Math Workbook for Collection System Operators

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Preface

For the majority of you, doing math problems is "not fun"! It is something you do because you have to, maybe do "just once in a while," or possibly do once or twice to help you "pass the exam." While this is understandable, it does present a problem. The only way you can develop complete confidence in coming up "with the right answer" is to follow a procedure for solving a math problem and then continue to practice using it! As someone once said, "practice makes perfect."

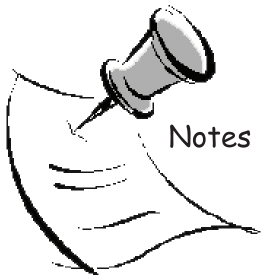
The intent of this workbook is to give you a chance to practice some collection system related problems and to build your confidence. Based on our experience in both doing and teaching wastewater math, mistakes are often made when you:

- go too fast,
- do not stop and think about what the problem is asking for,
- do not write down the formula,
- do not write down the units with the appropriate number, or
- come up with an answer in the incorrect units.

If you practice, follow the correct procedures as discussed in this workbook and understand what you did, you will be much more confident of your own ability to solve those "math problems."

Gene Erickson

Notes



Introduction to Math Concepts Review

As you use this workbook, some of you may come up with a slightly different answer than what is shown. This may be due to how you "rounded off" as you worked through the problem. Your answer is correct if you come within plus or minus 10% of what is given. If you are outside of that range, recheck your work. As you work problems within each topic, the problems become more difficult.

Answers are given in the back of the book. The first problem from each section and other selected problems are worked out completely.

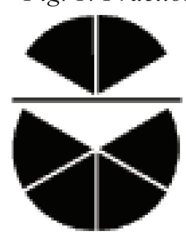
Fractions, Decimals, Ratios and Exponents

Fractions

Fractions are used when we want to express a portion of a whole object.

For example: If a pie is cut into six pieces and you eat two pieces, you have eaten 2/6 or 1/3 of the pie.

Fig. 1: Fractions, numerator and denominator



$$= \frac{2}{6} \text{ or } \frac{1}{3} \begin{matrix} \textit{numerator} \\ \textit{denominator} \end{matrix}$$

The top number, or *numerator*, represents how many parts we ate; the bottom number, or *denominator*, represents how many parts the whole pie has.

The bar in between divides the two numbers. This means the top number, *numerator*, is divided by the bottom number, *denominator*. The bar can also read *divided by* – for example, 1/2 is one *divided by* two.

Fractions can also be used in units of measurement such as, miles per hour (miles/hour) or miles per gallon (miles/gallon), where the word *per* means *divided by*.

Decimals

Decimal numbers, such as 3.25, are used when one needs more precision than whole numbers provide. Decimals are based on units of ten (tenths) and multiples of tenths. The value of a digit in a decimal number depends upon the place of the digit (see Table 1).

Table 1: Values of digits in decimal numbers

Place (underlined)	Name of Position
$\underline{1.}234567$	Ones (units)
$1.\underline{2}34567$	Tenths
$1.2\underline{3}4567$	Hundredths
$1.23\underline{4}567$	Thousandths
$1.234\underline{5}67$	Ten thousandths
$1.2345\underline{6}7$	Hundred thousandths
$1.23456\underline{7}$	Millionths

A fraction having a 10 or multiple of 10 in the denominator can be written as a decimal. For example, the fraction 2/10 could be written as the decimal number 0.2. The period or *decimal point* before the two indicates that this is a decimal. The decimal 0.2 could be pronounced as *two tenths* or *zero point two*. Decimals are similar to money. A dime is 1/10 of a dollar. Two dimes are 2/10 or 1/5 of a dollar. To visualize this, see Figure 2.

Fig. 2: Two-tenths

1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10

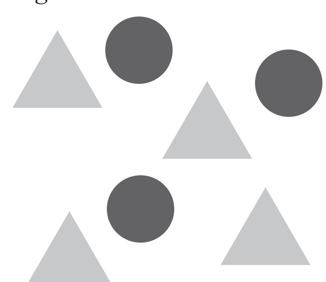
When adding or subtracting decimal numbers, remember to place the decimal points directly over and under each other.

Ratios

A ratio is a comparison of two numbers. Ratios can be written as:

- a fraction
- using the word "to"
- using a colon.

Fig.3: Ratios



For example, comparing the number of circles to the number of triangles in Fig.3, we can use a fraction and say "3/4", or say "three to four," or use a colon, 3:4.

Ratios tell how one number is related to another number. A ratio of 1:5 says that the second number is five times as large as the first.

Comparing Ratios

To compare ratios, write them as fractions. If ratios are equal when they are written as fractions, they are equal.

Multiplying or dividing each term by the same nonzero number will give an equal ratio. For example, the ratio 3:6 is equal to the ratio 1:2 because you can divide both 3 and 6 by 3 and produce 1:2. and To tell if two ratios are equal, use a calculator and divide. If the division gives the same answer for both ratios, then they are equal.

Proportion

A proportion is an equation with a ratio on each side. It is a statement that two ratios are equal. An example of an equal proportion: 1/2 = 3/6

Percent

A *percent* is a ratio whose second term is 100. Percent means “out of 100” or “parts per hundred. We can use the percent symbol (%) as a handy way to write a fraction whose denominator is 100. For example, instead of saying “27 out of every 100 professional volleyball players are female,” we can say “27% of professional volleyball players are female.”

A percent can also be written as a decimal by moving the decimal point two places to the left like this: 27% = 0.27 (Note: if there is no whole number, always use a zero before a decimal place.)

And a decimal can be written as a percent, by moving the decimal point two places to the right like this: 0.65 = 65%

Relationship Between Ratios, Fractions, Decimals and Percents

At some time, you may need to interchange ratios, fractions, decimals and percents. Table 2 shows the relationship between them.

Table 2: Comparing Ratio, Fraction, Decimal & Percent

Ratio	Fraction	Decimal	Percent
7 to 100	7/100	0.07	7%
29 to 100	29/100	0.29	29%
64 to 100	64/100	0.64	64%

Exponents

Exponents are a shorthand way to show how many times a number (called the *base*) is multiplied times itself. A number with an exponent is said to be “raised to the power” of that exponent; the exponent is the “power”.

Example 1: 6^2 means “six to the second power” or “six squared.” To calculate, you would multiply 6 times itself two times: 6 x 6 = 36

Example 2: 4^3 means “four to the third power” or “four cubed.” To calculate, multiply 4 times itself 3 times: 4 x 4 x 4 = 64

Exponents apply to units as well as numbers. For example:

1 ft x 1 ft x 1 ft = 1 ft^3 or 1 cubic foot (abbreviated cu ft)

Converting Units

When you are working math problems, numbers usually have units attached. Sometimes the units you are given are not the units in which you want to express your answer. So you need to *convert* units.

Converting units is easy when you use the *goalpost* method to set up your problems. *Conversion factors* (numbers **and units**) are placed within *goalposts* (├─┤). You can keep adding goalposts with conversion factors until you end up with the units you are seeking. If you want a unit in the *numerator* (above the line) to cancel, add a conversion factor with that unit in the *denominator* (below the line). Since, in a conversion factor, both sides are equal, you can place it within the goalpost either way.

When you solve a problem, numbers above the line are multiplied together, then divided by numbers below the line. (If you need to add or subtract, do that before you multiply and/or divide.)

Units (feet, gallons, seconds, etc.) above and below the line will cancel each other out. If a problem is set up properly, the only units to the left of the '=' sign that do not cancel are the units in which you want to express your final answer.

For example: Change 2 years to seconds. (Conversion factors are placed so the denominator of the following factor cancels the numerator of the existing factor.)

$$\begin{array}{l|l|l|l|l} 2\ \text{yrs} & 365\ \text{days} & 24\ \text{hrs} & 60\ \text{min} & 60\ \text{sec} \\ \hline & 1\ \text{yr} & 1\ \text{day} & 1\ \text{hr} & 1\ \text{min} \end{array} = 63{,}072{,}000\ \text{seconds}$$

You could also do the opposite: Change 93,000,000 seconds to years. (Note: we use the same factors, but place them so the denominator of the next factor cancels the numerator. Arrows show placement.)

$$\begin{array}{l|l|l|l|l} 93{,}000{,}000\ \text{sec} & 1\ \text{min} & 1\ \text{hr} & 1\ \text{day} & 1\ \text{yr} \\ \hline & 60\ \text{sec} & 60\ \text{min} & 24\ \text{hrs} & 365\ \text{days} \end{array} = 2.95\ \text{yrs}$$

There is no limit to the number of conversion factors you can use. Use as many as you need to get from the units you have to where you want to be.

Should you need to *convert* your answer from one unit to another, such as from cubic feet/second to gallons/minute, you can easily do that by adding *goalposts* with appropriate conversion factors to convert from seconds to minutes (60 seconds = 1 minute) and cubic feet to gallons (1 cubic foot = 7.48 gallons). Place conversion factors within the goalposts in such a way that the units you want to get rid of will cancel and the units you want to convert to will remain. You can find conversion factors on the inside back cover of this manual and in the booklet *Wastewater Formulas and Conversion Factors*.

The first and last goalpost "upright" is omitted to eliminate extra lines. When doing problems, be sure to write down the formula you will use! Circle your answer(s).

To see how problems are set up, see the examples on the pages 12 and 16.

Significant Figures

Every measurement has a degree of uncertainty. The uncertainty comes from the accuracy of the measuring device and from the skill of the person doing the measuring. Because measured quantities are often used in calculations, the precision of the calculation is limited by the precision of the measurements on which it is based. For example, if you calculate area based on measurements to the nearest foot, it is ridiculous to try to give an answer to the nearest tenth or hundredth of a square foot. For this reason, we use significant figures to help us determine how to express calculated answers. A calculated number cannot be more accurate than the measurements upon which it is based.

We use the following significant figure rules to determine how many significant figures in a number:

- All non-zero numbers are significant. (1, 2, 3, 4, 5, 6, 7, 8, 9)
- Zeros within a number are significant. (Example: Both '3076' and '60.02' contain four significant figures.)
- Zeros that do nothing but set the decimal point are not significant. (So, the number '630,000' has two significant figures.)
- Trailing zeros that aren't needed to hold the decimal point are significant. (For example, '2.00' has three significant figures.)
- If you are not sure whether a digit is significant, assume that it isn't. (For example, if a problem reads: "The height is 200 inches," assume the height is known to one significant figure.)

There are also rules when adding, subtracting, multiplying and dividing numbers:

- When measurements are added or subtracted, the answer can contain no more decimal places than the least accurate measurement.
  Example: 22.25 ft + 7.125 ft + 11 ft

  When added together, you get 40.375 ft, but you should give the sum as '40' feet. (See *Rounding Off* below.)

- When measurements are multiplied or divided, the answer can contain no more significant figures than the least accurate measurement.
  Example: $\frac{29.5}{7}$ should be given as '4,' not '4.214'
- When the answer to a calculation contains too many significant figures, it must be rounded off. (See *Rounding Off* below.)

Losing Significant Figures

You may sometimes 'lose' significant figures when performing calculations. For example, if you subtract 21.75 – 21.50, the answer, '0.25' has two significant figures even though the original values contained four significant figures. When that happens, don't worry about it – just give the answer in the number of significant figures it has.

Rounding Off Numbers

Using a calculator will often give you an answer with many digits – so many, in fact, that the answer doesn't make much sense because you can't really measure it. For example, if your measuring tool is a ruler, you can't really measure 1.5263792 inches. You can, however, *round off* the number to fewer digits following these **rules for rounding off**:

- Determine how many digits (numbers) you want in your answer.
- Then, look at the next number (the number after those digits). If it is less than 5, just drop that number and all remaining numbers.
- If the number is 5 or more, make the preceeding number one unit greater, then drop all remaining numbers.

In our example 1.5263792 inches, if we round off to *two* digits, we look at the *third* number. Since the third number, 2, is less than 5, we drop it and all remaining numbers and end up with 1.5 inches.

If we round off to *three* digits, we look at the *fourth* number. Since the fourth number, 6, is more than 5, we make the preceeding number one unit larger, then drop the remaining numbers. So our answer becomes 1.53 inches.

When working problems, always wait until you get the final answer before rounding off.

Examples

Conversions

1. How many feet in 30 inches?

$$\overbrace{\frac{30\ \cancel{\text{inches}}}{}}^{\text{Given information}}\ \Big|\ \overbrace{\frac{1\text{ foot}}{12\ \cancel{\text{inches}}}}^{\text{Conversion factor}} = 2.5\text{ feet}$$

2. How many cubic feet (ft^3) in one cubic yard (yd^3)?
(Note how units can also have exponents!)

$$\frac{1\ \cancel{yd^3}}{}\ \Big|\ \frac{3\text{ ft}}{1\ \cancel{yd}}\ \Big|\ \frac{3\text{ ft}}{1\ \cancel{yd}}\ \Big|\ \frac{3\text{ ft}}{1\ \cancel{yd}} = 27\text{ ft}^3\text{ or 27 cubic feet}$$

3. Express a flow rate of 1 cubic feet/second in gallons/minute.

$$\frac{1\ \cancel{\text{cubic foot}}}{1\ \cancel{\text{second}}}\ \Big|\ \frac{7.48\text{ gallons}}{1\ \cancel{\text{cubic foot}}}\ \Big|\ \frac{60\ \cancel{\text{seconds}}}{1\text{ minute}} = 448.8\text{ gallons/minute}$$

4. Express a flow rate of 1 gallon/minute in gallons/day.

$$\frac{1\text{ gallon}}{\cancel{\text{minute}}}\ \Big|\ \frac{60\ \cancel{\text{minutes}}}{1\ \cancel{\text{hour}}}\ \Big|\ \frac{24\ \cancel{\text{hours}}}{1\text{ day}} = 1440\text{ gallons/day}$$

5. If you know 1 gallon of water weights 8.34 pounds and that 1 cubic foot of water weighs 62.4 pounds, how many gallons are in 1 cubic foot of water?

Think it through: You want to know how many gallons per cubic foot, so set up the conversion factors so those are the units that are left after canceling.

$$\frac{1\text{ gallon}}{8.34\ \cancel{\text{pounds}}}\ \Big|\ \frac{62.4\ \cancel{\text{pounds}}}{1\text{ cubic foot}} = 7.48\text{ gallons/cubic foot}$$

Rearranging a Formula

Sometimes the way a formula is written, the item you are trying to find does not stand alone. You must rearrange or transpose the formula to solve for the unknown quantity.

When rearranging formulas, think of a formula as a balanced scale – the quantity on the left is equal to the quantity on the right. If we add an amount to one side of the scale, to keep balance we must also add the same amount to the other side. Similarly if we take away an amount from one side, we must also take the same amount away from the other side. The same applies to formulas. If we add an amount to one side, we must also add the same amount to the other to keep the formula equal. If we subtract an amount from one side we must also subtract the same amount from the other side.

Figure 4: Formulas are like a balanced scale.

This also applies to multiplication and division: if we multiply one side of a formula by any amount, we must also multiply the other side by the same amount. Similarly, if we divide one side of the formula by any amount we must also divide the other side by the same amount.

When you are trying to rearrange a formula, remember you may:

- **add or subtract the same quantity to or from both sides**
- **multiply or divide both sides by the same quantity**

Other operations are also allowed, such as squaring and taking the square root – as long as whatever you do to one side of the formula, you also do to the other.

How do you decide whether to add, subtract, multiply or divide? First, look at what you are trying to find and ask yourself: 'What has been done to it?' For example, suppose you are given the formula:

Formula $$\textbf{Detention time} = \frac{\textbf{Volume}}{\textbf{Flow rate}}$$

and you want to find the volume. You see that, the way the formula is written, *volume* is divided by *flow rate*. To get *volume* to stand alone, you must "undo" the division by doing the opposite: multiplication. But remember, when working with a formula, whatever you do to one side, you **must** do to the other. In this case, you would multiply both sides by *flow rate* as shown below:

$$\textbf{Flow rate} \times \text{Detention time} = \frac{\text{Volume}}{\cancel{\text{Flow rate}}} \times \cancel{\textbf{Flow rate}}$$

Flow rate cancels out on the right side leaving *Volume* standing alone. We can flip sides and write:

Volume = Flow rate x Detention time

Suppose you start with the same formula, but you want to solve for the flow rate.

Formula $$\textbf{Detention time} = \frac{\textbf{Volume}}{\textbf{Flow rate}}$$

Since *Flow rate* is on the bottom (in the denominator), multiple both sides by *Flow rate* so it is on the top (in the numerator):

$$\textbf{Flow rate} \times \text{Detention time} = \frac{\text{Volume}}{\cancel{\text{Flow rate}}} \times \cancel{\textbf{Flow rate}}$$

Flow rate still does not stand alone – it has been multiplied by *Detention time*. To undo multiplication, we must divide both sides by *Detention time*, then cancel as shown below:

$$\text{Flow rate} \times \frac{\cancel{\text{Detention time}}}{\cancel{\textbf{Detention time}}} = \frac{\text{Volume}}{\textbf{Detention time}}$$

So finally, $$\text{Flow rate} = \frac{\text{Volume}}{\text{Detention time}}$$

In another example you know Flow rate and Area, and want to find Velocity. You choose the formula:

Flow rate = Velocity x Area

Since the velocity has been multiplied by the area, you "undo" that by dividing **both sides of the equation** by area, then canceling, as shown below:

$$\frac{\text{Flow rate}}{\textbf{Area}} = \text{Velocity} \times \frac{\cancel{\text{Area}}}{\cancel{\textbf{Area}}}$$

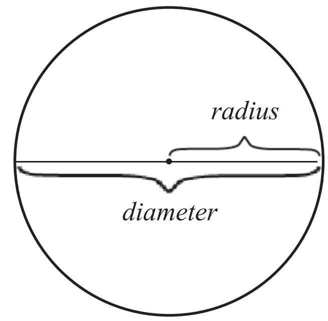
Then, flip sides to get: $$\textbf{Velocity} = \frac{\textbf{Flow rate}}{\textbf{Area}}$$

Sometimes you may need to substitute terms in a formula. The formula below is the common formula used to find the area of a circle.

Formula $\mathbf{A} = \pi\mathbf{r}^2$, where *r* is the radius

Often, however, you may know the diameter rather than the radius. Given the diameter, you could divide it by 2, since the radius is half the diameter. Or, you could replace *r* with *d/2* as shown below:

Figure 5: The radius of a circle is one-half the diameter.



$$A = \pi \times \left(\frac{d}{2}\right)^2$$

$$= 3.14 \times \frac{d^2}{4} \quad \text{or} \quad \frac{3.14 \times d^2}{4}$$

$$A = 0.785 \times d^2$$

Another formula that is used often in collection system calculations is:

Formula $\mathbf{Slope} = \dfrac{\mathbf{Rise}}{\mathbf{Run}}$

Slope is defined as Rise/Run (the upward rise divided by the length of the run). Because the rise is less than the run, slope is a decimal number – always less than one. Often, one wants to know the *percent* slope. Remember, to change a decimal number to a percent, you must multiply by 100. And, whatever you do to one side of a formula, you *must* do to the other. So the formula becomes:

$$\text{Slope} \times 100 = \frac{\text{Rise}}{\text{Run}} \times 100$$

$$\textbf{Slope (\%)} = \frac{\textbf{Rise}}{\textbf{Run}} \times \mathbf{100}$$

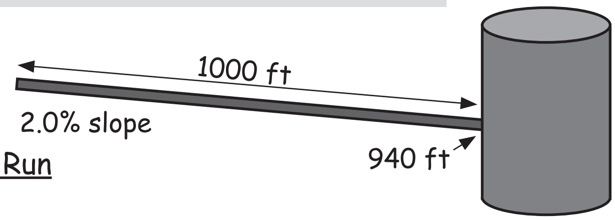
When using formulas to solve problems, take care to rearrange the formula correctly. If you must use several steps to do it, show those steps in your work so you can go back and see what you did. If you can't rearrange a formula correctly, you can't get a correct answer.

Don't forget that to get your final answer in the correct units, you may need to use one or more conversion factors!

Formula Examples

1. A 1000-foot pipe with a 2.0% slope enters a lift station at an invert elevation of 940.0 feet. What is the elevation at the other end of the pipe?

Formula $\text{Slope}(\%) = \dfrac{\text{Rise}}{\text{Run}} \times 100$



Rearrange formula: $\text{Rise} = \dfrac{\text{Slope }(\%) \times \text{Run}}{100}$

$\text{Rise} = \dfrac{2.0\% \times 1000 \text{ ft}}{100} = 20 \text{ feet}$ Reminder: dividing % by 100 changes the number to a decimal.

$\text{Elevation}_{\text{FINAL}} = \text{Elevation}_{\text{INITIAL}} + \text{Rise}$

$= 940 \text{ feet} + 20 \text{ feet} = 960 \text{ feet}$

2. What is the loading, in pounds/day, of wastewater with a strength of 500 mg/l and a flow rate of 0.89 million gallons/day?

Formula
Loading = concentration(mg/L) x flow (MGD) x 8.34 lb/gallon

When doing this problem, it is important to note that 1 mg/L is equivalent (equal) to 1 part per million (1 part/1 million parts). In this example, to show in a non-rigourous mathematical explanation that units cancel, we will use as a conversion factor a compound fraction – which is resolved by inverting the denominator and multiplying as shown in the second step.

$$\text{Loading} = \frac{500 \text{ mg}}{\text{L}} \left| \frac{0.89 \text{ million gal}}{\text{day}} \right| \frac{8.34 \text{ lb}}{\text{gallon}} \left| \frac{1 \text{ part/million parts}}{1 \text{ mg/L}} \right.$$

$$= \frac{500 \cancel{\text{mg}}}{\cancel{\text{L}}} \left| \frac{0.89 \cancel{\text{million gal}}}{\text{day}} \right| \frac{8.34 \text{ lb}}{\cancel{\text{gal}}} \left| \frac{1 \cancel{\text{L}}}{1 \cancel{\text{mg}}} \right| \frac{1 \cancel{\text{part}}}{1 \cancel{\text{million parts}}}$$

$\text{Loading} = 3{,}711.3 \text{ lb/day}$

Complex Fractions

If someone asks you how many half dollars there are in one dollar, you probably wouldn't think twice before you said, "Two." Or, if they asked you how many quarters in a dollar, you could easily come up with the correct answer: "Four." When you are figuring this out, you are actually using complex fractions. If we write it mathematically, it would look like this:

$$\frac{1}{\frac{1}{2}} \quad \text{and} \quad \frac{1}{\frac{1}{4}}$$

When you solve complex fractions, you simply *invert and multiply* – that is, turn the denominator (bottom number) upside-down, then multiply the two numbers.

When you figured out how many half dollars in a dollar and how many quarters in a dollar, you did this in your head:

$$\frac{1}{\frac{1}{2}} = \frac{1}{1} \times \frac{2}{1} = 2 \quad \text{and} \quad \frac{1}{\frac{1}{4}} = \frac{1}{1} \times \frac{4}{1} = 4$$

Sometimes you may have a fraction on top of a fraction. Don't let that throw you. Just do the same thing: *invert and multiply*! For example: How many quarters (quarter dollars) are there in a half dollar? The math would look like this:

$$\frac{\frac{1}{2}}{\frac{1}{4}} = \frac{1}{2} \times \frac{4}{1} = \frac{4}{2} \text{ or } 2$$

If you have numbers with units, keep the units and cancel them when appropriate:

$$\frac{\frac{1}{2}\cancel{\text{dollar}}}{\frac{1}{4}\cancel{\text{dollar}}} = \frac{1}{2} \times \frac{4}{1} = \frac{4}{2} \text{ or } 2$$

Example: Find the detention time when the volume is 10,000 gal and the flow rate is 250 gal/min.

Formula **Detention Time =** $\dfrac{\textbf{Volume}}{\textbf{Flow Rate}}$

$$\text{Detention time} = \frac{10{,}000 \text{ gal}}{\frac{250 \text{ gal}}{1 \text{ min}}} = 10{,}000\ \cancel{\text{gal}} \times \frac{1 \text{ min}}{250\ \cancel{\text{gal}}} = 40 \text{ minutes}$$

Solving Math Problems Checklist

Do not be tempted to look at a problem and start punching numbers into a calculator. Using a calculator this way only ensures you will get the wrong answer *quickly*. Instead, follow this checklist to help ensure success!

- ☐ Read the problem carefully. (You may need to read it twice!)
- ☐ Draw and label a picture of the problem.
- ☐ Think about the information you are given and what you want to know.
- ☐ Choose a formula (some problems may require more than one formula).
- ☐ Write down the formula as it is given. Rearrange it if it is not in the form you need.
- ☐ Replace the words in the formula with the numbers **and units** of the information you have been given (sometimes you may be given information you don't need – don't let that fool you!).
- ☐ If needed, add conversion factors to end up with the requested units. Cancel (cross off) units to make sure the only units left are the ones you want in your answer.
- ☐ Now, get out your calculator and multiply all the numbers on the top and divide by all the numbers on the bottom.
- ☐ Ask yourself if the final answer is reasonable for the question being asked.
- ☐ Double check to make sure your answer is in the units being asked for.
- ☐ Smile at your correct answer ☺

Notes

Essential Math Refresher

Answers page 63.

1. Convert to decimals:
   a. 1/2
   b. 2/3
   c. 5/7
   d. 1/8

2. Find the values of the following:
   a. 23^2
   b. 13^3
   c. $31^2 + 12^3$
   d. $(6 + 21)^4$
   e. $(3 \text{ x } 2)^2$
   f. 0.5^3
   g. 15.75^2
   h. $\frac{3^2}{15}$

3. Find the square root of the following:
   a. 16
   b. 625
   c. 1, 296

4. Convert to percent:
   a. 0.35
   b. 1.27
   c. 0.02
   d. 3/5
   e. 0.045
   f. 2 1/5

5. Convert to decimal numbers:
   a. 46%
   b. 178%
   c. 0.65%

Conversions –

To do these problems you will need to use one or more conversion factors found on the inside of the back cover of this manual or in the *Wastewater Formulas and Conversion Factors* booklet.

6. Convert the following:

   a. 14,000 cubic feet to gallons

14,000 cubic feet		=	______ gallons

   b. 16,348 cubic feet to gallons

   c. 14,000 gallons to cubic feet

   d. 1,050 gallons to cubic feet

   e. 103,842 square feet to acres

   f. 4.5 acres to square feet

   g. 5 cubic feet per second to gallons per minute

5 cu ft			=	gal
sec				min

Answers page 63.

h. 0.5 cubic feet per second to gallons per minute

i. 5 gallons per minute to cubic feet per second

j. 50 gallons per minute to cubic feet per second

k. 0.005 cubic feet per second to gallons per minute

l. 185 gallons per minute to cubic feet per second

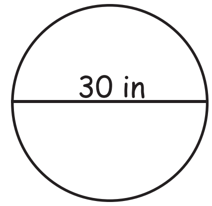
m. 0.035 cubic feet per second to gallons per minute

Circumference and Perimeter

7. Find the circumference, in feet of a circle with a diameter of 30 inches.

Formula **C = π x D** *(where C = circumference and D = diameter)*

$$C = \overbrace{3.14}^{\pi} \;\Big|\; \overbrace{30\ \text{in}\cancel{\text{ches}}}^{\text{diameter}} \;\Big|\; \overbrace{\frac{1\ \text{foot}}{12\ \text{in}\cancel{\text{ches}}}}^{\text{conversion factor}} \quad = \underline{\qquad\qquad}\text{feet}$$



8. Find the circumference, in inches, of a circle with a diameter of 30 feet.

Formula

9. Find the circumference, in feet, of a circle with a diameter of 22.3 inches.

Formula

10. Find the perimeter, in feet, of a rectangle that is 35 feet long and 15 feet wide.

Answers page 63.

Formula $P = S_1 + S_2 + S_3 + S_4$

P = 35 ft + 15 ft + 35 ft + 15 ft = ____________feet

11. Find the perimeter, in feet, of a rectangle that is 100 inches long and 8 inches wide. (Reminder: Use a conversion factor to change inches to feet!)

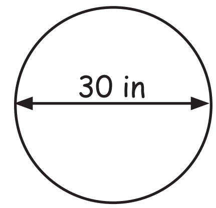
Formula

12. Find the perimeter, in feet, of a rectangle that is 85 feet long and 3 yards wide.

Formula

Area

13. Find the area, in square feet, of a circle with a diameter of 30 inches.



Formula $A = 0.785 \times D^2$

$$A = \begin{array}{c|c|c|c} 0.785 & 30\ \cancel{\text{inches}} & 30\ \cancel{\text{inches}} & 1\ \text{square feet} \\ \hline & & & 144\ \cancel{\text{square inches}} \end{array} = \underline{\hspace{3cm}}\ \text{sq ft}$$

Reminder: Square inches = inches^2 or inches x inches)

14. Find the area, in square feet, of a circle with a diameter of 30 feet.

Formula

15. Find the area, in square feet, of a circle with a diameter of 36 inches.

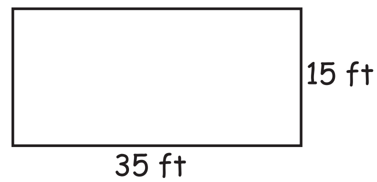
Formula

16. Find the area, in square feet, of a rectangle with dimensions of 35 feet long and 15 feet wide.

Answers page 63.

Formula **A = L x W**

A = 35 ft x 15 ft = __________ sq ft



17. Find the area, in square feet, of a rectangle with dimensions of 100 inches long and 8 inches wide. (Hint: Remember to use a conversion factor!)

Formula

18. Find the area, in acres, of a lot that is 200 feet long and 60 feet wide.

Formula

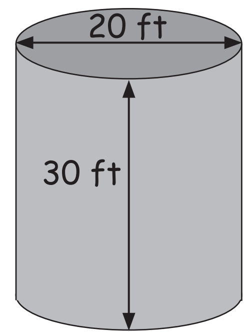
Volume

19. Find the volume, in gallons, of a tank with a diameter of 20 feet and a depth of 30 feet.

Formula $V = 0.785 \times D^2 \times H$

$$V = \frac{0.785}{} \Big| \frac{20\ \cancel{ft}}{} \Big| \frac{20\ \cancel{ft}}{} \Big| \frac{30\ \cancel{ft}}{} \Big| \frac{7.48\ \text{gallons}}{1\ \cancel{\text{cu ft}}}$$

= ____________ gallons



20. Find the volume, in gallons, of a tank with a diameter of 27.4 feet and a depth of 11 feet.

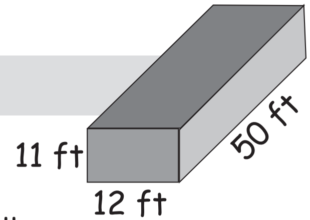
Formula

21. Find the volume, in gallons, of a tank with a diameter of 120 inches and a depth of 180 inches.

Formula

22. Find the volume, in gallons, of a tank that is 50 feet long, 12 feet wide and 11 feet deep.

Answers page 63.



Formula $V = L \times W \times H$

$$V = \overbrace{\cancel{ft} \;\Big|\; \cancel{ft} \;\Big|\; \cancel{ft}}^{\text{Volume}} \;\Big|\; \overbrace{\frac{\text{gallons}}{\cancel{ft^3}}}^{\text{Conversion factor}} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{gallons}$$

23. Find the volume, in gallons, of a tank that is 80 feet long, 20 feet wide and 10 feet deep.

Formula

24. Find the volume, in gallons, of a tank that is 97.2 feet long, 10.5 feet wide and 10.5 feet deep.

Formula

Essential Math Refresher

Rearranging Formulas

25. Calculate the length of one side of a rectangle, in feet, that has a perimeter of 280 feet and is 20 feet wide.

Formula

26. Calculate the diameter of a circle, in feet, that is 94.2 feet in circumference.

Formula

27. Calculate the diameter of a circle, with an area of 19.625 square feet.

Formula

28. Find the length of one side of a rectangle, in feet, that has an area of 2400 square feet and is 20 feet wide.

Answers page 63.

Formula

29. You have one gallon of paint to paint both sides of an 8-foot tall fence that is 45 feet long. If one gallon covers 400 square feet, do you have enough paint?

Formula

30. A 180,000-gallon equalization basin is 120 feet long and 20 feet wide. When the basin is full, how deep, in feet, will the water be?

Formula

31. Your family room measures 25 feet by 15 feet. How many square yards of carpet do you need to cover the floor? If carpet (including installation) is $35 per square yard, how much will it cost to recarpet?

Formula

32. How many feet of snow fence does it take to enclose an excavation 20 feet in diameter if the fence is located 4 feet from the hole? (Hint: Draw a picture!)

Formula

33. Find the volume, in gallons, of an 18-inch force main that is 2 miles long.

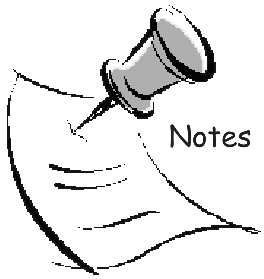
Answers page 64.

Formula

34. An 8-foot deep tank has a diameter of 10 feet. Will its contents fit into a 5,000-gallon tanker? (Show your work!)

Formula

Notes



Answers page 64.

Slope

1. What is the slope, in percent, of a pipe 7,000 feet long with a drop of 12 feet?

   Formula

2. What is the rise in a 400-foot pipe that has a 0.4% slope?

   Formula

3. A forcemain is 2 miles long and discharges at a point 12 feet higher. What is the average slope, in percent, over the forcemain?
   (Reminder: Pay attention to units!)

   Formula

4. You need to maintain a 0.50 percent slope on a gravity line from manhole #2 to a downstream manhole #3. If the elevation at manhole 2 is 1,345 feet and manhole 3 is 380 feet away, what is the elevation at manhole 3?

Formula

5. From the previous questions, what is the elevation at manhole #1 which is 450 away if the slope is 0.75 percent?

Formula

Answers page 64.

Loading / Population Equivalent

1. An industry discharges into your system with a BOD strength of 550 mg/l at a flow rate of 650,000 gallons per day. What is its loading in pounds per day?

Formula

2. What is the loading, in pounds per day, if the wastewater strength is 250 mg/l and the flow is 325,000 gallons per day?

Formula

Loading/Population Equivalent

3. Your lift station receives an average daily flow of 1.35 MGD. If you assume each person contributes 100 gallons per day, approximately how many people are using your collection system?

   Formula

4. How many pounds per day of BOD would a city of 13,500 people discharge to a treatment facility?

   Formula

Answers page 64.

5. Which would discharge more pounds per day of BOD to a treatment facility – a city with a population of 25,430 or an industry that discharges a BOD concentration of 750 mg/l at a flow of 125,500 gallons per day?

Formula

6. Determine the percent contribution of the following:

a. A city with a population of 34,700

b. Industry A which contributes a BOD of 300/mg/l at a flow of 0.60 MGD

c. Industry B which contributes a BOD of 750 mg/l at a flow of 1.25 MGD

Formula

7. Some root control work is needed in an 8-inch line that is 800 feet long. Chemical solution will be added at a concentration of 210 mg/l. How many pounds of chemical are needed? (Assume a full pipe.)

Formula

8. You are adding chlorine at 25 pounds per day to control odors in one of your 24-inch lines. If the flow rate in the line is 245 GPM and the total line length is 15,000 feet, what is the dosage of chlorine in mg/l?

Formula

Answers page 65.

Detention Time

1. How long will it take, in minutes, to fill up a tank 25 feet in diameter and 10 feet deep if your pump rate into it is 100 gallons per minute?

   Formula

2. What is the holding time, in hours, of a 24-inch interceptor that is 1.5 miles long and is receiving a flow of 1,240,000 gpd?

   Formula

3. How many hours will it take before a 50-foot diameter storage tank overflows if the bottom elevation is 942 feet, the overflow elevation is at 950 feet and the incoming flow rate is 250,000 gallons per day? (Assume the tank is empty.)

Formula

4. Using a pump that pumps 150 gallons per minute, how long, in hours, would it take to pump out a 30-foot diameter tank that has 15 feet of water in it?

Formula

Answers page 65.

5. Two manholes are located 375 feet apart. If downstream manhole is plugged and the pipe between them has a 12-inch diameter, how long would it take, in minutes, to fill up the pipe if the flow rate is 400 gallons per minute?

Formula

6. To do some work in a manhole, you need to plug the inlet pipe. Given the following information, how much time to you have before you can expect a backup in a house located 310 feet upstream?

   a. The inlet pipe has a 10-inch diameter.

   b. The inlet pipe invert elevation is 1,000.5 feet

   c. The first house basement elevation is 1,015.9 feet.

   d. The flow rate in this line is 30 gallons per minute.

Formula

7. You just received notification that the high water alarm, set to go off at elevation 950.5 feet, is on. The bottom elevation of this wet well is 925.0 feet; the overflow by-pass elevation in the wet well is 970.0 feet. The flow rate into the 8-foot diameter lift station is 400 gallons per minute. There is an 18-inch pipe coming in at an invert elevation of 940.0 feet and a slope of 2.5 percent. The closest basement is located 1,000 feet away. Which occurs first – a basement backup or bypass? How much time do you have before it happens?

Formula

Answers page 67.

Flow Rate

1. What is the flow rate, in gallons per minute, in an open channel with a width of 12 inches and a depth of 24 inches, flowing full, if the velocity in the channel is 2 feet per second?

   Formula

2. What is the flow rate, in gallons per minute, in an 8-inch pipe flowing full if the velocity is 1.5 feet per second?

   Formula

3. What is the flow rate, in gallons per minute, into a lift station if the 18-inch influent pipe is flowing half-full with a velocity of 4 feet per second?

Formula

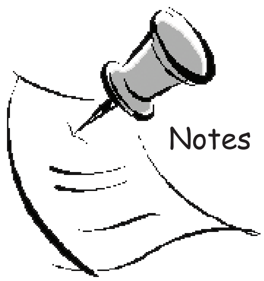
4. If the velocity in a 24-inch pipe flowing half-full is 2.5 feet per second, what is the flow rate in gallons per minute?

Formula

5. Wastewater is running into an 8-foot diameter tank. In 15 minutes the wastewater rises 3.7 feet. What is the flow rate, in gallons per minute, into the tank?

Formula

Notes



Answers page 68.

Velocity

1. Dye is placed in Manhole A located 400 feet upstream of Manhole B with a 10-inch line in between them. If the dye appears in Manhole B 5 minutes later, what is the velocity in feet per second?

Formula

2. To determine the velocity, dye is placed in an 8-inch line. If it takes 7 minutes and 30 seconds to travel a distance of 860 feet, what is the velocity in feet per second?

Formula

3. What is the velocity, in feet per second, in a 16-inch pipe that is flowing full at a rate of 2 cubic feet per second?

Formula

4. Find the velocity, in feet per second, in a 24-inch pipe that is flowing full at a rate of 5 cubic feet per second.

Formula

Answers page 68.

5. Find the velocity, in feet per second, in a 10-inch pipe that is flowing full at a rate of 725 gallons per minute?

Formula

6. An 8-inch pipe is flowing full at a rate of 315 gallons per minute. What is the velocity in feet per second?

Formula

7. The flow in an 8-inch pipe is 500 gallons per minute; it is half full. What is the velocity in feet per second?

Formula

8. If a 16-inch pipe is flowing one-half full at a rate of 825 gallons per minute, what is the velocity in feet per second?

Formula

9. A pipe must carry a minimum flow of 490 gallons per minute when flowing full. If the velocity must never be less than 2 feet per second, what diameter pipe would you select? (Express in appropriate units.)

Formula

10. If you increased the flow in #9 above from 490 to 700 gallons per minute, what diameter pipe would you need to maintain a velocity of 2 feet per second? (Express in appropriate units.)

Formula

11. You have a 10-inch line in which you want to maintain a velocity of no more than 2.5 feet per second. What is the maximum flow rate in gallons per minute?

Formula

12. How many times more carrying capacity has a 12-inch pipe compared to a 6-inch pipe? (Assume the same velocity in each.)

Formula

Answers page 68.

Cost

1. It took 4 hours to clean 4,000 feet of line. If your three-person crew is making $14.00/hr, $12.00/hour and $10.00/hour and the jetter rental costs $150/hour, how much did it cost per foot to do the work?

Formula

2. You are asked to prepare an estimate to construct a 10-inch gravity line 16,000 feet long with manholes every 400 feet (start and end with a manhole). Based on the following estimated costs, what is the total cost?
   - Excavation and backfill (includes pipe installation) – $20.00 per foot
   - Pipe cost (delivered) – $6.50 per foot
   - Manhole (installation included) – $1050.00 each

Formula

3. From past experience you know that it takes your three-person crew 32 hours to complete some repair work. You have been asked to complete this same work within 16 hours. How many people would you need and how much would it cost if the averate wage is $14.00 per hour?

Formula

4. A tank 10 feet long and 8 feet wide has 15 feet of water in it. If it costs $75 an hour to rent a 50-gallon per minute pump, how much would it cost to pump out this tank?

Formula

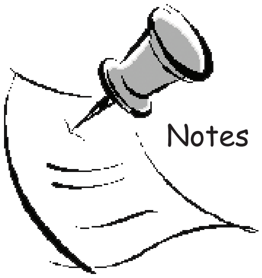
5. A chlorine dosage of 20 mg/l is to be used to control hydrogen sulfide. If the interceptor has a flow rate of 2,000 gallons per minute and the chlorine costs $0.95 per pound, how much would it cost per month?

Formula

6. You are using a chemical at a rate of 5 gal/day and a cost of $1.45/gal. If the flow rate is 500,000 gal/day, what is the monthly cost for the chemical?

Formula

Notes



Pump Calibration/Lift Station

Answers page 69.

1. Given the information below, what is the pumping rate, in gallons per minute, of a lift station pump?
   - Wet well diameter: 8 feet
   - Drawdown time: 255 seconds
   - Drawdown distance: 1.26 feet
   - Refill time: 410 seconds
   - Refill distance: 1.19 feet

Formula

2. Given the information below, what is the pumping rate, in gallons per minute of a lift station pump?
   - Wet well diameter: 8 feet
   - Drawdown time: 315 seconds
   - Drawdown distance: 2.26 feet
   - Refill time: 523 seconds
   - Refill distance: 2.35 feet

Formula

3. Given the information below, what is the pumping rate, in gallons per minute of a lift station pump?
    - Wet well diameter: 10 feet
    - Drawdown time: 5 minutes 7 seconds
    - Drawdown distance: 2 feet, 4 inches
    - Refill time: 7 minutes 23 seconds
    - Refill distance: 2 feet, 5 inches

Formula

4. Given the information below, what is the pumping rate, in gallons per minute of a lift station pump?
    - Wet well diameter: 6 feet
    - Drawdown information:
      – Time at start: 9:10:20 (Hours:Minutes:Seconds)
      – Time at end: 9:13:09
      – Distance down to water surface at start: 8 feet 4 inches
      – Distance down to water surface at end: 9 feet 6 inches
    - Refill information:
      – Time at start: 9:13:09 (Hours:Minutes:Seconds)
      – Time at end: 9:18:17
      – Distance down to water surface at start: 9 feet 6 inches
      – Distance down to water surface at end: 8 feet 1-1/2 inches

Formula

Answers & Selected Problems

Essential Math Refresher

1. a. 0.50; b. 0.67; c. 0.71; d. 0.13

2. a. 529; b. 2197; c. 2689; d. 531,441; e. 36; f. 0.13; g. 248.07; h. 0.60

3. a. 4; b. 25; c. 36

4. a. 35%; b. 127%; c. 2%; d. 60%; e. 4.5%; f. 220%

5. a. 0.46; b. 1.78; c. 0.0065

6. a. 104,720 gallons;
   $\frac{14{,}000\ \cancel{\text{cu ft}} \mid 7.48\ \text{gallons}}{\mid 1\ \cancel{\text{cu ft}}} = 104{,}720\ \text{gal}$

   b. 122,283.04 gallons; c. 1,871.66 cu ft; d. 140.37 cu ft; e. 2.38 acres;
   f. 196,020 sq ft; g. 2245 gpm;
   h. 224.5 gpm; i. 0.01 cfs; j. 0.11 cfs;
   k. 2.24 gpm; l. 0.41 cfs; m. 15.7 gpm

7. $C = \pi D = \frac{3.14 \mid 30\ \cancel{\text{in}} \mid 1\ \text{ft}}{\mid \quad \mid 12\ \cancel{\text{in}}} = 7.85\ \text{ft}$

8. 1130.4 inches

9. 5.84 feet

10. $P = S_1 + S_2 + S_3 + S_4$
    $= 35\ \text{ft} + 15\ \text{ft} + 35\ \text{ft} + 15\ \text{ft} = 100\ \text{feet}$

11. 18 feet

12. 189 feet

13. $A = 0.785 \times D^2$
    $= \frac{0.785 \mid 30\ \cancel{\text{in}} \mid 30\ \cancel{\text{in}} \mid 1\ \text{sq ft}}{\mid \quad \mid \quad \mid 144\ \cancel{\text{sq in}}} = 4.91\ \text{sq ft}$

14. 706.50 sq ft

15. 7.065 sq ft

16. A = L x W = 35 ft x 15 ft = 525 sq ft

17. 5.56 sq ft

18. 0.28 acres

19. $V = 0.785 \times D^2 \times H$
    $= \frac{0.785 \mid 20\ \cancel{\text{ft}} \mid 20\ \cancel{\text{ft}} \mid 30\ \cancel{\text{ft}} \mid 7.48\ \text{gallons}}{\mid \quad \mid \quad \mid \quad \mid 1\ \cancel{\text{cu ft}}}$

    $= 70461.60\ \text{gal}$

20. 48,491.44 gal

21. 8807.7 gal

22. $V = L \times W \times H$
    $= \frac{50\ \cancel{\text{ft}} \mid 12\ \cancel{\text{ft}} \mid 11\ \cancel{\text{ft}} \mid 7.48\ \text{gallons}}{\mid \quad \mid \quad \mid 1\ \cancel{\text{cu ft}}}$

    $= 49{,}368\ \text{gal}$

23. 119,680 gal

24. 80,157.92 gal

25. 120 ft

26. 30 ft

27. 5 ft

28. 120 ft

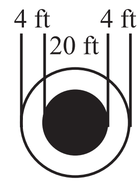
29. No – you need to buy one more gallon.

30. 10 feet

31. 41.67 sq yds; cost $1,458.33

32. $C = \pi d$

$= 3.14 \times 28 = 87.92$ feet

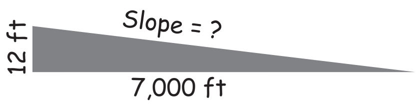


33. 139,513.96 gal

34. Yes. You need room for 4,697.44 gallons.

Slope

1.



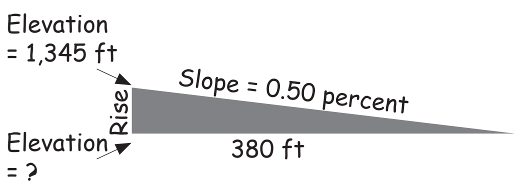
$$\text{Slope}(\%) = \frac{\text{Rise}}{\text{Run}} \times 100 = \frac{12\ \cancel{\text{ft}}}{7{,}000\ \cancel{\text{ft}}} \times 100$$

$= 0.17\%$

2. 1.6 feet

3. 0.11%

4.



$$\text{Slope}(\%) = \frac{\text{Rise}}{\text{Run}} \times 100$$

$$\text{Rise} = \frac{\text{Slope}(\%) \times \text{Run}}{100} = \frac{0.5\% \times 380\text{ ft}}{100}$$

$= 1.9$ ft

Manhole 3 elevation = 1345 ft – 1.9 ft

$= 1{,}343.1$ feet

5. 1,348.38 feet

Loading/Population Equivalent

1. Loading (lb/day) = concentration (mg/L) x flow (MGD) x 8.34 lb/gal

$$= \frac{550\text{ mg}}{\text{L}} \times \frac{0.65\text{ M gal}}{\text{day}} \times \frac{8.34\text{ lbs}}{\text{gal}}$$

$$= \frac{550\ \cancel{\text{parts}}}{\cancel{\text{M}}\ \cancel{\text{parts}}} \times \frac{0.65\ \cancel{\text{M}}\ \cancel{\text{gal}}}{\text{day}} \times \frac{8.34\text{ lbs}}{\cancel{\text{gal}}}$$

$= 2981.55$ lbs/day

For a discussion of units, see Example #2 on page 16.

2. 677.63 lbs/day

3. 13,000 people

4. 2,295 lbs/day

5. City: 4,323.10 lbs/day
   Industry: 785.00 lbs/day

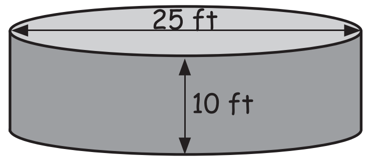
6. City: 5,899 lbs/day or 38.76%
   Industry A: 1,501.20 lbs/day or 9.86%
   Industry B: 7,818.75 lbs/day or 51.37%

7. 3.5 lbs

8. 8.5 mg/l

Detention Time

1. Detention Time = $\dfrac{\text{Volume}}{\text{Flow Rate}}$



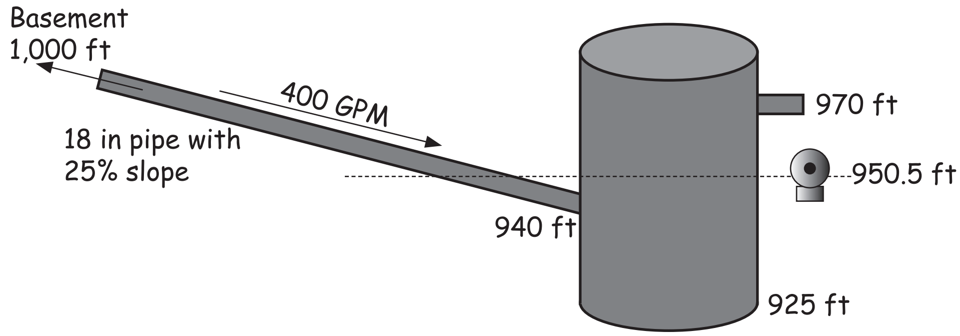
$$\text{Detention Time} = \overbrace{0.785 \times 25\,\cancel{\text{ft}} \times 25\,\cancel{\text{ft}} \times 10\,\cancel{\text{ft}}}^{\text{Volume}} \times \underbrace{\frac{1\text{ min}}{100\,\cancel{\text{gal}}}}_{\text{Flow rate}} \times \overbrace{\frac{7.48\,\cancel{\text{gal}}}{1\,\cancel{\text{cu. ft.}}}}^{\text{Conversion factor}}$$

$$= 367 \text{ min}$$

2. 3.60 hrs (3 hrs 36 minutes)
3. 11.27 hrs (11 hrs16 minutes 12 seconds)
4. 8.81 hrs (8 hrs 48 minutes 36 seconds)
5. 5.50 minutes (5 minutes 30 seconds)
6. 0.70 hours (42 minutes)
7. See next page.

Detention Time, continued

7.



Think it through:
If the basement elevation is less than the overflow bypass elevation (970 feet), water will back up in the basement first. If the basement elevation is more than 970 ft, water will flow out the bypass first.

Find the basement elevation:

$$\text{Slope (\%)} = \frac{\text{Rise}}{\text{Run}} \times 100$$

$$\text{Rise} = \frac{\text{Slope x Run}}{100} = \frac{2.5\% \mid 1000 \text{ ft}}{100 \mid}$$

Rise = 25 feet

Basement elevation = 940ft + 25 ft = 965 ft; therefore, water will back up in the basement first.

Think it through:
The water level is at 950.5 feet in the tank and in the pipe when the alarm goes off. The water will rise to a level of 965 feet in the tank, plus it will fill the pipe before it reaches the basement. So, it will rise (965 - 950.5) or 14.5 feet. Before you can determine detention time, you must first calculate the total volume of the tank and the pipe.

$$V_{TANK} = \frac{0.785 \mid 8 \cancel{\text{ft}} \mid 8 \cancel{\text{ft}} \mid 14.5 \cancel{\text{ft}} \mid 7.48 \text{ gal}}{\mid \quad \mid \quad \mid \quad \mid 1 \cancel{\text{cu ft}}}$$

$= 5{,}449$ gal (in tank)

Think it through:
To find the volume in the pipe, you must first use slope to determine how much of the pipe remains to be filled after the water reaches the 950.5 ft mark (run).

$$\text{Slope (\%)} = \frac{\text{Rise}}{\text{Run}} \times 100$$

$$\text{Run} = \frac{\text{Rise}}{\text{Slope (\%)}} \times 100 = \frac{14.5 \text{ ft} \mid 100}{2.5\% \mid}$$

= 580 feet

$$V_{PIPE} = \frac{0.785 \mid 1.5 \cancel{\text{ft}} \mid 1.5 \cancel{\text{ft}} \mid 580 \cancel{\text{ft}} \mid 7.48 \text{ gal}}{\mid \quad \mid \quad \mid \quad \mid 1 \cancel{\text{cu ft}}}$$

$= 7{,}663$ gal (in pipe)

$$V_{TOTAL} = V_{TANK} + V_{PIPE}$$

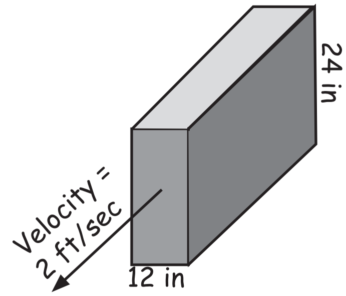
$= 5{,}449$ gal $+ 7{,}663$ gal
$= 13{,}112$ gal

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow rate}}$$

$$= \frac{13{,}112 \cancel{\text{gal}} \mid 1 \text{ min}}{\mid 400 \cancel{\text{gal}}} = 32.78 \text{ min}$$

Flow Rate

1. Flow Rate = Velocity x Area
   Area = Length x Width
   Flow Rate = Velocity x Length x Width



$$\text{Flow Rate} = \overbrace{\frac{2\ \cancel{\text{ft}}}{\cancel{\text{sec}}}}^{\text{Velocity}}\ \Bigg|\ \overbrace{24\ \cancel{\text{in}}}^{\text{Length}}\ \Bigg|\ \overbrace{12\ \cancel{\text{in}}}^{\text{Width}}\ \Bigg|\ \overbrace{\frac{1\ \cancel{\text{ft}}}{12\ \cancel{\text{in}}}\ \Bigg|\ \frac{1\ \cancel{\text{ft}}}{12\ \cancel{\text{in}}}\ \Bigg|\ \frac{60\ \cancel{\text{sec}}}{1\ \text{min}}\ \Bigg|\ \frac{7.48\ \text{gallons}}{1\ \cancel{\text{cu ft}}}}^{\text{Conversion factors}}$$

$$= 1795.2\ \text{gal/min}$$

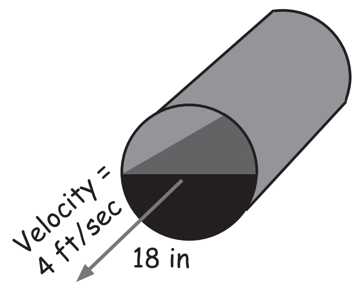
2. 234.87 gal/min

3. Flow Rate = Velocity x Area
   Area = 0.785 x D^2

   Think it through:
   Since the pipe is only half full,
   the area must be divided in half.

   So the complete equation for this situation is:

   $$\text{Flow Rate} = \text{Velocity} \times \frac{0.785 \times D^2}{2}$$

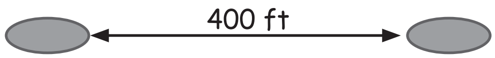


$$= \frac{4\ \cancel{\text{ft}}}{\cancel{\text{sec}}}\ \Bigg|\ \underbrace{\frac{0.785}{2}}_{\substack{\text{To divide}\\ \text{area in half}}}\ \Bigg|\ \overbrace{18\ \cancel{\text{in}}\ \Bigg|\ 18\ \cancel{\text{in}}}^{D^2}\ \Bigg|\ \overbrace{\frac{1\ \cancel{\text{ft}}}{12\ \cancel{\text{in}}}\ \Bigg|\ \frac{1\ \cancel{\text{ft}}}{12\ \cancel{\text{in}}}}^{\substack{\text{Conversion}\\ \text{factors –}\\ \text{inches to feet}}}\ \Bigg|\ \overbrace{\frac{60\ \cancel{\text{sec}}}{1\ \text{min}}\ \Bigg|\ \frac{7.48\ \text{gal}}{1\ \cancel{\text{cu ft}}}}^{\substack{\text{Conversion}\\ \text{factors}}} = 1585.39\ \text{gal/min}$$

4. 1761.54 gal/min

5. 92.70 gal/min

Velocity



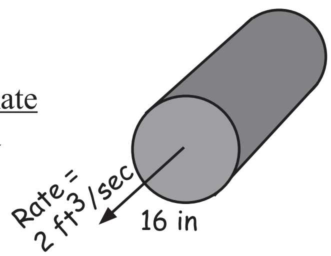
1. Velocity = $\frac{\text{Distance}}{\text{Time}}$

   $$\text{Velocity} = \frac{400\text{ feet}}{5\,\cancel{\text{min}}}\,\bigg|\,\frac{1\,\cancel{\text{min}}}{60\text{ sec}}$$

   $$= 1.33\text{ feet/sec}$$

2. 1.91 ft/sec

3. Velocity = $\frac{\text{Flow Rate}}{\text{Area}}$



   Area = $0.785 \times D^2$

   Velocity = $\frac{\text{Flow Rate}}{0.785 \times D^2}$

   $$= \frac{2\,\text{ft}^{\cancel{3}}}{\text{sec}}\,\bigg|\,\frac{}{0.785}\,\bigg|\,\frac{}{16\,\cancel{\text{in}}}\,\bigg|\,\frac{}{16\,\cancel{\text{in}}}\,\bigg|\,\frac{12\,\cancel{\text{in}}}{1\,\cancel{\text{ft}}}\,\bigg|\,\frac{12\,\cancel{\text{in}}}{1\,\cancel{\text{ft}}}$$

   $$= 1.43\text{ ft/sec}$$

4. 1.59 ft/sec
5. 2.93 ft/sec
6. 2.00 ft/sec
7. 6.36 ft/sec
8. 2.63 ft/sec
9. 10 inch
10. 12 inches
11. 613.28 gal/min
12. 4 times

> Note: $\text{ft}^3 = \text{ft} \times \text{ft} \times \text{ft}$
>
> So in this problem, $\frac{\text{ft}^3}{\text{ft} \times \text{ft}} = \frac{\text{ft}}{}\,\bigg|\,\frac{\cancel{\text{ft}}}{\cancel{\text{ft}}}\,\bigg|\,\frac{\cancel{\text{ft}}}{\cancel{\text{ft}}}$

Cost

1. $\text{Cost}_{\text{CREW}} = \frac{(\$14 + \$12 + \$10)}{\text{hr}}\,\bigg|\,\frac{4\text{ hrs}}{}$

   Remember: *Add first, then multiply!*

   $$= \frac{(\$36)}{\text{hr}}\,\bigg|\,\frac{4\text{ hrs}}{} = \$144$$

   $$\text{Cost}_{\text{JETTER}} = \frac{\$150}{\text{hr}}\,\bigg|\,\frac{4\text{ hrs}}{} = \$600$$

   $$\text{Cost}_{\text{TOTAL}} = \$144 + \$600 = \$744$$

   $$\text{Cost/sq ft} = \frac{\$744}{4{,}000\text{ ft}}$$

   $$= \$0.19\text{/foot}$$

2. $467,050
3. 6 persons; cost = $1344
4. $224.40
5. Feed rate = dosage x flow x 8.34 lb/gal

   $$= \frac{20\,\cancel{\text{parts}}}{\cancel{\text{M}}\,\cancel{\text{parts}}}\,\bigg|\,\frac{0.002\,\cancel{\text{M}}\,\cancel{\text{gal}}}{1\,\cancel{\text{min}}}\,\bigg|\,\frac{8.34\,\cancel{\text{lb}}}{\cancel{\text{gal}}}\,\bigg|\,\frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{hr}}}$$

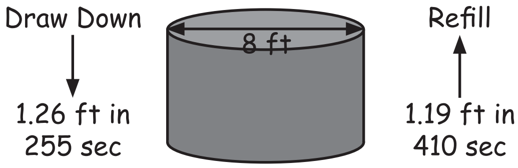
   (continued) $$\frac{24\,\cancel{\text{hrs}}}{1\,\cancel{\text{day}}}\,\bigg|\,\frac{365\,\cancel{\text{days}}}{12\text{ mon}}\,\bigg|\,\frac{\$0.95}{\cancel{\text{lb}}}$$

   $$= \$13{,}881.10\text{/month}$$

6. $220.52/month average

Pump Calibration/Lift Station

1.



$$\text{Pumping Rate} = \frac{\text{Drawdown Volume}}{\text{Drawdown Time}} + \frac{\text{Refill Volume}}{\text{Refill Time}}$$

where Volume = 0.785 x D² x H

$$\frac{\text{Drawdown Volume}}{\text{Drawdown Time}} = \frac{0.785 \mid 8\ \cancel{ft} \mid 8\ \cancel{ft} \mid 1.26\ \cancel{ft}}{255\ \cancel{sec}} \left| \frac{7.48\text{ gal}}{1\ \cancel{cu\ ft}} \right| \frac{60\ \cancel{sec}}{1\text{ min}} = 111.41\text{ gal/min}$$

$$\frac{\text{Refill Volume}}{\text{Refill Time}} = \frac{0.785 \mid 8\ \cancel{ft} \mid 8\ \cancel{ft} \mid 1.19\ \cancel{ft}}{410\ \cancel{sec}} \left| \frac{7.48\text{ gal}}{1\ \cancel{cu\ ft}} \right| \frac{60\ \cancel{sec}}{1\text{ min}} = 65.44\text{ gal/min}$$

Pumping Rate = 111.41 gal/min + 65.44 gal/min = 176.85 or 177 gal/min

2. 263.10 gpm

3. 460 gpm

4. 144.2 gpm

Common Formulas & Abbreviations

Perimeter

- Rectangle or square: $P = S_1 + S_2 + S_3 + S_4$
- Circle: $C = \pi \times D$ (*where* $\pi = 3.14$)

Area

- Rectangle or square: $A = L \times W$
- Circle: $A = 0.785 \times D^2$
- Triangle: $A = \frac{B \times H}{2}$

Volume

- Rectangle: Volume = Area x Height
  Volume = L x W x H
- Cylinder: Volume = Area x Height
  Volume = $0.785 \times D^2 \times H$
- Cone: Volume = $\frac{\text{Area} \times \text{Height}}{3}$
  Volume = $\frac{0.785 \times D^2 \times H}{3}$

Velocity

- Velocity = $\frac{\text{distance traveled}}{\text{time}}$
- Velocity = $\frac{\text{flow rate}}{\text{area}}$

Slope

- Slope = $\frac{\text{Rise}}{\text{Run}}$
- Slope (%) = $\frac{\text{Rise}}{\text{Run}} \times 100$

Flow/Pumping Rate

- Flow rate = velocity x area
- Pumping rate = $\frac{\text{volume pumped}}{\text{time pumped}}$
- Calibrated pumping rate (gals per minute)

$$= \frac{\text{drawdown volume (gallons)}}{\text{time to drawdown wet well (minutes)}} + \frac{\text{refill volume (gallons)}}{\text{time to refill wet well (minutes)}}$$

Chlorination

- Feed rate (lb/day) = dosage (mg/L) x flow (million gal/day) x 8.34 lbs/gal
- Detention time = $\frac{\text{volume of tank}}{\text{flow rate to or from tank}}$

Loading

- Loading (lb/day) = concentration (mg/L) x flow (million gal/day) x 8.34 lbs/gal
- A = Area

Common Abbreviations

- C = circumference
- Cu in = cubic inches or inches^3
- Cu ft = cubic feet or feet^3
- cfs = cubic feet per second
- D = diameter
- Ft = foot or feet
- Gal = gallons
- GPM = gallons per minute
- H = height
- In = inch
- L = length
- Lb = pound
- Mgal or MG = million gallons
- mg/L = milligrams per liter
- Min = minute
- P = perimeter
- Pi or π = 3.14
- ppm = parts per million
- R = radius
- Rise = vertical distance or height
- Run = horizontal distance or length
- S = side of a rectangle
- Sq in = square inches or inches^2
- Sq ft = square feet or feet^2
- V or Vol = volume
- Vel = velocity
- W = width
- Yr = year

Conversion Factors

Length

1 inch	= 2.54 centimeters	= 25.4 millimeters
1 foot	= 12 inches	= 0.305 meters
1 yard	= 3 feet	= 0.914 meters
1 mile	= 5,280 feet	= 1,760 yards
1 meter	= 39.37 inches	= 3,281 feet
1 kilometer	= 0.621 miles	= 1,000 meters

Volume

1 cubic foot	= 1,728 cubic inches
1 cubic foot	= 7.48 gallons
1 cubic yard	= 27 cubic feet
1 acre-inch	= 27,152 gallons
1 acre-foot	= 43,560 cubic feet
1 acre-foot	= 326,000 gallons
1 gallon	= 3.785 liters
1 gallon	= 231 cubic inches
1 gallon	= 4 quarts
1 cubic meter	= 35.3 cubic feet
1 cubic meter	= 1.3 cubic yards
1 liter	= 0.2642 gallons
1 liter	= 1,000 milliliters

Area

1 square foot	= 144 square inches
1 square yard	= 9 square feet
1 square mile	= 640 acres or 1 section
1 square meter	= 10.764 square feet
1 square meter	= 10,000 square centimeters
1 acre	= 43,560 square feet
1 hectare	= 2.471 acres

Flow

1 cubic foot/second	= 448.8 gallons/minute
1 gallon/second	= 0.133 cubic feet/second
1 gallon/second	= 8.028 cubic feet/minute
1 gallon/minute	= 0.00223 cubic feet/second
1 gallon/minute	= 1440 gallons/day

Weight

1 gallon	= 8.34 pounds of water
1 cubic foot	= 62.4 pounds of water
1 foot of water	= 0.433 pounds per square inch
1 pound	= 0.454 kilograms
1 kilogram	= 1,000 grams
1 pound per square inch	= 2.31 feet of water
1 liter	= 1,000 grams
1 mg/kg or 1 ppm or 1 mg/l	= 0.0022 pounds/ton or 0.0001%
1 mg/l	= 1000 µg/l

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