ $= 9 \times 10^{4}$ $E = \sqrt{9 \times 10^{4}}$ $= 3 \times 10^{2}$ = 300 volts
- Step 8. Find the phase angle by which the current leads or lags the applied voltage in the circuit.

$$\tan A = \frac{X_L - X_C}{R}$$
$$= \frac{8}{6}$$
$$= 1.33333$$
$$A = 53° 7' 48''.$$

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- Step 9. The circuit is predominantly capacitive; therefore, the current *leads* the applied voltage by a phase angle of 53° 7′ 48".
- Example 2: A 60-cycle ac generator is connected in series with a 10-ohm resistance, a 12-ohm inductive reactance, and a 20-ohm capacitive reactance (A, fig. 85). The current flowing through the circuit is 19 amperes. (1) Find the voltage drop across each circuit element. (2) Find the total voltage. (3) Find the phase angle between the current and the applied voltage.
- Step 1. Find the voltage drop across the resistance.

$$= IR$$
$$= 19 \times 10$$

E,

$$=$$
 190 volt

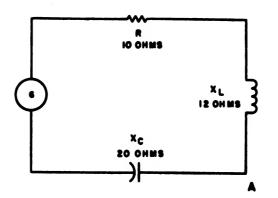
Step 2.

Find the voltage drop across the inductance.

$$E_L = IX_L$$

 $= 19 \times 12$

$$= 228$$
 volts



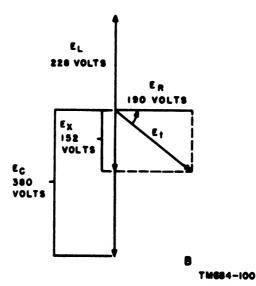


Figure 25. An ac series circuit having inductance, espacitance, and resistance, schematic and vector diagrams.

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Step 3.	Find the voltage drop across the capacitance.
-	$E_c = IX_c$
	$=$ 19 \times 20
	= 380 volts
Step 4.	Find the resultant reactive voltage.
	$E_{I} = E_{c} - E_{L}$
	= 380 - 228
	= 152 volts
Step 5.	Find the total voltage in the circuit.
	$E^2 = E_R^2 + E_X^2$
	$= (190)^2 + (152)^2$
	$= (1.9 \times 10^2)^2 + (1.52 \times 10^2)^2$
	$= 3.61 \times 10^4 + 2.31 \times 10^4$
	=
	$\hat{E} =$
	=
	= 243 volts
Step 6.	Find the phase angle by which the current lea

Step o.

Find the phase angle by which the current leads the applied voltage in the circuit. Since the capacitive reactance is greater and cancels the inductive reactance, the circuit is capacitive and the current leads the applied voltage by the phase angle A.

$$\tan A = \frac{X_c - X_L}{R} \\ = \frac{20 - 12}{10} \\ = \frac{8}{10} \\ = .80000 \\ A = 38^{\circ} 39' 35''$$

b. Parallel Circuits. The following example illustrates the method of solving parallel ac circuits having resistance, inductance, and capacitance (called parallel RLC circuits) by using the principles described in paragraphs 193 through 198.

Example:	A parallel circuit has a 300-volt input, a 150-ohm resist- ance, a 125-ohm inductive reactance, and a 100-ohm capaci- tive reactance (A, fig. 86).
Step 1.	Since this is a parallel circuit, the same voltage is impressed across the inductance, the resistance, and the capacitance. Thus, the voltage across each of them is 300 volts.
Step 2.	Find the current flowing through the resistor. $I_{R} = \frac{E}{R}$ $= \frac{300}{150}$ $= 2 \text{ amperes}$
Step 3.	Find the current flowing through the inductance. $I_{L} = \frac{E}{X_{L}}$ $= \frac{300}{125}$ $= 2.4 \text{ amperes}$

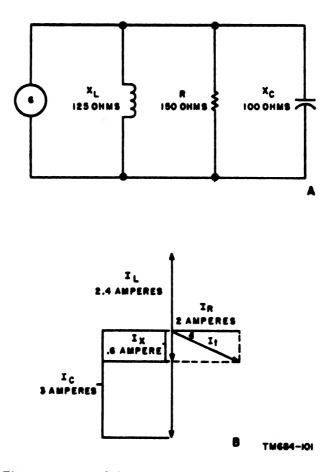


Figure 88. As parallel circuit having inductance, capacitance, and resistance, schematic and vector diagrams.

Step 4.

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Find the current flowing through the capacitor.

$$I_c = \frac{E}{X_o}$$
$$= \frac{300}{100}$$
$$= 3 \text{ amperes}$$

Step 5. Find the total current in the circuit (B, fig. 86).

$$I_{x} = I_{c} - I_{L}$$

= 3 - 2.4
= .6 ampere
$$I_{t}^{2} = I_{x}^{2} + I_{x}^{2}$$

= (2)² + (.6)²
= 4 + .36
= 4.36
$$I_{t} = \sqrt{4.36}$$

= 2.0889
= 2.089 amperes

-

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Step 6. Find the impedance of the circuit.

$$Z = \frac{E}{I_i}$$

= $\frac{300}{2.089}$
= 143.6
= 144 ohms (approx)

Step 7. Find the phase angle by which the current leads the applied voltage. Since this is a parallel circuit in which the inductive reactance is greater than the capacitive reactance, the circuit is capacitive and the current leads the applied voltage.

$$\cos A = \frac{Z}{R} \\ = \frac{144}{150} \\ = .96000 \\ A = 16^{\circ} 15' 38''$$

202. Resonance

In a series or parallel ac circuit containing inductance and capacitance, a condition known as resonance exists when the inductive reactance equals the capacitive reactance. This condition occurs at a specific frequency called the *resonant frequency*. A formula for finding the resonant frequency is derived by equating the formulas for inductive reactance and capacitive reactance, as follows:

$$X_{L} = X_{C}$$

$$2\pi f_{r}L = \frac{1}{2\pi f_{r}C}$$

$$4\pi^{2}f_{r}^{2}LC = 1$$

$$f_{r}^{2} = \frac{1}{4\pi^{2}LC}$$

$$f_{r} = \frac{1}{2\pi\sqrt{LC}}$$

where f_r is the resonant frequency.

Example:

ple: Find the resonant frequency of a circuit containing a 4millihenry inductance and a 40-micromicrofarad capacitor in series with a variable frequency ac source.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

= $\frac{1}{6.28\sqrt{4 \times 10^{-4} \times 4 \times 10^{-11}}}$
= $\frac{1}{6.28 \times 4 \times 10^{-7}}$
= $\frac{10^{7}}{25.12}$
= $\frac{10,000,0^{2}0}{25.12}$
= 398,000 cps or 398 kilocycles (kc).

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203. Ac Power

a. In an ac circuit containing both resistance and reactance the only power actually dissipated is the power absorbed by the resistance of the circuit (b below). However, if the circuit contained reactance only, large amounts of power would still appear to be consumed because of the phase difference between voltage and current. Consequently, in either case an ac generator supplying power to the circuit would receive less power from the circuit than it delivers to the circuit. The power which the generator delivers to the circuit is called the apparent power and is equal to the product of the effective value of the voltage $(E_{\rm max}/\sqrt{2})$ and the effective value of the current $(I_{max}/\sqrt{2})$. Therefore,

P (apparent power) =
$$\frac{E_{\text{max}}}{\sqrt{2}} \cdot \frac{I_{\text{max}}}{\sqrt{2}}$$

= $\frac{E_{\text{max}}}{2}$

b. Apparent power is different from the actual power consumed by the load, which is called the average or true power and is the energy absorbed by the resistance of the circuit. The average or true power is expressed by the formula $P = EI \cos \theta$, where

- E = effective value of the voltage across the circuit
- I = effective value of the current in the circuit
- θ = phase angle between current and voltage

c. Apparent power may also be expressed by the following formulas:

$$P = El$$

$$P = l^{2}Z$$

$$P = \frac{E^{2}}{Z}$$

d. In a purely resistive circuit, average or true ac power also may be expressed by Joule's law $(P = I^2 R)$ as in the dc case (par. 191).

e. The following examples illustrate some of the above principles.

Example 1: Find the power that an ac generator must deliver to a circuit if the peak voltage is 230 volts and the peak current is 5 amperes.

$$P = \frac{E_{max} I_{max}}{2}$$
$$= \frac{230 \times 5}{2}$$
$$= 575 \text{ watts.}$$

Example 2: Find the average power consumed in a circuit if the effective ac voltage is 115 volts, the effective current is 7 amperes, and the current leads the voltage by 60°.

$$P = EI \cos \theta$$

= 115 × 7 × cos 60°
= 115 × 7 × .5
= 402.5 watts.

204. Review Problems—Ac Electricity

a. An alternator is connected to a 520-volt, 60-cycle ac parallel circuit having a resistance of 96 ohms, an inductance of 249 millihenrys, and a capacity of 19.8 microfarads. (1) Find the inductive reactance of the circuit. (2) Find the capacitive reactance of the circuit. (3) Determine whether the current leads or lags the voltage. (4) Find the impedance of the circuit. (5) Determine the value of the current in the circuit.

b. Determine the inductive reactance of a coil if the ac in the circuit has a frequency of 60 cps, and the inductance of the coil is 0.025 henry.

c. A 110-volt, 25-cycle ac generator is connected in series with a 0.1-microfarad capacitance and a 2,000-ohm resistance. What is the capacitive reactance of the circuit?

d. What is the value of the reactance of a circuit if the impedance Z = 100 ohms and the resistance R = 60 ohms?

e. Find the resonant frequency of a series RLC circuit if the inductance is 0.478 millihenry and the capacitance is 256 micromicrofarads.

f. A series RLC circuit consists of 6 ohms resistance, 8 ohms inductive reactance, and 16 ohms capacitive reactance. (1) Find the current in the circuit. (2) Find the voltage drop across the resistance. (3) Find the voltage drop across the capacitance. (4) Find the voltage drop across the inductance.

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g. A parallel RLC circuit has an input voltage of 300 volts, an inductive reactance of 75 ohms, a capacitive reactance of 50 ohms, and a resistance of 100 ohms. (1) Find the current through the resistance. (2) Find the current through the inductance. (3) Find the current through the capacitance. (4) Find the total impedance of the circuit. (5) Find the phase angle between the line or total current and the applied voltage. (6) Find the average power. (7) Find the apparent power.



CHAPTER 16

APPLICATIONS OF LOGARITHMS TO TRANSMISSION PROBLEMS

205. The Transmission Unit

When signal power is transmitted along a transmission line, there is a power loss or attenuation; if an amplifier is used in the circuit, there may be a power gain. This loss or gain of power, resulting in a decrease or increase in the intensity of the signal, is measured in terms of the decibel (db). The decibel is a measure of power *ratio* and is probably the most widely used unit in communications. The formula for measuring transmission loss or gain is:

$$db = 10 \log_{10} \frac{P_1}{P_2}$$

where $\frac{P_1}{P_2}$ is the ratio of the two powers being compared (par. 206).

206. Converting Power Ratio to Decibels

When converting a power ratio into its decibel expression, represent the larger power as P_1 and the smaller power as P_2 , regardless of whether the larger power is the input or output. Thus, the power ratio will always be greater than 1, and its logarithm will be a positive number. Prefix a plus sign to the answer if the power change is a gain (the power output greater than the power input); prefix a minus sign if the power change is a loss.

Example 1: The input power to a transmission line is 10 milliwatts, and the output power is 2.46 milliwatts. Express the power change in db.

$$db = 10 \log \frac{P_1}{P_2} \\ = 10 \log \frac{10}{2.46} \\ = 10 \times \log 4.07 \\ = 10 \times .6096 \\ = -6.096$$

Thus, the loss of the transmission line is 6.096 db, since input is greater than output.

Example 2: A repeater amplifier has an input power of 2 milliwatts and an output power of 400 watts. Calculate the power change.

$$db = 10 \log \frac{P_1}{P_2} \\ = 10 \log \frac{400}{.002} \\ = 10 \times \log 200,000 \\ = 10 \times 5.3010 \\ = +53.01 \\ he gain of the repeater an$$

The gain of the repeater amplifier is 53.01 db, since output is greater than input.

207. Converting Decibels to Power Ratio

To find the power ratio when the gain or loss is expressed in decibels, reverse the procedure given in paragraph 206. If the number of decibels is positive, the circuit has a power gain and the output power is greater than the input power. If the number of decibels is negative, the circuit has a power loss and the output power is less than the input power. Insert the power change in decibels in the formula given in paragraph 200 and divide by 10; then find the antilog of both sides of the equation (par. 118) to obtain the power ratio.

Example 1: A circuit is known to have a
power change of +12 db.
Find the power ratio.
$$db = 10 \log \frac{P_1}{P_2}$$
$$12 \ db = 10 \log \frac{P_1}{P_2}$$
$$1.2 = \log \frac{P_1}{P_2}$$

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Find the antilog of both sides of the equation.

$$\frac{P_1}{P_2} = 15.85 \text{ of } 15.9$$

Since the number of decibels is given as positive, the circuit has a gain and its output power is 15.9 times its input power.

Example 2: A certain wire transmission circuit has a power change of -25 db. Calculate the power ratio.

$$db = 10 \log \frac{P_1}{P_2}$$

$$25 db = 10 \log \frac{P_1}{P_2}$$

$$2.5 = \log \frac{P_1}{P_2}$$

$$\frac{P_1}{P_2} = 316.2$$

Since the number of decibels has a minus sign, the circuit attenuates power. The output power is less than the input power by a ratio of 1 to 316.2.

208. Review Problems—Transmission Problems

a. A network has a loss of 16 decibels. What power ratio correspond to this loss?

b. The input to a powerline 50 miles long is 210 milliwatts. The power delivered at the end of the line is 40 microwatts. What is the attenuation in decibels per mile?

c. A power of 10 milliwatts is required to drive an audiofrequency (af) amplifier. The output of the amplifier is 120 milliwatts. What is the gain in decibels?

d. What is the ratio of the output power to the input power if there is a power gain of 14 decibels?





CHAPTER 17

MISCELLANEOUS ELECTRICAL PROBLEMS

209. Efficiency

Efficiency is the ratio of output to input and usually is expressed in percent (ch. 2). Generators, motors, and other electrical devices often are rated according to their efficiency. To express efficiency in percent, write the ratio of output to input as a fraction, convert to a decimal, and then convert the decimal to a percent (par. 4).

Example: What is the efficiency of a generator that has an output of 60 kilowatts (kw) and an input of 75 kilowatts?

Efficiency =
$$\frac{\text{Output}}{\text{Input}}$$

= $\frac{60}{75}$
= 0.80
= 80%

210. Percent Overload

Another application of percent is the overload rating of motors, generators, etc. In this application, the amount of power, that can be applied to or taken from an electrical device, above the rated output, is expressed as a percent of the rated output.

Example 1: What is the percent of overload capacity of a generator that has a rated output of 500 watts and can provide a maximum of 550 watts? Overload = maximum power —rated power

= 550 - 500 = 50 wattsPercent overload $= \frac{\text{Overload}}{\text{Rated power}}$ $= \frac{50}{500}$ = 10%

Example 2: Find the maximum output of a generator that is rated at 1,500 watts, and has a 10 percent overload capacity.

 $0.10 \times 1.500 = 150$ watts

1,500 + 150 = 1,650 watts maximum output.

211. Tolerances

A tolerance is an allowance for variations from the standard or specified value. In the manufacture of resistors, for example, the resistance is permitted to be within a specified percentage of the standard value. This percentage is indicated in the color code of the resistors.

Example: Find the possible low and high values of a 20,000-ohm

resistor with a tolerance of ± 5 percent.

 $0.05 \times 20,000 = 1,000$ ohms

20,000 + 1,000 = 21,000 ohms (high value)

20,000 - 1,000 = 19,000 ohms (low value)

Therefore, since the tolerance is plus or minus 5%, the value of the resistor should be between 21,000 and 19,000 ohms.

AGO SSSA

212. Transformer Relationships

a. General. In a transformer, relationships exist between the currents, voltages, impedances, and number of turns of wire in the windings. These relationships are expressed by equations containing ratios involving these quantities.

b. Relationship Between Voltage and Number of Turns. This relationship is expressed by the following equation:

$$\frac{E_{\bullet}}{N_{\bullet}} = \frac{E_{\bullet}}{N_{\bullet}}$$

where E_r is the voltage across the primary winding, N_r is the number of turns on the primary winding, E_r is the voltage across the secondary winding, and N_r is the number of turns on the secondary winding (fig. 87). The equation may also be written:

$$\frac{E_{s}}{E_{s}} = \frac{N_{s}}{N_{s}}$$

$$E_{p}N_{s} = E_{s}N_{s}$$

$$E_{s} = \frac{E_{p}N_{s}}{N_{s}} \text{ or } E_{s} \left(\frac{N_{s}}{N_{s}}\right)$$

$$E_{p} = \frac{E_{s}N_{p}}{N_{s}} \text{ or } E_{s} \left(\frac{N_{s}}{N_{s}}\right)$$

The ratios N_s/N_s and N_s/N_s are called the *turns ratios* and may be expressed as a single factor.

Example: Find the voltage across the secondary winding of a transformer if the primary voltage is 100 volts and the turns ratio from primary to secondary is 1 to 4.

$$\frac{N_{\bullet}}{N_{\bullet}} = \frac{1}{4} \text{ or } \frac{N_{\bullet}}{N_{\bullet}} = 4$$

$$E_{\bullet} = E_{\bullet} \left(\frac{N_{\bullet}}{N_{\bullet}}\right)$$

$$E_{\bullet} = 100 \text{ (4)}$$

$$= 400 \text{ volts}$$

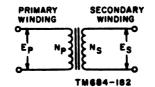


Figure 87. Simple Transformer.

c. Relationship Between Current and Number of Turns. This relationship is expressed by the following equation:

$$\frac{I_{\bullet}}{I_{\bullet}} = \frac{N_{\bullet}}{N_{\bullet}}$$

where I_p is the primary current, I_s is the secondary current, and N_p and N_s the number of turns on the primary and secondary as before. The equation may be written:

$$I_{p} N_{p} = I_{s}N_{s}$$

$$I_{p} = \frac{I_{s}N_{s}}{N_{p}} \text{ or, } I_{s}\left(\frac{N_{s}}{N_{p}}\right)$$

$$I_{s} = \frac{I_{p}N_{p}}{N_{s}} \text{ or, } I_{p}\left(\frac{N_{p}}{N_{s}}\right)$$

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Example: Find the primary current in a transformer if the secondary current is 5 milliamperes and the turns ratio from primary to secondary is 20 to 1.

$$\frac{N_{p}}{N_{s}} = \frac{20}{1} \text{ or, } \frac{N_{s}}{N_{p}} = \frac{1}{20}$$

$$I_{p} = I_{s} \left(\frac{N_{s}}{N_{p}}\right)$$

$$= 5 \times 10^{-s} \left(\frac{1}{20}\right)$$

$$I_{p} = \frac{10^{-s}}{4}$$

$$= \frac{0.00100}{4}$$

$$= 0.00025 \text{ amperes, or, } 0.25 \text{ milliamperes}$$

d. Relationship Between Current and Voltage. By combining the relationships given in b and c above, a relationship can be derived between primary and secondary currents as follows:

$$\frac{E_{p}}{E_{e}} = \frac{N_{p}}{N_{s}} \text{ (from } b \text{ above)}$$

$$\frac{I_{s}}{I_{p}} = \frac{N_{p}}{N_{s}} \text{ (from } c \text{ above)}$$
Therefore,
$$\frac{E_{p}}{E_{s}} = \frac{I_{s}}{I_{p}} \text{ (because both are equal to } \frac{N_{p}}{N_{s}}$$

The equation may also be written:

$$E_{p} = \frac{E_{e}I_{e}}{I_{p}}$$

$$I_{p} = \frac{E_{e}I_{e}}{E_{p}}$$

$$E_{e} = \frac{E_{p}I_{p}}{I_{e}}$$

$$I_{e} = \frac{E_{p}I_{p}}{E_{e}}$$

$$E_{e}I_{e} = E_{e}I_{e}$$

Since voltage multiplied by current equals power, the last form of the equation states that the power absorbed by the primary winding is equal to the power delivered to the secondary winding. This is true in an ideal transformer which has no loss, and is essentially true in an actual transformer which has very little loss; efficiencies of 98 percent are common in actual transformers.

Example: Find the voltage across the secondary winding of a transformer if the primary voltage is 150 volts, the primary current is 5 amperes, and the secondary current is 25 amperes.

$$E_{\bullet} = \frac{E_{\bullet}I_{\bullet}}{I_{\bullet}}$$
$$= \frac{150 \times 5}{25}$$
$$= 30 \text{ volts}$$

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e. Relationship Between Impedance and Number of Turns. This relationship also can be derived from the relationships given in b and c above by dividing one by the other, as follows:

$$\frac{E_p}{E_a} = \frac{N_p}{N_a} \text{ (from } b \text{ above)}$$

$$\frac{I_p}{I_a} = \frac{N_a}{N_p} \text{ (from } c \text{ above)}$$

$$\frac{E_p}{E_a} = \frac{N_p}{N_a} \text{ (dividing the first by the second)}$$

$$\frac{I_a}{I_a} \cdot \frac{E_p}{E_a} = \frac{N_p}{N_a} \frac{N_p}{N_a}$$

$$\frac{I_a}{I_p} \cdot \frac{I_a}{E_a} = \frac{N_p^2}{N_a^2}$$

$$Z_p \cdot \frac{1}{Z_a} = \frac{N_p^2}{N_a^2} \text{ (substituting } Z \text{ for } \frac{E}{1})$$

$$\frac{Z_p}{Z_a} = \frac{N_p^2}{N_a^2} \text{ or, } \frac{Z_p}{Z_a} = \left(\frac{N_p}{N_a}\right)^2$$

where Z_{s} is the impedance of the primary winding and Z_{s} is the impedance of the secondary winding in ohms. The equation may also be written:

$$Z_{p} = Z_{s} \left(\frac{N_{p}}{N_{s}}\right)^{2}$$
$$Z_{s} = Z_{p} \left(\frac{N_{s}}{N_{p}}\right)^{2}$$

Example:

Find the impedance of the secondary winding of a transformer if the impedance of the primary winding is 200 ohms and the turns ratio from primary to secondary is 5 to 1.

$$\frac{N_{s}}{N_{s}} = \frac{5}{1} \text{ or, } \frac{N_{s}}{N_{s}} = \frac{1}{5}$$
$$Z_{s} = Z_{s} \left(\frac{N_{s}}{N_{s}}\right)^{2}$$
$$= 200 \left(\frac{1}{5}\right)^{2}$$
$$= 200 \times \frac{1}{25}$$
$$= 8 \text{ ohms}$$

213. Conductance

Conductance is a measure of the ease with which current flows in a circuit. It is given the symbol G and is equal to the reciprocal of resistance: G = 1/R. The unit of conductance is the mho, which is the word ohm spelled backwards.

Example: Find the conductance of a circuit consisting of a 4-ohm resistor in parallel with a 5-ohm resistor. In a parallel circuit, the reciprocal of the total resistance is equal to the sum of the reciprocals of the individual resistances:

$$\frac{1}{R_{t}} = \frac{1}{R_{1}} + \frac{1}{R_{2}},$$

or $G = \frac{1}{R_{1}} + \frac{1}{R_{2}},$
 $G = \frac{1}{4} + \frac{1}{5},$
 $= .25 + .20,$
 $= .45$ mhos

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214. Energy Stored in an Inductance

The amount of energy stored in an inductance is determined from the formula $P = \frac{LI^2}{2}$, where

L = inductance in henrys

I = current in amperes

P = energy in joules.

Example: Find the energy stored in a coil if the inductance is 7 millihenrys and the current is 8 milliamperes. Using scientific notation (par. 106), the energy in joules is:

$$P = \frac{Ll^{2}}{2}$$

$$= \frac{7 \times 10^{-4} (8 \times 10^{-4})^{2}}{2}$$

$$= \frac{7 \times 10^{-4} 9 \times 10^{-4}}{2}$$

$$= \frac{68 \times 10^{-4}}{2}$$

$$= 81.5 \times 10^{-4} \text{ joules.}$$

215. Delta-Wye Transformations

a. A delta circuit consists of three resistors or other circuit components connected together to form the Greek letter delta (Δ). In a wye circuit, the resistors or other circuit components are connected together to form the letter Y. Figure 88 shows an example of each type of circuit constructed of resistors.

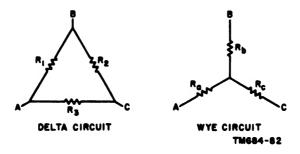


Figure 88. Delta and wys oircuits.

b. If the resistances are known for a delta circuit, they can be found for an equivalent wye circuit from the following equations:

$$R_{\bullet} = \frac{R_{1}R_{3}}{R_{1} + R_{2} + R_{3}}$$
$$R_{\bullet} = \frac{R_{1}R_{2}}{R_{1} + R_{2} + R_{3}}$$
$$R_{\sigma} = \frac{R_{2}R_{3}}{R_{1} + R_{2} + R_{3}}$$

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Example: Find the equivalent resistances for a wye circuit if the resistances of a delta circuit are 10, 20, and 70 ohms. Let $R_1 = 10$ ohms, $R_2 = 20$ ohms, and $R_3 = 70$ ohms.

$$R_{\bullet} = \frac{R_{1}R_{3}}{R_{1} + R_{2} + R_{3}}$$

$$= \frac{10 \times 70}{10 + 20 + 70}$$

$$= \frac{700}{100}$$

$$= 7 \text{ ohms}$$

$$R_{\bullet} = \frac{R_{1}R_{2}}{R_{1} + R_{2} + R_{3}}$$

$$= \frac{10 \times 20}{100}$$

$$= 2 \text{ ohms}$$

$$R_{c} = \frac{R_{2}R_{3}}{R_{1} + R_{2} + R_{3}}$$

$$= \frac{20 \times 70}{100}$$

$$= 14 \text{ ohms}$$

c. If the resistances are known for a wye circuit, they can be found for an equivalent delta circuit from the following equations:

$$R_{1} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{a}}$$

$$R_{2} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{b}}$$

$$R_{3} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{c}}$$

Example: Find the equivalent resistance for a delta circuit if the resistances of a wye circuit are 10, 20, and 30 ohms.

Let $R_a = 10$ ohms, $R_b = 20$ ohms, and $R_c = 30$ ohms.

$$R_{1} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{a}}$$

$$= \frac{10 \times 20 + 10 \times 30 + 20 \times 30}{10}$$

$$= \frac{200 + 300 + 600}{10}$$

$$= \frac{1,100}{10}$$

$$= 110 \text{ ohms}$$

$$R_{2} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{b}}$$

$$= \frac{1,100}{20}$$

$$= 55 \text{ ohms}$$

$$R_{3} = \frac{R_{a}R_{b} + R_{a}R_{c} + R_{b}R_{c}}{R_{c}}$$

$$= \frac{1,100}{30}$$

$$= 36.666$$

$$= 36.67 \text{ ohms}$$

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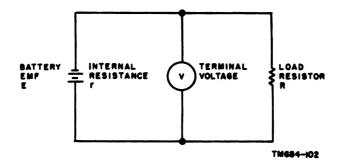


Figure 89. Maximum power transfer.

216. Maximum Power Transfer

a. Quadratic equations (par. 87-94) are used in problems involving the transfer of power from a source to a load. Such a problem can be illustrated by referring to figure 89. In the figure, the battery voltage is given as E, the internal resistance of the battery as r, the terminal voltage as V, and the load resistance as R. The total resistance of the circuit is (R + r). From Ohm's law, E = I(R + r), and the power delivered to the load is P = VI where V = E - Ir.

b. The current through the circuit passes through the battery and drops the battery voltage to what is called the *terminal voltage*. Substituting for V in the power equation, P = (E - Ir)I. or $P = EI - I^2 r$. A quadratic equation in I is obtained when the terms are rearranged. Thus, $-I^2r + EI - P = 0$. This equation can be solved for maximum current by using the method for finding the minimum value as a quadratic (par. 91). In the equation $-rI^2 + EI - P =$ f(I), a = -r, b = E, and c = -P. Substituting in the equation $I = \frac{-b}{2a}$, $I_{\text{max power}} = \frac{-E}{2(-r)}$ $=\frac{E}{2r}$. This equation will give the current through the circuit when maximum power is de-

livered.

If a 12-volt battery has an internal resistance of 3 ohms, Example: find the current flowing in the circuit when maximum power is being delivered to the load.

$$I = \frac{E}{2r}$$
$$= \frac{12}{2 \times 3}$$
$$= 2 \text{ amperent}$$

c. If the value for current at maximum power transfer $\left(\frac{E}{2r}\right)$ is substituted in the original equation I(R + r) = E, a relationship between the load resistance and the internal resistance of the battery for maximum power transfer can be derived as follows:

> l(R+r) = E $\frac{E}{2r}(R+r) = E$ (R+r) = 2r(dividing by E and multiplying by 2r) R = 2r - rR = r

Consequently, to obtain the maximum power transfer from the source to the load, the value of the load resistance must be equal to the internal resistance of the source.

AGO MAA



217. Review Problems—Miscellaneous Electrical Problems

a. A generator is rated at 2,000 watts with a maximum output of 2,100 watts. What is the percent of overload capacity?

b. If the power input of a rotary converter is 48,000 watts and the power output is 37,800 watts, what is the efficiency?

c. The output of a generator is increased from 2,560 watts to 2,944 watts. How much is the increase when expressed in percent? d. A 12,000-ohm resistance has a tolerance of plus or minus 5%. What is the maximum possible resistance?

e. If the input of an electric motor is 860 watts and the output is 746 watts, what is the efficiency of the motor?

f. A generator is rated at 2,000 watts and has a 10% overload capacity. What is the maximum output of the generator?

g. If the inductance L is 80 henrys and the energy P stored in the circuit is 100 joules, find the current I in amperes.





CHAPTER 18

GRAPHICAL REPRESENTATION AND SOLUTION OF ELECTRICAL PROBLEMS

- 218. Constructing and Reading Engineering Graphs
 - a. Constructing Graphs.
 - (1) Engineering graphs of operational or experimental data are constructed in the same manner as graphs of equations (pars. 100-102). First a chart is compiled of the available data, and then the data is plotted on an axis. The *independent variable* (the variable to which values are assigned) usually is plotted on the x axis, and the *dependent variable* on the y axis. The scales on the axes should be as large as practicable and, at the same time, keep the graph within the space available. Sometimes it may be convenient to choose a unit length for

the ordinate different from that of the abscissa. Before selecting the units on the axes, examine the table for the maximum and minimum values of the variables and then choose the units on the axes to fit these values in the space available for the graph. Number the points at uniform intervals along the length of each axis, and label each scale.

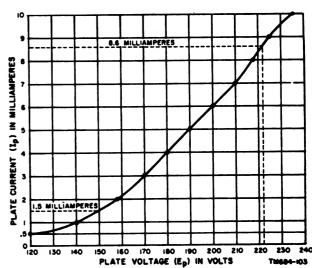
(2) As an example, an experiment is conducted to determine the plate current (I_{p}) of a 6J5 electron tube at various values of plate voltage (E_{p}) when the tube has a grid bias of —6 volts. The plate voltages applied range from 120 to 235 volts. The information is tabulated as follows:

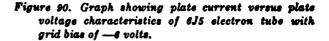
E,	120	140	158	170	180	190	200	210	218	225	285
I,	.5	1	2	8	4	5	6	7	8	9	10

(3) The plate current is then plotted against the plate voltage and the points joined by a smooth curve. The resulting graph (fig. 90) is a picture of the plate current-voltage characteristic of a 6J5 electron tube with a grid bias of --6 volts.

b. Reading Graphs. The process of finding properties of a function by inspection of the graph representing it is called *reading the* graph. From a study of the graph in figure 90, certain information is evident and additional information can be easily obtained.

> (1) There is a gradual increase in the plate current of the 6J5 tube when the plate voltage is increased from 120 to 158 volts. From 158 to 210 volts, the current increase is fairly





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steady. From 210 to 225 volts, however, the increase is sharper, but flattens out slightly from 225 to 235 volts.

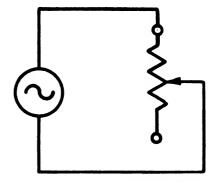
(2) To determine the plate voltage that must be applied to result in a plate current of 8.6 milliamperes, draw a horizontal line from the 8.6 point on the y axis to the curve (fig. 90). At the point where this horizontal line intercepts the curve, drop a vertical line to the x axis. The required plate voltage is 222 volts. Similarly, to obtain a plate current of 1.5 milliamperes, a plate voltage of 150 volts must be applied.

219. Application of Graphs to Electrical Laws

- a. Example 1.
 - (1) A variable resistance is connected across a generator that maintains a potential of 120 volts (fig. 91). The problem is to plot the current as the resistance is varied in 2-ohm steps from 0 to 20 ohms. Ohm's law, $I = \frac{E}{R}$, is used to obtain the coordinates. The voltage E is constant, the resistance R is the independent variable, and the current I is the dependent variable; thus, current will be plotted against resistance, and the independent variable, resistance, will be plotted along the x axis. The following chart is compiled:

R	0	2	4	6	8	10	12	14	16	18	20
1	80	60	30	20	15	12	10	8.5	7.5	6.6	6

- (2) After a study of the table, it will be found that it is more convenient to use a much smaller unit of measurement on the x axis than on the y axis. Also, the entire graph falls in the first quadrant as all values are positive. The resulting graph (fig. 92) is the current-resistance characteristic of the circuit. Note that the current decreases as the resistance increases. The current for any value of the variable resistance can be found by reading the graph.
- b. Example 2.
 - (1) Figure 93 shows an ac series circuit with a coil having a fixed inductance connected across an ac generator that can be varied in frequency from 100 to 1,000 cps in steps of 100 cycles. It is assumed that the effect of the inductance L is so much greater than the resistance of the coil that the effect of the resistance can be neglected. The problem is to plot induc-



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Figure 91. Series circuit showing variable resistance connected across generator.

tive reactance X_L in the formula $X_L = 2\pi f L$. The frequency f is varied to determine the effect upon the inductive reactance. L is constant at 0.04 henry, and 2π equals 6.28; thus, inductive reactance will be plotted against frequency, with the frequency plotted along the x axis. The following chart is compiled:

1	100	200	300	400	500	600	700	800	900	1,000
XL	25.1	50.2	75.4	100.5	125.5	150.7	175.8	201.0	226.1	251.2

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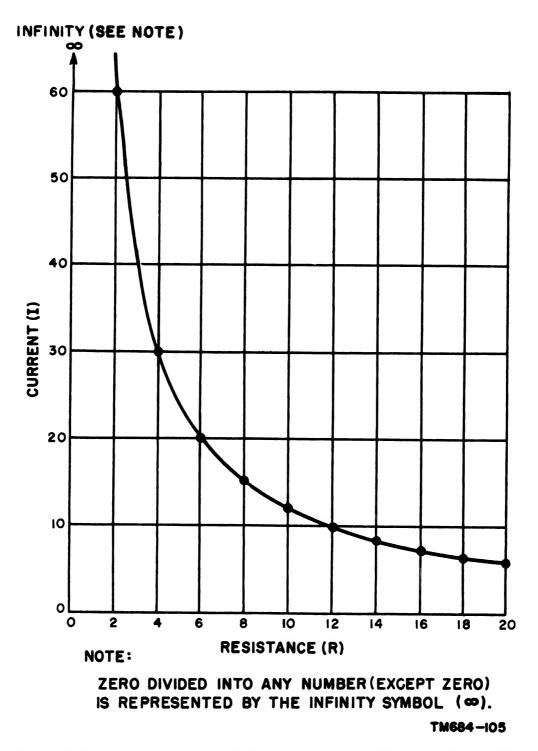


Figure 92. Graph showing current versus resistance curve for series circuit with 120-volt potential.

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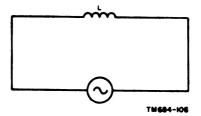


Figure 93. Series circuit showing inductance connected across ac generator.

(2) Since all values are positive, the entire graph will lie in the first quadrant. The resulting graph (fig. 94) pictures the increase in the reactance of the inductor as operating frequencies are increased from 100 to 1,000 cycles per second.

220. Review Problems—Graphical Representation and Solution of Electrical Problems

a. The antenna resistance R in ohms varies as the height H in wavelengths of a horizontal half-wave antenna according to the values given in the chart below. Plot the curve of the antenna resistance against the antenna height. At what height is the resistance at a maximum?

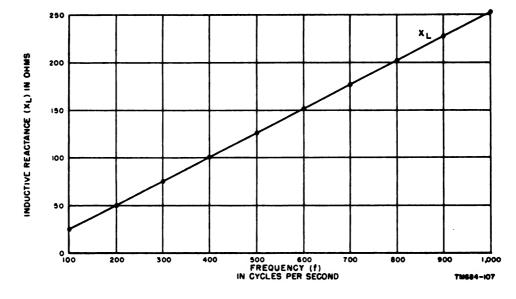


Figure 94. Graph showing reactance of 0.4-henry inductor at frequencies from 100 to 1,000 cps.

Н	0	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
R	0	30	87	95	68	60	77	85	68

b. As the output current I_o in milliamperes is varied by a full-wave rectifier voltage quadrupler, the output voltage E_o in volts changes in accordance with the following data. Plot the curve and determine the current at a voltage of 380 volts.

Ι.	45.5	42.0	39.5	36.0	32.5	28.5	24.0	19.5	14.0	8.0	4.0
E.	292	305	317	830	350	370	390	415	448	488	515

c. When two coils are arranged so that a change in current in one coil causes a voltage to be induced in the other, the coils are said to possess mutual inductance. Given the mutual inductance M in henrys for two coils S centi-

meters apart, plot the curve of the mutual inductance against the separation between the coils. What is the mutual inductance when the coils are separated by a distance of 7 centimeters?

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8	0	2	4	6	8	10	12	14
M	0.051	0.049	0.041	0.088	0.025	0.017	0.011	0.007

d. The vertical sag S in a powerline depends on the temperature T. With the sag being measured in feet and the temperature in $^{\circ}$ F. the following data is available for a 400-foot span. Plot the vertical sag against the temperature. If the sag is not to exceed 8.1 feet, what is the maximum permissible temperature?

T	-40	20	0	20	40	60	80	100
S	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2

e. The values of current I in milliamperes obtained by applying E volts to a selenium rectifier plate is shown in the following chart. Plot the current against the voltage and determine the current when the voltage is 0.8 volt.

E	1.5	1.8	1.1	0.9	0.7	0	2	-4	-6	8	-10
1	100	80	60	40	20	0	05	-1	2	8	-4

f. Using the formula $XC = \frac{1,000,000}{2\pi fC}$ to determine the values of variables, plot a graph showing reactance XC of a circuit having a capacitance of 2 microfarads at frequencies f variable from 1,000 to 10,000 cps in 1,000-cycle steps. $(2\pi = 6.28.)$

g. A circuit consists of a resistance of 5 ohms connected across a source of variable

potential. Using Ohm's law, plot the current through the resistance against the voltage across the resistance as the voltage is varied from 0 to 120 volts in 10-volt steps.

h. A variable resistance is connected across a generator that maintains a potential of 220 volts. Plot the current through the resistance as the resistance is varied in 5-ohm steps from 5 to 60 ohms.

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CHAPTER 19

BINARY NUMBERS

221. Scope and Background

a. This chapter serves as an introduction to the theory and arithmetic of binary numbers. It explains the difference between binary numbers and the more conventional decimal numbering system.

b. Binary numbers are of primary interest to the electronic technician because of their use in digital computers and similar devices. These computers fundamentally depend on either a conducting or nonconducting state of vacuum tubes or transistors, or they may depend on the storage states of magnetic cores. Hence they are bistable; that is, they are in one of two stable conditions.

c. The decimal numbering system uses 10 digits, 0 through 9. A digital computer using the decimal system would be large and complex; hence the binary system was adapted for digital computer use—the two digits, 0 and 1, of the binary system correspond to the bistable states discussed in b above. These two digits are called *bits*, a contraction of *Binary* dig*ITS*.

222. Comparison Between Decimal and Binary Systems

a. Decimal System. In the decimal system, the value of a number depends on the position of its digits. For example, in the decimal number 63, the digit 3 represents 3; however, in 63,444, the digit 3 represents 3,000; thus, changing the place of a digit in a number changes the value of the digit.

(1) As another example, decimal number 825 means $8 \times 10^2 + 2 \times 10^1 + 5 \times 10^0$. Ten (10) is considered the radix or base of the decimal system. Positional values for the equivalent powers of 10 are given in the following chart:

Position	Millions	Hundred thousands	Ten thousands	Thousands	Hundreds	Tens	Units
Value	1,000,000	100,000	10,000	1,000	100	10	1
Power	10 ⁶	10 ⁵	104	10 ³	10 ²	10 ¹	10º

(2) Again, using 63,444 as an example, the number can be analyzed as follows:

Position digit	6	3	4	4	4
Power	104	103	102	101	100

(3) Now multiply the position digit by the power (value) and add: 6×10^4 60,000 = $3 imes 10^3$ 3,000 = $4 imes 10^2$ 400 == 40 4×10^{1} $4 imes 10^{0}$ (or 1) $= \pm$ 4 63.444

b. Binary System. In place of 10, the binary system uses 2 as the base or radix. All powers are powers of 2. An expansion (multiplication) of some of the powers of 2 follows:

2 º		1
_		_
2 1	=	2
2²	=	4
2³	=	8
24	=	16
25	=	32
26	=	64
2 7	=	128
2 ⁸	=	256, etc.

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- (1) The binary system operates like the decimal system. Use the number 111111 as an example:
 - (a) In the decimal system: $1.11111 = 10^5 + 10^4 + 10^8 + 10^8 + 10^1 + 10^0 = 111,111.$

(0)	In the binary system:	
	$111111 = 2^5 + 2^4 + 2^5 + 2^2 + 2^1$	
	$+ 2^{\circ} = 68.$	

(2) A portion of the positional values and equivalent powers used in the binary system is now given.

Position	Sixty-four	Thirty-two	Sixteen	Eight	Four	Two	Units
Value	64	32	16	8	4	2	1 20
Power	26	25	24	2 ³	2 ²	21	

223. Tabular Conversion of Decimal Numbers to Binary Numbers

a. The following chart expresses the decimal numbers 0 through 10 in the binary system:

			Binary	numberi	•	
Decimal numbers	23	24	24	21	21	24
	82	16		4	2	1
0	0	0	L	0	0	0
1	0	0	0	0	0	1
2	0	0	0	0	1	0
8	0	0	0	0	1	1
4	0	0	0	1	0	0
5	0	0	0	1	0	1
6	0	0	0	1	1	0
7	0	0	0	1	1	1
8	0	0	1	0	0	0
9	0	0	1	0	0	1
10	0	0	1	0	1	0

- (1) If a power of 2 appears in the decimal number in the left column, place a 1 in the column in which the power of two appears. If a power of 2 is not used, place a 0 in that column.
- (2) The decimal number 0 is equivalent to the binary number 0. Thus, a 0 is required in the extreme right-hand position of the binary system.
- (3) The decimal number 2 equals 2¹ place a 1 under 2¹ and a 0 under all other powers of 2.
- (4) The decimal number 3 equals 2¹ + 2⁰.
 Place a 1 in each of these columns and a 0 under all other powers of 2.

- (5) The decimal number 4 equals 2². Place a 1 under 2² and a 0 under all other powers of 2.
- (6) The decimal number 5 equals 2² + 2⁶. Place a 1 under each of these powers of 2 and a 0 under all of the remaining powers.
- (7) Use the procedures outlined above to check the remaining values in the chart.
- b. Additional tabular conversions follow:

			Binary	numbers			
Decimal numbers	27	24	21	2*	3 1	20	
	82	16	8	4	8	1	
20	0	1	0	1	0	a	
30	0	1	1	1	1	0	
40	1	0	1	0	0	0	
45	1	0	1	1	0	1	
50	1	1	0	0	1	0	
57	1	1	1	0	0	1	

224. Nontabular Conversion of Decimal Numbers to Binary Numbers

The tabular conversion of decimal numbers to binary numbers is tedious and somewhat awkward. An easier method is to divide the decimal number by 2, and the answer again by two, continuing until you have a remainder of 1. In the example below, 37 will be converted to its binary equivalent. Notice that throughout the operation all numbers will be either exactly divisible by 2 or will be divisible with a remainder of 1. If 2 divides evenly, place a



0 to the right of that quotient; if 2 does not divide evenly, place a 1 to the right of that quotient; repeat until further division by 2 is impossible.

Example: 2/37 2/18 2/9 2/4 2/2

-/		
2 <u>/18</u>	1	
2/9	0	
2/4	1	
2/2	0	
$2\overline{/1}$	0	
0	1	

Bit position	1	0		1		1		0		1		Ű
Power value	26	25		24		28		22		21		20
Multiply bit position times power value	64	0		16		8		0		2		0
Add horizontally	64 +	0	+	16	+	8	+	0	+	2	+	0
Total	90.						-				-	

226. Nontabular Conversion of Binary Numbers to Decimal Numbers

The following procedure illustrates an alternative method of coverting from binary numbers to decimal numbers—the same binary number, 1011010 is used:

a. Start with the bit at the extreme left.

- (1) If the next bit to the right is a 0, double the leftmost bit.
- (2) However, if this next bit is a 1, double the leftmost bit and add 1.

b. The complete conversion of 1011010 follows:

- (1) At the first left bit, double 1 to get 2 since the second bit from left is a 0.
- (2) At the second lift bit, double 2 and add 1 to get 5 since the third bit from left is a 1.
- (3) At the third left bit, double 5 and add 1 to get 11 since the fourth bit from the left is a 1.
- (4) At the fourth bit, double 11 to get 22 since the fifth bit from the left is a 0.
- (5) At the fifth bit, double 22 and add 1 to get 45 since the sixth bit is a 1.
- (6) At the sixth bit, double 45 to get 90

The binary number, 100101, is obtained by reading from *bottom to top*. This result may be checked against the tabular system of conversion (par. 257).

225. Tabular Conversion of Binary Numbers to Decimal Numbers

Using the binary number 1011010, the following procedure illustrates one method of converting from binary numbers to decimal numbers:

> since the seventh bit is a 0. This is the answer and the end of the operation.

(7) Since the seventh bit is the last bit, no further operations are required. Remember that no mathematical operation is required for the extreme righthand bit when converting by the nontabular method.

227. Addition of Binary Numbers

a. Addition in the binary system is similar to addition in the decimal system. The rules for binary addition follow:

- (1) 0 + 0 = 0
- $(2) \ 0 \ + \ 1 \ = \ 1$
- (3) 1 + 1 = 10, 0 with 1 to carry into the next place. This rule may be expanded further to include: 1 + 1 =11, or 1 with 1 to carry to the next place. 1 + 1 + 1 + 1 = 100, or 0 with 10 to carry in the next place.

b. The following example illustrates binary addition.

Binary	Decimal
1101	13
+ 1111	15
11100	28

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- (1) Begin at the extreme right bit: 1 + 1 = 10. Write 0, carry 1.
- (2) 0 + 1 + 1 (carried over) = 10. Write 0, carry 1.
- (3) 1 + 1 + 1 (carried over) = 11. Write
 1, carry 1.
- (4) 1 + 1 + 1 (carried over) = 11. Write 11.
- (5) The answer is 11100. Check answer by converting to decimal numbers and then adding (as shown).

c. Binary addition is further illustrated by the next example:

Binary	Decimal
101 1101 1101	1501
+ 111 0010 1101	+ 1837
1101 0000 1010	8838

228. Subtraction of Binary Numbers

a. Subtraction in the binary system is similar to subtraction in the decimal system. The rules for binary subtraction follow:

- (1) 0 0 = 0
- (2) 1 1 = 0
- (3) 1 0 = 1
- (4) 0 1 = 1, and then proceed to change all numbers in the top row until you change a 1 to a 0.

b. The following example illustrates binary subtraction:

Binary		Decimal
1011	(minuend)	11
0101	(subtrahend)	5
0110	(remainder)	6

- Begin at the extreme right bit:
 1 1 = 0. Bring down 0, none to carry.
- (2) 1 0 = 1. Bring down 1, none to carry.
- (3) 0 1 = 1. The bit 1 to the extreme left in the minuend is changed to 0.
- (4) 0 0 = 0. End of operation.
- (5) The complete calculation may be

checked by adding	the subtrahend
and the remainder.	
Binary	Decimal
0101	5
+0110	+ 6
1011	-11

c. Binary subtraction is further illustrated in the next example:

	Binar	v		Decimal
1101	0000	1010	(minuend)	8888
- 111	0010	1101	(subtrahend)	
101	1101	1101	(remainder)	1501

Proof:

Binary	Decimal
101 1101 1101	1501
+ 111 0010 1101	+1837
1101 0000 1010	3338

229. Complementary Addition of Binary Numbers

The direct subtraction of binary numbers is not used in some data equipments. Instead, the subtraction processes are carried out by complement addition. To subtract two binary numbers using this system, proceed as follows:

a. Use the following problem as an example: 1101101 (minuend)

<u>– 10010</u> (subtrahend)

b. First determine the complement of the subtrahend.

- (1) Add zeros to the left until the subtrahend has the same number of bits as the minuend; for example, 0010010.
- (2) Note the first 1 counting from the right and bring down this 1 as well as any of the zeros to its right; then reverse all other bits proceeding toward the left. The subtrahend of (1) above becomes 1101110. This number is the complement.
- (3) Now add the minuend to the complement:

	110	1101
+	110	1110
	1101	1011

(4) Delete the 1 to the extreme left and the remainder becomes 1011011.

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(5) Check the answer by binary subtraction:

110	1101	(minuend)
- 1	0010	(subtrahend)
101	1011	(remainder)

c. The next problem is solved by using the principles explained in a and b above.

- (1) 11101101 (minuend) 111100 (subtrahend)
- (2) 00111100 becomes the complement 11000100.
- 1110 1101 (minuend) (3) + 1100 0100 (complement) (remainder) 11011 0001
- (4) Proof by subtraction 11101101 (minuend) 111100 (subtrahend) 10110001 (remainder)

230. Multiplication of Binary Numbers

a. Multiplication is the simplest of all the binary processes. The rules are:

(1)	0	Х	0	=	0
(2)	0	Х	1	=	0
(3)	1	×	1	=	1

b. Remember that binary addition is important to binary multiplication. Two examples of multiplication are given below.

Example 1: Binary	Decimal
1011	11
× 10	<u>× 2</u>
0000	
1011	
10110	22
Example 2: Binary	Decimal
111011	59
× 101	<u>× 5</u>
$\frac{\times 101}{111011}$	
111011	

231. Division of Binary Numbers

a. Division of binary numbers is similar to division in the decimal system. The simple rules are:

> (1) $0 \div 0 = 0$ (2) $0 \div 1 = 0$ (8) $1 \div 1 = 1$

b. Remember that binary subtraction is important to binary division. Two examples of binary division are given below.

Example 1:	Binary 111 10)1110 <u>10</u> 11 <u>10</u> 10 <u>10</u> <u>10</u>	Docimal 7 2)14 <u>14</u>
	Proof: <i>Binary</i> 111 × 10 1110	$\frac{Decimal}{7} \\ \frac{\times 2}{14}$
Example 2:	<i>Binary</i> 1001 ^{<u>100</u>}	Decimal 9 4

Proof:

$1001\frac{100}{110}$	9 4
110)111010	6)58
110	54
1010	4/6
<u>110</u>	
100	

Note the remainder of 100/110.

1001	(partial quotient)
\times 110	(divisor)
10010	
1001	
110110	(partial dividend)
+100	(add remainder)
111010	(total dividend)

232. Fractions in the Binary System

a. The system of expressing fractions with binary numbers is similar to the decimal numbering methods. For example, the common fraction $\frac{3}{5}$ may be expressed in binary numbers as $\frac{11}{101}$ Also, binary fractions may be expressed as decimal fractions when the powers of 2 are used with negative exponents. The binary fraction 0.011 is equivalent to the decimal fraction 0.375 and may be written as:

$$0 \times 2^{-1} + 1 \times 2^{-2} + 1 \times 2^{-4} = 0 + \frac{1}{4} + \frac{1}{8} = \frac{3}{8}$$
 or .375.

b. The following table lists some of the fractional values and their equivalents in both systems:

Decimal equivalente	Power of 8	Binary equivalent
1/2 or .5	2-1	.1
1/4 or .25	<u>9</u> —1	.01
1/8 or .125	2—8	.001
1 16 or .065	2-4	.0001
1 82 or .08125	25	.00001
1 64 or .015625	25	.000001
1 128 or .0078125	2-7	.0000001
1 256 or .00390625	28	.00000001
1 512 or .001953125	21	.000000001

c. Using values from the table, the decimal fraction 0.375 is equal to .25 + .125 and hence has the binary equivalency of .01 + .001 = .011.

233. Conversion of Decimal Fractions to Binary Numbers

Usually, the decimal fractions are converted to binary fractions by performing a series of multiplications by 2. This method is directly opposite to the method explained in paragraph 224. As a rule, decimal fractions cannot be converted to exact binary equivalents. The extent of error must be tolerable for a given application and the number of bits used must be reasonable.

- a. To convert 0.375 to a binary number, proceed as follows:
 - (1) Multiply the decimal 0.375 by 2 to obtain a new integer (whole number) and a new decimal, 0.75. Since in 0.75 the integer to the left of the decimal point is 0, place a 0 in the binary equivalent as .0.

$$\frac{\text{Decimal} \times 2}{0.375 \times 2} \qquad \frac{\text{New integer and decimal}}{0.75} \qquad \frac{\text{Partial binary equivalent}}{.0}$$

(2) Multiply the decimal 0.75 by 2 to obtain a new integer and decimal. Since the integer to the left of the decimal point is a 1, place a 1 in the binary equivalent as .01.

Decimal $\times 2$	New integer and decimal	Partial binary equivalent
0.75×2	1.50	.01

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(3) Drop the integer 1 and multiply the decimal 0.50 by 2 to obtain a new integer and decimal. Since the new integer to the left of the decimal is a 1, place another 1 in the binary equivalent as .011.

Decimal $\times 2$	New integer and decimal	Partial binary equivalent
0.50×2	1.00	.011

(4) Note that the operation ends when the decimal part has been expanded to 0.00. The decimal fraction, 0.875, is equivalent to the binary fraction, .011. In this instance, the binary and decimal fractions have exactly the same value.

b. The next example illustrates the conversion of 0.3465 to its binary equivalent. Note that the partial binary equivalents are added at the end of the operation to obtain the complete equivalent:

Multiplication = 2	Binary equivalent	Decimal value of binary equivalent
A	В	С
$0.3465 \times 2 = .6980$.0	.0
$0.693 \times 2 = 1.386$.01	.25
$-0.386 \times 2 = 0.772$.000	.00
$0.772 \times 2 = 1.544$.0001	.0625
$0.554 \times 2 = 1.108$.00001	.03125
Add up all entries under B and C.	.01011	.34375

c. In b above, the binary and decimal fractions differ in value and the amount of error may be determined by subtraction:

0.3465 - 0.34375 = 0.00275 (fraction of error)

234. Mixed Binary Numbers

a. A mixed binary number is a combination of whole numbers and binary fractions. Examples of this are:

Binary number	Decimal equivalent
1011.1	11.5
1110.011	14.375
10.000001	1.015625

b. The fundamental operations (addition, subtraction, multiplication, and division) for mixed binary numbers or binary fractional numbers alone are in accordance with the principles already explained in this chapter.





APPENDIX I BASIC SLIDE RULE OPERATIONS

1. General

This appendix describes the basic slide rule and covers the operations of multiplication, division, squaring, and square root.

2. Description of Slide Rule

a. Slide rules are made in several different sizes and styles, and in an assortment of scales. However, they all contain the same basic scales and use them in the same manner.

b. The most common type of slide rule is about 10 inches long and generally has scales on both sides. The most frequently used scales, and the ones covered here, are the A, B, C, and D. 'Figure 95 is a simplified drawing of a slide rule of this type, showing these scales and the other essential parts of the rule. Note that these scales have indexes (the number 1) on both ends. Also note that the A and B scales have an additional index in the center that divides these scales into two equal parts. The left-hand part of the scales is called Aleft or B-left, and the right-hand part, A-right or B-right.

3. Basic Principles of Operation

The slide rule is based on the principle of the logarithm; that is, the segments on the rule represent exponents, or logarithms, but are indicated by the antilogs, or numbers corresponding to those logarithms. Consequently, when the slide rule is used so that two line segments are added, the logarithms of the numbers shown are actually being added, and the sum of the two line segments is represented by the antilog of the sum of the logarithms. Since the sum of the logarithms of two numbers is equal to the logarithm of the product of the two numbers (par. 121), adding two line segments on a slide rule will give the product of the two numbers represented by the line segments. This is the technique used in multiplication with a slide rule (par. 6 of this app). In the division process, the reverse procedure is used; that is the two line segments are used so that one is subtracted from the other.

4. Accuracy

The accuracy of a slide rule depends on the length of the rule and on the portion of the rule being used. With the 10-inch rule shown in figure 95, numbers can be approximated to four significant figures on the left-hand end of the C or D scales, but only to three significant figures on the right-hand end of these scales. Despite this fact, the results obtained with the slide rule are sufficiently accurate for many practical purposes; in any case, the results serve as a rapid and efficient check of more complex computations.

5. Reading the Scales

a. Since the scales on a slide rule do not have uniform increments along their lengths,

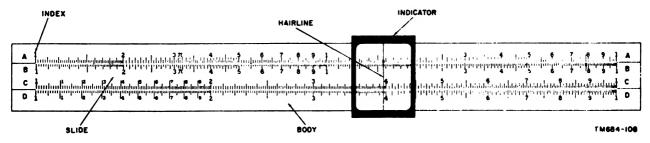


Figure 95. Typical slide rule, simplified drawing.

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Figure 96. Locating numbers on the D scale.

be careful when approximating numbers at different points on the scales. For example, the space between the larger numbers 1 and 2 on the D scale (fig. 96) is divided into 10 subgroups (identified by the small numbers 1 through 10) of 10 increments each; thus there are 100 increments between 1 and 2 on the D scale, and each increment is equal to one onehundredth of the difference. Between 4 and 5 on the D scale, however, there are only 20 increments, and each increment therefore, is equal to five one-hundredths of the difference. Consequently, the number 105 would be located 5 increments above 1, whereas 405 would be 1 increment above 4 on the scale. Figure 96 shows the location of these and other numbers on the D scale.

b. To locate a number on a scale, first determine its general location between two of the numbers on that scale; then determine the value of each increment between the numbers. Finally, determine its exact location based on the value of the increments.

c. In reading the scale, as in logarithms, the decimal point is neglected until after the absolute value of the result is obtained; therefore, in figure 96, the number 1245 could actually represent 1.245, 12.45, 124.5, .001245, etc. The use of scientific notation (par. 106) will greatly simplify the handling of very large or very small numbers.

6. Multiplication

a. Normally, the process of multiplication is performed by using the C and D scales. The A and B scales may also be used, but they are not as accurate because the increments are smaller. To multiply two numbers, proceed as follows:

- (1) Locate one number on the D scale. Slide the indicator until the hairline is over the number to mark its location.
- (2) Place one of the indexes of the C scale above the number on the D scale. Use the hairline of the indicator to aline the index and the number.
- (3) Locate the second number on the C scale. If the number is located on the portion of the C scale beyond the end of the D scale, reposition the slide so that the other index on the C scale is above the number on the D scale.
- (4) Slide the indicator so that the hairline is over the number on the C scale. The product of the two numbers is read under the hairline on the D scale.

b. The two examples below illustrate the method of multiplication described above. They also point out the use of the two indexes on the C scale.

Example 1: Multiply 2 by 3.

- Step 1. Locate the number 2 on the D scale and slide the indicator until the hairline is over it.
- Step 2. Place the left-hand index of the C scale above the number 2 on the D scale. Use the hairline on the indicator for alinement.
- Step 3. Locate the number 3 on the C scale and slide the indicator so that the hairline is over it. The



Figure 97. Slide rule arranged for multiplying 2 by 3.

ADD INA



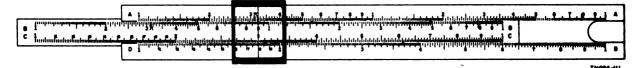


Figure 98. Slide rule arranged for multiplying 6 by 3.

product of 2 times 3 or 6 is read under the hairline on the D scale. Figure 97 shows a slide rule arranged for this product.

- Example 2: Multiply 6 by 3.
- Step 1. Locate the number 6 on the D scale and slide the indicator so that the hairline is over it.
- Step 2. Place the right-hand index of the C scale above the number 6 on the D scale. Use the hairline on the indicator for alinement. (The right-hand index is used because the number 3 on the C scale would be beyond the end of the D scale if the lefthand index were used.)
- Step 3. Locate the number 3 on the C scale and slide the indicator so that the hairline is over it. The product of 6 times 3 or 18 is read under the hairline on the D scale. Figure 98 shows a slide rule arranged for this product.

7. Division

a. The process of division, like multiplication, generally is performed by using the C and D scales. To divide one number by another number, proceed as follows:

- (1) Locate the dividend (number to be divided) on the D scale. Slide the indicator until the hairline is over the number to mark its location.
- (2) Locate the divisor on the C scale.

Move the slide until this number is above the dividend on the D scale. Use the hairline on the indicator for alinement.

(3) Slide the indicator until the hairline is over the index on the C scale that is above a portion of the D scale. The quotient of the two numbers is read under the hairline on the D scale.

b. The following example illustrates the use of the method of division described above.

Example: Divide 8 by 2.

- Step 1. Locate the dividend (8) on the D scale and slide the indicator until the hairline is over it.
- Step 2. Locate the divisor (2) on the C scale and move the slide until this number is above 8 on the D scale. Use the hairline on the indicator for alinement.
- Step 3 Slide the indicator until the hairline is over the left-hand index. The quotient of 8 divided by 2 is located under the hairline on the D scale. Figure 99 shows a slide rule arranged for this quotient.

8. Squaring a Number

a. The process of squaring a number is performed by using the A and D scales. To square a number, proceed as follows:

(1) Locate the number on the D scale. Slide the indicator until the hairline is over the number.

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CharlenforterEnter E. C. C. C.	e. e. i	muluuluut	And the second s
E <u><u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u> <u>e</u></u>			7.000.00

Figure 99. Slide rule arranged for dividing 8 by 2.

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(2) Read the square under the hairline on the A scale. Remember that the increments on the A scale are smaller than the increments on the D scale; be sure to evaluate the increment carefully.

b. The following example illustrates the procedure given above.

Example: Find the square of 12.5.

- Step 1. Locate 12.5 on the D scale. Slide the indicator until the hairline is over it (fig. 100).
- Step 2. Read the square of 12.5 under the hairline on the A scale. The three significant figures that can be obtained from the A scale are 156. To locate the decimal point, estimate the value of the square of 12.5. Since the square of 12 is 144, the square of 12.5 is 156.

9. Square Root of a Number

a. The process of finding the square root of a number is simply the reverse of the process of squaring a number (par. 8). To find the square root of a number, proceed as follows:

- (1) Locate the number of the A scale. Slide the indicator until the hairline is over the number.
- (2) Read the square root under the hairline on the D scale.

b. The following example illustrates the procedure given above.

Example: Find the square root of 9.5.

- Step 1. Locate 9.5 on the A scale. Note that there are two such numbers on the A scale, one on Aleft, and one on A-right. Since the square root of 9 is 3, the number on A-right would not yield the correct result; therefore, slide the indicator until the hairline is over the 9.5 on A-left.
- Step 2. Read the square root of 9.5, that is, 3.08, under the hairline on the D scale. Figure 101 shows a slide rule arranged for this square root.

A Junior		ſŧŧŧŧŧŧŧŧţĨįŧŧŧ ŧŧŧŢŧŧŧ ŢĸŧŧĸĨ <mark>ĸŧŀĸĨĸŧŢĸŢŦŢŦ</mark> ĸŧĸŧĸŧĸŧ ĸŧĸŦŦŢ ŧŧŧŧŧŀŧŧŧŧţŧŧŧŧ <mark>ŧŧŧŧŧŧ</mark> ĸŧ ŀĸĨĸŧŢŦĘŦŢ Ţ
D Intim	ulun ulun	to E + E + E + E + E + E + I ndantantantantantantantantantantantantanta
		TM884-113

Figure 100. Slide rule arranged for finding the square of 18.5.

<mark>· juntuntunturtutututututututututututututut</mark>	utententententententententententententent
	TWOD 4-114

Figure 101. Slide rule arranged for finding the square root of 9.5.

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APPENDIX II SYSTEMS OF MEASUREMENT

1. General

Two systems of measurement are in use in the United States today: the English system, based on the foot and the pound, and the metric system, based on the centimeter (or meter) and the gram (or kilogram). Both systems are used in electronics. For example, the wavelength of an antenna is calculated in the metric system; the physical length of each conductor is stated in feet and inches.

2. Metric Prefixes

In the field of communications, there are often wide ranges in electrical quantities. For example, the input of a radio receiver may be in millionths of a volt, and the output circuit of a transmitter may be in thousands of volts. Thus, metric prefixes are used in electronics in combination with basic units of measurement—volts, ohms, watts, amperes, farads, henrys, and cycles—to facilitate operations. The following chart gives the meaning of these prefixes with respect to various units of measurement.

Metric prefix	Meaning	Associated with	
Mega	Million	(1,000,000)	Volt, ohms, cycles, amperes
Kilo	Thousand	(1.000)	Volts, watts, cycles, meters, amperes
Hecto	Hundred	(100)	Meters
Deka	Ten	(10)	Meters
Deci	One-tenth	(0.1)	Meters
Centi	One-hundredth	(0.01)	Meters
Milli	One-thousandth	(0.001)	Volts, amperes, meters, henrys, watts, ohms
Micro	One-millionth	(0.000001)	Volts, amperes, farads, henrys, mhos, ohms
Micromicro	One-millionth of one-millionth	(0.000.000.000.001)	Volts, amperes, farads, coulombs

3. Conversion Factors

The table below lists the common units of measurement with one set of prefixes and the factor by which these units must be multiplied to convert them to units with another set of prefixes. The examples below illustrate the method in which the table is used.

Example 1: Convert 7.54 megacycles to cycles.

From the table, to convert from megacycles to cycles, multiply by 10^{6} .

 $7.54 \times 10^4 = 7.54 \times 1,000,000$ = 7,540,000 cycles

Example 2: Convert 5,500 watts to kilowatts.

> From the table, to convert watts to kilowatts, multiply by .001. $5,500 \times 0.001 = 5.5$ watts

> > AGO SELA



To convert from	То	Multiply by
Abamperes	Amperes	10.0000
Abamperes	Statampere	2.998 x 1010
Abcoulomba	Ampere-hours	2.778 x 10-3
Abcoulomba	Coulomba	10.0000
Abcoulomba	Faradays	1.036 x 10-4
Abcoulomba	Statcoulomba	2.998 x 1010
Abfarada	Farada	109
Abfarada	Microfarada	1016
Abfarada	Statfarada	8.988 x 1029
Abhenrys	Henrys	10-9
Abhenrys	Microhenrys	.001
Abhenrys	Millihenrys	10-6
Abhenrys	Stathenrys	1.118 x 10-21
Abohma	Megohms	10-15
Abohma	Microhms	0.001
Abohma	Ohms	
Abohma	Statohms	1.118×10^{-21}
Abvolts	Microvolta	.01
Abvolta	Millivolta	10-6
Abvolts	Statvolts	3.336×10^{-1}
Abvolts	Volts	10-8
Acres		
Acres	Ares (square dekameters)	40.46878
Acres	Hectares (square hectometers)	4.356 x 104
Acres	Square feet	
Acres	Square inches	6,272,640
Acres	Square kilometers	4.047 x 10-3 4047
Acres	Square meters	
Acres	Square miles	I.568 x 10-4 160
Acres	Square rods	4840
Amperes	Square yards	
	Abamperes	.1 1000
Amperes Amperes	Milliamperes Statamperes	2.998×10^{9}
Ampere-hours	Abcoulombs	
Ampere-hours Ampere-hours	Coulombs	860
Ampere-hours	Faradays	8600
Ampere-hours	Statcoulomba	8.731 x 10-2
Ares	Acres (US)	1.080×10^{13}
Ares		.02471044
Ares	Hectares	.01
Ares	Square feet	1076.4
Ares	Square meters Square miles	100
Ares		3.861 x 10-4
Bushels (dry)	Square yards Cubic centimeters	119.60 8524 x 104
Bushels (dry)	Cubic feet	1.2444
Bushels (dry)	Cubic inches	2150.4
Bushels (dry)	Cubic meters	8.524 x 10-2
Bushels (dry) Centimeters	Liters	85.24
Centimeters	Feet	3.281 x 10-2
	Inches	.3937
Centimeters Centimeters	Kilometers	10-5
Centimeters Centimeters	Meters	.01
Centimeters Centimeters	Mils Miles	398.7 6 914 - 10_5
Centimeters Centimeters		6.214 x 10-5
Centimeters Centimeters	Millimeters Vende	
	Yards Fact (minute	1.094 x 10-2
Centimeters/second	Feet/minute	1.969
Centimeters/second	Feet/second	3.282×10^{-2}
Centimeters/second	Kilometers/hour	.036

AGO MEA

To convert from	To	Multiply by
Centimeters/second	Kilometers/minute	.0006
Centimeters/second	Knots/hour	1.943 x 10-2
Centimeters/second	Meters/minute	.6
Centimeters/second	Meters/second	.01
Centimeters/second	Miles/hour	2.237 x 10-2
Centimeters/second	Miles/minute	8.728 x 10-4
Circular mils	Square centimeters	5.067 x 10-4
Circular mils	Square inches	7.854 x 10-7
Circular mils	Square millimeters	5.067 x 10-4
Circular mils	Square mils	.7854
Coulombs	Abcoulomba	.1
Coulombs	Ampere-hours	2.778 x 10-4
Coulombs	Faradays	1.036 x 10-5
Coulombs	Statcoulombs	2.998 x 10°
Cubic centim eters	Cubic feet	8.531 x 10
Cubic centimeters	Cubic inches	6.102 x 10-2
Cubic centimeters	Cubic meters	10
Cubic centimeters	Cubic yards	1.808 x 10-4
Cubic centimeters	Gallons (liquid)	2.642 x 10-4
Cubic centimeters	Liters	.001
Cubic centimeters	Pints (liquid)	2.118 x 10-4
Cubic centimeters	Quarts (liquid)	1.057 x 10-9
Cubic feet	Bushels (dry)	.8036
Cubic feet	Cubic centimeters	2.832 x 104
Cubic feet	Cubic inches	1728
Cubic feet	Cubic meters	2.832 x 10-2
Cubic feet (US)	Cubic yards	3.704 x 10-2
Cubic feet	Gallons (liquid)	7.481
Cubic feet	Liters	28.316
Cubic feet	Pints (liquid)	59.84
Cubic feet	Quarts (liquid)	29.922
Cubic hectometers	Cubic meters	106
Cubic inches	Bushels (dry)	4.6503 x 10-4
Lubic inches	Cubic centimeters	16.39
Cubic inches	Cubic feet	5.787 x 10-4
Lubic inches	Cubic meters	1.639 x 10-3
Cubic inches (US)	Cubic yards	2.148 x 10-4
Cubic inches	Gallons	4.829 x 10-4
Lubic inches	Liters	1.639 x 10-2
Cubic inches	Pints (liquid)	3.463 x 10-8
Cubic inches	Quarts (liquid)	1.732 x 10-2
Cubic meters	Bushels (dry)	28.38
Cubic meters	Cubic centimeters	104
Cubic meters	Cubic feet	85.81
Cubic m eters	Cubic inches	6.102 x 104
Cubic meters	Cubic yards	1.808
Cubic meters	Gallons (liquid)	264.2
Cubic meters	Liters	1000
Cubic meters	Pints (liquid)	2113
Cubic meters	Quarts (liquid)	1057
Cubic meters	Steres	1
ubic yards	Cubic centimeters	7.646 x 10 ⁵
Cubic yards	Cubic feet	27
Cubic yards	Cubic inches	46656
ubic yards	Cubic meters	.7646
Cubic yards	Gallons	202.0
Cubic yards	Liters	764.6
Cubic yards	Pints (liquid)	1616
Cubic yards	Quarts (liquid)	807.9
	Access (endana)	1

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To convert from	То	Multiply by
Decimeters	Meters	.1
Decigrams	Grams	.1
Decisteres	Cubic meters	.1
Degrees	Circumferences ^a (revolutions)	2.778 x 103
Degrees	Minutes	60
Degrees	Quadrants	1.111 x 10-2
Degrees	Radians	1.745×10^{-2}
Degrees	Seconds	3600
Degrees/second	Radians/second	1.745×10^{-2}
Degrees/second	Revolutions/minute	.1667
Degrees/second	Revolutions/second	2.778×10^{-3}
Dekagrams	Grams	10
Dekameters	Meters	10
Faradays	Abcoulomba	9649
Paradays	Ampere-hours	26.81
Faradays	Coulombs	9.649 x 104
Faradays	Statcoulombs	
Farads	Abfarada	2.893 x 10 ¹⁴ 10-9
Farads	Microfarada	1
Farads	Statfarada	106
Feet	Centimevers	8.988 x 10 ¹¹
Feet.	Inches	80.48
Feet	Kilometers	12
Feet	Meters	3.048 x 10-4
Feet	Miles (nautical)	.3048
Feet	Miles (statute)	1.645 x 10-4
Peet	Miles (statute)	1.894 x 10-4
Peet		1.2 x 104
Feet	Millimeters Yarda	304.8
Feet/minute		.8333
Feet/minute	Centimeter/second	.5080
Feet/minute	Feet/second	1.667×10^{-2}
Feet/minute	Kilometers/hour	1.829×10^{-2}
Feet/minute	Kilometers/second	3.048 x 10-4
Feet/minute	Knots	9.868 x 10-3
et/minute	Meters/minute	.3048
eet/minute	Meters/second	5.080 x 10-3
Feet/minute	Miles/hour	1.136×10^{-2}
reet/second	Miles/minute	1.894 x 10-4
reet/second	Centimeters/second	30.48
Pert/second	Feet/minute	60
reet/second	Kilometers/hour	1.097
reet/second	Kilometers/minute	1.829 x 10-2
reet/second reet/second	Knots/hour	.5921
reet/second reet/second	Meters/minute	18.29
reet/second reet/second	Meters/second	.3048
	Miles/hour	.6818
feet/second	Miles/minute	1.136 x 10-2
Sallons (liquid)	Cubic centimeters	3785.
Sallons (liquid)	Cubic feet	.1337
Sallons (liquid)	Cubic inches	231
Sallons (liquid)	Cubic meters	3.785 x 10-3
Sallons (liquid)	Cubic yards	4.951 x 10-8
allons (liquid)	Liters	3.785
allons (liquid)	Pints (liquid)	8
allons (liquid)	Quarts (liquid)	4
Frains	Grams	6.480 x 10-2
Frains	Kilograms	6.481 x 10-5
Faine	Milligrams	64.81

To convert from	То	Multiply by
Grains	Ounces (avoirdupois)	2.286 x 10-3
Grains	Pounds (avoirdupois)	1.429 x 10-4
Grams	Grains	15.43
Grams	Kilograms	6.480 x 10-5
Grams	Milligrams	64.80
Frams	Ounces (avoirdupois)	8.527 x 10-2
Frams	Pounds (avoirdupois)	2.205 x 10-5
Frams	Tons (long)	9.842 x 10-7
Frams	Tons (metric)	10-4
Frams	Tons (short)	1.102 x 10-4
lectares	Acres	2.471
lectares	Acres	100
lectares	Square feet	1.076 x 10 ⁵
lectares	Square meters	10000
Iectares	Square rods	3.954×10^2
lectares	Square yards	11959.85
lectograms	Grams	100
lectograms	Ounces (avoirdupois)	3.527
Iectoliters	Liters	100
Iectometers	Meters	100
fectometers	Rods	19.88
Iectometers	Yards	109.4
Iectowatts	Watts	100
Iemispheres	Spheres	.5
Iemispheres	Spherical right angles	4
Iemispheres	Steradians [*]	6.283
Ienrys	Abhenrys	109
Ienrys	Microhenrys	106
lenrys	Millihenrys	1000
Ienrys	Stathenrys	1.113×10^{-12}
nches	Centimeters	2.540
nches	Feet	8.333 x 10-2
nches	Kilometers	2.540 x 10-5
nches	Meters	2.540 x 10-2
nches	Miles	1.578 x 10-5
nches	Millimeters	25.40
nches	Mils	1000
nches	Yards	2.778 x 10-2
Cilograms	Grains	1.543 x 104
Cilograms	Grams	1000
lilograms	Milligrams	104
Cilograms	Ounces (avoirdupois)	35.27
Cilograms	Pounds (avoirdupois)	2.205
Cilograms	Tons (long)	9.842 x 10-4
lilograms	Tons (metric)	.001
Cilograms	Tons (short)	1.102 x 10-4
liloliters	Gallons (liquid)	264.18
liloliters	Liters	1000
Cilometers	Centimeters	105
Cilometers	Feet	3281
liometers	Inches	3.937 x 104
Cilometers	Meters	1000
Cilometers	Miles (nautical)	.5396
Cilometers	Miles (statute)	.6214
Cilometers	Millimeters	106
Cilometers	Mils	3.937 x 10 ⁷
Cilometers	Yards	1094
Cilom eters/hour	Centimeters/second	27.78

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See notes at end of table.

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To convert from	To	Multiply by
Kilometers/hour	Feet/minute	54.68
Cilometers/hour	Feet/second	.9118
Cilometers/hour	Kilometers/minute	1.667 x 10-2
Kilometers/hour	Knots/hour	.5396
Cilometers/hour	Meters/minute	16.67
Cilometers/hour	Meters/second	.2778
Cilometers/hour	Miles/hour	.6214
Kilometers/hour	Miles/minute	1.086 x 10-2
Cilometers/minute	Centimeters/second	1667
Cilometers/minute	Feet/minute	8281
Cilometers/minute	Feet/second	54.68
Cilometers/minute	Kilometers/hour	60
Kilometers/minute	Knots/hour	82.38
Cilometers/minute	Meters/minute	1000
Kilometers/minute	Meters/second	16.67
Lilometers/minute	Miles/hour	87.28
Lilometers/minute	Miles/minute	.6214
Cilowatt hours	Watt-hours	1000
Cilowatts	Watts	1000
Cnots/hour	Centimeters/second	51.48
Cnots/hour	Feet/hour	6080.20
(nots/hour	Feet/minute	101.8
Inots/hour	Feet/second	1.689
Inots/hour	Kilometers/hour	1.853
Cnots/hour	Kilometers/minute	8.088 x 10-2
Inots/hour	Meters/minute	80.88
Cnots/hour	Meters/second	.5148
Knots/hour	Miles/hour	1.152
Knots/hour	Miles/minute	1.919 x 10-2
liters	Bushels (dry)	2.838 x 10-2
liters	Cubic centimeters	1000
iters	Cubic feet	8.531 x 10-2
liters	Cubic inches	61.02
liters	Cubic meters	.001
liters	Cubic yards	1.308 x 10-8
liters	Gallons (liquid)	.2642
liters	Pints (liquid)	2.118
liters	Quarts (liquid)	1.057
legacycles	Cycles	104
legameters	Meters	104
legohms	Abohms	.001
Legohms	Abohms	1015
Legohms	Microhms	1012
legohms	Ohms	104
Legohms	Statohms	1.112 x 10-8
leters	Centimeters	100
leters	Feet	8.281
Leters	Inches	89.87
leters	Kilometers	.001
Leters	Megameters	10-4
Leters	Miles (statute)	6.214 x 10-4
Leters	Millimeters	1000
Keters	Millimicrons	109
Keters	Mils	8.987 x 104
Meters	Yards	1.094
Meters/minute	Centimeters/second	1.667
Meters/minute	Feet/minute	8.281
Seters/minute	Feet/second	5.468 x 10-8
	Kilometers/hour	.06

AGO SSEA

To convert from	To	Multiply by
eters/minute	Kilometers/minute	.001
eters/minute	Knots/hour	3.238 x 10-
eters/minute	Meters/second	1.667 x 10-2
eters/minute	Miles/hour	8.728 x 10-8
eters/minute	Miles/minute	6.214 x 10-4
eters/second	Centimeters/second	100
eters/second	Feet/minute	196.8
sters/second	Feet/second	8.281
sters/second	Kilometers/hour	8.6
eters/second	Kilometers/minute	.06
eters/second	Knots/hour	1.943
ters/second	Meters/minute	60
ters/second	Miles/hour	2.237
ters/second	Miles/minute	8.728 x 10-*
crofarads	Abfarads	10-15
crofarads	Farada	10
rofarads	Statfarads	8.988 x 10 ⁴
crograms	Grams	10-4
liograms	Milligrams	.001
rohenrys	Abhenrys	1,000
rohenrys	Henrys	10-4
rohenrys	Millihenrys	.001
rohenrys	Stathenrys	1.118 x 10-18
rohms	Abohms	1000
rohms	Megohms	10-12
ohms	Ohms	10-6
ohms	Statohms	1.118 x 10-18
roliters	Liters	10
romicrofarads	Farads	10-12
rovolts	Abvolts	100
rovolts	Millivolts	.001
rovolts	Statvolts	8.836 x 10-4
ovolts	Volts	10
8	Centimeters	1.609 x 10 ⁴
8	Feet	5280
8	Inches	6.836 x 104
S	Kilometers	1.609
5	Meters	1609
10	Miles (nautical)	.8684
	Rods	820
••	Yards	1760
es/hour	Centimeters/second	44.70
es/hour	Feet/minute	88
es/hour	Feet/second	1.467
es/hour	Kilometers/hour	1.609
es/hour	Kilometers/minute	2.682 x 10-2
es/hour	Knots (per hour)	.8684
es/hour	Meters/minute	26.82
s/hour	Meters/second	.4470
s/hour	Miles/minute	1.667 x 10-2
es/minute	Centimeters/second	2682
es/minute	Feet/minute	5280
es/minute	Feet/second	88
es/minute	Kilometers/hour	96.54
es/minute	Kilometers/minute	1.609
ss/minute	Knots/hour	52.10
es/minute	Meters/minute	1609
ss/minute	Meters/second	26.82
es/minute	Miles/hour	60

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To convert from	То	Multiply by
Milligrams	Greins	1.543 x 10-2
Milligrams	Grams	.001
Milligrams	Kilograms	10-6
Lilligrams		3.527×10^{-5}
-	Ounces (avoirdupois)	
Lilligrams	Pounds (avoirdupois)	2.205 x 10-4
Lilligrams	Tons (long)	9.842 x 10-10
Lilligrams	Tons (metric)	10-9
lilligrams	Tons (short)	1.102 x 10-9
fillihenrys	Abhenrys	106
fillihenrys	Henrys	.001
Cillihenrys	Microhenrys	1000
fillihenrys	Stathenrys	1.112×10^{-15}
Cilliliters	Liters	.001
Lillimeters	Centimeters	1.1
fillimeters	Feet	3.281 x 10-3
Lillimeters	Inches	3.937 x 10-2
Cillimeters	Kilometers	10-4
Lillimeters	Meters	.001
Millimeters	Miles	6.214×10^{-7}
Lillimeters	Mile	39.37
Millimeters	Yards	1.094 x 10-3
Millimicrons	Microns	.001
Millivolta	Abvolts	105
fillivolts	Microvolta	1000
Millivolts	Statvolts	3.336 x 10-4
Killivolts Kilo	Volts	.001
Mils	Centimeters	2.540×10^{-3}
fils	Feet	8.333 x 10-5
Mils	Inches	.001
Kils	Kilometers	2.540×10^{-5}
Kils	Millimeters	2.540 x 10-3
Mils	Yards	2.778 x 10-5
Minutes (angle)	Degrees	1.667 x 10-2
Minutes (angle)	Quadrants	1.852 x 10-4
Minutes (angle)	Radians [*]	2.909 x 10-4
Minutes (angle)	Revolutions [•] (circumferences)	4.630 x 10-5
Minutes (angle)	Seconds	60
Myriagrams	Grams	10,000
Myriagrams	Kilograms	10
Myriameters	Kilometers	10
Myriameters	Meters	10,000
fyriameters	Miles	6.21370
Dhms	Abohms	109
Dhms	Megohms	10-6
Dhms	Microhms	106
)hms	Statohms	1.112×10^{-12}
	Grains	437.5
Dunces (avoirdupois)		437.5 28.35
Dunces (avoirdupois)	Grams	28.35 2.835 x 10-2
Dunces (avoirdupois)	Kilograms	
Ounces (avoirdupois)	Milligrams	2.835 x 104
Ounces (avoirdupois)	Pounds (avoirdupois)	6.250×10^{-2}
Ounces (avoirdupois)	Tons (long)	2.790 x 10-5
Ounces (avoirdupois)	Tons (metric)	2.835 x 10 ⁻⁵
Ounces (avoirdupois)	Tons (short)	3.125×10^{-5}
Pints (liquid)	Cubic centimeters	473.2
Pints (liquid)	Cubic feet	1.671×10^{-2}
		1 00 05
Pints (liquid)	Cubic inches	28.87 4.732 x 10-4

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To convert from	To	Multiply by
Pints (liquid)	Cubic yards	6.189 x 10-4
ints (liquid)	Gallons (liquid)	.125
ounds (avoirdupois)	Grains	7000
ounds (avoirdupois)	Grams	458.6
ounds (avoirdupois)	Kilograms	.4586
ounds (avoirdupois)	Milligrams	4.536 x 105
ounds (avoirdupois)	Ounces (avoirdupois)	16
ounds (avoirdupois)	Tons (long)	4.464 x 10-4
ounds (avoirdupois)	Tons (short)	.0005
uadrants	Degrees	90
uadrants	Minutes	5400
uadrants	Radians*	1.571
uadrants	Revolutions ^a (circumferences)	.25
uadrants	Seconds	8.24 x 10 ⁵
uarts (liquid)	Cubic centimeters	946.4
uarts (liquid)	Cubic feet	8.342 x 10-2
uarts (liquid)	Cubic inches	57.75
uarts (liquid)	Cubic meters	9.464 x 10-4
uarts (liquid)	Cubic meters	1.238 x 10-4
uarts (liquid)	Gallons (liquid)	.25
adians ^a	Circumferences	.1591
adians [.]		57.80
	Degrees	
adians"	Degrees, minutes, seconds	57°, 17', 44.8"
dians.	Minutes	3438
dians'	Quadrants	.6366
dians	Revolutions*	.1591
dians"	Seconds	2.063 x 10 ⁵
dians/second	Degrees/second	57.30
dians/second	Revolutions/minute	9.549
dians/second	Revolutions/second	.1592
volutions (circumferences)	Degrees	360
evolutions [*] (circumferences)	Minutes	2.16 x 104
evolutions [*] (circumferences)	Quadrants	4
evolutions [•] (circumferences)	Radians	6.283
evolutions ^e (circumferences)	Seconds	1.296 x 10 ⁶
evolutions/minute	Degrees/second	6
evolutions/minute	Radians/second	.1047
evolutions/minute ²	Revolutions/second ²	1.667 x 10-2
evolutions/second	Degrees/second	860
evolutions/second	Radians/second	6.283
evolutions/second	Revolutions/minute	60
econds (angle)	Degrees	2.778 x 10-4
econds (angle)	Minutes	1.667 x 10-2
econds (angle)	Quadrants	3.087 x 10-4
econds (angle)	Radians ^a	4.848 x 10-5
econds (angle)	Revolutions ^a (circumferences)	7.716 x 10-7
pheres	Hemispheres	2
pheres	Spherical right angles	8
phercs	Steradians	12.57
pherical right angles	Hemispheres	.25
oherical right angles	Spheres	.125
pherical right angles	Steradians	1.571
quare centimeters	Circular mils	1.973 x 10 ⁵
guare centimeters	Square decimeters	.01
quare centimeters quare centimeters	Square feet	1.076 x 10-3
-	Square inches	.1550
quare centimeters		
quare centimeters quare centimeters	Square kilometers Square meters	10 ⁻¹⁰ .0001
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Te convert from	To	Multiply by
Square centimeters	Square miles	3.861×10^{-11}
Square centimeters	Square millimeters	100
Square centimeters	Square yards	1.196 x 10-4
Square feet	Acres	-2.296 x 10-5
Square feet	Acres	9.290 x 10-4
quare feet	Circular mils	1.833 x 10 ⁸
quare feet	Square centimeters	929.0
quare feet	Square inches	144
quare feet	Square kilometers	9.290 x 10 ⁻⁸
quare feet	Square meters	9.290 x 10 ⁻²
quare feet	Square miles	3.587 x 10 ⁻⁸
quare feet	Square millimeters	9.290 x 104
quare inches	Circular mils	1.273 x 10 ⁶
quare inches	Square centimeters	6.452
quare inches	Square feet	6.944 x 10-3
quare inches	Square kilometers	6.452 x 1010
quare inches	Square meters	6.452 x 10-4
quare inches	Square millimeters	645.2
quare inches	Square yards	7.716 x 10-4
guare kilometers	Acres	247.1
guare kilometers	Square centimeters	1010
quare kilometers	Square feet	1.076×10^7
guaro kilometers	Square inches	1.550 x 10 ⁹
square kilometers	Square meters	106
Square kilometers	Square miles	.3861
guare kilometers	Square millimeters	1012
Square kilometers	Square yards	1.196 x 106
quare meters	Acres	2.471 x 10-4
quare meters	Acres	.01
quare meters	Circular mils	1.973 x 109
Square meters	Square centimeters	104
Square meters	Square feet	10.76
Square meters	Square inches	1550
Square meters	Square kilometers	10
Square meters	Square miles	3.861×10^{-7}
Square meters	Square millimeters	106
Square meters	Square yards	1.196
Square miles	Acres	640
Square miles	Square centimeters	2.590 x 1010
Square miles	Square feet	2.788 x 107
Square miles	Square inches	4.015 x 10 ⁹
Square miles	Square kilometers	2.590
Square miles	Square meters	2.590 x 10 ⁶
Square miles	Square yards	3.098 x 10 ⁶
Square millimeters	Circular mils	1973
Square millimeters	Square centimeters	.01
Square millimeters	Square feet	1.076 x 10-5
Square millimeters	Square inches	1.550×10^{-3}
Square millimeters	Square kilometers	10-12
Square millimeters	Square meters	10-6
Square millimeters	Square miles	3.861×10^{-18}
Square millimeters	Square yards	1.196 x 10-6
Square rods	Acres	.00625
Square rods	Square feet	272.25
Square rods Square rods	Square inches	39204
•		
•		
•		
Square rods Square rods Square rods Square yards	Square meters Square miles Square yards Acres	25.293 9.766 x 10-6 30.25 2.066 x 10-4

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To convert from	To	Multiply by
Square y ards	Square centimeters	8361
Square yards	Square feet	9
Square yards	Square inches	1296
Square yards.	Square kilometers	8.361 x 10-7
Square yards	Square meters	.8361
Square yards	Square miles	3.228 x 10-7
Square yards	Square millimeters	8.361 x 10-5
Statamperes	Abamperes	3.335×10^{-11}
Statamperes	Amperes	3.335 x 10-10
Statcoulombs	Abcoulombs	3.335×10^{-11}
Statcoulombs	Ampere-hours	9.259×10^{-14}
Statcoulombs Statcoulombs	Coulombs Faradays	3.335 x 10-10 3.457 x 10-15
Statcoulombs Statfarads (or centimeters)	Abfarads	1.112×10^{-21}
Statiarads (or centimeters)	Farads	1.112×10^{-12}
Statiarads	r araus Microfarads	1.112 x 10 ⁻¹²
Stathenrys	Abhenrys	8.988 x 10 ²⁰
Stathenrys	Henrys	8.988 x 10 ¹¹
Stathenrys	Microhenrys	8.988 x 1017
Stathenrys	Millihenrys	8.988 x 1014
Statohms	Abohms	8.988 x 1020
Statohms	Megohms	8.988 x 10 ⁵
Statohms	Microhms	8.988 x 10 ¹⁷
Statohms	Ohms	8.988 x 10 ¹¹
Statvolts	Abvolts	2.998 x 1010
Statvolts	Microvolts	2.998 x 10 ⁸
Statvolts	Millivolts	2.998 x 10 ⁵
Statvolts	Volts	299.8
Steradians	Hemispheres	.1592
Steradians	Spheres	7.958 x 10-2
Steradians	Spherical right angles	.6366
Steres	Cubic meters	1
Steres	Liters	999.973
Tons (long)	Grams	1.016 x 10 ⁵
Tons (long)	Kilograms	1016
Fons (long)	Milligrams	1.016 x 10 ⁹
Fons (long)	Ounces (avoirdupois) Pounds (avoirdupois)	3.584 x 104 2240
Γons (long) Γons (long)	Tons (metric)	1.016
Fons (long)	Tons (short)	1.120
Fons (metric)	Grams	108
Tons (metric)	Kilograms	1000
Tons (metric)	Milligrams	10•
Tons (metric)	Ounces (avoirdupois)	3.527 x 104
Tons (metric)	Pounds (avoirdupois)	2205
Fons (metric)	Tons (long)	.9842
Tons (metric)	Tons (short)	1.102
Fons (short)	Grams	9.072 x 10 ⁵
Cons (short)	Kilograms	907.2
Fons (short)	Milligrams	9.072 x 10 ⁸
Fons (short)	Ounces (avoirdupois)	3.2 x 104
Fons (short)	Pounds (avoirdupois)	2000
Tons (short)	Tons (long)	.8929
Tons (short)	Tons (metric)	.9072
Volts	Abvolts	108
Volts	Microvolts	105
Volts	Millivolts	1000
Volts	Statvolts	3.335 x 10-3
Watts	Horsepower	.0013410

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To convert from	То	Multiply by
Watts	Kilowatts	.001
Yards	Centimeters	91.44
Yards	Feet	8
Yards	Inches	86
Yards	Kilometers	9.144 x 10-4
Yards	Meters	.9144
Yards	Miles	5.682 x 10-4
Yards	Miles (nautical)	4.984 x 10-4
Yards	Millimeters	914.4
Yards	Mils	8.6 x 104

• 2 T radians = 1 circumference = 360• • 4 T steradians = 1 sphere.



APPENDIX III

TABLES

1. Squares, Cubes, Square Roots, and Cube Roots

 No.		Cube	Square	Cube	Ne. =	= Diem,	Γ.
M0.	Square	Cube	Reet	Reet	Circum.	Area	No.
1	1	1	1.0000	1.0000	3.142	0.7854	1
2	4	8	1.4142	1.2599	6.283	3.1416	2
3	9	27	1.7321	1.4423	9.425	7.0686	3
4	16	64	2.0000	1.5874	12.566	12.5664	4
5	25	125	2.2361	1.7100	15.708	19.6350	5
6	36	216	2.4495	1.8171	18.850	28.2743	6
7	49	343	2.6458	1.9129	21.991	38.4845	7
8	64	512	2.8284	2.0000	25.133	50.2655	8
9	81	729	3.0000	2.0801	28.274	63.6173	9
10	100	1000	3.1623	2.1544	31.416	78.5398	10
11	121	1331	3.3166	2.2240	34.558	95.0332	11
12	144	1728	3.4641	2.2894	37.699	113.097	12
13	169	2197	3.6056	2.3513	40.841	132.732	13
14	196	2744	3.7417	2.4101	43.982	153.938	14
15	225	3375	3.8730	2.4662	47.124	176.715	15
16	256	4096	4.0000	2.5198	50.265	201.062	16
17	289	4913	4.1231	2.5713	53.407	226.980	17
18	324	5832	4.2426	2.6207	56.549	254.469	18
19	361	6859	4.3589	2.6684	59.690	283.529	19
20	400	8000	4.4721	2.7144	62.832	314.159	20
21	441	9261	4.5826	2.7589	65.973	346.361	21
22	484	10648	4.6904	2.8020	69.115	380.133	22
23	529	12167	4.7958	2.8439	72,257	415.476	23
24	576	13824	4.8990	2.8845	75.398	452.389	24
25	625	15625	5.0000	2.9240	78.540	490.874	25
26	676	17576	5.0990	2.9625	81.681	530.929	26
27	729	19683	5.1962	3.0000	84.823	572.555	27
28	784	21952	5.2915	3.0366	87.965	615.752	28
29	841	24389	5.3852	3.0723	91.106	660.520	29
30	900	27000	5.4772	3.1072	94.248	706.858	30
31	961	29791	5.5678	3.1414	97.389	754.768	31
32	1024	32768	5.6569	3.1748	100.531	804.248	32
33	1089	35937	5.7446	3.2075	103.673	855.299	33
34	1156	39304	5.8310	3.2396	106.814	907.920	34
35	1225	42875	5.9161	3.2711	109.956	962.113	35
36	1296	46656	6.0000	3.3019	113.097	1017.88	36
37	1369	50653	6.0828	3.3322	116.239	1075.21	37
38	1444	54872	6.1644	3.3620	119.381	1134.11	38
39	1521	59319	6.2450	3.3912	122.522	1194.59	39

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Mare Cons. Ans. Ans. <t< th=""><th>No. No. No.<th>512000 531441 551368 551368 571787 592704 614125 636056 636056 638503 681472</th><th>]</th><th></th></th></t<>	No. No. <th>512000 531441 551368 551368 571787 592704 614125 636056 636056 638503 681472</th> <th>]</th> <th></th>	512000 531441 551368 551368 571787 592704 614125 636056 636056 638503 681472]	
64000 63146 34200 135.66 166.66 166.66 166.66 165.66 135.67 135.67 135.67 135.67 135.66 135.66 135.66 135.66 135.66 135.66 135.66 135.66 135.66 135.66 135.66 135.67 136.66 136.66 <th>64000 63246 34200 12556 125566 40 80 6400 7950 65574 3503 13155 13505 44 82 6724 7950 65574 3503 13155 13505 45 82 6724 7950 65574 3503 13515 155053 44 84 7556 91125 65782 35038 14451 159045 4754 87 7556 91125 65782 35038 14755 153494 47 87 7255 91125 65827 35038 14451 159344 47 87 7255 91125 65700 3553 14451 159346 157345 17449 1921 1175649 7011 36831 157.08 1965.5 212372 52 92 8836 125616 7.4416 38030 1885.74 49 8836 191 8836 1557616 <td< th=""><th>512000 531441 551368 571787 592704 614125 636056 636056 681472</th><th></th><th></th></td<></th>	64000 63246 34200 12556 125566 40 80 6400 7950 65574 3503 13155 13505 44 82 6724 7950 65574 3503 13155 13505 45 82 6724 7950 65574 3503 13515 155053 44 84 7556 91125 65782 35038 14451 159045 4754 87 7556 91125 65782 35038 14755 153494 47 87 7255 91125 65827 35038 14451 159344 47 87 7255 91125 65700 3553 14451 159346 157345 17449 1921 1175649 7011 36831 157.08 1965.5 212372 52 92 8836 125616 7.4416 38030 1885.74 49 8836 191 8836 1557616 <td< th=""><th>512000 531441 551368 571787 592704 614125 636056 636056 681472</th><th></th><th></th></td<>	512000 531441 551368 571787 592704 614125 636056 636056 681472		
66921 6.4031 3.4462 1320.25 4.1 81 6.661 531441 9.0000 4.3651 7908 6.4607 14.700 13182.44 4.2 82 67745 531365 541125 91136 4.3021 91125 6.57082 135034 1382.34 4.5 86 77256 631475 9.1106 4.3021 91125 6.57082 135034 1382.34 49 86 77245 641472 9.3036 4.4197 110592 6.59281 156080 147.56 137.344 47 8 7744 64147 9.105 110592 50282 15630 15304 1800.55 51 91 88 440 447 110592 70414 7706 9150.50 9151.50 9156.50 9176.51 9176.51 4497 1125000 70416 15768 804.57 91 804.57 914.66 4461 1125000 71414 27044 <t< td=""><td>66921 64031 34462 13195 13203 13203 13203 13503 <th< td=""><td>531441 551368 571787 592704 614125 636056 638503 681472</td><td></td><td>.33 5026.55</td></th<></td></t<>	66921 64031 34462 13195 13203 13203 13203 13503 <th< td=""><td>531441 551368 571787 592704 614125 636056 638503 681472</td><td></td><td>.33 5026.55</td></th<>	531441 551368 571787 592704 614125 636056 638503 681472		.33 5026.55
74088 6.4807 3.4760 13195 1385.44 4.2 8.2 6.724 553168 5.0556 5.3344 5.0556 5.3368 5.0556 5.3364 3.65 3.3445 3.65 3.345 3.365 3.3655 3.3645 3.3655 3.3655 3.3655 3.3650 1.3530 1.455 1.661.30 4.55 8.5 7.3556 5.1736 5.05056 9.3736 4.4107 3.3655 9.3736 4.4107 9.3766 9.3736 4.4479 9.4497 1105922 6.7021 3.6683 13345 150.30 19055 48 88 7746 681.472 9.3306 4.4475 1105922 6.7021 3.6689 196.50 2.042.22 51 91 88.44 4.475 1110649 7.7011 3.6680 150.56 190.55 134.56 134.67 1125000 7.011 3.6830 166.50 2.042.22 51 91 84.91 4.47 1126501 7.7481 3	74088 64807 34760 13195 13823 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15303 13823 15503 15505 13823 15505 13823 15505 13823 15505 13823 15505 13823 15505 13823 15506 1744 17569 17944 17569 17944 17569 17944 17569 17349 47 87 7569 7395 15904 15904 15904 15904 1791 15693 7744 17056 17044 17056 17044 17056 17044 17056 16022 15032 15032 15032 15032 15032 15033 15033 15033 15033 15033 15033 15033 15033 15033 15033 15033 15033	551368 571787 592704 614125 636056 636056 681472 681472	4.3267	
79307 65574 35034 13509 145203 45203 45203 45203 45203 45305 597187 91104 45313 97136 677823 35503 14451 15003 46 55 7256 614125 92126 44140 97136 677823 35530 14451 150033 4553 35056 92736 44140 1103923 65282 35030 15033 15204 45514 490 8440 1103923 65282 35030 150323 5503 50 918 7744 65173 92036 44814 1103924 77416 37030 1505.2 204.2517 5303 92366 44814 146606 77460 37746 451.7 77649 554.45 554.45 15616 7483 38236 15707 232022 54 9216 9216 554.45 15616 7483 38236 17410 3215775 94489	79507 6.5574 3.5034 135.09 145.220 43 83 7569 911125 6.7082 3.5569 141.37 1590.43 6 85 7255 911125 6.7082 3.5569 141.37 1590.43 45 85 7255 91125 6.7082 3.5569 141.37 1590.43 45 86 7744 91125 6.7082 3.5508 144.51 150.80 1805.56 48 88 7745 9117649 7.0000 3.6591 157.08 1865.74 49 89 7921 132651 7.1414 3.7084 165.22 2042.82 51 91 88 7744 132651 7.4162 3.8259 160.22 2042.82 51 91 8836 157464 7.3483 156.50 2205.18 53 93 883 649 157464 7.4833 3.8259 196.32 273337 59 92 8264 <td>571787 592704 614125 636056 658503 681472</td> <td>4.3445</td> <td>.61 5281.02</td>	571787 592704 614125 636056 658503 681472	4.3445	.61 5281.02
85184 66332 33303 138.23 155053 155053 155053 155053 155053 155053 155053 155054 4410 91622 43968 44480 91325 657323 55369 141.37 155043 155053 155043 155043 155043 155043 155043 155043 155043 155043 91325 913265 913265 913265 913265 91340 91467 91467 91464 4447 117649 70000 35533 15334 1857.74 49 95 721 709509 91496 44491 4477 117649 70011 35633 165.30 213372 51<91	85184 6.6332 3.5303 138.23 15205 44 7056 91125 6.7082 3.5569 14137 159043 45 85 7325 91125 6.7082 3.5569 14137 159043 45 85 7225 91125 6.7782 3.5593 153.94 157.08 1885.74 49 89 7744 1175649 7.0000 3.5593 155.305 209 88 7744 125000 7.0111 3.8325 163.55 2206.18 53 93 884 1375616 7.1414 3.7088 166.550 2206.18 53 93 8846 157464 7.1414 3.7088 166.550 2206.18 53 93 8846 157464 7.3833 3.8259 172.79 23753 55 94 883 1575616 7.4833 3.8259 172.79 23753.31 56 92 883 155619 7.6811<	592704 614125 636056 658503 681472		
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97336 6.7823 3.5830 144.51 1661.90 46 85 7734 6.50556 9.2736 4.4447 110592 50382 3.6533 153.34 1885.74 49 89 7744 658503 9.2736 4.4414 110592 50382 3.6533 153.36 1157.06 1805.55 51 91 8281 7744 681472 9.3204 4.4617 1125600 7.0711 3.6840 156.35 2.02.282.82 51 91 8281 7.5551 9.5394 4.4514 157464 7.2801 3.553 185.51 55 92 9.8569 9.4507 9.4507 157464 7.3433 3.8230 179.07 2.2012.83 53 9.5366 9.5364 4.5502 157465 7.4833 3.8230 179.07 2.545.01 9.7633 9.5367 9.5954 4.5502 1575613 7.4833 3.8230 188.57 2.465.02 9.5450 9.5959 4.5502 <td>97336 6.7823 3.5830 144.51 1661.90 46 86 7396 110592 6.8557 3.6088 147.65 1734.94 47 87 7569 110592 6.8557 3.6088 147.65 1734.94 47 87 7569 117649 7.0000 3.6533 155.36 50 90 8100 125000 7.0111 3.8435 155.36 204.282 51 91 8281 132651 7.1414 3.7084 166.50 2.204.282 55 92 8281 132651 7.1414 3.8325 166.50 2.206.18 53 93 8849 157616 7.4462 3.8030 172.79 2375.83 55 92 9216 157616 7.4453 3.8293 175.79 2375.83 55 92 92 155616 7.4463 3.8293 175.79 2375.397 59 96 900 185103 5631</td> <td>636056 658503 681472</td> <td>4.3968</td> <td></td>	97336 6.7823 3.5830 144.51 1661.90 46 86 7396 110592 6.8557 3.6088 147.65 1734.94 47 87 7569 110592 6.8557 3.6088 147.65 1734.94 47 87 7569 117649 7.0000 3.6533 155.36 50 90 8100 125000 7.0111 3.8435 155.36 204.282 51 91 8281 132651 7.1414 3.7084 166.50 2.204.282 55 92 8281 132651 7.1414 3.8325 166.50 2.206.18 53 93 8849 157616 7.4462 3.8030 172.79 2375.83 55 92 9216 157616 7.4453 3.8293 175.79 2375.83 55 92 92 155616 7.4463 3.8293 175.79 2375.397 59 96 900 185103 5631	636056 658503 681472	4.3968	
103223 68857 36088 14765 17144.94 47 87 7744 681472 9.3274 4.4810 110592 692857 36442 155.08 155.09 155.09 155.36 4.485 110592 69285 355.31 155.34 155.30 1809.56 4.88 7744 681472 9.5396 4.4450 125000 7.1414 3.7035 156.50 2.004.28 53 93 8649 80.355 9.5917 4.5144 132651 7.4162 38035 156.50 2.206.18 53 93 8843 9.5917 4.5168 157465 7.4162 38031 179.01 55 97 9.593 4.507 157465 7.446 3.9129 175/35 2.373.37 55 92 88473 9.5949 4.5073 157465 7.4465 3.913 9216 887.35 9.7468 4.5073 155103 7.5413 38930 9216 884737 <td>103823 6.8557 3.6088 147.65 1734.94 47 87 7569 117649 7.0000 3.6593 153.94 185.74 49 89 7744 117649 7.0000 3.6593 153.94 155.394 185.70 89 7744 117649 7.0000 3.6593 153.36 193.35 166.50 200.20.18 53 93 8649 132651 7.1414 3.7084 166.50 200.20.22 55 91 8281 157464 7.3485 3.8709 185.35 206.51.8 53 93 8649 157464 7.4833 3.8455 179.07 2375.83 55 95 9025 157461 7.8112 3.83709 185.35 2463.01 56 96 9216 155161 7.6811 3.8930 175.51 54 98 9604 185193 7.5611 3.8350 185.35 273.397 59 99 960</td> <td>658503 681472</td> <td>4.4140</td> <td></td>	103823 6.8557 3.6088 147.65 1734.94 47 87 7569 117649 7.0000 3.6593 153.94 185.74 49 89 7744 117649 7.0000 3.6593 153.94 155.394 185.70 89 7744 117649 7.0000 3.6593 153.36 193.35 166.50 200.20.18 53 93 8649 132651 7.1414 3.7084 166.50 200.20.22 55 91 8281 157464 7.3485 3.8709 185.35 206.51.8 53 93 8649 157464 7.4833 3.8455 179.07 2375.83 55 95 9025 157461 7.8112 3.83709 185.35 2463.01 56 96 9216 155161 7.6811 3.8930 175.51 54 98 9604 185193 7.5611 3.8350 185.35 273.397 59 99 960	658503 681472	4.4140	
110552 69282 3.6342 150.30 1809.56 48 88 7744 681472 9.3308 4.4647 117649 7.0000 3.6593 153.361 155.05 50 90 8100 7.35571 9.5394 4.4647 117649 7.0111 3.6840 153.36 123.23 153.36 123.23 51.33 51.91 8281 7.35571 9.5394 4.4647 148877 7.2111 3.8235 169.36 2.206.18 53 93 8649 80.457 9.5344 4.5502 157464 7.3483 3.7798 169.05 2.200.22 54 9.464 7.5468 9.5917 4.5144 157464 7.5438 3.8709 185.35 2.465.01 57 94 9.5692 9.5957 4.5629 155169 7.5483 3.8709 185.35 2.733.37 59 9.9959 4.5104 155169 7.6811 3.8930 185.35 2.733.3959 9.49699 9.569	110592 6.9282 3.6342 153.394 185.74 49 88 7744 117649 7.0000 3.6593 153.394 185.35 51 91 8281 117649 7.0000 3.6593 153.36 157.08 196.350 50 90 8100 132651 7.1414 3.7084 166.50 2.006.18 53 93 8649 132651 7.4113 3.7598 166.50 2.006.18 53 93 8649 157464 7.3485 3.7798 166.50 2.006.18 53 93 8649 155464 7.3485 3.8709 185.35 2355.1.76 57 94 960 175616 13.8485 179.07 2551.76 57 94 960 195112 7.6113 38930 185.35 233.337 55 92 92 195112 7.6113 38930 185.35 233.337 55 93 960 1951	681472	4.4310	
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120	14400	1728000	10.9545	4.9324	376.99	11309.7	120	160	25600	4096000	12.6491	5.4288	502.65	20106.2	160
121	14641	1771561	11.0000		380.13	11499.0	121	161	25921	4173281	12.6886	5.4401	505.80	20358.3	101
122	14884	1815848		4.9597	383.27	11689.9	122	162	26244	4251528	12.7279	5.4514	508.94	20612.0	162
123	15129	1860867	11.0905	4.9732	386.42	11882.3	123	163	26569	4330747	12.7671	5.4626	512.08	20867.2	163
124	15376	1906624	11.1355	4.9866	389.56	12076.3	124	164	26896	4410944	12.8062	5.4737	515.22	21124.1	164
125	15625	1953125	11.1803	5.0000	392.70	12271.8	125	165	27225	4492125	12.8452	5.4848	518.36		165
126	15876	2000376	11.2250	5.0133	395.84	12469.0	126	166	27556	4574296	12.8841	5.4959	521.50		166
127	16129	2048383	11.2694	5.0265	393.98	12667.7	127	167	27889	4657463	12.9228	5.5069	524.65	21904.0	167
128	16384	2097152	11.3137	5.0397	402.12	12868.0	128	168	28224	4741632	12.9615	5.5178	527.79	22167.1	168
129	16541	2146689	11.3578	5.0528	405.27	13069.8	129	169	28561	4826809	13.0000	5.5288	530.93	22431.8	169
															1
130	16900	2197000	11.4018		408.41	13273.2	130	170	28900	4913000	13.0384	5.5397	534.07	22698.0	170
131	17161	2248091	11.4455		411.55	13478.2	131	171	29241	5000211	13.0767	5.5505	537.21	22965.8	171
132	17424	2299968	11.4891	5.0916	414.69	13684.8	132	172	29584	5088448	13.1149	5.5613	540.35	23235.2	172
133	17689	2352637	11.5326	5.1045	417.83	13892.9	133	173	29929	5177717	13.1529	5.5721	543.50	23506.2	173
134	17956	2406104	11.5758	5.1172	420.97	14102.6	134	174	30276	5268024	13.1909	5.5828	546.64	23778.7	174
135	18225	2460375	11.6190	5.1299	424.12	14313.9	135	175	30625	5359375	13.2288	5.5934	549.78	24052.8	175
136	18496	2515456	11.6619	5.1426	427.26	14526.7	136	176	30976	5451776	13.2665	5.6041	552.92	24328.5	176
137	18769	2571353	11.7047	5.1551	430.40	14741.1	137	177	31329	5545233	13.3041	5.6147	556.06	24605.7	177
138	19044	2628072	11.7473	5.1676	433.54	14957.1	138	178	31684	5639752	13.3417	5.6252	559.20	24884.6	178
139.	19321	2685619	11.7898	5.1801	436.68	15174.7	139	179	32041	5735339	13.3791	5.6357	562.35	25164.9	179
140	19600	2744000	11.8322	5.1925	439.82	15393.8	1	180	32400	5832000	13.4164	5.6462	565.49	25446.9	180
141	19881	2803221	11.8743	5.2048	442.96	15614.5	141	181	32761	5929741	13.4536	5.6567	568.63	25730.4	181
142	20164	2863288	11.9164	5.2171	446.11	15836.8	142	182	33124	6028568	13.4907	5.6671	571.77	26015.5	182
143	20449	2924207	11.9583	5.2293	449.25	16060.6	143	183	33489	6128487	13.5277	5.6774	574.91	26302.2	183
Ŧ	20736	2985984	12.0000	5.2415	452.39	16286.0	Ŧ	184	33856	6229504	13.5647	5.6877	578.05	26590.4	184
145	21025	3048625	12.0416	5.2536	455.53	16513.0	145	185	34225	6331625	13.6015	5.6980	581.19	26880.3	185
146	21316	3112136	12.0830	5.2656	458.67	16741.5	146	186	34596	6434856	13.6382	5.7083	584.34	27171.6	186
147	21609	3176523	12.1244	5.2776	461.81	16971.7	147	187	34969	6539203	13.6748	5.7185	587.48	27464.6	187
148	21904	3241792	12.1655	5.2896	464.96	17203.4	148	188	35344	6644672	13.7113	5.7287	590.62	27759.1	188
149	22201	3307949	12.2066	5.3015	468.10	17436.6	140	189	35721	6751269	13.7477	5.7388	593.76	28055.2	189
150	22500	3375000	12.2474	5.3133	471.24	17671.5	150	180	36100	6859000	13.7840	5.7489	596.90	28352.9	190
151	22801	3442951	12.2882	5.3251	474.38	17907.9	151	191	36481	6967871	13.8203	5.7590	600.04	28652.1	161
152	23104	3511808	12.3288	5.3368	477.52	18145.8	152	192	36864	7077888	13.8564	5.7690	603.19	28952.9	192
153	23409	3581577	12.3693	5.3485	480.66	18385.4	153	193	37249	7189057	13.8924	5.7790	606.33	29255.3	193
154	23716	3652264	12.4097	5.3601	483.81	18626.5	154	2	37636	7301384	13.9284	5.7890	609.47	29559.2	194
155	24025	3723875		5.3717	486.95	18869.2	155	195	38025	7414875	13.9642	5.7989	612.61	29864.8	195
156	24336	3796416		5.3832	490.09	19113.4	156	<u>8</u>	38416	7529536	14.0000	5.8088	615.75	30171.9	18
157	24649	3869893	12.5300	5.3947	493.23	19359.3	157	197	38809	7645373	14.0357	5.8186	618.99	30480.5	197
158	24964	3944312	12.5698	-	496.37	19606.7	156	158	39204	7762392	14.0712	5.8285	622.04	30790.7	198
5	25261	4019679	12.0095	5.4175	15.64	19855.7	2	8	39601	7880599	14.1067	5.8383	625.18	31102,6	8
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416.0 640.09 2365.5 200 244 555.5 14266784 555.55 428.45 664.112 3365.55 207 247 600.25 14566784 556.55 428.45 664.013 3365.55 207 247 600.25 14566784 556.55 432.46 654.05 3365.55 207 247 600.25 155.4200 155.4340 438.6 650.31 3365.55 207 246 605.05 145.6758 155.797 438.6 650.31 3365.55 207 246 605.05 145.6758 155.797 449.00 9123320 14.2568 509.23 558.31 151.564.30 155.797 449.01 923931 14.5266 509.31 356.31.7 211 256 655.00 155.414 457.96 960.35 556.31 356.31.7 211 257 650.00 155.416 457.96 960.35 556.31 3563.31 157.756 155.360	2 6	- 000-+	20171700	1717.11			1.11040		11		200077111		110403	17.00/	1.05554	
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42035 6403 330064 205 245 60025 14706175 15.6844 42346 8869743 14.4325 59059 647.17 3332.32 207 245 60025 14706155 15.6844 43261 9123329 14.4525 59256 655.45 33975.5 206 15.6944 15.6843 43516 9939301 14.4015 59435 655.83 33975.5 255.6 65300 15.6143 44571 9339315 14.5602 59627 665.02 35306.1 210 255 65304 1600300 15.6177 445710 9309347 14.5602 59071 66016 35366.1 255 65375 15.600 15.5476 45706 9800344 14.5602 59071 665.1 3555.1 255 65375 16.5000 15.5475 45706 10009 158.0475 15.5463 3601.3 255 65025 15.5475 15.5460 45706 10009 <	2	41616	8489664	14.2829		640.89	32685.1	204	244	59536	14526784	15.6205	6.2488	766.55	46759.5	244
42436 8741816 14.3522 5.9059 647.17 33329.2 206 246 60516 14885936 15.5780 43264 9999912 14.4362 5.9155 656.59 34307.0 200 155.7162 43264 9999912 14.4525 5.9345 5.937.3 346.36.1 33975.3 200 155.5390 15.57907 44510 9261000 14.4914 5.9435 65.053 346.36.1 235.631 235.630 15.5780 44521 9990311 14.2528 5.9333 66.230 335.63.7 211 251 65.001 15.8443 45306 9603345 14.4508 5.9333 66.16 355.37.7 213 259 65.001 15.8443 45506 9007369 14.4508 6.018 66.48 7777516 16.0023 15.967 45061 10077964 6.0185 5.6915 356.335 216 650.64 1777516 16.0023 45761 10077966 60186	05	42025	8615125	14.3178		644.03	33006.4	205	245	60025	14706125	15.6525	6.2573	769.69	47143.5	245
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43264 899917 14422 59230 655.59 33979.5 206 230 236 61504 1525392 15.7497 44100 9261000 144914 59435 655.59 34656.7 211 251 63001 15438249 15.7497 44944 9263397 145058 59927 55337 211 251 65001 1581251 15.8440 45306 9663397 145058 59907 65734 35633.7 213 255 65001 1593745 159374 45306 10077096 140545 59914 6723.3 35633.7 213 255 65035 1693773 159063 45506 10077096 140546 60185 58043 33533.5 216 255 65034 1093745 1600312 47504 1007696 140377 68015 333936 215 36943.5 216 65036 1693773 1600312 47504 10050446 10186461 60185	5	47840	8860743	14 2875		65031	326525	207	247	61000	15060273	157162	6 2743	775 07	470164	747
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46656 10077696 14.7968 6.0002 681.73 36643.5 216 256 655.36 16777216 16.000312 47524 100360232 14.79648 6.0177 688.07 35983.6 217 257 66049 16777216 16.00034 47504 100360232 14.77948 6.0175 688.01 37668.5 219 259 65081 1773512 16.00034 47504 10503459 14.7964 6.0175 688.01 37668.5 219 259 67081 1773512 16.00034 48841 1059406 14.8961 6.0459 6.0312 385756 222 266 670600 15576000 16.12545 49729 11039567 14.9966 6.0732 703.72 394081 222 265 689655 16.2173 5016 11539424 14.8661 6.0732 703.72 394081 222 265 70225 18891447 16.2173 5016 111539426 6.0732	15	46225	9938375	14.6629		675.44	36305.0	215	255	65025	16581375	15.9687	6.3413	801.11	51070.5	255
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48400 10648000 148361 6.0368 691.15 38013.3 220 260 67600 17576000 16.1245 48841 10793861 148661 6.0459 694.29 38359.6 221 261 68121 1779581 16.1555 49729 11099567 149332 6.0541 700.58 39057.1 223 261 68121 1779581 16.1555 49729 112039424 149332 6.0541 700.58 39057.1 223 263 68147 16.2481 50055 112039424 1490566 6.0732 703.72 394981 18337944 16.2481 51076 115230625 110300 40115.0 223 266 70756 1881096 16.3095 51529 11697083 15.06367 6.1001 716.28 40828.1 223 266 71289 19034163 16.3012 51529 11697083 15.06365 6.1002 716.28 40828.1 223 266 712																
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49284 10941048 14.8997 6.0530 697.43 38707.6 222 265 686.44 17984728 16.1854 49729 11089567 14.9332 6.0641 700.58 39057.1 223 263 69169 18191447 16.2173 50176 11239424 14.9332 6.0641 700.58 39057.1 223 263 69169 18191447 16.2173 50076 11543176 15.0333 6.0912 710.00 40115.0 225 265 70255 18609625 16.2788 51529 11697083 15.0665 6.1002 713.14 40470.8 227 267 71289 19.24013 51984 11852352 15.0997 6.1001 716.28 40828.1 229 266 72361 19465109 16.4012 52940 1236391 15.1807 6.1180 7197.1 229 266 72361 19465109 16.4012 52441 12008989 15.1987 6.1307 7		48841	10703861	14 8661		604 20	383506	100	190	68121	17779581	161555	6 3907	81996	535021	261
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515291169708315.06656.1002713.1440470.8227267712891903416316.3401519841185235215.09976.1091716.2840828.1228268718241924883216.3707524411200898915.13276.1180719.4241187.1229269723611946510916.4012523011216700015.16586.1269722.5741547.6230270729001968300016.4317533611223639115.19876.1358722.5741547.6230270729001968300016.4317533611223639115.19876.1358722.5741547.6231271734411990251116.4621533611223639115.26436.1358723.532332332777359616.5227533241248716815.26436.1534731.9942638.52332777359616.5227547561281290415.23156.1446728.85733.35234274750762034641716.5227547561281290415.23296.1710738.2743373.6235275775052079687516.5323556961314425615.332946.1797744.5644115.023727777184921745633316.6433556641331202315.475915.8827744.5644115.0238276772833316.67335664	97:	: 51076	11543176	15.0333	6.0912	710.00	40115.0	226	200	70756	18821096	16.3095	6.4312	835.66	55571.6	266
51984 11852352 15.0997 6.1091 716.28 40828.1 228 268 7182.4 19248832 16.3707 52441 12008989 15.1327 6.1180 719.42 41187.1 229 269 72361 19465109 16.4012 52441 12008989 15.1327 6.1269 722.57 41547.6 230 270 72900 19683000 16.4317 53361 122365391 15.1987 6.1358 722.571 41909.6 231 271 73441 19902511 16.4021 53361 12326391 15.1987 6.1358 722.57 41547.6 231 271 73441 19902511 16.4021 53324 12487168 15.2043 6.1534 731.99 42638.5 233 272 73594 16.4021 53824 12487168 15.2071 6.1622 735.13 43005.3 233 272 74599 20123648 16.4924 54756 12487168 15.2273 <t< td=""><td>27</td><td>51529</td><td>11697083</td><td>15.0665</td><td>6.1002</td><td>713.14</td><td>40470.8</td><td>227</td><td>267</td><td>71289</td><td>19034163</td><td>16.3401</td><td>6.4393</td><td>838.81</td><td>55990.3</td><td>267</td></t<>	27	51529	11697083	15.0665	6.1002	713.14	40470.8	227	267	71289	19034163	16.3401	6.4393	838.81	55990.3	267
52441 12008989 15.1327 6.1180 719.42 41187.1 229 269 72361 19465109 16.4012 52900 12167000 15.1327 6.1180 719.42 41187.1 229 269 72361 19465109 16.4012 53361 12326391 15.1987 6.1368 722.57 41547.6 230 270 72900 19683000 16.4317 53361 12326391 15.1987 6.1358 722.57 41909.6 231 271 73441 19902511 16.4024 53824 15.1987 6.1534 731.99 42633.5 2331 271 73441 19902511 16.4024 53824 12487168 15.2347 5.31.93 43005.3 273 745.99 20123648 16.4924 54275 152473 5.332 272 738.34 731.99 42638.5 233 273 745.99 20123648 16.4924 54756 152473 5.332 273 273 74359 20123648 16.4924 16.5523 55225 1297976<	¢	51984	11852352	15.0397	-	716.28	40828.1	228	268	71824	19248832	16.3707	6.4473	841.95	56410.4	268
52900 12167000 15.168 6.1269 722.57 41547.6 230 270 72900 19683000 16.4317 53361 12326391 15.1987 6.1358 722.57 41909.6 231 271 73441 19902511 16.4621 53361 12326391 15.1987 6.1358 722.57 41909.6 231 271 73441 19902511 16.4621 53824 12487168 15.2345 6.1534 731.99 42638.5 233 272 73984 20123648 16.4924 54289 15.264337 15.2643 6.1534 731.99 42638.5 233 272 73984 20123648 16.4924 54756 12812904 15.2643 6.1522 735.13 43005.3 233 274 75076 20346417 16.5529 55225 12977875 15.1672 733.13 43005.3 233 275 75625 20796875 16.6133 55225 15.977865 15.170 738.27 43373.6 235 277 76729 21024576 16.6133 <td>07</td> <td>52441</td> <td>12008989</td> <td>15 1327</td> <td>_</td> <td>719.42</td> <td>41187.1</td> <td>229</td> <td>269</td> <td>72361</td> <td>19465109</td> <td>16.4012</td> <td>6.4553</td> <td>845.09</td> <td>56832.2</td> <td>269</td>	07	52441	12008989	15 1327	_	719.42	41187.1	229	269	72361	19465109	16.4012	6.4553	845.09	56832.2	269
529001216700015.16586.1269722.5741547.6230270729001968300016.4317533611232639115.19876.1358725.7141909.6231271734411990251116.46215336112348716815.19876.1358725.7141909.6231271734411990251116.4621538241248716815.23156.1446728.854273.3232272739842012364816.4924547561264933715.26436.1534731.9942638.5233273745292013364816.4924547561281290415.2071535.1343005.3233274750762034641716.5529552251297787515.20736.1710738.2743373.6235275756252079687516.61325526961314425615.36236.1707738.2744115.0237277767292125393316.6433566441331205315.42726.1972747.7044488.1238278772842171763910.7033566441348127215.45766.1972777.70237237277767292102457616.6132566441348127215.45726.1972747.7044488.12382782171763910.7033566441365191915.45966.1972777.7023727977842171763910.7033571																
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538241248716815.23156.1446728.8542273.3232272739842012364816.4924542891264933715.26436.1534731.9942638.523327374529201236481716.5227547561281290415.29716.1622735.1343005.3233273745292057082416.5529547561281290415.29716.1622735.1343005.3233274750762057082416.5529552551297787515.32236.1710738.2743373.6235275756252079687516.5831556961314425615.36236.1977741.4243743.5237277767292102457616.613256644134817215.36236.1972744.5644115.0237277767292102457616.61335664413481721355191915.45926.1972747.7044488.1238278772842171763916.6733566441365191915.45966.2058750.8444862.7239279778412171763910.7033571211365191915.45966.2058750.8444862.7239279778412171763910.7033571211365191915.45966.2058750.8444862.723927977910.7033	31	53361	12326391	15.1987		725.71	41909.6	231	271	73441	19902511	16.4621	6.4713	851.37	57680.4	271
54289 12649337 15.2643 6.1534 731.99 42638.5 233 273 74529 20346417 16.5227 54756 12812904 15.2071 6.1622 735.13 43005.3 233 273 74529 20346417 16.5227 54756 12812904 15.2071 6.1622 735.13 43005.3 234 274 75076 20570824 16.5529 55225 12977875 15.3297 6.1710 738.27 43373.6 235 275 75625 20796875 16.5831 55696 13144256 15.3623 6.1997 741.42 43743.5 237 76729 21024576 16.6132 56644 13312053 15.3948 6.1885 744.56 44115.0 237 277 76729 21024576 16.6132 56644 13481272 15.4272 6.1972 747.70 44488.1 238 278 217484952 16.6733 56644 136551919 15.4596 6.20584	32	53824	12487168	15.2315		728.85	42273.3	232	272	73984	20123648	16.4924	6.4792	854.51	58106.9	272
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288	82944	23887872	16.9706	6.6039	904.78	65144.1	288	328	107584	35287552	18.1108	6.8964	1030.4	84496.3	328
289	83521	24137569	17.0000	6.6115	907.92	65597.2	289	329	108241	35611289	18.1384	6.9034	1033.6	85012.3	329
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293	85849	25153757	17.1172	6.6419	920.49	67425.6	293	333	110889	36926037	18.2483	6.9313	1046.2	87092.0	333
204	86436	25412184	17 1464	66494	923.63	67886.7	294	334	111556	37259704	18.2757	6.9382	1049.3	87615.9	334
100	87075	25677275	17 1756	66560	07677	683403	205	335	112225	37595375	18.3030	6.9451	1052.4	88141.3	335
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267	26564	20402392	1707.11	_	920.19	C.04/60	0.00	320	114021	38058710	184120	6 0777	1065.0	902587	330
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110	00100	29791000	17 6068	6.7679	973.89	75476.8	310	350	122500	42875000	18.7083	7.0473	1099.6	96211.3	350
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312	01060	30664237	17 6018	-	983.32	76944.7		353	124609	43986977	18.7883	7.0674	1109.0	97867.7	353
314	08506	30059144	17 7200		986.46	774371		354	125316	44361864	18.8149	7.0740	1112.1	98423.0	354
315	00225	31255875	17.7482		09.60	77931.1	315	355	126025	44738875	18.8414	7.0807	1115.3	98979.8	355
316	95500	31554406	17 7764	-	992.74	78426.7	316	356	126736	45118016	18.8680	7.0873	1118.4	99538.2	356
317	100480	31855013	17,8045		995.88	78923.9	317	357	127449	45499293	18.8944	7.0940	1121.5	100098	357
318	101124	32157432	17.8326	-	0.099	79422.6	318	358	128164	45882712	18.9209		1124.7	100660	358
919	101761	32461759	17.8606	-	1002.2	79922.9	319	359	128881	46268279	18.9473		1127.8	101223	359

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146689 531 17802 332 423 17802 75660 1328 14053 147456 5603104 19.5704 72632 115203 315 32 14196 147456 5603104 19.5704 72632 115203 31532 14196 147456 5751456 19.5704 72632 115217 117021 386 424 179776 75156 1332.0 141963 148926 57512456 19.6573 72874 115847 385 426 181476 75055 20.6155 7.5185 143531 149769 57512455 19.6773 72874 118237 386 429 179776 75126 1334.6 1438723 155044 5841000 19.4737 7.3124 1122.2 118847 389 429 178376 20.50582 7.5361 1344.5 144545 155044 5841007 19.4772 18244 183764 605382 7.5361 145372 144545 </td <td>146665 56181887 195746 72523 115209 333 423 179776 75686667 20.5670 75067 1332.0 141196 147456 56613104 195797 72635 1200.4 115127 115100 383 424 179776 75686967 20.5670 75067 1332.9 140531 148755 57512456 196679 72811 1212.7 117021 386 426 181476 77368762 20.5913 755126 1332.0 141196 1489769 57512456 196677 72094 1212.8 117021 386 426 181476 7736874 1333.2 14338.2 143531 150477 72096 12189 11847 389 426 18400 77354483 20.6640 75302 1347.7 144545 150311 19677 7209 1222.1 118847 389 420 186624 80621568 20.7123 75420 144545 155381 5976471 19777 12234 121304 392 431 186624 80621568</td> <td></td> <td>101041</td> <td>333300341</td> <td>7610.61</td> <td></td> <td>1.0001</td> <td>600411</td> <td>100</td> <td>422</td> <td>178084</td> <td>75151448</td> <td>2015476</td> <td>2003 2</td> <td>1375.8</td> <td>130867</td> <td>400</td>	146665 56181887 195746 72523 115209 333 423 179776 75686667 20.5670 75067 1332.0 141196 147456 56613104 195797 72635 1200.4 115127 115100 383 424 179776 75686967 20.5670 75067 1332.9 140531 148755 57512456 196679 72811 1212.7 117021 386 426 181476 77368762 20.5913 755126 1332.0 141196 1489769 57512456 196677 72094 1212.8 117021 386 426 181476 7736874 1333.2 14338.2 143531 150477 72096 12189 11847 389 426 18400 77354483 20.6640 75302 1347.7 144545 150311 19677 7209 1222.1 118847 389 420 186624 80621568 20.7123 75420 144545 155381 5976471 19777 12234 121304 392 431 186624 80621568		101041	333300341	7610.61		1.0001	600411	100	422	178084	75151448	2015476	2003 2	1375.8	130867	400
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148996 57512456 19.6469 72811 1212.7 117021 386 426 181476 77308776 20.6398 7.5244 1338.3 145531 150544 5971603 19.6773 7.2874 1215.8 117628 387 427 182329 77364483 20.6640 7.5302 1341.5 143531 150544 59411072 19.6977 7.2936 1222.1 118847 389 429 184041 76955369 20.7123 7.5420 1347.7 144545 155120 59319000 19.7484 7.3061 1225.2 119847 389 429 184041 76953589 20.7123 7.5420 1347.7 144545 152100 59319000 19.7484 12284 120072 391 431 185761 8405764 7.5478 1356.0 145574 152864 60236288 19.7990 7.3186 392 433 187489 81182737 20.8087 7.5478 1356.0 145574	148996 57512456 19.6469 72811 1212.7 117021 386 426 181476 77308776 20.6398 7.5244 1338.3 142531 149769 57960603 19.6723 72874 1215.8 117628 387 427 182329 77854483 20.6640 7.5302 1341.5 143231 150544 58411072 19.6977 7.2999 1222.1 118847 388 429 188.3184 8402752 20.6689 7.5570 1347.5 143520 152100 59319000 19.7231 7.2999 1222.1 118847 389 430 184900 7950700 20.7123 7.5420 1347.5 144545 15210 59319000 19.7484 7.3061 1223.5 119459 390 430 186574 8062991 20.7123 7.5420 1347.5 144545 155861 60236288 19.7990 73186 12234.6 121304 392 433 186524 8062991 20.7123 7.5770 146574 155866 61162984 19.3496 1231.8	5	148225	57066625	19.6214	7.2748	1209.5	116416	385	425	180625	76765625	20.6155	7.5185	1335.2	141863	425
149769 57960603 19.6723 7.2874 1215.8 117628 387 427 182329 77854483 20.6640 7.5302 1341.5 143201 150544 58411072 19.6977 7.2936 1218.9 118237 388 428 183184 8402752 20.6882 7.5361 1344.6 143872 150544 58411072 19.6977 7.2936 1218.9 118237 388 428 183184 8402752 20.6882 7.5361 143475 144545 152100 59319000 19.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7364 7.5478 1350.9 145220 152364 602362981 19.7737 7.3124 12231.6 12234.8 12072 391 437 186574 186574 145574 1556025 61162984 19.73316 121922 394 435 186624 80621568 20.7846 7.5579 145674 1556025	149769 57960603 19,6723 72874 1215.8 117628 387 427 182329 77854483 20,6640 75302 1341.5 143201 150544 58411072 19,6977 72936 1218.9 118237 388 428 183184 8402752 20,6882 75361 1344.6 143872 150544 58411072 19,6977 72936 118237 388 428 183184 8402752 20,6882 75561 1344.5 143872 152100 59319000 19,7484 73061 1225.2 119459 390 430 188761 80062991 20.7163 75478 1355.0 145568 155364 60536288 19,7990 73186 1221.0 391 431 185761 80062991 20.7066 75595 145720 155364 60598457 19,8494 73316 121304 393 431 185761 816274 75654 1356.0 145764 155356 61629845 19,8494 73316 121304 393 431 188356 81746504	۰. ص	148996	57512456	19.6469	7.2811	1212.7	117021	386	426	181476	77308776	20.6398	7.5244	1338.3	142531	426
ISO544 58411072 I9.6977 7.2936 1218.9 118237 388 428 183184 8402752 20.6882 7.5361 1344.6 143875 I51321 58863869 19.7231 7.2999 1222.1 118847 389 429 184041 78953589 20.7123 7.5478 1354.0 144545 I52100 59319000 19.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7123 7.5478 1357.2 144545 I52364 60236288 19.737 7.3124 1228.4 120072 391 431 185761 800621568 20.7765 1357.2 145596 I55364 60236288 19.7397 7.3126 12213.5 120687 393 434 185761 800621568 20.7786 145596 I55364 601629847 19.8494 7.3410 1237.8 121922 394 434 1885761 800621568 20.77864 145596 147574 <	150544 58411072 19.6977 7.2936 1218.9 118237 388 428 183184 8402752 20.6882 7.5361 1344.6 143872 151321 58863869 19.7231 7.2936 1222.1 118847 389 429 184001 78953589 20.7123 7.5420 1347.7 144545 152100 59319000 19.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7364 7.5478 1350.9 145220 152100 59319000 19.7484 7.3061 1225.2 119459 390 430 186761 80062991 7.5478 1357.2 145596 153646 60236288 19.7737 7.3124 12234.6 121304 392 433 186524 80652961 7.55737 1357.2 146574 155364 60236288 19.7337.8 121304 392 433 186524 80652961 20.78667 7.55763 147526 155364 61620887 7.310 12231.4 121204 392 436 186524 <td>2</td> <td>149769</td> <td>57960603</td> <td>-</td> <td>7.2874</td> <td>1215.8</td> <td>117628</td> <td>387</td> <td>427</td> <td>182329</td> <td>77854483</td> <td>20.6640</td> <td>7.5302</td> <td>1341.5</td> <td>143201</td> <td>427</td>	2	149769	57960603	-	7.2874	1215.8	117628	387	427	182329	77854483	20.6640	7.5302	1341.5	143201	427
ISI321 58863869 I9.7231 7.2999 I222.1 I18847 389 429 I84041 78953589 20.7123 7.5420 I347.7 144545 I52100 59319000 I9.7231 7.2051 I1225.2 I19459 390 430 I84900 79507000 20.7123 7.5420 I347.7 144545 I52100 59319000 I9.7737 7.3124 12255.2 119459 390 431 185761 80062991 20.7605 7.5537 I354.0 145546 I53664 60236288 I9.7990 7.3186 121304 393 431 185751 80062991 20.7605 7.5573 1354.0 145574 I54449 60698457 198447 7.3124 121304 393 434 188566 80621568 20.7846 7.5770 146574 I55236 61162984 1984967 7.3573 20.8087 7.5770 1360.3 147254 I55025 6162984 1984964 7.46504 20.83	151321 58863869 19.7231 7.2999 1222.1 118847 389 429 184041 78953589 20.7123 7.5420 1347.7 144545 152100 59319000 19.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7123 7.5478 1350.9 145220 152841 59776471 19.7737 7.3124 12225.2 119459 390 431 185761 80062991 20.7646 7.55737 1354.0 145240 153664 60236288 19.7396 7.3124 122164 392 433 185761 80062991 20.7646 7.5573 1356.0 145574 153664 60236288 19.7396 7.3124 12213.4 12072 393 434 188761 80621568 7.5772 145574 146574 155025 61162984 19.8494 7.3310 12237.8 121922 394 434 188356 81182737 2.5816 7.5772 1366.5 144617 155025 6162984 19.84947 7.3573 12892	80	150544	58411072	_	7.2936	1218.9	118237	388	428	183184	8402752	20.6882	7.5361	1344.6	143872	428
I52100 59319000 I9.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7364 7.5478 1350.9 145220 I52100 59319000 19.7737 7.3124 1225.2 119459 390 430 184900 79507000 20.7364 7.5478 1350.9 145220 I53664 60236288 19.7397 7.3124 1228.4 120072 391 431 185761 80621568 20.7846 7.5537 1357.0 145574 I53664 60236288 19.8494 7.3310 1237.8 120627 392 434 188556 8174554 147554 147554 I55236 611629877 19.8494 7.3310 1237.8 121922 395 435 188356 8174554 147554 I55025 61629877 19.8494 7.3302 122442 123363 147554 I55025 61629877 19.84947 7.35128 1236.2 124753 147554	152100 59319000 19.7484 7.3061 1225.2 119459 390 430 184900 79507000 20.7364 7.5478 1350.9 145220 152100 59776471 19.7737 7.3124 1228.4 120072 391 431 185761 80062991 20.7364 7.5478 1350.9 145220 153664 60236288 19.7990 7.3186 1231.5 120687 392 431 185761 800621568 20.7864 7.5595 1357.2 146574 153605 611629847 19.8494 7.3310 1237.8 121304 393 434 188556 861746564 20.8327 7.5712 1360.3 147554 155035 611629847 19.8494 7.3310 122742 395 434 188356 81746504 7.5712 1360.7 147554 155035 61629847 19.8494 7.3372 1221922 395 434 188356 81746504 7.5712 1360.7 147534 155036 1926917 123323 3124410 122353 395 435 <td>6</td> <td>151321</td> <td>58863869</td> <td>_</td> <td>7.2999</td> <td>1222.1</td> <td>118847</td> <td>389</td> <td>429</td> <td>184041</td> <td>78953589</td> <td>20.7123</td> <td>7.5420</td> <td>1347.7</td> <td>144545</td> <td>429</td>	6	151321	58863869	_	7.2999	1222.1	118847	389	429	184041	78953589	20.7123	7.5420	1347.7	144545	429
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	152100 59319000 197484 7.3061 1225.2 119459 390 790 7.3124 1225.2 119459 390 790 7.5537 7.5537 1354.0 147536 153664 60236288 197737 7.3124 1228.4 120072 391 431 185761 80062991 20.7605 7.5537 1354.0 147534 153664 60236288 197737 7.3124 1228.4 1220672 392 433 187569 80621568 20.7605 7.5537 1356.0 147534 155236 61162984 198244 7.3310 1237.8 121904 393 434 188556 80621568 20.7605 7.55712 1360.3 147534 155236 611629847 198494 7.3372 121904 122163 395 436 188356 82.08806 7.55712 1360.5 147934 155236 159404 122163 395 436 188356 82.08806 7.55712 1366.7 149987 155616 60099136 198949 1244.1 123363 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>007</td><td>000701</td><td>200020300</td><td>1962.00</td><td>7 6 4 7 0</td><td>1260.0</td><td>146330</td><td>007</td></td<>									007	000701	200020300	1962.00	7 6 4 7 0	1260.0	146330	007
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	153664 597/764/1 196/574 196/574 116/574 </td <td>5,</td> <td>152100</td> <td>59319000</td> <td>19.7484</td> <td>7.3001</td> <td>1225.2</td> <td>119459</td> <td>390</td> <td></td> <td>196701</td> <td>000/066/</td> <td>2027505</td> <td>1.37/0</td> <td>V.)CCI</td> <td>145906</td> <td></td>	5,	152100	59319000	19.7484	7.3001	1225.2	119459	390		196701	000/066/	2027505	1.37/0	V.)CCI	145906	
153064 60236288 19,7990 7.3186 1231.5 120687 392 434 180449 60021506 7.5595 1.557.2 149057 154449 60698457 198444 7.3310 1237.8 121304 393 434 188356 8114554 1360.3 147554 155236 61162984 19.8494 7.3310 1237.8 121922 394 434 188356 81146504 20.8327 7.55712 1366.3 147934 155025 61629875 19.8494 7.3372 1240.9 122542 395 435 189225 82312875 20.8087 7.55712 1366.5 149937 155025 61629875 19.8997 7.3434 12244.1 123363 396 436 1900996 82881856 20.8806 7.55797 1499301 1557049 65570773 19.92949 7.3548 1236.4 12236.5 123365 149416 84027672 20.9284 7.5944 1376.0 150674 155804 65570773 19.92499 7.3558 12253.5 125036 399	153664 60236288 19,7990 7.3186 1231.5 120687 392 434 187489 81021306 20.0.087 7.5595 147054 154449 60698457 198242 7.3316 1234.6 121304 393 433 187489 81182737 20.8087 7.5554 1360.3 147254 155236 611629845 198494 7.3310 1237.8 121922 394 434 188356 81174554 1360.3 147554 155025 61629845 198494 7.3372 122422 395 435 188356 81745564 20.8367 7.5770 1366.5 149617 155025 616299875 1998997 7.3434 122363 395 436 1982255 823818556 20.8806 7.5770 1366.7 149301 155099 65570773 199249 12247.2 123786 3972.9 149301 149301 155040 652604919 1281856 20.98466 7.58466 1376.9 149301 158404 63044792 1992499 7.34410 398	-	152881	59770471	19.7737	7.3124	1228.4	120072	391		10/001	14670000	CO0/.07	1000.1	0.4001	060041	104
154449 60698457 19.8242 7.3248 1234.6 121304 393 434 187459 81182737 20.8087 7.5504 1360.3 147254 155236 611629845 19.8494 7.3310 1237.8 121922 394 434 188356 81746504 20.8327 7.5712 1363.5 147934 155025 61629875 19.8746 7.3372 1240.9 122542 395 435 188356 82312875 20.8367 7.5770 1365.6 148617 156026 61629875 19.8997 7.3434 122363 396 436 198225 82312875 20.8806 7.5770 1365.6 149301 156029 62570773 19.9249 7.3496 12247.2 123786 397 437 190969 83453453 20.9045 7.5729 149987 15709 199249 7.3558 12247.2 123786 397.9 149987 15709 199449 84027672 20.9284 7.5944 1376.0 150674 158404 63521199 19.9750 7.3619	154449 60698457 19.8242 7.3248 1234.6 121304 393 434 187489 81182737 20.8087 7.5504 1360.5 147254 155236 61162984 19.8494 7.3310 1237.8 121922 394 434 188356 81746504 20.8327 7.5712 1366.5 147634 155025 61629875 19.8494 7.3310 1227.8 121922 395 434 188356 81746504 20.8327 7.5772 1366.5 148617 155025 61629875 19.8997 7.3434 12244.1 123163 395 436 199225 82.0881856 7.5770 1366.7 149301 155069 65270773 19.98997 7.3496 12247.2 123165 395 437 190969 83453453 20.9045 7.5586 1372.9 149987 155040 65270773 19.92499 7.3558 122410 396 438 1919649 84004519 7.5544 1376.0 149987 158404 63044792 19.92499 7.3558 12233.6 <td< td=""><td>2</td><td>153664</td><td>60236288</td><td>19.7990</td><td>7.3186</td><td>1231.5</td><td>120687</td><td>392</td><td>432</td><td>150024</td><td>800212008</td><td>20./840</td><td>5655.1</td><td>1357.2</td><td>1405/4</td><td>432</td></td<>	2	153664	60236288	19.7990	7.3186	1231.5	120687	392	432	150024	800212008	20./840	5655.1	1357.2	1405/4	432
155236 61162984 19.8494 7.3310 1237.8 121922 394 434 188356 81746504 20.8327 7.5712 1363.5 147934 156025 61629875 19.8746 7.3372 1240.9 122542 395 435 189225 82312875 20.8367 7.5770 1366.6 148617 156016 62099136 19.8997 7.3434 123163 396 436 190096 82881856 20.8806 7.5878 1369.7 149301 157609 62570773 19.9249 7.3496 1247.2 123786 397 437 1900969 83453453 20.9045 7.5886 1372.9 149987 157609 62570773 19.92499 7.3558 1223786 397 437 1909699 83453453 20.9045 7.5844 1376.0 150674 158404 63044792 19.9750 7.3619 12253.5 1225036 399 439 192721 84604519 20.9523 7.6001 1379.2 150674 159201 63521199 19.9750 7.3619	155236 61162984 19.8494 7.3310 1237.8 121922 394 434 188356 81746504 20.8327 7.5712 1363.5 147934 156025 61629875 19.8746 7.3372 1240.9 122542 395 435 189225 82312875 20.8367 7.5770 1366.6 148617 156025 61629875 19.8746 7.3372 12240.9 122542 395 435 189225 82312875 20.8567 7.5770 1366.6 148617 15609 62570773 19.9249 7.3436 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 157609 62570773 19.9249 7.3558 124410 398 437 190969 83453453 20.9045 7.5846 1372.9 149987 158404 63044792 19.9499 7.3558 1256.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1255.3 125636	m	154449	60698457	19.8242	7.3248	1234.6	121304	393	433	18/489	81182737	20.8087	7.5054	1300.3	147254	433
156025 61629875 19.8746 7.3372 1240.9 12.542 395 435 189225 82312875 20.8567 7.5770 1366.6 148617 156816 62099136 19.8997 7.3434 123163 396 436 190096 82881856 20.8806 7.5870 1369.7 149301 157609 62570773 19.9249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149301 158404 63044792 19.97499 7.3558 12250.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1255.5 12503.6 399 439 192721 84604519 20.9523 7.6001 1379.2 1516674	156025 61629875 19.8746 7.3372 1240.9 12.542 395 435 189225 82312875 20.8567 7.5770 1366.6 148617 156816 62099136 19.8997 7.3434 123163 396 436 190096 82881856 20.8806 7.5870 1369.7 149301 157609 62570773 19.9249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149301 157609 62570773 19.9249 7.3558 12247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 158404 63044792 19.9499 7.3558 1250.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363 159201 63521199 19.9750 7.361	•	155236	61162984	19.8494	7.3310	1237.8	121922	394	434	188356	81746504	20.8327	7.5712	1363.5	147934	434
156816 62099136 19.8997 7.3434 1244.1 123(63 396 436 190096 82881856 20.8806 7.5828 1369.7 149301 157609 62570773 19.9249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 157609 62570773 19.92499 7.3558 12247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 158404 63044792 19.9750 7.3558 1256.4 124410 398 438 191844 84027672 20.9284 7.5001 150674 159201 63521199 19.9750 7.3619 1253.5 12503.6 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	156816 62099136 19.8997 7.3434 123163 396 436 190096 82881856 20.8806 7.5828 1369.7 149301 157609 62570773 199249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 158404 63044792 19.9499 7.3558 122604 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363 159201 635211199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	Ś	156025	61629875	19.8746	7.3372	1240.9	122542	395	435	189225	82312875	20.8567	7.5770	1366.6	148617	435
157609 62570773 19.9249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 158404 63044792 19.9499 7.3558 1250.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3519 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	157609 62570773 19.9249 7.3496 1247.2 123786 397 437 190969 83453453 20.9045 7.5886 1372.9 149987 158404 63044792 19.9459 7.3558 1250.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363 159201 635211199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	9	156816	62099136	19.8997	7.3434	1244.1	123 : 63	396	436	190096	82881856	20.8806	7.5828	1369.7	149301	436
158404 63044792 19.9499 7.3558 1250.4 124410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	158404 63044792 19.9499 7.3558 1250.4 12410 398 438 191844 84027672 20.9284 7.5944 1376.0 150674 159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363 TM684-i30 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	2	157609	62570773	19.9249	7.3496	1247.2	123786	397	437	190969	83453453	20.9045	7.5886	1372.9	149987	437
159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363	159201 63521199 19.9750 7.3619 1253.5 125036 399 439 192721 84604519 20.9523 7.6001 1379.2 151363 TM684-130	60	158404	63044792	19.9499	7.3558	1250.4	124410	398	438	191844	84027672	20.9284	7.5944	1376.0	150674	438
	TM684-130 ·	6	159201	63521199	19.9750	7.3619	1253.5	125036	399	439	192721	84604519	20.9523	7.6001	1379.2	151363	139

AGO 648A

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216225 100544625 21.5639 7.7473 1460.8 169823 465 505 255025 12377625 22.4722 7.9634 15865.5 2 211756 1011947656 21.5870 7.7529 1464.0 170554 465 506 255036 129554216 22.4944 7.9636 15959.7 2 2119024 10184756 7.7529 1467.0 177021 468 506 2550036 131096512 22.55167 7.9739 1599.1 2 219904 103161709 21.6564 7.7695 1470.3 172021 466 500 259081 131872229 22.5510 7.9791 1599.1 2 219904 103161709 21.65795 7.7805 1479.7 174234 471 511 21.1872229 22.5610 7.9848 1605.4 2 2205040 103161709 21.7715 7.7905 1479.7 174234 471 511 21.1728 22.5610 7.9848 1605.4 2 <t< td=""><td>464</td><td>215296</td><td></td><td>21.5407</td><td></td><td>1457.7</td><td>169093</td><td>464</td><th>Ś</th><th>254016</th><th>128024064</th><td>22.4499</td><td>7.9581</td><td>1583.4</td><td>199504</td><td>So</td></t<>	464	215296		21.5407		1457.7	169093	464	Ś	254016	128024064	22.4499	7.9581	1583.4	199504	So
217156 101194696 215870 7.7529 1464.0 170554 466 506 256036 129554216 22.4944 7.9686 1589.7 2 218089 101847563 216102 7.7584 1467.1 171287 467 507 257049 130323843 22.5167 7.9739 1599.1 2 219024 103161709 216504 7.7639 1470.3 172021 468 508 255064 131096512 22.53389 7.9791 1599.1 2 219021 103161709 216505 7.7550 1470.3 172051 470 511 261101 131872229 22.5610 7.9948 1602.2 2 220900 103823000 216795 7.7750 1470.3 177234 471 511 261121 131872229 7.9948 1602.2 2 2220900 10382034012 21.6795 7.7790 14797.4 472 511 261121 134217728 2.06053 1602.4 2 2 </td <td>465</td> <td>216225</td> <td></td> <td>21.5639</td> <td>-</td> <td>1460.8</td> <td>169823</td> <td>465</td> <th>505</th> <th>255025</th> <th>128787625</th> <td>22.4722</td> <td>7.9634</td> <td>1586.5</td> <td>200296</td> <td>505</td>	465	216225		21.5639	-	1460.8	169823	465	505	255025	128787625	22.4722	7.9634	1586.5	200296	505
218089 101847563 21.6102 7.7584 1467.1 171287 467 507 257049 130323843 22.5167 7.9739 1595.9 2 219061 103161709 21.6564 7.7639 1470.3 172021 468 508 258064 131096512 22.5389 7.9791 1595.9 2 219061 103823300 21.6333 7.7695 1470.3 172021 468 508 258064 131872229 22.5389 7.9791 1595.9 2 220900 1038233000 21.6795 7.7750 1476.5 177434 471 511 261121 131872229 22.5513 7.9948 1602.2 2 2221841 1064487111 21.7025 7.7780 1482.4 472 511 261121 1334217728 2.6053 7.9948 1605.4 2 2221476 1051649642 473 512 262144 134217728 2.26534 8.0000 1608.5 2 2 2 2	466	217156		21,5870	_	1464.0	170554	466	200	256036	129554216	22.4944	7.9686	1589.7	201090	506
219024 102503232 21.6333 7.7639 1470.3 172021 468 508 258064 131096512 22.5389 7.9791 1595.9 2 219961 103161709 21.6533 7.7750 1476.5 173494 470 510 259081 131872229 22.5383 7.9948 1602.2 2 220900 103823300 21.6795 7.7750 1476.5 173494 470 510 260100 132651000 22.5832 7.9896 1602.2 2 2220900 1038223000 21.6795 7.7790 1476.5 174234 471 511 261121 133432831 22.6574 8.0000 1608.5 2 2221729 1058233817 21.7715 7.7915 1482.4 472 512 262144 134217728 22.6573 8.0000 1608.5 2 2 22.6514 1602.2 2 2 265165 1608.5 2 2 2 2 2 2 2 2	467	218089	_	21.6102	-	1467.1	171287	467	507	257049	130323843	22.5167	7.9739	1592.8	201886	507
219961 103161709 21.6564 7.7695 1473.4 172757 469 509 259081 131872229 22.5610 7.9843 1599.1 2 220900 1038233000 21.6795 7.7750 1476.5 174974 471 511 261121 133432831 22.6053 7.9948 1602.2 2 2221841 105154048 21.7256 7.7805 1479.7 174234 471 511 261121 133432831 22.6053 7.9948 1602.2 2 2221784 105154048 21.7256 7.7860 1482.8 174974 472 512 262144 134217728 22.6748 8.0000 1608.5 2 2221752 105696424 21.7715 7.7915 1492.3 177505 475 513 266196 135506597 8.0104 1614.8 2 2226575 107171875 21.7115 7.7915 1492.3 177205 475 513 266196 1357055987 266196 8.0104	468	219024	102503232	21.6333	7.7639	1470.3	172021	468	508	258064	131096512	22.5389	7.9791	1595.9	202683	508
220900 103823000 216795 7.7750 1479.7 173494 470 510 260100 132651000 22.5832 7.9896 1602.2 2 2211841 104487111 21.7025 7.7805 1479.7 174234 471 511 261121 133452831 22.6053 7.9996 1602.2 2 2217841 105154048 21.7256 7.7805 1482.8 174974 472 511 261121 1334517728 2.6053 7.9996 1605.4 2	469	219961	103161709	21.6564	7.7695	1473.4	172757	469	200	259081	131872229	22.5610	7.9843	1599.1	203482	200
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2227784 105154048 21.7256 7.7860 1482.8 174974 472 512 262144 134217728 22.6274 8.0000 1608.5 2 2223729 105823817 21.7256 7.7915 1480.0 175716 473 513 265169 134217728 22.6495 8.0000 1608.5 2 2234576 105823817 21.7715 7.7970 1489.1 176460 474 514 264196 1357965974 22.6716 8.0104 1614.8 2 2225575 107171875 21.7945 78025 1492.3 177505 475 515 265256 135796744 22.6716 8.0104 1614.8 2 2225575 107771875 21.7945 78079 1495.4 177952 475 517 266256 13773889096 22.7756 8.0260 1624.1.2 2 2225575 107850176 21.8104 78079 14955.4 177952 475 517 266256 137388096 22.77596		193100	104487111	200210	7 7805	1470.7	174734	471		261121	133432831	22 6053	7 0048	1605 4	205084	5
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	470	229441	109902239	21.8861	7.8243	1504.8	180203	479	510	260361	130708350	22.7816	8.0363	1630.5	211556	510

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777575 14307564 22860 66431 21485 553 516669 17757 24807 257776 257776 257776 257776 257776 257764 2577764 257776 255776 255776 257764 257764 257776 2557777 2557777 2557777 <td>52</td> <td></td> <td>142236648</td> <td>22.8473</td> <td>8.0517</td> <td>1639.9</td> <td>214008</td> <td>522</td> <td>563</td> <td>315544</td> <td>177504328</td> <td>23.7065</td> <td>8 2 5 7 4</td> <td>1765.6</td> <td>242062</td> <td>5</td>	52		142236648	22.8473	8.0517	1639.9	214008	522	563	315544	177504328	23.7065	8 2 5 7 4	1765.6	242062	5
777/55 1437/357 2337/35 2518/05 177/5 2457/5 177/5 2457/5 2537/3 2537/3 7765/5 14470135 2239/7 80071 15645 216455 2166 31035 1177/1 2530/1 7766/7 144701315 2239/7 80071 15649 21978 523 561 31771 2530/1 777714 146023689 23304 16619 21978 533 513 513 533	52		143055667	22.8692	8.0569	1643.1	214829	523	563	316969	178453547	23.7276	8 2 5 7 3	17687	748047	2622
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777675 14553157 223347 60773 1652.5 217301 253497 253497 253497 253497 777755 145331570 223347 80774 1653.8 218736 253437 253497 253497 777754 14403589 230000 80774 1653.8 21000 10771 253497 280906 14977291 230441 80781 1665.0 23165 533 533 533 533 533 533 533 533 533 533 533 533 537 55001 55001 55001 55001 55003 5505 550 557 530 557 530 557 530 557 55001 55001 55001 55001 55001 55003 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 55073 550733 55073 55073	52		144703125	22.9129	8.0671	1649.3	216475	525		310775	180362125	1071.64	8 2670	1775.0	250710	5 5
277775 16636318 225655 6077 1557 567 327644 13228456 178.13 525439 279941 14035895 220061 80855 1655.0 210855 525 327654 132357 23665 179.44 255338 2800900 14877000 230271 8.0978 1665.0 270145 531490 130295 120341 137907 255433 2800900 14877000 230271 8.0978 1665.0 270145 53176 114720009 230055 17907 255973 280090 14877000 231076 1147201027 230478 83010 119707 255973 28010 15310475 231016 8310 188135 10010375 231976 10010375 230978 13005 17907 256977 28850 15310475 23106 133261 16813217 230178 13112 10727 259978 13112 10727 259678 256103 256103 256103 256103 </td <td>52</td> <td></td> <td>145531576</td> <td>22 9347</td> <td>8.0723</td> <td>1652.5</td> <td>217301</td> <td>526</td> <td></td> <td>220256</td> <td>181301406</td> <td></td> <td>0.01.0</td> <td>17701</td> <td>21 1007</td> <td></td>	52		145531576	22 9347	8.0723	1652.5	217301	526		220256	181301406		0.01.0	17701	21 1007	
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283024 1502666768 230651 81/13 22227 522 577 327194 881/3517 23016 81001 1797.0 256967 285156 15114937 230868 8.1079 16745 232113 533 23377 13005 236070 1800.1 2578697 285156 153705675 311311 8.1131 8.1131 16830 255641 537 331775 19110227 231966 1803.1 25677 285756 15370671 8.1331 16830 255644 537 331755 19110227 23196 8.3331 1812.7 256706 285756 1537061 1537067 24003 8.3351 1812.7 256146 25306 1812.8 255139 295610 15570677 23279 8.133 1696.5 229737 551 99113766 23301 1812.8 255139 295610 15770601 157707 23075 1391055 240616 18337 1814.7 256196	53		14972:291	23.0434	8.0978	1668.2	221452	531	571	326041	186169411		8.2962	1793.9	256072	571
286109 1511191477 23.0068 8.1109 16745 22.3113 51.3 57.3 23.823 18811257 71.9071 8.1100 157.460 57.4 57.4 57.4 57.4 57.4 57.4 57.4 57.4 57.4 57.4 57.4 57.6 53.177 13.010 8.3137 11.00 12.57 13.005 13.006 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.016 13.0	53		150568768	23.0651	8.1028	1671.3	222287	532	572	327184	187149248	23.9165	8.3010	1797.0	256970	572
285156 15273304 23.107 1800.1 5677 33075 19019376 23.967 38677 286525 15311075 8.1130 1687.0 25.467 55 53 33075 19010376 23.000 33.03 1800.4 250673 286545 1531075 8.1321 1683.0 22.6444 537 53753 23.000 33.231 1800.6 23.037 287441 15572087 8.1321 1669.0 22.7437 53.306 183.01 1803.6 23.501 290501 15575001 33.2417 19310655 24.007 83.33 1819.0 23.501 290501 15575001 33.25417 19310655 24.007 83.57 1813.2 109.55 25.500 25.5	53.		151419437	23.0868	8.1079	1674.5	223123	533	573	328329	188132517	23.9374	8.3059	1800.1	257869	573
286225 1530375 231517 18106 1806.4 559673 286256 15390666 531517 81132 16607 256440 535 577 331776 191102976 5300 83261 1890.6 266576 286369 155720872 231576 81132 1660.0 227329 538 577 332751 191102976 83203 1891.5 561420 290501 155720872 231761 191102906 26003 24064 83231 1891.5 561420 290501 155570081 2312376 81143 16065 220972 540 337561 195112000 24064 83231 18221 266023 290501 15553041 15721024 81433 1702.7 220971 54146 83364 1834.7 18261 265120 290501 169702 231324 541 8133 1712.2 220774 543 1834.7 266133 290306 16099865 231406 545 <td>S3</td> <td></td> <td>152273304</td> <td>23.1084</td> <td>8.1130</td> <td>1677.6</td> <td>223961</td> <td>534</td> <td>574</td> <td>329476</td> <td>189119224</td> <td>23.9583</td> <td>8.3107</td> <td>1803.3</td> <td>258770</td> <td>574</td>	S3		152273304	23.1084	8.1130	1677.6	223961	534	574	329476	189119224	23.9583	8.3107	1803.3	258770	574
2871206 155305 511517 81151 82564 535 575 331776 19110276 24.0000 82303 1815.8 265037 285445 155720872 5.1331 1687.0 225484 537 577 331751 19110276 8.3305 1815.8 265192 285445 155720872 5.1164 8.1382 1690.5 226474 533 537561 191106552 24.04016 533766 1815.8 265120 290561 1553340421 23.3294 81433 1690.5 230272 540 581 337561 1961122941 24.1039 8.3454 1832.6 265033 290561 155340421 23.3294 81633 1702.7 233728 545 585 3337561 1961122941 24.1039 8.3443 1837.6 265043 290501 16099007 233024 81533 1702.7 233728 545 585 3337561 196122941 24.1039 8.3443 1837.6 265033 290501 16099007 233478 545 585 343396 191777 </td <td>S. S.</td> <td></td> <td>153130375</td> <td>23.1301</td> <td>8.1180</td> <td>1680.8</td> <td>224801</td> <td>535</td> <td>575</td> <td>330625</td> <td>190109375</td> <td>23.9792</td> <td>8.3155</td> <td>1806.4</td> <td>259672</td> <td>575</td>	S. S.		153130375	23.1301	8.1180	1680.8	224801	535	575	330625	190109375	23.9792	8.3155	1806.4	259672	575
288369 158654153 231733 81281 1667/0 226484 537 577 332929 192100033 24,0208 8.3251 1812.7 261482 205218 22339 28644 15570872 23164 8.1332 1696/2 227329 559 557 334684 193100552 14.04616 8.3300 1815.8 262399 29051 15569601 1576464000 232316 8.1333 1696/5 229072 540 550 335640 195112000 24.0827 8.3356 18221 264208 291600 157464000 232379 8.1433 1696/5 229072 540 550 337640 195112000 24.0829 8.3356 18221 264208 291660 157464000 232379 8.1333 17027 23072 541 551 337561 196122941 24.1039 8.3357 18253 265024 292651 159220088 232809 8.1533 17027 23072 541 551 337561 196122941 24.1039 8.3357 18242 256024 29055 169090184 233238 1.1633 170027 23072 541 554 3337561 196122941 24.1039 8.4343 18254 266034 290107 233302 8.1533 17005 233177 455 543 333355 199155287 24.1661 8.3393 18316 266048 290356 16878625 233328 8.1633 17027 231574 545 583 333756 201230056 24.1074 8.563 18316 266048 290326 16878625 233452 8.1633 17152 233398 545 583 333755 200201252 24.1668 8.563 18316 2667333 200304 16656592 233458 8.1633 17152 233438 545 583 34355 200201252 24.1668 8.563 18316 269783 200304 16656592 234698 545 585 34255 200201252 24.1661 8.3771 18332 23397 200304 165669149 23473 8.1983 17156 233438 555 200201525 24.1669 8.3377 18532 273377 200304 16566592 234094 8.1883 17126 233538 548 543 34356 20154003 24.2691 8.3654 273471 2003050 166375000 23451 8.1932 1777 23553 555 599 34692 20143669 20144467 24305 8.3919 18567 273471 200306 166375000 23451 8.1932 1777 23553 555 599 34692 201436467 20143468 243318 8.966 1277117 20031464 25357 82031 17342 239314 552 555 5399 335040 201230456 24.3431 8.3654 277471 200305 1770272 23554 8.2130 17436 25435 555 2393 20031464 235752 82329 8.108 8568 24131 8595 277117 20031464 23575 8239 8.198 1773 24495 8594 24731 8.966 1377114 2003361 166469149 23477 84188 84108 18693 27664 20043468 243318 8.966 20043468 243318 8.966 277114 2003361 17712432 239314 555 599 335040 2062571 24.3456 8.4130 8.4156 18630 27651 20031464 235752 82329 81722 84408 255 23934 855 237657 23448 855 237624 255 555 2393 83504 2064557 244	53		153990656	23.1517	8.1231	1683.9	225642	536	576	331776	191102976	24.0000	8.3203	1809.6	260576	576
29544 155720872 27.946 8.133 1690.2 227329 533 531 193100552 24,0416 6.3300 1815.8 265339 290521 155590819 23.2164 8.1332 1690.3 229817 531 194104539 24,0624 8.3356 1825.3 265120 290501 155340400 33.2379 8.1433 1605.5 230727 53072 197117368 23.4134 8.5533 1825.3 265120 290505 15534061 23.3024 8.1633 1705.0 233756 198155297 24,1456 8.3559 1833.1 26702 290505 16090507 23.3024 543 543 3355 24.3076 8.333.1 26702 290505 16090507 23.3048 547 547 547 8.3451 267063 290505 1609665723 23.3490 8.1783 1715.2 233498 547 24.3468 8.377 1844.1 270624 2901010 165566793 34.34	53		154854153	23.1733	8.1281	1687.0	226484	537	577	332929	192100033	24.0208	8.3251	1812.7	261482	577
290521 156590819 23.2164 8:382 1693.3 228175 539 579 33540 195112000 24.0824 8.3348 1819.0 26329 291600 157464000 23.2379 8.1433 1696.5 229072 540 580 336600 195112000 24.083 8.3356 182.1 264208 292681 158340421 23.2594 8.1583 1705.9 231574 541 581 337561 196122941 24.1039 8.3433 1825.3 266033 293956 160999184 23.3289 8.1533 1705.9 231578 543 583 333959 19915700 24.1693 8.3433 1824.2 266033 295936 160999184 23.3289 8.1533 1705.9 231578 545 585 3337561 196122941 24.1039 8.3433 1824.2 266033 295936 160999184 23.3280 8.1583 1705.9 231578 545 585 334396 199155704 24.1661 8.3587 1834.7 26603 297025 161878655 23.3456 8.1733 1705.9 23148 545 585 342256 200201652 24.1661 8.3587 1834.1 270624 297036 15367333 23.3680 8.1733 1715.3 233498 545 585 342262 24.2074 8.3652 184.10 269701 299006 15367333 23.3680 8.1733 1715.5 233498 545 585 345245 200201652 24.1661 8.3587 1844.1 270624 300304 16566592 23.4094 6.1833 1715.5 233498 545 545 34574 2012976703 24.2693 8.3654 184.1. 270624 300304 16566592 23.4094 6.1833 1715.5 233498 551 54744 502 2025003 24.2693 8.3872 185.0.2 27147 3025001 165469149 23.4307 8.1882 1727.9 23758 550 596 34510 205379000 24.2899 8.3872 185.0.2 273357 303600 165775000 23.4521 8.1932 17779 23758 550 596 34510 205379000 24.2899 8.3872 185.0.2 277354 303601 1657284151 23.4734 8.1982 1737.3 240182 555 593 355649 20747468 24.3311 8.3667 277117 3025005 1236779 23.5584 8.2081 1737.3 240182 555 593 355649 20747468 24.3311 8.365.2 273254 303916 1102177 24566 23.5577 82.209 1774.6 241925 555 593 355649 20747458 24.3311 8.365.2 277327 300916 110011457 23.5578 82.081 1774.2 230314 552 593 355649 2014875 24.3958 8.3021 2855.2 277327 301260 16577687 23.5578 82.281 1774.2 230314 552 595 595 555 595 536699 211768735 24.3958 8.3423 1856.3 277117 308915 1777808093 23.4978 8.2031 1774.2 241928 555 595 595 536699 211768735 24.3928 8.3956 277117 308916 1100031464 23.5577 82.289 1774.2 241958 555 595 595 555 570 2005557 24.3926 8.3919 1856.1 277117 308916 1100031464 23.5577 8.2128 1774.2 230314 552 555 595 536699 211768735 24.	S		155720872	23.1948	8.1332	1690.2	227329	538	578	334084	193100552	24.0416	6.3300	1815.8	262389	578
291600 157464000 23.2379 8.1433 1696.5 229022 540 581 33761 196122941 24.1039 8.3443 1825.3 265120 292681 158340421 23.2594 8.1433 1696.5 229022 542 581 337561 196122941 24.1039 8.3443 1825.3 265033 292681 158340421 23.2594 8.1533 1702.7 230722 542 581 337561 196122941 24.1039 8.3443 182.8 266033 299766 159220088 23.3202 8.1533 1702.7 230722 543 583 333889 198155287 24.1454 8.3539 1831.6 266033 2997057 1536 16098018 23.3328 8.1633 1715.3 234128 545 585 34326 199715704 24.1661 8.3587 1834.7 267865 2997025 161878652 23.3466 8.1733 1715.5 234349 546 586 343305 2012.30056 24.1868 8.3654 1837.8 267865 2997029 165667323 23.3380 8.1783 1715.5 234998 547 585 343305 2012.30056 24.2074 8.3687 1837.8 267865 299209 165667323 23.3380 8.1783 1715.5 234998 547 586 343305 2012.30056 24.2069 8.3677 1837.8 267865 299209 16566792 23.4094 5.1833 1715.3 234140 546 543 343365 2012.30056 24.2099 8.3677 1877.3 276787 300304 1655669149 23.4307 8.1882 1724.7 236720 549 546 2043066 24.2093 8.3857 185.4 27687 301401 165469149 23.4307 8.1882 1774.7 236720 549 588 34594 201330646 24.2693 8.3857 185.6 273377 301401 165469149 23.4307 8.1882 1774.7 236720 549 588 5462 204336469 24.2693 8.38567 274325 301401 165469149 23.4377 8.1932 17737 23914 552 599 35649 2047468 24.3311 8.3961 277117 302501 1677284151 23.5568 8.1932 1774.7 236720 549 535 559 590 355649 2047468 24.3311 8.3961 277117 305601 1677284151 23.5578 8.2180 1773.4 239124 552 559 559 556 556 20584587 2.43356 8.4018 1865.1 277117 300515 1770953875 23.5584 8.2280 1774.6 241951 555 559 556 355216 211708765 24.3318 8.3954 24351 88.3624 276184 300716 1677284151 23.5578 8.2180 1774.6 241925 555 599 355649 20747468 24.313 8.4051 1866.1 277117 300525 1770876 23.5584 8.2280 1774.6 22422 555 595 355402 217708765 24.3326 8.4018 1866.1 277117 300516 177031464 23.5577 1733 239184 555 555 555 556 355216 217708756 24.3356 8.4018 1866.1 277117 300526 170031464 17771112 23.6528 8.2192 5555 555 555 555 555 556 355216 24.313 8.4051 12770876 8.4051 1866.1 277117 310249 177087687 23.5558 555 555 556 35521	S3		156590819	23.2164	8.:382	1693.3	228175	539	579	335241	194104539	24.0624	8.3348	1819.0	263298	579
292681 158340421 23.2594 8.1483 16996 229871 541 581 337561 197137368 24.1247 8.3491 182.84 266033 229936 169003007 2332428 543 543 543 543 543 543 543 543 543 17025 299358 545 544 563 19915794 24.1039 8.3559 1831.6 269703 299948 1533 17025 239358 545 583 333899 198155287 24.1454 8.3559 1837.8 266033 299936 169704533 233452 81633 17025 233458 544 583 333899 198155287 24.1454 8.3559 1837.8 269703 299705 1657704 2.1456 8.3559 1837.8 269703 299705 105771336 233452 81633 1712.2 2332438 545 586 334336 2012300565 24.2074 8.3652 1841.0 269701 269701 269701 24.1661 8.3777 1847 3 271547 25764 23007465 24.2074 8.3652 1847.3 271547 26763 230301 165469149 233477 235758 548 546 549 20021655 24.2074 8.3657 1837.1 270624 3303 1721.6 233498 547 531 7032397472 24.2693 8.3877 1847.3 271547 301401 155469149 233477 8.1882 1724, 23556 549 20021655 24.2074 8.3657 273357 3377 1847.3 271547 301401 155469149 233477 8.1882 1724, 23556 549 20021655 24.2074 8.3657 273357 3377 34735 301401 155469149 233477 8.1882 1771, 235758 559 596 346921 204336469 24.2693 8.3872 1850.4 27747117 30691 177713 24316 8.3019 1865.1 277117 30691 177713 24316 8.3019 1865.1 277117 30691 177713 24315 8.3019 1865.1 277117 30691 177713 24315 8.4014 1865.0 275754 3058 555 55 55 55 55 55 55 55 55 55 55 55	4	- 3	157464000	23.2379	8.1433	1696.5	229022	540	680	UUF925	105112000	24 0823	8 33CK	1 6 2 2 1	364208	Ş
297764 159220088 233872 19713756 24.1247 83.591 1828.4 266033 294849 160103007 233224 81533 1702.7 231574 543 583 333872 19713756 24.1247 83.591 1831.6 266033 297025 160103007 2332328 81633 1705.9 231574 543 583 333872 199175704 24.1661 83.571 1831.6 266033 297025 161878655 23.3409 81763 177.2 233233 545 585 347305 201201625 24.1868 83.654 18733 1874.1 270701 297025 16197655 23.480 8.173 1715.5 234140 546 586 347465 20201625 24.2487 83.373 127674 27071 297030 165659149 23.4904 8.1882 1727.9 237438 545 546 202327725 202327725 2072411 270741 27071 270741 27074 27475 27475 27475 27475 27475 274325 2724711 27056	4		158340471	232504	8 1483	9 0091	220871	5A1		193255	00071761	2000110		1.1201	007407	
294849 160103007 233304 8153 1705.9 233574 543 533 339589 191155287 241446 83347 2656948 297025 160103007 233348 81633 1705.0 233748 545 585 341056 199176704 241466 83377 267865 297025 160989184 2333480 81733 1715.3 233783 545 585 341306 20120055 24.1661 8.3537 18317 265948 299205 16187652 233498 545 585 345749 235736 1844.1 270624 299205 165469149 233430 8.1882 1715.5 234998 547 585 345749 23573 88733 1844.1 270624 300301 165469149 23.4307 8.1882 17715 235736 5493465 24.2693 8.3877 1847.1 270624 300301 165469149 23.4307 8.1982 1731.6 237535 237397 2374.5 237554 300470 168196608 23.4971 8.1931			150220088	032204	8 1533	12027	230722	547	100	100/00	190122941	24.1039	0.443	1020.5	071 007	
295336 100989184 23.3738 8.1633 1712.2 2332428 545 586 341056 199176704 24.1661 8.3587 1833.4 2665785 297025 161878625 23.3456 8.1733 1715.3 2334140 545 586 343396 201230056 24.1661 8.3587 1837.8 2665733 297025 161878625 23.3466 8.1733 1715.5 233498 547 586 343396 201230056 24.1661 8.3587 1841.0 269701 299209 16566592 23.4004 5.1833 1715.5 233498 547 586 343396 201230056 24.2074 8.3677 1847.1 279624 200304 165469149 23.4507 8.1982 1772.7 235720 549 586 345744 203297472 24.2074 8.3577 1847.3 271471 200304 165469149 23.4504 8.1982 177279 235726 53928 348100 2652507 24.2693 8.3537 1835.5 273397 3035001 1672841518 237506 </td <td>5</td> <td>-</td> <td>160103007</td> <td>233024</td> <td>8 1583</td> <td>1705 0</td> <td>231574</td> <td>543</td> <td>105</td> <td>1000000</td> <td>100155707</td> <td></td> <td></td> <td>1.0201</td> <td>200002</td> <td></td>	5	-	160103007	233024	8 1583	1705 0	231574	543	105	1000000	100155707			1.0201	200002	
297025 161878655 23.3452 81663 1712.2 233283 545 555 343225 200201025 24.1866 8.3777 1844.1 270624 297025 1618766532 23.34666 8.1733 1715.3 234140 546 586 343225 200201025 24.1866 8.3777 1844.1 270624 299209 165667333 23.33860 8.1783 1715.3 234140 546 586 345744 203297472 24.2487 8.3777 1844.1 270624 200304 165665732 23.4307 8.1882 1724.7 236720 549 586 345921 24.2047 8.3653 1844.1 270624 300304 165469149 2.3.4307 8.1882 1724.7 236720 549 586 24.544 203297472 24.2487 8.3777 1847.1 270624 301401 165469149 23.4504 8.3650 24.2693 8.3872 1847.1 270624 273397 302500 166375000 23.4914 8.3021 24.2693 8.38591 273397 24.316 <td>N 4</td> <td></td> <td>160989184</td> <td>23 3238</td> <td>8 1633</td> <td>1709.0</td> <td>232428</td> <td>544</td> <td>200</td> <td>203009</td> <td>107661061</td> <td>1931 40</td> <td>2000 C</td> <td>0.1001</td> <td>046007</td> <td></td>	N 4		160989184	23 3238	8 1633	1709.0	232428	544	200	203009	107661061	1931 40	2000 C	0.1001	046007	
298116 162771336 233566 81733 1715.3 234140 546 587 343596 201200056 242867 8.3682 1844.1 270624 299209 163667323 23.33860 8.1783 1715.5 234998 547 200262003 24.2693 8.3377 1844.1 270624 299209 1654667323 23.33860 8.1783 1715.5 234998 547 202262003 24.2693 8.3377 1844.1 270624 300304 165466592 23.4309 549 58 545744 203297472 24.2487 8.3777 1847.3 271547 301301 165466592 23.4904 5.1820 549 589 345021 20252003 24.2693 8.3350 27471 303501 167284151 234573 84108 551 553 591 349281 23771 8.4661 1867.3 273327 303501 167284458 551 5301 244584 555 559 355469 20257693 273356 277117 305010 168196668 235516 <td>5</td> <td></td> <td>161878625</td> <td>23.3452</td> <td>8,1683</td> <td>1712.2</td> <td>233283</td> <td>545</td> <td>100</td> <td></td> <td>1991/0/1691</td> <td>1001.72</td> <td>100000</td> <td>1024.1</td> <td>200/07</td> <td></td>	5		161878625	23.3452	8,1683	1712.2	233283	545	100		1991/0/1691	1001.72	100000	1024.1	200/07	
299209 163667323 23.3880 8.1783 17115.5 234998 547 587 34559 202262003 24.2281 8.3777 1844.1 270624 300304 164566592 23.4094 51833 1721.6 235838 548 588 34574 203297472 24.2487 8.3777 1847.3 270471 301401 165466149 23.4094 51833 1724.7 235838 550 590 346921 204336469 24.2693 8.3877 1847.3 271547 301401 165466149 23.4094 51823 550 590 346921 204336469 24.2693 8.3877 184.1 2706724 302500 166375000 23.4547 8.317 18.401 1856.7 274325 303501 166112377 23.4947 8.510 236464 207474688 24.311 8.3967 1876.1 276184 3036016 167284151 23.4947 8.523 593 351649 2064455 24.3216 8.4014 1865.3 276184 3058016 17031464 23.53130	S		162771336	23.3666	8.1733	1715.3	234140	546	200	902282	200201023		0.2034	0.1001	102030	
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302500 166375000 23.4521 8.1932 1727.9 237583 550 596 348100 205379000 24.2899 8.3872 1853.5 273397 303601 167284151 23.4734 8.1982 1731.0 238448 551 591 349281 206-25071 24.3105 8.3919 1856.7 274325 30470 ⁶ 168196608 23.4947 8.2031 1734.2 239314 552 592 350464 207474688 24.311 8.3967 1859.8 275254 305809 169112377 23.5160 8.2081 1737.3 240182 553 593 351649 208527857 24.3516 8.4014 1865.0 276184 306916 170031464 235372 8.2130 1740.4 241051 554 594 352836 209584584 24.3711 8.3967 1866.1 277117 308025 170953875 23.5584 8.2180 1740.5 241051 555 595 595 354025 210644875 24.3216 8.4016 1866.1 277117 308025 170953875 23.5584 8.2180 1746.7 241051 555 595 354025 210644875 24.3216 8.40161 1866.1 277117 308025 170953875 23.5584 8.2180 1746.7 241051 555 595 354025 210644875 24.3216 8.40161 1866.1 277117 309136 171879616 23.5777 8.2229 1746.7 241922 555 595 356409 212776173 24.4336 8.4202 1876.5 278986 310249 177808693 23.6008 8.2278 1749.9 245669 557 597 356409 212776173 24.4336 8.4202 1876.5 279926 311364 173741112 23.6220 8.2377 1756.2 245455 556 596 3557064 213847192 24.4745 8.4296 1878.7 280862 311364 173741112 23.6220 8.2377 1756.2 245425 558 599 358801 214921799 24.4745 8.4296 1881.8 28180 71664-134	54		165469149	23.4307	8.1882	1724.7	236720	549	589	346921	204336469	24.2693	8.3825	1850.4	272471	589
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		5	1885.0	1888.1	1891.2	1894.4	1897.5	1900.7	1903.8	1907.0	1910.1	1913.2	10164		2.6161	1922.7	1925.8	1928.9	1932.1	1935.2	1938.4	1941.5	1944.7	_	1947.8	1950.9	1954.1	1957.2	1960.4	1963.5	1966.6	1969.8	1972.9	1.0/61	1979.2	1982.4	1985.5	1988.6	1991.8	1994.9	1998.1	2.1002	2.002
	j]		8.4343	8.4390	8.4437	8.4484	8.4530	8.4577	8.4623	8.4670	8.4716	8.4763	8 4800		8.4850	8.4902	8.4948	8.4994	8.5040	8.5086	8.5132	8.5178	8.5224		8.5270	8.5316	8.5462	8.5408	8.5453	8.5499	8.5544	8.5590	8.5035	10000	8.5726	8.5772	8.5817	8.5862	8.5907	8.5952	8.5997	8.004	0.0060
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	ļ		360000	361201	362404	363609	364816	366025	367236	368449	369664	370881	001025		373321	374544	375769	376996	378225	379456	380689	381924	383161		384400	385641	386884	388129	389376	390625	391876	393129	394384	TLOCKC	396900	398161	399424	400689	401956	403225	404496	40/204	++0/0+
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	-		0,00,0	2002 0		031626	009	720	518400	373248000	26.8328	8.9628	2261.9	407150	720
3		314432000	20.0708	8.1931	2130.3	202100	000	100	510041	374805361	26.8514	8 0670	22651	408787	721
691	463761	315821241	26.0960	8.7980	2139.4	364237	081	17/	140410		11000		1.0044	101001	
682	465124	317214568	26.1151	8.8023	2142.6	365308	682	177	521284	3/030/048	10/2.01	11/6.0	7.0077	403410	77
1.83	466489	318611987	26.1343	8.8066	2145.7	366380	683	723	522729	377933067	26.88887	8.9752	2271.4	410550	123
684	_	320013504	26.1534	8.8109	2148.9	367453	684	724	524176	379503424	26.9072	8.9794	2274.5	411687	724
A B C		321410125	261725	8.8152	2152.0	368528	685	725	525625	381078125	26.9258	8.9835	2277.7	412825	725
3			261016	0100	21551	369605	686	726	527076	382657176	26.9444	8.9876	2280.8	413965	726
020		00070770	20.1910	10.00			200	100	579570	384740583	26.0670	8 00 18	27830	415106	727
687		324242703	20.2107	8.8231	5.8612	510084	100	171	670070	307474000	20.9025		1 1 0 0 0 0	arcare	12
688	473344	325660672	26.2298	8.8280	2161.4	371764	688	272	229984	382828332	20.9810	90999	1.1022	047014	
689	474721	327082769	26.2488	8.8323	2164.6	372845	689	729	531441	387420489	27.0000	9.0000	2.090.2	417393	67/
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690	476100	328509000	26.2679	8.8366	2167.7	373928	690	/30	006255	28901/000	C010.12	1+00.6	1.0000	A00014	3
691	477481	329939371	26.2869	8.8408	2170.8	375013	691	731	534361	390617891	27.0370	7900.6	C.0622	419080	731
692	478864	331373888	26.3059	8.8451	2174.0	376099	692	732	535824	392223168	27.0555	9.0123	2299.7	420835	732
603		332812557	26.3249	8.8493	2177.1	377187	693	733	537289	393832837	27.0740	9.0164	2302.8	421986	733
404		334255384	26.3439	8.8536	2180.3	378276	694	734	538756	395446904	27.0924	9.0205	2305.9	423138	734
		335702375	263629	8.8578	2183.4	379367	695	735	540225	397065375	27.1109	9.0246	2309.1	424293	735
		337153536	263818	8.8621	2186.6	380459	696	736	541696	398688256	27.1293	9.0287	2312.2	425448	736
203		238608873	264008	8 8663	2189.7	381554	697	737	543169	400315553	27.1477	9.0328	2315.4	426604	737
		340068307	26 4107	8 8706	2107 R	382640	698	738	544644	401947272	27.1662	9.0369	2318.5	427762	738
020		24000040	1611-07	0.0100	0.1010	202020		730	546121	403583410	27.1846	9.0410	2321.6	428922	739
669	488601	341552099	20.4360	0-0/40	7190.0	01/000	~~~	5							
25		14200000	764575	8 8700	21001	384845	700	740	547600	405224000	27.2029	9.0450	2324.8	430084	740
3			20.0102	0 0 0 2 3 3	22023	285045	101	741	549081	406869021	27.2213	9.0491	2327.9	431247	741
502		3454/2101	2014.02	0.0000	22022	387047	202	742	550564	408518488	27.2397	9.0532	2331.1	432412	742
		001016010			10000	200161	202	742	552040	410172407	27.2580	9 0572	2334.2	433578	743
203		347428927	20.5141	0.091/	C.00/22	101000	202	744	923235	411830784	27 2764	0.0613	23373	434746	744
22		348913664	26.5330	8.8959	2211./	389250				10/000114	1017.17	C100.6		A26016	745
705		350402625	26.5518	8.9001	2214.8	390363	705		213233	415493025	1467.12	+ COD.4	2.04C2	127067	246
706	_	351895816	26.5707	8.9043	2218.0	391471	206		010000	101000000	0010.12			100/04	
707	499849	353393243	26.5895	8.9085	2221.1	392580	707	/4/	600800	410852/23	21.3313	9.0/02	0.04.02	4070C4	14
708	s 501264	354894912	26.6083	8.9127	2224.3	393692	708	42	400600	418508992	21.3490	c//0.6	2.949.9	00107¢	
202	502681	356400829	26.6271	8.9169	2227.4	394805	209	/49	100105	420189/49	21.30/9	9.0810	1.5052	440009	4
012		357011000	26.645R	8 07 1 1	22305	305010	710	750	562500	421875000	27.3861	9.0856	2356.2	441786	750
112		359425431	26.6646	8.9253	2233.7	397035	711	751	564001	423564751	27.4044	9.0896	2359.3	442965	751
712		360944128	26.6833	8.9295	2236.8	398153	712	752	565504	425259008	27.4226	9.0937	2362.5	444146	752
113		362467097	26.7021	8.9337	2240.0	399272	713	753	567009	426957777	27.4408	9.0977	2365.6	445328	753
		363994344	26.7208	8.9378	2243.1	400393	714	754	568516	428661064	27.4591	9.1017	2368.8	446511	754
715		365525875	26.7395	8.9420	2246.2	401515	715	755	570025	430368875	27.4773	9.1057	2371.9	447697	755
716		367061696	26.7582	8.9462	2249.4	402639	716	756	571536	432081216	27.4955	9.1098	2375.0	448883	756
717		368601813	26.7769	8.9503	2252.5	403765	717	757	573049	433798093	27.5136	9.1138	2378.2	450072	757
718		370146232	26.7955	8.9545	2255.7	404892	718	758	574564	435519512	27.5318	9.1178	2381.3	451262	758
719		371694959	26.8142	8.9587	2258.8	406020	719	759	576081	437245479	27.5500	9.1218	2384.5	452453	759
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761	579121	440711081	27 5862	0 1208	2300.8	454841	761	801	641601	513022401	28 3010	0.7870	25164		5
762	580644	442450728	27.6043	0 1338	2303.0	456037	762	500	643204	515840608	20100.07		20105		
763	582169	444194947	27.6225	9.1378	2397.0	457234	763	803	644800	517781627	28 3373	0 2048	25227	506437	
764	583696	445943744	27.6405	9.1418	2400.2	458434	764	804	646416	510718464	28.3540	9.2986	25258	201000	
765	585225	447697125	27.6586	9.1458	2402.3	459635	765	805	648075	521660125	26.22.95	0 3075	25200	50.005	
766	586756	449455096	27.6767	9.1498	2406.5	460837	766	806	640636	523606616	28 3001	0 3063	25321	510223	
767	588289	451217663	27.6948	0.1537	2409.6	462042	767	200	651240	575557043	1060.01	01150	25353	511400	200
768	589824	452984832	27.7128	9.1577	24127	463247	768	a de	652864	57514112	28 4753	0 3144	25.284		
769	591361	454756609	27.7308	9.1617	2415.9	464454	769	008	654481	529475129	28 4420	93179	25415		
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770	592900	456533000	27.7489	9.1657	2419.0	465663	770	810	656100	531441000	28.4605	9.3217	2544.7	515300	810
771	59441	458314011	27.7669	9.1696	2422.2	466873	171	811	657721	533411731	28.4781	9.3255	2547.8	516573	811
772	595984	460099648	27.7849	9.1736	2425.3	468085	772	812	659344	535387328	28.4956	9.3294	2551.0	517848	812
773	597529	461889917	27.8029	9.1775	2428.5	469298	773	813	696099	537367797	28.5132	9.3332	2554.1	519124	813
774	599076	463684824	27.8209	9.1815	2431.6	470513	774	814	662596	539353144	28.5307	9.3370	2557.3	520402	814
775	600625	465484375	27 8388	9.1855	2434.7	471730	775	815	664225	541343375	28.5482	9.3408	2560.4	521681	815
776	602176	467288576	27.8568	9.1894	2437.9	472948	:76	816	665856	543338496	28.5657	9.3447	2563.5	522962	816
177	603729	469097433	27.8747	9.1933	2441.0	474168	777	817	667489	545338513	28.5832	9.34.95	2566.7	524245	817
778	605284	470910952	27.8927	9.1973	2444.2	475389	778	818	669124	547343432	23.6007	9.3523	2569.8	525529	818
6.1	606841	472729139	27.9106	9.2012	2447.3	476612	779	819	670761	549353259	28.6182	9.3561	2573.0	526814	819
760	608400	474552000	27.9285	9.2052	2450.4	477836	780	008	672400	551368000	28 6356	0 3506	25761	528102	820
781	609961	476379541	27 0464	0 2001	24526	470062	781	103	674041	199282839	79.6521	0 2627	2670.2	520201	5
782	611524	478211768	27.9643	9.2130	2456.7	480290	782	877	1404/0	555412248	1660.02	1000.6	25824		822
783	613089	480048687	27.9821	9.2170	2459.9	481519	783	823	677329	557441767	28.6880	9.3713	2585.5		823
784	614656	481890304	28.0000	9.2209	2463.0	482750	784	324	678976	559476224	28.7054	9.3751	2588.7		824
785	616225	483736625	28.0179	9.2248	2466.2	483982	785	825	680625	561515625	28.7228	9.3789	2591.8		825
786	617796	485587656	28.0357	9.2287	2469.3	485216	786	826	682276	563559976	28.7402	9.3827	2595.0	535858	826
787	619369	487443403	25.0535	9.2326	2472.4	486451	787	827	683929	565609283	28.7576	9.3865	2598.1	537157	827
788	620944	489303572		9.2365	2475.6	487688	788	828	685584	567663552	28.7750	9.3902	2601.2	538456	828
789	622521	451169069	28.0891	9.2404	2478.7	488927	789	829	687241	569722789	28.7924	9.3940	2604.4	539758	329
20	624100	493039000	23 1069	9.2443	2431.9	490167	06.	830	688900	571787000	28.8097	9.3978	2607.5	541061	830
791	62.5681	4949:3671	28.1247	9.2482	2485.0	491409	161	831	690561	573856191	28.8271	9.4016	2619.7	542365	831
23	627264	496793088	25.1425	9.2521	2488.1	492652	792	832	692224	575930368	28.8444	9.4053	2613.8	543671	832
793	628849	498677257	28 1603	<u>9.2560</u>	2401.3	493897	793	833	693839	578009537	28.8617	9.4091	2616.9	544979	833
ž	630436	\$20566184	28.1780	9.2599	2494.4	495143	\$65	634	695556	580093704	28.8791	9.4129	2620.1	546288	834
795	632025	502459375	28.1957	9.2638	2497.6	496391	795	835	697225	582182875	28.8964	5.4166	2623.2	547599	835
8	633616	504358336	28.2135	9.2677	2500.7	497641	796	836	698896	584277056	28.9137	9.4204	2626.4	548912	836
797	635209	506261573	28.2312	9.2716	2503.8	498892	797	837	700569	586376253	28.9310	9.4241	2629.5	550226	837
200	02020	508169592	28.2489	9.2754	2507.0	500145	798	8.8	702244	588480472	28.9482	9.4279	2632.7		
2	INARCO	510062399	28.2000	9.2793	2519.1	501399	200	839	/03921	590589719	28.9055	9.4316	2035.8	552858	2
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11	Circum.	2638.9	2642.1	2645.2	2648.4	2651.5	2654.6	2657.8	2660.9	2664.1	2667.2	2670.4	2673.5	2676.6	2679.8	2682.9	2686.1	2689.2	2692.3	2695.5	2698.6	2/01.8	2704.9	2708.1	2711.2	2714.3	2717.5	2/20.0	2/23.8	2/20.9	0.0012	2733.2	2736.3	2739.5	2742.6	2745.8	2748.9	2752.0	2755.2	2761.5	
3	3	9.4354	9.4391	9.4429	_						9.4690	9.4727			9.4838		9.4912	9.4949	9.4986	9.5023	9.5060	 					_	2	2	1656.9	Ň	<u> </u>	0	0	0	9				9.5792	
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9.4. 857475 700040 9.4.00 2002.6 60541 9.7.06 9.7.106 9.7.06 9.7.106 9.7.06 9.7.17.106 9.7.106 9.7.106		776	820084	1021/1440	50.5045	9.1349	C.0602	+co/oo	776	706	111076	031111000		0.0761	2025	778354	Ś
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C.5 65547 79(25115) 0.4131 g 7435 2906 67206 225 965 31125 9652125 311126 5988 30343 73193 732899 07431053 11026 9888 30343 732899 07431053 111076 9888 30343 732899 07431053 111076 9888 30343 732899 07431053 11076 9888 30343 732899 07431053 111076 9888 30343 732899 07431053 111076 9888 30343 732899 07431053 111076 95043 03443 735974 7364744 736474 736474 736474 736474 736474 736474		5 7	853776	788889024	30.3974	9.7400	2902.8	670554	924	964	929296	895841344	31.0483	9.8785	3028.5	10867/	5
Cold Fights Cold Cold <thcold< th=""> <thcold< th=""> <thcold< td="" th<=""><th></th><td>\$7.5</td><td>855625</td><td>791453125</td><td>30.4138</td><td>9.7435</td><td>2906.0</td><td>672006</td><td>925</td><td>965</td><td>931225</td><td>898632125</td><td>31.0644</td><td>9.8819</td><td>3031.6</td><td>731382</td><td>963</td></thcold<></thcold<></thcold<>		\$7.5	855625	791453125	30.4138	9.7435	2906.0	672006	925	965	931225	898632125	31.0644	9.8819	3031.6	731382	963
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923 661164 79017875 30.4611 9756 57912 505 398061 909831203 3111158 99955 30441 773458 933 66406 80045705 30.4473 713748 9133004 311500 311163 94930 30441 745507 933 666761 800557440 30.5514 97750 29314 600573 90049 90504 30556 740506 933 56746 800557440 30.5514 9374 66514 93750 93166 93056 740566 933 877356 817460537 30.5514 9374 95484 913300 91569 93056 93056 93056 93056 93056 93056 93556 94741 914966 9509 30556 74515 933 871721 827056 30556 9375 93756 93756 757378 933 881770 80556 9391 959349 935661 930556 930567 930755 <th></th> <td></td> <td>859329</td> <td>796597983</td> <td>30.4467</td> <td>9.7505</td> <td>2912.3</td> <td>674915</td> <td>927</td> <td>967</td> <td>935089</td> <td>904231063</td> <td>31.0966</td> <td>9.8888</td> <td>3037.9</td> <td>734417</td> <td>967</td>			859329	796597983	30.4467	9.7505	2912.3	674915	927	967	935089	904231063	31.0966	9.8888	3037.9	734417	967
93 65490 8045700 30443 30443 30443 30453 773458 931 66676 800945700 30453 3751 3197 34484 91500 310473 73986 931 66676 800954768 30525 7560 30556 74205 933 877689 814780037 305453 74005 30556 74205 933 877689 814780037 305463 74302 90556 74302 935 870689 812106527 30541 39475 941676 9410045 30556 74305 935 870689 300541 31757 30556 74302 30556 74302 935 870689 300541 74517 93955 95563 30756 75778 936 870844 8127105 30575 92911 631069 97405 97505 97576 75778 937 870644 9407614 312500 99105 976647		800	861184	799178752	30.4631	9.7540	2915.4	676372	928	968	937024	907039232	31.1127	9.8922	3041.1	735937	88
931 8645(1) 8035(7) 915(1) 915(9) 916(1) 711(5) 915(1) 7135(1)		0.0	863041	801765080	30.4795	97576	29185	677831	929	969	938961	909853209	31.1288	9.8956	3044.2	737458	8
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931 866761 800554991 30512 9745 97109411 311979 99084 30536 74002 932 86824 0055766 07576 9775 977 94779 9110717 311769 90058 30536 74505 935 874255 817400375 05576 97756 57539 74505 935 877256 817400375 05576 97756 58555 937 975759 92116717 311709 90568 30554 74505 935 877066 8700553 05591 75955 937 97453 921167 91761 91766 90554 74505 93706 817721 82750673 005165 9378 66055 937 95544 9313773 31280 99154 30755 75732 931721 82750610 306543 79130 95544 9313773 31280 99053 99756 75758 931721 83590618 306577 9793 <		030	864900	804357000	30.4959	9.7610	2921.7	679291	930	970	940900	912673000	31.1448	9.8990	3047.3	738981	970
9.33 566.24 500555/56 3055.67 747364 9113.006 311.766 90058 3055.6 743559 9.33 872355 814706547 305516 97755 934 74 946675 920104.4 311200 99160 3065.1 745569 9.35 874255 814706054 305514 97785 934 75 95556 937517 312570 99160 3065.1 746519 9.35 87356 9755 9576 95774 95756 95774175 312170 99196 3065.3 74915 9.36 87366 954619 95454 95471 951377 30755 95167 30755 757378 9.38 871701 872906 805454 9441 98131379 311260 99265 3075 757378 9.38 87360 805666 95331 954649 954466 954649 954666 975361 975361 954646 954661 975375 954644 95		031	866761	806954491	30.5123	9.7645	2924.8	680752	931	971	942841	915498611	31.1609	9.9024	3050.5	740506	971
933 8774490 811166237 305450 97715 29311 665159 37 945729 921167317 311929 99106 30553 745539 934 872558 814700355 30578 97715 59347 66515 3755 97505 305578 9716 74553 935 876096 820055663 305619 97810 29437 66515 975 57575 312410 99196 30653 74651 936 87705 87305 9734 56505 305758 75121 75026 92257 30653 77655 75778 938 81721 8279461 30561 97792 59356 90756 752758 938 81721 8779461 9331739 311260 97745 751271 938 865481 8332761 30756 752778 93366 97644 9331739 31266 752778 941 887441 8313739 311280 90766 97		032	868674	800557568	30 5287	9 7680	2928.0	682216	932	972	944784	918330048	31.1769	9.9058	3053.6	742032	972
9.44 877.3/6 8147.80504 005614 97756 583.47 934 948.67 924010424 31.2000 93106 30591 76008 9.35 877056 8147.80504 00561 7760 305 757 59665 30501 97750 76003 76003 76003 76003 76601 77601 7712 75126 7601 77127 75127 75127 75127 75127 75127 75127 75127 75127 75126 7501 7501 7501 7501 7501 7501 7501 7501 7501 7501 7501 7501 75010 75016 75016			870480	812166237	30 5450	9 7715	29311	683680	933	973	945729	921167317	31.1929	9.9092	3056.8	743559	973
935 87,255 8174037 300513 37756 93257483 312250 99164 30651 76611 936 877605 8205413 312510 99247 30631 76611 936 877605 820555 305615 9785 59355 30551 76611 30651 74611 937 877050 820555 305615 9784 95441 93311750 99247 30552 74611 938 898441 8257936015 305501 97835 95441 9381135139 312800 99267 30756 757378 941 88136 83550618 30557 97993 956424 9544132 312309 99363 30756 757378 941 88136 305501 97032 956424 9564204 976461 93651 76013 757378 944 89112 8813 30750 91328 90415 94056161 311302 97614 9565111 944 <			222220	01470050.4	30 56 14	07750	2024.2	695147	024	074	048676	024010424	31 2000	00126	3059.9	745088	974
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936 837944 855464 936441 93541373 91257 75121 757356 75735 936 881721 82793607 305568 97893 29643 94076141 31250 92561 30756 75537 940 883600 830584000 30557 97934 59441 93331373 312305 30756 755735 941 885461 830584000 30557 97932 2955.5 69415 941 94076141 313209 99363 3075.6 755837 941 885461 8313739 31256 69375 69415 94076141 313209 99363 3075.6 755837 941 885461 8307 20615 9073 69639 94076141 313209 99363 3085.0 755837 945 89136 846769 94407614 313209 9365.0 3075.6 75737 945 89205 8412338 3077.6 97120 955671625 3097.6 75		936		820025856	30.5941	9.7819	2940.5	088084	930	0/6	0/079690	929/141/0	31.2210	0 0007	3060.2	740685	017
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930 881721 827936019 30.6431 9.790 958441 94813739 31.1890 99299 307.50 75.2783 940 883600 830584000 306594 97959 29551 69334 942 944076141 31.2050 93365 3078.8 754206 941 885481 8330500 306594 97959 29551 69334 942 944076141 31.2305 93955 75823 941 885481 307050 93032 29555 69344 946556 31.3205 939567 75823 945 891135 84570525 97120 944 94665165 31.1406 9545 70013 760465 945 899135 307743 98167 77435 986239 972165 95445 70013 70745 944 891136 57784 9807 77735 98177 70330 985 955671655 31.0405 976 756761 944 89171364 771654<		938		825293672	30.6268	9.7889	2946.8	691028	938	8/6	950484	935441352	31.2/30	1076.6	30/2.0	17710/	0/0
940 833600 833651800 306594 77959 2953.1 69378 940 980 960400 941192000 31.3050 93365 3081.9 755337 941 8835481 833.327621 30657 97939 2955.5 641324 946066168 31.3050 99365 3081.9 755337 942 8873454 835601807 30.703 2805.5 693415 942 9664369 944076141 31.3205 99363 3081.9 755337 943 891346 81306555 30.733 98097 2965.7 69397 944 944076141 31.3205 99363 3081.9 755337 945 993055 30.734 98097 2965.7 69397 9455 955671630 31.3460 99945 765361 946 894015 845709536 30.754 9817 70730 949 966526 31.4463 99365 31.4463 99945 765013 947 89497046 867.97194		939	881721	827936019	30.6431	9.7924	2950.0	692502	939	979	958441	938313739	31.2890	9.9295	3075.0	752758	5/5
940 883560 8.3058400 30.554 9.7953 29531 653978 940 981 964105 31.1305 93363 3081.9 75378 941 8835481 833237521 30575 97933 3081.9 755837 942 887364 83561807 30.7033 98033 29555 659415 941 981 94666168 31.3309 993963 3050.0 3081.9 755378 944 891136 841232384 30.0371 98037 944 94666168 31.3309 3081.9 755372 945 893015 8450055 30.7409 98121 966239 97166 953555 944665183 31.0405 95467 75013 945 893015 8457015 8107714 98107 29714 968355 31.0405 95555 3109.6 755414 944 899701 85171392 307465 98107 297146 964430272 31.4643 99665 31.0496 31.03.9 7575																	
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943 \$89249 \$83561807 30.7083 9.86515 50323 994967 3088.2 75940 944 \$91136 \$41123384 30.714 98077 944 9813 971565 9555756 955753904 31.3528 99497 3094.5 75013 945 \$993055 30.774 98167 702865 946 987 971595 9555756 31.4067 99497 3094.5 76111 945 \$993055 30.774 98177 701380 946 987 971616 955566 31.4066 99531 3097.6 765561 945 \$99509 \$447 986 9827313 30.774 98060 31.4166 99531 310076 765161 949 \$99509 \$8477049 9817 70380 9449 99666 3110.2 769769 31038 766662 769769 31038 76966 3113.3 774441 77441 77441 77441 77441 77441 77441 77441 77441 77441 77441 77441 77441 77441 77441		942	887364	835896888	30.6920	9.8028	2959.4	696934	942	982	964324	946966168	31.3369	9.9396	3085.0	757378	982
944 F91136 841132384 30.7146 98075 50987 944 968256 955671625 31.3647 99464 3091.3 760466 3091.45 75013 945 593025 843908625 30.751 98167 701380 945 955571625 31.3647 99497 3097.65 755013 946 894015 84590536 30.751 98167 701380 945 97516 9555671625 31.3647 99495 755111 946 894015 84570349 948 97116 955671625 31.4166 99556 3100.8 760769 948 89609 851971392 30.8251 98339 98144 964530272 314.45 99656 3110.2 769769 949 90660 85.537730 20813 20813 99712 96736166 9723165 31448 99656 3110.2 769769 949 90660 38.5477349 98333 20813 971169 9731675 99533 3110.2 769769 950 902660 38.5477348 31.4463 <t< td=""><th></th><td>943</td><td>889249</td><td>838561807</td><td>30.7083</td><td>9.8063</td><td>2962.5</td><td>698415</td><td>943</td><td>983</td><td>966289</td><td>949862087</td><td>31.3528</td><td>9.9430</td><td>3088.2</td><td>758922</td><td>983</td></t<>		943	889249	838561807	30.7083	9.8063	2962.5	698415	943	983	966289	949862087	31.3528	9.9430	3088.2	758922	983
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2. Common Logarithms

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17 0.00495 0.99999 0.2240 99974 0.0384 .99911 0.5727 .99836 0.7485 .99719 42 18 0.0524 .99998 0.2226 .99974 .04042 .99918 .05756 .99833 .07527 .99716 41 10 .00532 .99998 .02236 .99972 .04104 .99911 .05814 .99829 .07535 .99712 34 12 .00640 .99998 .02345 .99772 .04100 .99913 .05844 .99829 .07545 .99710 38 21 .00669 .99998 .02443 .99971 .04139 .99911 .05980 .98224 .07614 .99703 .36 25 .00727 .999997 .02501 .999010 .04246 .99911 .05980 .98221 .07701 .997013 .43 26 .00755 .999997 .02560 .99976 .04346 .99901 .06017 .99811 .07787 .99663 .2437 .99917 .07785 .99663 .2431 .99964												
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24 .00698 .99998 .02443 .99970 .04188 .99911 .05960 .99821 .07701 .99705 .35 25 .00727 .99997 .02472 .99969 .04216 .99911 .05960 .99821 .07730 .99701 .34 27 .00755 .99997 .02530 .99966 .04217 .99900 .06018 .99817 .07738 .99696 .32 28 .00844 .99996 .02589 .99966 .04333 .99906 .06134 .99817 .07875 .99692 .0 31 .00902 .99996 .02647 .99965 .04321 .99810 .06134 .99817 .07875 .996923 33 .00900 .99996 .02761 .99963 .04449 .99901 .06132 .98801 .07875 .99682 .27875 .99633 .04449 .99901 .06122 .99804 .07875 .99680 .253 .01018 .99595 .02763 .99963 .04478 .99900 .06122 .99804 .07875 .99680 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>												
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45.4896         0.3990         2.55.417         0.5662         17           224.558         0.2111         45.2261         0.3999         2.5.2644         0.5676         17           224.558         0.2211         45.2261         0.3999         2.5.2644         0.5766         17           224.486         0.22240         44.6386         0.3999         2.5.2644         0.5766         17           200.219         0.22340         4.5.2261         0.3996         2.5.	163.700         02357         42.4335         0.4104         24.3675         05854         17           156.259         02386         41.9158         04104         24.3675         05854         17           143.265         02415         41.4106         04101         24.3675         05883         16           143.265         02415         41.4106         04101         23.4055         05941         16           113.7507         02475         40.9174         04101         23.6995         05941         16           117.507         02476         40.9174         04101         23.6995         05991         16           117.2714         02302         39.9659         04220         23.51718         06099         16           112.774         02360         39.0559         04307         23.31718         06099         16           112.774         02360         39.0559         04307         23.31718         06099         16           112.774         02360         39.0559         04307         23.21717         060156         16           112.774         02360         39.0559         04307         23.21718         06039         16           1	110.892         0.2648         37.7686         0.4395         22.7519         0.6145         16           107.426         0.2667         37.3579         0.6434         22.6070         06145         16           101.107         0.2751         37.3579         0.6444         22.6021         06115         16           101.107         0.2735         36.567         0.4434         22.6021         06123         16           98.2179         0.2735         36.3677         0.4483         22.1640         06223         15           99.82179         0.2793         35.8076         0.4451         22.1640         06221         15           99.82179         0.2764         35.8076         0.4512         22.1640         06221         15           99.82179         0.2783         35.8076         0.4512         22.1671         06221         15           99.4633         0.2822         35.6130         04570         21.813         06321         15           90.4656         0.2832         35.6958         04558         21.7476         05439         15           90.4568         0.2831         35.0658         04558         21.4704         05408         15	83.8435         0.02939         34.0273         0.4667         21.3369         0.6637         11           78.1347         0.2968         33.6535         0.4716         21.2049         0.6496         11           78.1347         0.2906         33.6535         0.4716         21.2049         0.6496         11           78.1343         0.3026         33.6452         0.4716         21.2049         0.6536         13           78.1360         0.3026         33.6452         0.4716         20.9460         0.6525         13           76.3907         0.3026         33.7421         0.4802         20.8189         0.6525         13           76.1390         0.3025         0.3114         32.1181         0.4802         20.5691         0.6613         17           71.1519         0.3114         31.8126         0.4802         20.5691         0.6613         17           71.1513         0.3114         31.8226         0.4920         20.3553         0.6671         18           71.1513         0.3112         31.8226         0.49920         20.3553         0.6671         18           71.1513         0.31201         31.2416         0.49992         20.3566         0.6671	30 9599         04978         20 0872         06730         14           30 416         05007         199702         06730         14           30 416         05007         197403         06877         14           30 1446         05006         197403         06817         14           30 1446         05006         197403         06817         14           30 1446         05006         197403         06817         14           30 1446         05095         197403         06817         14           29 1711         05095         194051         06805         14           29 3771         05153         194051         06905         14           29 3771         05112         191879         06905         14           28 8771         05121         191879         06905         14           28 8751         05121         191899         06905         14           28 8751         05121         191899         06905         14           28 8751         05121         191899         06905         14	mg Catang Tang Catang Tang 87.
Tang Canang Tang Canang Tang	Infinities         01746         57.2900         03492         28.6363         05241         19           137.75         01774         57.3906         03492         28.6363         05241         19           1718.87         01774         55.3906         03347         28.5394         05270         18           1115.57         01804         55.4415         03570         28.1664         05299         18           1145.92         01803         54.5613         03579         28.1664         05299         18           1145.92         01803         54.5613         03579         28.7994         05378         18           6859.436         01862         23.7086         27.7117         05338         18           6875.439         01861         23.7080         03569         27.7117         05338         18           5672.949         01862         27.821         03567         27.7117         05337         18           577.957         01920         52.8007         03657         27.7117         05347         18           577.957         01920         52.8007         03667         27.7117         05347         18           577.9755         019	4.91.10         0.978         0.1.978         0.1.078         0.1.078         0.1.078         0.1.078         0.1.078         0.1.078         0.1.078         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017         0.1.017        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137.507         02478         004358         04220         23.6945         05901         16           137.507         02478         004328         04220         23.5346         05901         16           137.74         02560         39.0595         04279         23.31718         06029         16           122.774         072560         39.0595         04337         23.2171         06028         16           122.774         072560         39.0565         04337         23.2171         06028         16           118.40         02260         39.0565         04336         23.9037         06016         16           1118.490</td><td>110.892         .02648         37.7686         .04395         22.7519         .06145         16           107.426         .02677         37.3550         .04434         22.6020         .06145         16           101.107         .02735         .35.567         .04434         22.6020         .06155         16           101.107         .02735         .36.567         .04434         .22.6020         .06155         16           98.2179         .02735         .36.567         .04433         .22.6020         .06153         16           98.2179         .02735         .36.567         .04433         .22.1640         .06231         15           92.4195         .02793         .35.8006         .04512         .22.1640         .06231         15           92.4813         .02821         .35.6413         .04570         .21.7426         .06321         15           92.4813         .02821         .35.6413         .04570         .21.813         .06321         15           92.4813         .02810         .04558         .04558         .04536         .05391         15           92.4813         .02810         .04558         .04558         .04536         .05391         15</td><td>01193         83,4435         02939         34,0273         04667         21,3369         06437         11           01222         81,8470         02968         33,6935         04716         21,2049         06496         11           01280         78,1263         03026         33,6935         04716         21,2049         06496         11           01380         78,1263         03026         33,6932         04714         20,9460         06525         15           01309         76,1960         03026         33,0452         04774         20,9460         06525         15           01309         76,1960         03026         32,713         04802         20,6193         065354         15           01367         73,1181         04802         20,5691         06613         16         06413         11         11         11         11         11         11         11         11         11         11         11         11         12         16         06613         16         06613         16         11         11         11         11         11         11         11         11         11         11         11         11         11         <td< td=""><td>0019         03230         30 9599         04978         20 0872         06730         14           1055         0.3229         30.6823         05007         19,9702         06730         14           5550         0.3317         30.1446         05006         19,9703         06617         14           5557         0.3117         30.1446         05006         19,9703         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5092         03146         29,8723         05124         19,5756         06876         14           5082         03405         29,8721         05123         19,4051         06896         14           2038         03405         29,112         05123         19,2939         06905         14           20591         03482         19,2123         19,2939         06905         14           2041         05112         19,2939         06905         14         29,005         14         14           2040         05182</td><td>Teng Colong Teng Colong 1000</td></td<></td></th0.117<></th0.117<></th0.117<>	163.700         07337         24.4335         04104         24.3675         05854         17           156.259         07386         41.9158         04104         24.3675         05883         16           156.259         07386         41.9158         04131         24.1957         05883         16           149.465         07346         00174         04191         24.3673         05883         16           137.507         02444         409174         04191         24.3693         05941         16           137.507         02478         004358         04220         23.6945         05901         16           137.507         02478         004328         04220         23.5346         05901         16           137.74         02560         39.0595         04279         23.31718         06029         16           122.774         072560         39.0595         04337         23.2171         06028         16           122.774         072560         39.0565         04337         23.2171         06028         16           118.40         02260         39.0565         04336         23.9037         06016         16           1118.490	110.892         .02648         37.7686         .04395         22.7519         .06145         16           107.426         .02677         37.3550         .04434         22.6020         .06145         16           101.107         .02735         .35.567         .04434         22.6020         .06155         16           101.107         .02735         .36.567         .04434         .22.6020         .06155         16           98.2179         .02735         .36.567         .04433         .22.6020         .06153         16           98.2179         .02735         .36.567         .04433         .22.1640         .06231         15           92.4195         .02793         .35.8006         .04512         .22.1640         .06231         15           92.4813         .02821         .35.6413         .04570         .21.7426         .06321         15           92.4813         .02821         .35.6413         .04570         .21.813         .06321         15           92.4813         .02810         .04558         .04558         .04536         .05391         15           92.4813         .02810         .04558         .04558         .04536         .05391         15	01193         83,4435         02939         34,0273         04667         21,3369         06437         11           01222         81,8470         02968         33,6935         04716         21,2049         06496         11           01280         78,1263         03026         33,6935         04716         21,2049         06496         11           01380         78,1263         03026         33,6932         04714         20,9460         06525         15           01309         76,1960         03026         33,0452         04774         20,9460         06525         15           01309         76,1960         03026         32,713         04802         20,6193         065354         15           01367         73,1181         04802         20,5691         06613         16         06413         11         11         11         11         11         11         11         11         11         11         11         11         12         16         06613         16         06613         16         11         11         11         11         11         11         11         11         11         11         11         11         11 <td< td=""><td>0019         03230         30 9599         04978         20 0872         06730         14           1055         0.3229         30.6823         05007         19,9702         06730         14           5550         0.3317         30.1446         05006         19,9703         06617         14           5557         0.3117         30.1446         05006         19,9703         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5092         03146         29,8723         05124         19,5756         06876         14           5082         03405         29,8721         05123         19,4051         06896         14           2038         03405         29,112         05123         19,2939         06905         14           20591         03482         19,2123         19,2939         06905         14           2041         05112         19,2939         06905         14         29,005         14         14           2040         05182</td><td>Teng Colong Teng Colong 1000</td></td<>	0019         03230         30 9599         04978         20 0872         06730         14           1055         0.3229         30.6823         05007         19,9702         06730         14           5550         0.3317         30.1446         05006         19,9703         06617         14           5557         0.3117         30.1446         05006         19,9703         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5992         0.3117         30.1446         05006         19,7403         06617         14           5092         03146         29,8723         05124         19,5756         06876         14           5082         03405         29,8721         05123         19,4051         06896         14           2038         03405         29,112         05123         19,2939         06905         14           20591         03482         19,2123         19,2939         06905         14           2041         05112         19,2939         06905         14         29,005         14         14           2040         05182	Teng Colong Teng Colong 1000

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	6ue I	.26795 .26826 .26857	.26920	26951	.27013	27044	000000	.27169	.27201	.27263	27326	.27357	.27419	.27451	.27513	27545	.27607	.27670	.27732	.27764	.27795	.27858	.27921	.27983	.28015	.28077	.28140	.28172	.28234	.28297	.28329	.28391	28454	.28480	28549	.28612	.28643	Sucie).	74
1.1	Letong	4.01078 4.00582 4.00086	3.99592	3.98607	3.97627	3.96651		3.95196	3.94713	3.93751	3.93271	3.92316	3.91364	3.90890	3.89945	3.89474	3.88536	3.87601	3.87136 3.86671	3.86208	3.85745 3.85284	3.84824	3.83906	3.82992	3.82537 3.82083	3.81630	3.80726	3.79827	3.79378	3.78485	3.78040	3.77152	3.76268	3.753828	3.74950	3.74075	3.73205	Tang	0
	6uo:	24933 24964 24995	.25026	25087	.25149	.252180		.25304	.25335	25397	25459	25490	.25552	.25583	.25645	.25676	.25738	.25800	.258831	.25893	25924	.25986	.26048	.26110	.26141	26203	.26266	.26297	.26359	.26421	.26452	.26515	.26577	.26639	26701	.26733	.26795	Cotang	75
	Cetong	4.33148 4.32573 4.32001	4.30860	4.30291	4.29159	4.28595		4.26352	4.25795	4.24685	4.24132	4.23030	4.21933	4.21387	4.20298	4.19756	4.18675	4.18137	4.17064 4.16530	4.15997		4.14405			4.11778 4.11256	4.10736	4.09699	4.09182	4.08152	4.07127	4.06616	4.05599	4.04586	4.04081	4.03075	4.02074	4.01576	Tang	0
1	6u01	.23087 .23117 .23148	.23179	.23240	.23301	.23332		23455	.23485	.23547	23578	.23639	.23670	.23731	.23793	.23823	.23885	.23946	.23977	.24039	.24069	24131	24193	.24254	.24285	.24347	.24408	24470	.24501	24562	.24593	.24655	.24717	.24747	24809	.24871	24902	Celang	76
	Celang	4.70463 4.69791 4.69121	4.68452 4.67786	4.67121	4.65797	4.65138		4.62518	4.61868	4.60572	4.59927	4.58641	4.58001	4.56726		4.54826	4.53568	4.52941	4.51693		4.49832	4.48600	4.47374	4.46155	4.45548	4.44338	4.43135	4.41936	4.41340	4.40152	4.39560	4.38381	4.37207	4.36623	4.35459	4.34300	4.33723	Tang	0
	Bung	.21256	21347	21408	21469	.21529	00517	215390	.21651	.21712	21743	.21804	21834	.21895	21956	.21986	22047	22108	.22139	.22200	22231	.22292	22353	.22414	.22444	.22505	.225567	22628	.22658	.22719	.22750	.22811	22872	22934	.22964	23026	.23056	Cetang	11
	T	0-0	m 4	5			2	12	13	15	16	18	50	21	23	24	56	28	30	31	32	34	36	38	39	41	43	44	40	- 00	50	15	23	* 55	56	28	609	1.	
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0	Colong	5.14455 5.13658 5.13658					+9:00.5	5.05809	5.04267	5.02734	5.01971	5.00451	4.99695	4.98188	4.96690	4.95945	4.94460	4.93721	4.92249	4.90785	4.90056	4.88605	4.87162	4.86444	4.85013	4.83590	4.82682	4.81471	4.80068	4.79370	4.77978	4.76595	4.75906	4.74534	4.73170	4.71813	4.71137	Tene	0
=	I	19438	.19529	.19589	19649	.19680	0+/61	19801	.19831	19891	19921	19982	.20012	.20073	20103	20164	20224	20254	20315	.20376	20406	20466	20527	20557	20618	.20679	20709	.20770	.20830	.20861	.20921	.20982	.21013	.21073	21134	21195	21225	Cetene	
0	Coloma	5.67128 5.66165 5.65205	5.64248	5.62344	5.F1452	5.59511 5.58573	900/0.0	5.56706	5.54851	5.53007	5.52090	5.50264	5.49356 5.48451	5.47548	5.45751	5.44857	5.43077	5.42192	5.40429	5.38677	5.37805	5.36070	5.34345	5.33487	5.31778	5.30080	21 64	64.6	4 64	300	5.23391 5.22566	2	5.20925	5.19293	5.17671	5.16058	5.15256		0
01	Lang	.17633	.17723	.17783	.17843	.17873	CC6/1-	17963	18023	18083	.18113	.18173	18203	.18263	.18323	18353	18414	.18444	.18504	18564	18594	.18654	16714	.18745	18805	.18865	.18925	.18955	190161	.19046	.19106	.19166	.19197	.19257	19317	19347	.19408	Colone	74
	Catang	6.31375 6.30189 6.29007	23	25	53	202	5	20 -	-	17	12	101	6.09552 6.08444	01	000	10	00	88	5.97576	96	56	6	56	808	5.87080	5.86051	5.85024	5.82982	5.80953	5.79944	5.77936	5.75941	5.74949	5.72974	5.71013	5.69064	5.68094	5	0
• [	Inter	.15838 .15868	.15928	15988	16047	.16107	16101.	16167	.16226	.16286	.16316	.16376	.16405	.16465	.16495	.16555	.16615	.16645	16734	16764	.16794	16854	.16914	16944	.17004	.17063	17123	.17153	.17213	.17243	.17303	.17363	.17393	.17453	.17513	17573	.17603		- 6
	Catal	7.11537 7.10038 7.08546	7.05579	7.04105	7.01174	604	0.90623	6.95385	6.92525	6.89688	6.88278	6.85475	6.84082	6.81312	6.79936	6.77199	6.74483	6.73133	6.70450	6.67787	6.66463	6.63831	6.61219	6.59921	6.57339	6.54777	6.53503	6.50970	6.48456	6.45961	6.44720	6.42253	6.41026	6.38587	6.36165	6.33761	6.32566		1
•	I	14054	.14143	14202	14262	14291	16641.	14410	14440	14499	.14529	14588	.14618	.14678	14737	.14767	.14826	14856	14945	14075	.15005	15064	.15124	.15153	.15213	.15272	.15302	.15362	15421	.15451	.15511	.15570	.15600	.15660	15719	97721.	15809	Ceteme	10
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Corners	3 24444	2.35205	2.35015	2.34636	2.34258	2.34069	2,33693	3 3 3 8 6 4 6	2.33317	2.33130	2.32943	2.32570	2.32383	2 32012	2.31826	2.31641	2.31456	2.51/11	2.30902	2.30718	2.30534	2.30167	2.29984	2.29801	2.29437	2.29254	2.28891	2.28710	2.28528	2.28167	2.27987	2.27626	2.27447	2.27088	2.26909	2.26552	2.26374	2.26196	2.25840	2.25663	2.25309	2.25132	2.24780	2.24604	t.	0
Ī	74474	42516	425581	42619	42688	.42722	42757	47874	42860	42894	42929	42998	43032	19064	43136	43170	.43205	42224	43308	13343	43378	43447	18955.	.43516	43585	43620	P2024	43724	43758	.43828	43862	43932	.43966	44036	44071	44140	.44175	44210	44279	44314	44384	.44418	44488	.44523	Colony	3
Cateng		2.47302	2.46888	2.46476	2.46065	2.45860	2.45451	2 46746	2.45043	2.44839	2.44636	2.44230	2.44077	2.45825	2.43422	2.43220	2.43019	2.42819	2.42418	2.42218	2.42019	2.41620	12515.2	2.41223	2.40827	2.40629	2.40432	2.40038	2.39841	2.39449	2.39253	2.38.862	2.38668	2.38279	2.38084	2.37697	2.37504	2.37311	2.36925	2.36733	2.36349	2.36158	2.35976	2.35585	Inny	2
Inny		40401	40504	40572	40640	40674	40707	40776	40809	40843	40877	51604	40979	1019	41081	.41115	41149	-1183	41251	41285	41319	41387	12414.	.41455	41524	41558	41626	41660	41728	41763	79714.	418.51	41899	41955	42002	42070	42105	42139	41207	41242	42310	42345	11724	42447	Cotung	63
Column		2.60509 2.60283 2.60057	2.59606	2.59381	2.59130	2.58708	2.58484	5 6803.8	2.57815	2.57593	2.57371	2.56928	2.56707	2.56487	2.56046	2.55827	2.55608	2.55389	2.54952	2.54734	2.54516	2.54082	2.53865	2.53648	2.53217	2.53001	2 52571	2.52357	2.52142	2.51715	2.51502	2.51289	2.50864	2.50440	2.50229	2.49807	2.49597	2.49386	2.48967	2.48758	2.48340	2.48132	2.47924	2.47509	long	2
I		38186 38420 38453	.38487	38553	38620	38654	38721	1076.0	38787	12882	-SHSA	17681	38955	SCOOL	19055	39089	39122	39156	29223	39257	0676E	39357	16565	39425	19492	39526	10505	39626	39660	12795	39761	56795 92898	39862	06965	39963	15004	40065	40098	99105	40200	40267	10201	40169	40403	Conneg	3
Cotone		2.74748 2.74299 2.74251	2.73756	2.73509	2.73017	2.72771	2.72526	. 91016	2.71792	2.71548	2.71305	2.70819	2.70577	2.70335	2.69853	2.69612	2.69371	1.69131	2.68653	2.68414	2.68175	2.67700	2.67462	2.67225	2.00989	2.66516	2.66046	2.65811	2.65576	2.65109	2.64875	2.64642	2.149.2	2.63714	2.6.1483	2.63021	2.62791	2.62561	262103	2.61874	2.61418	2.61190	2 60716	2.60509	famil	£.0
Tomy		36430	36496	36562	36628	36661	.36727	10000	36793	36826	36859	36925	36958	16695	37057	37090	.37124	37157	37223	37256	37289	37355	37388	37422	37488	37521	17588	37621	17687	37720	37754	378787	17853	37920	19533	38020	12085.	38086		-	-	_		-	Catoring	53
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J		2.996/3	2.99400	2.09055	2.00511	2.86240	2.67700	01010	2.87161	2.86892	2.86624	2.96099	2.85822	2.85555	2.45023	2.84758	2.84494	2.84229		2.63439	2.43176	2.82653	14623.5	2.82130	2.515/0	2.81350	2.51091	2.80574	2.80316 2.80316	2.79802	2.79545	2.79285	2.78778	2.72260	2.78014	2.77507	2.77254	2.77002	2.76496	2.76247	2.75746	2.75496	2.75246	2.74748		•
1			34530	34596		1	14726			14856			19646.	13019	15005	71125.	35150	.35185	35248	35281	1152	15379	21455	35455		.35543	35576	INSE.	.35674	35740	35772		35671		5965	36035	36065	36101	36167	.36199	36265	36298	16695.	16196	J	2
J		3.07764 3.07464 3.07160	3.066554	3.06252	3.05950	3.05349	3.05049			3.03054	3.03556	3.02963	3.02667	3.02372	3.01783							2.99156							2.96573		2.95721	2.95437	2.94872	2.94890	2.94028	2.93748 2.93468	2.93189	2.92910	2.92354	2.92076	2.91523	2.91246	2.90971	2.90421	Ĩ	•
		32524 32524 32556	32508	.32653	1111	32749	32702		STATE.	11625	.329A3	33007	1000	13072	35155	13166	33201	33233	11200	OELEC	.33363	33427	.33460	33492	\$25E	33569	33621	33666	33718	1170	31966.	33848	1965	33945	34010	14045. 14075	34106	34140	34205	34238	0/745	24335	34368	5644E	J	7
J		3.27085 3.26745 3.26406	~ ~				~ ~								3.20406			_	_		-	3.17481	_	_	_	_	_		_	3.13972	_					3.11464		3.10532		•••		•	9,0		1	
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J		3.48741 3.48359 3.47977	3.47596	1.46837	3.46458	1.45703	3.45327		3.44576	3.43629	3.43456	3.43064	3.42343	3.41973	3.41604		3.40502	3.40136	3.39771	3.39042	3.38679	3.37955	3.37594	3.37234	3.36875	3.36156	3.35000	1 15067	3.34732	3.34023	3.33670	3.33317	3.32614	3.32264	3.31565	3.31216		3.30174								
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Cotema		66318 56318 56200	66099	06659.1	1.65881	2//2011	00000		C++C0.	1.65337	85338	07770	11059	100079	20243	26/107	100101	1242	19292	1.64256		1.64148	1.64041	1.63934	079201	61/201	1.03012	1.63505	1.03398	1.03292	1.03185	1.63079	1.62972	1.62866	1 62760	429691	1 62548	1 62442	1.62336	1.62230	1.62125	1 62019	1.61914	1.61808	1.61703	1.61598	1.61493	1.01388	1.01283	1 61074		1.60970	1.60865	10/001	100001	00000	1 60345	1.60241	1.60137	1.60033	Teme	0
Tana		.60126	60205	.60245	.60284	60324	+0000	50400-	00443	.60483	60533	77500	10000	20000	74000	19000	17/00.	10/007	10000	18809		.60921	.60960	.61000	01040	01080	07119	.61160	.61200	.61240	.61280	.61320	61360	61400	61440	61480	61520	61561	61601	.61641	.61681	61771	61761	.61801	.61842	.61882	.61922	29619	50070	52029		.62124	.62164	+0770-	20000	20770.	62366	62406	62446	.62487	Column	9
Cetane		1.73089	1.72857	1.72741	1.72625	1.72509	1./2393	8/77/1	1.//103	1.72047	. 71022	2061/-1	1101/1	101111	1.11366	1.71473	1.71358	4671/1	21012	10001		1.70787	1.70673	1.70560	1.70440	1.70332	1.70219	1.70106	1.69992	1.69879	1.69766	1.69653	1 69541	1 60428	912091	200091	1 60001	1 68979	1 68866	1.68754	1.68643	1 69631	1.68419	1.68308	1.68196	1.68085	1.67974	1.67863	1.67752	1.070.1		1.67419	1.67309	1.67198	220/07	2/600.1	1.00001	1 66647	1.66538	1.66428	Tame	0
Tana		57775	57851	.57890	57929	57968	28007	58040	.58085	.58124	10100	70192	10792.	04795	6/792	.58318	58357	06585	22422	11585		.58552	16585.	.58631	.58670	.58709.	.58748	.58787	.58826	.58865	*068S*	58944	58083	00005	19005	10105	20140	50170	50218	59258	.59297	20236	59376	.59415	. 59454	.59494	.59533	.59573	-20012	10905	TENEC.	.59730	.59770	60865	64865	28885	27666	20009	60046	60086	Colours	
Cetane		1.80405	80034	11662.1	1.79788	1.79665	1.79542	1.79419	1.79296	1.79174		1006/1	6769/-1	1./880/			1.78441		96192	1.7055		1.77834	1.77713	1.77592	1.77471	1.77351	1.77230	1.77110	1.76990	1.76869	1.76749	1.76630	1 76510	1 76300	11031	1 76151	1 76027	1 75013	1 75704	1.75675	1.75556		1.75319	1.75200	1.75082	1.74964	1.74846	1.74728	1.74610	1.74492	CICLI-1	1.74257	1.74140	1.74022	1.73905	1.73788	1 72555	72428	1 73321	1.73205	1	0
Tana		.55469	-	_		40.000	-	-		_		.55850	992267	07655	10055	.56003	.56041	50019	11100	00100		.56232	.56270	.56309	.56347	.56385	.56424	.56462	.56500	.56539	.56577	\$6616	1000	10993	16.93	10100	80895	94845	28895	56923	.56962	6 7000	57039	.57078	.57116	.57155	.57193	.57232	.57271	-57509	8401C.	.57386	.57425	-57464	50525	14675-	080/22	13915	27696	57735	Calman	
Catana	Aunter	1.88073	1.87677	1.87546	1.87415	1.87283	1.87152	1.87021	1.86891	1.86760		1.86630	1.80499	1.80309	1.86239	1.86109	1.85979	1.85850	1.85720	165581	70400.1	1.85333	1.85204	1.85075	1.84946	1.84818	1.84689	1.84561	1.84433	1.84305	1.84177	1 84040	1.01079	1.0776	1.00.1	100000.1		21100T	1.82150	83033	1.82906	. 60.00	1.82654	1.82528	1.82402	1.82276	1.82150	1.82025	1.81899	1.81774	ALO10-1	1.81524	1.81399	1.81274	1.81150	1.81025	10608-1	1100.1	1 80520	1.80405		
Taxa I	-	53171	53240	53320	53358	.53395	.53432	.53470	.53507	53545		.53582	.53620	153657	+69ES.	.53732	.53769	.53807	.53844	.53882	07600.	53957	53995	.54032	.54070	.54107	.54145	.54183	.54220	.54258	.54296	11113	14673	11040	50000	04440		17CLC.	10212	14645	54673		24748	54786	54824	.54862	.54900	54938	.54975	.55013	TENES.	55089	.55127	.55165	.55203	.55241	6/200	11000	10133	15432		
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	1	60 59	28	10	000	54	23	52	15	205		49	48	47	46	45	++	43	42	41	40	-	-	-	-	-		-	-	-	30	-	29	28	-	-	-	-		12	-	-	6	-	-	-	-	-	-	-	-	•		-	0	5	**	• •	-	- 0	+	-
	Cotang	1.96261	1.95979	1.95838	1.95557	1.95417	1 95277	1.95137	1 94997	1 94858		1.94718	1.94579	1.94440	1.94301	1.94162	1.94023	1.93885	1.93746	1.93608	1.93470	1 03333	201101	1 93057	1.92920	1 92782	1 92645	1 92508	1.92371	1 92235	1.92098		1.91962	1.91826	1.91690	1.91554	1.91418	1.91282	1.91147	1.91012	1.90741		1.90607	1 90337	1 00200	1.90069	1.89935	1.89801	1.89667	1.89533	1.89400	1.89266	1.89133	1.89000	1.88867	1.88734	1.88602	10100.1	100001	1.88073		
270	Tang	50953	.5:026	.51063	86015	51173	00/15	51246	51.783	61310		.51356	51393	51430	.51467	51503	.51540	.51577	.51614	.51651	.51688	1734	51761	51798	51835	51872	00015	97615	519K3	07075	52057		.52094	.52131	.52168	.52205	.52242	.52279	.52316	52353	52427		.52464	81965	37362	52613	52650	.52687	.52724	.52761	.52798	52836	.52873	.52910	.52947	.52984	-53022	ACOCC.	WELES	12165		
	Cotang	2.05030	2.04728	2.04577	075470	2 04125	2 010 75	201875	2 02675	901020		2.03376	2.03227	2.03078	2.02929	2.02780	2.02631	2.02483	2.02335	2.02187	2.02039	10010 0	24210.5	201596	01440	101 10 0	11155	800107	1 00860	2 00715	2.00569		2.00423	2.00277	2.00131	1.99986	1.99841	1.99695	1.99550	1.99406	107661		1.98972	1 04644	1 08540	1 98196	1.98253	1.98110	1.97966	1.97823	1.97680	1 97538	1.97395	1.97253	1.97111	1.96969	1.96827	1.90063	CU190 1	1 96261		
26	Tang	48809	48345	18881	11684	45989	40016	40062	40008	TEIDE	LOIL.	49170	49206	49242	49278	40115	19361	49387	19423	49459	56161		10224	FUYDE	49640	10677	10713	10740	40786	CCN08	49858		49H94	49931	49967	: +0005.	.50040	.50076	-50113	-50149	CCC05		.50258	CA20C	100000	80404	50441	50477	\$150S.	.50550	.50587	\$0623	50000	.50696	.50733	.50769	.50806	5480C.	\$190C.	15005		
2	Catong	2.14451	4	-	-							_	-	-	-			-	-	2.11392	_						17				2.09654		0	0	0	9	9	2.08716	9	0,0	2 08094		2.07939	2.0		20	20	-	-	2.06706	~	2 06400								2010202		[
35	Tang	46631			- 40							47021	47056	47002	47128	47163	47196	47234	47270	47305	14241		11515.	27448	47483	01325	47555	00524	96924	12011	47698		.47733	.47769	47805	47840	.47876	.47912	47948	47984	21084-		16081	17124-		41.104	48270	48306	.48342	48378	48414	ARASO	48486	.48521	.48557	.48593	48629	48005	10/84-	12/24		
2	Cetang	2.24604	2.24252	2.24077	2.23902	12152.2	01010	1000000	01010	2.23030	10077.7	2 22681	2 22510	72226 6	1 22164	1 2 2 1 0 0 1	2 21810	2 21647	2.21475	2.21304	2.21132		10407.7	01907.7	1 10440	8107.7	80101 6	210010	010100	1 10500	19430		2.19261	2.19092	2.18923	2.18755	2.18587	2.18419	2.18251	2.18084	2.17740		2.17582	-		-			-	-	-	2 1 502 5	2.15760	2.15596	2.15432	2.15268	2.15104	2.14940	2.14777	1.14614		[
24	Imi	44523		-		-		-			-	44007	44047	11011	1010	11001	10000			45187			10224	26765	192251	10001	16005	10104	10101	10004	12524		45608	45643	45678	.45713	45748	45784	45819	.45854	V8864.		45960	CAACT.	00004	10194	10104-	:6171	46206	.46242	.46277	46113	46148	46383	.46418	46454	46489	.46525	90200	CACUS.		5
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87031         114995         90003         110995         931360         107117         59         7         96681         101493         59         21           87031         114695         90195         110857         93415         10703         53415         10703         53415         10703         53150         107117         57         23151         114675         90195         110877         53151         107493         59152         57         56681         103137         557         235         57         256         2317         57         235         57         256         566907         103137         557         235         235         235         235         256         200137         531         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         237         23
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•	ž	1 0016	1.0075	1.0076	1.0077	1.0078	1.0079	1.0079	1.0080	1.0000	1.0061	1.0082	1.0062	1.0083	1.0083	1.0084	1.0001	1.0065	1.0006	1.0086	1.0087	1.0087	1.0088	1.0089	1.0089	1.0090	1.0090	1.0001	1.0092	1.0092			1.0094	1.0095	1.0096	1.0097	1.0097	1.00 <b>96</b> 1.00 <b>96</b>	Teek		F
	Ż		9.5141	9.4520	9.4105	9.3596	9.3092	9.2842	9.2346	9.2100	9.1612	9.1129	9.0690	9.0414	9.0179	8.9711	8.9479 8.9248	8.9010	8.8790 8.8563	8.8337	8.8112	8.7665	8.7223	8.7004 8.6786	8.6569	8.6138	8.5924	1.2490 1.2490	8.5289 8.5289	8.4871	8.4457	8.4046	8.3843		8.3238	8.2840	8.2012 8.2446	8.2250 8.2055	ž	0	
•	ž		1.0056	1.0056	1.0057	1.0057	1.0058	1.0056	1.0059	1.0059	1.0060	1.0061	1.0061	1.0062	1.0062	1.0063	1.0063	100	1.000	1.0065	1.0065	1.0066	1.0006	1.0067	1.0067	1.0068		-			2283		1.0072	1.0073	1.0073	1.0074	1.0074	1.0075	Ceer.	2	
	Ż		11.396	11.323	11.249	11.176	11.104	11.069	10.988	10.903	10.894	10.826	10.792	10.725	10.692	10.626	10.593	10.529	10.497	10.433	10.402	10.340	10.278	10.248	10.187	10.137	10.096	10.039	10.010	9.9525	9.8955	9.8391	9.8112	9.7558	9.7283	9.6739	9.6409	9.5933	ž	•	
	ž		1.0038	1.0039	1.0040	1.0040	1.0041	110001	100	1.0042	1.0042	1.0043	1.0043	1.0044	1.0044	00	1.0045	.0045	1.0046	1.0046	1.0046	1.0047	1.00	1.0048	1.0048	1.0049	1.0049	1.0050	1.0050	1.0051	1.0051	1.0052	1.0052	1.0053	1.0053	1.0054	1.0054	1.0055	Cett.	3	
	j		14.235 14.276 14.217 14.159	14.101	13.986	13.874	13.763	13.706	13.600	13.547	13.441	13.337	13.286	13.184	13.134	13.034	12.965	12.888	12.840	12.745	12.698	12.606	12.514	12.469	12.379	12.335	12.248	12.204	12.118	12.034	956	11.868	11.828	11.787		11.628		11.512	Şer.	0	
	ľ		1.0024 1.0025 1.0025	1.0025	1.0026	1.0026	1.0026	1.0027	1.0027	1.0027	1.0028	1.0028	1.002 <b>8</b> 1.0029	1.0029	1.0029	1.0029	1.0030	1.0030	1.0030	1.0031	1 0031	1.0032	1.0032	1.0032	1.0033	1.0033	1.0033	1.0034	1.0034	1.0035	1.0035	1.0036	1.0036	1.0036	1.0037	1.0037	1.0038	1.0038	Ceser.	3	
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		ž	1.0014			1.0015		1.0015	1.0016	1.0016	1.0016	1.0016	1.0017		1.0017	1.0018	1.0018	1.0018	1.0018	1.0019	1.0019	1.0019	1.0019	1.0020	1.0020	1.0020	1.0021	1.0021	1.0021	1.0022	1.0022	1.0022	1.0023	1.0023	1.0023	1.0024	1.0024	1.0024	Ceter.	8	F
			28.654 28.417 28.184	27.730	27.290	27.075	26.450 26.450	26.249	26.050 25.854	25.661	25.284	25.100 24 918	24.739		24.216	23.880	23.716	23.393	23.235	22.925	22.774	22.476	22.330	22.044	21.765	21.629	21.360	21.228	20.970	20.717	20.471	20.230	20.112	19.995 19.880	19.766	19.541	19.431	19.214	ž	0	
	"[	ž	1.0006	1.0006	1.0007	1.0007	1.0007	1.0007	1.0007	1.0008	1.000	1.0008	1.0008		1.000	0000	0000	6000	1.0009	1.0009	1.0010	1.0010	1.0010	1.0010	1.0010	1.0011	1.0011	110011	1100.1	1.0012	1.0012	1.0012						1.0014	Ceter	8	
		ġ	57.299 56.359 55.450				49.820	48.422	47.096	46.460	45.237	44.650	43.520	20.00	:8:	28	48		39.069		37.782		<b>~</b> ~	30 ¥	+0	34.729	- 0		0.	32.437	31.836	31.257	30.976	30.428	30.161	29.641	29.388	28.894	ž		
	-[	ž	1.0001	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0002	1.0003		1.0003	1.0003	1.0003	1.0003	1.0003	1.0003					-	1.0004	-	1.0004	1.0004	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0006	1.0006	1.0006	Ceser.	3	
	•	j	Infinite 3437.70 1718.90	859.44	572.96	491.11	381.97	312.52	286.48	245.55	214.86	202.22	180.73		156.26	149.47	137.51	132.22	122.78	114.59	110.90	104.17	101.11 98.223	95.495	90.469	88.149 85.946	83.849	81.853	78.133	74.736	71.622	68.757	67.409	66.113 64.866	63.664	61.391	59.274	58.270 57.299			
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*	Cours. Ter. Cours.	•         1.8361         1.2062         1.7833           16         1.8352         1.2066         1.7855           18         1.834         1.2065         1.7855           18         1.2066         1.7856         1.2865           18         1.2065         1.7867         1.7855           18         1.2076         1.7852         1.2865           18         1.2076         1.7852         1.2865           18         1.2076         1.7852         1.2864           18         1.2076         1.7852         1.2864           18         1.2076         1.7852         1.2864           18         1.2076         1.7852         1.2864           18         1.2076         1.7852         1.2864           18         1.2079         1.7823         1.2816           18         1.2019         1.7823         1.2816           18         1.2016         1.7824         1.2816           1.8         1.2016         1.7824         1.2816           1.8         1.2016         1.7824         1.2816	1         1.208         1.7798           1         1.2091         1.7791           1         1.2093         1.7793           1         1.2093         1.7796           1         1.2093         1.7795           1.8255         1.2093         1.7796           1.8256         1.2093         1.7796           1.8258         1.2096         1.7796           1.8238         1.2093         1.7766           1.8236         1.2103         1.7765           1.8236         1.2103         1.7753           1.8216         1.2105         1.7753           1.8216         1.2105         1.7753           1.8216         1.2107         1.7754           1.8216         1.2107         1.7754	8190         1.2112         1.7723           8182         1.2112         1.7715           8166         1.2119         1.7700           8168         1.2119         1.7700           8158         1.2112         1.7700           8158         1.2112         1.7693           8158         1.2112         1.7663           8158         1.2112         1.7663           8158         1.2122         1.7663           8142         1.2123         1.7667           8134         1.2123         1.7663           8134         1.2123         1.7663           8138         1.2123         1.7663           8138         1.2123         1.7663	8110         1.2136         1.7648         1.2           8004         1.21136         1.7648         1.2           8005         1.21141         1.7643         1.2           8078         1.2144         1.7643         1.2           8078         1.2144         1.7643         1.2           8076         1.2144         1.7643         1.2           8076         1.2146         1.7643         1.2           8076         1.2146         1.7643         1.2           8054         1.2145         1.7643         1.2           8054         1.2153         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7963         1.2           8054         1.2156         1.7964         1.2	8031         1.2161         1.7573         1           8023         1.2164         1.7566         1           8007         1.2163         1.7566         1           8007         1.2164         1.7556         1           8007         1.2164         1.7556         1           7999         1.2173         1.7554         1           7996         1.2173         1.7554         1           7944         1.2173         1.7554         1           7946         1.2176         1.7552         1           7946         1.2176         1.7552         1           7946         1.2176         1.7552         1           7946         1.2178         1.7552         1           7946         1.2178         1.7552         1           7946         1.2183         1.7552         1	7953         1.2185         1.7500         1.2337         1.7935           7945         1.2185         1.7403         1.2340         1.7343           7945         1.2185         1.7403         1.2340         1.7343           7946         1.2193         1.7478         1.2345         1.7345           7941         1.2193         1.7478         1.2346         1.7478           7941         1.2193         1.7478         1.2346         1.7478           7941         1.2193         1.7478         1.2346         1.7456           7946         1.2200         1.7446         1.2346         1.7466           7891         1.2203         1.7445         1.2345         1.7446           7881         1.2203         1.7446         1.2335         1.7446           7881         1.2204         1.7446         1.2345         1.7446	See Coust Sec. Coust.	
°   11°   24	Coust. Soc. Coust. Soc. Coust.	1         1.1924         1.3361         1.2062         1.7835           1         1.1926         1.8336         1.2065         1.7855           1         1.928         1.8334         1.2065         1.7867           1         1.930         1.8334         1.2065         1.7867           1         1.930         1.8334         1.2065         1.7867           1         1.933         1.8334         1.2066         1.7867           1         1.933         1.8328         1.2072         1.7867           1         1.933         1.8328         1.2076         1.7864           1         1.933         1.8328         1.2076         1.7863           1         1.933         1.8313         1.2076         1.7864           1         1.942         1.8313         1.2081         1.7783           1         1.942         1.8287         1.2083         1.7781           1         1.942         1.8287         1.2083         1.7781           1         1.942         1.8287         1.2083         1.7781           1         1.946         1.8287         1.2083         1.7781           1         1.946 </th <th>1.1948         1.8271         1.2088         1.7798           1.1951         1.8263         1.2091         1.7798           1.1953         1.8263         1.2093         1.7798           1.1953         1.8263         1.2095         1.7796           1.1953         1.8263         1.2095         1.7796           1.1953         1.8253         1.8263         1.7796           1.1953         1.8253         1.2095         1.7796           1.1953         1.8238         1.2093         1.7766           1.1954         1.8238         1.2093         1.7766           1.1956         1.8238         1.2103         1.7766           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753</th> <th>971         1.5190         1.2112         1.7723           974         1.8182         1.2112         1.7715           978         1.8167         1.2112         1.7715           978         1.8166         1.2112         1.7700           998         1.8158         1.2112         1.7700           980         1.8158         1.2112         1.7700           981         1.8158         1.2122         1.7603           981         1.8158         1.2122         1.7603           982         1.8153         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8118         1.2123         1.7663</th> <th>994         1.8110         1.2136         1.7648         1.2           997         1.8102         1.2136         1.7648         1.2           9997         1.8102         1.2139         1.7643         1.2           9994         1.8002         1.2144         1.7643         1.2           0004         1.8078         1.2144         1.7643         1.2           0005         1.8076         1.2144         1.7643         1.2           0006         1.8076         1.2144         1.7643         1.2           0101         1.8076         1.2144         1.7643         1.2           0101         1.8076         1.2144         1.7643         1.2           0102         1.8047         1.2153         1.7568         1.2           0113         1.8047         1.2153         1.7568         1.2           012         1.8039         1.2153         1.7568         1.2           013         1.80047         1.2153         1.7568         1.2           013         1.80049         1.2156         1.7568         1.2</th> <th>2017         1.8031         1.2161         1.7573         1           2020         1.8033         1.2161         1.7566         1           20202         1.8033         1.2161         1.7566         1           20202         1.8033         1.2163         1.7566         1           2027         1.8037         1.2166         1.7556         1           2027         1.7999         1.2117         1.7544         1           2021         1.7999         1.2117         1.7544         1           2021         1.7994         1.2117         1.7544         1           2021         1.7994         1.2117         1.7544         1           2021         1.7994         1.2117         1.7549         1           2034         1.7966         1.2118         1.7552         1           2034         1.7966         1.2118         1.7567         1</th> <th>2041         1 7953         1.2185         1.7500         1.2337         1.           2043         1 7945         1.2185         1.7493         1.2346         1.           2044         1 7945         1.2185         1.7493         1.2346         1.           2046         1 7945         1.2185         1.7493         1.2346         1.           2048         1 7949         1.2193         1.7463         1.2346         1.           2050         1 7941         1.2193         1.7478         1.2346         1.           2051         1 7941         1.2193         1.7478         1.2346         1.           2051         1 7941         1.2193         1.7446         1.2346         1.           2053         1 7206         1.7446         1.2333         1.         2065         1.7446         1.2346         1.           2060         1 7891         1.2205         1.7446         1.2345         1.         2065         1.7446         1.2345         1.           2062         1 7841         1.2364         1.7446         1.2345         1.         2.066         1.7446         1.2345         1.  </th> <th>See Cover See Cover Sec. Cover</th> <th></th>	1.1948         1.8271         1.2088         1.7798           1.1951         1.8263         1.2091         1.7798           1.1953         1.8263         1.2093         1.7798           1.1953         1.8263         1.2095         1.7796           1.1953         1.8263         1.2095         1.7796           1.1953         1.8253         1.8263         1.7796           1.1953         1.8253         1.2095         1.7796           1.1953         1.8238         1.2093         1.7766           1.1954         1.8238         1.2093         1.7766           1.1956         1.8238         1.2103         1.7766           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753           1.1966         1.8216         1.2103         1.7753	971         1.5190         1.2112         1.7723           974         1.8182         1.2112         1.7715           978         1.8167         1.2112         1.7715           978         1.8166         1.2112         1.7700           998         1.8158         1.2112         1.7700           980         1.8158         1.2112         1.7700           981         1.8158         1.2122         1.7603           981         1.8158         1.2122         1.7603           982         1.8153         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8126         1.2122         1.7663           982         1.8118         1.2123         1.7663	994         1.8110         1.2136         1.7648         1.2           997         1.8102         1.2136         1.7648         1.2           9997         1.8102         1.2139         1.7643         1.2           9994         1.8002         1.2144         1.7643         1.2           0004         1.8078         1.2144         1.7643         1.2           0005         1.8076         1.2144         1.7643         1.2           0006         1.8076         1.2144         1.7643         1.2           0101         1.8076         1.2144         1.7643         1.2           0101         1.8076         1.2144         1.7643         1.2           0102         1.8047         1.2153         1.7568         1.2           0113         1.8047         1.2153         1.7568         1.2           012         1.8039         1.2153         1.7568         1.2           013         1.80047         1.2153         1.7568         1.2           013         1.80049         1.2156         1.7568         1.2	2017         1.8031         1.2161         1.7573         1           2020         1.8033         1.2161         1.7566         1           20202         1.8033         1.2161         1.7566         1           20202         1.8033         1.2163         1.7566         1           2027         1.8037         1.2166         1.7556         1           2027         1.7999         1.2117         1.7544         1           2021         1.7999         1.2117         1.7544         1           2021         1.7994         1.2117         1.7544         1           2021         1.7994         1.2117         1.7544         1           2021         1.7994         1.2117         1.7549         1           2034         1.7966         1.2118         1.7552         1           2034         1.7966         1.2118         1.7567         1	2041         1 7953         1.2185         1.7500         1.2337         1.           2043         1 7945         1.2185         1.7493         1.2346         1.           2044         1 7945         1.2185         1.7493         1.2346         1.           2046         1 7945         1.2185         1.7493         1.2346         1.           2048         1 7949         1.2193         1.7463         1.2346         1.           2050         1 7941         1.2193         1.7478         1.2346         1.           2051         1 7941         1.2193         1.7478         1.2346         1.           2051         1 7941         1.2193         1.7446         1.2346         1.           2053         1 7206         1.7446         1.2333         1.         2065         1.7446         1.2346         1.           2060         1 7891         1.2205         1.7446         1.2345         1.         2065         1.7446         1.2345         1.           2062         1 7841         1.2364         1.7446         1.2345         1.         2.066         1.7446         1.2345         1.	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<b>N N</b>	Coust. Soc. Coust. Soc. Coust.	22         1.8871         1.1924         1.8361         1.2062         1.7833           A         1.8853         1.1926         1.8352         1.7867         1           A         1.8853         1.1926         1.8352         1.7865         1           A         1.8853         1.1926         1.8352         1.2065         1.7865         1           A         1.8854         1.1926         1.8356         1.2066         1.7865         1           A         1.8816         1.9336         1.8326         1.2066         1.7865         1           A         1.8316         1.8318         1.2076         1.7852         1           A         1.8317         1.8318         1.2076         1.7852         1           A         1.8318         1.8310         1.2076         1.7852         1           A         1.8311         1.2076         1.7827         1         1         1         1         1         1         1.7827         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         1         <	1.4775         1.1975         1.1946         1.8271         1.2088         1.7798           1.8757         1.951         1.8263         1.2091         1.7798         1           1.8757         1.953         1.8263         1.2093         1.7798         1           1.8757         1.953         1.8253         1.2095         1.7798         1           1.8750         1.1953         1.8253         1.2095         1.7796         1           1.8710         1.1953         1.8253         1.2095         1.7766         1           1.8711         1.1956         1.8213         1.2093         1.7766         1           1.8713         1.1956         1.8223         1.2093         1.7766         1           1.8714         1.1966         1.8212         1.2103         1.7765         1           1.8714         1.1966         1.8216         1.2103         1.7755         1           1.8714         1.1966         1.8206         1.2103         1.7755         1           1.8705         1.8206         1.2103         1.7756         1         1         1	1.8648         1.1971         1.8190         1.2112         1.7733           1.8650         1.1974         1.8152         1.2112         1.7715           1.8651         1.974         1.8156         1.2112         1.7715           1.8651         1.978         1.8156         1.2112         1.7706           1.8651         1.978         1.8166         1.2112         1.7706           1.8651         1.978         1.8156         1.2112         1.7706           1.8651         1.9930         1.8156         1.2122         1.7693         1.8156           1.8650         1.91983         1.8156         1.2122         1.7693         1.8156           1.8650         1.9137         1.2122         1.7663         1.8656         1.8656           1.8650         1.9132         1.8126         1.2122         1.7663         1.7655           1.86510         1.1992         1.8118         1.2123         1.7655         1.7655         1.7655	8603         1.1994         1.8110         1.2136         1.7646         1.2           8595         1.1997         1.8102         1.2136         1.7646         1.2           8586         1.1997         1.8102         1.2149         1.7633         1.2           8576         1.2001         1.8076         1.2144         1.7633         1.2           8569         1.2006         1.8078         1.2144         1.7633         1.2           8564         1.2006         1.8076         1.2149         1.7618         1.2           8564         1.2006         1.8074         1.2153         1.2         1.2         1.2           8564         1.2006         1.8070         1.2149         1.7618         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2         1.2<	8519         1.2017         1.8031         1.2161         1.7573         1           8510         1.2020         1.8023         1.2161         1.7596         1           8451         1.2022         1.8023         1.2165         1.7596         1           8493         1.2027         1.8007         1.2166         1.7596         1           8483         1.2027         1.7999         1.2173         1.7534         1           8485         1.2027         1.7999         1.2173         1.7534         1           8485         1.2031         1.7994         1.2173         1.7534         1           8466         1.2014         1.7794         1.2173         1.7534         1           8460         1.2014         1.7794         1.2175         1.7539         1           8460         1.2016         1.7996         1.2176         1.7539         1           8460         1.2016         1.7994         1.7753         1         1         1           8443         1.2016         1.7960         1.2183         1.7567         1         1	R415         1         2041         1         7953         1.2185         1.7500         1.2337         1.           8417         1         2044         1         7955         1.2185         1.7403         12337         1.           8410         1.2048         1         7945         1.2185         1.7403         12337         1.           8410         1.2048         17949         1.2193         1.7478         1.2346         1.           8400         1.2050         17941         1.2193         1.7478         1.2346         1.           8402         1.2050         17941         1.2193         1.7478         1.2346         1.           8402         1.2050         17943         1.21353         1.2346         1.         1.2333         1.           8403         1.2055         1.7206         1.2135         1.7446         1.2335         1.           84361         1.2055         1.7205         1.7446         1.2335         1.           84361         1.2055         1.7446         1.2335         1.           84361         1.2055         1.7446         1.2335         1.	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• 4	ž		1.4065	1.4069	1.4073	1 4077				1.4009	1.4093	1.4097	1.4101	1.4105		1.4109	1.4113	1 4117	1 4122	1 4126	1.4130	1.4134	1.4138	1.4142		Ī	ž	0.84	3						
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#### sin A tan A cot A Angle cos A 800 A cac A 0. 0 1 0 1 80 80 $\frac{\sqrt{8}}{2}$ $\frac{\sqrt{3}}{8}$ $\frac{2\sqrt{3}}{3}$ **√**8 2 30. ł $\frac{\sqrt{2}}{2}$ $\frac{\sqrt{2}}{2}$ $\sqrt{2}$ $\sqrt{2}$ 1 1 45' $\frac{\sqrt{3}}{2}$ $\frac{2\sqrt{3}}{3}$ $\frac{\sqrt{3}}{8}$ √3 **60*** 2 ł 1 0 1 90. 0 00 00 $\frac{\sqrt{8}}{2}$ $\frac{2\sqrt{3}}{3}$ $\frac{-\sqrt{3}}{8}$ √3 120' ---2 -1 180° 0 0 --1 œ -1 80 270° --1 0 ---1 0 œ 80 860* 0 1 0 1 œ 80

# 4. Frequently Used Angles and Their Functions

## 5. All Functions of an Angle Expressed in Terms of Any One Function

Function	sine	cosino	tangent	cotangent	secant	cosecant
Sin A	sin A	$\pm \sqrt{-\cos^2 A}$	$\frac{\tan A}{\pm \sqrt{1 + \tan^2 A}}$	$\frac{1}{\pm\sqrt{1+\cot^2 A}}$	$\frac{\pm\sqrt{\sec^2 A-1}}{\sec A}$	$\frac{1}{\csc A}$
Cos A	$\pm\sqrt{1-\sin^2 A}$	cos A	$\frac{1}{\pm\sqrt{1+\tan^2 A}}$	$\frac{\cot \mathbf{A}}{\pm \sqrt{1 + \cot^2 \mathbf{A}}}$	1 sec A	$\frac{\pm\sqrt{\csc^2 A - 1}}{\csc A}$
Tan A	$\frac{\sin A}{\pm \sqrt{1-\sin^2 A}}$	$\frac{\pm\sqrt{1-\cos^2 A}}{\cos A}$	tan A	$\frac{1}{\cot A}$	$\pm \sqrt{\sec^2 \mathbf{A} - 1}$	$\frac{1}{\pm\sqrt{\csc^2 A - 1}}$
Cot A	$\frac{\pm\sqrt{1-\sin^2 A}}{\sin A}$	$\frac{\cos A}{\pm \sqrt{1 - \cos^2 A}}$	$\frac{1}{\tan A}$	cot A	$\frac{1}{\pm\sqrt{\sec^2 A - 1}}$	$\pm \sqrt{\csc^2 A - 1}$
Sec A	$\frac{1}{\pm\sqrt{1-\sin^2 A}}$	$\frac{1}{\cos A}$	$\pm \sqrt{1 + \tan^2 A}$	$\frac{\pm\sqrt{1+\cot^2 A}}{\cot A}$	sec A	$\frac{\csc A}{\pm \sqrt{\csc^2 A - 1}}$
Cac A	$\frac{1}{\sin A}$	$\frac{1}{\pm\sqrt{1-\cos^2 A}}$	$\frac{\pm\sqrt{1+\tan^2 A}}{\tan A}$	$\pm \sqrt{+\cot^2 \mathbf{A}}$	$\frac{\sec A}{\pm \sqrt{\sec^2 A - 1}}$	csc A



Paragraph 12.

$$a(1) \frac{8}{5}; .6; 60\%. (2) \frac{1}{2}; .5; 50\%. (8)$$
  

$$\frac{8}{8}; .375; 87\frac{1}{2}\%. (4) \frac{1}{4}; .25; 25\%.$$
  

$$(5) \frac{5}{8}; .625; 62\frac{1}{2}\%. (6) \frac{8}{5}; .6; 60\%.$$
  

$$(7) \frac{3}{10}; .8; 80\%. (8) \frac{7}{10}; .7; 70\%. (9)$$
  

$$2\frac{1}{4}; 2.25; 225\%. (10) \frac{7}{8}; .875; 87\frac{1}{2}\%.$$
  

$$(11) \frac{2}{25}; .08; 8\%. (12) \frac{8}{50}; .06; 6\%.$$
  

$$(13) \frac{9}{50}; .18; 18\%. (14) \frac{1}{400}; .0025;$$
  

$$25\%. (15) \frac{1}{40}; .025; 2\frac{1}{2}\%. (16) \frac{1}{20};$$
  

$$05; 5\%. (17) \frac{1}{12}; .08\frac{1}{8} (See note be-
low); 8\frac{1}{8}\%. (18) \frac{8}{8}; .875; 87\frac{1}{2}\%. (19)$$
  

$$1\frac{1}{20}; 1.05; 105\%. (20) \frac{1}{25}; .04; 4\%.$$

Note. This mixed decimal and fractional form is often used when an unending decimal would result.

- b(1) 150; (2) 50; (8) 4; (4) 900.
- c(1) 150%; (2) 275%; (8) 150%; (4) 550%.
- d(1) 1.64; (2) 2,496; (8) .84; (4) 4.42.
- e(1) .207%; (2) .028%.
- f(1) 433 $\frac{1}{8}$ ; (2) 2,500; (8) 520; (4) 200; (5) 200.

Paragraph 21.

a 336.6 pounds. b  $3\frac{8}{7}$  days. c \$5.00. d \$1400.00. e .872 ohm. .298 ohm; .459 ohm; .898 ohm. f 2.820 pounds; 8.776 pounds; 4.119 pounds; 2,567 pounds. g 300 rpm. h 157.5 rpm. Paragraph 25.

a(1) 21; (2) 33; (3) 50; (4) 2.90; (5) 50.1; (6) 70.01; (7) 86.5; (8) 75.89.<math>b(1) 2.286; (2) 2.646; (3) 3.817; (4) 8.606; (5) 8.878; (6) 4.123.c(1) .158 ampere; (2) .085 ampere; (8) .283 ampere; (4) 1.118 amperes.

#### Paragraph 42.

a(1) 17; (2) 58; (3) -21; (4)  $-189^{\circ}$ ; (5) -252 volta. b(1) 251 amperes; (2) -8 volts; (3) -.6875cy; (4)  $-.81.99ax^{\circ}$ ; (5)  $1.810x^{\circ}y$ . c(1) -.17.92; (2) -.72; (3)  $\frac{3}{35}$ ; (4) .075852; (5) .0028125; (6) 120. d(1) 9; (2)  $-\frac{20}{21}$ ; (3) 700; (4) 250; (5)  $-\frac{2}{3}$  ampere; (6) -.0025. e(1) -.4; (2) 14; (3) -.25; (4) 19; (5) 11; (6) 16; (7) 44; (8) 66; (9) -.46; (10) 18.

Paragraph 50.

 $a(1) 4a^{4} - 4a^{2}b^{2} + 4b^{4}. (2) E + 8RI + 20ZI. (3) w + x + 9y + 8z.$   $b(1) 19ax + 17by - 9cz. (2) -25w - 3x + 8y + 2z. (3) 4a^{2} - 34ab + 6b^{2}.$  c(1) 7. (2) 1. (3) 1.  $d(1) f^{10}. (2) y^{a+b}. (3) y^{2a}. (4) r^{5}. (5) R^{3m}. (6) r^{m+1}.$   $e(1) \frac{4}{x^{4}}. (2) \frac{1}{r^{4}s^{4}}. (3) \frac{1}{36^{5}a^{2b}}. (4) \frac{1}{r^{5}R}. (5) \frac{a^{2}}{8b^{3}}. (6) \frac{3E}{4I^{2}R}.$  $f(1) 10a^{3}b - 15a^{2}b^{2} + 35ab^{3}. (2) 4a^{3} + 12a^{2} + 4a. (8) i^{3} - 27. (4) 2x^{4} + 5x^{3}y + 4x^{2}y^{2} + 2xy^{3} - y^{4}. (5) 9x^{4} - 4x^{2}y^{2} + 2xy^{4} - y^{4} - 4x^{4} - 4$ 

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 $20xy^{2} - 25y^{4} \cdot (6) \frac{a - e}{ca} \cdot (7) \frac{3L - R^{2}}{R}$ (8)  $1 - 2a^{2}b + 3a^{4}b^{3} \cdot (9) 2z^{2} + z - 1 + \frac{3z + 4}{z^{2} - z + 3} \cdot (10) 4b^{2} - b.$ 

## Paragraph 61.

a(1) 5(5 + 1 - 6); (2) 4(2 + 1 - 8); (3) 8(3 - 6 + 7); (4) 7r(1 - 8 + 5); (5) 2(5x + 4y + 3z). b(1)  $49x^2y^3$ ; (2)  $4w^{10}$ ; (3)  $64a^4b^8$ ; (4)  $729a^9x^3$ ; (5)  $-27b^3z^{12}$ . c(1) 5; (2) -8; (3)  $\pm ab^3$ ; (4)  $\pm 6yz^2$ ; (5)  $-10ab^5$ ; (6)  $\pm 20a$ ; (7) -3; (8)  $-x^3$ ; (9) 4; (10)  $5x^4y^5z^2$ . d (1) 3(x + 2); (2) 5a(a + 3); (3)  $2x(5x^2$  -7x - 1; (4) 3z(2ay + 3bx - 4c); (5)  $m(m^2 + m - 5x)$ ; (6)  $3a^3(a^2 - 2ab - b^2)$ ; (7)  $7ry^3(1 - 2 + 3)$  or  $14^3ry$ ; (8) 2xam(6x + 7a + 8m); (9)  $\pi(r_1^2 + r_2^2)$ ; (10)  $\frac{1}{16}cd(4c^2 - 2cd + d^2)$ .

### Paragraph 69.

$$a(1) \ x = 5 \frac{2}{5}; \ (2) \ x = 4; \ (3) \ r = 2; \ (4)$$

$$x = -1\frac{1}{12}; \ (5) \ t = 1; \ (6) \ x = 7\frac{3}{4}; \ (7)$$

$$r = 4; \ (8) \ x = 1.$$

$$b(1) \ 8; \ (2) \ x; \ (3) \ 3(r + s); \ (4) \ 3(a - s);$$

$$(5) \ (I - 6)(I - 9); \ (6) \ \frac{8E^2I^2}{2I^2R}; \ (7)$$

$$\frac{2f}{6\pi f^2c}.$$

$$c(1) \frac{rR}{rR^2}, \frac{r}{rR^2}, \frac{R^2}{rR^2}; (2) \frac{a-1}{a^2-1}, \\ \frac{x(a+1)}{a^2-1}; (3) \frac{3b}{6x}, \frac{2c}{6x}; (4) \frac{y(y+3)}{2(y+3)}, \\ \frac{y}{2(y+3)}; (5) \frac{2(c+1)}{c(c+1)}; \frac{3c}{c(c+1)}; \\ (6) \frac{2i}{2e-10}, \frac{i}{2e-10}; (7) \frac{y}{C^2-d^2}, \\ \frac{z(c+d)}{C^2-d^2}.$$

$$d(1) \frac{12}{a}; (2) \frac{7s+11}{4t};$$

$$(3) \frac{9y^{2}a+10xb}{12x^{2}y^{3}}; (4) \frac{6(z^{2}-2)}{z^{4}-5z^{2}+14};$$

$$(5) \frac{9c+2cd-12d}{12c^{2}d^{2}}; (6) \frac{2r^{2}+r-13}{r^{2}+2r-15};$$

$$(7) \frac{12y-1}{4}; (8) \frac{4ab}{a^{2}-b^{2}};$$

$$(9) \frac{16(2-5q)}{25q^{2}}; (10) \frac{3t+4y}{12tv^{2}};$$

$$e(1) \frac{3y^{2}}{8}; (2) \frac{a^{6}}{b^{6}}; (3) \frac{xz}{21my};$$

$$(4) \frac{(s-r)^{2}}{s^{2}}; (5) \frac{3}{5x}; (6) \frac{1}{a^{3}};$$

$$(7) 15z; (8) \frac{a^{3}}{6cd}; (9) \frac{4su}{5};$$

$$(10) \frac{e+3}{e+2}.$$

Paragraph 76.

a(1) 2; (2) 16; (3)  $5\sqrt{2}$ ; (4)  $\frac{\sqrt[4]{4}}{4}$ ; (5)  $3\sqrt{2x-1}$ ; (6)  $\frac{x^{4}\sqrt[6]{6}}{y}$ ; (7)  $x^{4}y$ ; (8)  $d^{\frac{1}{2}}e^{3}$ ; (9)  $\frac{4r^{2}}{r}$ ; (10)  $a^{3}b$ . b(1)  $\sqrt[3]{4}$ ; (2)  $\sqrt[4]{a^{9}b^{4}}$ ; (3)  $\sqrt[3]{6^{2}}$ ; (4)  $\sqrt[4]{27}$ ; (5)  $\sqrt[5]{x}$ ; (6)  $\sqrt[4]{a^3b^4}$ ; (7)  $6\sqrt[3]{r}$ ; (8)  $26\sqrt[3]{a^3}$ ; (9)  $\sqrt{2r_1+3r_2}$ ; (10)  $8y\sqrt[6]{x}$ .  $c(1) a^{i}; (2) (5x)^{i}; (3) 6xd^{i}; (4) z^{i};$ (5)  $(3a^{3}b^{5})^{1}$ ; (6)  $y^{3}a^{1}$ ; (7)  $8(3e)^{1}$ ; (8)  $9g^{\dagger}$ ; (9)  $3bc^{\dagger}d^{\dagger}$ ; (10)  $(x - y)^{\dagger}$ .  $d(1) = 2\sqrt{3};$  (2)  $3\sqrt{7};$  (3)  $3x\sqrt{7};$ (4)  $12ab^2\sqrt{2}$ ; (5)  $2bd\sqrt{15}$ ; (6)  $2l\sqrt{2R}$ ; (7)  $9pz\sqrt{7p}$ ; (8)  $12dr^4s\sqrt{3ds}$ ; (9)  $45a^2\sqrt{b}$ ; (10)  $112w^4x^2y\sqrt{2xz}$ .  $e(1)\frac{\sqrt{2}}{10}; (2)\frac{\sqrt{x}}{2\pi}; (3)\frac{\sqrt[4]{3a}}{3}; (4)\frac{\sqrt[4]{x^{1}}}{x};$ (5)  $\frac{\sqrt[4]{27a^3x^3}}{3ax}$ ; (6)  $\frac{\sqrt[4]{(3-2x)^3}}{3-2x}$ ; (7)  $\frac{\sqrt[3]{a}(a+b)}{a}$ ; (8)  $\frac{\sqrt[3]{ab^2c^2}}{ba}$ ;  $(9) \frac{\sqrt[6]{s+1}}{s+1}; (10) \sqrt[6]{(i+3)^3}.$ 

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$$f(1) 10; (2) 14\sqrt{5}; (3) x - \frac{x\sqrt{3}}{2}; (4)$$

$$\frac{3a\sqrt{2} + a}{2}; (5) (r + 1)\sqrt{rst}; (6)$$

$$\frac{2y\sqrt{x^2 - y^2}}{x^2 - y^2}; (7) \sqrt[3]{5} + 8\sqrt{x}; (8) 7\sqrt{a} - 6\sqrt{b}; (9) 3\sqrt{x + y} - 4\sqrt{x - y}; (10)$$

$$7ab\sqrt{5a}.$$

$$g(1) 12\sqrt{10}; (2) 18; (3) 8ab^2; (4)$$

$$2z^3\sqrt{3z}; (5) 2xy\sqrt[5]{xy}; (6) 24pq^2r\sqrt[3]{qr^2}; (7) a + b + c + 2(\sqrt{ab} + \sqrt{ac} + \sqrt{bc}); (8) ax\sqrt{a} (a + x + 1); (9) 8; (10)$$

$$2axy^2\sqrt[3]{2a}.$$

$$h(1) 2; (2) 5; (3) 2\sqrt[3]{x}; (4) 3\sqrt{zy}; (5)$$

$$\sqrt{6} + 2; (6) 12a^{1/2}2^3 \cdot 3^5 \cdot 5^4 \cdot a^2; (7)$$

$$\frac{c - \sqrt{2c} - 4}{c - 8} \quad (8) \sqrt{15}; (9)$$

$$\frac{e^2 + f^2 + 2f\sqrt{e^2}}{e^2} \quad \overline{f^2}; (10) \frac{4b\sqrt{1 - 4b^2} + 1}{8b^2 - 1}$$
Paragraph 79.  

$$a(1) \ j5\sqrt{3}; \ (2) \ j\sqrt{} ; \ (3) \ -j8x^2\sqrt{ax}; (4) \ -j10x^2y^2\sqrt{x}; \ (5) \ -\frac{3}{3}; (6) \ -4xy\sqrt[3]{2x^2y^2}.$$

$$b(1) \ 16 + j109; \ (2) \ 41 - j22; \ (3) \ 61 - j251; \ (4) \ 4 + j10: \ (5) \ 6 + j11; \ (6) \ -2 - j47.$$

$$c(1) \ 779 - j371; \ (2) \ 59 + j114; \ (3)$$

-j8; (6) 46 -j48; (7)  $f^2 + jfg - g^2;$ (8)  $I^2 + E^2;$  (9) -68 - j239; (10) 71 -j17.

$$e(1) \frac{3}{13} - j\frac{2}{13}; (2) 1 - j6; (3) - \frac{6}{25} + j\frac{17}{25}; (4) 1 + j2; (5) \frac{x^2 + j^2xy - y^2}{x^2y^2}; (6) 2(1 - j2); (7) \frac{3(1 + j)}{2}; (8) \frac{1 + j13}{10}; (9) \frac{38 + j34}{65}; (10) \frac{l^2 + j2lE - E^2}{l^2 - E^2}$$

Paragraph 86.

a(1) 3; (2) 2; (3) 85; (4) 3; (5) 1; (6) x = -5, y = 8; (7) a = 3, b = 1; (8) x = 3, y = 4; (9) m = 3, n = 5; (10) r = 8, s = 1 $b(1) d = \frac{Wh}{F}$  (2)  $g = \frac{v^2 - v^2_o}{2h}$ . (3)  $a = \frac{Fg}{m}$ . (4)  $N = \frac{2.534H}{Dt}$ . (5) l = $\frac{10^{s}F}{22.5BI}.$ c(1) 15; (2) 0; (3)  $\frac{10}{8}$ ; (4) 4; (5)  $\frac{28}{9}$ ; (6)  $\frac{12}{119}$ ; (7)  $-2\frac{12}{25}$ ; (8) 8; (9)  $\frac{40}{109}$ ;  $(10) - \frac{1}{10}$ . d(1) x = 4, y = 5; (2) a = 4.95, b = 2.61;(3) x = 4, y = 7; (4) x = -2, y = -4; (5) x = -3, y = 1; (6) I = 18, Z = 17; (7) x = 4,  $y = \frac{1}{2}$ ; (8) a = 6, b = -4; (9) x = 5, y = -1; (10)  $r = \frac{(a+b)}{2},$  $s=\frac{(a-b)}{2}$ 

e(1) 1 volt; (2) R - 20 ohms; (3) 110 volts; (4) 75 ohms; (5) 100 milliamperes, 80 milliamperes, 60 milliamperes; (6) 5.5 amperes.

Paragraph 94.

$$a(1) 0, -\frac{3}{2}; (2) 0, 4; (3) 0, -3; (4) 0, -2; (5) \pm 8; (6) \pm 3; (7) \pm 3; (8) \pm 4; (9) 7, -6; (10) 1, 12.$$
  

$$b(1) \frac{-3 \pm \sqrt{13}}{2}; (2) -3 \pm \sqrt{19}; (8)$$
  

$$2 \pm \sqrt{3}; (4) -2 \pm \frac{\sqrt{22}}{2}; (5) \frac{1}{2} \pm \frac{\sqrt{14}}{4}; (6) -\frac{5}{3} \pm \frac{2\sqrt{10}}{3}; (7) -1, 8; (8) -1 \pm \frac{\sqrt{6}}{2}; (9) 1 \pm \sqrt{6}; (10) \frac{1}{2} \pm \frac{\sqrt{5}}{2}$$

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$$c(1)-1;(2)-\frac{3}{4}, \frac{2}{3}; (3) \frac{-5 \pm \sqrt{13}}{6};$$

$$(4) \frac{3}{2}, \frac{4}{3}; (5) -3, 1; (6) -\frac{1}{5}, \frac{5}{3};$$

$$(7) \pm \sqrt{2}; (8) \pm \sqrt{19}; (9) -1, 2;$$

$$(10) \frac{-5 \pm \sqrt{7}}{3}$$

Paragraph 111.

a(1) 1,613 × 10³; (2) 500 × 10³, or  $5 \times 10^{5}$ ; (3) 6,166 × 10⁻⁸. b(1) 8,109 × 10²; (2) 19 × 10⁻⁴; (3) 4,492 × 10⁻⁴. c(1) 892 × 10³; (2) 2,464 × 10⁻², or 24.64; (3) 8,168 × 10⁻¹¹; (4) 14,640. d(1) 167; (2) 1,608 × 10⁷; (3) 107; (4) 33 × 10⁻⁵. e(1) 4 × 10², or 400; (2) 13 × 10⁻⁴; (3) 27 × 10⁻⁹; (4) 9 × 10², or 900. Paragraph 127. a(1) 2.8949; (2) 0.5527; (3) 8.5378-10;

a(1) 2.8949; (2) 0.5527; (3) 8.5378-10; (4) 6.6776-10; (5) 1.6955; (6) 2:4370; (7) 2.8809; (8) 0.8593; (9) 7.9946-10; (10) 5.7205-10.

b(1) 70,100; (2) 271; (3) .351; (4) .000676; (5) 3.99; (6) 370.67; (7) .00002718; (8) 500,500; (9) 1.5915; (10) .000003445.

c(1) 164.2; (2) 39,982; (3) 1,376; (4) .006764; (5) 5,710.

d(1) .4983; (2) .3874; (3) .3984; (4) .7487; (5) .2437.

e(1) .0000007372; (2) 51.46; (3) 8.47; (4) 19.43; (5) 783; (6) .2367; (7) 5.343; (8) 87.74; (9) 1.55; (10) .09456.

f(1) 2.298; (2) 11.77; (3) 24.43; (4) 83.28; (5) .4509; (6) .4725; (7) .04088; (8) .6153; (9) .0576; (10) .35367. Paragraph 142.

a 96 square inches. b 36 square inches. c 25 square inches. d 15 square inches. e 14.422 square inches. f 5.657 square inches. g(1) Parallelogram, A = bh, 120 square inches; (2) Triangle,  $A = \frac{bh}{2}$ 4.025 square inches; (3) Circle,  $A = \pi r^2$ , 814 square centimeters,  $C = \pi D$ , 62.8 centimeters; (4) Trapezoid,  $A = \frac{B+b}{2}$  h, A = 60 square inches. h(1) 3 inches; (2)  $4\frac{1}{2}$  inches; (3) 8.8 inches; (4) 5 inches. i 78.5 square inches. j 100 feet. k 82.5 square feet. l 48.496 inches.

Paragraph 153.

a(1) c = 8.608. (2) a = 6.08. (3) b =39.5. (4)  $c = b\sqrt{10}$ . (5)  $b = m^2 - 1$ .  $b(1) \sin A = \frac{4}{7}, \cos A = \frac{\sqrt{88}}{7}, \tan A = \frac{1}{7}$  $\frac{4}{\sqrt{33}}$ , cot A =  $\frac{\sqrt{33}}{4}$ , sec A =  $\frac{7}{33}\sqrt{33}$ ,  $\csc A = \frac{7}{4}$ (2) sin A =  $\frac{2}{18}\sqrt{13}$ , cos A =  $\frac{8}{18}\sqrt{13}$ ,  $\tan A = \frac{2}{9}$ ,  $\cot A = \frac{3}{2}$ ,  $\sec A = \frac{\sqrt{13}}{3}$ ,  $\csc A = \frac{\sqrt{13}}{2}$ (3)  $\sin A = \frac{1}{2}$ ,  $\cos A = \frac{\sqrt{8}}{2}$ ,  $\tan A = \frac{\sqrt{8}}{2}$ cot A =  $\sqrt{3}$ , sec A =  $\frac{2}{9}\sqrt{3}$ , csc A = 2. (4)  $\sin A = \frac{1}{2.4}$ ,  $\cos A = \frac{1.09}{1.2}$ ,  $\tan A =$  $\frac{1}{2.18}$ , cot A = 2.18, sec A =  $\frac{1.2}{1.09}$ , csc A = 24 (5) sin A =  $y \frac{\sqrt{y^2} + 1}{y^2 + 1}$ , cos A =  $\frac{\sqrt{y^2} + 1}{y^2 + 1}$ .  $\tan A = y, \cot A = \frac{1}{y}, \sec A = \sqrt{y^2 + 1},$  $\csc = \frac{\sqrt{y^2} + 1}{y}.$ 



(6)  $\sin A = \frac{\sqrt{55}}{8}$ ,  $\cos A = \frac{3}{8}$ ,  $\tan A = \frac{\sqrt{55}}{3}$ ,  $\cot A = \frac{3\sqrt{55}}{55}$ ,  $\sec A = 2\frac{2}{3}$ ,  $\csc A = \frac{8\sqrt{55}}{55}$   $c(1) \ a = 17, \ b = 29.4, \ c = 84.$  (2) a = 9,  $b = 12, \ c = 15.$  (3)  $a = 12, \ b = 16, \ c = 20.$  (4)  $a = 17.5, \ b = 10\sqrt{11}, \ c = 37.5.$ (5)  $a = 10, \ b = 6, \ c = 2\sqrt{34}.$  (6)  $a = 37.08, \ b = 18.4, \ c = 41.4.$  $d(1) \ b = 10\sqrt{3}, \ c = 20.$  (2)  $a = 7, \ c = 7\sqrt{2}.$  (3)  $a = 4\sqrt{3}, \ b = 4.$  (4)  $b = 3\sqrt{3}, \ c = 6\sqrt{3}.$  (5)  $a = 12.5, \ b = 12.5\sqrt{3}.$ 

Paragraph 164.

a(1) .02618, .99966, .02619, 38.1885. (2) .26584, .96402, .27576, 3.62636. (3) .53238, .62892, 1.59002. (4) .59693, .84650, .74402, 1.34405. (5) .70690, .80230, .70706, .70731, .99942, 1.00058. (6) .70716, .99986, 1.00014. .57649, (7) .81710, .70553, 1.41737. (8) .81370, .58129. 1.39982, .71438. (9) .74811, .66357, 1.12740, .88700. (10) .92429, .38169, 2.42158, .41295.

b(1) 14° 54' 51"; (2) 66° 35' 51"; (3) 19° 56' 54"; (4) 25° 17' 5"; (5) 40° 23' 35"; (6) 68° 45' 2"; (7) 22° 11' 47"; (8) 34° 5' 19"; (9) 52° 13' 2"; (10) 51° 29' 49"

c(1) 44° 43′ 29″; (2) 10.29; (3) 32.9; (4) 19.76; (5) 12.4; (6) 54° 18′ 52.5″; (7) 33.69; (8) 16.5; (9) 36° 28′ 9″; (10) 128.3; (11) 32.9; (12) 29° 3′ 15″

d(1) 43.845 feet; (2) 80.027 feet; (3) 12.226 feet, 8.69 feet high; (4) 3,149 feet; (5) 11.734 feet; (6) 91.77 feet; (7) 206 feet; (8) 3,578 feet; (9) 16,647 feet (3.153 miles); (10) 82.12 feet; (11) 1.414 inches each; (12) side opposite  $60^{\circ} \leq 5.196$ inches, side opposite  $30^{\circ} \leq 3$  inches. Paragraph 178.

 $a \ C = 62^{\circ} \ 16' \ 38'', \ a = 14.59.$   $b \ B = 69^{\circ} \ 58'.$   $c \ A = 23^{\circ} \ 33' \ 22'', \ B = 45^{\circ} \ 16' \ 31'', \ C = 111^{\circ} \ 10' \ 7''.$   $d \ A = 81^{\circ} \ 31' \ 41' \ B = 41^{\circ} \ 7' \ 29''.$   $e \ 240$  square inches. 97.880 square feet.  $g \ 55.424$  square inches.  $h \ A = 32^{\circ} \ 33' \ 45'', \ B = 84^{\circ} \ 36' \ 15'', \ c = 15.95$  inches.

Paragraph 176.

a(1) .4 radian; (2) 4 radians; (8) { radians; (4) 2.78 radians.

b(1) 35 inches; (2) 17.6 feet; (3) 18.9 miles; (4) .00198 inch.

c(1) .52 radian; (2) 4.6 radians; (3) 2.77 radians; (4) 5.89 radians.

d(1) 45° 50' 11.8"; (2) 1482° 23' 40.2" (3) 197° 40' 18.44"; (4) 540°.

 $e(1)\pi/6$ ; (2)  $\pi/3$ ; (3)  $5\pi/4$ ; (4)  $4\pi$ .

Paragraph 192.

 $I_T = 35$  amperes.

a(1) 5.5 amperes; (2) 1.80 amperes. b(1) 28 to 100 ohms; (2) 7 to 25 ohms. c 221 volts; 7.514 watts. d(1) .8 ampere; (2) 24 volts; (8) 80 volts.  $e(1)G_{T} = .35$  inch; (2) 2.857 ohms; (3)  $I_{2} = 10$  amperes,  $I_{3} = 5$  amperes; (4)

f(1)  $G_1 = 1$  mho,  $G_2 = .333$  mho,  $G_3 = .1$  mho,  $G_4 = .05$  mho,  $G_5 = .02$  mho; (2)  $G_T = 1.503$  mhos; (3)  $R_T = .665$  mho.

g(1) 17.08 ohms; (2) 86.4 volts; (8) 100.8 volts; (4) 228.192 volts.

h(1) 4.62 ohms; (2) 5.859 ohms; (8) 4.783 ohms; (4) 15.246 ohms.

i(1) 125 volts; (2)  $E_1 = 50$  volts,  $E_2 = 75$  volts.

j(1) 10.754 volts; (2)  $I_1 = .7028$  ampere,  $I_2 = 8.269$  amperes,  $I_3 = 1.0237$  amperes;

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(3)  $I_1R_1 = 10.753$  volts,  $I_2R_2 = 10.750$  volts,  $I_3R_3 = 10.749$  volts.

k(1) 5,500 amperes; (2) .22729 ampere.

*l* A, 5 ohms; B,  $6\frac{2}{5}$  ohms; C, 8 ohms.

*m* A, 3 ohms; B, 12 ohms; C, 7 ohms; D, 25 ohms.

**n** A,  $8\frac{8}{9}$  ohms; B,  $8\frac{1}{8}$  ohms; C, 10 ohms.

o A, 3 ohms; B, 4 ohms; C, 2 ohms.

 $p I_{R1} = 7.519$  amperes;  $I_{R2} = 3.214$  amperes;  $I_{R3} = 1.176$  amperes;  $I_{R4} = I_{R7} = I_{R8} = 0.392$  ampere;  $I_{R5} = I_{R10} = 4.782$  amperes;  $I_{R6} = I_{R9} = 1.568$  amperes,  $I_{R11} = 12.801$  amperes.

q R = 239.1688 ohms.

r I = .457 ampere.

## Paragraph 204.

a(1) 94 ohms; (2) 184 ohms; (3) current leads voltage because capacitive reactance exceeds inductive reactance; (4) 104 ohms; (5) 5 amperes.

b. 9.425 ohms.

d. 80 ohms.
e. 455 kc.
f(1) 30 amperes; (2) 180 volts; (3) 480 volts; (4) 240 volts.
g(1) 3 amperes; (2) 4 amperes; (3) 6 amperes; (4) 83 ohms; (5) 34°; (6) 896.4 watts; (7) 1080 watts, or 1.08 kw
Paragraph 208.
a. 39.8 to 1.

b. --.744 db per mile.

c. 63,662 ohms (approx).

- c. +10.8 db.
- d. 25.1 to 1.

Paragraph 217.

- a. 5%.
- b. 77.7%
- c. 15%.
- d. 12,600 ohms.
- e. 86.7%.
- f. 2,200 watts.
- g. 1.58 amperes.



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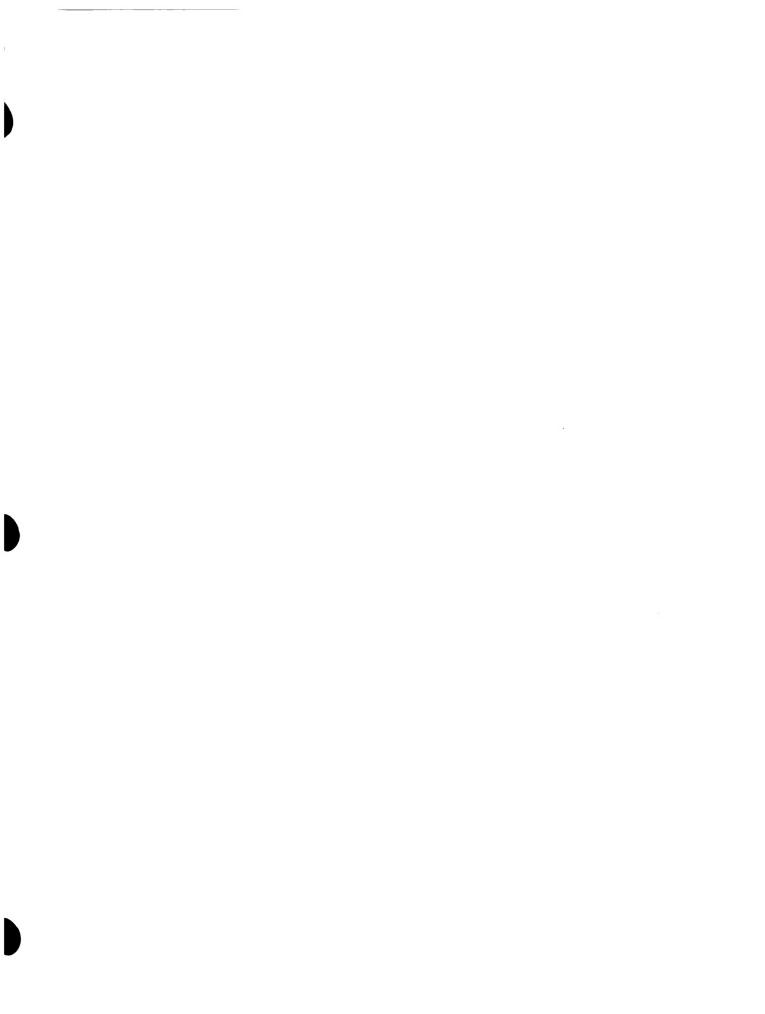
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