Waterworks Math – The Basics

Chapter 13

What Is In This Chapter?

1. The principles of working with fractions
2. The principles of working with decimals
3. How to round numbers
4. How to determine significant digits
5. How to read powers
6. Conversions using standard conversion factors
7. The weight of one cubic foot of water
8. The volume in gallons of one cubic foot of water
9. The number square feet in an acre
10. How to average a set of numbers
11. How to determine area of rectangles and circles
12. How to determine volume of rectangular, circular, and cone-shaped objects
13. How to covert whole numbers to percent
14. How to calculate percent
15. How to make common waterworks conversions
16. Common abbreviations found in waterworks math
17. How to convert pressure to feet of head
18. The number of gpm that equals one cfs
19. How to calculate the radius and circumference of a circle
20. How to calculate the perimeter of a rectangle
21. How to calculate flow
22. How to calculate detention time

Key Words

- Area
- Averages
- cfs
- Circumference
- Cross-sectional Area
- Cubic Feet
- Cylinder
- Demand
- Detention Time Flow
- Diameter
- Head
- MGD
- mg/L
- pi
- Radius
- Rectangle
- Velocity
- Volume

Introduction

Lesson Intent

This lesson on math basics is intended as a review and introduction to those math concepts believed to be critical and minimum to the "Certified Operator" in an Alaskan community of fewer than 500 population. This does not mean that these are the only math concepts that a competent operator needs in order to solve routine operation and maintenance problems.

Lesson Content

This lesson on basic math is a review of the principles needed for working with fractions and decimals, rounding numbers, determining the correct number of significant digits, raising numbers to powers, calculating percent, making simple conversions, calculating **flow**[1], calculating volume, and calculating **detention time**[2].

[1] Flow – To be in constant movement, typically in a single direction. In regards to water, this term typically relates to a volume per unit of time, gallons per minute, cubic feet per second, etc.

[2] Detention time – The theoretical time required to displace the contents of a tank or unit at a given rate of discharge or flow.

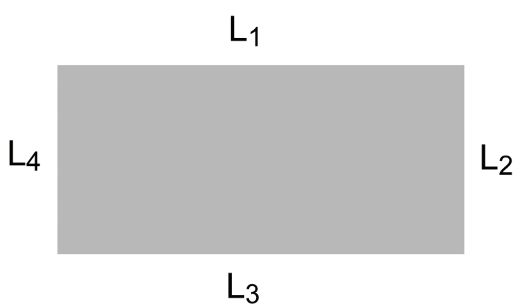
Basic Equations

The following is a listing of the basic formulas found in the math section of this text. They have been compiled here for your convenience.

Perimeter/Circumference

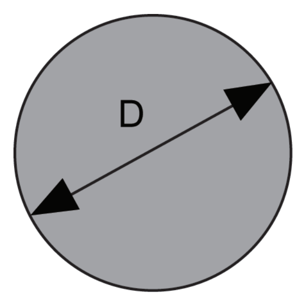
Square or Rectangle

Perimeter = L1 + L2 + L3 + L4



Circle

Circumference = πD



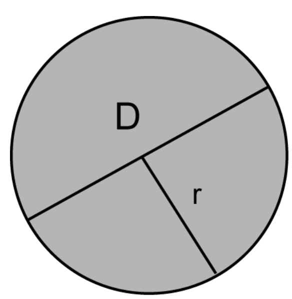
Area

Rectangle or Square

A = L x W

Circle

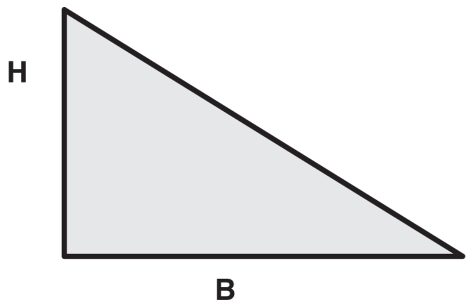
$A = \pi r^2$ or $0.785D^2$



Area

Triangle

$$A = \frac{B \times H}{2}$$

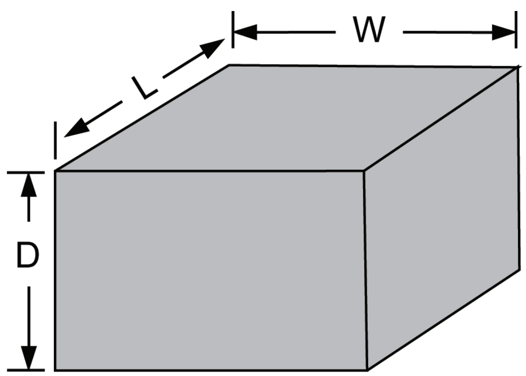


Other Equations

Volume

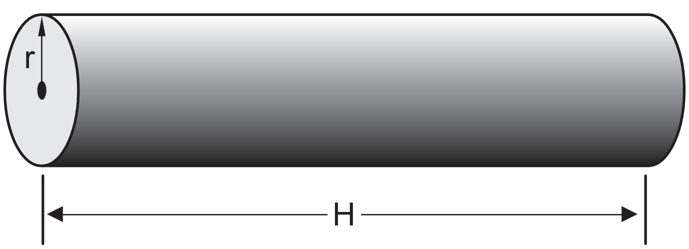
Rectangle or Square

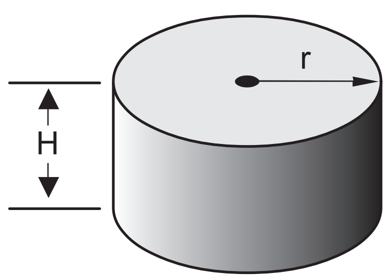
V = L x W x D



Cylinder

$V = \pi r^2 \times H$ or L

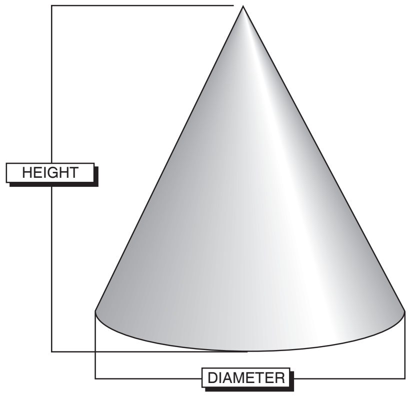




Volume

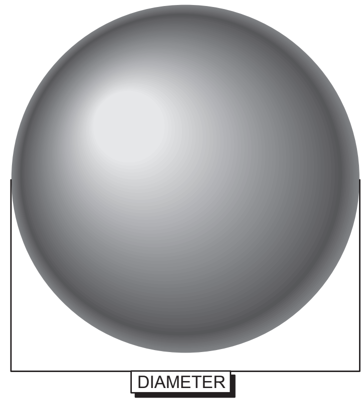
Cone

$$\frac{\pi r^2 H}{3} \quad \text{or} \quad \frac{.785\, D^2\, H}{3}$$



Sphere

$$\frac{2}{3} \times (.785\, D^2) \times D$$



Pounds

Lbs = V, MG x 8.34 lbs/gal x Conc, mg/L

Where:
Lbs = pounds
V = flow or volume in millions of gallons
Conc = concentration or dosage in mg/L

Removal Efficiency

$$\frac{\text{In - Out}}{\text{In}} \times 100 = \%\ \text{efficiency}$$

Pump Efficiency

$$\frac{\text{Output Horsepower}}{\text{Input Horsepower}} \times 100 = \%\ \text{efficiency}$$

Weir Overflow Rate

$$\text{Weir Overflow Rate (WO)} = \frac{\text{Flow rate in gpd}}{\text{Weir length in feet}} = \text{gal/day/ft}$$

Temperature

°C = 5/9 (°F – 32°)   °F = (9/5 x °C) + 32

Detention Time

$$\text{Detention Time (DT)} = \frac{\text{Volume}}{\text{Flow}}$$

Working with Math

Steps in Solving Problems

Introduction

There are many methods that can be successfully used to solve waterworks problems. We tend to select and adapt problem-solving styles that fit our individual system. If you have selected one or more methods that are beneficial to your style, we suggest that you continue to use what has worked in the past. However, if waterworks problems have frustrated you then we suggest that you consider some version of the following procedure:

Procedure

1. When appropriate, make a drawing of the information in the problem.
2. Place the data that is available on the drawing.
3. Ask, "What is the question?"
4. Write down what you are to find. Sometimes the answer has more than one piece. For instance, you may need to find "X" and then find "Y."
5. Write down any equation that you are going to need.
6. Fill in the data in the equation.
7. Rearrange the equation, if necessary.
8. Pick up the calculator and make the calculation.
9. Write down the answer.

Word Problems

Words to Symbols

In word problems, certain words can be used to determine the correct math function or meaning. Here are a few of the basic word meaning examples:

Word	Meaning
of	multiply
and	add
per	divide
less than	subtract

Symbols to Words

In writing mathematical formulas or expressions, symbols are used to indicate an mathematical operation. Here are a few examples:

Math Operation	Symbol	Example
Multiplication	x	Q = V x A
Multiplication	•	Q = V • A
Multiplication	No space	Q = VA
Multiplication	( ) ( )	Q = (V) (A)
Division	÷	r = D ÷ 2
Division	——	$r = \frac{D}{2}$
Division	/	r = D/2

Help with the Calculator

Introduction

The calculator has made the solution of waterworks problems much easier and improved our accuracy. At the same time the calculator brings with it its own problems. The following are few hints that may make using the calculator less stressful.

Hint #1 – Type of Calculator

The calculator used by a waterworks operator is not a toy; it is a tool like any other tool. As such, it is best to purchase for quality rather than price. Quality will be easier to use and last much longer. A quality calculator used by a waterworks operator should have the following:

- The keys should be large enough to allow your fingers to be easily placed on them.
- The calculator should have a **pi**[3] (π) key. This makes calculating pipe and circular tank volumes much easier.
- Solar calculators do not offer the freedom of use that battery calculators offer.
- A protective case will add life to the calculator.
- The display should allow for 10 characters.
- A scientific calculator is more appropriate and useful than a business calculator.

[3] pi – Greek letter (π) used as a symbol denoting the ratio of the circumference of a circle to its diameter.

Hint #2 – Read the Book

The small booklet that comes with the calculator is designed to help you understand the functions of the calculator. You should read and then store the book for easy access. This allows you to use the book to help solve unique problems that show up only on occasion.

Hint #3 – Division by 2

One of the common problems confronted by operators is the proper method to solve the following:

- One incorrect method that is used is to divide 7 by 0.25 and then multiply that answer by 8.34. This will yield an incorrect answer of 233.52 **mg/L**[4] .
- A second less serious mistake is to multiply 0.25 x 8.34 and write the answer down on a piece of scratch paper (2.085). Typically the answer is rounded off to 2. The rounding reduces the accuracy, and writing the number down is a step that is not necessary.
- The CORRECT APPROACH would be to place 7 in the calculator, press the divide key (÷), enter the number 0.25 and press the divide key (÷) again. Now enter in the number 8.34, and press the equal key (=). The correct answer of 3.357 should be displayed. This can be rounded off to 3.4 mg/L. Yes, this is one more character than the correct number of significant digits. This is done not because of accuracy but because the answer is most likely larger than 3.

[4] mg/L (milligrams per Liter) – A unit of the concentration of a constituent in water. It is 0.001g of the constituent in 1,000 ml of water. mg/L has replaced the PPM (parts per million) in reporting results in water.

Math Principles

Fractions

Use

With the calculators that are available today, the need to work with fractions is not what it once was. However, the operator is often faced with routine situations that require thinking in fractions and on occasion actually working with fractions. One of the common uses for the rules governing the use of fractions in a math problem is dealing with units of a problem. Units like gpm is actually a fraction gal/min, and **cfs**[5] is actually ft^3/sec. So as you can see, understanding fractions may help you solve other problems.

[5] cfs – To be in constant movement, typically in a single direction. In regards to water, this term typically relates to a volume per unit of time, gallons per minute, cubic feet per second, etc.

Components of a Fraction

A fraction is composed of three items: two numbers and a line. The number on the top is called the numerator, the number on the bottom is called the denominator, and the line in between them means to divide.

$$\text{Divide} \longrightarrow \frac{3}{4} \begin{array}{l}\text{Numerator}\\ \text{Denominator}\end{array}$$

Principles of Working With Fractions

Introduction

Like all other math functions, how we deal with fractions is governed by rules or principles. The following is a discussion of 11 principles associated with using fractions.

Same Numerator and Denominator

When the numerator and denominator of a fraction are the same, the fraction can be reduced to 1. For example:

$$\frac{4}{4} = 1,\quad \frac{24}{24} = 1,\quad \frac{8}{8} = 1,\quad \frac{12}{12} = 1,\quad \frac{125}{125} = 1$$

Whole Numbers to Fractions

Any whole number can be expressed as a fraction by placing a “1” in the denominator. For example:

$$2 \text{ is the same as } \frac{2}{1} \text{ and } 45 \text{ is the same as } \frac{45}{1}$$

Adding Fractions

Only fractions with the same denominator can be added, and only the numerators are added. For example:

$$\frac{1}{8} + \frac{3}{8} = \frac{4}{8} \text{ and, } \frac{6}{32} + \frac{12}{32} = \frac{18}{32}$$

Subtracting Fractions

Only fractions with the same denominator can be subtracted, and only the numerators are subtracted. The denominator remains the same. For example:

$$\frac{7}{8} - \frac{3}{8} = \frac{4}{8} \text{ and, } \frac{18}{25} - \frac{6}{25} = \frac{12}{25}$$

Mixed Numbers

A fraction combined with a whole number is called a mixed number. For example:

$$4\frac{1}{8},\quad 16\frac{2}{3},\quad 8\frac{3}{4},\quad 45\frac{1}{2} \text{ and, } 12\frac{17}{32}$$

These numbers are read, four and one eighth, sixteen and two thirds, eight and three fourths, forty-five and one half, and twelve and seventeen thirty seconds.

Changing a Fraction

A fraction can be changed by multiplying the numerator and denominator by the same number. This does not change the value of the fraction, only how it looks. For instance:

$$\frac{1}{2} \text{ is the same as } \frac{1 \times 2}{2 \times 2} \text{ which is } \frac{2}{4}$$

Simplest Terms

Fractions should be reduced to their simplest terms. This is accomplished by dividing the numerator and denominator by the same number. The result of this division must leave both the numerator and the denominator as whole numbers. For instance:

$\frac{2}{4}$ is not in its simplest terms, by dividing both by 2, we obtain $\frac{1}{2}$

The number 2/3 cannot be reduced any further since there is no number that can be divided evenly into the 2 and the 3.

Practice Problems – Fractions

1. Reduce the following to their simplest terms.

   A. 4/8 = ______________________
   B. 12/18 = ______________________
   C. 3/4 = ______________________
   D. 6/8 = ______________________
   E. 24/32 = ______________________
   F. 9/18 = ______________________
   G. 15/27 = ______________________

Key to Reducing – Even Numbers

When the starting point is not obvious, do the following: if the numerator and denominator are both even numbers (2, 4, 6, 8, 10, etc.), divide them both by 2. Continue dividing by 2 until a division will no longer yield a whole number with the numerator and denominator.

Key to Reducing – Odd Numbers

When the numerator and denominator are both odd numbers (3, 5, 7, 9, 11, 13, 15), attempt to divide by three, continue dividing by 3 until a division will no longer yield a whole number with the numerator and denominator. It is obvious that some numbers such as 5, 7, and 11 cannot be divided by 3 and may in fact be in their simplest terms.

Different Denominators

To add or subtract fractions with different denominators, the denominators must be changed so that all denominators are the same. To find the "common denominator," multiply the denominators together. Then convert each fraction to a new value based on this new common denominator.

For instance, to add 1/8 and 2/3 together:

1. Start by multiplying the denominators 8 x 3 = 24.
2. Change 1/8 to a fraction with 24 as the denominator.

   $$\frac{24}{8} = 3, \qquad 3 \text{ x } 1 = 3 \text{ (the numerator), new fraction is } \frac{3}{24}$$

   Notice that this is the same as 1/8 except 3/24 is not reduced to its simplest terms.

3. Change 2/3 to a fraction with 24 as the denominator.

   $$\frac{24}{3} = 8, \qquad 8 \text{ X } 2 = 16 \text{ (the numerator), new fraction is } \frac{16}{24}$$

4. Complete the addition.

   $$\frac{3}{24} + \frac{16}{24} = \frac{19}{24}$$

Numerator Larger

Any time the numerator is larger than the denominator, the fraction should be turned into a mixed number. This is accomplished by the following procedure:

1. Determine the number of times the denominator can be divided evenly into the numerator. This will be the whole number portion of the mixed number.
2. Multiply the whole number times the denominator, and subtract from the numerator. This value, the remainder, becomes the numerator of the fraction portion of the mixed number.

$\frac{28}{12}$, 28 is divisible by 12 twice. 2 is the whole number

2 x 12 = 24

$\frac{28}{12} - \frac{24}{12} = \frac{4}{12}$ dividing top and bottom by 4 = $\frac{1}{3}$

New mixed number is 2 $\frac{1}{3}$

Multiplying Fractions

This is accomplished by the following procedure:

1. Multiply the numerators together.
2. Multiply the denominators together.
3. Reduce to the simplest terms.

   For example: Find the result of multiplying 1/8 x 2/3

$$\frac{1}{8} \times \frac{2}{3} = \frac{2}{24}\text{, reduced } = \frac{2}{24} \div \frac{2}{2} = \frac{1}{12}$$

Dividing Fractions

This is accomplished by the following procedure:

1. Invert the denominator (turn it upside down).
2. Multiply and reduce to simplest terms. For example:
3. Divide 1/8 by 2/3.

$$\frac{1}{8} \div \frac{2}{3} = \frac{1}{8} \times \frac{3}{2} = \frac{1 \times 3 = 3}{8 \times 2 = 16} = \frac{3}{16}$$

The divide symbol can be ÷ or / or ——.

Converting Fractions to Decimals

To convert a fraction to a decimal, simply divide the numerator by the denominator.

Example – Converting Fractions to Decimals

$$\frac{1}{2} = 0.5,\ \frac{7}{8} = 0.875,\ \frac{7}{16} = 0.875,\ \frac{1}{4} = 0.25\text{, and } \frac{2}{3} = 0.667$$

Changing Inches to Feet

To change inches to feet, multiply the number of inches by the conversion 1/12.

Example – Changing Inches to Feet

Change 3 inches to feet:

$$3 \text{ in x } \frac{1}{12} = \frac{3 \text{ x } 1}{12} = \frac{3}{12} = 0.4 \text{ ft}$$

Practice – Changing Inches to Feet

Change the following to feet:

2 inches, 4 inches, 6 inches, 8 inches

$$\frac{2}{12} = 0.167 \text{ feet}$$

$$\frac{4}{12} = 0.34 \text{ feet}$$

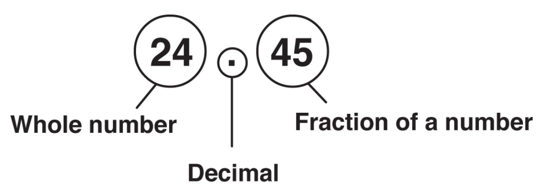
$$\frac{6}{12} = 0.5 \text{ feet}$$

$$\frac{8}{12} = 0.667 \text{ feet}$$

Decimals

The Components

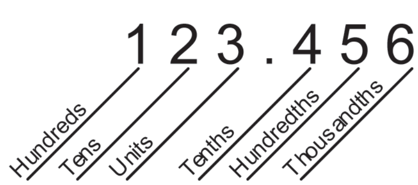
A decimal is composed of two sets of numbers: the numbers to the left of the decimal are whole numbers, and numbers to the right of the decimal are parts of whole numbers, a fraction of a number.



Fraction Component

The terms used to express the fraction component is dependent on the number of characters to the right of the decimal.

- The first character after the decimal point is tenths: 0.1 – tenths
- The second character is hundredths: 0.01 – hundredths
- The third character is thousandths: 0.001 – thousandths



Principles

Calculators

With today's use of calculators, we seldom need the rules for handling decimals. As a result, when we need to make a computation manually, we often cannot remember the basic rules. Therefore, this brief review is provided.

Number Less Than One

When a number is less than one and is expressed as a decimal, place a "0" (zero) to the left of the decimal. This makes it clear that the number is less than one. For instance 0.25 is much clearer than .25.

Subtraction

When subtracting decimals, simply line up the numbers at the decimal, and subtract. For example:

$$\begin{array}{r} 28.65 \\ -\ 12.25 \\ \hline 16.40 \end{array} \qquad \begin{array}{r} 145.600 \\ -\ 13.212 \\ \hline 132.388 \end{array}$$

Addition

To add numbers with a decimal, use the same rules as subtraction: line up the numbers on the decimal, and add.

$$\begin{array}{r} 28.65 \\ +\ 12.25 \\ \hline 40.90 \end{array} \qquad \begin{array}{r} 145.600 \\ +\ 13.212 \\ \hline 158.812 \end{array}$$

Multiplication

To multiply two or more numbers containing decimals, follow these few basic steps:

1. Multiply the numbers as whole numbers. Do not worry about the decimals.
2. Write down the answer.
3. Count the total number of digits (numbers) to the right of the decimal in all of the numbers being multiplied.
4. To place the decimal in the answer, count from the right to the left the number of digits counted in the previous step.

Example – Multiplication

Multiplying 3.04 x 8.6 yields the number 26144.

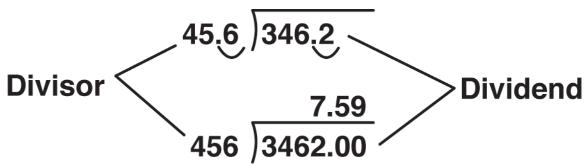
There are a total of three digits to the right of the decimal point (2 for the number 3.04 and 1 for the number 8.6). Therefore, the decimal point should be placed three places to the left from the right of the last 4.

26.144

Division

To divide a number by a number containing a decimal, the divisor must be made into a whole number by moving the decimal point to the right until you have a whole number.

1. Count the number of places the decimal needed to be moved.
2. Move the decimal in the dividend by the same number of places.
3. Make the division.



Using the Calculator

With today's calculators, this problem would simply be set up as follows:

$$\frac{346.2}{45.6} = 7.59$$

Rounding

Why Round?

Numbers are rounded to reduce the number of digits to the right of the decimal point. This is for convenience, not accuracy.

Process of Rounding

1. Start by deciding how many places you want to the right of the decimal. Remember this is done for convenience.
2. If the number to the right of the last number that you wish to report is 5 or greater than 5, increase the size of the last number by 1.
3. If the number to the right of the last number that you wish to report is less than 5, the size of the last number remains the same.

Example 1 – Rounding

A calculation has just been completed, and the answer is 24.55836. A decision is made to have two places to the right of the decimal. Two places takes you to 25.55. The next number is "8." Therefore, the last five is rounded up to a six. The number is 24.56.

Example 2 – Rounding

A calculation has just been completed, and the answer is 24.55436. A decision is made to have two places to the right of the decimal. Two places takes you to 25.55. The next number is "4." Therefore, all of the numbers to the right of the .55 are dropped. The reported number is 24.55.

Practice Problems – Rounding

1. Round the following to the nearest hundredths (the second place after the decimal).

   A. 2.4568 ____________________
   B. 27.2534 ____________________
   C. 128.2111 ____________________
   D. 364.8762 ____________________
   E. 354.777777 ____________________
   F. 34.666666 ____________________
   G. 67. 33333 ____________________

2. Round the following to the nearest tenths (the first place after the decimal).

   A. 2.4568 ____________________
   B. 27.2534 ____________________
   C. 128.2111 ____________________
   D. 364.8762 ____________________
   E. 354.777777 ____________________
   F. 34.666666 ____________________
   G. 67. 33333 ____________________

Determining Significant Digits

The Concept

The concept of significant digits is related to rounding. It can be used to determine where to round off. The basic idea is that no answer can be more accurate than the least accurate piece of data used to calculate the answer.

Process

The process involves two steps:

1. Determine the number of decimal places in the least accurate piece of data.
2. Round off the answer to this position.

Example – Significant Digits

The following calculation was made:

25.456 x 4.6 = 117.0976

The least accurate piece of data is number 4.6. This piece of data has only one place to the right of the decimal. Therefore, the answer can have only one place to the right of the decimal. The answer should be rounded off to 117.1.

Practice Problems – Significant Digits

1. Round the following answers off to the most significant digit.

   A. 26.34 x 124.34567 = 3,275.26495 ________________

   B. 25.1 + 26.43 = 51.53 ________________

   C. 128.456 – 121.4 = 7.056 ________________

   D. 23.5 ft x 34.25 ft = 804.875 ft^2 ________________

   E. 12,457.92 x 3 = 37,373.76 ________________

Working with Powers

Principle

Powers are used to identify **area**[6], as in square feet, and volume as in **cubic feet**[7]. Powers can also be used to indicate that a number should be squared, cubed, etc. This later designation is the number of times a number must be multiplied by itself.

[6] Area – The extent of a surface, measured by the number of squares of equal size it contains.

[7] Cubic Feet – A measurement of volume in the number of cubes that are one foot on a side.

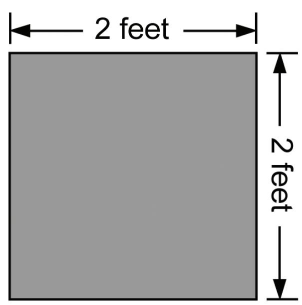
Example – Powers

We could find these two numbers:

4^2 or 4 ft^2

The number 4^2 means 4 x 4 = 16.

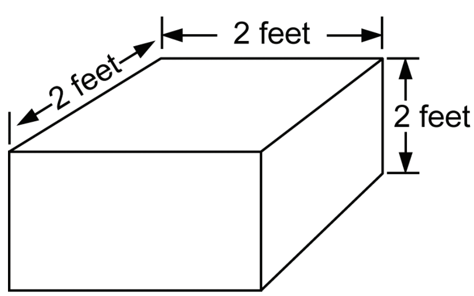
The number 4 ft^2 means four square feet, an area 2 ft x 2 ft.



Or we might see these two numbers 4^3 or 4 ft^3.

The number 4^3 means 4 x 4 x 4 = 64.

The number 4 ft^3 means 4 cubic feet, a block 2 ft x 2 ft x 1 foot deep.



Finding Averages

Use

Finding an **average**[8] of a series of numbers is accomplished by adding the numbers and dividing by the number of numbers in the group. This is an activity that is required on the monthly report for chlorine, fluoride, and turbidity readings. The average for the month is commonly figured on all chemicals added, and on most test results.

[8] Average – An arithmetic mean. The value is arrived at by adding the quantities in a series and dividing the total by the number in the series.

Example 1 – Averages

Find the average of the following series of numbers: 12, 8, 6, 21, 4, 5, 9, and 12. Adding the numbers together we get 77. There are 8 numbers in this set. Divide 77 by 8.

$$\frac{77}{8} = 9.6 \text{ is the average of the set}$$

Example 2 – Averages

Here is a series of daily turbidities. Obtain the average for them.

0.3, 0.4, 0.3, 0.1, 0.8

The total is 1.9. There are 5 numbers in the set. Therefore:

$$\frac{1.9}{5} = 0.38\text{, rounding off} = 0.4$$

Practice Problem – Averages

1. Find the average of the following set of numbers:

0.2
0.2
0.1
0.3
0.2
0.4
0.6
0.1
0.3

Equations

Description

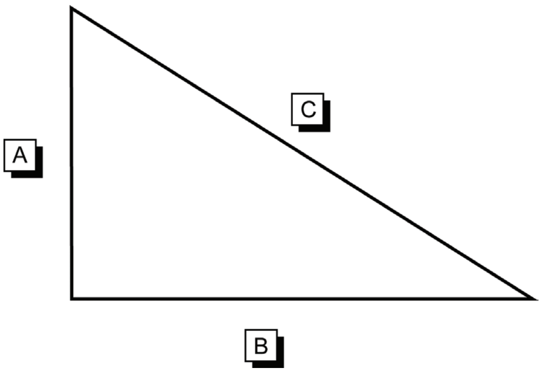
An equation is a symbolic representation of how to combine certain information in order to obtain the proper result. Equations are written using letters and symbols to represent unknown or standard values.

Use

Equations (also called formulas) are used by operators to solve a wide variety of problems associated with treatment and collection. In fact, most operators use formulas without thinking about them to solve routine problems. For instance, to determine the perimeter or distance around a building requires using a formula.

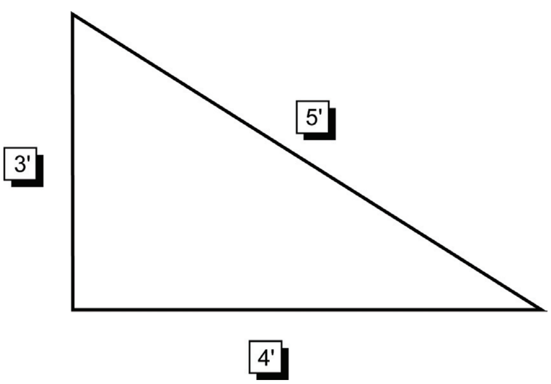
Example 1 – Equations

The equation for determining the perimeter of a triangle is P = a + b + c. P is the letter used to designate the perimeter and a, b, and c are used to identify the lengths of the sides. The mathematical symbols (=) and (+) tell the user what math functions are to be carried out. This formula says to add the lengths of all of the sides to obtain the perimeter.



Example 2 – Equations

In the example below, the numbers 3', 4', and 5' have been substituted for the letters a, b, and c. To solve the equation substitute the numbers for the appropriate letters, a = 3', b = 4', and c = 5'. Now add the three together to obtain a perimeter of 12'. The distance around this triangle is 12 feet.



Works on All Triangles

This equation will work for all triangles, regardless of the lengths of their sides.

Formulas with Symbols

Some equations such as the one for the area of a circle ($A = \pi r^2$) use symbols. The symbol π (pi) is used to represent a constant: 3.14. This is done in equations to simplify the writing of the equation.

Listing of Formulas

A listing of common equations used in water/wastewater systems can be found at the end of this chapter. In addition, equations are used in most of the other sections of this chapter.

Rearranging Equations

Types of Equations

The equations that are commonly used in water math are called linear equations (follow a straight line). To be successful in solving math problems, an operator must be able to solve a linear equation with one unknown (perimeter of a triangle, pounds formula, area of a circle are all examples of this type of equation).

Why Rearrange?

To solve a problem, an operator is often required to solve the equation for a component that is not normally part of the solution. For instance, the perimeter and the length of two sides of a triangle may be known, and you wish to solve for the length of the third side.

Two Sides

Equations have two sides that are separated by the equal sign (=) . To solve an equation, there must be only one unknown and the unknown must be on one side of the equation by itself.

Rearranging Equations with Addition and Subtraction

Rule

The rule of equality must be maintained! Thus, if you subtract a value from the right side of the equal sign, you must subtract the same value from the left side of the equal sign. The is true for adding, dividing, and multiplying.

Example – Addition and Subtraction

Solve the equation $12 = 3 + b + 5$

The first step is to rearrange the equation so that the unknown is on one side of the equation by itself. This is accomplished by subtracting 3 and 5 from both sides of the equation.

$12 - 3 - 5 = 3 + b + 5 - 3 - 5$

On the right side of the equation $3 - 3 = 0$ and $5 - 5 = 0$

The resulting new equation would look like this:

$12 - 3 - 5 = b$

The last step is to do the math. That is, subtract 3 and 5 from 12. The result is: $4 = b$

Rearranging Equations with Multiplication and Division

Process

To solve for an unknown value in an equation using multiplication or division, move the unknown value to one side of the equation by itself.

Top and Bottom

As stated above, an equation has two sides. A multiplication and division equation also has a top and bottom that are separated by a division line. When the equation is just multiplication, the division line is not shown and all of the items are above the line.

Rule

To move an item from one side of an equation to the other in a multiplication or division equation, the item is moved from the top of one side to the bottom of the other or from the bottom of one side to the top of the other.

Summary

To state it another way, if the item that is being moved is on top of the equation, then it must be placed below when moved. If an item is below in the equation, then it must be placed above when it is moved.

Example 1 – Multiplication and Division

Solve this equation for V:

$$254 = V \text{ X } 8.34 \text{ X } 35$$

$$\frac{254}{\bigcirc \text{ X } \bigcirc} = V \text{ X } 8.34 \text{ X } 35$$

$$\frac{254}{8.34 \text{ X } 35} = V$$

Result:

$$V = 0.87$$

Example 2 – Multiplication and Division

Solve for X in the following equation:

$$6 = \frac{x}{10}$$

Step 1 – Rearrange the equation by multiplying both sides by 10.

$$\bigcirc \quad 6 = \frac{x}{10}$$

10 x 6 = X

Step 2 – Solve the equation.

60 = X

Special Note

Many equations are written without the use of the multiplication sign. For instance, $A = \pi r^2$ and $C = \pi D$.

πr^2 is the same as $\pi \times r^2$, or pi times r^2.

Also, $\pi (r^2)$ is the same as $\pi \times (r^2)$ or pi times r^2.

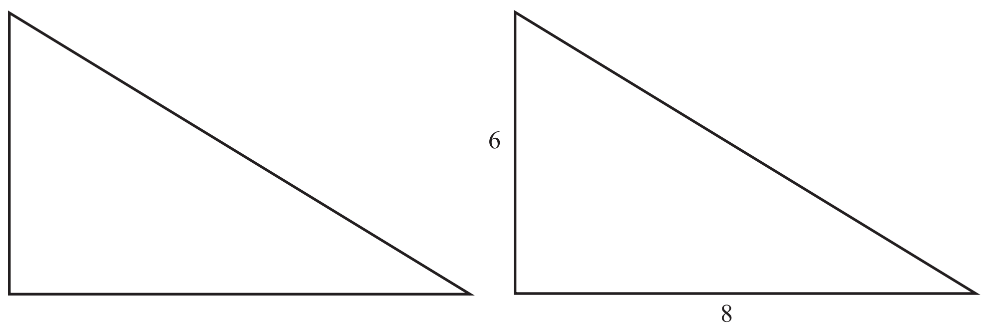
Equation Problems

Example 1 – Equation Problems

A triangle has a perimeter of 24', the length of the bottom is 8', and the length of the left side is 6'. What is the length of the long side?

Step 1 – Draw a diagram of the triangle.

Step 2 – Place the known values on the diagram.



Step 3 – Write the equation.

$P = a + b + c$

Step 4 – Fill in the known values in the equation.

$24' = 6' + 8' + c$

Step 4 – Subtract 6' and 8' from both sides of the equation.

$24' - 6' - 8' = c$

Step 5 – Solve the equation.

$10' = c$

Example 2 – Equation Problems

Find the diameter of a pipe with a circumference of 18 7/8 inches.

Step 1 – Draw a diagram of the pipe.

Step 2 – Place the known values on the diagram.

Circumference = 18 7/8"

Step 3 – Make any obvious conversions.

The circumference is given in inches and fractions of inches. This must be converted to a decimal before proceeding.

18 7/8" = 18.875"

Step 4 – Select an equation.

$C = \pi D$

Step 5 – Fill in the known values.

$18.75'' = \pi D$

Step 6 – Divide both sides of the equation by pi.

$$\frac{18.75''}{\pi} = D$$

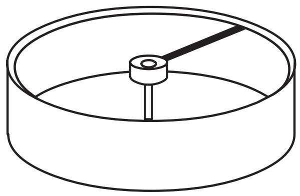
Step 7 – Solve the equation.

$6'' = D$

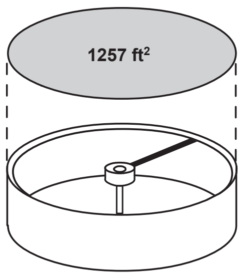
Example 3 – Equation Problems

Find the diameter of a settling basin with a surface area of 1257 ft^2.

Step 1 – Draw a diagram of the clarifier.



Step 2 – Place the known values on the diagram.



Step 3 – Select an equation.

$A = \pi r^2$

Step 4 – Fill in the known values.

$1257\ ft^2 = \pi r^2$

Step 5 – Divide both sides of the equation by pi (π).

This rearrangement will require two steps. The second step is to change the r^2 to r. This is accomplished by finding the square root of all of the values on both sides of the equation.

$$\sqrt{\frac{1257\,ft^2}{\pi}} = r$$

20 feet = r

Step 6 – Determine the diameter from the radius.

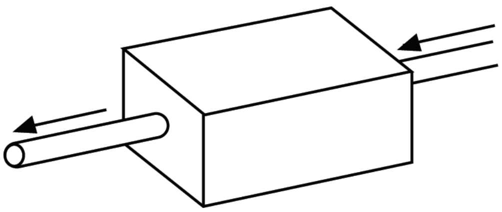
Since the radius is one half of the diameter this value must be multiplied by 2.

2 x 20 ft = 40 ft – the diameter of the clarifier

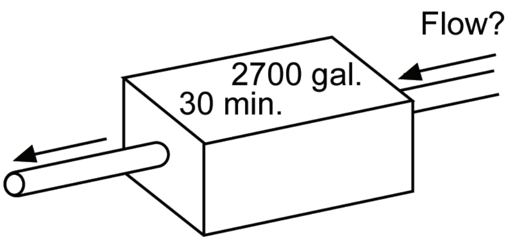
Example 4 – Equation Problems

A chlorine contact chamber holds 2700 gallons. It is desired to have a contact time of 30 minutes in the chamber. What is the maximum flow rate that can pass through this chamber at this detention time.

Step 1 – Draw a diagram of the situation.



Step 2 – Place the unknown values on the diagram.



Step 3 – Select an equation.

$$DT = \frac{\text{Volume}}{\text{Flow}}$$

Step 4 – Place the known values in the equation.

$$30 \text{ min} = \frac{2{,}700 \text{ gal}}{\text{gpm}}$$

Step 5 – Divide both sides of the equation by 30 minutes.

$$\text{gpm} = \frac{2{,}700 \text{ gal}}{30 \text{ min}}$$

Step 6 – Solve the equation.

gpm = 90 gpm

Practice Problems – Formulas

1. Find the diameter of a settling basin that has a circumference of 126 feet.

2. Find the diameter of a pipe that has a circumference of 12 9/16".

3. Find the diameter of a settling basin that has a surface area of 113 ft^2.

4. Find the diameter of a storage tank that has a surface area of 314 ft^2.

5. The detention time in a chlorine contact chamber is 42 minutes. If the chamber holds 3200 gallons, what is the flow rate in gpm?

6. A clearwell has a detention time of 2 hours. What is the flow rate in gpm if the clearwell holds 8000 gallons?

7. A rectangular settling basin has a weir length of 10 feet. What is the weir overflow rate when the flow is 80,000 gpd?

Finding Perimeter/Circumference

Units

The perimeter is the total distance, or length around an object, like a parcel of land, a building, or a box. **Circumference**[9] is the distance around a circle. Distance is a linear measurement, and therefore the standard units for linear measurements are used. Typical samples would be inches, feet, miles, etc.

Formula for a Rectangle

The perimeter of a **rectangle**[10] is obtained by adding the lengths of the four sides.

Formula for a Circle

The circumference of a circle is found by multiplying pi (π) times the **diameter**[11].

$C = \pi \times D$

Where:

C = Circumference	π = Greek letter pi
D = diameter	π = 3.1416

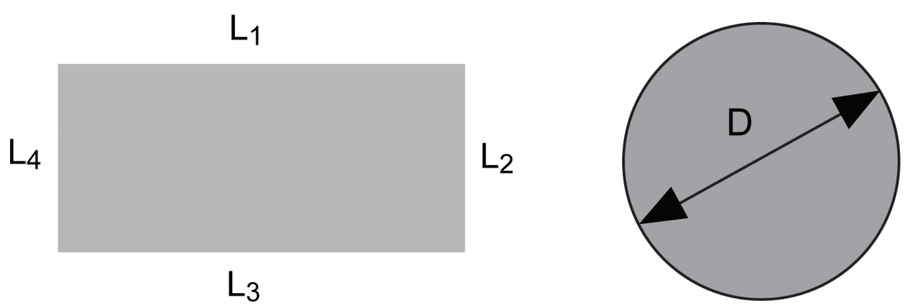
[9] Circumference – The perimeter of a circle.

[10] Rectangle – A four-sided figure with four right angles.

[11] Diameter – The distance across a circle. A straight line passing through the center of a circle.

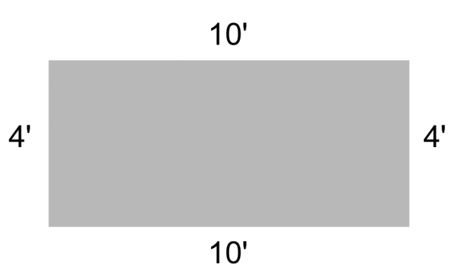
Perimeter/Circumference

Square or Rectangle	Circle
Perimeter = L1 + L2 + L3 + L4	Circumference = πD



Example – Rectangle

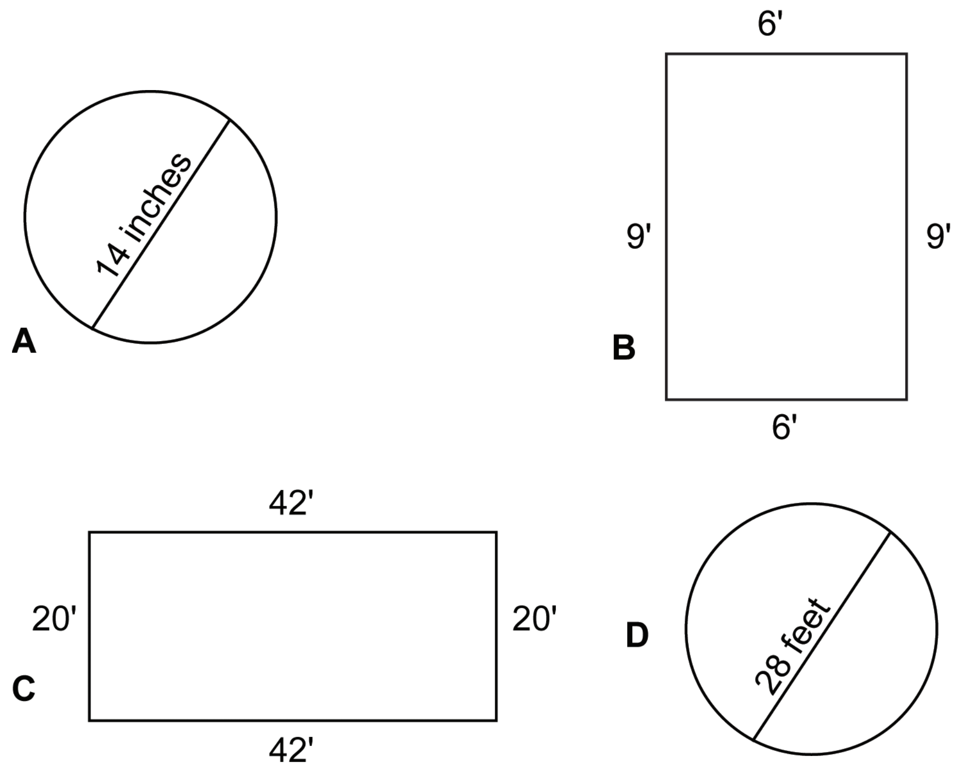
Find the perimeter of the following rectangle:



P = 10' + 4' + 10' + 4' = 28'

Practice Problems – Perimeter and Circumference

1. Find the perimeter or circumference of the following items:



Finding Area

Units

Area is an expression of the square unit measurement of the surface of an item or a parcel of land. The area on top of a sedimentation basin is called the surface area. The area of the end of a pipe is called the **cross-sectional area**[12]. Area is usually expressed in squared terms such as square inches (in^2) or square feet (ft^2). Land may also be expressed in terms of sections (1 square mile) or acres (43,560 ft^2) or in the metric system as hectares (10,000m^2).

[12] Cross-sectional Area – The area at right angles to the length of a pipe or basin.

Formula for a Rectangle

The area of a rectangle is found by multiplying the length times the width.

Where:

L = length W = width

Formula for a Circle

The surface area of a circle is determined by multiplying pi times the radius squared (r^2).

Where:

A = area π = Greek letter pi

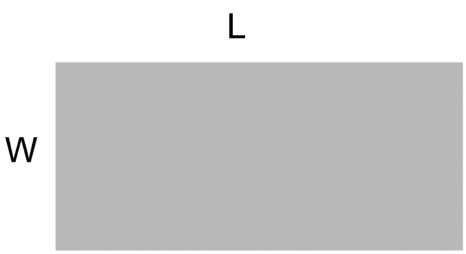
r = **radius**[13] of a circle π = 3.1416

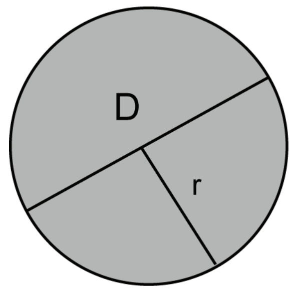
Radius is one-half of the diameter

[13] Radius – A line from the center of a circle or sphere to the circumference of the circle or surface of the sphere.

Area

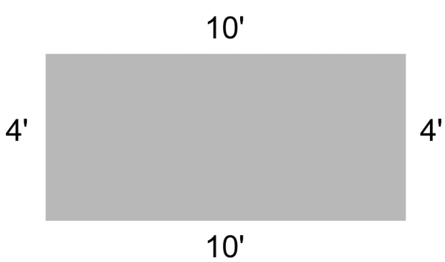
Rectangle or Square	Circle
A = L x W	$A = \pi r^2$ or $.785D^2$





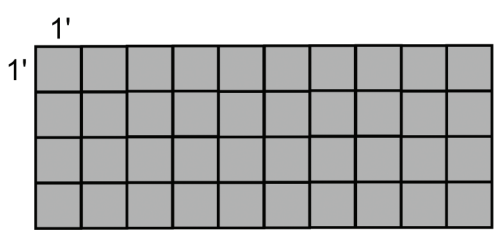
Example – Rectangle

Find the area of the following rectangle:



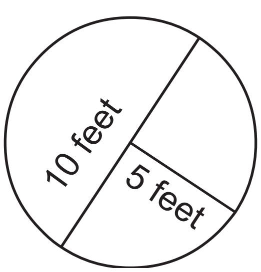
$A = 4' \times 10' = 40\ ft^2$

This is the same as saying that 40 individual pieces of paper one foot by one foot could be placed on this surface.



Example – Circle

Find the surface area of the following circle with a radius of 5 ft:



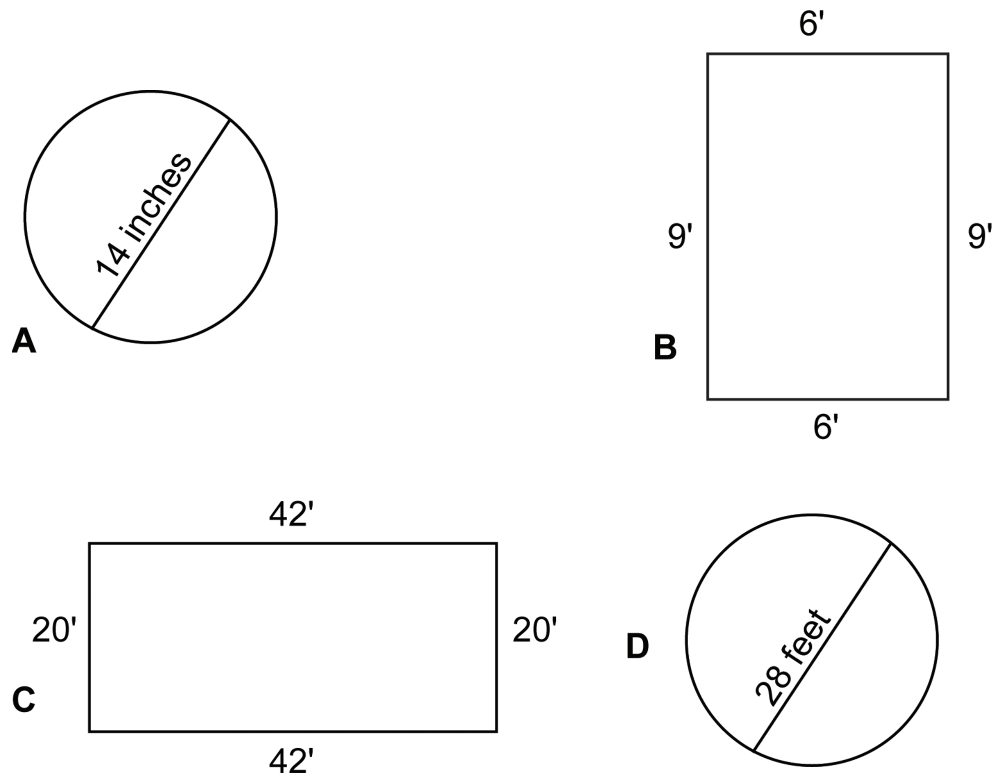
$A = \pi \times r^2$
$A = \pi \times 5^2$
$A = \pi \times 25\ ft^2$
$A = 78.5\ ft^2$

Or

$A = .785 \times D^2$
$A = .785 \times 10^2$
$A = .785 \times 10 \times 10$
$A = 78.5\ ft^2$

Practice Problems – Area

1. Find the area of the following items:



Finding the Volume

Units

Volume[14] is expressed in cubic units, such as cubic inches (in^3), cubic feet (ft^3), acre feet (1 Acre foot = 43,560 ft^3), etc.

[14] Volume – The amount of space occupied by or contained in an object. Measured by the number of cubes, each with an edge 1 unit long that can be contained in the object.

Formula for Rectangular Object

The volume of a rectangular object is obtained by multiplying the length times the width times the depth or height.

$$V = L \times W \times D$$

Where: L = length W = width
D = depth or H = height

Formula for a Cylinder

The volume of a **cylinder**[15] (such as a piece of pipe or a tank) is equal to its height times pi times the radius of the cylinder squared. The length (L) and height (H) of a cylinder are the same dimension.

[15] Cylinder – A solid or hollow figure, traced out when a rectangle rotates using one of its sides as the axis of the rotation.

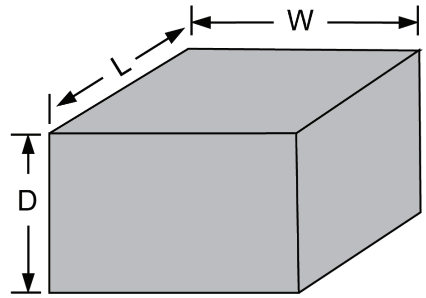
$$V = H \times \pi r^2$$
$$\text{or } V = H \times .785\, D^2$$

Where: $\pi = 3.1416$
r = radius of the cylinder
H = height or length of the cylinder

Volume

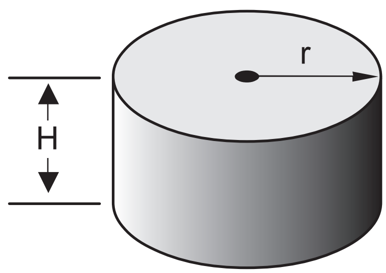
Rectangle or Square

$V = L \times W \times D$



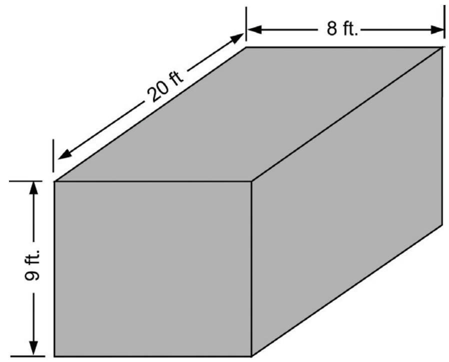
Cylinder

$V = H \times \pi r^2$ or $V = H \times .785\ D^2$



Example – Volume

Find the volume in cubic feet of the sedimentation basin below:

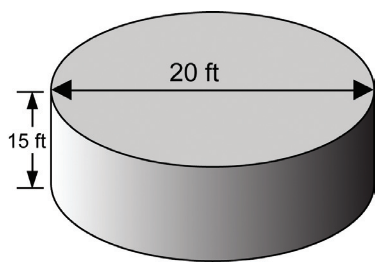


V = L x W x D
V = 20 ft x 8 ft x 9 ft
V = 1,440 ft^3

Example – Cylinder
Find the volume of a tank 20 feet in diameter and 15 feet tall.

Volume = H x π r^2 or Volume = H x .785 D^2

The radius of a circle is one-half the diameter. Since the diameter is 20 feet, the radius is 10 feet.



V = 15 ft x π (10 ft)^2
V = 15 ft x π x 100 ft^2
V = 4,712 ft^3

Or

V = 15 ft x .785 x 20^2
V = 15 ft x .785 x 20 x 20
V = 4,712 ft^3

Practice Problems – Volume

1. Find the volume of the following:
   A. A 3-inch pipe 200 feet long. (Hint, change the diameter of the pipe from inches to feet by dividing by 12.)
   B. A fuel tank 4 feet in diameter and 10 feet long.
   C. A chlorine barrel that is 20 inches in diameter and 42 inches tall.
   D. A trench 2.5 feet wide, 6 feet deep, and 60 feet long.

Working with Percent

Definition

Percent means parts of 100 parts. The symbol for percent is %. We use percent to describe portions of the whole. For instance, if a tank is 1/2 full, we say that it contains 50% of the original solution. We also use percent to describe the portion of a budget spent or a project completed. For example, "There is only 25% of the budgeted amount remaining." "The water line project is 80% complete."

How Expressed

Percentage is expressed as a whole number with a % sign after it, except when it is used in a calculation. In a calculation, percent is expressed as a decimal. The decimal is obtained by dividing the percent by 100. For instance, 11% is expressed as the decimal 0.11, since 11% is equal to 11/100. This decimal is obtained by dividing 11 by 100.

Finding Percentage

To determine what percentage a part is of the whole, divide the part by the whole.

Example 1 – Percent

There are 80 water meters to read, Jim has finished 24 of them. What percentage of the meters have been read?

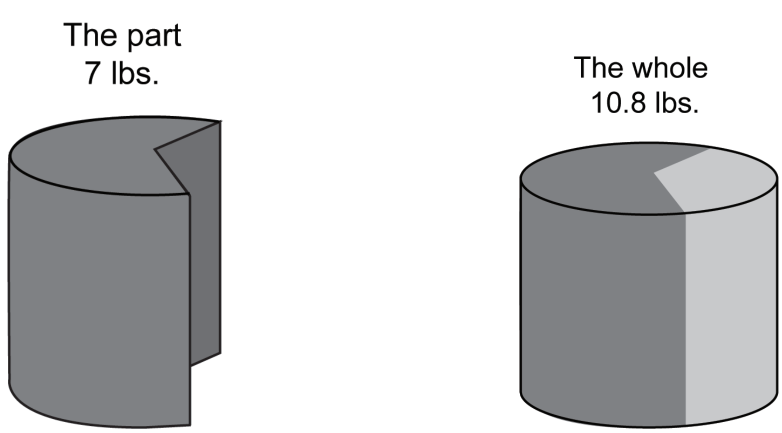
24 ÷ 80 = 0.30

The 0.30 is converted to percent by multiplying the answer by 100.
0.30 x 100 = 30%

Thus 30% of the 80 meters have been read.

Finding the Whole

To determine the whole when the part and its percentage is given, divide the part by the percentage.



Example 2 – Percent

How much 65% calcium hypochlorite is required to obtain 7 pounds of pure chlorine? The part is the 7 pounds, which is 65% of the whole.

1. Convert the percentage to a decimal by dividing by 100.

   65% ÷ 100 = 0.65

2. Divide the part by the decimal equivalent of the percentage.

   7lbs ÷ 0.65 = 10.769 – rounding 10.8 lbs.

Changing Decimals to Percent

To change the percent obtained above to the decimal equivalent, divide the percent by 100.

Example – Changing Decimals to Percent

Change 30% to a decimal.

30% ÷ 100 = 0.30 (0.30 is the decimal equivalent of 30%.)

Percentage of a Number

To find the percentage of a number, multiply the number by the decimal equivalent of the percentage given in the problem.

Example – Percentage

What is 28% of 286?

1. Change the 28% to a decimal equivalent.

   28% ÷ 100 = 0.28

2. Multiply 286 x 0.28 = 80

   28% of 286 is 80. 80 is 28% of 286.

Increase a Value by a Percent

To increase a value by a percent, add the decimal equivalent of the percent to "1," and multiply it times the number.

Example – Increasing a Value by a Percent

A filter bed will expand 25% during backwash. If the filter bed is 36 inches deep, how deep will it be during backwash?

1. Change the percent to a decimal.

   25% ÷100 = 0.25

2. Add the whole number 1 to this value.

   1 + 0.25 = 1.25

3. Multiply times the value.

   36 in x 1.25 = 45 inches

Percentage Concentrations

The concentration of chemicals, such as fluoride and hypochlorites, is commonly expressed as a percentage.

Example – Percentage Concentrations

A chlorine solution was made to have a 4% concentration. It is often desirable to determine this concentration in mg/L. This is relatively simple: the 4% is four percent of a million.

To find the concentration in mg/L when it is expressed in percent, do the following:

1. Change the percent to a decimal.

   4% ÷ 100 = 0.04

2. Multiply times a million.

   0.04 x 1,000,000 = 40,000 mg/L

We get the million because a liter of water weighs 1,000,000 mg. 1 mg in 1 liter is 1 part in a million parts (ppm). 1% = 10,000 mg/L.

Practice Problems – Percentage

A. 25% of the chlorine in a 30-gallon vat has been used. How many gallons are remaining in the vat?

B. The annual public works budget is $147,450. If 75% of the budget should be spent by the end of September, how many dollars are to be spent? How many dollars will be remaining?

C. There are 50 pounds of pure chlorine in a container of 67% calcium hypochlorite. What is the total weight of the container?

D. 3/4 is the same as what percentage?

E. A 2% chlorine solution is what concentration in mg/L?

F. A water plant produces 84,000 gallons per day. 7,560 gallons are used to backwash the filter. What percentage of water is used to backwash?

[16] Demand – When related to use, the amount of water used in a period of time. The term is in reference to the "demand" put onto the system to meet the need of customers.

G. The average day winter **demand**[16] of a community is 14,500 gallons. If the summer demand is estimated to be 72% greater than the winter, what is the estimated summer demand?

Pump Efficiency

Horsepower

There are three types of horsepower associated with a pumping installation:

- Electrical Horsepower (EHp) – The horsepower that is purchased from the power company.
- Brake Horsepower (BHp) – The horsepower that is the output of the electric motor. This is the input horsepower to the pump.
- Water Horsepower (WHp) – The horsepower that is the output of the pump.

Process – Pump or Motor

To determine the efficiency of a pump or motor, divide the output horsepower by the input horsepower. Then multiply the result by 100 to change the decimal into percent.

$$\frac{\text{Output Horsepower}}{\text{Input Horsepower}} \times 100 = \%\ \text{efficiency}$$

Process – When % is Given

If the efficiency of each unit is known and you wish to determine the efficiency of the entire pump station, then merely multiply the decimal equivalency of the two percentages together.

Efficiency of Motor x Efficiency of Pump = Station %

Example 1 – Pump Efficiency

It has been determined that the water horsepower of a pump is 5 Hp and the brake horsepower output of the motor is 7.2 Hp. What is the efficiency of the motor?

$$\frac{5 \text{ WHp}}{7.2 \text{ BHp}} \text{ x } 100 = 69.4\%$$

Example 2 – Pump Efficiency

If a motor is 90% efficient and the output is 7.5 BHp, what is the electrical horsepower requirement?

$$\frac{7.5 \text{ BHp}}{0.90} = 8.3 \text{ EHp}$$

Example 3 – Well Efficiency

If a pump is 70% efficient and the motor is 90% efficient, what is the efficiency of the well?

1. Change the efficiency into decimals by dividing each by 100.
   $$\frac{70\%}{100} = 0.70, \quad \frac{90\%}{100} = 0.90$$
2. Multiply the two values.
   0.70 x 0.90 = 0.63
3. Multiply the value by 100 to convert the decimal to a percentage.
   0.63 x 100 = 63%

Practice Problems – Efficiency

A. The water horsepower of a pump is 10 Hp, and the brake horsepower output of the motor is 15.4 Hp. What is the efficiency of the motor?

B. The water horsepower of a pump is 25 Hp, and the brake horsepower output of the motor is 48 Hp. What is the efficiency of the motor?

C. The efficiency of a well pump is determined to be 75%. The efficiency of the motor is estimated at 94%. What is the efficiency of the well?

D. If a motor is 85% efficient and the output of the motor is determined to be 10 BHp, what is the electrical horsepower requirement of the motor?

E. The water horsepower of a well with a submersible pump has been calculated at 8.2 WHp. The output of the electric motor is measured as 10.3 BHp. What is the efficiency of the pump?

Making Conversions

Use

Conversions are a process of changing the units of a number in order to make the number usable in a specific instance. Common conversions in water works include the following:

- gpm to cfs
- Million gallons to acre feet
- Cubic feet to acre feet
- Cubic feet of water to weight
- Cubic feet of water to gallons
- Gallons of water to weight
- gpm to **MGD**[17]
- psi to feet of **head**[18]

[17] MGD (Million gallons per day) – A unit of flow and a unit of volume.
[18] Head – The measure of the pressure of water expressed as height of water in feet: 1 psi = 2.31 feet of head.

Working with Formulas

To use a formula, you must change the units of the data given to meet the requirements of the formula.

Example – Formulas

The formula for finding **velocity**[19] in a pipe is V = Q ÷ A, where Q is the flow in cubic feet per second. We most often measure flow in gallons per minute. To use this formula, we must often convert the flow from gpm to cfs.

---

[19] Velocity – The speed at which water moves, expressed in feet per second.

What Is a Conversion?

A conversion is a number that is used to multiply or divide into another number in order to change the units of the number.

Known Conversions

In most instances, the conversion factor cannot be derived. It must be known. Therefore, tables such as the one below are used to find the common conversions.

Committing to Memory

Most operators memorize some standard conversions. This happens as a result of using the conversions, not as a result of attempting to memorize them.

Some Common Conversions	
Linear Measurements	Weight
1 inch = 2.54 cm 1 foot = 30.5 cm 1 meter = 100 cm = 3.281 feet = 39.4 inches 1 acre = 43,560 ft^2 1 yard = 3 feet	1 ft^3 of water = 62.4 lbs 1 gal = 8.34 lbs 1 lb = 453.6 grams 1 kg = 1000 g = 2.2 lbs 1 % = 10,000 mg/L 1 pound = 16 oz dry wt 1 ft^3 = 62.4 lbs
Volume	Pressure
1 gal = 3.78 liters 1 ft^3 = 7.48 gal 1 L = 1000 mL 1 gal = 16 cups	1 ft of head = 0.433 psi 1 psi = 2.31 ft of head
Flow	
1 cfs = 448 gpm 1gpm = 1440 gpd	

Selecting a Conversion

The key to selecting which conversion to use is to look at the units. If you wish to convert cubic feet of water to pounds, then you need a conversion that has both of these units (1 ft^3 of water = 62.4 lbs).

Complex Process

The process of converting units can be highly complex and require several steps. A working understanding of the processes used requires a basic understanding of algebra. Because this is outside of the scope of this material, a process that does not require the understanding of algebra is described below. This process works only if there is an existing conversion and only a single conversion is required.

Straight Line Conversion

The technique described below is for working with straight line conversions. A straight line conversion is one that is direct: gpm to cfs, gal to liters, gallons to pounds, etc.

Process

The best way to describe this process is with an example.

Example – Straight Line Conversion

Convert 865 gpm to cfs.

1. Place the known value on the paper with the units as a fraction and with 1 as the denominator to that fraction.
2. Place a multiplication sign (x) after the units.
3. Place a straight line after the x.
4. Follow the straight line with an equal sign (=).

$$865 \frac{\text{gpm}}{1} \times$$

5. Ask the following question, "What units do I want to get rid of?"

$$865 \frac{\text{gpm}}{1} \times \frac{?}{\text{gpm}} =$$

6. Place this unit under the straight line. In this case, we want to get rid of the gpm.
7. Ask yourself, "What units do we want when we get done?"
8. Place this unit above the straight line. The original question ask that we convert gpm to cfs. So cfs is what we want when we get done.
9. Find a conversion that goes between these two units. From the conversion table, we find the following conversion:
   1 cfs = 448 gpm
10. Place the conversion next to the proper units above or below the line. In our example, the conversion was 448 gpm, so the 448 goes below the line next to its proper units.

$$865 \frac{\text{gpm}}{1} \times \frac{1 \text{ cfs}}{448 \text{ gpm}} =$$

11. Solve the problem. The information above could be rewritten into a fraction.

$$\text{cfs} = \frac{865 \text{ gpm} \times 1 \text{ cfs}}{1 \times 448 \text{ gpm}} = \frac{865 \text{ gpm} \times 1 \text{ cfs}}{448 \text{ gpm}} = 1.92 \text{ cfs}$$

Practice Problems – Conversion

1. Convert the following:

   A. 750 ft^3 of water to gallons

   B. 50 gallons of water to pounds

   C. 560 gpm to cfs

   D. 4 lbs to ounces

E. 128 ft^3 of water to weight in pounds

F. 340 in^2 to ft^2

G. 3.4 cfs to gpm

H. H. 65 ft^3 to yd^3

I. 3,000 gallons to ft^3

J. 250,000 gallons to MG

K. 75 gpm to MGD

L. 8 inches to feet

M. 2.4 MGD to cfs

N. 2.4 MGD to gpm

O. 65 pints to gallons

P. 2.5 ft^2 to square inches

Q. 7 yards to feet

R. 36,000 gpd to gpm

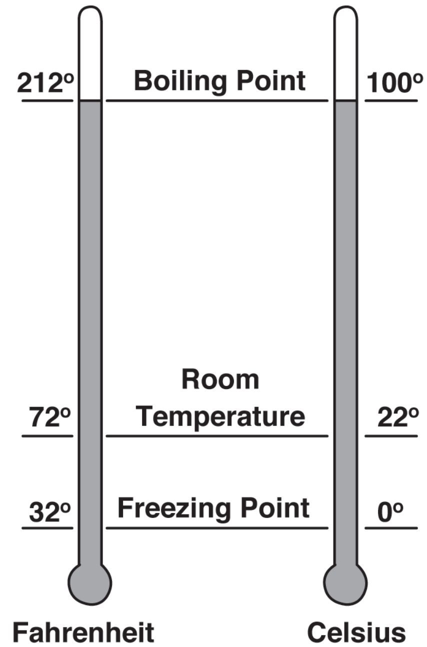
S. 125 gpm to gph

Temperature Conversion

Two Scales

There are two scales used to report temperature: the English scale of Fahrenheit and the metric scale of Celsius. There are two classic equations used to convert between these two scales:

°C = 5/9 (°F - 32°)
°F = (9/5 X °C) + 32°



Confusion

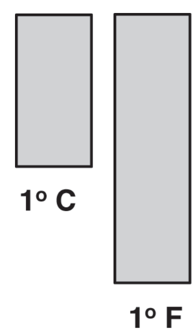
Typically, these two formulas provide more confusion than clarity. The following is our attempt to share a method that we find helpful in making these conversions.

The Scales

To understand how to make these conversions, start with comparing the two scales. With the Fahrenheit scale, water freezes at 32° and boils at 212°. On the Celsius scale, water freezes at 0° and boils at 100°.

Difference of 32°

We can see that if we want to go from Fahrenheit to Celsius we must start by subtracting 32°. To go from Celsius to Fahrenheit, we must add 32°.



Size of the Division

The difference between 32° and 212° is 180°. This is the difference between water freezing and boiling on the Fahrenheit scale. The difference between freezing and boiling on the Celsius scale is 100°. Therefore, we can see that each 1° change in the Celsius scale is the same as a 1.8° change in the Fahrenheit scale.

Changing Scales

As a result, to change from Celsius to Fahrenheit, we must multiply the result by 1.8. To change from Fahrenheit to Celsius we must divide by 1.8.

Final Confusion

The most confusing part is to determine if you should adjust for the 32° first or adjust for the size of the scale first. Here are the rules:

Rule 1 – To change °F to °C - subtract 32° then divide by 1.8.
Rule 2 – To change °C to °F - multiply by 1.8 and add 32°.

Conclusion

We now have two new formulas:

$$°C = \frac{°F - 32°}{1.8}$$

$$°F = °C \times 1.8 + 32°$$

A Third Choice

Several textbooks show a third method of making this conversion. This is a three-step method:

Step 1 – Add 40° to the existing value.
Step 2 – Multiply by 1.8 if going to °F and divide by 1.8 if going to °C.
Step 3 – Subtract 40°.

Example – Temperature Conversion

Change 212°F to °C.

1. 212°F + 40° = 252°F
2. 252°F ÷ 1.8 = 140 °
3. 140° - 40° = 100°C

Your Choice

It makes little difference which technique you use. Select the one that fits your style and proceed.

Practice Problems – Temperature Conversion

A. Change 70 °F to °C

____

B. Change 140 °F to °C

____

C. Change 20 °C to °F

____

D. Change 85 °C to °F

____

E. Change 4 °C to °F

____

Calculating Pressure and Head

Definition

Pressure is the weight per unit area. Typical pressure units are pounds per square inch (lbs/in^2 – psi) and pounds per square foot (lbs/ft^2). The pressure on the bottom of a container is not related to the volume of the container or the size of the bottom. The pressure depends on the height of the fluid in the container. (For more information, see the Hydraulics section of Chapter 2.)

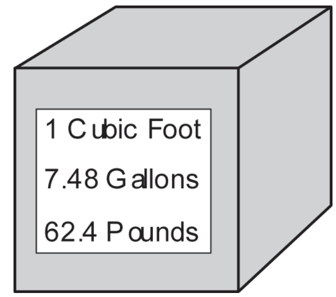
Pressure and Head

The height of the fluid in a container is referred to as head. Head is a direct measurement in feet and is directly related to pressure.

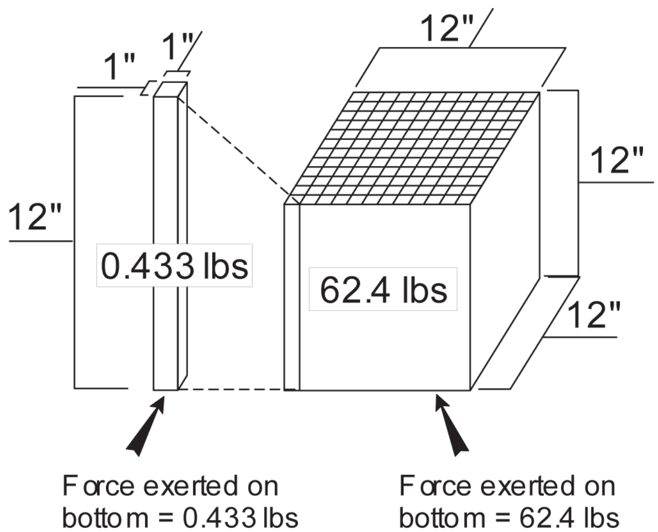
Relationship Between Feet and Head

Weight of Water

Water weighs 62.4 pounds per cubic foot.



The surface of any one side of the cube contains 144 square inches (12" x 12" = 144 in^2). Therefore, the cube contains 144 columns of water one foot tall and one inch square.



The weight of each of these pieces can be determined by dividing the weight of the water in the cube by the number of square inches.

$$\text{Weight} = \frac{62.4 \text{ lbs}}{144 \text{ in}^2} = 0.433 \text{ lbs/in}^2$$

or 0.433 psi

Since this is the weight of one column of water one foot tall, the true expression would be 0.433 pounds per square inch per foot of head or 0.433 psi/ft.
What formula do you want here?

Conversion

We now have a conversion between feet of head and psi.

1 foot of head = 0.433 psi

While it can be calculated from the relationship above, it is also desirable to know the relationship between pressure and feet of head. In other words, 1 psi represents how many feet of head. This is determined by dividing 1 by 0.433 psi.

$$\text{foot of head} = \frac{1 \text{ ft}}{0.433 \text{ psi}} = 2.31 \text{ ft/psi}$$

In other words, if a pressure gauge were reading 10 psi, we know that the height of the water necessary to represent this pressure would be 10 psi x 2.31 ft/psi = 23.1 ft.

Both Conversions

1 ft = 0.433 psi
1 psi = 2.31 feet

Which Conversion to Use

Many operators find having two conversions for the same thing is confusing. They agree that it is best to memorize one and stay with it. The most accurate conversion is the 1 ft = 0.433 psi. This is the conversion used in this text.

Example – Conversion

To convert 40 psi to feet of head, use the standard conversion technique described earlier.

$$40\ \frac{\text{psi}}{1} \times \frac{\text{ft}}{0.433\ \text{psi}} = 92.4\ \text{feet}$$

Convert 40 feet to psi.

$$40\ \frac{\text{ft}}{1} \times \frac{0.433\ \text{psi}}{1\ \text{ft}} = 17.3\ \text{psi}$$

Another Way

As you can see, if you are attempting to convert psi to feet, you divide by 0.433, and if you are attempting to convert feet to psi, you multiply by 0.433. It can become confusing about when to divide and when to multiply. The above process can be most helpful in making that determination. However, there is another way. Notice that the relationship between psi and feet is almost two to one. It takes slightly more than two feet to make one psi. Therefore, when looking at a problem where the data is in pressure and you want it in feet, we can see that the answer will be at least twice as large as the number we are starting with. For example, if the pressure were 20 psi, we know that the head is over 40 feet. Therefore, we must divide by 0.433 to obtain the correct answer.

Practice Problems – Pressure and Head

1. Make the following conversions:
   A. Convert a pressure of 45 psi to feet of head.

   B. Convert 12 psi to feet of head.

   C. Convert 85 psi to feet of head.

   D. It is 112 feet in elevation between the top of the reservoir and the watering point.

E. What will the static pressure be at the watering point?

E. A reservoir is 20 feet deep. What will the pressure be at the bottom of the reservoir?

Determining Flow

Units

Flow is expressed in the English system of measurements using many terms. The most common flow terms include the following:

- gpm – Gallons per minute
- cfs – Cubic feet per second
- gpd – Gallons per day
- MGD – Million gallons per day

Conversions

Flow rates can be converted to different units using the conversion process describe above. The most common flow conversions are 1 cfs = 448 gpm and 1 gpm = 1440 gpd.

Gallons per Day (gpd) to MGD

To convert gallons per day to MGD, divide the gpd by 1,000,000.

Example – Conversion of gdp to MGD

Convert 125,000 gallons to MGD.

$$\frac{125{,}000 \text{ gpd}}{1{,}000{,}000} = 0.125 \text{ MGD}$$

Convert 2,300,000 gpd to MGD.

$$\frac{2{,}300{,}000 \text{ gpd}}{1{,}000{,}000} = 0.2.3 \text{ MGD}$$

Conversion of MGD to gpm

There are many instances where the design or plant information is given in MGD, and we wish to have the flow in gpm. This conversion is accomplished in two steps:

1. Convert to gpd by multiplying by 1,000,000.
2. Convert to gpm by dividing by the number of minutes in a day (1440 min/day).

Example – Conversion of MGD to gpm

Convert 0.125 MGD to gpm.

1. Convert the flow in MGD to gpd.

   0.125 MGD x 1,000,000 = 125,000 gpd

2. Convert to gpm by dividing by the number of minutes in a day (24 hrs per day x 60 min per hour) 1440 min/day.

$$\frac{125{,}000 \text{ gpd}}{1{,}440 \text{ min/day}} = 86.6 \text{ or } 87 \text{ gpm}$$

Convert gpd to gpm

The process of converting gpd to gpm is shown in the example above. The process is to divide the flow in gpd by the number of minutes in a day (1440 min/day).

Conversion of gpm to cfs

The conversion from gpm to cfs is shown in the examples in the above section on conversions. The conversion is 1 cfs = 448 gpm.

Determining Flow Equation

Flow in a pipeline, channel, or stream is found using the equation:

Q = V x A
Where
Q = cubic feet per second (cfs)
V = velocity in feet per second (ft/sec)
A = area in square feet (ft^2)

Example – Determining Flow

Find the flow in cfs in a 6 -inch line, if the velocity is 2 feet per second.

1. Determine the cross-sectional area of the line in square feet. Start by converting the diameter of the pipe to inches.

   The diameter is 6 inches: therefore, the radius is 3 inches. 3 inches is 3/12 of a foot or 0.25 feet.

2. Now find the area in square feet.

$A = \pi \times r^2$		$A = 0.785 \times D^2$
$A = \pi \times (0.25\ ft)^2$	Or	$A = 0.785 \times 0.5^2$
$A = \pi \times 0.0625\ ft^2$		$A = 0.785 \times .05 \times .05$
$A = 0.196\ ft^2$		$A = 0.196\ ft^2$

3. Now find the flow.

   $Q = V \times A$
   $Q = 2\ ft/sec \times 0.196\ ft^2$
   $Q = 0.3927$ cfs or 0.4 cfs

Practice Problems – Flow

A. Find the flow in MGD when the flow is 34,000 gpd.

B. Find the flow in gpm when the total flow for the day is 65,000 gpd.

C. Find the flow in gpm when the flow is 1.3 cfs.

D. Find the flow in gpm when the flow is 0.25 cfs.

E. Find the flow in a 4-inch pipe when the velocity is 1.5 feet per second.

Calculating Detention Time

Detention time is the amount of time that a fluid stays in a container.

Units

Detention time is expressed in units of time. The most common are seconds, minutes, hours, and days.

Calculations

The simplest way to calculate the detention time is to divide the volume of the container by the flow rate into the container. The theoretical detention time of a container is the same as the amount of time it would take to fill the container if it were empty.

Volume Units

The most common volume units used are gallons. However, on occasion cubic feet may also be used.

Time Units

The time units will be in whatever units are used to express the flow. For instance, if the flow is in gpm, then the detention time will be in minutes. If the flow is in gpd, then the detention time will be in days. If in the final result the detention time is in the wrong time units, then simply convert to the appropriate units.

Example – Detention Time

The reservoir for the village is 85,000 gallons. The well will produce 55 gpm. What is the detention time in the tank in hours?

$$DT = \frac{85{,}000 \text{ gal}}{55 \text{ gpm}} = 1{,}545 \text{ min or } \frac{1{,}545 \text{ min}}{60 \text{ min/hr}} = 25.8 \text{ hrs}$$

Practice Problems – Detention Time

A. How long will it take to fill a 50-gallon hypochlorite tank if the flow is 5 gpm?

B. Find the detention time in a 45,000 gallon reservoir if the flow rate is 85 gpm.

C. If the fuel consumption to the boiler is 35 gallons per day, how many days will the 500 gallon tank last?

D. The sedimentation basin of a water plant contains 5,775 gallons. What is the detention time if the flow is 175 gpm?

Ratio and Proportion

What is a Ratio?

A ratio is a relationship between two numbers. A ratio can be written using a colon (1:2, 5:9, 20:60) or a fraction (1/2, 5/9, or 20/60).

What Is a Proportion?

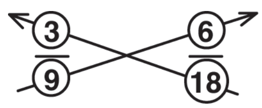
A proportion exists when the relationship between one ratio is the same as the relationship between a second ratio.

How Is This Determined?

To determine if two ratios are proportional, the two are cross-multiplied. If the answers are equal, then they are proportional.

Example 1 – Ratio and Proportion

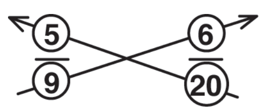
Determine if 3/9 is proportional to 6/18.



9 x 6 = 54 and 3 x 18 = 54; therefore, the two ratios are proportional.

Example 2 – Ratio and Proportion

Determine if 5/9 and 6/20 are proportional.



9 x 6 =54 and 5 x 20 = 100; therefore, the two are not proportional.

So Now What?

While this process is nice to know, it is basically academic, but it is a lead in to the practical use of ratios and proportions to solve common problems. To use this process, we need to discuss one more major step and then provide some basic rules. The first step is what to do when one part of a ratio is unknown.

The Unknown

To solve for an unknown portion of a ratio, follow these steps:

Step 1 – Set up the ratios in a proportion format and place an “X” in ratio for the unknown value. Notice that we have set the two ratios up as a proportion with the colon (:) between them.

$$\frac{2}{15} : \frac{X}{50}$$

Step 2 – Cross-multiply.

(15) (X) = (2) (50)

Step 3 – To get the X on the left side of the equation, divide both sides by 15.

$$X = \frac{(2)\,(50)}{15}$$

Step 4 – Solve for X.

$X = 6.67$

Practical Application

Proportion problems deal with larger and smaller values of the same units. For instance, a common proportion problem might be the following:

If it takes 5 pounds of calcium hypochlorite to give the correct dosage in a 35 gallon tank, then how many pounds will it take to make 12 gallons?

Rule 1 – Set up the proportion with the same types of units on one side of the colon. Using our example above, pounds would go on one side and gallons on the other.

Rule 2 – The numerators must contain the same size of units (either larger or small units), and the denominator must contain the same size units (either larger or smaller). For instance:

$$\frac{\text{Smaller Value}}{\text{Larger Value}} : \frac{\text{Smaller Value}}{\text{Larger Value}}$$

or

$$\frac{\text{Larger Value}}{\text{Smaller Value}} : \frac{\text{Larger Value}}{\text{Smaller Value}}$$

Rule 3 – Place an “X” in the unknown value, and solve for “X.”

Hint

Using our example above, you can set up a verbal relationship. For instance, 5 pounds is to 35 gallons as X pounds is to 12 gallons. To place these in the equation, start in the upper left with the 5 pounds. The “is to” represents the equal sign. For instance:

$$\frac{5 \text{ lbs}}{X} : \frac{35 \text{ gal}}{12 \text{ gal}}$$

$(X)\,(35 \text{ gal}) = (5 \text{ lbs})\,(12 \text{ gal})$

$$X = \frac{(5 \text{ lbs})\,(12 \text{ gal})}{35 \text{ gal}} = 1.7 \text{ lbs}$$

Example 3 – Ratio and Proportion

If one chlorine cylinder is used in 20 days, how many will be used in 100 days?

Step 1 – Set up the proportion.

1 cylinder is to 20 days as X cylinders is to 100 days.

$$\frac{1 \text{ cylinder}}{X} : \frac{20 \text{ days}}{100 \text{ days}}$$

Step 2 – Cross-multiply.

(X cylinders) (20 days) = (1 cylinder) (100 days)

Step 3 – Rearrange the equation to get "X" on the left by its self; divide both sides by 20 days.

$$X \text{ cylinders} = \frac{(1 \text{ cylinder})\ (100 \text{ days})}{20 \text{ days}}$$

Step 4 – Solve for X cylinders.

X = 5 cylinders

Practice Problems – Ratio and Proportion

A. It takes 6 gallons of chlorine solution to obtain a proper residual when the flow is 45,000 gpd. How many gallons will it take when the flow is 62,000 gpd?

B. A motor is rated at 41 amps average draw per leg at 30Hp. What is the actual Hp when the draw is 36 amps?

C. If it takes 2 operators 4.5 days to clean an aeration basin, how long will it take three operators to do the same job?

D. If it takes 20 minutes to pump a wet well down with one pump pumping at 125 gpm, then how long will it take if a 200 gpm pump is used?

E. It takes 3 hours to clean 400 feet of collection system using a sewer ball. How long will it take to clean 250 feet?

F. It takes 14 cups of HTH to make a 12% solution, and each cup holds 300 grams. How many cups will it take to make a 5% solution?

Pounds Formula

Use

One of the most common formulas used by water and wastewater operators is the pounds formula. This formula is used to determine the loading on the plant and its various process units; the loading on the receiving water; and the amount of chemicals needed for a specific function, such as disinfection. The formula can also be used to determine the amount of mixed liquor in the aeration basin and the amount of sludge to be disposed of in the landfill.

Basic Assumption

The formula assumes that all of the material found in water (TSS, BOD, MLSS, Chlorine, etc.) weighs the same as water, that is, 8.34 pounds per gallon.

The Formula

The basic pounds formula is

Lbs = Flow, MG x 8.34 x Conc, mg/L

Where
Lbs = pounds
MG = Flow or volume in millions of gallons
Conc = concentration or dosage in mg/L

Process

The process of using the pounds formula to determine pounds of a substance in water is relatively simple. Just plug the values into the appropriate slots and multiply. However, there are two items that can cause some confusion: flows of less than one million gallons and concentrations in ppm.

Flow

Flow and volume are often expressed in gallons per day, gallons per minute and millions of gallons per day. Regardless of how they are expressed, they must be converted to MG in order for them to be placed in this formula. When the flow is in gallons or million gallons per day (MGD), the pounds must be expressed in lbs/day.

Flow or Volume in gpd

When a flow or volume is expressed in gallons, it must be converted to MGD by dividing it by 1,000,000. For instance, a flow of 120,000 gpd is 0.12 MGD, and a flow of 40,000 gpd is 0.04 MGD.

Flow or Volume in gpm

When a flow or volume is expressed in gpm, it must be first converted to gpd by multiplying by the number of minutes per day (1440) and then divided by 1,000,000 to get MGD.

Example 1 – Flow

The flow is 250 gpm. What is the flow in MGD?

250 gpm X 1440 min/day = 360,000 gpd

360,000 gpd ÷ 1,000,000 = 0.36 MGD

PPM

PPM or ppm is an abbreviation for parts per million. Parts per million is the same as mg/L (milligrams per liter). While they mean the same, mg/L is the preferred and more accepted unit.

Example 2 –Flow

A water treatment plant feeds alum at a dosage of 26 mg/L. The flow is 2.5 MGD. How many pounds of alum are used each day?

lbs/day = MGD x 8.34, lbs/gal x Conc, mg/L
lbs/day = 2.5 MGD x 8.34 lbs/gal x 26 mg/L
lbs/day = 542 pounds/day

Practice Problems – Pounds Formula

A. How many pounds of 100% gas chlorine are needed to disinfect a flow of 85,000 gpd at 12 mg/L?

B. The suspended solids in a stream are measured at 360 mg/L. The stream flow is estimated to be 3.2 MGD. How many pounds of solids are carried by the stream each day?

C. The backwash water of a treatment plant contains 320 mg/L of solids. 4,000 gallons of water are used for backwash. How many pounds of solids are deposited in the backwash lagoon with each backwash?

D. A 400,000-gallon storage tank is to be disinfected with 50 mg/L of chlorine. How many pounds of gas chlorine would it take to disinfect this tank?

E. How many pounds of calcium hypochlorite at 67% is needed to disinfect 125,000 gallon per day flow with a dosage of 8 mg/L?

Metric System (SI)

Description

The system of units and measures that is commonly called the metric system is more correctly titled the SI (or System International). This is the system that is used throughout most of the world, except the United States. The metric system is a base 10 system. This base makes it very easy to convert between various units. While the system has not gained widespread acceptance in the US, it is widely accepted in most of the world, and it is highly desirable that the operator be familiar with the basic components of the system.

Base Units

The following are the base units of this system.

Quantity	Unit	Symbol
Length	meter	m
Mass	gram	g
Time	second	s
Temperature	Kelvin	K
Volume	liter	L

Description of the Units

Length

The basic unit of measurement of length is the meter. A meter is approximately 3 feet in length (3.281 ft).

Mass

Mass in the metric system is used as a comparison with pounds in the English system. The base unit is the gram. There are approximately 454 grams in a pound.

Time

The time base of seconds in the metric system is the same as the time base in the English system.

Temperature

The basic unit of temperature in the metric system is the Kelvin unit. However, Celsius is the unit that is most commonly associated with this system. One degree Kelvin is the same size as one degree Celsius. The major difference is in the starting point (zero). In the Kelvin thermometer, 0°K is equal to -273.15 °C.

Metric Prefixes

English

When a number becomes too large to handle easily, we convert it by dividing it by a value and call it something else. For instance, when we have too many feet, we divide by 3 and call the result yards, or we divide by 5,280 and call the result miles. Seldom are the divisions even numbers, and they change with each set of units. Notice that yards are feet divided by 3, but miles are feet divided by 5,280. This makes it difficult to remember how to make the proper conversion.

Metric
In the metric system, there are standard prefixes to numbers that have been divided in order to reduce their size. In addition, the divisions are always in multiples of 10. The following is a listing of the basic metric prefixes:

Prefix	Symbol	Mathematical Value
giga	G	1,000,000,000
mega	M	1,000,000
kilo	k	1,000
hecto*	h	100
deka*	da	10
Base	none	1
deci*	d	0.1
centi*	c	0.01
milli	m	0.001
micro	µ	0.000,001
nano	n	0.000,000,0001

* Under normal circumstances these prefixes are seldom used and should, if possible, be avoided.

Metric Abbreviations
Limitations
The following is a listing of common abbreviations are used in math problems in the water and wastewater field. With a few exceptions, this listing is limited to those abbreviations that are associated with the SI or metric system units of measurement. Abbreviations associated with the English system of measurements are found at the beginning of this lesson on metric units.

Unit	Symbol	Unit	Symbol
year	A	newton	N
gram	g	pascal	Pa
hour	h	second	s
hectare	ha	watt	w
joule	j	milliliter	mL
kilogram	kg	kilowatt	KW
kilometer	km		
liter	L		
meter	m		
milligram	mg		
minute	min		

Metric to English Conversions

Area

From	To	Multiply	by	to get
square feet	square meters	ft^2	0.0929	m^2
square inches	square meters	in^2	6.4516×10^{-4}	m^2
acre	hectare	ac	0.4047	ha
square meter	square feet	m^2	10.76	ft^2
hectare	acre	ha	2.471	ac

Energy - Work

From	To	Multiply	by	to get
kilowatt-hour	joules	kwh	3.6×10^6	j
horsepower-hour	joules	Hph	2.6845×10^6	j

Flow Rate

From	To	Multiply	by	to get
cubic feet per second	meters per second	cfs	0.028317	m^3/s
gallons per minute	liters per second	gpm	0.06309	L/s
liters/second	gallons per minute	L	15.85	gpm

Force

From	To	Multiply	by	to get
pounds	Newtons	lbs	4.4482	N

Length

From	To	Multiply	by	to get
inch	meters	in	0.0254	m
inch	centimeters	in	2.54	cm
foot	meters	ft	0.3048	m
mile	meters	mi	1609.3	m
mile	kilometers	mi	1609	km
meter	foot	m	3.281	ft
kilometer	mile	km	0.6214	mi

Mass

From	To	Multiply	by	to get
ounce	kilogram	oz	0.02835	kg
pound	kilogram	lb	0.45359	kg
pound	gram	lb	453.6	g
liter of water	kilogram	L	1	kg
kilogram	pounds	kg	2.205	lb

Metric to English Conversions

Power				
From	To	Multiply	by	to get
horsepower	watts	Hp	746	w
Joules/second	watts	J/s	1	w
Pressure				
From	To	Multiply	by	to get
pounds /square inch	pascal	psi	6895	Pa
pounds /square inch	kilopascal	psi	6.9	kPa
pounds /square inch	newtons /square meter	psi	6895	N/m^2
kilopascal	pounds/square inch	kPa	0.145	psi
Velocity				
From	To	Multiply	by	to get
foot/second	meter/second	ft/s	0.3048	m/s
miles/hour	meter/second	mph	0.44704	m/s
kilometers/hour	meter/second	km/hr	0.27778	m/s
Volume				
From	To	Multiply	by	to get
acre-foot	cubic meters	ac-ft	1233.5	m^3
cubic foot	cubic meters	ft^3	0.028317	m^3
gallon (U.S.)	cubic meters	gal	3.7854×10^{-3}	m^3
gallon (U.S.)	liters	gal	3.78	L
gallon (Imperial)	cubic meters	gal(I)	4.5459×10^{-3}	m^3
liter	cubic meters	L	1000	m^3
yard	cubic meters	yd	0.76455	m^3
cubic meters	gallons	m^3	264.2	gal
cubic meters	cubic feet	m^3	35.31	ft^3
cubic meters	yards	m^3	1.308	yd

Metric Conversions

Two Types

Like the English system, there are two types of conversions: reducing or enlarging a value within the same base and converting between bases.

Conversions in the Same Base

Prefix Is the Key

The key to making conversions within the same base lies in understanding the prefixes and their associated values. For instance, the prefix kilo indicates 1000; therefore, a kilogram is 1000 grams, and a kilometer is 1000 meters.

Linear Conversions

The base unit of linear measurement is the meter. The common divisions of the meter are the following:

Kilometer = 1000 meters
Centimeter = 1/100 of a meter or there are 100 centimeters in a meter.
Millimeter = 1/1000 of a meter or there are 1000 millimeters in a meter.

Example 1 – Conversion

Convert 4500 meters to kilometers.

Step 1 – Divide the number of meters by 1000 (kilo).

$$\frac{4{,}500 \text{ meters}}{1{,}000 \text{ meters/kilometers}} = 4.5 \text{ kilometers}$$

Example 2 – Conversion

Convert 4.6 meters to centimeters.

Step 1 – Multiply meters times 100 (centi).

4.6 meters x 100 cm = 4600 cm

Volume Conversions

The most common volume conversion is from liters to milliliters. Since milli is the prefix for 0.001, liters can be converted to milliliters by multiplying times 1000. Likewise, milliliters can be converted to liters by dividing by 1000.

1L = 1000 mL

Example 3 – Conversion

Convert 2,400 mL to liters.

Step 1 – Divide the number of milliliters by 1000.

$$\frac{2{,}400 \text{ mL}}{1{,}000 \text{ mL/L}} = 2.4 \text{ L}$$

Example 4 – Conversion

Convert 0.35 L to milliliters.

Step 1 – Multiply the number of liters times 1000.

0.35 L X 1000 mL/L = 350 mL

Mass Conversion

The two most common mass conversions are between kilograms and grams and between milligrams and grams. Since kilo is 1000 grams, it can be converted to kilograms by dividing by 1000. Since milli is 1000, grams can be converted to milligrams by multiplying by 1000.

Example 5 – Conversion

Convert 2,600 mg to grams.

Step 1 – Divide the 2,600 mg by 1,000.

$$\frac{2{,}600 \text{ g}}{1{,}000 \text{ mg/g}} = 2.6 \text{ g}$$

Example 6 – Conversion

Convert 1,345,000 g to kilograms.

Step 1 – Divide 1,345,000 g by 1,000.

$$\frac{1{,}345{,}000 \text{ g}}{1{,}000 \text{ g/kg}} = 1345 \text{ kg}$$

Conversion to Another Base

Key

The common conversion made between basic units is between mass and volume. Volume in the metric system is expressed as liters, cubic meters, or cubic centimeters. The relationship between mass and volume is the following:

1g =1ml =1cc, (one gram is equal to 1 milliliter is equal to 1 cubic centimeter)

Other Relationships

1 cubic meter (m^3) = 1000 liters

1kg = 1 L

Cubic Measurements

It is common practice to convert liters to cubic meters when the volume exceeds 1000 liters.

Example 7 – Conversion

Convert 500 kilograms of water to liters.

Since kilograms and liters are the same base, the conversion is a simple matter of changing the units. 500 kg = 500 L

Example 8 – Conversion

Convert 3,600 L to cubic meters.

Step 1 – Divide the liters by 1000.

$$\frac{3{,}600\ \text{L}}{1{,}000\ \text{L/m}^3} = 3.6\ \text{m}^3$$

Practice Problems – Metric Conversion

A. Convert 4.2 kg to g.

B. Convert 0.5 kg to g.

C. Convert 4600 g to kg.

D. Convert 3.4 km to m.

E. Convert 0.5 km to m.

F. Convert 10,000 m to km.

Practice Problems - Answers

Practice Problem Answers – Fractions

1. Reduce the following to their simplest terms.

   A. 1/2 Both were divided by 2
   B. 2/3 Both were divided by 6
   C. 3/4 Is in its simplest terms
   D. 3/4 Both were divided by 2
   E. 3/4 Both were divided by 8
   F. 1/2 Both were divided by 9
   G. 5/9 Both were divided by 3

Practice Problem Answers – Rounding

1. Round the following to the nearest hundredths:

   A. 2.4568 = 2.46
   B. 27.2534 = 27.25
   C. 128.2111 = 128.21
   D. 364.8762 = 364.88
   E. 354.777777 = 354.78
   F. 34.666666 = 34.67
   G. 67. 33333 = 67.33

1. Round the following answers off to the most significant digit:

   A. 26.34 x 124.34567 = 3,275.26495 = 3,275.26
   B. 25.1 + 26.43 = 51.53 = 51.5
   C. 128.456 – 121.4 = 7.056 = 7.1
   D. 23.5 ft x 34.25 ft = 804.875 ft^2 = 804.9 ft^2
   E. 12,457.92 x 3 = 37,373.76 = 37,374

Practice Problem Answer – Averages

1. The total is 2.4. There are 9 numbers in the set. Therefore 2.4 ÷ 9 = 0.2667, rounding to 0.3.

Practice Problem Answers – Formulas

1. Find the diameter of a settling basin that has a circumference of 126 feet.

$$C = \pi D$$

$$126' = \pi D$$

$$D = \frac{126'}{\pi} = 40 \text{ ft}$$

2. Find the diameter of a pipe that has a circumference of 12 9/16".

   12 9/16" = 12.56"

   $C = \pi D$

   $12.56" = \pi D$

   $$D = \frac{12.56 \text{ in}}{\pi} = 4 \text{ in}$$

3. Find the diameter of a settling basin that has a surface area of 113 ft^2.

   $A = \pi r^2$

   $113 \text{ ft}^2 = \pi r^2$

   $$r = \sqrt{\frac{113 ft^2}{\pi}} = 5.997 \text{ or } 6 \text{ ft}$$

   6 ft x 2 = 12 ft diameter

4. Find the diameter of a storage tank that has a surface area of 314 ft^2.

   $A = \pi r^2$

   $314 \text{ ft}^2 = \pi r^2$

   $$r = \sqrt{\frac{113 ft^2}{\pi}} = 9.997 \text{ or } 10 \text{ ft}$$

   D = 10 ft x 2 = 20 ft

5. The detention time in a chlorine contact chamber is 42 minutes. If the chamber holds 3200 gallons, what is the flow rate in gpm?

$$DT = \frac{\text{Volume}}{\text{Flow}}$$

$$42 \text{ min} = \frac{3200 \text{ gal}}{\text{flow, gpm}} = \text{flow, gpm} = \frac{3200 \text{ gal}}{42 \text{ min}}$$

flow = 76 gpm

6. A clearwell has a detention time of 2 hours. What is the flow rate in gpm if the clarifier holds 8000 gallons?

$$DT = \frac{\text{Volume}}{\text{Flow}}$$

$$120 \text{ min} = \frac{8000 \text{ gal}}{\text{flow, gpm}} = \text{flow, gpm} = \frac{8000 \text{ gal}}{120 \text{ min}}$$

flow, gpm = 67 gpm

7. A rectangular settling basin has a weir length of 10 feet. What is the weir overflow rate when the flow is 80,000 gpd?

$$WO = \frac{\text{Flow rate in gpd}}{\text{Weir length in feet}}$$

$$WO = \frac{80{,}000 \text{ gpd}}{10 \text{ ft}} = 8{,}000 \text{ gpd/ft}$$

Practice Problem Answers – Perimeter/Circumference

1. Find the perimeter or circumference of the following items:

   A. = π x 14 inches = 44 inches
   B. 6 ft + 9 ft + 6 ft + 9 ft = 30 ft
   C. 42 ft + 20 ft + 42 ft + 20 ft = 124 ft
   D. π x 28 feet = 88 feet

Practice Problem Answers – Area

1. Find the area of the following items:

   A. Diameter is 14 inches. Therefore, the radius, being 1/2 of the diameter, is 7 inches.
   $A = \pi \times (7")^2$
   $A = \pi \times 49 \text{ in}^2$
   $A = 154 \text{ in}^2$

   B. A = L x W
   $A = 9' \times 6' = 54 \text{ ft}^2$

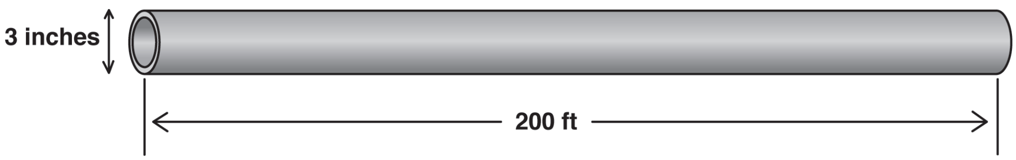
   C. A = L x W
   $A = 42' \times 20'$
   $A = 840 \text{ ft}^2$

   D. The diameter is 28 feet. The radius is one-half of the diameter; therefore, the radius is 14 feet.
   $A = \pi \times r^2$
   $A = \pi \times (14 \text{ feet})^2$
   $A = \pi \times 196 \text{ ft}^2$
   $A = 616 \text{ ft}^2$

Practice Problem Answers – Volume

1. Find the volume of the following:

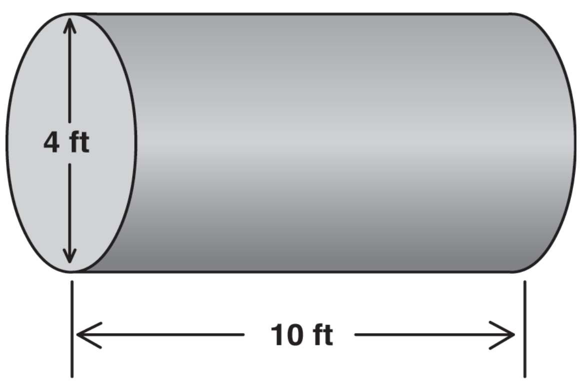
   A. 3-inch pipe 200 feet long



Hint: change the diagram of the pipe from inches to feet by dividing by 12.

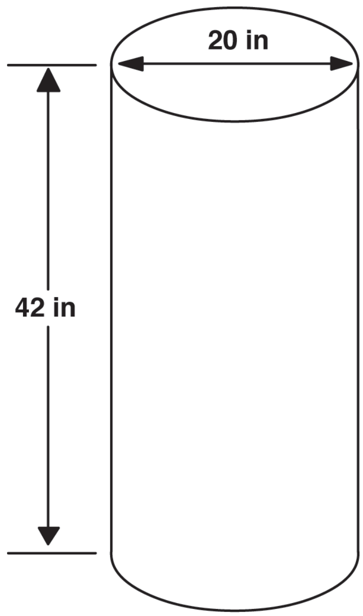
1. Change diameter to feet $3 \div 12 = 0.25$ ft.
2. Find the radius by dividing the diameter by 2.
   $0.25 \text{ ft} \div 2 = 0.125 \text{ ft}$
3. Find the volume.
   $V = L \times \pi r^2$
   $V = 200 \text{ ft} \times \pi (0.125\text{ft})^2$
   $V = 200 \text{ ft} \times \pi \times 0.01563 \text{ ft}^2$
   $V = 9.8 \text{ ft}^3$

B. Find the volume of a fuel tank 4 feet in diameter and 10 feet long.



1. Find the radius of the tank. The radius is one-half of the diameter.
   $4 \text{ ft} \div 2 = 2 \text{ ft}$
2. Find the volume.
   $V = L \times \pi r^2$
   $V = 10 \text{ ft} \times \pi (2 \text{ ft})^2$
   $V = 10 \text{ ft} \times \pi \times 4 \text{ ft}^2$
   $V = 125.7 \text{ ft}^3$

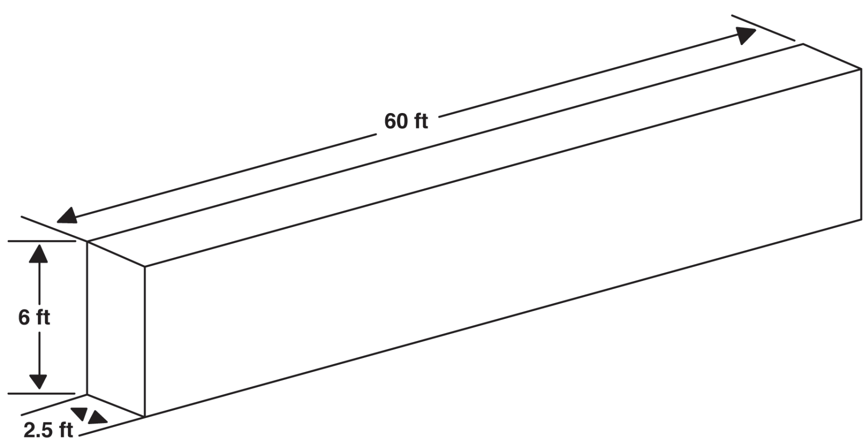
C. Find the volume of a chlorine barrel that is 20 inches in diameter and 42 inches tall.



1. Find the radius of the tank. The radius is one-half of the diameter.
   20 inches ÷ 2 = 10 inches

2. Find the volume.
   $V = H \times \pi r^2$
   $V = 42 \text{ in} \times \pi (10 \text{ in})^2$
   $V = 42 \text{ in} \times \pi \times 100 \text{ in}^2$
   $V = 13{,}195 \text{ in}^3$

D. Find the volume of a trench 2.5 feet wide, 6 feet deep, and 60 feet long.



$V = L \times W \times D$
$V = 60 \text{ ft} \times 2.5 \text{ ft} \times 6 \text{ ft}$
$V = 900 \text{ ft}^3$

Practice Problem Answers – Percentage

A. 25% of the chlorine in a 30 gallon vat has been used. How many gallons are remaining in the vat?

1. Find the percentage of chlorine remaining.
100% – 25% = 75%

2. Change the percent to a decimal.
75% ÷ 100 = 0.75

3. Multiply the percent as a decimal times the tank volume.
0.75 x 30 gal = 22.5 gal

B. The annual public works budget is $147,450.00. If 75% of the budget should be spent by the end of September, how many dollars are to be spent? How much is remaining?

1. Change the percentage to a decimal.
   75% ÷ 100 = 0.75

2. Multiply the budget amount by the percent to be used.
   $147,450.00 x 0.75 = $110,587.50 to be spent

3. Find what will be remaining.
   $147,450.00 – 110,587.50 = $36,862.50

C. There are 50 pounds of pure chlorine in a container of 67% calcium hypochlorite. What is the total weight of the container?

1. Change the percent to a decimal.
67% ÷ 100 = 0.67

2. Divide the weight by the percentage.

$$\frac{50 \text{ lbs}}{0.67} = 74.6 \text{ lbs}$$

D. 3/4 is the same as what percentage?

1. Change the fraction into a decimal.

$$\frac{3}{4} = 0.75$$

2. Convert to a percentage.
0.75 x 100 = 75%

E. A 2% chlorine solution is what concentration in mg/L?

1. Change the percentage to a decimal.
2% ÷ 100 = 0.02

2. Multiply times one million.
   0.02 x 1,000,000 = 20,000 mg/L

F. A water plant produces 84,000 gallons per day. 7,560 gallons are used to backwash the filter. What percentage of water is used to backwash?

1. Divide the part by the whole.

$$\frac{7{,}560 \text{ gal}}{84{,}000 \text{ gal}} = 0.09$$

2. Change the value to a percentage.

0.09 X 100 = 9%

G. The average day winter demand of a community is 14,500 gallons. If the summer demand is estimated to be 72% greater than the winter, what is the estimated summer demand?

1. Change the percent to a decimal.

72% ÷ 100 = 0.72

2. Add this value to 1.

1 + 0.72 = 1.72

3. Multiply the demand times this value.

14,500 gal x 1.72 = 24,940 gal

Practice Problem Answers – Efficiency

A. The water horsepower of a pump is 10 Hp and the brake horsepower output of the motor is 15.4 Hp. What is the efficiency of the motor?

$$\frac{10 \text{ BHp}}{15.4 \text{ EHp}} \times 100 = 64.94 \text{ or } 65\%$$

B. The water horsepower of a pump is 25 Hp and the brake horsepower output of the motor is 48 Hp. What is the efficiency of the motor?

$$\frac{25 \text{ BHp}}{48 \text{ EHp}} \times 100 = 52\%$$

C. The efficiency of a well pump is determined to be 75%. The efficiency of the motor is estimated at 94%. What is the efficiency of the well?

0.75 X 0.94 = 0.705 X 100 = 70.5%

D. If a motor is 85% efficient and the output of the motor is determined to be 10 BHp, what is the electrical horsepower requirement of the motor?

$$\frac{10 \text{ BHp}}{0.85} = 11.8 \text{ EHp}$$

E. The water horsepower of a well with a submersible pump has been calculated at 8.2 WHp. The Output of the electric motor is measured as 10.3 BHp. What is the efficiency of the pump?

$$\frac{82\text{ WHp}}{10.3\text{ BHp}} \text{ x } 100 = 79.6\%$$

Practice Problem Answers – Conversion

1. Convert the following:

A. 750 ft³ of water to gallons

$$750\ \frac{\text{ft}^3}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{?}{\text{ft}^3} \quad =$$

$$750\ \frac{\text{ft}^3}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{\text{gal}}{\text{ft}^3} \quad =$$

$$750\ \frac{\text{ft}^3}{1} \quad \text{x} \quad \frac{7.48\text{ gal}}{\text{ft}^3} = 5{,}610\text{ gal}$$

B. 50 gallons to pounds

$$50\ \frac{\text{gal}}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{?}{\text{gal}} \quad =$$

$$50\ \frac{\text{gal}}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{\text{lbs}}{\text{gal}} \quad =$$

$$50\ \frac{\text{gal}}{1} \quad \text{x} \quad \frac{8.34\text{ lbs}}{\text{gal}} = 417\text{ lbs}$$

C. 560 gpm to cfs

$$560\ \frac{\text{gpm}}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{?}{\text{gpm}} \quad =$$

$$560\ \frac{\text{gpm}}{1} \quad \text{x} \quad \underline{\qquad\qquad} \quad \frac{\text{cfs}}{\text{gpm}} \quad =$$

$$560\ \frac{\text{gpm}}{1} \quad \text{x} \quad \frac{1\text{ cfs}}{448\text{ gpm}} = 1.25\text{ cfs}$$

D. 4 lbs to ounces

$$4\ \frac{\text{lbs}}{1} \times \underline{\qquad\qquad} \ \frac{?}{\text{lbs}} =$$

$$4\ \frac{\text{lbs}}{1} \times \underline{\qquad\qquad} \ \frac{\text{oz}}{\text{lbs}} =$$

$$4\ \frac{\text{lbs}}{1} \times \frac{16 \text{ oz}}{\text{lbs}} = 64 \text{ oz}$$

E. 128 ft^3 of water to weight in pounds

$$128\ \frac{\text{ft}^3}{1} \times \underline{\qquad\qquad} \ \frac{?}{\text{ft}^3} =$$

$$128\ \frac{\text{ft}^3}{1} \times \underline{\qquad\qquad} \ \frac{\text{lbs}}{\text{ft}^3} =$$

$$128\ \frac{\text{ft}^3}{1} \times \frac{62.4 \text{ lbs}}{\text{ft}^3} = 7{,}987 \text{ lbs}$$

G. 3.4 cfs to gpm

$$340\ \frac{\text{cfs}}{1} \times \underline{\qquad\qquad} \ \frac{?}{\text{cfs}} =$$

$$340\ \frac{\text{cfs}}{1} \times \underline{\qquad\qquad} \ \frac{\text{gpm}}{\text{cfs}} =$$

$$340\ \frac{\text{cfs}}{1} \times \frac{448 \text{ gpm}}{1 \text{ cfs}} = 1{,}523 \text{ gpm}$$

H. 65 ft^3 to yd^3

$$65\ \frac{\text{ft}^3}{1} \times \frac{1 \text{ yd}^3}{27 \text{ ft}^3} = 2.4 \text{ yd}^3$$

I. 3,000 gallons to ft^3

$$3{,}000\ \frac{\text{gal}}{1} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} = 401 \text{ ft}^3$$

J. 250,000 gallons to MG

$$250{,}000\ \frac{\text{gal}}{1} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 0.25 \text{ MG}$$

K. 75 gpm to MGD

75 gpm x 1440 min/day = 108,000 gpd

$$108{,}000\ \frac{\text{gpd}}{1} \times \frac{1 \text{ MGD}}{1{,}000{,}000 \text{ gpd}} = 0.108 \text{ MGD}$$

L. 8 inches to feet

$$8\ \frac{\text{in}}{1} \quad x \quad \frac{1\ \text{ft}}{12\ \text{in}} = 0.667\ \text{ft}$$

M. 2.4 MGD to cfs

$$2.4\ \frac{\text{MGD}}{1} \quad x \quad \frac{1{,}000{,}000\ \text{gpd}}{1\ \text{MGD}} = 2{,}400{,}000\ \text{gpd}$$

$$2{,}400{,}000\ \frac{\text{gal}}{\text{day}} \quad x \quad \frac{1\ \text{day}}{1{,}440\ \text{min}} = 1{,}667\ \text{gpm}$$

$$1{,}667\ \frac{\text{gpm}}{1} \quad x \quad \frac{1\text{cfs}}{448\ \text{gpm}} = 3.7\ \text{cfs}$$

N. 2.4 MGD to gpm

$$2.4\ \frac{\text{MGD}}{1} \quad x \quad \frac{694.5\ \text{gpm}}{1\ \text{MGD}} = 1{,}668.8\ \text{cfs}$$

O. 65 pints to gallons

$$65\ \frac{\text{pint}}{1} \quad x \quad \frac{1\ \text{gal}}{8\ \text{pint}} = 8.125\ \text{gal}$$

P. 2.5 ft^2 to square inches

$$2.5\ \frac{\text{ft}^2}{1} \quad x \quad \frac{144\ \text{in}^2}{1\ \text{ft}^2} = 360\ \text{in}^2$$

Q. 7 yards to feet

$$7\ \frac{\text{yd}}{1} \quad x \quad \frac{3\ \text{ft}}{1\ \text{yd}} = 21\ \text{ft}$$

R. 36,000 gpd to gpm

$$36{,}000\ \frac{\text{gpd}}{1} \quad x \quad \frac{\text{gpm}}{1{,}440\ \text{gpd}} = 25\ \text{gpm}$$

S. 125 gpm to gph

125 gpm x 60 min/hr = 7,500 gph

Practice Problem Answers – Temperature Conversion

A. Change 70° F to °C

$$°\text{C} = \frac{70°\ \text{F} - 32°}{1.8} = 21°\ \text{C}$$

B. Change 140° F to °C

$$°C = \frac{140° F - 32°}{1.8} = 60° C$$

C. Change 20°C to °F

°F = °C x 1.8 + 32°

°F = 20° C x 1.8 + 32°

°F = 68° F

D. Change 85 °C to °F

°F = °C x 1.8 + 32°

°F = 85° C x 1.8 + 32°

°F = 185° F

E. Change 4 °C to °F

°F = °C x 1.8 + 32°

°F = 4° C x 1.8 + 32°

°F = 39°F

Practice Problem Answers – Pressure and Head

1. Make the following conversions:

A. Convert a pressure of 45 psi to feet of head.

$$45 \frac{\text{psi}}{1} \times \frac{\text{ft}}{0.433 \text{ psi}} = 103.9 \text{ feet}$$

B. Convert 12 psi to feet.

$$12 \frac{\text{psi}}{1} \times \frac{\text{ft}}{0.433 \text{ psi}} = 27.7 \text{ feet}$$

C. Convert 85 psi to feet.

$$85 \frac{\text{psi}}{1} \times \frac{\text{ft}}{0.433 \text{ psi}} = 196.3 \text{ feet}$$

D. It is 112 feet in elevation between the top of the reservoir and the watering point. What will the static pressure be at the watering point?

$$112 \frac{\text{ft}}{1} \times \frac{0.433 \text{ psi}}{1 \text{ ft}} = 48.5 \text{ feet}$$

E. A reservoir is 20 feet deep. What will the pressure be at the bottom of the reservoir?

$$20 \frac{\text{ft}}{1} \text{ x } \frac{0.433 \text{ psi}}{1 \text{ ft}} = 8.7 \text{ feet}$$

Practice Problem Answers – Flow

A. Find the flow in MGD when the flow is 34,000 gpd.

$$\frac{34{,}000 \text{ gpd}}{1{,}000{,}000} = 0.034 \text{ MGD}$$

B. Find the flow in gpm when the total flow for the day is 65,000 gpd.

$$\frac{65{,}000 \text{ gpd}}{1{,}440 \text{ min/day}} = 45 \text{ gpm}$$

C. Find the flow in gpm when the flow is 1.3 cfs.

$$1.3 \frac{\text{cfs}}{1} \text{ x } \frac{448 \text{ gpm}}{1 \text{ cfs}} = 582 \text{ gpm}$$

D. Find the flow in gpm when the flow is 0.25 cfs.

$$0.25 \frac{\text{cfs}}{1} \text{ x } \frac{448 \text{ gpm}}{1 \text{ cfs}} = 112 \text{ gpm}$$

E. Find the flow in a 4-inch pipe when the velocity is 1.5 feet per second.

The diameter of the pipe is 4 inches. Therefore, the radius is 2 inches. Convert the 2 inches to feet.

$$\frac{2}{12} = 0.6667 \text{ ft}$$

$A = \pi \text{ x } r^2$
$A = \pi \text{ x } (0.167 \text{ ft})^2$
$A = \pi \text{ x } 0.028 \text{ ft}^2$
$A = 0.09 \text{ ft}^2$

$Q = V \text{ x } A$
$Q = 1.5 \text{ ft/sec x } 0.09 \text{ ft}^2$
$Q = 0.14 \text{ ft}^3\text{/sec (cfs)}$

Practice Problem Answers – Detention Time

A. How long will it take to fill a 50 gallon hypochlorite tank if the flow is 5 gpm?

$$\frac{50 \text{ gal}}{5 \text{ gal/min}} = 10 \text{ min}$$

B. Find the detention time in a 45,000 gallon reservoir if the flow rate is 85 gpm.

$$\text{DT} = \frac{45{,}000 \text{ gal}}{85 \text{ gal/min}} = 529 \text{ min} \quad \text{or} \quad \frac{529 \text{ min}}{60 \text{ min/hr}} = 8.8 \text{ hrs}$$

C. If the fuel consumption to the boiler is 35 gallons per day. How many days will the 500 gallon tank last.

$$\text{Days} = \frac{500 \text{ gal}}{35 \text{ gal/day}} = 14.3 \text{ days}$$

D. The sedimentation basin on a water plant contains 5,775 gallons. What is the detention time if the flow is 175 gpm.

$$\text{DT} = \frac{5{,}775 \text{ gal}}{175 \text{ gal/min}} = 33 \text{ min}$$

Practice Problem Answers – Ratio and Proportion

A. It takes 6 gallons of chlorine solution to obtain a proper residual when the flow is 45,000 gpd. How many gallons will it take when the flow is 62,000 gpd?

$$\frac{6 \text{ gallons}}{X \text{ gallons}} : \frac{45{,}000 \text{ gpd}}{62{,}000 \text{ gpd}}$$

$$(X \text{ gallons})\ (45{,}000 \text{ gpd}) = (6 \text{ gallons})\ (62{,}000 \text{ gpd})$$

$$X \text{ gal} = \frac{(6 \text{ gal})\ (62{,}000 \text{ gpd})}{45{,}000 \text{ gpd}} = 8.3 \text{ gal}$$

B. A motor is rated at 41 amps average draw per leg at 30 Hp. What is the actual Hp when the draw is 36 amps?

$$\frac{41 \text{ amps}}{36 \text{ amps}} : \frac{30 \text{ Hp}}{X \text{ Hp}}$$

$$(41 \text{ amps})\ (X \text{ Hp}) = (36 \text{ amps})\ (30 \text{ Hp})$$

$$X \text{ Hp} = \frac{(36 \text{ amps})\ (30 \text{ Hp})}{41 \text{ amps}} = 26.3 \text{ Hp}$$

C. It it takes 2 operators 4.5 days to clean an aeration basin, how long will it take three operators to do the same job?

$$\frac{2 \text{ operators}}{3 \text{ operators}} : \frac{\text{X days}}{4.5 \text{ days}}$$

(2 operators) (X days) = (3 operators) (4.5 days)

$$\text{X days} = \frac{(2 \text{ operators})\ (4.5 \text{ days})}{3 \text{ operators}} = 3 \text{ days}$$

D. If it takes 20 minutes to pump a wet well down with one pump pumping at 125 gpm, then how long will it take if a 200 gpm pump is used?

$$\frac{20 \text{ min}}{\text{X min}} : \frac{200 \text{ gpm}}{125 \text{ gpm}}$$

(X min) (200 gpm) = (20 min) (125 gpm)

$$\text{X min} = \frac{(20 \text{ min})\ (125 \text{ gpm})}{200 \text{ gpm}} = 12.5 \text{ min}$$

E. It takes 3 hours to clean 400 feet of collection system using a sewer ball. How long will it take to clean 250 feet?

$$\frac{3 \text{ hrs}}{\text{X hrs}} : \frac{400 \text{ ft}}{250 \text{ ft}}$$

(X hrs) (400 ft) = (3 hrs) (250 ft)

$$\text{X hrs} = \frac{(3 \text{ hrs})\ (250 \text{ ft})}{400 \text{ ft}} = 1.9 \text{ hrs}$$

F. It takes 14 cups of HTH to make a 12% solution. Each cup holds 300 grams, how many cups will it take to make a 5% solution?

$$\frac{14 \text{ cups}}{\text{X cups}} : \frac{12\%}{5\%}$$

(X cups) (12%) = (14 cups) (5%)

$$\text{X cups} = \frac{(14 \text{ cups})\ (5\%)}{12\%} = 5.8 \text{ cups}$$

Practice Problem Answers – Pounds Formula

A. How many pounds of 100% gas chlorine are needed to disinfect a flow of 85,000 gpd at 12 mg/L?

lbs = 0.085 MGD x 8.34 lbs/gal x 12 mg/L

lbs = 8.5 pounds

B. The suspended solids in a stream are measured at 360 mg/L. The stream flow is estimated to be 3.2 MGD. How many pounds of solids are carried by the stream each day?

lbs = 3.2 MGD x 8.34 lbs/gal x 360 mg/L

lbs = 9,607 pounds

C. The backwash water of a treatment plant contains 320 mg/L. 4,000 gals of water are used for backwash. How many pounds of solids are deposited in the backwash lagoon with each backwash?

lbs = 0.004 MGD x 8.34 lbs/gal x 320 mg/L

lbs = 10.7 pounds

D. A 400,000 gallon storage tank is to be disinfected with 50 mg/L of chlorine. How many pounds of gas chlorine would it take to disinfect this tank?

lbs = 0.4 MG x 8.34 lbs/gal x 50 mg/L

lbs = 166.8 pounds

E. How many pounds of calcium hypochlorite at 67% is needed to disinfect 125,000 gallon per day flow with a dosage of 8 mg/L?

For 100% chlorine

lbs = 0.125 MGD x 8.34 lbs/gal x 8 mg/L

lbs = 8.34 pounds of 100%

This is the part of the whole.

$$\text{Percent} = \frac{\text{Part}}{\text{Whole}} \text{ X } 100$$

$$67\% = \frac{8.34 \text{ lbs}}{\text{Whole}} \text{ X } 100$$

$$\text{Whole} = \frac{8.34 \text{ lbs}}{67\%} \text{ X } 100 = 12.45 \text{ pounds}$$

Practice Problem Answers – Metric Conversion

A. Convert 4.2 Kg to g

4.2 kg x 1000 g/Kg = 4,200 g

B. Convert 0.5 Kg to g

0.5 Kg x 1000 g/Kg = 500 g

C. Convert 4600 g to Kg

$$\frac{4600 \text{ g}}{1000 \text{ g/Kg}} = 4.6 \text{ kg}$$

D. Convert 3.4 Km to m

3.4 Km x 1000 m/Km = 3,400 m

E. Convert 0.5 Km to m

0.5 Km x 1000 m/Km = 500 m

F. Convert 10,000 m to Km

$$\frac{10{,}000 \text{ m}}{1000 \text{ m/Km}} = 10 \text{ Km}$$

Abbreviations and Common Conversions

Limitations

The following is a listing of common abbreviations used in math problems in the water/wastewater field. With a few exceptions, this listing is limited to those abbreviations associated with the English units of measurement. Abbreviations associated with the SI (metric) system of measurements are found in the section of this lesson on metric units.

Abbreviations			
Ac	acre	hr	hour
ac-ft	acre-feet	Hp	horsepower
Af	acre-feet	in	inch
amp	ampere	in^2	square inches
BHp	Brake horsepower	in^3	cubic inches
°C	degrees Celsius	kw	Kilowatt
cfm	cubic feet per minute	kwh	Kilowatt-hour
cfs	cubic feet per second	lb	pound
cu-ft	cubic feet (ft^3)	M	Million
cu-in	cubic inch	MGD	million gallons per day
EHp	electrical horsepower	mg/L	milligrams per liter
°F	degrees Fahrenheit	min	minute
ft	feet or foot	psi	pounds per square inch
ft^2	square feet	ppm	parts per million
ft-lb/min	foot pounds per minute	sq ft	square feet (ft^2)
gal	gallon	W	watt
gpd	gallons per day	WHp	Water horsepower
gpcpd	gallons per capita per day	yd^3	cubic yard
gpm	gallons per minute		

Some Common Conversions

Area	Weight
1 acre = 43,560 ft^2 1 ft^2 = 144 in^2	1 ft^3 of water = 62.4 lbs 1 gal = 8.34 lbs 1 lb = 453.6 grams kg = 1000 g = 2.2 lbs 1% = 10,000 mg/L
Linear Measurements	
1" = 2.54 cm 1' = 30.5 cm 1 yard = 3 feet 1 meter = 100 cm = 3.281 feet = 3.94 inches	
Pressure	**Flow**
1 ft of head = 0.433 psi 1 psi = 2.31 ft of head	1 cfs = 448 gpm 1 cfs = 0.6463 MGD 1 MGD = 694.5 gpm
Volume	
1 gal = 3.78 liters 1 ft^3 = 7.48 gal 1 ft^3 = 62.4 lbs 1 gal = 8.34 lbs 1 Liter = 1000 mL 1 acre foot = 43,560 cubic feet 1 gal = 8 pint 1 gal = 16 cups 1 pint = 2 cups 1 pound = 16 oz dry wt 1 yd^3= 27 ft^3 1 gpm = 1440 gpd	