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MATHEMATICS FOR THE SERVICE ENGINEER

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INTRODUCTION

One of the most useful tools a refrigeration service engineer can have in his possession is a good understanding of basic mathematics. With practice he will find that this knowledge can be very helpful in his day to day work.

In the study of Principles of Refrigeration, an understanding of basic mathematics is very important in order to understand the calculations involved in such processes as heat transfer, fluid flow, temperature-pressure relationships and many others. If further advance study is desired, a good understanding of basic mathematics including algebra is an absolute necessity. Without it such things as compression ratios, heat gain calculations, and sizing of components for particular application, become very cumbersome mathematical calculations.

This Section is written specifically for the Refrigeration Service Engineer, and the practical examples at each step of the way, are designed to help solve problems with which he will be confronted daily.

An understanding of simple adding, subtracting, multiplying and dividing is assumed. Any lack of understanding in these basic processes must, by all means, be eliminated through study and practice, before an attempt is made to understand the subjects presented in this Section. Care has been taken to present the topics in their most logical order, and the transition steps have been made as gradual as possible. It is very important, however, that each step be thoroughly understood before going on to the next stage.

A thorough understanding of common and decimal fractions is necessary in the mastery of mathematics. Also, the fundamental processes involved in the use of fractions are applied to algebra. Therefore, the use of fractions and decimal fractions is offered first, followed by percent and square root. The study of algebra will be presented in a later Chapter.

FRACTIONS

In order to understand the steps that will be described, we must first know the names of the parts of fractions as well as the different types of fractions.

DEFINITIONS

FRACTIONS - One or more of the equal parts into which a unit may be divided. It is always written in the form of a division problem. As an example, one eighth indicates one unit divided into eight equal parts and is written 1/8, which would express the fact that it is equal to 1 divided by 8. (See Figure 1.)

NUMERATOR - The number of equal parts within the fraction. For example, in the fraction 3/8, the number 3 is the numerator of the fraction.

DENOMINATOR - The number of equal parts into which the unit is divided. For example, in the fraction 3/8, the number 8 is the denominator of the fraction.

PROPER FRACTION - When the numerator of the fraction is less than the denominator. For example, 1/2, 1/4, 3/8 etc., are proper fractions.

IMPROPER FRACTIONS - The numerator of a fraction is equal to or greater than the denominator. For example, 8/3, 4/4, 20/15 etc., are improper fractions.

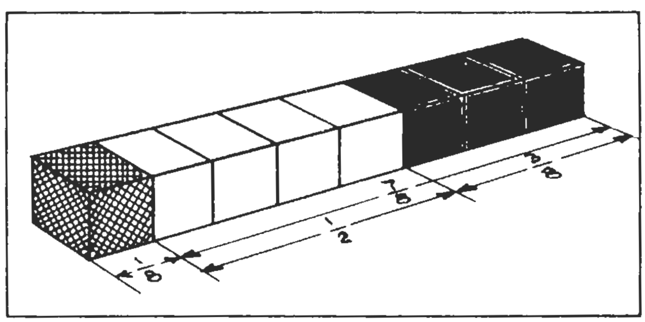


Figure 1
Shaded Portion Represents 1/8 of Total Volume. Solid Black Represents 3/8 of the Total Volume. Remaining Portion Equals 4/8 or 1/2 the Total.

MIXED NUMBERS - A number made up of a whole number and a fraction. For example, 3-1/2, 2-5/8, 1-3/4 etc., are mixed numbers.

Whole numbers or mixed numbers may be changed to improper fractions, and since improper fractions are equal to or greater than whole numbers, improper fractions may be reduced to whole numbers or mixed numbers.

Example: Change the mixed number 5-1/4 to an improper fraction. Since the denominator, in this case 4, indicates the number of equal parts into which each unit is divided, multiplying the whole number by 4 gives the total number of parts. This added to the numerator, 1, gives the total value of the fraction. Therefore, 5-1/4 equals:

$4 \times 5 = 20 + 1 = \frac{21}{4}$, an improper fraction.

Example: Reduce the improper fraction 16/4 to a whole number. Since the numerator equals the total number of parts and the denominator indicates the number of equal parts into which each unit is divided, dividing the numerator by the denominator will give the total number of units in the fraction. Therefore:

$\frac{16}{4} = 16 \div 4 = 4$, a whole number.

Example: Reduce the improper fraction 8/3 to a mixed number. Since 3 will not go into 8 an even number of times, the remainder is placed over the denominator, to indicate the number of parts in addition to the whole number. Therefore:

$\frac{8}{3} = 8 \div 3 = 2\frac{2}{3}$, a mixed number.

The final answer to any problem involving fractions should always be reduced to its lowest terms. If the fractions come out to numbers such as 4/8 or 15/25, for example, they should be reduced to 1/2 and 3/5 respectively.

EXERCISES: Change 1 through 5 to improper fractions. Reduce 6 through 10 to their lowest terms.

(1). $1\frac{1}{2}$ (2). $5\frac{2}{3}$ (3). $10\frac{25}{32}$ (4). $100\frac{3}{4}$ (5). $987\frac{57}{64}$

(6). $\frac{32}{64}$ (7). $\frac{27}{30}$ (8). $\frac{64}{32}$ (9). $\frac{100}{7}$ (10). $\frac{1000}{64}$

ADDING AND SUBTRACTING FRACTIONS

LOWEST COMMON DENOMINATOR

Before attempting to add or subtract fractions, all fractions within the problem must be reduced to their lowest common denominator. This is the smallest denominator that will contain the denominators of all the fractions involved in the problem. For example, in the fractions 1/4 and 1/3, the smallest number that will contain both 4 and 3 an even number of times is the number 12. With the fractions 1/3, 3/5 and 13/15, we can see that the lowest number that will satisfy the definition of lowest common denominator, is 15.

If the lowest common denominator is not obvious, the simplest means of finding a common denominator is to multiply two of the denominators together. If this doesn't satisfy the requirement, the result can be multiplied by the third denominator, etc. The result may have to be reduced to obtain the lowest common denominator.

Example: Find the lowest common denominator of 1/3, 3/8, and 7/16. 3 x 8 = 24, which is not satisfactory as a denominator for 16. 8 x 16 = 128, which is suitable for all three denominators, but is larger than necessary. 3 x 16 = 48, which is suitable as a denominator for all three.

Changing 1/3; 48 ÷ 3 = 16/48. Changing 3/8; 48 ÷ 8 = 6 x 3 = 18/48. Changing 7/16; 48 ÷ 16 = 3 x 7 = 21/48.

Once the lowest common denominator has been determined, adding the fractions becomes a simple process. The denominator in the answer or sum is the same as the lowest common denominator in the fractions being added. We merely add the numerators to obtain the answer. The sum of the numerators placed over the common denominator equals the sum of the fractions being added. In this example; 16/48 + 18/48 + 21/48 = 55/48. Since this is an improper fraction it should be reduced to a mixed number. Therefore; 55 ÷ 48 = 1-7/48.

ADDING MIXED NUMBERS

When adding mixed numbers, the whole numbers are added first. Then the lowest common denominator of the fraction is determined, and these are added as in the previous example.

Example: $11\frac{5}{8} + 2\frac{3}{4} + 5\frac{15}{16} = 11\frac{10}{16}$

$$+\ 2\frac{12}{16}$$

$$+\ 5\frac{15}{16}$$

$$18\frac{37}{16}$$

Since 37/16 is an improper fraction, we divide 37 by 16 to get the mixed number 2-5/16. This is added to the whole number 18, so the answer is 20-5/16.

FACTORING

If there are too many fractions involved to multiply their denominators all together, the lowest common denominator may be found by factoring, as shown in the following example:

$$\frac{1}{15} + \frac{2}{5} + \frac{3}{16} + \frac{5}{8} + \frac{17}{24} =$$

First select a number that can be divided evenly into two or more of the denominators. Bring these results down, along with the undivided numbers, and select another factor that can be divided into two or more of these numbers. Continue this until no more numbers can be factored out. Then multiply all the factors to obtain the lowest common denominator.

$$\frac{1}{15} + \frac{2}{5} + \frac{3}{16} + \frac{5}{8} + \frac{17}{24} =$$

8	15	5	~~16~~	~~8~~	~~24~~
5	~~15~~	~~5~~	2	1	3
3	~~3~~	1	2	1	~~3~~
2	1	1	~~2~~	1	1

The lowest common denominator equals 8 x 5 x 3 x 2 = 240.

SUBTRACTING FRACTIONS

In the subtraction of fractions, we must also first determine the lowest common denominator of the fractions involved. After this, it is simply a matter of subtracting the numerators. The answer will have the same denominator as the lowest common denominator of the fractions being subtracted. The numerator will be the remainder of subtracting the smaller from the greater numerator in the fractions being subtracted. Again, it may be necessary to reduce the answer to its lowest terms.

When subtracting mixed numbers, it may be necessary to borrow one from the whole number if the fraction is smaller than the one being subtracted from it. For example: 10-1/3 - 5-7/16. Common denominator = 3 x 16 = 48

This becomes:

$$\begin{array}{r} 10\frac{16}{48} \\ -\ 5\frac{21}{48} \\ \hline \end{array}$$

Since 21 cannot be conveniently subtracted from 16, the problem must be changed to:

$$\begin{array}{r} 9\frac{64}{48} \\ -\ 5\frac{21}{48} \\ \hline 4\frac{43}{48} \end{array}$$

EXERCISES

The following exercises will be used to practice the various steps involved in adding and subtracting fractions. It will be necessary to find the lowest common denominators, reduce fractions to their lowest terms and to change whole numbers to improper fractions, and improper fractions to whole numbers, as covered in the previous examples.

(1). $\frac{1}{16} + \frac{3}{16} + \frac{5}{16} + \frac{7}{16} =$

(2). $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} =$

(3). $\frac{2}{7} + \frac{3}{9} =$

(4). $1\frac{3}{8} + \frac{13}{15} + 5\frac{25}{32} =$

(5). $\frac{3}{4} + \frac{5}{16} + 12\frac{1}{2} + \frac{5}{8} =$

(6). $\frac{3}{4} - \frac{1}{2} =$

(7). $\frac{5}{16} - \frac{9}{32} =$

(8). $1\frac{17}{32} - \frac{11}{27} =$

(9). $7\frac{3}{16} - \frac{7}{16} =$

(10). $175\frac{2}{3} - 15\frac{27}{32} =$

11. A refrigeration installer has to run a discharge line as shown in the drawing in Figure 2. How many inches will be required in all?

12. In checking out an electrical circuit, the service engineer found three motors, one drawing 7-1/2 amps, one drawing 1-3/10 amps and the other 22-3/4 amps. What was the total current flowing in the circuit?

13. If a piece of pipe 24-2/3 inches long is cut from a length that is 100-3/4 inches long, how much pipe will remain?

14. A wall which has a total area of 85-1/2 sq. ft. has a window with an area of 12-9/10 feet. What is the area of the remaining wall?

15. A contractor received a shipment of parts weighing 57-3/4 lbs. He removed 3 pieces weighing 15-5/16 lbs, 2-2/3 lbs, and 3-5/24 lbs, and then returned the remainder to the supplier. What was the weight of the return shipment in pounds and ounces?

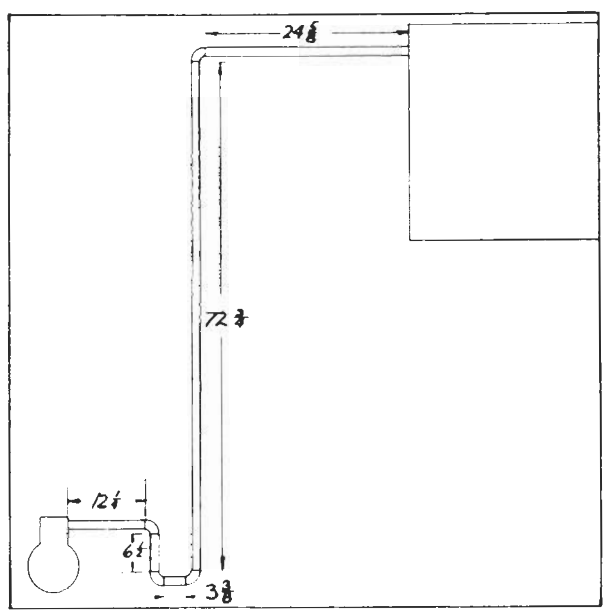


Figure 2
Piping Layout For Discharge Line
(Question 11)

MULTIPLICATION AND DIVISION OF FRACTIONS

MULTIPLICATION

When multiplying fractions, the numerators are first multiplied together and placed above the line to become the numerator of the answer. The denominators are then multiplied together and placed below the line to become the denominator of the answer.

Example: 1/2 x 3/4. In this case, 1 x 3 = 3; 2 x 4 = 8. Therefore the answer is 3/8.

Certain fractions can be reduced in size by canceling out common factors from the numbers above and below the line.

Example: $\frac{5}{9} \times \frac{3}{16} = \frac{5}{\cancel{9}_3} \times \frac{\cancel{3}^1}{16} = \frac{5}{48}$

It would be possible to solve the problem without canceling by multiplying out the numerators and denominators to obtain 15/144. This would then have to be reduced to its lowest terms where 15/144 equals 5/48, which gives the same answer. However, it is quicker and more convenient to cancel.

When multiplying mixed numbers, they must first be converted to improper fractions, as shown earlier.

Example: 2-3/8 x 5/9 x 1-13/19. Changing the whole numbers to improper fractions we now have 19/8 x 5/9 x 32/19. By cancellation, the number is reduced as follows:

$$\frac{\cancel{19}}{\cancel{8}} \times \frac{5}{9} \times \frac{\cancel{32}^4}{\cancel{19}} = \frac{20}{9} = 2\frac{2}{9}$$

In the above example, the number 19 was completely cancelled out by dividing both factors by 19. The number 8 was also completely cancelled out by dividing both 8 and 32 by 8. In instances like this where numbers cancel completely, they have a value of 1. In normal practice the number is simply ignored, since it has no effect on the answer.

DIVISION

The division of fractions is very similar to multiplication, with the exception that the divisor is first inverted and then the problem is solved by straight multiplication.

Example: 3/4 ÷ 1/2. Inverting 1/2, it becomes 2/1. Therefore the problem becomes 3/4 x 2/1. Multiplying the numerator, we have 3 x 2 = 6 above the line in the answer; multiplying the denominator, we have 4 x 1 = 4 below the line in the answer. Since 6/4 is an improper fraction, it must be changed to the mixed number 1-1/2.

When dividing a fraction by a whole number, the whole number is written as a fraction by placing it over a 1. This does not change the value of the number, but simply makes it easier to follow the steps for division.

Example: 3/8 ÷ 3. This then becomes 3/8 ÷ 3/1. Inverting the divisor and multiplying, the problem becomes 3/8 x 1/3. By canceling and multiplying, the answer is found as follows:

$$\frac{\cancel{3}}{8} \times \frac{1}{\cancel{3}} = \frac{1}{8}$$

When dividing a fraction by a mixed number, the mixed number must first be converted to an improper fraction, just as with multiplication.

Example: 2-3/4 ÷ 1-5/8. In this example both mixed numbers must be changed to improper fractions before the division can be made. The resulting problem is 11/4 ÷ 13/8. Inverting the divisor, the problem becomes 11/4 x 8/13. By canceling and multiplication, the solution is as follows:

$$\frac{11}{\cancel{4}} \times \frac{\cancel{8}^2}{13} = \frac{22}{13}; \quad \frac{22}{13} = 1\frac{9}{13}$$

EXERCISES

The following exercises will give further practice in multiplying and dividing fractions. The solutions will require further work in changing mixed numbers to improper fractions, changing improper fractions to mixed numbers, and changing whole numbers to improper fractions.

(1). $\frac{1}{2} \times \frac{1}{2} =$ (2). $\frac{3}{16} \times 4\frac{2}{3} =$ (3). $3\frac{3}{4} \times 4\frac{4}{5} =$

(4). $\frac{25}{32} \times 2\frac{7}{10} \times 12\frac{2}{3} =$ (5). $5\frac{33}{200} \times 2\frac{1}{2} \times \frac{20}{1033} =$

(6). $\frac{1}{2} \div \frac{1}{2} =$ (7). $4 \div \frac{4}{5} =$ (8). $\frac{3}{16} \div 6 =$

(9). $11\frac{21}{33} \div 10\frac{12}{15} =$ (10). $100 \div \frac{1}{10} =$

11. A man has a refrigerant cylinder holding 12-1/2 lbs of R-12. If he uses 1/4 of it, how many lbs will be remaining in the cylinder?

12. A 50 ft. roll of copper tubing weighs 14-2/3 lbs. How much should 30 ft. weigh?

13. In making 15 solder joints, a man found he used 3 ounces of solder. At that rate, how many joints can be made with a 2-1/2 lb roll of solder?

14. To clean out a cooling tower, acid is mixed at the rate of one gallon to three of water. If 4-1/4 gallons of acid are used, what must the sump capacity be?

15. An estimator determined that one installer could complete a certain job in 12-1/2 days. If his helper can do 7/8 as much as the installer, how long will both men require to complete the job?

DECIMALS

The word decimal is taken from the latin word meaning tenth, therefore a decimal fraction is one whose denominator is always some multiple of 10, such as 10, 100, 1000, 10,000, etc. Numbers such as 6/10, 15/100 and 75/1000, are decimal fractions. These will normally be written 0.6, 0.15 and 0.075, respectively. Note that in a decimal, there are the same number of digits to the right of the decimal point, as there are zeros in the denominator of the decimal fraction.

FRACTION EQUIVALENTS

A decimal fraction may be changed to a common fraction, and vice-versa. Table 1 shows the decimal equivalents of the most commonly used fractions.

CHANGING DECIMALS TO FRACTIONS

Example: Reduce the decimal 0.25 to a common fraction.

Since 0.25 contains two figures to the right of the decimal point, the numerator of the decimal fraction is 25 written over 100. (25/100) The decimal fraction 25/100 can be changed to a common fraction by reducing it to its lowest terms. Thus it will become the common fraction 1/4.

COMMON FRACTIONS AND THEIR DECIMAL EQUIVALENTS											
1/64	=	.015625	17/64	=	.265625	33/64	=	.515625	49/64	=	.765625
1/32	=	.031250	9/32	=	.281250	17/32	=	.531250	25/32	=	.781250
3/64	=	.046875	19/64	=	.296875	35/64	=	.546875	51/64	=	.796875
1/16	=	.062500	5/16	=	.312500	9/16	=	.562500	13/16	=	.812500
5/64	=	.078125	21/64	=	.328125	37/64	=	.578125	53/64	=	.828125
3/32	=	.093750	11/32	=	.343750	19/32	=	.593750	27/32	=	.843750
7/64	=	.109375	23/64	=	.359375	39/64	=	.609375	55/64	=	.859375
1/8	=	.125000	3/8	=	.375000	5/8	=	.625000	7/8	=	.875000
9/64	=	.140625	25/64	=	.390625	41/64	=	.640625	57/64	=	.890625
5/32	=	.156250	13/32	=	.406250	21/32	=	.656250	29/32	=	.906250
11/64	=	.171875	27/64	=	.421875	43/64	=	.671875	59/64	=	.921875
3/16	=	.187500	7/16	=	.437500	11/16	=	.687500	15/16	=	.937500
13/64	=	.203125	29/64	=	.453125	45/64	=	.703125	61/64	=	.953125
7/32	=	.218750	15/32	=	.468750	23/32	=	.718750	31/32	=	.968750
15/64	=	.234375	31/64	=	.484375	47/64	=	.734375	63/64	=	.984375
1/4	=	.250000	1/2	=	.500000	3/4	=	.750000	1	=	1.000000

Table 1

To reduce a decimal to the nearest given fraction, such as to the nearest 32nd, 64th etc., divide the decimal by that fraction.

Example: Find the value of .175" to the nearest 64th of an inch.

$$\frac{175}{1000} \div \frac{1}{64} = \frac{\overset{7}{\cancel{175}}}{\underset{\underset{5}{\cancel{125}}}{\cancel{1000}}} \times \frac{\overset{8}{\cancel{64}}}{1} = \frac{56}{5} = 11\frac{1}{5}$$

This result is then placed over the denominator of the fraction being sought. Since 11-1/5 is nearer 11 than 12, the correct answer is 11/64.

CHANGING FRACTIONS TO DECIMALS

A common fraction can be reduced to a decimal fraction, by adding zeros to the numerator of the common fraction and then dividing it by the denominator.

Example: Reduce the common fraction 1/4 to a decimal fraction. Since 1/4 is the same as 1 ÷ 4, it is solved as a straight division problem. As many zeros as necessary, are placed to the right of the decimal point. This does not change the value of the numerator. The decimal point in the answer is always placed directly above the decimal point of the number being divided. Therefore, the common fraction 1/4 equals .25.

Many common fractions do not reduce to an exact decimal. We could carry out the division indefinitely and never have it come out even. The degree of accuracy required should govern the number of zeros used. Four figures will probably meet most requirements.

ROUNDING OFF DECIMALS

If the problem specifies the number of decimal places, or the degree of precision required, it will be necessary to round off the answer at that point. The general rule is that if the next number is over 5, add 1 to the last digit. If it is less than 5, leave the last digit as it is. When the following digit is exactly 5 round off to the even number.

Examples: 1.0038 = 1.004; 10.013 = 10.01
1.125 = 1.12 ; 12.155 = 12.16

DOLLARS AND CENTS AS DECIMALS

The U.S. money system is a good example of decimals and decimal fractions, since 1 cent equals 1/100 of a dollar. When converting dollars to cents, it is necessary to move the decimal two places to the right. To convert cents to dollars, the decimal two places to the left.

Examples: $1.00 = 100 cents; 818 cents = $ 8.18
$ .50 = 50 cents; 1000 cents = $10.00

ADDITION AND SUBTRACTION OF DECIMALS

The addition and subtraction of decimals is carried out in exactly the same manner as addition and subtraction of whole numbers. It is important to note that the numbers to be added or subtracted are arranged so that the decimal points are in a vertical column.

Example:	Addition	Subtraction
	17.6	26.750
	.035	1.375
	100.5	
	118.135	25.375

EXERCISES

The following exercises will give further practice in the addition and subtraction of decimal fractions. You will find that to solve some of the problems, it will be necessary to perform the operation of changing common fractions to decimal fractions and you will be asked to change decimal fractions to common fractions.

(1). 35.25 + 0.75 =

(2). 1.273 + 127.3 =

(3). $10.05 + $2.37 =

(4). 1.035 + 25.35 + 1000.105 =

(5). 10.59 + 24/100 + 2/10 =

(6). $25.25 - $7.50 =

(7). 987.1 - 87.15 =

(8). 1167.76 - 1000.00 =

(9). 10-24/100 - 5.5 =

(10). 105.87 - 3-9/10 =

11. A pipe fitter cut the pieces of pipe illustrated In Figure 3, from a single length of pipe. If the hacksaw cut equaled .125 of an inch, what was the total length of pipe before he started?

12. The pipe illustrated in Figure 4 measures 1-3/8" O.D. If the wall thickness is .0625", what is the inside diameter in decimals?; in fraction of an inch?

13. In order to line up a motor with the fan shaft, the service engineer had to put shims of .010, .040 and .060 under the front mount. What was the original misalignment, to the nearest 64th of an inch.

14. A service truck stops at a gas station. It requires $15.45 worth of gas, 2-1/2 dollars worth of oil, and $1.25 for power steering fluid. What is the total cost?.

15. The dealers cost of a part is $13.75. After adding $6.35 for overhead and $1.20 for postage and handling, the dealer sells the part for $25.00. What is the dealer's net profit on the sale?

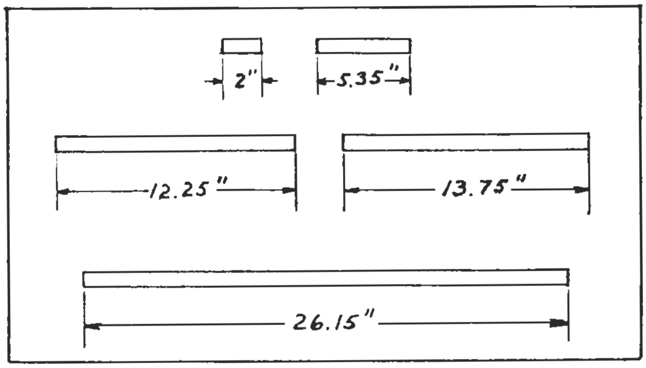


Figure 3

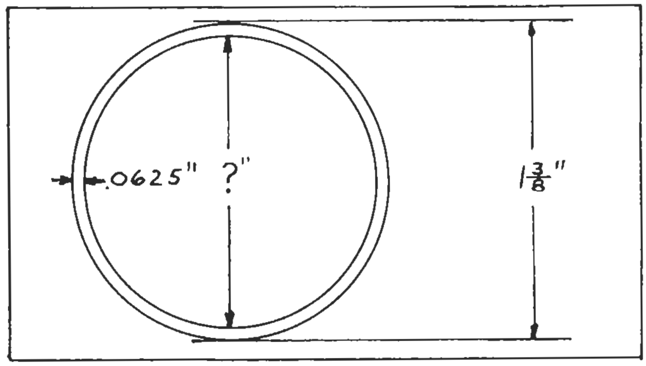


Figure 4

MULTIPLYING AND DIVIDING DECIMALS

The multiplication and division of decimal fractions is carried out in exactly the same manner as the multiplication and division of whole numbers.

MULTIPLICATION

To place the decimal point in the answer when multiplying, simply count the number of figures to the right of the decimal point in the numbers being multiplied. Then point off this number of figures to the right of the decimal in the answer.

Example:

```
   3.75 }
   1.25 } (4 here)
   1875
   750
 3 75
 4.6875
   (4 here)
```

DIVISION

When dividing by a whole number, the decimal point in the answer is placed directly above the decimal point in the number being divided. When the divisor is not a whole number, we can make it a whole number by moving the decimal point the required number of places to the right. At the same time we must move the decimal point in the number being divided, the same number of places to the right. This does not change the value of the problem.

Example:

```
                          3.75
             1/25.) 4/68.75    Moved from here
                    3 75              to here
Moved from here      93 7
        to here      87 5
                      6 25
                      6 25
```

Note that moving the decimal point two places to the right made the divisor a whole number. Therefore, the decimal point in the answer appears directly over the decimal point in the number being divided.

Note also that moving the decimal point two places to the right had the same effect as multiplying the number by 100. It is a simple rule that moving the decimal point one place to the right is the same as multiplying by 10. Moving the decimal point one place to the left is the same as dividing by 10. Moving the decimal two or three places to the right or the left is the same as multiplying or dividing by 100 or 1000 respectively.

EXERCISES

The following problems will give further practice in multiplying and dividing decimal fractions both by whole numbers and by decimal fractions. You will note that some of the problems will require changing common fractions to decimal fractions.

(1). 1.25 x .0034 = (2). 12.37 x 1000 =

(3). 4.40 x 1-1/2 x 20-3/4 =

(4). 9,387.6 x .0001 =

(5). $11.50 x 0.22 = (in cents) (6). 36.09 ÷ 3 =

(7). 128.4 ÷ 1-1/2 = (8). 7.28 ÷ .004 =

(9). $585.35 ÷ 3 = (to the nearest cent)

(10). 18-1/2 cents ÷ .125 = (in dollars)

11. If an installer can make 28 soldered joints in an hour, how many should he get done from 8:00 to 10:15?

12. A certain refrigeration system circulates 10.75 lbs of refrigerant per minute. If the refrigerant has a net refrigerating effect of 51.83 Btu/lb, how much heat is removed per hour?

13. A wholesaler bought a shipment of 1000 small hand tools for $1,670.00 and sold them for $2.00 each, what was his gross profit on each? On the total sale?

14. One ton of refrigeration equals 12,000Btu/hr. Find the capacity, in tons, of a system which removes 375,000 Btu's per hour.

15. An air conditioner is found to have a capacity of 240,000 Btu/hr. If the air flow through the coil equals 400 cfm per ton of refrigeration, what should the total air flow be through this air conditioner?

PERCENT

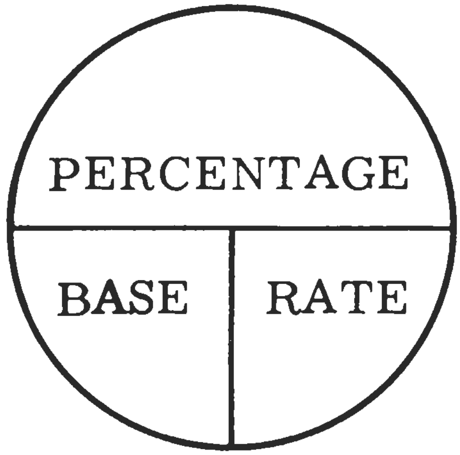
The definition of percent is by the hundred count. The symbol for percent is %. Percent is related to decimals, and may be expressed as a fraction. A thorough understanding of both fractions and decimals will aid in understanding percentage. Table 2 illustrates equivalent expressions for percent.

FORMULAS USED

In calculating percent, three factors are involved. They are the BASE, RATE, and PERCENTAGE. BASE is the number from which the percent is taken. PERCENTAGE is the number taken from the base. RATE is the number of percent taken and can be written in %. The formulas in Figure 5 show the relationship between BASE, RATE, and PERCENTAGE. Do not confuse Percentage with Percent (%) as used in these examples.

EQUIVALENT EXPRESSIONS FOR PERCENT			
Percent =	Decimal =	Decimal Fraction =	Common Fraction
5%	0.05	$\frac{5}{100}$	$\frac{1}{20}$
10%	0.10	$\frac{10}{100}$	$\frac{1}{10}$
20%	0.20	$\frac{20}{100}$	$\frac{1}{5}$
25%	0.25	$\frac{25}{100}$	$\frac{1}{4}$
30%	0.30	$\frac{30}{100}$	$\frac{3}{10}$
40%	0.40	$\frac{40}{100}$	$\frac{2}{5}$
50%	0.50	$\frac{50}{100}$	$\frac{1}{2}$
60%	0.60	$\frac{60}{100}$	$\frac{3}{5}$
70%	0.70	$\frac{70}{100}$	$\frac{7}{10}$
75%	0.75	$\frac{75}{100}$	$\frac{3}{4}$
80%	0.80	$\frac{80}{100}$	$\frac{4}{5}$
90%	0.90	$\frac{90}{100}$	$\frac{9}{10}$
100%	1.00	$\frac{100}{100}$	$\frac{1}{1}$

Table 2



PERCENTAGE = BASE X RATE

BASE = $\frac{\text{PERCENTAGE}}{\text{RATE}}$

RATE = $\frac{\text{PERCENTAGE}}{\text{BASE}}$

Figure 5
The Three Formulas Used
In Calculating Percent

From Figure 5 we can see that if any two of the three factors are known, the third can be found.

Example: Find 20% (RATE) of 50 (BASE).

Since we know the RATE and the BASE, we have to determine PERCENTAGE. Therefore, we use the formula PERCENTAGE = BASE x RATE. In the above example, percentage equals 50 x 0.20. Multiplying this out: Percentage equals 10.

Example: 75 (Percentage) = 50% (Rate) of what number? To find the base, use the formula BASE = PERCENTAGE ÷ RATE. Therefore, since 50% is the same as 0.50, we divide 0.50 (Rate) into 75 (Percentage, the answer, 150, is the Base).

Example: What percent of 1000 is 750? To find the RATE, use the formula RATE = PERCENTAGE ÷ BASE. In this example the formula becomes RATE equals 750/1000. This may be reduced to the common fraction 3/4, or the decimal fraction 75/100, which equals .75 or 75%.

EXERCISES

The following problems will give you practice in determining percentage, base and rate, for many applications. Doing these problems will also give you further practice in the foregoing problems of adding, subtracting, multiplying and dividing of both common and decimal fractions.

1. In the example 20% of 200 = 40, which is the Base?; Rate?; Percentage?

2. 59% of 300 =

3. 2 = what % of 16?

4. 175 = 20% of what?

5. 3/8 = what percent?

6. A 3 hp motor is running 75% loaded. What will its wattage be if full load watts equal 3100 watts?

7. On his first job, a refrigeration service engineer was able to replace a liquid line dehydrator in 48 minutes. Within one month he was able to do it 25% faster. How long does it take him at that rate?

8. An electric motor is designed for 208 to 220 volts, plus or minus 10%. What is the voltage range under which this motor will operate satisfactorily?

9. The commission of a certain Air Conditioning salesman is 1/8th of his gross sales. If his income for one week is $625.00, what did his sales amount to for the week?

10. In its first month in business, a service company did $57,500 worth of business and made $6,900.00 profit. In its fifth month, the company did $103,200.00 in total business and made $9,804.00 profit. How did the percent of profit for the fifth month compare with that for the first month?

SQUARE ROOT

The square root of a number is defined as one of two equal factors into which a given number can be separated. In other words, it is that part of the original number which multiplied by itself equals the original number. For example, the square root of 4 = 2, since 2 x 2 = 4. The square root of 16 = 4, therefore, 4 x 4 = 16. The radical sign $\sqrt{\ }$ is used to indicate the square root of a number.

USING A SQUARE ROOT TABLE

Many practical problems involve the use of squares and square roots. It is often possible to save considerable time by using a table of squares and square roots. (See Table 3).

This table makes it possible to find either the square or square root of any whole number from 1 to 150.

The basic number is shown in the center of each column. Its square is found in the same horizontal row, to the right, while its square root is found to the left.

Note that any number in the "SQUARES" column has its square root to the left in the "BASIC NUMBER" column. Also, any number in the "SQUARE ROOT" column has its square to the right, in the "BASIC NUMBER" column.

A perfect square is any number whose square root can be expressed as a whole number. Examples of a perfect square are 16, 25, 36, 49, etc. The square roots of these numbers are 4, 5, 6, and 7 respectively.

Often it is necessary to determine the square root of a number which though it may or may not be a perfect square, it is too large to determine by appearance, or from a chart. Most hand-held calculators in use today include this function.

USING THE HYPOTENUSE RULE

The side opposite the right angle of a right triangle is known as the "hypotenuse". (See Figure 6). There is a rule that states: "In any right triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides". This is known as the "Pythagorean Theorem", named after the Greek mathematician Pythagoras, and it is a very important rule to remember. With it, we can construct a perfect right angle, using certain sets of numerical values. Numbers 3, 4, and 5, or any multiple of them such as 15, 20, and 25 may be used. Also we can find the length of any side of a right triangle, if the two other sides are known.

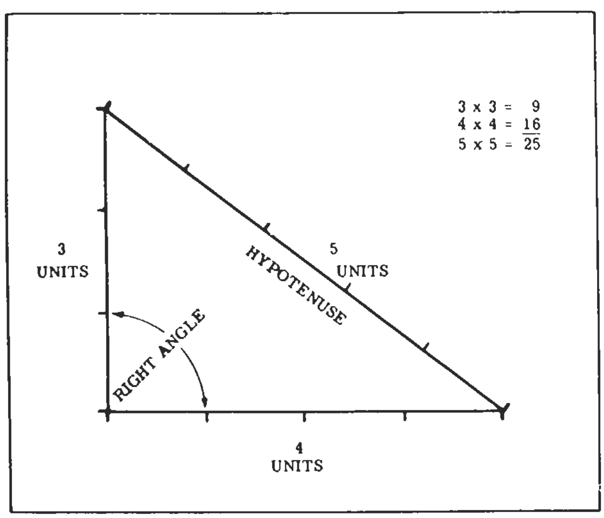


Figure 6
Using the Hypotenuse Rule
To Construct A Right Angle

SQUARES AND SQUARE ROOTS

Square Root	Basic Number	Square	Square Root	Basic Number	Square	Square Root	Basic Number	Square
1.000	1	1	7.141	51	2,601	10.050	101	10,201
1.414	2	4	7.211	52	2,704	10.100	102	10,404
1.732	3	9	7.280	53	2,809	10.149	103	10,609
2.000	4	16	7.348	54	2,916	10.198	104	10,816
2.236	5	25	7.416	55	3,025	10.247	105	11,025
2.449	6	36	7.483	56	3,136	10.296	106	11,236
2.646	7	49	7.550	57	3,249	10.344	107	11,449
2.828	8	64	7.616	58	3,364	10.392	108	11,664
3.000	9	81	7.681	59	3,481	10.440	109	11,881
3.162	10	100	7.746	60	3,600	10.488	110	12,100
3.317	11	121	7.810	61	3,721	10.536	111	12,321
3.464	12	144	7.874	62	3,844	10.583	112	12,544
3.606	13	169	7.937	63	3,969	10.630	113	12,769
3.742	14	196	8.000	64	4,096	10.677	114	12,996
3.873	15	225	8.062	65	4,225	10.724	115	13,225
4.000	16	256	8.124	66	4,356	10.770	116	13,456
4.123	17	289	8.185	67	4,489	10.817	117	13,689
4.243	18	324	8.246	68	4,624	10.863	118	13,924
4.359	19	361	8.307	69	4,761	10.909	119	14,161
4.472	20	400	8.367	70	4,900	10.954	120	14,400
4.583	21	441	8.426	71	5,041	11.000	121	14,641
4.690	22	484	8.485	72	5,184	11.045	122	14,884
4.796	23	529	8.544	73	5,329	11.091	123	15,129
4.899	24	576	8.602	74	5,476	11.136	124	15,376
5.000	25	625	8.660	75	5,625	11.180	125	15,625
5.099	26	676	8.718	76	5,776	11.225	126	15,876
5.196	27	729	8.775	77	5,929	11.269	127	16,129
5.292	28	784	8.832	78	6,084	11.314	128	16,384
5.385	29	841	8.888	79	6,241	11.358	129	16,641
5.477	30	900	8.944	80	6,400	11.402	130	16,900
5.568	31	961	9.000	81	6,561	11.446	131	17,161
5.657	32	1,024	9.055	82	6,724	11.489	132	17,424
5.745	33	1,089	9.110	83	6,889	11.533	133	17,689
5.831	34	1,156	9.165	84	7,056	11.576	134	17,956
5.916	35	1,225	9.220	85	7,225	11.619	135	18,225
6.000	36	1,296	9.274	86	7,396	11.662	136	18,496
6.083	37	1,369	9.327	87	7,569	11.705	137	18,769
6.164	38	1,444	9.381	88	7,744	11.747	138	19,044
6.245	39	1,521	9.434	89	7,921	11.790	139	19,321
6.325	40	1,600	9.487	90	8,100	11.832	140	19,600
6.403	41	1,681	9.539	91	8,281	11.874	141	19,881
6.481	42	1,764	9.592	92	8,464	11.916	142	20,164
6.557	43	1,849	9.644	93	8,649	11.958	143	20,449
6.633	44	1,936	9.695	94	8,836	12.000	144	20,736
6.708	45	2,025	9.747	95	9,025	12.042	145	21,025
6.782	46	2,116	9.798	96	9,216	12.083	146	21,316
6.856	47	2,209	9.849	97	9,409	12.124	147	21,609
6.928	48	2,304	9.899	98	9,604	12.166	148	21,904
7.000	49	2,401	9.950	99	9,801	12.207	149	22,201
7.071	50	2,500	10.000	100	10,000	12.247	150	22,500

Table 3

Example: (Refer to Figure 6). Find the value of the Hypotenuse if the other two sides are known:

$3 \times 3 = 9;\ 4 \times 4 = 16;\ 9 + 16 = 25;\ \sqrt{25} = 5$

Find the value of one side if the other side and Hypotenuse are known:

$3 \times 3 = 9;\ 5 \times 5 = 25;\ 25 - 9 = 16;\ \sqrt{16} = 4$

EXERCISES

The following problems will give you further practice in finding the square root of whole numbers and numbers with decimals. Questions 6 through 10 will give practice in using the hypotenuse rule. Carry all answers out to three places where applicable.

(1). $\sqrt{2500}$ =

(2). $\sqrt{160}$ =

(3). $\sqrt{7500}$ =

(4). $\sqrt{21,316}$ =

(5). $\sqrt{2557.015}$ =

6. Two installers were laying out a form for a condensing unit base. To ensure that the corners were square, they measured 9 feet along one side and 12 feet along the other. What should the length of the resulting diagonal be? (Figure 7).

7. In framing up a doorway, a man used a 2-1/2 ft. diagonal brace, nailed 2 feet down from the corner. If the frame is square, how far should the other end of the brace be from the corner? (Figure 8).

8. To go from his house to the shop, Joe Serviceman used to drive 12 miles East and 5 miles North. A new highway was put through, running North-East directly by his home and the shop. How far must Joe now drive?

9. A 16 ft. ladder placed with its base just 4 ft. from the wall reaches the edge of the roof. What is the approximate height of the roof, from the ground?

10. The machine room is in the North-East corner of a 20' x 60' building, and the air conditioning coil is to be placed in the South-West corner. How many feet of tubing could be saved by running the liquid and suction lines diagonally, rather than along the walls of the building?

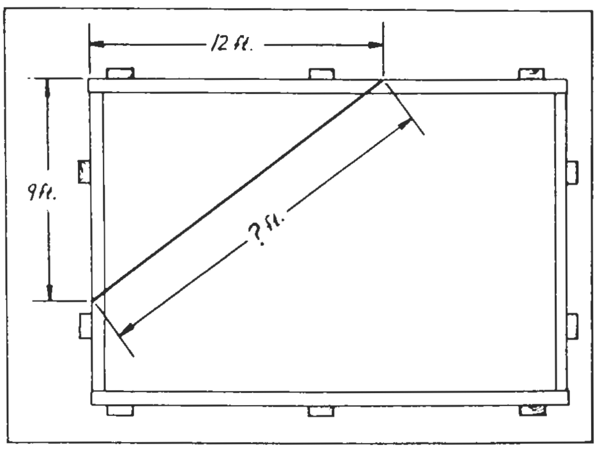


Figure 7
Using Hypotenuse Rule To Ensure Concrete Form Corners Are Square

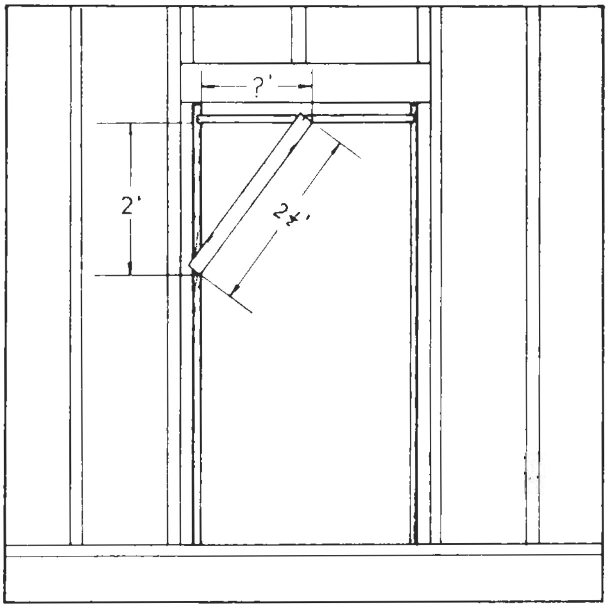


Figure 8
Using Hypotenuse Rule For Squaring A Door Frame

DECIMALS

The word decimal is taken from the latin word meaning tenth, therefore a decimal fraction is one whose denominator is always some multiple of 10, such as 10, 100, 1000, 10,000, etc. Numbers such as 6/10, 15/100 and 75/1000, are decimal fractions. These will normally be written 0.6, 0.15 and 0.075, respectively. Note that in a decimal, there are the same number of digits to the right of the decimal point, as there are zeros in the denominator of the decimal fraction.

FRACTION EQUIVALENTS

A decimal fraction may be changed to a common fraction, and vice-versa. Table 1 shows the decimal equivalents of the most commonly used fractions.

CHANGING DECIMALS TO FRACTIONS

Example: Reduce the decimal 0.25 to a common fraction.

Since 0.25 contains two figures to the right of the decimal point, the numerator of the decimal fraction is 25 written over 100. (25/100) The decimal fraction 25/100 can be changed to a common fraction by reducing it to its lowest terms. Thus it will become the common fraction 1/4.

COMMON FRACTIONS AND THEIR DECIMAL EQUIVALENTS

1/64	=	.015625	17/64	=	.265625	33/64	=	.515625	49/64	=	.765625
1/32	=	.031250	9/32	=	.281250	17/32	=	.531250	25/32	=	.781250
3/64	=	.046875	19/64	=	.296875	35/64	=	.546875	51/64	=	.796875
1/16	=	.062500	5/16	=	.312500	9/16	=	.562500	13/16	=	.812500
5/64	=	.078125	21/64	=	.328125	37/64	=	.578125	53/64	=	.828125
3/32	=	.093750	11/32	=	.343750	19/32	=	.593750	27/32	=	.843750
7/64	=	.109375	23/64	=	.359375	39/64	=	.609375	55/64	=	.859375
1/8	=	.125000	3/8	=	.375000	5/8	=	.625000	7/8	=	.875000
9/64	=	.140625	25/64	=	.390625	41/64	=	.640625	57/64	=	.890625
5/32	=	.156250	13/32	=	.406250	21/32	=	.656250	29/32	=	.906250
11/64	=	.171875	27/64	=	.421875	43/64	=	.671875	59/64	=	.921875
3/16	=	.187500	7/16	=	.437500	11/16	=	.687500	15/16	=	.937500
13/64	=	.203125	29/64	=	.453125	45/64	=	.703125	61/64	=	.953125
7/32	=	.218750	15/32	=	.468750	23/32	=	.718750	31/32	=	.968750
15/64	=	.234375	31/64	=	.484375	47/64	=	.734375	63/64	=	.984375
1/4	=	.250000	1/2	=	.500000	3/4	=	.750000	1	=	1.000000

Table 1

Page 6 (continued)

(8). 1167.76 − 1000.00 = 167.76

(9). 10.24 − 5.50 = 4.74

(10). 105.87 − 3.90 = 101.97

(11). .125 + .125 + .125 + .125 = .500 saw cuts equal

.5 + 2.0 + 5.35 + 12.25 + 13.75 + 26.15 = 60.00 inches pipe length equals

(12). $1\frac{3}{8} = 1.375$

.0625 + .0625 = .1250

I.D. = 1.375 − .125 = 1.250 or 1-1/4 in.

(13). .010 + .040 + .060 = .110

$\frac{\not{1}\not{1}\not{0}^{22}}{\not{1}\not{0}\not{0}\not{0}_{\not{1}\not{2}\not{5}\ 25}} \times \frac{\not{6}\not{4}^{8}}{1} = \frac{176}{25} = 7 \text{ (approx.)}$

$.110 = \frac{7}{64}$

(14). \$15.45 + 2.50 + 1.25 = \$19.20

(15). \$13.75 + 6.35 + 1.20 = \$21.30

\$25.00 − 21.30 = \$ 3.70 profit

Page 7

(1). .00425 (2). 12370 (3). \$4.40 x 1.5 = \$6.60; \$6.60 x 20.75 = \$136.95 (4). .93876 (5). 253 cents

(6). 3) 36.09 = 12.03 (7). 15.) 1284.0 = 85.6 (8). 4) 7280. = 1820. (9). 3) \$585.350 = \$195.116 = \$195.12, or 19,512 cents

(10). 125) 18500. = 148 cents = \$1.48 (11). 28 x 2.25 = 63 joints (12). 10.75 x 51.83 x 60 = 33430.35 Btu/hr.

(13). \$2.00 − 1.67 = \$ .33 each; \$330.00 total (14). 12) 375.00 = 31.25 tons (15). 12) 240 = 20; 20 x 400 = 8000 cfm

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Page 9

(1). Base = 200; Rate = 20%; Percentage = 40 (2). .59 x 300 = 177 (3). 2 ÷ 16 = .125 = 12.5%

(4). 2) 1750 = 875 (5). 8) 3.000 = .375 = 37.5% (6). 3100 x .75 = 2325 watts (7). 25% faster = 75% as long; 48 x .75 = 36 minutes

(8). 208 − 20.8 = 187.2; 220 + 22 = 242; 187.2 to 242 volts

(9). 1/8 = 12.5%; $\frac{\$625.00}{.125} = \$5000.00$

(10). 575) 69.00 = .12 = 12.0%; 1032) 98.040 = .095 = 9.5%; 12.0% − 9.5% = 2.5% lower

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Page 11

(1). $\sqrt{25'00.} = 5\ 0.$

(2). $\sqrt{1'60.00'00'00} = 1\ 2.6\ 4\ 9$

(3). $\sqrt{75'00.00'00'00} = 8\ 6.6\ 0\ 2$

(4). $\sqrt{21,316} = 146$ (Table 3)

(5). $\sqrt{25'57.01'50'00} = 50.566$

(6). 9 x 9 = 81
12 x 12 = 144
225

$\sqrt{225} = 15$ feet

(7). 2.5 x 2.5 = 6.25
2 x 2 = 4.0
2.25

$\sqrt{2.25} = 1.5$ feet

(8). 12 x 12 = 144
5 x 5 = 25
169

$\sqrt{169} = 13$ miles

(9). 16 x 16 = 256
4 x 4 = .16
240

$\sqrt{2'40.00'00} = 15.49$ or 15-1/2 ft. approx.

(10). 20 x 20 = 400
60 x 60 = 3600
4000

$\sqrt{40'00.00'00'00} = 63.245$ or 63-1/4 ft. approx.

20 ft.
+60 ft.
80 ft.
-63-1/4 ft.
16-3/4 ft. each

therefore, 33-1/2 ft. of tubing could be saved by running both the liquid and suction lines diagonally.

This Section has been checked for technical accuracy by Mr. Richard F. Lynch, Mathematics instructor at Lane Technical High School, Chicago, Illinois.

NOTES:

Refrigeration Service Engineers Society

BETTER SERVICE THROUGH KNOWLEDGE

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