Applied Process Mathematics

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Applied Process Mathematics

WWW 5830

7 contact hours

9 CC10 hours

Operators often have to use higher level mathematical formulas to perform their day to day work functions. This course will build on mathematical concepts taught in Introduction to Applied Process Mathematics and is designed to provide operators with problem solving skills specific to the water and wastewater industry. Participants will practice manipulating formulas for unknown variables, analyze operational problems using math skills, and review math skills necessary for certification exams. Upon completion of this course, the student should be able to calculate operational problems, such as flow quantity, effluent treatment and sludge volume.

1. Practice manipulating formulas for unknown variables
2. Practice analyzing operational problems using math skills
3. Demonstrate math skills necessary for certification exams

Agenda:

1. Introduction (30 minutes)
2. Sedimentation (60 minutes)
    a. Process loadings
    b. Detention times
    c. Exercises
3. Chemical Addition (60 minutes)
4. Filtration (60 minutes)
    a. Process loadings
    b. Exercises
5. Activated sludge (60 minutes)
    a. Process loadings and control
    b. Exercises
6. Fixed film (60 minutes)
    a. Process loadings
    b. Exercises
7. Solids handling (60 minutes)
8. Review; Final Exam (30 minutes)

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Applied Process Mathematics for Water and Wastewater Operators

McET
ENVIRONMENTAL, HEALTH, AND SAFETY TRAINING

Maryland Center for Environmental Training
College of Southern Maryland
La Plata, MD

Process Training Sessions

Before class starts, please:
- **Sign in** on Attendance Sheet

During classes, please:
- **Asks questions**
- Feel free to get up and leave the classroom at any time (i.e., rest rooms, phone calls, etc.)
- **Answer questions** on worksheets and exercises

Housekeeping

- Start class – 8:00 am
- Please mute/silence cell phones and pagers
- 10-minute Breaks – every hour
- Lunch – 11:30 am ~ 12:30 pm
- End class ~ 3:30 to 4:00 pm

Ice Breaker and Discussion

- Before we start, let's introduce ourselves:
  - Name
  - What do you do
  - What are your specific math needs?
    - How to find math formulas?
    - How to improve learning math?
    - How to apply math at work?
    - How to answer math questions on certification exams?
    - Other?

(Allow 20 to 30 minutes for reflection and discussion)

Instructor Expectations

- Begin and end class on time
- Be interactive
- Share experiences and needs
- Less lecture, more discussions
- ***Make this an enjoyable and informative experience!***

Ground Rules

- Discussion is encouraged
- Participate at your own comfort level
- Use terms we all can understand
- Everyone is different, so please show respect for others in the room
- Listen with an open mind
- Express opinions - of things, not people
- Maintain confidences

Introduction

Class Purpose and Objectives

Learning Objectives

1. To practice and build confidence using math skills
2. To select correct conversion values and formulas in math calculations
3. To apply math in treatment operations, pumps and motors, and hydraulics calculations
4. To practice manipulating formulas for unknown values
5. To practice analyzing operational problems using math skills
6. To demonstrate math skills for certification exams

At the conclusion of the course, students should be able to:

- Calculate basic math operations and conversions
  - Areas (ft^2) and volumes (ft^3) of tanks
  - Flow rates (MGD, gpm)
  - Pounds and pounds/day from concentrations (mg/L)
  - Water pressure (psi) and head (ft)
  - Water, pump (brake), and motor horsepower (HP)
  - Treatment process parameters

Calculators

- Reliable
- Battery preferred
- Easy to read – large viewing screen
- Large buttons
- Square root (√) key
- Practice with it

Why is Math Important?

- Operation monitoring, data reporting, and record keeping
  - Water – Safe Drinking Water Act requirements
  - Wastewater – Clean Water Act requirements
- Trending and troubleshooting
- Pass your operator certification exams

Math Focus

- Math Fundamentals & Applications:
  - Calculator use
  - Efficiency
  - Unit conversions and converting
  - Tank surface areas and volumes
  - Flows and Velocities
  - Pressure & Head
  - Pumping & Horsepower

Mathematical Terms

- Parenthesis (…): Used to separate different parts of the problem.
- Numerator: the number above the line in a fraction
- Denominator: the number below the line in a fraction

Math - Rules of Operation

- Work from left to right
- Do all work inside parentheses (…) first
- Do all multiplication and division in the numerator and denominator next
- Then do all addition and subtraction above and below the line
- Lastly, divide the numerator by the denominator

Math Fundamentals

Averages

Average

- Determines representative daily, weekly, monthly, or annual data
- Applied in:
  - Plant operations to determine "typical" performance parameters
  - Reporting of plant operating performance to state
  - Recordkeeping

Average

- By calculating an average, one number will represent a group of numbers
- Most water applications use "arithmetic mean"

$$\frac{\text{The sum of all measurements}}{\text{Total number of measurements}}$$

Average

- Average = Sum of all numbers / Number of values
- Example:

  Sum = 25 + 30 +20 + 21 + 12 + 45 + 8 = 161

  Number of values = 7

  Average = 161/7 = 23

CALCULATING AVERAGES

Given:
Average flow for 3 days:

Day 1 - 235 Gallons
Day 2 – 275 Gallons
Day 3 – 240 Gallons

$$\text{Average Flow} = \frac{\text{Sum of Measurements}}{\text{Number of Measurements}}$$

$$\text{Average Flow} = \frac{\text{750 Gallons}}{\text{3 Days}}$$

Average Flow = 250 Gallons/day

Math – Solving Word Problems

- Read the problem…What type of problem is it?...What needs to be determined? Draw a diagram, if it would help.
- What information is needed to solve the problem? From question, determine formula(s) to use. Determine units of answer
- Fill data in the formula(s). Make the calculation…Does answer make sense?

Steps in Solving Problems

1. **What does the problem tell you?**
2. **What does the problem ask?**
3. **Determine the solution (Work the problem)**

Steps in Solving Problems

1. **What does the problem tell you?**
   – Read the problem twice, underlining the key words and data
   – List "Givens"
   – Draw a picture of the situation
   – Label the picture with the given information

Steps in Solving Problems

2. **What does the problem ask?**
   – Determine from the problem and picture the "unknown" you are trying to find
   – Perform the math to solve for the unknown
   – Select the formula which solves for the unknown

Steps in Solving Problems

- **Determine the solution (Work the problem)**
  - Write down selected formula
  - Plug in information from problem and picture
  - Check units of conversion
  - Compute the solution
  - Check results…reasonable?

Monitoring and Control

Process Efficiencies

Percentages and Efficiency, %

1. Removal Efficiency = $\frac{(\text{In} - \text{Out})}{\text{In}} \times 100$,%
2. Return Rate, % = $\frac{\text{QRAS} \times 100}{\text{QInf}}$, %
3. Reduction in VS, % = $\frac{(\text{In} - \text{Out}) \times 100}{\text{In} - (\text{In} \times \text{Out})}$,%**

**Note: All volatile solids information (In and Out) must be in decimal form.

PERCENT (%) REMOVAL OR EFFICIENCY

- Definition:

The portion of pollutants removed in a process (unit) expressed as a percentage of what goes into the process (unit).

Removed = In – Out

% Removal = (In – Out/ In) X 100

- Importance

Calculation of treatment unit efficiency.

Percent Volatile Solids Loss

- If the VS content of the sludge going into the digester is 68% and the VS content of the digested sludge is 56%, what is the percent destruction of volatile solids in the digester?

Answer: $\frac{0.68 – 0.56) \times 100,\%}{0.68 – (0.68 \times 0.56)} = \frac{0.12 \times 100,\%}{0.68 – 0.38}$

$\frac{0.12 \times 100,\%}{0.30} = 0.4 \times 100,\% = 40\%$

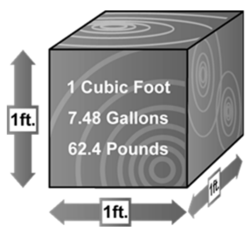
SAMPLE PROBLEM

- A tank has an influent suspended solids (SS) concentration of 180 mg/L and an effluent SS concentration of 60 mg/L. What is the percent (%) reduction in suspended solids in the tank?
  - % removal = (In-Out)/In X 100
  - % removal = (180-60)/180 X 100
  - % removal= 67%

Math Fundamentals

Conversions and Unit Converting

Weight/Volume Relationship

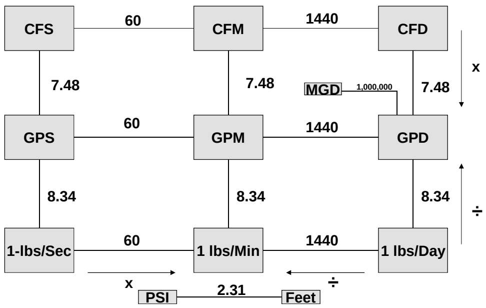


1 gallon weighs = $\frac{62.4 \text{ lbs/ft}^3}{7.48 \text{ gal/ft}^3}$ = 8.34 lbs/gal

Common Conversion Factors

- 60 seconds in a minute
- 60 minutes in an hour
- 24 hours in a day
- 7.48 gallons per cubic foot
- 8.34 pounds per gallon
- 2.31 feet of head = 1 psi

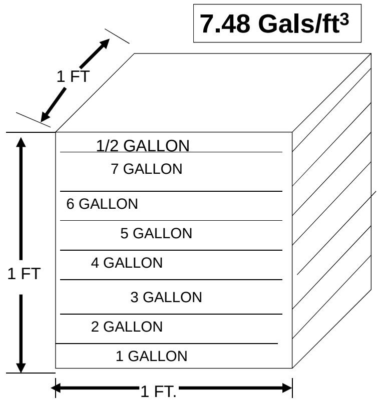
Conversion Flow Chart



Other Conversion Factors

- 1 KW = 1.34 HP
- 1 Acre = 43,560 sq ft
- 1 ft = 12 inches
- 3.28 ft = 1 meter
- 1 yd = 3 ft
- 1 mile = 5280 ft
- 1 HP = 0.746 KW
- 1 lb = 454 grams
- 1 cu ft = 28.32 liters
- 1 gal = 3.785 liters

7.48 Gals/ft^3



Converting Volumes from Cubic Feet and Gallons

ft³ — x 7.48 → Gallons

Gallons — ÷ 7.48 → ft³

Converting Volumes Cubic Feet and Gallons

If you know ft^3: (multiply)

1,000 ft^3 x 7.48 gallons/ft^3 = 7,480 gals

ft^3 x 7.48 = **Gallons**

Converting Volumes Cubic Feet and Gallons

If you know gallons: (divide)

$$\frac{7{,}480 \text{ gals}}{7.48 \text{ gals/ft}^3} = 1{,}000 \text{ ft}^3$$

1,000 gals ÷ 7.48 = ft^3

Converting Temperatures

$$F^{\circ} = (C^{\circ} \times 9/5) + 32$$
$$= (C^{\circ} \times 1.8) + 32$$

$$C^{\circ} = (F^{\circ} - 32) \times 5/9$$
$$= (F^{\circ} - 32)/1.8$$

$$\frac{(F^{\circ} - 32)}{180} = \frac{C^{\circ}}{100}$$

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Temperature Conversion

To convert Celsius to Fahrenheit:

$$F^{\circ} = (C^{\circ} \times 1.8) + 32$$

Example:

$20°$ C = ? F°

$F° = (20 \text{ X } 1.8) + 32$

$F° = (36) + 32$

$F° = 68°$

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Temperature Conversion

To convert Fahrenheit to Celsius:

$$C^{\circ} = \frac{(F^{\circ} - 32^{\circ})}{1.8}$$

Example:

85° F = ? C°

$$C^{\circ} = \frac{(85 - 32)}{1.8}$$

$$C^{\circ} = \frac{(53)}{1.8}$$

$C^{\circ} = 29.44^{\circ}$

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Common Flow Units

- gpm – gallons per minute
- cfs – cubic feet per second
- gpd – gallons per day
- MGD – million gallons per day

Converting Million Gallons into MGD

- Divide the number by 1,000,000

$$\frac{2{,}600{,}000}{1{,}000{,}000} = 2.6$$

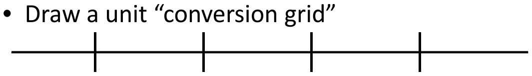
Or

- Move decimal point 6 places to the left

2,600,000 ⟶ 2 . 6 0 0 0 0 0 . ⟶ 2.6 MGD

Converting Units

- Determine what units are provided
- Decide what units are needed
- Draw a unit "conversion grid"



- Fill in number and units
- Enter conversion factors
- Verify that units cancel
- "Run the numbers"

Converting Units - Example

- Convert 60 miles per hour to feet per second
  - Draw a unit "conversion grid"
  - Fill in number, units, and conversion factors

60 miles	5280 ft	1 Hour	1 min	88 feet
Hour	mile	60 min	60 sec	Sec

Math Class Exercise #1

- Convert the following numbers:

4 yards = 144 inches

2.5 MGD = 1736 gpm

1.0 = MGD 1.55 ft^3/sec

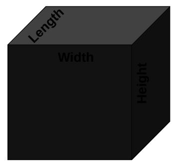
Math Fundamentals

Areas and Volumes

Finding Area and Volume – Rectangular Tank

- Area of a Rectangle: A = L x W
  - Area (A) equals length (L) times width (W)
- Volume of a Rectangle:

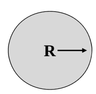
  V = L x W x H
  - Volume (V) equals length (L) times width (W) times height (H)

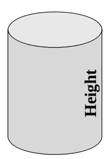


Finding Area and Volume – Circular Tank

- AREA of a Circular tank (**Radius**)
  - **3.14 x R** x **R**

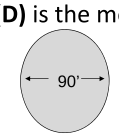
    or
  - $\pi R^2 = \frac{\pi D^2}{4} = 0.785 D^2$
- VOLUME of a Circular tank
  - $\pi R^2 \times H = 0.785 D^2 \times H$



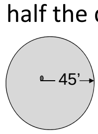


Diameter and Radius of Circles

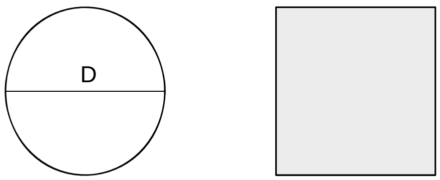
- **DIAMETER (D)** is the measurement across the circle:
  - 90 feet



- **RADIUS (R)** is half the diameter:
  - 45 feet



Square and Circle Areas

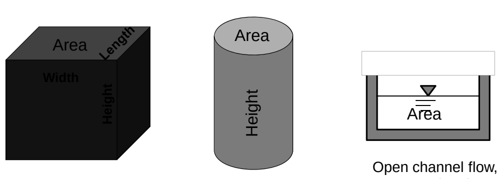


A_{circle} = 0.785 x D x D
A_{square} = D x D
A_{circle} = 78.5% x A_{square}

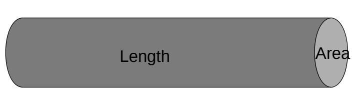
Areas and Volumes

Rectangular	**Circular**
• L – Length • W – Width • H – Height	• D – Diameter • H – Height or depth
(1) A – Surface Area = L x W (2) V – Volume = L x W x H	(1) A – Surface Area = $0.785 \times D^2$ (2) V – Volume = $0.785 \times D^2 \times H$

Areas and Volumes

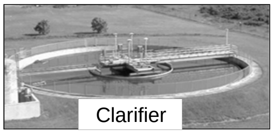


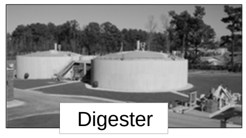
Rectangular tank — Circular or cylindrical tank — Open channel flow, cross sectional area

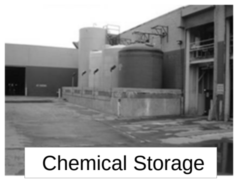


Pipe

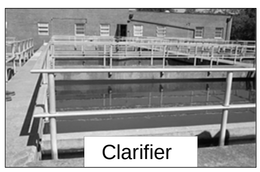
Circular Tanks







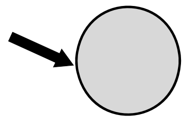
Rectangular Tanks



Pipes

Circumference of Circle

- Distance around the outside edge



- Circumference = C = π**D** = 3.14 x D
  = 3.14 x 2 x R

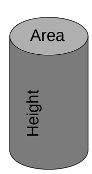
Units of Volume

- A cubic unit measurement of the inside capacity of an object
  - Expressed in cubed terms (ft^3)
- To obtain volume you multiply the object's surface area by the objects length (height)

Volume of a Circular Tank

Volume of a circular tank: V = A x H

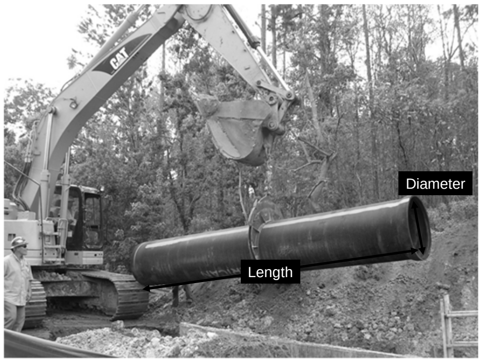
Volume (V) equals area (A) times height
Area = 0.785 x D^2
Volume = (0.785 x D^2) x H



For a cylinder that has a diameter of 3 ft and is 4 ft long:

Volume= 0.785 x D^2 x H = 0.785 x $(3)^2$ x 4
= 0.785 (9) x 4 = 7.065 x 4
= 28.26 ft^3

Figuring gallons in a pipe



Gallons in a pipe:

- Our example pipe has a diameter of 18 inches
- Is 20 feet long
- Is made of ductile iron with a cement liner

Gallons in a pipe:

(1) First convert the inches of diameter to feet:

$$\frac{18'' \text{ diameter}}{12'' \text{ per ft}} = 1.5 \text{ ft diameter}$$

Gallons in a pipe:

(2) Next, calculate the pipe opening in ft^2

0.785 x 1.5’ x 1.5’ = 1.766 sq ft

Or

3.14 x 0.75’ x 0.75’ = 1.766 sq ft

Gallons in a pipe

(3) Now calculate the cubic feet of the pipe:

1.766 ft^2 x 20 ft length = 35.325 ft^3

(4) Next, convert the cubic feet to gallons:

35.325 ft^3 x 7.48 gallons/ft^3 = 264.23 gallons

Math Class Exercise #2

- Calculate the surface areas of the following tanks:

W = 30 ft = 1650 ft^2
L = 55 ft

Dia. = 37 ft = 1075 ft^2

Dia. = 110 ft = 9499 ft^2

Math Class Exercise #3

- Calculate the volumes of the following tanks:

W = 30 ft = 19,800 ft^3
L = 55 ft, D = 12 ft

Dia. = 37 ft = 11,825 ft^3
Depth = 11 ft

Dia. = 110 feet = 113,982 ft^3
Depth = 12 ft

Solving for the Unknown

- An unknown in an equation is a variable that is being solve for
- When solving for an unknown, say "x";
  - It must be in the numerator
    - 23 x = 145
    - 1 + x = 27
    - 107 = 42 - x
  - It must be by itself on one side of the equation

Solving for the Unknown

- How to get "x" by itself:
  - Addition and Subtraction:
    - Get numbers away from "x" by moving the numbers across the "=" sign
    - When a number crosses the "=" sign, it does the opposite of what it was doing on the other side
    - $x - 10 = 35$ ➔ $x = 35 + 10 = 45$
    - $16 = x + 4$ ➔ $16 - 4 = x = 12$

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Solving for the Unknown

- How to get "x" by itself:
  - Multiplication and division:
    - To get "x" by itself, numbers must be moved across the "=" sign by dividing or multiplying the number by itself
    - Numbers will move at a diagonal when crossing the "=" sign
    - $6x = 60$ ➔ $\frac{6x}{6} = \frac{60}{6}$ ➔ $x = 10$
    - $\frac{x}{3} = 12$ ➔ $\frac{3x}{3} = 3 \times 12$ ➔ $x = 36$

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Solving for the Unknown

- If "x" is in the denominator, it can trade places with a number on the other side of the "=" sign; e.g., flip-flop

$\frac{2}{x} = 4$ ➔ $\frac{2}{4} = x = 0.5$

$\frac{80}{x} = 3700$ ➔ $\frac{80}{3700} = x = 0.0216$

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Solving for the Unknown

- Order of operations when solving for an unknown that involves +, -, X, and ÷:
  - Do addition and subtraction first
  - Then do the multiplication and division

$2x - 5 = 40 \rightarrow 2x = 40 - 5 \rightarrow x = \frac{45}{2}$

$2x - 5 = 40 \rightarrow 2x = 45 \rightarrow x = 22.5$

Solving for the Unknown

- The procedure for solving for x in x^2 is the same as solving for x
- One extra step is involved at the end, taking the square root of both sides of the equation

$(x^2)(0.785) = 2826 \rightarrow x^2 = \frac{2826}{0.785} = 3600$

$x = 60$

Math Class Exercise #4

- Solve for the unknown:

$(23)(x)(7.48) = 542$ — $x = 3.15$

$\frac{(8)(x)}{(3)(3)} = 21$ — $x = 23.625$

$56.5 = \frac{3800}{(x)(8.34)}$ — $x = 8.06$

$(0.785)(D^2) = 5024$ — $D = 80$

Applied Math

Flow and Velocity

Common Flow Units

- Formula: $Q = V(ft/sec) \times A(ft^2)$
- MGD millions of gallons/day
- gpd gallons/day
- gph gallons/hour
- gpm gallons/minutes
- ft/sec feet/second (Velocity)

Flow and Velocities

- A – Cross sectional area of flow, ft^2
- V – Velocity of flow, ft/sec
- Q – Flow, ft^3/sec
- Flow and velocity equations:

(1) $Q = V \times A$, ft^3/sec

(2) $V = Q/A$, ft/sec

- Flow units can be converted to:
  - MGD, GPD, gpm

Flow Rate

- Flow (or Discharge)
  - The quantity of water passing a given point in a channel or pipe during a given period of time.

$$Q = V \times A$$

Where:

Q = Flow in cubic feet per second (cfs)

V = Water velocity in feet per second (ft/sec)

A = Cross-sectional area of flow (ft^2)

Flow Calculation Examples

A 3-ft diameter pipe is flowing full at 2 feet per second. What is the flow rate in cubic feet per second?

1. Calculate the pipe cross-sectional area:
   Area = $0.785 \times D^2 = 0.785(3)^2 = .785(9) = 7.07\ ft^2$
2. Substitute values into the equation Q = V x A:
   V = 2 fps (Given)
   A = 7.07 ft^2 (Calculated in step 1)
   $Q = V \times A = 2\ ft/sec \times 7.07\ ft^2 = 14.1\ ft^3/sec$

VELOCITY

<u>Two formulas can be used:</u>

$$\frac{\text{Distance (Ft)}}{\text{Time (Sec)}} \quad \textbf{OR} \quad \frac{\text{Flow (Q) (Ft}^3\text{/Sec)}}{\text{Area (Ft}^2\text{)}}$$

NOTE: This is a re-arrangement of Q = V X A

Calculate Velocity

What is the water velocity in a pipe flowing full if:

The pipe is 600 feet long and
disinfectant takes 2 minutes to reach the end

Calculate velocity in Feet/Second (fps)

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What's the Velocity, fps?

$$V = \frac{\text{distance, feet}}{\text{time}}$$

$$V = \frac{600 \text{ ft}}{2 \text{ min}}$$

2 minutes x 60 sec./minute = 120 seconds

$$V = \frac{600 \text{ ft}}{120 \text{ sec}}$$

V = 5.00 fps

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Velocity and Flow Calculation

Water is flowing 33 inches deep in a 4-foot wide channel. A float dropped in the channel travels 28 feet in 10 seconds.

What is the flow in gallons per day ?

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FLOW = V x A

Depth = 33 in /12 in/ft = 2.75 ft
Area = 2.75 Ft deep X 4 Ft wide = 11 Ft^2

V = Distance/time = 28 Ft /10 Sec = 2.8 ft/sec

Q = V x A = 2.8 ft/sec x 11 Ft^2 = 30.8 Ft^3/sec
Q = 30.8 ft^3/sec x (60 x 1440) sec/day x 7.48 gals/ft^3
Q = 19,905,178 gals/day

Math Class Exercise #5

- Solve for velocity (V = Q ÷ A):

Channel: 3 ft wide = 2.5 ft/sec
Depth of flow: 2.75 ft
Q = 13.5 MGD

Full Pipe
Dia. = 18 inch
Q = 5.5 MGD = 4.8 ft/sec

Math Class Exercise #6

- Solve for Flow, (Q = VA):

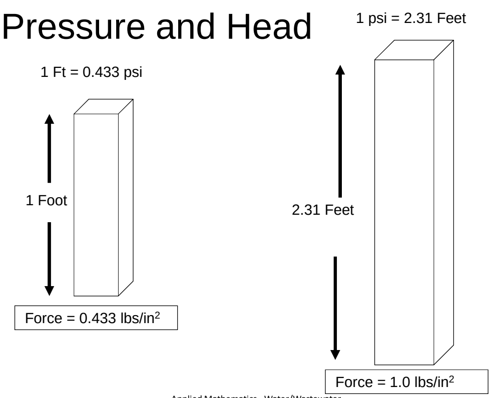
Channel: 3 ft wide = 21.8 MGD
Depth of flow: 2.75 ft
V = 4.1 ft/sec

Full Pipe
Dia. = 18 inch
V = 3.75 ft/sec = 4.2 MGD

Applied Math

Pressure and Head

Pressure and Head



Pressure and Head

- psi – Pressure, pounds per square inch
- H – Head, feet of water pressure
- 1 psi = 2.31 feet of water pressure

(1) H = 2.31 x psi

(2) psi = H/2.31

Converting Pressure into Head

PSI	x 2.31 → / ← ÷	Feet of Head

*Memory hint: To make the small number (psi) into the large number (feet), you multiply. To make the large number (feet) into the small number (psi), you divide

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Converting Pressures

If you know psi: (multiply)

30 psi x 2.31 feet/psi = 69.3 feet

30 psi x 2.31 = Head in feet

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Converting Pressures

If you know feet: (divide)

$$\frac{69.3 \text{ feet}}{2.31 \text{ feet/psi}} = 30 \text{ psi}$$

69.3 Head in feet / 2.31 = psi

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Sample Questions

- What is the pressure at the bottom of a tank filled with 100 feet of water?

100 feet/2.31 = **43.3 psi**

- A pump discharge gauge reads 35 psi when the pump is off. What is the pressure head, in feet, above the gauge?

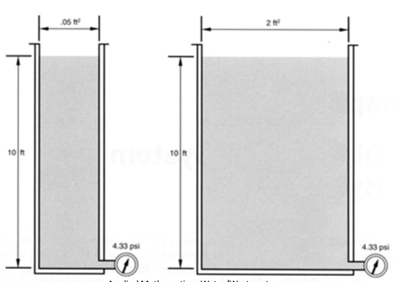
35 psi x 2.31 = **80.85 feet**

The level indicator has broken on the elevated water storage tank. The pressure gauge near the bottom is reading 39.8 psi. How many feet of water are in the tank?

39.8 psi x 2.31 =

91.9 feet

Pressure is dependent only on the height (head) of the water, not the size (volume) of the tank



Math Class Exercise #7

- Solve for the pressure and feet of head:

25 psi =	57.75 ft
150 feet =	64.9 psi
65 psi =	150 feet
98 feet =	42.4 psi
201 feet	87 psi

Applied Math

Pounds Formulas

Basic Units

- Concentrations:
  - mg/L milligrams per Liter
  - ppm parts per million
  - 1 mg/l = 1 ppm
  - 1.0% solids = 10,000 mg/l
- Pound Loadings, lbs/day
- Pound Loadings, lbs/day/ft^2 and lbs/day/ft^3

LOADING FORMULAS

1. Pounds

Pounds = mg/l x 8.34 x MG

Pounds = Conc (mg/l) x 8.34 x Vol (MG)

2. Pounds/day (ppd)

ppd = mg/L x 8.34 x MGD

ppd = Conc (mg/L) x 8.34 x Flow (MGD)

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Math Class Exercise #8

- Solve for the unknown:

15.5 MGD = 12,398 lbs/day
181 mg/L

2.1 MGD = 0.07 mg/L
1.22 lbs/day =

10.7 MGD 3.1 mg/L
278 lbs/day

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Process Math

Pumping and Horsepower

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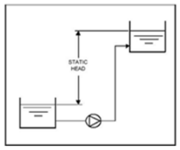
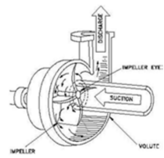
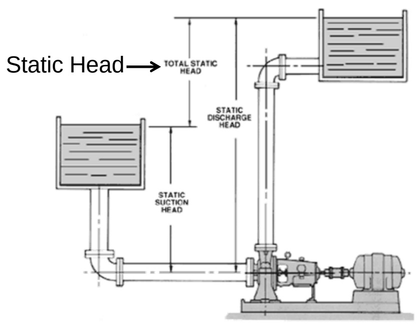
Pumping

- Moving fluid requires pumps
- Pumps and motors need to overcome discharge head
- Motor horsepower depends on:
  - Total Dynamic Head
  - Pump efficiency
  - Motor efficiency

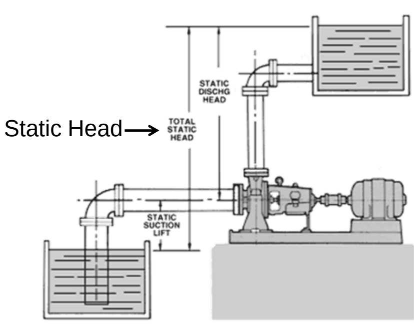




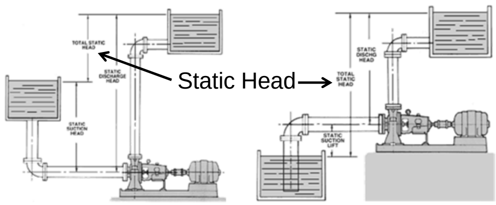
Pumping - Suction Head



Pumping - Suction Lift

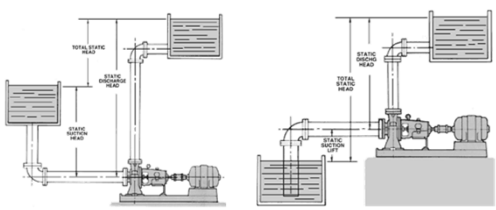


Total Static Head



- Vertical distance between the free levels of supply source and discharge liquid

Total Dynamic Head (TDH)

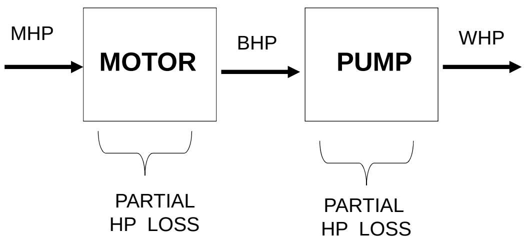


- TDH = Static Head + friction losses
- Friction losses due to piping and velocity

HORSEPOWER

$$\text{WHP} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$$

WHP, BHP, and MHP



WHP, BHP, and MHP

- What is Horse Power (hp)?
  - The amount of horse power required to lift water a certain amount of vertical distance
  - Water hp
  - Brake hp
  - Motor hp

WHP, BHP, and MHP

1. $\text{WHP} = \dfrac{\text{Flow (gpm)} \times \text{Head (Ft)}}{3960}$
2. $\text{BHP} = \dfrac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times eff_{pump}}$
3. $\text{MHP} = \dfrac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times eff_{motor} \times eff_{pump}}$

WHP Example

What minimum water horsepower is needed to pump 1,200 gpm against a total dynamic head of 70 feet?

$$WHP = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$$

$$= \frac{1{,}200 \text{ gpm} \times 70 \text{ ft}}{3960} = 21.2 \text{ HP}$$

MHP Example

What minimum motor horsepower is needed to pump 1,200 gpm against a total dynamic head of 70 feet, if the pump efficiency is 85% and the motor efficiency is 92%?

$$WHP = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times eff_p \times eff_m}$$

$$= \frac{1{,}200 \text{ gpm} \times 70 \text{ ft}}{3960 \times 0.85 \times 0.92} = 27.1 \text{ HP}$$

MHP Example

Determine motor horsepower, if flow is 1.5 mgd, total dynamic head is 40 feet, pump efficiency is 80% and motor efficiency is 90%.

$$MHP = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times eff_m \times eff_p}$$

$$= \frac{(1.5 \text{ mgd} \times 1{,}000{,}000 \text{ gals/mg} \div 1440 \text{ mins/day}) \times 40 \text{ ft}}{3960 \times 0.9 \times 0.8}$$

$$= \frac{1042 \text{ gpm} \times 40 \text{ ft}}{3960 \times 0.9 \times 0.8} = \frac{41{,}667}{2851} = 14.6 \text{ HP}$$

Fluids other than Water

1. WHP = $\frac{\text{Flow (gpm)} \times \text{Head (Ft)} \times \text{sp. gr.}}{3960}$

2. BHP = $\frac{\text{Flow (gpm)} \times \text{Head (ft)} \times \text{sp. gr.}}{3960 \times eff_{pump}}$

3. MHP = $\frac{\text{Flow (gpm)} \times \text{Head (ft)} \times \text{sp. gr.}}{3960 \times eff_{motor} \times eff_{pump}}$

Process Math

Detention Time

Detention Time

- D.T. = $\frac{\text{Volume of Tank}}{\text{Flow}}$ = V/Q
- Detention time in clarifiers and aeration tanks is in hours
- Detention time in digesters is in days
- Detention time in UV Light disinfection units is in seconds
- Detention time in chlorine disinfection tanks is in minutes

Detention Time Example

What is the detention time, in hours, of a clarifier with a capacity of 200,000 gallons receiving a flow of 1.2 MGD?

$$\text{D.T.} = \frac{V}{Q} = \frac{200{,}000 \text{ gals}}{(1.2 \text{ MGD} \times 1{,}000{,}000 \text{ gals/MG})/24 \text{ hrs/day}}$$

$$= \frac{200{,}000 \text{ gal}}{50{,}000 \text{ gals/hour}} = 4.0 \text{ hours}$$

Process Math

Chemical Addition

CHLORINE DOSE, DEMAND and RESIDUAL

- **DOSE:** **TOTAL amount delivered**
- **DEMAND:** **what's in the water that consumes the chlorine**
- **RESIDUAL:** **what's left over**

CHLORINE DOSE, DEMAND and RESIDUAL

DOSAGE = demand + residual

Questions

Post Test

Acknowledgements/Resources

- ABC Formula/Conversion Tables for Water and Wastewater Treatment
- "Applied Math for Water Plant Operators", Joanne Kirkpatrick Price
- Fleming Training Center, Murfreesboro, TN – "Water and Wastewater Treatment Mathematical Formulas"
- "Math Handbooks for Water and Wastewater Treatment Plant Operators", Bob Larson
- State of Virginia, "Wastewater Treatment Plant Math" 4th Edition, March 2010