Applied Math for Water Treatment

For All Grades

Course # 1101

Fleming Training Center

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Section 1

Basic Math Review

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

  - X must be by itself on one side of equal sign
    - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

    - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$3x = 14$$

- Since X is multiplied by 3, you can get rid of the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{3x}{3} = \frac{14}{3}$$

$$x = \frac{14}{3}$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

$$0.5=\frac{(165)(3)(8.34)}{x}$$

Simplify

$$0.5 = \frac{4128.3}{x}$$

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(0.5)}{0.5} = \frac{4128.3}{0.5}$$

$$x = \frac{4128.3}{0.5}$$

$$x = 8256.6$$

Solving for X^2

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{(0.785)(x^2)}{0.785} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

$0.46. \rightarrow 46.0\%$

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

$.79.5\% \rightarrow 0.795$

- Remember:

  You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"

- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 = x\% \times 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾

2. ⅝

3. ¼

4. ½

Convert the following percents to decimals:

5. 35%

6. 99%

7. 0.5%

8. 30.6%

Convert the following decimals to percents:

9. 0.65

10. 0.125

11. 1.0

12. 0.05

Calculate the following:

13. 15% of 125

14. 22% of 450

15. 473 is what % of 2365?

16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1.	1.8	8.	360	15.	2816.67
2.	5.73	9.	1649.4	16.	4903.48
3.	5.30	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117.31
5.	8256.6	12.	4.99	19.	508,000
6.	8.06	13.	7993.89	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.94
22.	12	24.	0.83		

Percent Practice Problems

1.	0.75	7.	0.005	13.	18.75
2.	0.625	8.	0.306	14.	99
3.	0.25	9.	65%	15.	20%
4.	0.5	10.	12.5%	16.	20%
5.	0.35	11.	100%		
6.	0.99	12.	5%		

Section 2

Dimensional Analysis

DIMENSIONAL ANALYSIS

MATHEMATICS MANUAL FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS
BY FRANK R. SPELLMAN

DIMENSIONAL ANALYSIS

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a faction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

DIMENSIONAL ANALYSIS

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{Kg}{\cancel{day}} \times \frac{\cancel{day}}{min} = \frac{Kg}{min}$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

EXAMPLE 1

- Convert 1800 ft^3 into gallons.
- Use the factor $7.48\ gal/ft^3$
- Would we divide or multiply? Use only the dimensions first to determine the correct setup.
  - Divide

$$\frac{ft^3}{gal/ft^3} = \frac{ft^3}{\frac{gal}{ft^3}}$$

$$ft^3 \times \frac{ft^3}{gal} = \frac{ft^6}{gal}$$ ✗

  - Multiply

$$\cancel{ft^3} \times \frac{gal}{\cancel{ft^3}}$$

$$gal$$ ✓

EXAMPLE 1 CONTINUED

- Plug in numbers
  - Multiply factor to achieve answer

$$1800\ ft^3 \times 7.48\ {}^{gal}/_{ft^3}$$

$$13{,}464\ gal$$

EXAMPLE 2

- Determine the square feet given $70\ ft^3/sec$ and $4.5\ ft/sec$
- Use units to determine set up
  - Multiply

$$\frac{ft^3}{sec} \times \frac{ft}{sec} = \frac{ft^4}{sec^2}$$ ✗

  - Divide

$$\frac{\frac{ft^3}{sec}}{\frac{ft}{sec}} = \frac{ft^3}{sec} \times \frac{sec}{ft}$$

$$\frac{(ft)(ft)(ft)}{sec} \times \frac{sec}{ft}$$

$$ft^2$$ ✓

EXAMPLE 2 CONTINUED

- Plug in numbers
  - Divide to achieve answer

$$\frac{70\,{}^{ft^3}/_{sec}}{4.5\,{}^{ft}/_{sec}}$$

$$15.56 ft^2$$

THE METRIC SYSTEM

- The metric system is founded on base units.
- The base unit of mass is the **gram**.
- The base unit of length is the **meter**.
- The base unit of volume is the **Liter**.
- To go from small to large quantities the base units are described by prefixes which represent a power of ten.

THE METRIC SYSTEM

Prefix	Symbol	It means	What it means in words
mega	M	1 000 000	One million
kilo	k	1 000	One thousand
hecto	h	100	One hundred
centi	c	0.01	One hundredth
milli	m	0.001	One thousandth
micro	µ	0.000 001	One millionth
nano	n	0.000 000 001	One billionth

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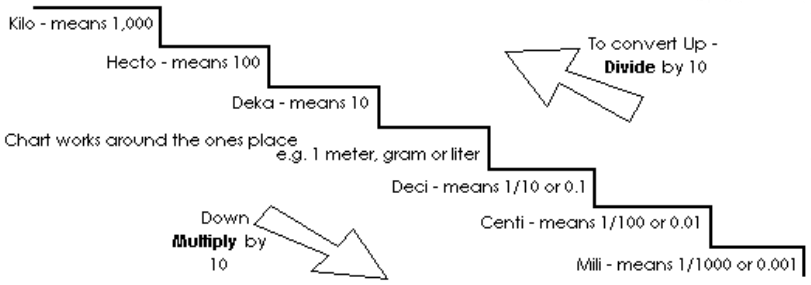
THE METRIC SYSTEM: CONVERSIONS



When converting any type of measures
- To convert from a **larger to smaller** metric unit you always **multiply**
- To convert from a **smaller to larger** unit you always **divide**
- The Latin prefixes used in the metric system literally mean the number they represent.

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METRIC SYSTEM PROBLEMS

Convert 0.5 L into mL.

Large to small (multiply)

Kilo - means 1,000
Hecto - means 100
Deka - means 10 — 0.5 L
Chart works around the ones place e.g. 1 meter, gram or liter
Deci - means 1/10 or 0.1 — X 10
Centi - means 1/100 or 0.01 — X 10
Mili - means 1/1000 or 0.001 — X 10 = **500 mL**

To convert Up - **Divide** by 10

Down **Multiply** by 10

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METRIC SYSTEM PROBLEMS

Convert 8,540 grams into Kg.

Small to large (divide)

8.54 Kg = Kilo - means 1,000 ÷ 10
Hecto - means 100 ÷ 10
Deka - means 10 ÷ 10 — 8,540 g
Chart works around the ones place e.g. 1 meter, gram or liter
Deci - means 1/10 or 0.1
Centi - means 1/100 or 0.01
Mili - means 1/1000 or 0.001

To convert Up - **Divide** by 10

Down **Multiply** by 10

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Basic Math
Dimensional Analysis

Dimensional analysis is not just a way to work math problems. It is an easy way to verify that your formula is set up properly before the calculation is performed.

Rules to follow:

- ✓ Units written in abbreviated or horizontal form should be rewritten in a vertical format. For example:

$$\text{cfs} \Rightarrow \frac{\text{ft}^3}{\text{sec}} \qquad \text{gal/cu ft} \Rightarrow \frac{\text{gal}}{\text{ft}^3}$$

- ✓ Any unit that is a common factor to both the numerator and denominator of a fraction may be divided out. For example:

$$\left(\frac{20\ \text{ft}^3}{\text{sec}}\right)\left(\frac{60\ \text{sec}}{\text{min}}\right) = \frac{(20)(60)\text{ft}^3}{\text{min}}$$

- ✓ An exponent of a unit indicates how many times that unit is to be multiplied together. For example:

$$\text{ft}^3 = (\text{ft})(\text{ft})(\text{ft})$$

  - o Sometimes it is necessary to write terms with exponents in expanded form, while other times it is advantageous to keep the unit in exponent form. This choice depends on which other units are part of the calculation and how these units might divide out.

Remember: Fractions must be multiplied or divided to do any canceling. Fractions that are added and subtracted can't be cancelled.

Basics:
Use dimensional analysis to determine the **units** of the answers:

1. (0.785)(ft)(ft)(ft)

2. (120 ft^3/min)(1440 min/day)

3. $\frac{(8ft)(10ft)(xft)}{sec}$

Verify the mathematical setup for each problem. If the setup is incorrect, correct the setup:

4. (1.6 fpm)(60 sec/min) = fps

5. (70 in)(1 ft/12 in)(0.3048 m/ft) = m

1. ft^3 2. ft^3/day 3. ft^3/sec 4. Incorrect 5. Correct

Complex Fractions:

- ✓ When the units of a given problem are written as a complex fraction:
  - o Invert the denominator and multiply. For example:

$$\frac{2{,}808{,}000 \text{ gpd}}{1440 \text{ min/day}} = \frac{\frac{\text{gal}}{\text{day}}}{\frac{\text{min}}{\text{day}}} = \left(\frac{\text{gal}}{\text{day}}\right)\left(\frac{\text{day}}{\text{min}}\right)$$

  - o Shortcut: If the numerator is the same in both the top and bottom fractions, they will cancel when the bottom fraction inverts and multiplies. The same goes if the denominator is the same in both the top and the bottom fractions.

Use dimensional analysis to determine the **units**:

1. $\frac{(4140 \text{ gpm})}{(60 \text{ sec/min})}$

2. $\frac{(880 \text{ cu ft})(1440 \text{ min/day})}{6.2 \text{ cu ft/day}}$

3. $\frac{587 \text{ gal}}{246 \text{ gph}}$

Verify the mathematical setup for each problem. If the setup is incorrect, correct the setup:

4. $\frac{(40 \text{ in})(1.5 \text{ ft})(2.3 \text{ fpm})}{12 \text{ in/ft}} = \text{cfm}$

5. $\frac{\left(\frac{2{,}400{,}000 \text{ gpd}}{7.48 \text{ gal/ft}^3}\right)}{635{,}400 \text{ ft}^2} = \text{ft/day}$

1. gal/sec 2. min 3. hour 4. ft^3/min 5. ft/day

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 21 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a meter?

8. How many meters in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

11. Express a flow of 5 cfs in terms of gpm.

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

20. Convert a flow of 4,270,000 gpd to cfm.

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

Volume and Flow Conversions

1. 2,431 gal
2. 5,533 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.05 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gal/min
14. 2,620,800 gal/day
15. 6.02 gal/sec
16. 5,968.4 gpm
17. 16,911.67 lb/min
18. 4,416,912 gal/day
19. 19,959,955.2 lb/day
20. 2.43 MGD
21. 5,428,684.8 gal/day
22. 585.82 ft^3/min

Basic Conversions Extra Problems

1. 60 sec/min
2. 60 min/hr
3. 24 hr/day
4. 1440 min/day
5. 12 in/ft
6. 5280 ft/mi
7. 3 ft/yd
8. 1760 yd/mi
9. 8.34 lbs/gal
10. 62.4 lbs/ft^3
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.03 gpm
18. 83.56 ft^3/min
19. 6684.49 ft^3/hr
20. 396.43 ft^3/min
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

Metric System and Temperature Conversion Practice Problems

Convert the following.

1. 23 g into _____ mg
2. 12,456 m into _____ km
3. 4235 mL into _____ L
4. 200 mg into _____ kg
5. 1000 watts into_____ kwatts
6. 0.05 g into _____ *u*g
7. 20 deciliters into _____ mL
8. 140 kg into _____ g
9. 9.5 cm into _____mm
10. 100 milliseconds into_____seconds

Answers

1. 23,000 mg
2. 12.456 km
3. 4.235 L
4. 0.0002 kg
5. 1 kwatt
6. 50,000 *u*g
7. 2000 mL
8. 140,000 g
9. 95 mm
10. 0.1 seconds

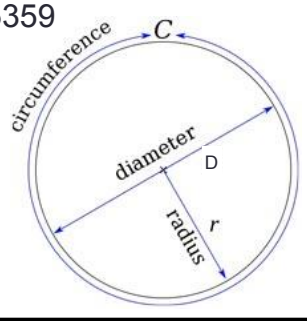
Section 3

Circumference, Area, and Volume

CIRCUMFERENCE AND AREA

Parts of a Circle

- Diameter is distance across the center of circle
- Radius is distance from circle's center to the edge
- Circumference is the distance around a circle or a circular object
- Pi (π) is a mathematical constant
  - $\pi = 3.14159265359$



Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (\pi)(Diameter) \quad \text{OR}$$
$$Circumference = 2(\pi)(radius)$$

- Perimeter is obtained by adding the lengths of the four sides of a square or rectangle

$$Perimeter = 2(length) + 2(width)$$

Example 1

- Find the circumference of a 6 inch diameter pipe.

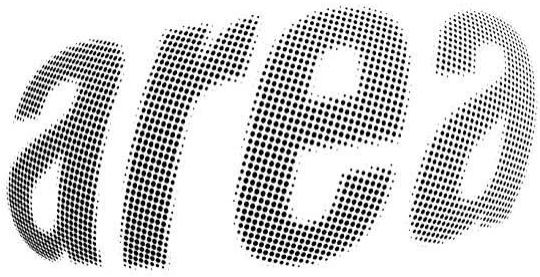
$$Circumference = (\pi)(diameter)$$
$$C = (\pi)(6\ inches)$$
$$C = 18.85\ inches$$

- Find the perimeter of a rectangular tank that is 15 ft by 22 ft.

$$Perimeter = 2(length) + 2(width)$$
$$P = 2(15\ ft) + 2(22\ ft)$$
$$P = 30\ ft + 44\ ft$$
$$P = 74\ ft$$

Area

- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, acres, etc.

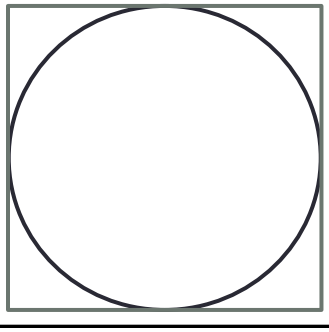


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

$$A = (0.785)(D)^2$$



A circle takes up 78.5% of a circle.

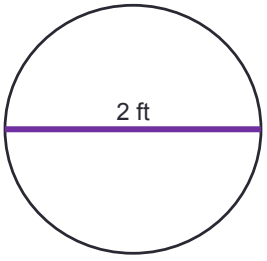
Example 2

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

$$A = (0.785)(2ft)(2ft)$$

$$A = 3.14\ ft^2$$

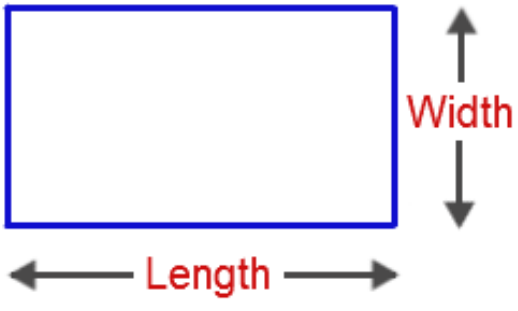


Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



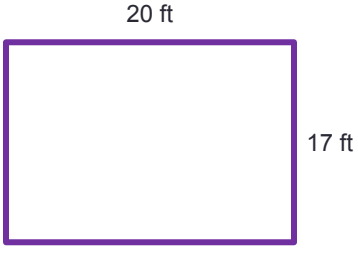
Example 2

- Find the area in ft² of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

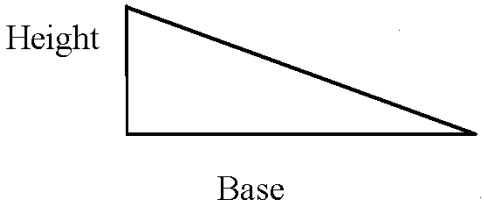


Area

- Area of Right Triangle

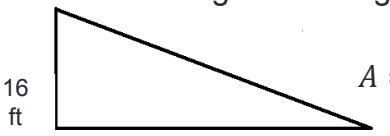
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft² of a right triangle where the base is 23 feet long with a height of 16 feet.



$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$

$$A = \frac{368ft^2}{2}$$

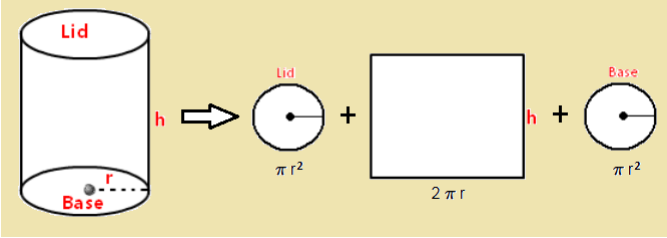
$$A = 184ft^2$$

Area

- Area of Cylinder (total exterior surface area)

$$Area = [surface\ area\ of\ end\ \#1] + [surface\ area\ of\ end\ \#2] + [(\pi)(Diameter)(height)]$$

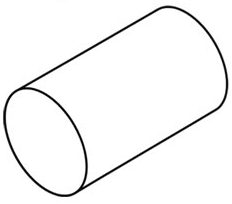
$$A = A_1 + A_2 + [(\pi)(D)(h)]$$



Example 4

- Find the total surface area in ft² of a pipeline that is 2 ft in diameter and 20 feet long.

$$A = A_1 + A_2 + [(\pi)(D)(h)]$$



$$A_1 = (0.785)(D)^2$$

$$A_1 = (0.785)(2ft)(2ft)$$

$$A_1 = 3.1416ft^2$$

$A_1 = A_2$

$$A = 3.1416ft^2 + 3.1416ft^2 + [(\pi)(2ft)(20ft)]$$

$$A = 3.1416ft^2 + 3.1416ft^2 + 125.6637ft^2$$

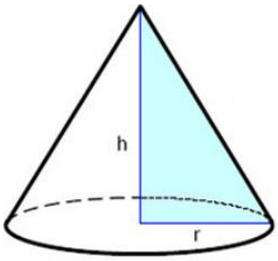
$$A = 131.95\ ft^2$$

Area

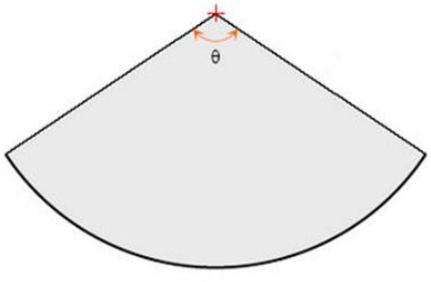
- Area of Cone (lateral area)

$$Area = (\pi)(radius)\sqrt{radius^2 + height^2}$$

$$A = (\pi)(r)\sqrt{r^2 + h^2}$$



Right Circular Cone



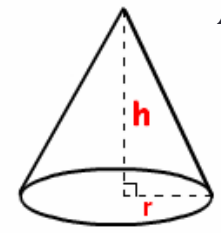
Unrolled Lateral Area

Example 5

- Find the lateral area (in ft²) of a cone that is 3 feet tall and has a radius of 1.5 feet.

$$A = (\pi)(r)\sqrt{r^2 + h^2}$$

$$A = (\pi)(1.5ft)\sqrt{(1.5ft)(1.5ft) + (3ft)(3ft)}$$



$$A = (\pi)(1.5ft)\sqrt{2.25ft^2 + 9ft^2}$$

$$A = (\pi)(1.5ft)\sqrt{11.25ft^2}$$

$$A = (\pi)(1.5ft)(3.3541ft)$$

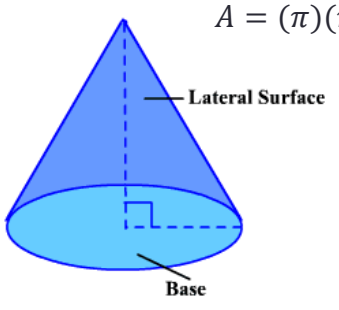
$$A = 15.81ft^2$$

Area

- Area of Cone (total surface area)

$$Area = (\pi)(radius)(radius + \sqrt{radius^2 + height^2}\ )$$

$$A = (\pi)(r)(r + \sqrt{r^2 + h^2}\ )$$



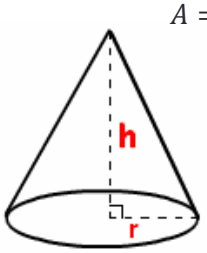
Example 6

- Find the total surface area in ft^2 of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$A = (\pi)(r)(r + \sqrt{r^2 + h^2}\ )$$

$$A = (\pi)(3ft)(3ft + \sqrt{(3ft)(3ft) + (4.5ft)(4.5ft)}\ )$$

$$A = (\pi)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2}\ )$$



$$A = (\pi)(3ft)(3ft + \sqrt{29.25ft^2}\ )$$

$$A = (\pi)(3ft)(3ft + 5.4083ft)$$

$$A = (\pi)(3ft)(8.4083ft)$$

$$A = 79.25ft^2$$

$$radius = \frac{1}{2}D$$

$$r = \left(\frac{1}{2}\right)6ft$$

$$r = 3\ ft$$

Volume

Volume

- Volume is the capacity of a unit or how much it will hold
- Measured in
  - cubic units (ft^3, m^3, yd^3) or
  - liquid volume units (gallons, liters, million gallons)
- The answer will come out in cubic units
  - You must then convert it to liquid volume units

Volume of a Cylinder

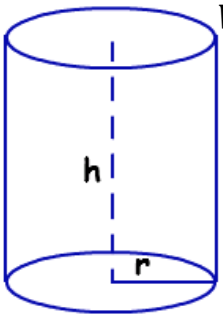
$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$

OR

$$Volume = (\pi)(radius^2)(height)$$

$$Vol = (\pi)(r^2)(h)$$



Example 1

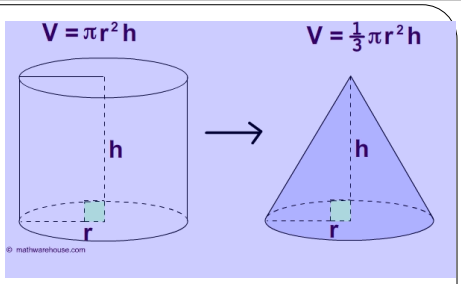
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone



$$Volume = (1/3)(0.785)(Diameter^2)(height)$$

$$Vol = (1/3)(0.785)(D^2)(h)$$

OR

$$Volume = (1/3)[(\pi)(radius^2)(height)]$$

$$Vol = (1/3)[(\pi)(r^2)(h)]$$

Example 2

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (^1/_3)(0.785)(D^2)(h)$$

$$Vol = (^1/_3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

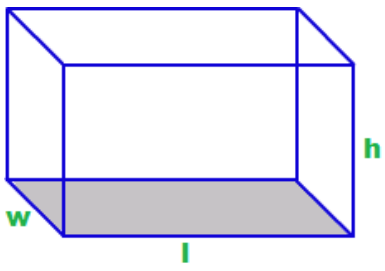
$$Vol, gal = (251.1749\ \cancel{ft^3})(7.48\ \frac{gal}{\cancel{ft^3}})$$

$$Vol, gal = 1878.78\ gallons$$

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 3

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

$$Vol = (l)(w)(h)$$

$$Vol = (30m)(15m)(25m)$$

$$Vol = 11250m^3$$

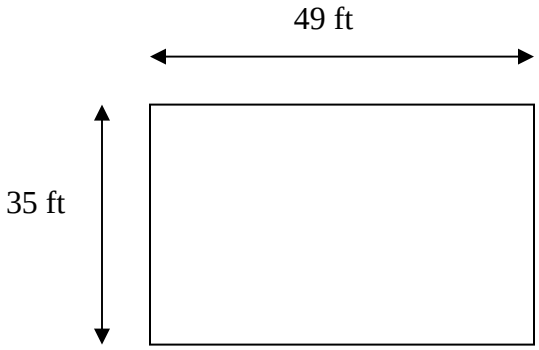
Math Problem Strategies

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known		**Unknown**
Length = 35 ft Width = 49 ft	$A = (l)(w)$ $A = (35\ ft)(49\ ft)$ $A = 1715\ ft^2$	Area = ?

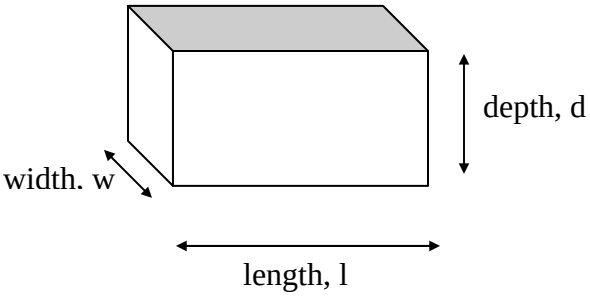


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)	..	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	..	micro (μ)
1,000,000		1,000	100	10	1	$^1/_{10}$	$^1/_{100}$	$^1/_{1,000}$		$^1/_{1,000,000}$

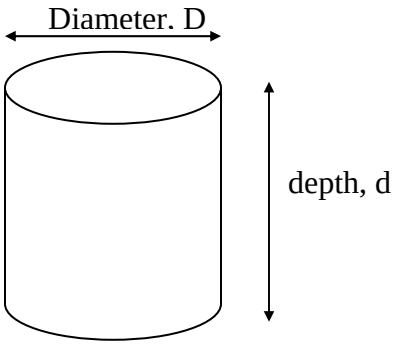
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



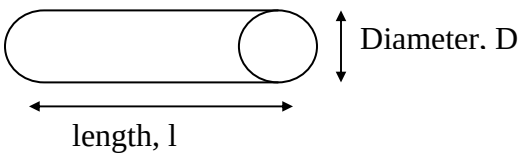
Volume = (l)(w)(d)

Cylindrical Tank



Volume = $(0.785)\ (\ D\ )^2\ (\ d\ )$

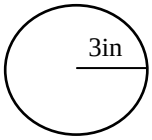
Portion of a Pipeline

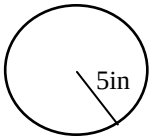


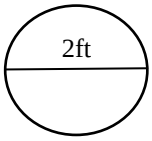
Volume = $(0.785)\ (\ D\ )^2\ (\ l\ )$

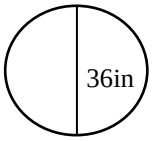
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

Circumference

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) of the notched weir of a circular clarifier that has a diameter of 32 feet?

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. Calculate the lateral surface area (in ft^2) of a cone with a radius of 3 feet and a height of 9 feet.

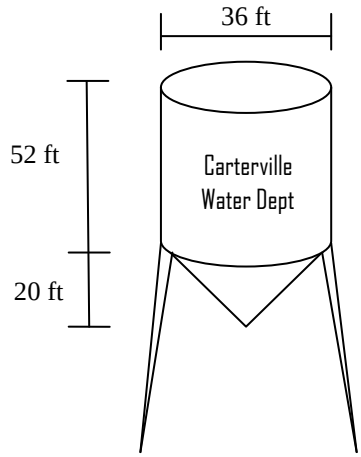
3. Calculate the surface area (in ft^2) of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

5. A chemical hopper is cone shaped and covered. It has a diameter of 4 feet and a depth of 7 feet. Calculate the total surface area of the hopper (in ft^2).

6. Calculate the area (in ft^2) for an 18" main that has just been laid.

7. A circular water tower that is tapered at the bottom has a diameter of 36 feet and a height of 52 feet from the top to the beginning of the taper. The cone created by the taper has a height of 20 feet. Calculate the total exterior surface area of the water tower.



Volume

1. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

2. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

3. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

5. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

6. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

7. Refer back to the water tower in Carterville in problem 7 of the last section. Calculate the total volume (in gallons) when the tower is full.

DON'T THINK TOO HARD ON THIS ONE…

8. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference

1. 18.85 in
2. 31.42 in
3. 6.28 ft
4. 113.10 in
5. 75.40 ft
6. 150.80 in
7. 100.53 ft

Area

1. 540 ft^2
2. 89.41 ft^2
3. 2250 ft^2
4. 3.14 ft^2
5. 58.31 ft^2
6. 1.77 ft^2
7. 8420.51 ft^2

Volume

1. 1000 ft^3
2. 9050.8 gal
3. 359.04 gal
4. 678.58 ft^3
5. 48442.35 gal
6. 150000 gal
7. 446671.14 gal
8. No, it quadruples it (4X)

Section 4

Flow and Velocity

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\ ft}{3\ min}$$

$$Vel = 41.67\ {}^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - ${}^{ft^3}/_{sec}$ ${}^{ft^3}/_{min}$ ${}^{gal}/_{day}$ ${}^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ {}^{ft}/_{sec}\right)$$

$$Q = 9\ {}^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft^3/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$$Q = AV$$

$6in \div 12\frac{in}{ft} = 0.5ft$

$Area = (0.785)(D^2)$

$$Q = (0.785)(D)^2(vel)$$

$$Q = (0.785)(0.5ft)(0.5ft)\left(4.5\ {}^{ft}/_{sec}\right)$$

$$Q = 3.53\ {}^{ft^3}/_{sec}$$

Velocity

$$Velocity = \frac{Flow\ rate, {ft^3}/{sec}}{Area, ft^2}$$

- Use this formula when given the flow and area or dimensions

Example 4

- The flow through a 1.5 foot pipeline is 9.7 gallons per minute. What is the velocity of the water in ft/minute?

$$Velocity = \frac{Flow\ rate, {ft^3}/{sec}}{Area, ft^2}$$

$$\frac{9.7 \frac{gal}{min}}{7.48 \frac{gal}{ft^3}}$$

$$= 1.30\ {ft^3}/{min}$$

$$Area = (0.785)(D^2)$$

$$Vel = \frac{1.30 {ft^3}/{sec}}{(0.785)(1.5ft)(1.5ft)}$$

$$Vel = \frac{1.30 {ft^3}/{sec}}{1.7663\ ft^2}$$

$$Vel = 0.74\ {ft}/{sec}$$

Velocity and Flow

1. A bobber is placed in a channel and travels 450 feet in 2 ½ minutes. What is the velocity of the water flowing in the channel in ft/min?

2. A channel 30 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 2.75 ft/sec, what is the flow in the channel in ft^3/sec? And gal/min?

3. The flow through a 24 inch pipe is moving at a velocity of 5.4 ft/sec. What is the flow rate in gal/min?

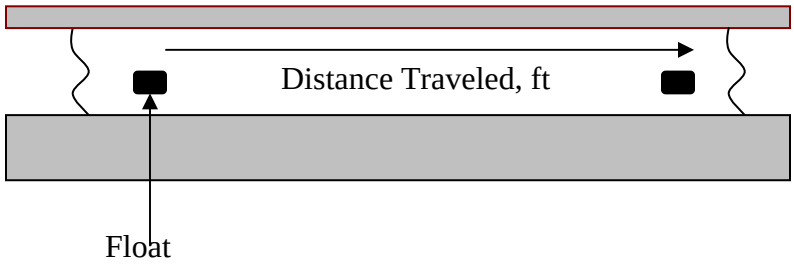
Applied Math for Water Treatment
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

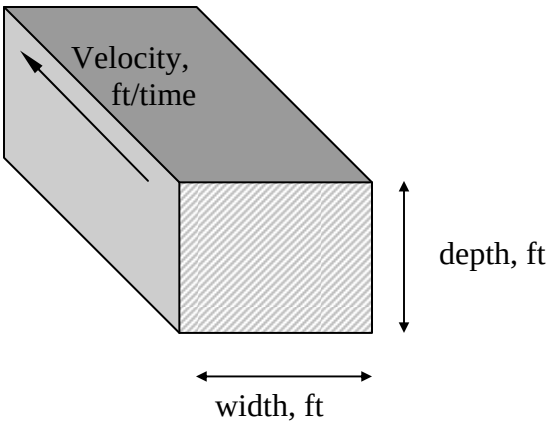
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

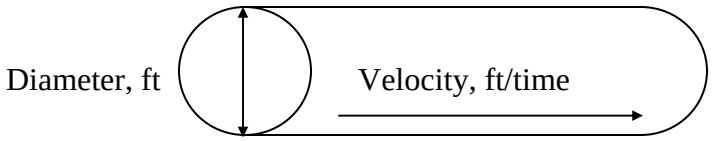
Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

4.) 16.8 ft^3/sec 5.) 900 ft^3/min; 9.7 MGD 6.) 1.8 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\,(D)^2\,(vel) \qquad (ft)(ft)\ (ft/time)$$

Flow through a full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

APPLIED MATH FOR WATER FLOW RATE

$Q = AV$

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. If the main is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flowing at a velocity of 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe?

VELOCITY (OPEN CHANNEL)

10. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the flow velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

11. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

12. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

AQUIFER FLOW

13. Geologic studies show that the water in an aquifer moves 25 feet in 60 days. What is the average velocity of the water in ft/day?

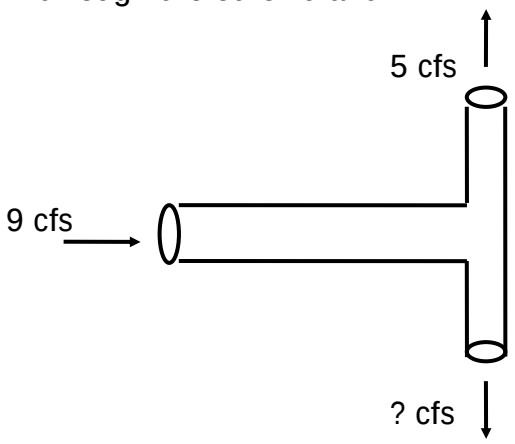
14. If the water in a water table aquifer moves 2 feet per day, how far will the water travel in 13 days?

15. If the water in a water table aquifer moves 2.25 feet per day, how long will it take the water to move 61 feet?

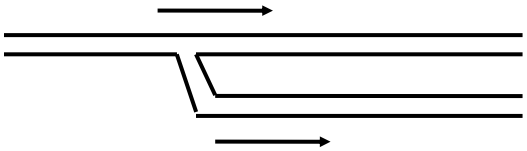
FLOW

16. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24" main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that one month?

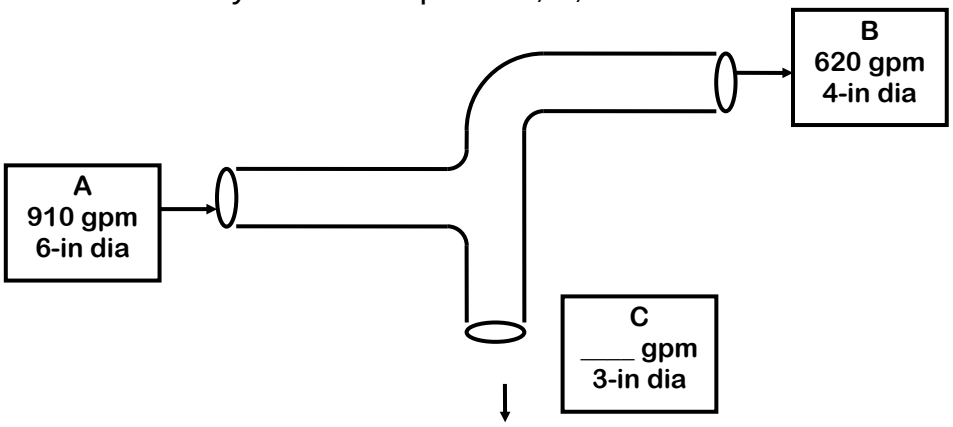
17. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



18. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?



19. Determine the velocity in ft/sec at points A, B, & C.



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 95.37 ft/min
10. 120 ft/min
11. 1.5 ft/sec
12. 1,533.3 ft^3/min
13. 0.42 ft/day
14. 26 ft
15. 27.11 days
16. 136.83 MG
17. 4 ft^3/sec
18. 258 gpm
19. A. 10.33 ft/sec
    B. 15.84 ft/sec
    C. 13.17 ft/sec

Section 5

Disinfection

Disinfection

Chlorination

- The pounds formula will be one of the most important formulas to learn this week.

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\frac{lb}{gal})}{\%\ purity}$$

If they ask for gpd, convert from lb/day

- If no purity provided, assume it is 100%
  - Can also use Mass or Mass Flux formula

Example 1

- A water plant that treats 3,200,000 gallons per day. If the required dosage is 5.4 mg/L of 12.5 % sodium hypochlorite, what is the feed rate in lb/day?

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\frac{lb}{gal})}{\%\ purity}$$

$$feed\ rate, \frac{lb}{day} = \frac{(5.4\ mg/L)(3.2\ MGD)(8.34\frac{lb}{gal})}{0.125}$$

$$feed\ rate, \frac{lb}{day} = 1152.92\ lb/day$$

Chlorination

- When asked to find dose, solve pounds formula for the unknown (dose).

$$dose, \frac{mg}{L} = \frac{(feed\ rate, \frac{lb}{day})(\%\ purity)}{(flow, MGD)(8.34\frac{lb}{gal})}$$

Example 2

- Determine the dosage for a plant, in mg/L, that feeds 115 lbs/day of chlorine gas to treat a flow of 2,700,000 MGD.

$$dose, \frac{mg}{L} = \frac{(feed\ rate, \frac{lb}{day})(\%\ purity)}{(flow, MGD)(8.34 \frac{lb}{gal})}$$

$$dose, \frac{mg}{L} = \frac{(115 \frac{lb}{day})(1)}{(2.7\ MGD)(8.34 \frac{lb}{day})}$$

$$dose, \frac{mg}{L} = 5.11\ \frac{mg}{L}$$

CT Calculation

Kill = C x T

- Concentration and contact time are two of the most important parameters in chlorination
- They are inversely proportional
  - As one decreases, the other must increase
- CT is simply the concentration of chlorine in your water times the time of contact that the chlorine has with your water
  - Measured in $\frac{mg \cdot min}{L}$

$$CT = (disinfectant\ residual, \frac{mg}{L})(time, min)$$

Example 3

- Treated water is dosed with 5 mg/L of chlorine for 30 minutes. What is the CT?

$$CT = (disinfectant\ residual, \frac{mg}{L})(time, min)$$

$$CT = (5\,\frac{mg}{L})(30\ min)$$

$$CT = 150\,\frac{mg \cdot min}{L}$$

Hypochlorite

- 2 types of hypochlorite used for disinfection in typical drinking water systems
  - Sodium hypochlorite
    - NaOCl
    - Bleach
    - 5-15% concentration
  - Calcium hypochlorite
    - $Ca(OCl)_2$
    - High test hypochlorite (HTH)
    - 65% concentration

Hypochlorite Strength

$$Hypochlorite\ strength, \% = \frac{chlorine\ required, lbs}{(hypochlorite\ solution\ needed, gal)(8.34\frac{lb}{gal})} x100$$

- To be used when using bleach in the place of chlorine gas
- Can be used for HTH
  - Just drop the 8.34 conversion

Example 4

- A water plant is switching from chlorine gas to sodium hypochlorite. If 133 lbs of gas was fed each day and they now feed 130 gallons of bleach, what concentration of NaOCl is being used?

$$\%\ strength = \frac{chlorine\ required, lbs}{(hypochlorite\ solution\ needed, gal)(8.34\frac{lb}{gal})} x100$$

$$\%\ strength = \frac{133\ lbs}{(130\ gal)(8.34\frac{lb}{gal})} \times 100$$

$$\%\ strength = 12.3\%$$

Two Normal equation

- $N = normality$
  - Can be replaced with concentration
- $V = volume\ or\ flow$

$$N_1 \times V_1 = N_2 \times V_2$$

OR

$$C_1 \times V_1 = C_2 \times V_2$$

Example 5

- A distribution operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

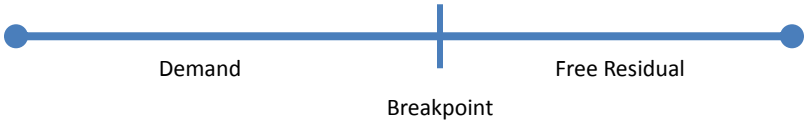
$$C_1 \times V_1 = C_2 \times V_2$$

$$(25\,mg/L)(10\,gal) = (100\ mg/L)(V)$$

$$\frac{(25\ mg/L)(10\,gal)}{100\ mg/L} = V$$

$$2.5\,gal = V$$

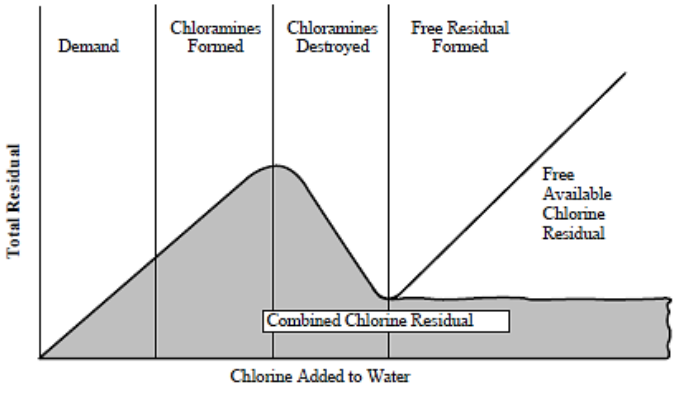
Breakpoint Chlorination



- Total chlorine dose = residual + demand

Breakpoint Chlorination

- Total chlorine = free residual + combined residual



Applied Math for Water Treatment
Disinfection

1. Determine the chlorinator setting in lb/day required to treat a flow of 3.5 MGD with a chlorine dose of 1.8 mg/L.

2. A flow totalizer reading at 9 am on Thursday was 18,815,108 and at 9 am on Friday was 19,222,420 gallons. If the chlorinator setting is 16 lb for this 24 hour period, what is the chlorine dosage in mg/L?

3. Water from a well is disinfected by a hypochlorinator. The flow totalizer indicates that 2,330,000 gallons of water were pumped during a 7 day period. The 3% sodium hypochlorite solution used to treat the well water is pumped from a 3-foot diameter storage tank. During the 7 day period, the level in the tank dropped 2 ft 10 inches. What is the chlorine dosage in mg/L?

4. A storage tank is to be disinfected with 60 mg/L of chlorine. If the tank holds 86,000 gallons, how many lb of chlorine (gas) will be needed?

5. The chlorine demand of a water process is 1.6 mg/L. If the desired chlorine residual is 0.5 mg/L, what is the desired chlorine dose (in mg/L)?

6. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

7. How many lb of chloride of lime (25% available chlorine) will be required to disinfect a well if the casing is 18 inches in diameter and 200 ft long with the water level 95 ft from the top of the well? The desired chlorine dosage is 100 mg/L

8. A chlorinator setting is 43 lb per 24 hours. If the flow being treated is 3.35 MGD, what is the chlorine dosage expressed as mg/L?

9. The chlorine dosage at a plant is 5.2 mg/L. If the flow rate is 6,250,000 gpd, what is the chlorine feed rate (in lb/day)?

10. A sodium hypochlorite solution (3% available chlorine) is used to disinfect water pumped from a well. A chlorine dose of 2.9 mg/L is required for adequate disinfection. How many gallons per day of sodium hypochlorite will be required if the flow being chlorinated is 955,000 gpd?

11. A flow of 3,021,000 gpd is disinfected with calcium hypochlorite (65% available chlorine). If 49 lb of hypochlorite are used in a 24-hour period, what is the chlorine dosage (in mg/L)?

12. A storage tank that is going to be put back into service requires disinfection at a dosage of 30 mg/L. If the tank has a diameter of 102 ft and is 28.1 ft in height at the overflow, how many gallons of 10.25% sodium hypochlorite solution will be needed if the tank is filled to 10% capacity?

13. The chlorine dosage for a water process is 2.9 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.7 mg/L, what is the chlorine demand expressed in mg/L?

14. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

15. A chlorine dose of 42 lb/day is required to disinfect a flow of 2,220,000 gpd. If the calcium hypochlorite to be used contains 65% available chlorine, how many lb/day hypochlorite will be required?

16. Determine the chlorinator setting (lb/day) required to treat a flow of 5.5 MGD with a chlorine dose of 2.5 mg/L.

17. Hypochlorite is used to disinfect water pumped from a well. The hypochlorite solution contains 3% available chlorine. A chlorine dose of 2.2 mg/L is required for adequate disinfection throughout the distribution system. If the flow from the well is 245,000 gpd, how much sodium hypochlorite (gallons per day) will be required?

18. A total chlorine dosage of 10 mg/L is required to treat the water in a unit process. If the flow is 1.8 MGD and the hypochlorite has 65% available chlorine, how many lb/day of hypochlorite will be required?

19. Determine the chlorinator setting (lb/day) needed to treat a flow of 980,000 gpd with a chlorine dose of 2.3 mg/L.

20. A water flow of 928,000 gpd requires a chlorine dose of 2.7 mg/L. If calcium hypochlorite (65% available chlorine) is to be used, how many lb/day of hypochlorite are required?

21. A chlorine dose of 2.7 mg/L is required for adequate disinfection of a water unit. If a flow of 810,000 gpd will be treated, how many gallons per day of sodium hypochlorite will be required? The sodium hypochlorite contains 12% available chlorine.

22. A new well is to be disinfected with chlorine at a dosage of 40 mg/L. If the well casing diameter is 6 inches and the length of the water-filled casing is 140 ft, how may lb of chlorine will be required?

23. A flow of 1.34 MGD is to receive a chlorine dose of 2.5 mg/L. What should be the chlorinator setting in lb/day?

24. What should the chlorinator setting be (in lb/day) to treat a flow of 4.8 MGD if the chlorine demand is 8.8 mg/L and a chlorine residual of 3 mg/L is desired?

25. A flow of 3,880,000 gpd is to be disinfected with chlorine. If the chlorine demand is 2.6 mg/L and a chlorine residual of 0.8 mg/L is desired, what should be the chlorinator setting lb/day?

26. The water-filled casing of a well has a volume of 540 gallons. If 0.48 lb of chlorine were used in disinfection, what was the chlorine dosage in mg/L?

27. A hypochlorite solution (4% available chlorine) is used to disinfect a water unit. A chlorine dose of 1.8 mg/L is desired to maintain an adequate chlorine residual. If the flow being treated is 400 gpm, what hypochlorite solution flow (in gallons per day) will be required?

28. A total of 54 lb of hypochlorite (65% available chlorine) is used in a day. If the flow rate treated is 1,512,000 gpd, what is the chlorine dosage (in mg/L)?

29. A flow of 0.83 MGD requires a chlorine dosage of 8 mg/L. If the hypochlorite has 65% available chlorine, how many lb/day of hypochlorite will be required?

30. A total of 36 lb/day sodium hypochlorite is required for disinfection of a flow of 1.7 MGD. How many gallons per day sodium hypochlorite is this?

31. A new well with a casing diameter of 12 inches is to be disinfected. The desired chlorine dosage is 40 mg/L. If the casing is 190 ft long and the water level in the well is 81 feet from the top of the well, how many lb of chlorine will be required?

32. A chlorine dose of 42 mg/L is required to disinfect a flow of 2.22 MGD. If the calcium hypochlorite to be used contains 65% available chlorine, how many lb/day hypochlorite will be required?

33. The chlorine demand of a water unit is 1.8 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose (in mg/L)?

34. A total of 51 lb/day sodium hypochlorite is required for disinfection of a flow of 2.28 MGD. How many gallons per day sodium hypochlorite is this?

35. The chlorine dosage for a water unit is 3.1 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.6 mg/L, what is the chlorine demand expressed in mg/L?

36. What chlorinator setting (in lb/day) is required to treat a flow of 1620 gpm with a chlorine dose of 2.8 mg/L?

37. A chlorine dose of 2.8 mg/L is required for adequate disinfection of a water unit. If a flow of 1.33 MGD will be treated, how many gpd of sodium hypochlorite will be required? The sodium hypochlorite contains 12.5% available chlorine.

38. A pipeline 8 inches in diameter and 1600 ft long is to be treated with a chlorine dose of 60 mg/L. How many lb of chlorine will this require?

39. The average calcium hypochlorite use at a plant is 34 lb/day. If the chemical inventory in stock is 310 lb, how many days' supply is this?

40. The flow totalizer reading at 7 a.m. on Wednesday was 43,200,000 gallons and at 7 a.m. on Thursday was 44,115,670 gallons. If the chlorinator setting is 18 lb for this 24-hour period, what is the chlorine dosage (in mg/L)?

41. A chlorine dose of 32 mg/L is required to disinfect a flow of 1,990,000 gpd. If the calcium hypochlorite to be used contains 60% available chlorine, how many lb/day hypochlorite will be required?

42. Water from a well is disinfected by a hypochlorinator. The flow totalizer indicates that 2,666,000 gallons of water were pumped during a 7-day period. The 2% sodium hypochlorite solution used to treat the well water is pumped from a 4-foot-diameter storage tank. During the 7-day period, the level in the tank dropped 3 ft 4 inches. What is the chlorine dosage (in mg/L)?

43. A flow of 3,350,000 gpd is to be disinfected with chlorine. If the chlorine demand is 2.5 mg/L and a chlorine residual of 0.5 mg/L is desired, what should be the chlorinator setting (in lb/day)?

44. A total of 72 lb of hypochlorite (65% available chlorine) is used in a day. If the flow rate treated is 1,885,000 gpd, what is the chlorine dosage (in mg/L)?

45. How many lb of dry hypochlorite (65% available chlorine) must be added to 80 gallons of water to make a 2% chlorine solution?

46. An average of 32 lb of chlorine is used each day at a plant. How many lb of chlorine would be used in a week if the hour meter on the pump registers 140 hours of operation that week?

47. An average of 50 lb of chlorine is used each day at a plant. How many 150-lb chlorine cylinders will be required each month? Assume a 30-day month.

Answers

1. 52.54 lb/day
2. 4.7 mg/L
3. 19.27 mg/L
4. 43.03 lb
5. 2.1 mg/L
6. 1.38 gal
7. 4.67 lb
8. 1.53 mg/L
9. 271.05 lb/day
10. 92.32 gal/day
11. 1.26 mg/L
12. 0.25 gal
13. 2.2 mg/L
14. 3.84 lb
15. 1.47 mg/L
16. 114.68 lb/day
17. 17.97 gal/day
18. 230.95 lb/day
19. 18.80 lb/day
20. 32.3 lb/day
21. 18.23 gal/day
22. 0.07 lb
23. 27.94 lb/day
24. 472.38 lb/day
25. 110.02 lb/day
26. 106.58 mg/L
27. 25.92 gal/day
28. 2.78 mg/L
29. 85.20 lb/day
30. 4.32 gal/day
31. 0.16 lb
32. 1,196.34 lb/day
33. 2.7 mg/L
34. 6.12 gal/day
35. 2.5 mg/L
36. 54.48 lb/day
37. 248.47 lb/day
38. 2.09 lb
39. 9.12 days
40. 2.36 mg/L
41. 885.15 lb/day
42. 2.35 mg/L
43. 83.82 lb/day
44. 2.98 mg/L
45. 20.53 lb
46. 186.67 lb/week
47. 10 cyl/month

Section 6

Pumps, Pressure, and Power

Pumps, Power and Force

Horsepower and Efficiency

TDEC - Fleming Training Center

Understanding Work & Horsepower

- Work: The exertion of force over a specific distance.
  - Example: Lifting a one-pound object one foot.
- Amount of work done would be measured in foot-pounds
  - (feet) (pounds) = foot-pounds
- (1 pound object) (moved 20 ft) = 20 ft-lbs of work

TDEC - Fleming Training Center 3

Understanding Power

- Power is the measure of how much work is done in a given amount of time
- The basic units for power measurement is foot-pounds per minute and expressed as (ft-lb/min)
  - in electric terminology ⇒ Watts
- This is work performed per time (work/time)
- One Horsepower
  - 1 HP = 33,000 ft-lb/min
- In electric terms
  - 1 HP = 746 Watts

TDEC - Fleming Training Center 4

Types of Horsepower

- **Motor Horsepower** is related to the watts of electric power supplied to a motor
- **Brake Horsepower** is the power supplied to a pump by a motor
- **Water Horsepower** is the portion of power delivered to a pump that is actually used to lift the water
  - Water horsepower is affected by elevation and location of the pump.

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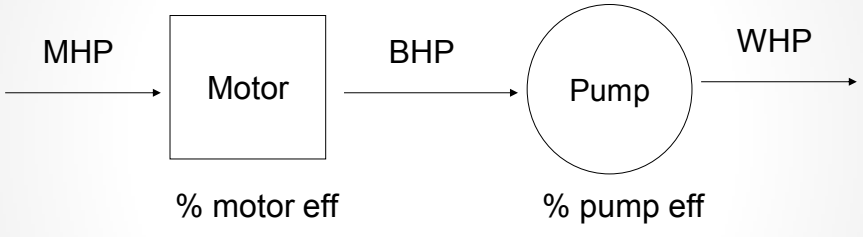


Left to right → multiply

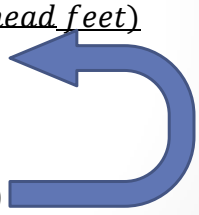
Right to left → divide

Computing Water Horsepower

- Water horsepower is the amount of horsepower required to lift the water

$$WHP = \frac{(flow\ gpm)\ (total\ head\ feet)}{3{,}960}$$

$$\frac{33{,}000\ {}^{ft-lb}/_{min}}{8.34\ {}^{lbs}/_{gal}} = 3960$$



Example 1

- A pump must pump 3,000 gpm against a total head of 25 feet. What water horsepower will be required?

$$WHP = \frac{(flow)(head)}{3960}$$

$$WHP = \frac{(3000\ gpm)(25\ ft)}{3960}$$

$$WHP = 18.94\ hp$$

Brake Horsepower

$$bhp = \frac{(flow, gpm)(head, ft)}{(3960)(\%\ pump\ eff.)}$$

OR

$$bhp = \frac{water\ hp}{\%\ pump\ eff.}$$

Example 2

- Determine the horsepower produce by a motor at a flow of 1500 gpm against a total head of 25 ft if the pump is 82% efficient.

$$bhp = \frac{(flow, gpm)(head, ft)}{(3960)(\%\ pump\ eff.)}$$

$$bhp = \frac{(1500\ gpm)(25\ ft)}{(3960)(0.82)}$$

$$bhp = \frac{37500}{3247.2}$$

$$bhp = 11.5\ hp$$

Motor Horsepower

$$mhp = \frac{(flow, gpm)\ (head, ft)}{(3960)(\%\ pump\ eff)(\%\ motor\ eff)}$$

$$mhp = \frac{water\ hp}{(\%\ pump\ eff)(\%\ motor)}$$

$$mhp = \frac{bhp}{\%\ motor\ eff}$$

Example 3

- A certain pumping job will require 9 hp. If the pump is 80% efficient and the motor is 72% efficient, what motor horsepower will be required?

$$mhp = \frac{water\ hp}{(\%\ pump\ eff)(\%\ motor)}$$

$$mhp = \frac{9\ hp}{(0.80)(0.72)}$$

$$mhp = \frac{9\ hp}{0.576}$$

$$mhp = 15.6\ hp$$

Motor and Pump Efficiency

- Neither the motor nor the pump will ever be 100% efficient
- Not all the power supplied by the motor to the pump (Brake Horsepower) will be used to lift the water (Water Horsepower)
- Power for the motor and pump is used to overcome friction
- Power is also lost when energy is converted to heat, sound, etc.

Typical Efficiency

- Pumps are generally 50-85 % efficient
- Motors are usually 80-95% efficient

- Combined efficiency of the motor and pump is called wire-to-water efficiency

Wire-to-Water Efficiency

$$w - w = \frac{water\ hp}{motor\ hp} \times 100$$

OR

$$w - w = \frac{(flow, gpm)(head, ft)(0.746\ {}^{kW}/_{hp})}{(3960)(electric\ demand, kW)} \times 100$$

Example 4

- A pump must move 2500 gpm against a total dynamic head of 115 feet. If the motor requires 75 kW of power, what is the wire-to-water efficiency?

$$w - w = \frac{(flow, gpm)(head, ft)(0.746\ {}^{kW}/_{hp})}{(3960)(electric\ demand, kW)} \times 100$$

$$w - w = \frac{(2500gpm)(115ft)(0.746\ {}^{kW}/_{hp})}{(3960)(75kW)} \times 100$$

$$w - w = \frac{214475}{297000} \times 100$$

$$w - w = 72.2\%$$

Electrical

A Few Electrical Terms...

- Power (Watts) - amount of work done
- Voltage (volts) - electrical "pressure" available to cause flow of electricity
- Amperage (amps) - the amount of flow of electricity
- Power = (voltage)(amperage)

  or
- Watts = (volts)(amps)

Amperage

- Current is equal to the voltage applied to the circuit divided by the resistance of the circuit
- Ohm's Law:

$$amps = \frac{volts}{ohms}$$

Example 5

- A circuit contains a resistance of 6 ohms and a source voltage of 3 volts. How much current (amps) flows in the circuit?

$$amps = \frac{volts}{ohms}$$

$$amps = \frac{3\ volts}{6\ ohms}$$

$$amps = 0.5\ amps$$

Electromotive Force

- Electromotive force is the characteristic of any energy source capable of driving electric charge around a circuit
  - Aka voltage

$$emf, volts = (current, amps)(resistance, ohms)$$

Example 6

- A circuit has a resistance of 12 ohms with a current of 0.25 amps. What is the electromotive force in volts?

$$emf, volts = (current, amps)(resistance, ohms)$$

$$emf = (0.25\ amps)(12\ ohms)$$

$$emf = 3\ volts$$

Watts

- Unit of power
- $1\ Watt\ =\ 0.746\ hp$
- $1\ kW\ =\ 746\ W$
- Alternating current (AC circuit)

$$Watts = (volts)(amps)(power\ factor)$$

$$W = V * A * pf$$

- Direct current (DC circuit)

$$Watts = (volts)(amps)$$

$$W = V * A$$

Example 7

- An alternating current motor has a voltage of 5 volts and a current of 3 amps. If the nameplate show that the motor has a power factor of 0.97, what is the power of the motor in watts?

$$Watts = (volts)(amps)(power\ factor)$$

$$W = (5\ volts)(3\ amps)(0.97)$$

$$W = 14.55\ watts$$

Force

Force

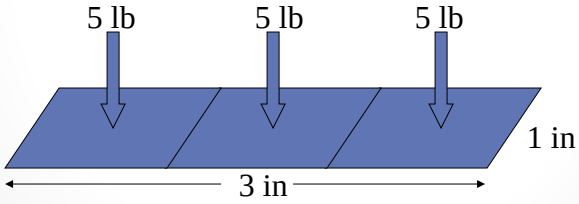
- Force is a push or pull on an object resulting from the object's interaction with another object
- Measured in pounds (lbs)
- $1\ psi\ =\ 2.31\ ft\ of\ head$

$$Force, lbs = (pressure, psi)(area, in^2)$$

$$F = P * A$$

Force

- Pressure exerted on a surface corresponds to the force applied to the surface.
- Force = pressure x area



$$Force = (5\ psig)(3in)(1in) = 15\ lb$$

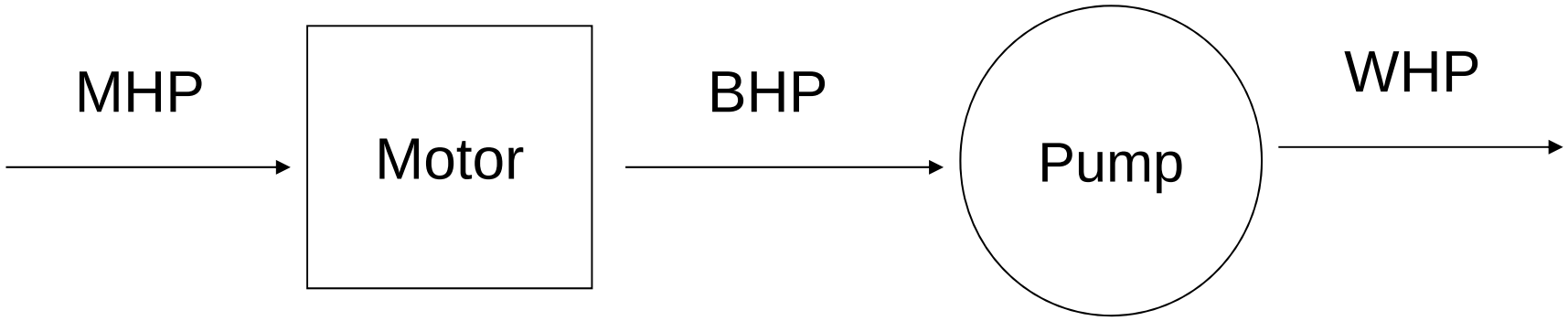
Example 8

- Determine the force, in lbs, being exerted on a surface that is 3 inches by 4 inches with 15 psi of pressure.

$$Force, lbs = (pressure, psi)(area, in^2)$$

$$Force, lbs = (15\ psi)(3\ in)(4\ in)$$

$$Force, lbs = 180\ lbs$$



Left to right → multiply

Right to left → divide

Applied Math for Distribution Systems
Pumps, Pressure, and Power

1. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

2. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

3. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

4. If 20 hp is supplied to a motor (mhp), what is the whp if the motor is 85% efficient and the pump is 80% efficient?

5. Convert a pressure of 26 ft to pounds per square inch.

6. A supply tank is located at an elevation of 118 ft. The discharge point is at an elevation of 215 ft. What is the static head (in feet)?

7. A pump must pump against a total dynamic head of 70 ft at a flow rate of 700 gpm. The liquid to be pumped has a specific gravity of 1.3. What is the water horsepower required for this pumping application?

8. If the pressure at the bottom of the tank is 14.7 psi, what is the height of the water in the tank?

9. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

10. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

11. What would be the horsepower on a motor that is rated at 36 amps and 440 volts?

12. The motor horsepower requirement has been calculated to be 45 hp. How many kilowatts electric power does this represent? (Remember, 1 hp = 746 watts)

13. A pump must pump 1600 gpm against a total head of 50 ft. What horsepower is required for this work?

14. A pressure of 42 psig is equivalent to how many feet of water?

15. What is the motor horsepower for a pump with the following parameters?
    Motor eff: 91% Total head: 98 ft
    Pump eff: 81% Flow: 2.44 MGD

16. A hypochlorite solution is being pumped from a small tank that is 2.5 ft in diameter. If the level in the tank drops 2.05 ft in 3.5 hrs, how many gallons per minute of hypochlorite solution was used?

17. What is the motor hp if the bhp is 68 and the motor efficiency is 87%?

18. If a pump is to deliver 360 gpm of water against a total head of 95 feet, and the pump has an efficiency of 85 percent, what horsepower must be supplied to the pump?

19. You have calculated that a certain pumping job will require 9 whp. If the pump is 80 percent efficient and the motor is 72 percent efficient, what motor horsepower will be required?

20. The brake horsepower of a pump is 22 hp. If the water horsepower is 17 hp, what is the wire to water efficiency of the pump?

21. A pump must pump 1500 gpm against a total head of 40 ft. What horsepower is required for this work?

22. The pressure gauge on the discharge line from an influent pump reads 72.3 lbs per square inch (psi). What is the equivalent head in feet?

23. Determine the number of gallons a pump discharges in 1 hour if it is pumped at a rate of 1,340 gpm.

24. If the water level in a tank is 31.78 ft, what is the pressure in psi at the bottom?

25. If 25 horsepower is supplied to a motor (mhp), what is the brake horsepower (bhp) and water horse power (whp) if the motor is 80% efficient and the pump is 75% efficient?

26. The elevations of two water surfaces are 780 ft and 624 ft what is the total dynamic head in feet?

27. Suppose a pump is pumping against a total head of 46 feet. If 850 gpm is to be pumped, what is the horsepower requirement?

28. What is the water horsepower of a pump that is producing 1,523 gpm against a head of 65 feet?

29. Suppose that 10 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 12 bhp, what is the wire-to-water efficiency of the motor?

30. The motor nameplate indicated that the output of a certain motor is 20 hp. How much horsepower must be supplied to the motor if the motor is 90 percent efficient?

31. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

32. The motor horsepower is 25 hp. If the motor is 89% efficient, what is the brake horsepower?

33. The brake horsepower is 34.4 hp. If the motor is 86% efficient, what is the motor horsepower?

34. What is the depth of water in a lake if the psi is 56.7?

35. Convert 32 psig to ft of head.

36. A water tank has 250 feet of water in it. What is the pressure gage reading at ground level?

37. A water tank has a pressure gage located 2 ft below the ground level in a pit. Its current reading is 60 psig. How many feet of water are in the tank?

38. The elevations of two water surfaces are 320 ft and 241 feet. What is the total static head in feet?

39. What is the pressure head at a fire hydrant in feet if the pressure gauge reads 189 psi?

40. The pressure at the bottom of a reservoir is 132 psi. What is the depth at that point?

41. If a pump discharges 7,880 gal in 2 hours and 13 minutes, how many gallons per minute is the pump discharging?

42. If the water level in a reservoir is 625 ft, what is the pressure in pounds per square in at an inlet if it is 165 ft from bottom?

43. A total of 50 hp is supplied to a motor. If the wire-to-water efficiency of the pump and motor is 62%, what will the Whp be?

44. A total of 35 hp is required for a particular pumping application. If the pump efficiency is 85%, what is the brake horsepower required?

45. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

46. A pump must pump 3,000 gpm against a total head of 25 feet. What horsepower (water horsepower) will be required to do the work?

47. If a pump is to deliver 450 gpm of water against a total head of 90 feet, and the pump has an efficiency of 70 percent, what horsepower must be supplied to the pump?

48. You have calculated that a certain pumping job will require 6 whp. If the pump is 80 percent efficient and the motor is 90 percent efficient, what motor horsepower will be required?

49. If a pump discharges 840 gpm, how many gallons will it discharge in 4 hours and 20 minutes?

50. If the pressure head at a fire hydrant is 210 ft, what is the psi?

51. What is the brake horsepower if 62 hp is supplied to a motor with 87% efficiency?

52. A head of 310 ft of water is equivalent to what pressure in psi?

53. A water tank has a pressure gage located 4 ft above the ground. Its current reading is 60 psig. How many feet of water are in the tank?

54. Suppose a pump is pumping a total head of 76.2 feet. If 900 gpm is to be pumped, what is the water horsepower requirement?

55. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

56. Suppose that 31 kilowatts (kW) power is supplied to a motor. If the brake horsepower is 19 bhp, what is the efficiency of the motor?

57. A pump is delivering a flow of 835 gpm against a total head of 35.6 feet. What is the water horsepower?

58. What would be the horsepower on a motor that is rated at 12 amps and 440 volts?

59. If the motor horsepower is 50 hp and the brake horsepower is 43 hp, what is the percent efficiency of the motor?

60. What is the psi at the bottom of a tank if the water level is 28.14 ft deep?

61. A total of 40 hp is required for a particular pumping application. If the pump efficiency is 80%, what is the brake horsepower required?

62. If the pressure head on a fire hydrant is 210 ft, what is the pressure in psi?

63. Determine the brake horsepower if the motor has an efficiency of 88 % and the horsepower is 45.

64. If the pressure head at a blow off valve is 136, what is the pressure in pounds?

ANSWERS

1. 5.6 hp	17. 78 hp	33. 40 hp	49. 218,400 gal
2. 88.1%	18. 10.2 hp	34. 131 ft	50. 90.93 psi
3. 16.5 hp	19. 15.6 hp	35. 73.92 ft	51. 54 hp
4. 17 bhp; 13.6 whp	20. 77%	36. 108 psig	52. 134 psig
5. 11 psig	21. 15.15 hp	37. 136.6 ft	53. 142.6 ft
6. 97 ft	22. 167 ft	38. 79 ft	54. 17.3 hp
7. 16.1 hp	23. 80,400 gal	39. 437 ft	55. 46 hp
8. 34.0 ft	24. 13.8 psi	40. 304.85 ft	56. 45.7%
9. 38.9 hp	25. 20 bhp; 16 whp	41. 59.25 gpm	57. 7.5 hp
10. 9.4 hp	26. 174 ft	42. 199 psi	58. 7.1 hp
11. 21.2 hp	27. 9.9 hp	43. 31 hp	59. 86%
12. 33.57 kW	28. 25 hp	44. 41.18 hp	60. 12.2 psi
13. 10.1 hp	29. 89.55%	45. 12.2 hp	61. 50 hp
14. 97 ft	30. 22.2%	46. 18.9 hp	62. 91 psi
15. 57 mhp	31. 20.8 hp	47. 14.6 hp	63. 40 hp
16. 0.36 gpm	32. 22.25 hp	48. 8.3 hp	64. 58.9 psi

Section 7

Chemical Feeders

Chemical Feeders

Mass and Mass Flux

- Mass is a measurement of how much matter is in an object
  - On Earth, it will be the same as weight

$$mass, lbs = (volume, MG)\left(concentration, \frac{mg}{L}\right)\left(8.34\frac{lb}{gal}\right)$$

- Mass flux is the rate of mass flow per unit area

$$mass\ flux, \frac{lb}{day} = (flow, MGD)(concentration, \frac{mg}{L})(8.34\frac{lb}{gal})$$

Feed Rate

- When adding chemicals to the water flow, a measured amount of chemical is required that depends on such factors as the type of chemical being used, the reason for dosing and the flow rate being treated.
- To convert from mg/L to lb/day:

$$mass\ flux, \frac{lb}{day} = (dose)(flow)(8.34\ {}^{lb}/_{gal})$$

Example 1

- Jar tests indicate that the best alum dose for a water is 8 mg/L. If the flow to the be treated is 2,100,000 gpd, what should the lb/day setting be on the dry alum feeder?

$$mass\ flux, \frac{lb}{day} = (dose)(flow)(8.34\ {}^{lb}/_{gal})$$

$$\frac{lb}{day} = (8\ {}^{mg}/_{L})(2.10MGD)(8.34\ {}^{lb}/_{gal})$$

$$\frac{lb}{day} = 140\ {}^{lb}/_{day}$$

Chemical Dry Feeder Calibration

- To check the calibration of a dry feeder, collect a sample from the feeder for a period of time
  - Repeat this 3 times to get an average feed rate
- Convert the grams per minute collected to lb/day to compare to the documented feed rate

$$\frac{lb}{day} = \frac{(grams)\left(60\ {}^{min}/_{hr}\right)\left(24\ {}^{hr}/_{day}\right)}{\left(454\ {}^{gram}/_{lb}\right)(time, min)}$$

Example 2

- An operator collects three 1 minute samples of lime form the dry feeder. The weights collected are 5 grams, 7 grams and 5 grams, respectively. Determine the average feed rate in lbs/day.

$$\frac{lb}{day} = \frac{(grams)\left(60\ {}^{min}/_{hr}\right)\left(24\ {}^{hr}/_{day}\right)}{\left(454\ {}^{gram}/_{lb}\right)(time, min)}$$

$$\frac{lb}{day} = \frac{(5.67\ g)\left(60\frac{min}{hr}\right)\left(24\frac{hr}{day}\right)}{(454\frac{g}{lb})(1\ minute)}$$

$$\frac{lb}{day} = \frac{8164.8}{454}$$

$$\frac{lb}{day} = 17.98\ lb/day$$

$$average = \frac{5g + 7g + 5g}{3} = \frac{17g}{3} = 5.67 grams$$

Chemical Solution Feeder Setting

- When solution concentration is expressed as lb chemical per gallon solution (lb/gal), the required feed rate can be determined
  - Use the lb/day formula and convert it to gal/day

$$solution\ (gpd) = \frac{chemical\ (^{lb}/_{day})}{^{lb\ chemical}/_{gal\ solution}}$$

Example 3

- Jar tests indicate that the best alum dose for a water is 7 mg/L. The flow to be treated is 1.52 MGD. Determine the gallons per day setting for the alum solution feeder if the liquid alum contains 5.36 lbs of alum per gallon of solution.

$$mass\ flux, \frac{lb}{day} = (dose)(flow)(8.34\ ^{lb}/_{gal})$$

$$\frac{lb}{day} = (7\ ^{mg}/_{L})(1.52\ MGD)(8.34\ ^{lb}/_{gal})$$

$$\frac{lb}{day} = 88.7376\ ^{lb}/_{day}$$

Example 3 Cont'd

- Convert lb/day to gal/day

$$solution\ (gpd) = \frac{chemical\ (^{lb}/_{day})}{^{lb\ chemical}/_{gal\ solution}}$$

$$gpd = \frac{88.7376\ ^{lb}/_{day}}{\frac{5.36\ lb\ alum}{gal\ sol'n}}$$

$$gpd = 16.6\ gpd$$

Chemical Feed Pump Setting

- Some solution chemical feeders dispense chemical as millimeters per minute (mL/min).

$$\frac{mL}{min} = \frac{(Flow, MGD)\left(dose, \frac{mg}{L}\right)\left(3.785\frac{L}{gal}\right)\left(1{,}000000\frac{gal}{MG}\right)}{\left(liquid, \frac{mg}{mL}\right)\left(24\frac{hr}{dau}\right)\left(60\frac{min}{hr}\right)}$$

Example 4

- A flow of 2.12 MGD is to be treated with a solution of chemical. The desired dose is 1.4 mg/L. The chemical to be fed weighs 1175.5 mg/mL. What should be the mL/min solution feed rate?

$$\frac{mL}{min} = \frac{(Flow, MGD)\left(dose, \frac{mg}{L}\right)\left(3.785\frac{L}{gal}\right)\left(1{,}000{,}000\frac{gal}{MG}\right)}{\left(liquid, \frac{mg}{mL}\right)\left(24\frac{hr}{dau}\right)\left(60\frac{min}{hr}\right)}$$

$$\frac{mL}{min} = \frac{(2.12MGD)\left(1.4\frac{mg}{L}\right)(3.785\frac{L}{gal})(1{,}000{,}000\frac{gal}{MGD})}{(1175.5\frac{mg}{mL})(24\frac{hr}{day})(60\frac{min}{hr})}$$

$$\frac{mL}{min} = \frac{11{,}233{,}880mg}{1692720\frac{mg \cdot min}{mL}} = \quad 6.64\frac{mL}{min}$$

Chemical Feed Pump Setting

- Chemical feed pumps are generally positive displacement pumps (e.g. piston pumps)
- This type of pump displaces, or pushes out, a volume of chemical equal to the volume of the piston
- The length of the piston, called the stroke, can be lengthened or shortened to increase or decrease the amount of chemical delivered by the pump

$$\%\ stroke = \frac{desired\ flow}{maximum\ flow} \times 100$$

Example 5

- The required chemical pumping rate has been calculated as 8 gpm. If the maximum pumping rate is 90 gpm, what should the percent stroke setting be?

$$\%\ stroke = \frac{desired\ flow}{maximum\ flow} \times 100$$

$$\%\ stroke = \frac{8\ gpm}{90\ gpm} \times 100$$

$$\%\ stroke = 8.9\%$$

Chemical Feeders

1. A jar test indicates the 4.3 mg/L of liquid alum is required in treating 6.7 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution. 117.41 mL/min

2. An operator is checking the calibration on a chemical feeder. The feeder delivers 102 grams in 5 minutes. How many grams per minute does the feeder deliver? How many pounds per day does the feeder deliver?

3. The average flow for a water plant is 3.25 MGD. A jar test indicates that the best alum dosage is 2.5 mg/L. How many pounds per day will the operator feed? 67.76

4. Jar tests indicate that the best liquid alum dose for a water unit is 11 mg/L. The flow to be treated is 2.13 MGD. Determine the gallons per day setting for the liquid alum chemical feeder if the liquid alum is a 60% solution. Assume the alum solution weighs about 8.34 lb/gal. 39 MGD

5. You collect three 2-minute samples from an Alum dry feeder. What is the feed rate in mg/L when the flow rate is 2 MGD? 2.25

   Sample 1 = 25 grams
   Sample 2 = 22 grams
   Sample 3 = 24 grams

6. A water plant fed 130 lbs of alum treating 1.3 MGD. Calculate the dose in mg/L. 11.99

7. The average daily flow for a water plant is 7.5 MGD. Jar test results indicate the best polymer dosage is 1.8 mg/L. How many pounds of polymer will be used in 90 days? 10133

8. The operator measured the amount of dry chemical fed in one day as 114.5 lbs. How many grams/min should the dry feeder have delivered? 36.07

9. A water treatment plant used 14 pounds of cationic polymer to treat 2.0 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L? 0.84

10. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 15 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the flow is 7.2 MGD. There are 3.785 liters in one gallon. 8441.97

11. A jar test indicates the 4.3 mg/L of liquid alum is required in treating 6.7 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution. 117.41

12. A pond has an average length of 250 ft, an average width of 75 ft and an average depth of 10 ft. If the desired dose of copper sulfate is 0.8 lbs/ acre ft, how many pounds of copper sulfate will be required?

13. Jar tests indicate that the best alum dose for a water unit is 8 mg/L. The flow to be treated is 1,440,000 gpd. Determine the gallons per day setting for the liquid alum chemical feeder if the liquid alum contains 6.15 lb of alum per gallon of solution. 15.6 gpd

14. The required chemical pumping rate has been calculated to be 22 gpm. If the maximum pumping rate is 80 gpm, what should the percent stroke setting be? 27.5%

15. Jar tests indicate that the best liquid alum dose for a water unit is 10 mg/L. The flow to be treated is 4.10 MGD. Determine the gallons per day setting for the liquid alum chemical feeder if the liquid alum contains 5.88 lbs of alum per gallon of solution. 58 gpd

16. An operator collects 3 two-minute samples from a dry feeder:

    Sample 1 weighs 47.3 grams
    Sample 2 weighs 44.8 grams
    Sample 3 weighs 42.4 grams

17. The water plant is treating 4.5 MGD. What is the average dose in mg/L? 1.9 mg/L

18. The average flow for a water plant is 8.3 MGD. A jar test indicates that the best alum dosage is 2.2 mg/L. How many grams per minute should the feeder deliver? 47.99

19. A water plant used 167 gallons of a liquid chemical in one day. How many mL/min was pumped? 438.95 mL/min

20. A jar test indicates the 3.4 mg/L of liquid alum is required in treating 7.6 MGD. How many mL/min should the metering pump deliver? The liquid alum delivered to the plant contains 645 mg alum per mL of liquid solution. 105.3

21. A water plant is treating 1.8 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon. 5.6

22. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 15 mg/L. Determine the setting on the liquid alum chemical feeder if milliliters per minute when the flow is 7.2 MGD. There are 3.79 liters in one gallon. 441.97 mL/min (or close due to different L:gal ratio.)

23. The flow to the plant is 4,440,000 gpd. Jar testing indicates that the optimum alum dose is 9 mg/L. What should the gallons per day setting be for the solution feeder if the alum solution is 60% solution. Assume the solution weighs 8.34 lb/gal. 66.6 gpd

24. a. An operator checks the calibration of a dry feeder by catching samples and weighing them on a balance. Each catch lasts 1 minute. Calculate the average feed rate in grams per minute based on the following data:

Sample 1 weighs 37.0 grams
Sample 2 weighs 36.2 grams
Sample 3 weighs 39.4 grams
Sample 4 weighs 38.6 grams

b. How many pounds per hour is being fed?

25. $KMnO_4$ has been made according to the manufacturer recommendations (30 mg/mL). The water plant operators wants to dose 3.6 MGD with 2.0 mg/L KMnO4. How many ml/min must be delivered by the metering pump? 630.83 mL/min

26. Determine the setting on a dry alum feeder in pounds per day when the flow is 1.3 MGD. Jar tests indicate that the best alum dose is 12 mg/L. 130.10

27. A water treatment plant used 27 pounds of cationic polymer to treat 1.6 million gallons of water during a 24-hour period. What is the polymer dosage in mg/L? 2.02

28. a. An operator collects 5 two-minute samples from a dry feeder:

Sample 1 weighs 49.2 grams
Sample 2 weighs 44.0 grams
Sample 3 weighs 41.9 grams
Sample 4 weighs 48.3 grams
Sample 5 weighs 47.6 grams

b. What is the average grams per minute?

c. What is the average dose in mg/L if the plant treats 1,200,000 gpd?

29. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of alum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 8 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute if the flow is 2.2 MGD. 72.02

30. The required chemical pumping rate has been calculated to be 30 gpm. If the maximum pumping rate is 80 gpm, what should the percent stroke setting be? 37.5%

31. Determine the setting on a dry alum feeder when the flow is 5.4 MGD. Jar tests indicate that the best alum dose is 8 mg/L. What would be the setting in grams per minute? 113.55

32. A water plant is treating 8.2 MGD with 2.0 mg/L liquid alum. How many gpd of liquid alum will be required? The liquid alum contains 5.36 lbs dry alum/gallon. 25.52

33. The average daily flow for a water plant is 0.75 MGD. If the polymer dosage is kept at 1.8 mg/L, how many pounds of polymer will be used in 30 days? 337.77

34. A chemical feeder feeds a liquid chemical to a 1000 mL graduated cylinder for 48 seconds. At the end of the 48 seconds, the graduated cylinder is completely full. What is the chemical feed rate for the metering pump in gallons per day? 475.56

35. The required chemical pumping rate has been determined to be 14 gpm. What is the percent stroke setting if the maximum rate is 70 gpm? 20%

36. An operator collects 3 two-minute samples from a dry feeder. What is the average grams per minute?

Sample 1 weighs 22.2 grams
Sample 2 weighs 24.0 grams
Sample 3 weighs 21.9 grams

37. What is the average dose in mg/L for the feeder in question 3.a. if the plant treats 420,000 gpd?

38. A water plant treats 3.5 MGD with a dose of 2.2 mg/L $KMnO_4$. If the water plant uses 257 gallons of permanganate per day, how many ml/min must be pumped?

39. A jar test indicates that 1.8 mg/L of liquid ferric chloride should be fed to treat 2,778 gpm of water. How many mL/min should be fed by a metering pump? Ferric chloride contains 4.59 lbs dry chemical per gallon of liquid solution. 34.41

40. Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of liquid polymer should be used to make 55 gallons of a 0.5% polymer solution? 3.44

41. The maximum pumping rate is 110 gpm. If the required puming rate is 40 gpm, what is the percent stroke setting? 36%

42. The average flow for a water plant is 13.5 MGD. The jar test indicates that the best alum dose is 1.8 mg/L. How many pounds per day will the operator feed? 202.66

43. For algae control of a reservoir, a dosage of 0.5 mg/L copper is desired. The reservoir has a volume of 20 MG. How many pounds of copper sulfate (25% available copper) will be required?

44. The average flow for a water plant is 6.3 MGD. A jar test indicates that the best alum dosage is 19 mg/L. How many pounds per day will the operator feed? 998.3

45. The average flow for a water plant is 8,890 gpm. A jar test indicates that the best polymer dose is 3.1 mg/L. How many pounds will the plant feed in one week? (Assume the plant runs 24 hour/day, 7 days/week.) 2316.81

46. A water plant fed 52 grams per minute of dry alum while treating 2.6 MGD. Calculate the mg/L dose. 7.61

47. A water plant fed 48.5 grams per minute while treating 2.2 MGD. Calculate the mg/L dose. 8.39

48. The desired copper sulfate dose in a reservoir is 5 mg/L. The reservoir has a volume of 62 acre-ft. How many lbs of copper sulfate (25% available copper) will be required?

1.	17.	33.
2.	18.	34.
3.	19.	35.
4.	20.	36.
5.	21.	37.
6.	22.	38.
7.	23.	39.
8.	24.	40.
9.	25.	41.
10.	26.	42.
11.	27.	43.
12.	28.	44.
13.	29.	45.
14.	30.	46.
15.	31.	47.
16.	32.	48.

Section 8

Sedimentation

Sedimentation

Sedimentation

- Sedimentation is the separation of solids and liquids by gravity
- Calculating volume must be done based on the shape of the tank
  - Typically rectangular or cylindrical
- Detention time is the amount of time the water is supposed to spend in the tank

Volume

- Cylindrical tank

$$volume, ft^3 = (0.785)(D^2)(h)$$

- Rectangular tank

$$volume, ft^3 = (l)(w)(d)$$

Detention Time

$$detention\ time = \frac{volume}{flow}$$

- Units must be compatible within the equation

Example 1

- A sedimentation tank has a volume of 137,000 gallons. If the flow to the tank is 121,000 gph, what is the detention time in the tank (in hours)?

$$detention\ time = \frac{volume}{flow}$$

$$DT = \frac{137{,}000\ gal}{121{,}000\frac{gal}{hr}}$$

$$DT = 1.13\ hours$$

Surface Overflow Rate

- Hydraulic loading rate (HLR) is used to determine loading on sedimentation basins and circular clarifiers
  - Measures the total water entering the process

$$HLR = \frac{total\ flow\ applied, gpd}{area, ft^2}$$

- Surface overflow rate (SOR) measures only the water overflowing the process

$$SOR = \frac{flow, gpd}{area, ft^2}$$

Example 2

- A circular clarifier has a diameter of 80 ft. If the flow to the clarifier is 2.6 MGD, what is the surface overflow rate in gpm/sq.ft?

$A = (0.785)(D^2)$

$$SOR = \frac{flow, gpd}{area, ft^2}$$

$$SOR = \frac{2{,}600{,}000\ gpd}{(0.785)(80ft)(80ft)}$$

$$SOR = \frac{2{,}600{,}000\ gpd}{5024\ ft^2}$$

$$SOR = 517.51\ \frac{gpd}{ft^2}$$

Weir Overflow Rate

- Weir overflow rate (WOR) is the amount of water leaving the settling tank per linear foot of weir
- Calculation result can then be compared to design
- Mesaured in gpd/ft

$$WOR = \frac{flow, gpd}{weir\ length, ft}$$

Example 3

- A circular clarifier receives a flow of 3.55 MGD. If the diameter of the weir is 90 ft, what is the weir overflow rate in gpd/ft?

$$circumference = \pi * Diameter$$
$$Circ = (\pi)(90ft)$$
$$Circ = 282.7433\ ft$$

$$WOR = \frac{flow, gpd}{weir\ length, ft}$$

$$WOR = \frac{3{,}550{,}000\ gpd}{282.7433\ ft}$$

$$WOR = 12555.56\ \frac{gpd}{ft}$$

Reduction in Flow

- To determine the reduction in flow after a period of time

$$Reduction\ in\ flow, \% = \left(\frac{original\ flow - reduced\ flow}{original\ flow}\right) \times 100$$

Example 4

- A sedimentation tank was designed to produce 500,000 gpd at start up. After 5 years in operation, the tank produces 425,000 gpd. What is the reduction in flow?

$$Reduction\ in\ flow, \% = \left(\frac{original\ flow - reduced\ flow}{original\ flow}\right) \times 100$$

$$Reduction = \left(\frac{500{,}000\ gpd\ - 425{,}000\ gpd}{500{,}000\ gpd}\right) \times 100$$

$$Reduction = \left(\frac{75{,}000\ gpd}{500{,}000\ gpd}\right) \times 100$$

$$Reduction = 15\%$$

Solids

- Total suspended solids are the amount of filterable solids in a water sample
  - Weigh dried filter
- Settleable solids will settle out due to gravity
  - Imhoff cone
- Dissolved solids are the amount of solids that pass through a filter in a water sample
  - Weigh filtered water

Solids Concentration

$$Solids\ concentration, \frac{mg}{L} = \frac{weight, mg}{volume, L}$$

$$Solids, \frac{mg}{L} = \frac{(dry\ solids, grams)(1{,}000{,}000)}{sample\ volume, mL}$$

Settleable Solids

- The settleable solids test is an easy, quantitative method to measure sediment found in water
- An Imhoff cone is filled with 1 liter of sample, stirred and allowed to settle for 60 minutes

$$Removal, \% = \left(\frac{in - out}{in}\right) \times 100$$

Example 6

- Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent is 13 mL/L and the settleable solids of the effluent is 0.5 mL/L.

$$Removal, \% = \left(\frac{in - out}{in}\right) \times 100$$

$$Removal = \left(\frac{13\frac{mL}{L} - 0.5\frac{mL}{L}}{13\frac{mL}{L}}\right) \times 100$$

$$Removal = \left(\frac{12.5\frac{mL}{L}}{13\frac{mL}{L}}\right) \times 100$$

$$Removal = 0.96 \times 100$$

$$Removal = 96\%$$

Applied Math for Water Treatment
Sedimentation

1. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 21.2 mL/L and the settleable solids of the effluent are 1.3 mL/L.

2. A sedimentation basin is 70 ft long by 30 ft wide. If the water depth is 14 ft, what is the volume of water in the tank in gallons?

3. A rectangular sedimentation basin is 70 ft long 25 ft wide and has water to a depth of 10 ft. The flow to the basin is 2,220,000 gpd. Calculate the detention time in hours for the sedimentation basin.

4. A rectangular sedimentation basin is 60 ft long and 25 ft wide. When the flow is 510 gpm, what is the surface overflow rate in gpm/ft^2?

5. A 22 ac pond receives a flow of 3.6 ac-ft per day. What is the hydraulic loading rate in gpd/ft^2?

6. A circular clarifier receives a flow of 2,520,000 gpd. If the diameter of the weir is 70 ft, what is the weir overflow rate (in gpd/ft^2)?

7. A tank is 30 ft wide and 80 ft long. If the tank contains water to a depth of 12 ft, how many gallons of water are in the tank?

8. The flow to a sedimentation tank that is 80 ft long, 20 ft wide, and 12 ft deep is 1.8 MGD. What is the detention time in the tank (in hours)?

9. A rectangular clarifier receives a flow of 5.4 MGD. The length of the clarifier is 99 feet 7 inches and the width is 78 feet 6 inches. What is the SOR in gpd/ft^2?

10. The weir in a basin measures 30 feet by 15 feet. What is the weir overflow rate (gpd/ft) when the flow is 1,098,000 gpd?

11. A flash mix chamber is 6 ft long, 5 ft wide, and 5 ft deep. It receives a flow of 9 MGD. What is the detention time in the chamber in seconds?

12. A sedimentation basin is 80 ft long and 25 ft wide. To maintain a surface overflow rate of 0.5 gallons per day per square foot, what is the maximum flow to the basin in gallons per day?

13. A circular clarifier receives a flow of 2.12 MGD. If the diameter of the weir is 60 ft, what is the weir overflow rate (in gpd/ft)?

14. A flocculation basin is 8 ft deep, 16 ft wide, and 30 ft long. If the flow through the basin is 1.45 MGD, what is the detention time (in minutes)?

15. A flash mix chamber is 4 ft square and has a water depth of 42 inches. If the flash mix chamber receives a flow of 3.25 MGD, what is the detention time (in seconds)?

16. A sedimentation tank has a total of 150 feet of weir over which the water flows. What is the weir overflow rate in gallons per day per foot of weir when the flow is 1.7 MGD? 11,333.33 gpd/ft

17. A sedimentation tank is 90 feet long and 40 feet wide and receives a flow of 5.04 MGD. Calculate the SOR in gpd/ft^2.

18. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the area of the water's surface in ft^2?

19. What is the gpd/ft^2 overflow to a circular clarifier that has the following:
    Diameter: 70 feet
    Flow: 1,950 gpm

20. The flow to a sedimentation tank that is 75 ft long, 30 ft wide, and 14 ft deep is 1,640,000 gpd. What is the detention time in the tank (in hours)?

21. A sedimentation tank 70 ft by 25 ft receives a flow of 2.05 MGD. What is the surface overflow rate (in gpd/sq ft)?

22. A flocculation basin is 50 ft long by 20 ft wide and has a water level of 8 ft. What is the detention time (in minutes) in the basin if the flow to the basin is 2.8 MGD?

23. The diameter of a tank is 90 ft. If the water depth in the tank is 25 ft, what is the volume of water in the tank (in gallons)?

24. A backwash lagoon receives a flow of 18,800 gpd. If the surface area of the pond is 16 acres, what is the hydraulic loading rate in gpd/ft^2?

25. The average width of a pond is 400 ft and the average length is 440 ft. The depth is 6 ft. If the flow to the pond is 200,000 gpd, what is the detention time (in days)?

26. A rectangular sedimentation basin has a total of 170 ft of weir. If the flow to the basin is 1,890,000 gpd, what is the weir overflow rate in gpd/ft^2?

27. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the length of the weir around the clarifier in ft?

28. The diameter of the weir in a circular clarifier is 125 feet. The flow is 6.33 MGD. What is the weir overflow rate (gpd/ft)?

29. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the surface area of the clarifier in ft^2?

30. A clarifier has a flow rate of 4,600 gpm and a diameter of 75 feet. What is the surface overflow rate in gpd/ft^2?

31. The flow rate to a particular clarifier is 528 gpm and the tank has a length of 30 feet and a width of 17.5 feet. What is the gpd/ft of weir?

32. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 13.9 mL/L and the settleable solids of the effluent are 0.7 mL/L.

33. The flow to a flocculation basin is 6,625,000 gpd. If the basin is 60 ft long, 25 ft wide, 15 ft deep, and contains water to a depth 9 ft, what is the detention time of the flocculation basin in minutes?

34. A circular clarifier has a diameter of 70 ft. If the flow to the clarifier is 1610 gpm, what is the surface overflow rate in gpm/ft^2?

35. A waste treatment pond is operated at a depth of 6 ft. The average width of the pond is 500 ft and the average length is 600 ft. If the flow to the pond is 222,500 gpd, what is the detention time (in days)?

36. A sedimentation tank has a total of 200 feet of weir which the water flows over. What is the weir overflow rate (gpd/ft) when the flow is 2.2 MGD?

37. A tank has a length of 100 feet, a width of 25 feet, and a depth of 15 feet. What is the weir length around the basin in feet?

38. The flow to a sedimentation tank is 3.05 MGD. If the tank is 80 feet long and 20 feet wide, what is the surface overflow rate in gallons per day per square foot?

39. What is the weir overflow rate of a clarifier that is 50 feet 4 inches by 44 feet 3 inches and has an influent flow of 1.87 MGD?

40. The flow through a flocculation basin is 1.82 MGD. If the basin is 40 ft long, 20 ft wide, and 10 ft deep, what is the detention time (in minutes)?

41. A tank is 80 ft long, 20 ft wide, and 16 ft deep. What is the volume of the tank (in cubic feet)?

42. The flow to a circular clarifier is 2.66 MGD. If the diameter of the clarifier is 70 ft, what is the surface overflow rate (in gpd/sq ft)?

43. The flow rate to a clarifier is 1400 gpm. If the diameter of the weir is 80 ft, what is the weir overflow rate (in gpd/ft)?

44. A clarifier with a diameter of 55 feet receives a flow of 2.075 MGD. What is the surface overflow rate (gpd/ft^2)?

45. A circular clarifier has a diameter of 60 ft and an average water depth of 12 ft. What flow rate (MGD) corresponds to a detention time of 3 hours?

46. A circular clarifier has a diameter of 80 feet. If the water depth is 12 ft, how many gallons of water are in the tank?

47. A basin 3 ft by 4 ft is to be filled to the 3-ft level. If the flow to the tank is 6 gpm, how long will it take to fill the tank (in hours)?

48. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

49. A sedimentation tank is 110 ft long and 50 ft wide. If the flow to the tank is 3.45 MGD what is the surface overflow rate (in gpd/sq ft)?

50. A tank 6 ft in diameter is to be filled to the 4-ft level. If the flow to the tank is 12 gpm, how long will it take to fill the tank (in minutes)?

51. A rectangular clarifier has a total of 163 ft of weir. What is the weir overflow rate (in gpd/ft) when the flow is 1,410,000 gpd?

52. A circular clarifier has a diameter of 80 feet. If the flow to the clarifier is 3.8 MGD, what is the surface overflow rate (gpd/ft^2)?

53. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

54. A rectangular clarifier has a total of 240 ft of weir. What is the weir overflow rate (in gpd/ft) when the flow is 2.7 MGD?

55. A tank has a diameter of 49.4 feet. What is the gallons/day per foot of weir overflow when the tank receives 1,953,000 gpd?

56. The flow to a flocculation basin is 3,625,000 gpd. If the basin is 60 ft long by 25 ft wide and contains water to a depth of 9 ft, what is the detention time of the flocculation basin (in minutes)?

57. A flocculation basin is 50 ft long by 20 ft wide and has a water depth of 10 ft. If the flow to the basin is 2,250,000 gpd, what is the detention time (in minutes)?

58. The flow to a sedimentation tank is 50,000 gpd. If the tank is 55 feet long and 15 feet wide, what is the surface overflow rate (gpd/ft^2)?

59. A pre-sedimentation pond receives a flow of 1.2 MGD. This particular pond is 115 ft long, 40 ft wide and averages a depth of 15 ft. Determine the hydraulic loading rate in gpd/ft^2?

60. A circular clarifier has a diameter of 80 ft and an average water depth of 12 ft. If the flow to the clarifier is 2,920,000 gpd, what is the detention time in hours?

61. A rectangular sedimentation basin has a total weir length of 189 ft. If the flow to the basin is 4.01 MGD, what is the weir-loading rate (in gpd/ft)?

62. The flow rate to a circular clarifier is 5.20 MGD. If the clarifier is 80 ft in diameter with water to a depth of 10 ft, what is the detention time (in hours)? 1.7 hr

ANSWERS

1. 93.9%
2. 219,912 gal
3. 1.43 hrs
4. 0.34 gpm/ft^2
5. 1.22 gpd/ ft^2
6. 11,459.16 gpd/ft
7. 215,424 gal
8. 1.91 hrs
9. 690.78 gpd/ ft^2
10. 12,200 gpd/ft
11. 10.77 sec
12. 1000 gpd
13. 11,246.95 gpd/ft
14. 28.51 min
15. 11.13 sec
16. 11,333.33 gpd/ft
17. 1,400 gpd/ ft^2
18. 2,500 ft^2
19. 730.01 gpd/ ft^2
20. 3.45 hr
21. 1,171.43 gpd/ ft^2
22. 30.82 min
23. 1,189,039.5 gal
24. 0.027 gpd/ ft^2
25. 40.39 days
26. 11,117.65 gpd/ft
27. 257.61 ft
28. 80,596.06 gpd/ft
29. 5,278.34 ft^2
30. 1,500.13 gpd/ ft^2
31. 8,003.37 gpd/ft
32. 95%
33. 21.89 min
34. 0.42 gpm/ ft^2
35. 60.5 days
36. 11,000 gpd/ft
37. 250 ft
38. 1,906.25 gpd/ ft^2
39. 9,885.47 gpd/ft
40. 47.38 min
41. 25,600 ft^3
42. 691.54 gpd/ ft^2
43. 8,021.41 gpd/ft
44. 873.82 gpd/ ft^2
45. 2.03 MGD
46. 450,954.24 gal
47. 0.75 hrs
48. 8,388.40 gpd/ft
49. 627.27 gpd/ ft^2
50. 70.46 min
51. 8,650.31 gpd/ft
52. 756.37 gpd/ ft^2
53. 394.95 gpd/ ft^2
54. 11,250 gpd/ft
55. 12,584.19 gpd/ft
56. 40.18 min
57. 47.81 min
58. 60.61 gpd/ ft^2
59. 260.87 gpd/ ft^2
60. 3.71 hr
61. 212,168.93 gpd/ft
62. 1.74 hr

Section 9

Filtration

Filtration

Filtration

- Process of separating suspended and colloidal particles waste by passing the water through a granular material
- Involves straining, settling, and adsorption

Filter Flow & Backwash Rate

- Rate at which water flows through the filter
- Can be used to verify flow meter readings

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

Example 1

- A filter 18 ft by 22 ft receives a flow of 1750 gpm. What is the filtration rate in gpm/ft^2?

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

$$\frac{gpm}{ft^2} = \frac{1750\ gpm}{18ft \times 22ft}$$

$$\frac{gpm}{ft^2} = 4.4\ {}^{gpm}/_{ft^2}$$

Example 2

- A filter that is 30 ft by 10ft has a backwash rate of 3120 gpm. What is the back wash rate in gpm/sq. ft?

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

$$\frac{gpm}{ft^2} = \frac{3120\ gpm}{30ft \times 10ft}$$

$$\frac{gpm}{ft^2} = 10.4\ {}^{gpm}/_{ft^2}$$

Filter Drop Test Velocity

- Speed at which water flows through the filter

$$\frac{ft}{min} = \frac{water\ drop, ft}{time\ of\ drop, min}$$

Example 3

- The influent to a filter is closed while the effluent valve remains open. It is measured that in 1 minute, the water level drops 1.5 feet. What is the filter drop test velocity?

$$\frac{ft}{min}=\frac{water\ drop,ft}{time\ of\ drop,min}$$

$$\frac{ft}{min}=\frac{1.5\ ft}{1\ min}$$

$$\frac{ft}{min}=1.5\frac{ft}{min}$$

Filter Backwash Rise Rate

- Upward velocity of the water during backwashing

$$\frac{in}{min}=\frac{(backwash\ rate,\frac{gpm}{ft^2})(12\frac{in}{ft})}{7.48\frac{gal}{ft^3}}$$

Example 4

- A filter has a backwash rate of 16 gpm/sq. ft. What is the backwash rate?

$$\frac{in}{min} = \frac{(backwash\ rate, \frac{gpm}{ft^2})(12\ \frac{in}{ft})}{7.48\ \frac{gal}{ft^3}}$$

$$\frac{in}{min} = \frac{(16\ \frac{gpm}{ft^2})(12\ \frac{in}{ft})}{7.48\ \frac{gal}{ft^3}}$$

$$\frac{in}{min} = 25.7\ \frac{in}{min}$$

Applied Math for Water Treatment
Filtration

1. A filter 40 ft by 20 ft receives a flow of 2230 gpm. What is the filtration rate (in gpm/sq ft)?

2. The influent valve to a filter is closed for a 5-minute period. During this time, the water level in the filter drops 12 inches. If the filter is 45 ft long by 22 ft wide, what is the gpm flow rate through the filter?

3. The influent valve to a filter is closed for 6 minutes. The water level in the filter drops 18 inches during the 6 minutes. If the filter is 35 ft long by 18 ft wide, what is the gpm flow rate through the filter?

4. During an 80 hour filter run, a total of 14.2 million gallons of water are filtered. What is the average gpm flow rate through the filter during this time?

5. A filter 18 ft long by 14 ft wide has a backwash flow rate of 3580 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

6. A backwash flow rate of 6750 gpm for a total of 6 minutes would require how many gallons of water?

7. The desired backwash pumping rate for a filter is 20 gallons per minute per square foot. If the filter is 36 ft long by 26 ft wide, what backwash pumping rate (gallons per minute) will be required?

8. A filter 38 ft long by 22 ft wide receives a flow of 3,550,000 gpd. What is the filtration rate (in gallons per minute per square foot)?

9. A filter 40 ft by 20 ft treats a flow of 2.2 MGD. What is the filtration rate (in gpm/sq ft)?

10. A filter is 40 ft long by 30 ft wide. To verify the flow rate through the filter, the filter influent valve is closed for a 5-minute period and the water drop is measured. If the water level in the filter drops 14 inches during the 5 minutes, what is the gpm flow rate through the filter?

11. A filter has a surface area of 32 ft by 18 ft. If the filter receives a flow a 2,150,000 gpd, what is the filtration rate (in gallons per minute per square foot)?

12. The backwash flow rate for a filter is 3700 gpm. If the filter is 15 ft by 20 ft, what is the backwash rate expressed as gpm/ft?

13. A filter is 38 ft long by 18 ft wide. During a test of filter flow rate, the influent valve to the filter is closed for 5 minutes. The water level drops 22 inches during this period. What is the filtration rate for the filter (in gallons per minute per square foot)?

14. A backwash flow rate of 6650 gpm for a total backwashing period of 6 minutes would require how many gallons of water for backwashing?

15. A filter 30 ft by 18 ft has a backwash flow rate of 3650 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

16. The desired backwash pumping rate for a filter is 24 gallons per minute per square foot. If the filter is 26 ft long by 22 ft wide, what backwash pumping rate (gallons per minute) will be required?

17. A filter 14 ft by 14 ft has a backwash flow rate of 4750 gpm. What is the filter backwash rate in gpm/sq ft?

18. A filter with a surface area of 380 square feet has a backwash flow rate of 3510 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

19. A filter 38 ft long by 24 ft wide produces a total of 18.1 million gallons during a 71.6-hour filter run. What is the average filtration rate for this filter run in gpm/ft^2?

20. During an 80-hour filter run, a total of 14.2 million gallons of water are filtered. What is the average gpm flow rate through the filter during this time?

21. A filter 40 ft by 25 ft receives a flow of 3100 gpm. What is the filtration rate (in gpm/sq ft)?

22. A filter 20 ft long by 18 ft wide receives a flow of 1760 gpm. What is the filtration rate (in gallons per minute per square foot)?

23. A filter is 42 ft long by 22 ft wide. If the desired backwash rate is 19 gallons per minute per square foot, what backwash pumping rate (gallons per minute) will be required?

24. For a backwash flow rate of 9100 gpm and a total backwash time of 7 minutes, how many gallons of water will be required for backwashing?

25. A total of 59,200 gallons of water will be required to provide a 7-minute backwash of a filter. What depth of water in feet is required in the backwash water tank to provide this backwashing capability? The tank has a diameter of 40 ft.

26. At an average flow rate through a filter of 3200 gpm, how long a filter run (in hours) would be required to produce 16 million gallons of water?

27. A filter is 33 ft long by 24 ft wide. During a test of flow rate, the influent valve to the filter is closed for 6 minutes. The water level drops 21 inches during this period. What is the filtration rate for the filter (in gallons per minute per square foot)?

28. A backwash rate of 7150 gpm is desired for a total backwash time of 7 minutes. What depth of water in feet is required in the backwash water tank to provide this much water? The diameter of the tank is 40 ft.

29. A filter 25 ft by 15 ft. If the backwash flow rate is 3400 gpm, what is the filter backwash rate (in gpm/sq. ft)?

30. A filter 33 ft long by 24 ft wide produces a total of 14.2 million gallons during a 71.4-hour filter run. What is the average filtration rate for this filter run in gpm/ft^2?

31. A filter has a surface area of 880 sq ft. If the flow treated is 2850 gpm, what is the filtration rate (in sq. ft)?

32. At an average flow rate through a filter of 3200 gpm, how long a filter run (in hours) would be required to produce 16 million gallons of filtered water?

33. A filter 26 ft by 60 ft receives a flow of 2500 gpm. What is the filtration rate (in gpm/sq ft)?

34. A filter 25 ft by 30 ft at a rate of 3300 gpm. What is this backwash rate expressed as gpm/ft^2?

35. The flow rate through a filter is 2.97 MGD. What is the flow rate in gpm?

36. How many gallons of water would be required to provide a backwash flow rate of 4670 gpm for a total of 5 minutes?

37. A filter is 22 ft square. If the desired backwash rate is 16 gallons per minute per square foot, what backwash pumping rate (gallons per minute) will be required?

38. A filter 18 ft long by 14 ft wide has a backwash rate of 3080 gpm. What is this backwash rate expressed in inches minute of water?

39. The Quahog Water Treatment Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter measures 12 feet wide by 16 feet long and 24 feet deep. The influent to Filter 6 is closed while the effluent remains open to perform a drop test. Using a stop watch and a hook gauge, it is noted that the water level in the filter drops 6 inches in 80 seconds. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 15 seconds.

    a. What is the filtration rate in gallons per minute per square foot?

    b. What is the backwash rate in gallons per minute per square foot?

40. The Central City Water Treatment Plant treats an average of 7.2 MGD. The water is split equally to each of the 12 filters. Each filter measures 12.5 feet wide by 16.5 feet long and 24 feet deep. Influent to Filter 6 is closed while the effluent remains open to perform a drop test. Using a stop watch and a hook gauge, it is noted that the water level in the filter drops 6 inches in 75 seconds. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 13 seconds.

    a. What is the filtration rate in gallons per minute per square foot?

    b. What is the backwash rate in gallons per minute per square foot?

Answers

1. 2.78 gpm/ft^2
2. 481.04 gpm
3. 1178.1 gpm
4. 2958.33 gpm
5. 14.21 gpm/ft^2
6. 40,500 gal
7. 936 ft^2
8. 2.95 gpm/ft^2
9. 1.91 gpm/ft^2
10. 2094.46 gpm
11. 2.59 gpm/ft^2
12. 12.33 gpm/ft^2
13. 2.74 gpm/ft^2
14. 39,900 gal
15. 6.76 gpm/ft^2
16. 13,728 gpm
17. 24.23 gpm/ft^2
18. 9.24 gpm/ft^2
19. 4.62 gpm/ft^2
20. 2958.33 gpm
21. 3.1 gpm/ft^2
22. 4.89 gpm/ft^2
23. 11,556 gpm
24. 63,700 gal
25. 6.3 ft
26. 83.33 hr
27. 2.18 gpm/ft^2
28. 5.33 ft
29. 9.07 gpm/ft^2
30. 4.19 gpm/ft^2
31. 3.24 gpm/ft^2
32. 83.33 hr
33. 1.6 gpm/ft^2
34. 4.4 gpm/ft^2
35. 2061.8 gpm
36. 23,350 gal
37. 7744 gpm
38. 19.61 in/min
39. a. 2.81 gpm/ft^2
    b. 14.96 gpm/ft^2
40. a. 2.99 gpm/ft^2
    b. 17.26 gpm/ft^2

Section 10

Laboratory Calculations

LABORATORY CALCULATIONS

MOLARITY & NORMALITY

AWWA Basic Science Concepts and Applications

MOLARITY

- Once the number of moles of solute has been determined, the molarity of a solution may be calculated
  - Molarity is the concentration of a solution

$$Molarity = \frac{moles\ of\ solute}{liters\ of\ solution}$$

$$M = \frac{mol}{L}$$

EXAMPLE 1

- If 0.4 mol of NaOH is dissolved in 2 L of solution, what is the molarity of the solution?

$$Molarity = \frac{moles\ of\ solute}{liters\ of\ solution}$$

$$M = \frac{0.4\ mol}{2\ L}$$

$$M = 0.2\ \mathrm{M}$$

NUMBER OF MOLES

- If 150 g of sodium hydroxide (NaOH) is mixed into water to make a solution, how many moles of solute have been used? (molecular weight of NaOH is 40.00)

$$\#\ of\ moles = \frac{total\ weight}{molecular\ weight}$$

$$\#\ of\ mol = \frac{150\ g}{40.00\ g}$$

$$\#\ of\ mol = 3.75\ mol\ of\ NaOH$$

EQUIVALENT WEIGHTS

- The equivalent weight of an element or compound is the weight of that element or compound that in a given reaction has the same combining capacity as 8 grams of oxygen or as 1 gram of hydrogen
- The equivalent weight of a reactant will be *equal* to the reactant's molecular weight

$$milliequivalent = (mL\ of\ sol'n)(normality)$$

NUMBER OF EQUIVALENT WEIGHTS

- If 90 grams of sodium hydroxide (NaOH) were used in making up a solution, how many equivalent weights were used. Use 40.00 g as the equivalent weight for NaOH.

$$\#\ equivalent\ weights = \frac{total\ weight}{equivalent\ weight}$$

$$\frac{amt.\ used\ in\ sol'n}{weight\ of\ compound}$$

$$\#\ equivalent\ weights = \frac{90\ g}{40\ g}$$

$$\#\ equivalent\ weights = 2.25\ equivalent\ weights$$

NORMALITY

- When you have determined the number of equivalent weights of the dissolved solute, you can determine the normality of the solution
- Normality is a measure of the reacting power of a solution
  - i.e. 1 equivalent of a substance reacts with 1 equivalent of another substance

$$Normality = \frac{\#\ of\ equivalent\ weights\ of\ solute}{liters\ of\ solution}$$

$$N = \frac{equivalents}{L}$$

EXAMPLE 2

- If 2.1 equivalents of NaOH were used in making up 1.75 L of solution, what is the normality of the solution?

$$Normality = \frac{\#\ of\ equivalent\ weights\ of\ solute}{liters\ of\ solution}$$

$$N = \frac{2.1\ equivalents}{1.75\ liters}$$

$$N = 1.2\ N$$

TWO NORMAL EQUATION

- $N = normality$
- $V = volume\ or\ flow$

$$N_1 \times V_1 = N_2 \times V_2$$

EXAMPLE 3

- To titrate a sample for alkalinity, 200 mL 0.02 N H_2SO_4 is needed. How much mL of 1.0 N H_2SO_4 is needed to obtain the desired amount and concentration?

$$N_1 \times V_1 = N_2 \times V_2$$

$$(0.02\ N)(200\ mL) = (1.0\ N)(V_2)$$

$$\frac{(0.02\ N)(200\ mL)}{1.0\ N} = V_2$$

$$4.0\ mL = V_2$$

THREE NORMAL EQUATION

- $N = normality$
- $V = volume\ or\ flow$

$$(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3)$$

Be sure to follow order of operations!

HARDNESS, ALKALINITY

AWWA Basic Science Concepts and Applications

HARDNESS

- Measurement of the effects that water impurities have on corrosion scaling and soap
- Measured in mg/L as $CaCO_3$

$$Hardness = \frac{(Titrant\ volume, mL)(1000)}{sample\ volume, mL}$$

EXAMPLE 4

- If 18 mL of EDTA were used to titrate a sample to the end point of a 100 mL sample, what is the hardness in mg/L as $CaCO_3$?

$$Hardness = \frac{(titrant\ volume, mL)(1000)}{sample\ volume, mL}$$

$$Hardness = \frac{(18\ mL)(1000)}{100\ mL}$$

$$Hardness = 180\ {}^{mg}/_{L}\ as\ CaCO_3$$

ALKALINITY

- A measure of the water's ability to resist change to pH
- Measured in mg/L as $CaCO_3$
- Composed of the carbonate, bicarbonate, and hydroxide content of the water

$$Alkalinity = \frac{(titrant\ vol, mL)(acid\ normality)(50{,}000)}{sample\ volume, mL}$$

EXAMPLE 5

- A 100 mL sample was titrated a pH of 8.3 with 9 mL of 0.02N H_2SO_4. What is the alkalinity?

$$alkalinity = \frac{(titrant\ vol., mL)(acid\ normality)(50{,}000)}{sample\ volume, mL}$$

$$alkalinity = \frac{(9\ mL)(0.02\ N)(50{,}000)}{100\ mL}$$

$$alkalinity = 90\ {}^{mg}/_{L}\ CaCO_3$$

TOTAL AND PHENOLPHTHALEIN ALKALINITY

- Phenolphthalein alkalinity (P) found by titrating sample to pH of 8.3
  - Phenolphthalein powder pillow
- Total alkalinity (T) found by titrating sample to pH of 4.5
  - Bromcresol green – methyl red powder pillow
  - Methyl orange powder pillow
- Alkalinity is composed of the carbonate, bicarbonate, and hydroxide content of the water

ALKALINITY RELATIONSHIPS

Result of Titration	Hydroxide	Carbonate	Bicarbonate
$P = 0$	0	0	T
$P < {}^{1}/_{2}\ T$	0	$2P$	$T - 2P$
$P = {}^{1}/_{2}\ T$	0	$2P$	0
$P > {}^{1}/_{2}\ T$	$2P - T$	$2(t - p)$	0
$P = T$	T	0	0

P = Phenolphthalein alkalinity
T = Total alkalinity

EXAMPLE 6

- A water sample is tested for phenolphthalein and total alkalinity. If the phenolphthalein alkalinity is 10 mg/L as $CaCO_3$, and the total alkalinity is 52 mg/L as $CaCO_3$, what are the bicarbonate, carbonate, and hydroxide alkalinities of the water?

$$52 \div 2 = 26\ {}^{mg}/_{L}$$

$$10 < 26$$

$$P < {}^{1}/_{2}T$$

EXAMPLE 6 CONT'D

$$Hydroxide = 0$$

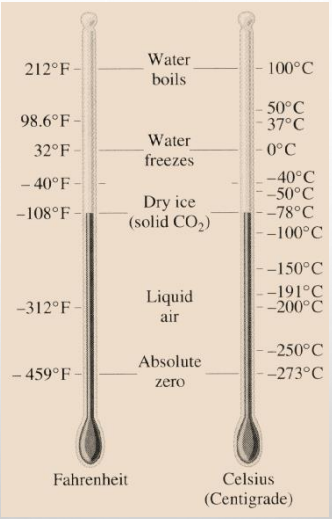
$$Carbonate = 2P$$
$$Carbonate = 2(10)$$
$$Carbonate = 20\ mg/L$$

$$Bicarbonate = T - 2P$$
$$Bicarbonate = 52 - 2(10)$$
$$Bicarbonate = 52 - 20$$
$$Bicarbonate = 32\ mg/L$$

TEMPERATURE CONVERSIONS

TEMPERATURE SCALES

The **Fahrenheit** scale is named for the 18th-century German physicist Daniel Fahrenheit.
His scale is based on 32 for the freezing point of water and 212 for the boiling point of water, the interval between the two being divided into 180 parts.
The scale was in common use in English speaking countries until the 1970's when Europe and Canada adopted the centigrade (Celsius) scale.
The U.S is the only country that still uses the Fahrenheit scale.



The **Celsius** temperature scale is named for the in the Swedish astronomer Anders Celsius who invented the scale in 1742.

The scale is based on 0 for the freezing point of water and 100 for the boiling point of water.

It is sometimes called the centigrade scale because of the 100-degree interval between the defined points.

23

TEMPERATURE FORMULAS

- Degrees Fahrenheit

$$°F = (°C)\left(^{9}/_{5}\right) + 32$$

$$°F = (°C)(1.8) + 32$$

- Degrees Celsius

$$°C = (°F - 32)\left(^{5}/_{9}\right)$$

$$°C = \frac{(°F - 32)}{1.8}$$

Remember your Order of Operations!!

EXAMPLE 7

- Determine the temperature in °F if the temperature is measured as 43°C.

$$°F = (°C)(1.8) + 32$$

$$°F = (43)(1.8) + 32$$

$$°F = 77.4 + 32$$

$$°F = 109.4°F$$

EXAMPLE 8

- Water temperature is measured with a pH probe to be 87 °F. What is this in Celsius?

$$°C = \frac{(°F - 32)}{1.8}$$

$$°C = \frac{(87 - 32)}{1.8}$$

$$°C = \frac{55}{1.8}$$

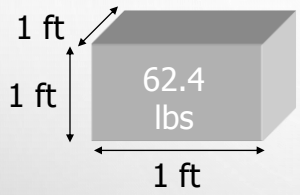
$$°C = 30.56°C$$

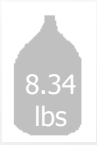
SPECIFIC GRAVITY AND DENSITY

DENSITY

- weight per unit volume
  - solids and gases expressed in lb/ft^3
  - liquids measured in lb/gal or lb/ft^3
- density of water varies slightly with temperature and pressure
- density of gases changes significantly with changes in temperature and pressure

DENSITY OF WATER





1 gal

The density of water is

62.4 lbs/ft^3

or

8.34 lbs/gal

SPECIFIC GRAVITY

- compares density of a substance to a standard density
- does not have units
- for solids and liquids
  - compare to standard density of water
    - 62.4 lb/ft^3
    - 8.34 lb/gal

SPECIFIC GRAVITY

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

- Weights can be measured in $^{lb}/_{gal}$ or $^{lb}/_{ft^3}$
  - Be sure the units are consistent within the equation

EXAMPLE 9

- Determine the specific gravity of a liquid chemical that has a density of 10.5 lb/gal.

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

$$S.G. = \frac{10.5\ ^{lb}/_{gal}}{8.34\ ^{lb}/_{gal}}$$

$$S.G = 1.26$$

COMPOSITE SAMPLES

COMPOSITE SAMPLES

- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

EXAMPLE 10

- Filter effluent flows at 2.0 gpm/ft^2 on average. You want to collect 5 samples for a composite sample of 10 gallons. If the water is flowing at 2.7 gpm/ft^2 at the time of sampling, what should the volume of sample #1 be in gallons?

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

EXAMPLE 10 CONT'D

Avg flow= 2.0 gpm/ft^2
samples = 5
Total volume = 10 gal
Inst. Flow = 2.7 gpm/ft^2

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

$$= \frac{(2.7\ gpm/ft^2)(10\ gal)}{(5)(2.0\ gpm/ft^2)}$$

$$= \frac{27\ gal}{10}$$

$$= 2.7\ gal$$

Applied Math for Water Treatment
Laboratory Calculations

1. Mechanical seals should never exceed 160°F. What is this temperature expressed in °C?

2. A sample of water contains 25 mg/L phenolphthalein alkalinity as $CaCo_3$. If the total alkalinity of the water is 121 mg/L as $CaCo_3$, what is the hydroxide, carbonate, and bicarbonate alkalinity?

3. What is the percent removal across a settling basin if the influent turbidity is 8.8 ntu and the effluent turbidity at the settling basin is 0.89 ntu?

4. The phenolphthalein alkalinity of a water sample is 12 mg/L as $CaCO_3$, and the total alkalinity is 23 mg/L as CaCO3. What are the bicarbonate, carbonate, and hydroxide alkalinities of the water? 0; 22; 1

5. The atomic weight of a certain chemical is 66. If 35 grams of the chemical are used to make up a 1 liter solution, how many moles are used? 1.9 moles

6. To determine the average turbidity coming into a plant, an operator collects 5 samples to combine into a 250 mL composite sample. The average flow at the intake is 230,000 gpd. If the flow at the time of the sample collection is 180 gpm. How many mL should the sample portion be at the time of collection?

7. A 100-milliliter (mL) sample of water is tested for alkalinity. The normality of the sulfuric acid used for titrating is 0.02 N. If 0.5 mL titrant is used to pH 8.3 and 5.7 mL titrant to pH 4.6, what are the phenolphthalein and total alkalinity of the sample? 5; 57

8. A 100 mL water sample is tested for phenolphthalein alkalinity. If 2 mL of titrant is used to reach pH of 8.3 and the sulfuric acid solution has a normality of 0.02 N, what is the phenolphthalein alkalinity of the water (in mg/L as $CaCo_3$)? 20 mg/L as $CaCo_3$

9. Determine the specific gravity of a gold bar that weighs 521.47 lb and occupies a space of 0.433 ft^3.

10. What is the molarity of 2 moles of solute dissolved in 1 liter of solvent? 2M

11. How many pounds of liquid can be pumped per day?
    Pump rate desired: 25 gpm
    Liquid weight: 74.9 lbs/ft^3

12. Find the density (lbs/ft^3) of a certain oil that has a S.G. of 0.92. 57.41 lb/ft^3

13. If 2 equivalents of a chemical are dissolved in 1.5 liters of solution, what is the normality of the solution? 1.33 N

14. Convert 170°F to °C.

15. Three hundred grams of calcium is how many equivalents of calcium? (The equivalent weight of calcium is 20.04.) 15

16. Find the density (lbs/gal) of caustic soda that has a S.G. of 1.530.

17. A gallon of solution is weighed. After the weight of the container is subtracted, it is determined that the weight of the solution is 9.1 lb. What is the density of the solution in lb/ft^3?

18. An 800 mL solution contains 1.6 equivalents of a chemical. What is the normality of the solution? 2 N

19. What is the turbidity removal efficiency through a water plant if the source water turbidity is 18.8 ntu and the treated water entering the distribution system is 0.035 ntu?

20. The magnesium content of water is 25 mg/L. How many milliequivalents/liter is this? The equivalent weight of magnesium is 12.15.) 2.06 milliequivalents/liter

21. The density of an unknown liquid is 74.1 lb/ft^3. What is the specific gravity of the liquid?

22. What is the iron removal efficiency through a water plant if the source water iron content is 4.25 mg/L and the treated water entering the distribution system is 0.030 mg/L?

23. A 100-milliliter (mL) water sample is tested for phenolphthalein alkalinity. If 1.40 mL titrant is used to pH 8.3 and the normality of the sulfuric acid solution is 0.02 N, what is the phenolphthalein alkalinity of the water (in mg/L as $CaCO_3$)? 14 mg/L

24. The effluent of a treatment plant is 23°C. What is this expressed in degrees Fahrenheit?

25. What is the specific gravity of a polymer solution that weighs 11.1 lb/gal?

26. If 2.9 moles of solute are dissolved in 0.8 liter of solution, what is the molarity of the solution? 3.6 M

27. Convert 17°C to degrees Fahrenheit.

28. A water sample is found to have a phenolphthalein alkalinity of 0 mg/L and a total alkalinity of 67 mg/L. What are the bicarbonate, carbonate, and hydroxide alkalinities of the water? 67; 0; 0

29. What is the density of a substance in pounds per cubic foot if it weighs 29.27 kg and occupies a space of 0.985 ft^3?

30. Alkalinity titrations on a 100-mL water sample gave the following results: 1.5 mL titrant used to pH 8.3, and 2.9 mL total titrant used to pH 4.5. The normality of the sulfuric acid was 0.02 N. What are the phenolphthalein, total, bicarbonate, carbonate, and hydroxide alkalinities of the water? 0; 30; 0

31. The magnesium content of a water source averages 0.24 mg/L. What is the percent removal if the treated water averages 0.020 mg/L Mg?

32. A 100-milliliter (mL) sample of water is tested for phenolphthalein and total alkalinity. A total of 0 mL titrant is used to pH 8.3 and 6.9 mL titrant is used to titrate to pH 4.4. The normality of the acid used for titrating is 0.02 N. What are the phenolphthalein and total alkalinity of the sample (in mg/L as CaCO3)? 0; 69 mg/L

33. A 1.7 molar solution is to be prepared. If a 900 mL solution is to be prepared, how many moles solute will be required? 1.53 moles

34. A certain pump delivers 14 gallons of water per minute.
    A. How many lbs of water does the pump deliver in 24 hours?
    B. How many lbs/day will the pump deliver if the liquid weighs 8.1 lbs/gal?

35. A tank holds 1,240 gallons of a certain liquid. The specific gravity is 0.93. How many pounds of liquid are in the tank?

36. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16 mL and the settleable solids of the effluent are 0.8 mL/L. 95%

37. Determine the specific gravity of a polymer solution that weighs 1067 lb/gal.

38. The molecular weight of calcium is 40. If a total of 28 grams of calcium are used in making up a 1-liter solution, how many moles are used? 0.7 moles

39. Convert 43°C to degrees Fahrenheit.

40. If 2.3 equivalents of a chemical are dissolved in 1.4 liters of solution, what is the normality of the solution? 1.6N

41. The influent to a treatment plant has a temperature of 75°F. What is the temperature expressed in degrees Celsius?

42. If the influent turbidity for a water plant is 17.5 ntu and the effluent turbidity is 0.03, what is the percent removal?

43. What is the molarity of a solution that has 0.5 moles solute dissolved in 1800 mL of solution? 0.28

44. What is the specific gravity for a solution that weighs 9.44 lb/gal?

45. To preserve a bacteriological sample, the sample must be cooled to 4°C. What is this expressed in degrees Fahrenheit?

46. What is the turbidity removal efficiency through a water plant if the source water turbidity is 22.6 ntu and the treated water entering the distribution system is 0.040 ntu?

47. A certain pump delivers 23 gallons per minute.
    A. How many lbs of water does the pump deliver in 1 minute?
    B. How many lbs/min will the pump deliver if the liquid weighs 71.9 lbs/ft^3?

48. Find the density (lbs/gal) of ferric chloride that has a S.G. of 1.140.

49. A 780 milliliter solution contains 1.3 equivalents of a chemical. What is the normality of the solution? 1.7N

50. Find the density (lbs/ft^3) of potassium permanganate that has a S.G. of 1.522.

51. What is the specific gravity of an unknown liquid that has a density of 68.4 lb/ft^3?

Answers

1. 71.1°C
2. H=0; C=50; B=71
3. 89.9%
4. H=1; C=22; B=0
5. 1.88
6. 56.4 mL
7. 5 mg/L; 57 mg/L
8. 20 mg/L
9. 19.3
10. 2 M
11. 360,481.28 lb/day
12. 57.41 lb/ft^3
13. 1.33N
14. 76.67°C
15. 15
16. 12.76 lb/gal
17. 68.07 lb/ft^3
18. 2 N
19. 99.81%
20. 2.06
21. 1.19
22. 99.29%
23. 14 mg/L
24. 73.4°F
25. 1.33
26. 3.63 M
27. 62.6°F
28. H=0; C=0; B=67
29. 65.45 lb/ft3
30. H=1; C=28; B=0
31. 91.67%
32. 69%
33. 1.53 moles
34. A. 168,134.4 lb/day
    B. 163,296 lb/day
35. 9,617.69 lb
36. 95%
37. 127.94
38. 0.7
39. 109.4°F
40. 1.64 N
41. 23.89°C
42. 99.83%
43. 0.28
44. 1.13
45. 39.2°F
46. 99.82%
47. A. 191.82 lb/min
    B. 221.08 lb/min
48. 9.51 lb/gal
49. 1.67 N
50. 94.97 lb/ft^3
51. 1.10

Section 11

Fluoridation

Fluoridation

Fluoridation

- The process of adding fluoride to drinking water to prevent dental caries in children

Common Name	Chemical Formula	% Purity	Available Fluoride Ion (AFI)
Sodium Fluoride	NaF	98%	45.2%
Sodium Fluorosilicate	Na_2SiF_6	98.5%	60.7%
Fluorsilicic Acid	H_2SiF_6	23%	79.2%

Fluoride Feed Rate

$$Feed\ rate, \frac{lb}{day} = \frac{\left(dose, \frac{mg}{L}\right)(flow, MGD)\left(8.34\frac{lb}{gal}\right)}{(Available\ fluoride\ ion)(Purity)}$$

- For fluoride saturators

$$Feed\ rate, gpm = \frac{(flow, gpm)\left(dose, \frac{mg}{L}\right)}{18{,}000\ \frac{mg}{L}}$$

Example 1

- A water plant produces 2 MGD. The desired fluoride concentration in the finished water is 1.3 mg/L. If they feed sodium fluorosilicate, what is the feed rate in lb/day? (AFI=60.7%; % purity=98.5%)

$$Feed\ rate, \frac{lb}{day} = \frac{\left(dose, \frac{mg}{L}\right)(flow, MGD)\left(8.34\frac{lb}{gal}\right)}{(Available\ fluoride\ ion)(Purity)}$$

$$\frac{lb}{day} = \frac{\left(1.3\ \frac{mg}{L}\right)(2\ MGD)\left(8.34\frac{lb}{gal}\right)}{(0.607)(0.985)}$$

$$\frac{lb}{day} = 36.27\ \frac{lb}{day}$$

Example 2

- A saturator is used to fluoridate 180 gpm to achieve a concentration of 0.9 mg/L in the finished water, what would be the feed rate in gpm? (AFI=98%; % purity=45.2%)

$$feed\ rate, gpm = \frac{(flow, gpm)\left(dose, \frac{mg}{L}\right)}{18{,}000\ \frac{mg}{L}}$$

$$gpm = \frac{(180\ gpm)\left(0.9\frac{mg}{L}\right)}{18{,}000\frac{mg}{L}}$$

$$gpm = 0.009\ \frac{gal}{min}$$

$$flow = \frac{(4000\frac{gal}{min})\left(1440\frac{min}{day}\right)}{1{,}000{,}000\frac{gal}{MG}}$$

$$flow = 5.76\ MGD$$

Example 3

- If a plant's flow rate is 4000 gpm and the dosage needed is 0.8 mg/L, what is the fluoride feed rate when feeding fluorosilicic acid? (AFI=23%; % purity=79.2%)

$$Feed\ rate, \frac{lb}{day} = \frac{\left(dose, \frac{mg}{L}\right)(flow, MGD)\left(8.34\frac{lb}{gal}\right)}{(Available\ fluoride\ ion)(Purity)}$$

$$\frac{lb}{day} = \frac{\left(0.8\ \frac{mg}{L}\right)(5.76MGD)\left(8.34\frac{lb}{gal}\right)}{(0.23)(0.792)}$$

$$\frac{lb}{day} = 210.97\frac{lb}{day}$$

Applied Math for Water Treatment
Fluoridation

1. A fluoride dosage of 1.6 mg/L is desired. The flow to be treated is 989,000 gpd. How many lb/day dry sodium silicofluoride (Na2SiF6) will be required if the commercial purity of the Na2SiF6 is 98% and the percent of fluoride ion in the compound is 60.6%? Assume the raw water contains no fluoride.

2. A plant feeds 1.0 gallons per minute of sodium fluoride from its saturator to treat 20,000 gpm of water. What is the calculated dosage?

3. If it is known that the plant rate is 4,000 gpm and the dosage needed is 0.8 mg/L, what is the fluoride feed rate in lbs/day using fluorosilicic acid?

4. A small water plant has a daily production rate of 180 gpm and the natural fluoride level is 0.1 mg/L. If 1.0 mg/L fluoride is desired in the water, what feed rate in mL/min of sodium fluoride from a saturator must be maintained?

5. A flow of 330,000 gpd is treated with sodium fluoride (NaF) at the rate of 6 lb/day. The commercial purity of the sodium fluoride is 98%, and the fluoride ion content of NaF is 45.25%. Under these conditions, what is the fluoride ion dosage (in mg/L?

6. A plant uses 1.9 gpm of solution from its saturator in treating 36,000 gallons per minute of water. What is the calculated dosage in mg/L?

7. Express a concentration of 27 lb per million gallons as milligrams per liter.

8. A flow of 810,000 gpd is to be treated with sodium fluoride (NaF). The raw water contains 0.08 mg/L fluoride, and the desired fluoride level in the finished water is 1.2 mg/L. What should be the chemical feed rate (in lb/day)? The chemical purity of the sodium fluoride is 98% while the percent fluoride ion in the compound is 45.2%.

9. A desired solution feed rate has been determined to be 80 gpd. What is this feed rate expressed in milliliters per minute?

10. Convert 1.6 mg/L to lb/million gallons.

11. A small water plant uses sodium fluoride from a saturator at a rate of 1.0 gpm and the plant treats 4500 gpm. What is the calculated dosage in mg/L?

12. Convert 28,000 mg/L to percent.

13. A flow of 1,880,000 gpd is to be treated with sodium fluoride (NaF) containing 0.44 lb of fluoride ion. The raw water contains 0.09 mg/L and the desired fluoride level in the finished water is 1.4 mg/L. What should be the chemical feed rate (in lb/day)? The chemical purity of the sodium fluoride is 98% while the percent fluoride ion in the compound is 45.2%.

14. How many lb of sodium fluoride (98% pure) must be added to 600 gallons of water to make a 3% solution of sodium fluoride?

15. A water plant produces 1.0 MGD and has less than 0.1 mg/L of natural fluoride. What would the fluoride feed rate be in gpm to obtain 1.0 mg/L in the water using a fluoride saturator?

16. A flow of 2,880,000 gpd is to be treated with sodium silicofluoride (Na2SiF6). The raw water contains no fluoride. If the desired fluoride concentration in the water is 1.4 mg/L, what should be the chemical feed rate (in lb/day)? The manufacturer's data indicate that each lb of Na2SiF6 contains 0.8 lb of fluoride ion. Assume the raw water contains no fluoride. The chemical purity of the sodium fluoride is 98.5% while the percent fluoride ion in the compound is 60.7%.

17. Express a concentration of 25 lb/million gallons as milligrams per liter.

18. Convert 6600 mg/L to percent.

19. Express 2.6% concentration in terms of milligrams per liter concentration.

20. A flow of 3.08 MGD is to be treated with sodium fluoride (NaF). The raw water contains no fluoride, and the desired fluoride concentration in the finished water is 1.1 mg/L. What should be the chemical feed rate (in lb/day)? The chemical purity of the sodium fluoride is 98% while the percent fluoride ion in the compound is 45.2%.

21. A flow of 2.88 MGD is to be treated with a 20% solution of hydrofluosilicic acid. The raw water contains no fluoride, and the desired fluoride concentration is 1.1 mg/L. The acid weighs 9.8 lb/gal. What should be the solution feed rate (in milliliters per minute)? The percent fluoride content of acid is 80%.

22. Express a concentration of 22 lb/million gallons as milligrams per liter.

23. Express 29% concentration in terms of milligrams per liter.

24. A fluoride dosage of 1.5 mg/L is desired. How many lb/day of 98% pure dry sodium fluoride (NaF) will be required if the flow to be treated is 2.45 MGD? The percent fluoride ion in NaF is 45.25%.

Answers

1. 22.22 lb/day
2. 0.9 mg/L
3. 211.12 lb/day
4. 34.11 mL/min
5. 0.97 mg/L
6. 0.95 mg/L
7. 3.24 mg/L
8. 17.08 lb/day
9. 210.56 mL/min
10. 13.36 lb/MG
11. 4.0 mg/L
12. 2.8%
13. 46.37 lb/day
14. 153.18 lb
15. 55.52 gal/day
16. 56.24 lb/day
17. 2.99 mg/L
18. 0.66%
19. 26,000 mg/L
20. 63.79 lb/day
21. 44.35 mL/min
22. 2.64 mg/L
23. 290,000 mg/L
24. 69.11 lb/day
25. 10.84 lb/gal

Section 12

Miscellaneous

Miscellaneous

Gallons/capita/day

- The average amount of water each person in a particular area uses on a daily basis

$$gallons/capita/day = \frac{volume\ of\ water\ produced, gpd}{population}$$

Example 1

- A water utility is expanding their treatment plant. The want to be able to supply 21 MGD to 125,000 persons. What would be the gallons/capita/day?

$$gal/_{capita}/_{day} = \frac{volume\ of\ water\ produced, gpd}{population}$$

$$gal/_{capita}/_{day} = \frac{21{,}000{,}000\ gpd}{125{,}000\ capita}$$

$$gal/_{capita}/_{day} = 168\ gpd/capita$$

Averages

- By calculating averages, a group of data is represented by a single number

$$Mean\ = \frac{Sum\ of\ all\ measurements}{Number\ of\ measurements\ used}$$

Example 3

- What is the average temperature for a week given the following data:

$$72°\text{F}, 70°\text{F}, 79°\text{F}, 80°\text{F}, 77°\text{F}, 77°\text{F}, 73°\text{F}$$

$$Mean = \frac{Sum\ of\ all\ measurements}{Number\ of\ measurements\ used}$$

$$Mean = \frac{72 + 70 + 79 + 80 + 77 + 77 + 73}{7}$$

$$Mean = \frac{528}{7}$$

$$Mean = 75.4°\text{F}$$

Geometric Mean

- Indicates the central tendency or typical value of a set of numbers by using the product of their values
- The n^{th} root of the product of *n* numbers

$$[(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$$

$$or$$

$$\sqrt[n]{(X_1)(X_2)(X_3)(X_4)(X_n)}$$

- When calculating geometric mean, any value of **0** will be put into the equation as a **1**

Geometric Mean

$$60 \quad 100 \quad 0 \quad 0$$

$$Geometric\ Mean = [(X_1)(X_2)(X_3) \ldots (X_n)]^{1/n}$$

- Step 1: 1/n
  - 1 divided by the number of test results. For our example above, there are four test results.
  - $1 \div 4 = 0.25$ (write this number down, you will use it in Step 3)
- Step 2: Multiply all of the test results together and punch the = button on the calculator. Remember to count 0 as a 1.
  - $60\ x\ 100\ x\ 1\ x\ 1 = 6000$ (Do Not clear out your calculator)
- Step 3: Input into calculator

$$6000^{0.25} = 8.8011$$

Example 2

- Calculate the geometric mean for the following fecal coliform test results: 60, 100, 0, 0, 40, 20, 20, 45, 55, 60, 20, 20

$$[(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$$

Step 1

$$^1/_{12} = 0.08333$$

Step 2

$$(60)(100)(1)(1)(40)(20)(20)(45)(55)(60)(20)(20) = 5{,}702{,}400{,}000{,}000{,}000$$

Step 3

$$5{,}702{,}400{,}000{,}000{,}000^{\ 0.08333}$$

$$20.3$$

Leakage

- To determine the amount of water lost due to a leak

$$leakage, gpd = \frac{volume, gal}{time, days}$$

Example 2

- A water leak is found in a pipe gallery. It is estimated that approximately 3,000 gallons was lost over a day and a half. What is the leakage in gallons per day?

$$leakage, gpd = \frac{volume, gal}{time, days}$$

$$leakage, gpd = \frac{3{,}000\ gal}{1.5\ days}$$

$$leakage, gpd = 2{,}000\ gpd$$

Slope

- The **slope** is a measure of the steepness of a line, or a section of a line, connecting two points

$$slope, \% = \frac{elevation\ change}{distance} \times 100$$

Example 3

- Determine the slope between two meters that are 500 feet apart if the elevation of the first meter is 45 ft and the elevation of the second meter is 79 ft.

$$slope, \% = \frac{drop\ or\ rise}{distance} \times 100$$

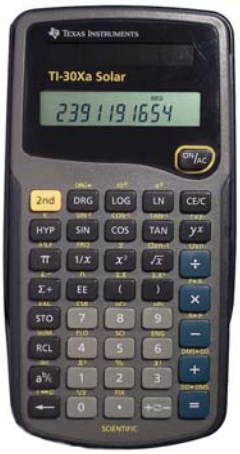
$$slope, \% = \frac{79ft - 45ft}{500\ ft} \times 100$$

$$slope, \% = \frac{34\ ft}{500\ ft} \times 100$$

$$slope, \% = 6.8\%$$

Applied Math for Wastewater Treatment
Geometric Mean

Geometric Mean Using a Texas Instrument TI-30Xa



Example:
60 100 0 0

Geometric Mean – $(X_1)(X_2)(X_3)...(X_n)^{1/n}$

Step 1: 1/n → 1 divided by the number of test results. For our example above, there are four test results.

- 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)

Step 2: Multiply all of the test results together and punch the = button on the calculator. Remember to count 0 as a 1.

- 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)

Step 3: Punch the y^x button and then type in the number from Step 1, then punch =.

- 6000 y^x 0.25 = 8.8011

Geometric Mean Using a Texas Instrument TI-30XIIB

Example:
60 100 0 0

Geometric Mean – $(X_1)(X_2)(X_3)...(X_n)^{1/n}$

Step 1: 1/n → 1 divided by the number of test results. For our example above, there are four test results.

- 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)

Step 2: Multiply all of the test results together and punch the = button on the calculator. Remember to count 0 as a 1.

- 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)

Step 3: Punch the ^ button, then type in the number from Step 1, & then punch =.

- 6000 y^x 0.25 = 8.8011

Applied Math for Water Treatment
Miscellaneous

1. What is the average in pounds per day for chlorine used given the following data? 76.7 lb/day

Mon	Tue	Wed	Thur	Fri	Sat	Sun
74	78	81	84	77	73	70

2. Determine the geometric mean for the following samples: 79.7 mg/L

   Sample #1 = 45.0 mg/L
   Sample #2 = 61.0 mg/L
   Sample #3 = 98.0 mg/L
   Sample #4 = 150.0 mg/L

3. If a water treatment plant treats 15 MGD, and serves 150,900 persons, what are the gallons per capita per day? 99.4 gal/capita/day

4. A 45 ft diameter storage tank loses 15 psi of pressure due to a leak over a 24 hour period. What is the leakage rate in gpd? 412,002.19 gpd

5. Determine the slope for a pipe if the upstream pressure gauge reads 154 psig and the downstream pressure reads 149 psi. The two gauges are 3,820 ft apart. 0.30%

6. Pressure readings on a main are measured at 2 hydrants separated by 750 feet. The pressure reading at hydrant #1 is 92 psi and the pressure reading at hydrant #2 is 75 psi. What is the slope of the main? 5.24%

7. What is the leakage rate in gpd for a 48 inch main that ruptures? It is determined that in 6 hours the break emptied a storage tank that is 30 feet in diameter and contained water 17 feet deep. 359,354.16 gpd

8. The following flows were recorded for the week: 8.6 MGD, 7.6 MGD, 7.2 MGD, 7.8 MGD, 8.4 MGD, 8.6 MGD, 7.5 MGD. What was the average daily flow for the week? 8.0 MGD

9. Determine the geometric mean for the following samples: 131 mg/L
   Sample #1 = 20.0 mg/L
   Sample #2 = 20.0 mg/L
   Sample #3 = 210.0 mg/L
   Sample #4 = 3,500.0 mg/L

10. Two hydrants are 750 ft apart. Hydrant 1 is located at an elevation of 129 feet. Hydrant 2 is located at an elevation 157 feet apart. What is the slope? 3.73%

11. The pressure reading of a pitot gauge at an elevation of 231 feet is 45 psi. The pressure reading of another pitot gauge 2500 feet away is 69 psi at an elevation of 200 ft. What is the slope? 3.5%

12. A 0.5 million gallon storage tank leaks 200 gallons over a 24 hour period. What is leakage rate in gpd? 200 gpd

13. A water plant serves 59,400 people. If it treats a yearly average of 7.82 MGD, what are the gallons per capita per day? 132 gal/capita/day

14. A water system has four storage tanks. Three of them have a capacity of 100,000 gallons (gal) each, while the fourth has a capacity of 1 million gallons. What is the mean capacity of the storage tanks? 325,000 gal

15. The friction loss in a 10-inch pipe flowing at 1,400 gpm is 18.7 feet of head per 1,000 feet. At the storage tank, the pressure is 85 psi with the water flowing at 1,400 gpm. What will the pressure be 1/2 mile from the tank?

Answers

1. 76.71 lb/day
2. 79.37 mg/L
3. 99.4 gal/capita/day
4. 412,002.19 gal/day
5. 0.30%
6. 5.24 %
7. 359,354.16 gal/day
8. 7.96 MGD
9. 130.94 mg/L
10. 3.73%
11. 4.7%
12. 200 gal/day
13. 131.65 gal/cap/day
14. 325,000 gal
15. 63.62 psi