

OPERATOR MATH

Areas and Volumes

Flows

Dosage Formula

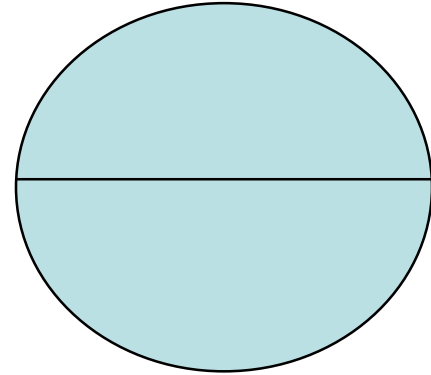
Area Calculation

- Area measurements defines the size or surface of an object. Sometimes an area is described as the X-section (cross section) of an object.
- U.S. units of area:
 1. Square inches = in^2
 2. Square feet = ft^2
 3. Square yards = yd^2
 4. Square mile = mi^2

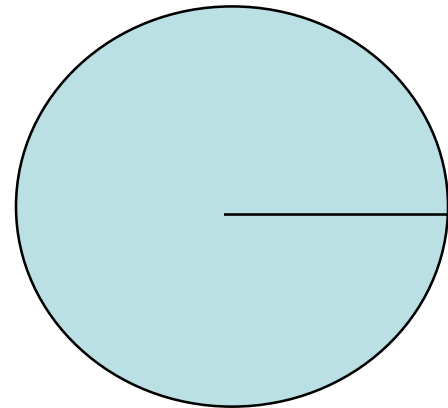
Area Formulas

- Circle:

$$\text{Area} = (0.7854) \times (\text{diameter}^2)$$

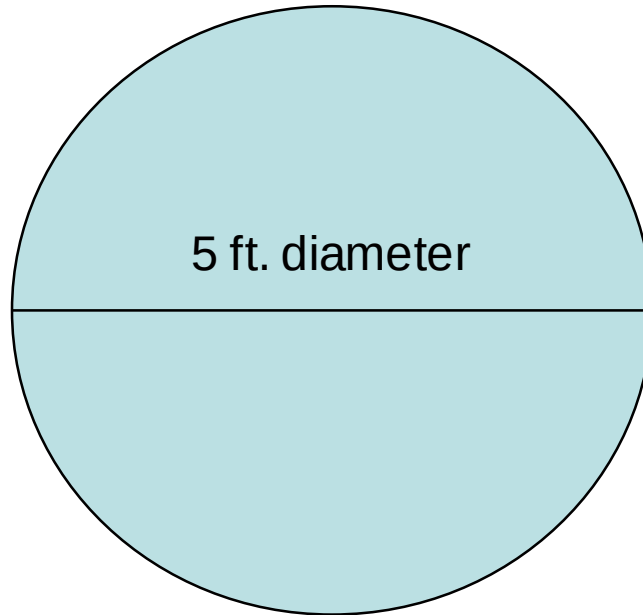


$$\text{Area} = \pi \text{ or } (3.1416) \times (\text{radius}^2)$$



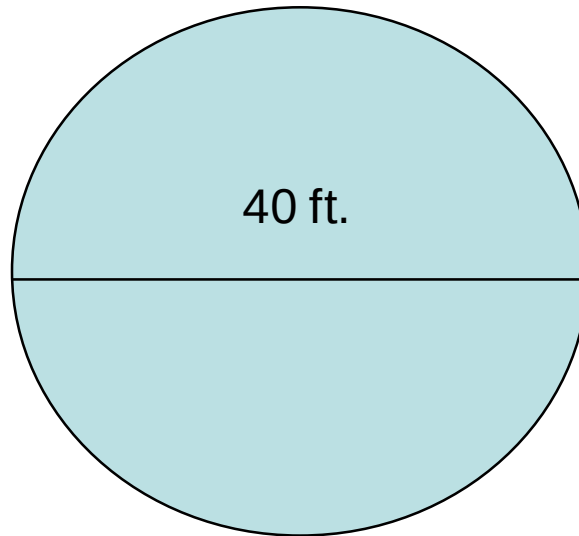
Problem # 1

Question: Calculate the area of a circle shown.



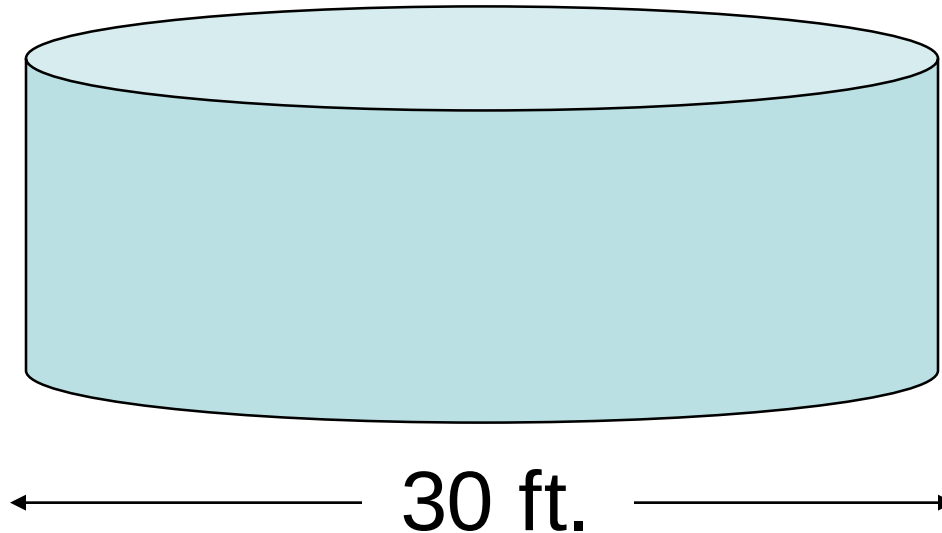
Problem # 2

- Question: A circular clarifier has a diameter of 40 ft. What is the surface area of the clarifier?



Problem # 3

- The bottom inside of a cylindrical storage tank needs to be painted. The diameter of the tank is 30 ft. If 1 gallon will cover 250 square feet, how many gallon of paint will be needed to paint the bottom of the tank?

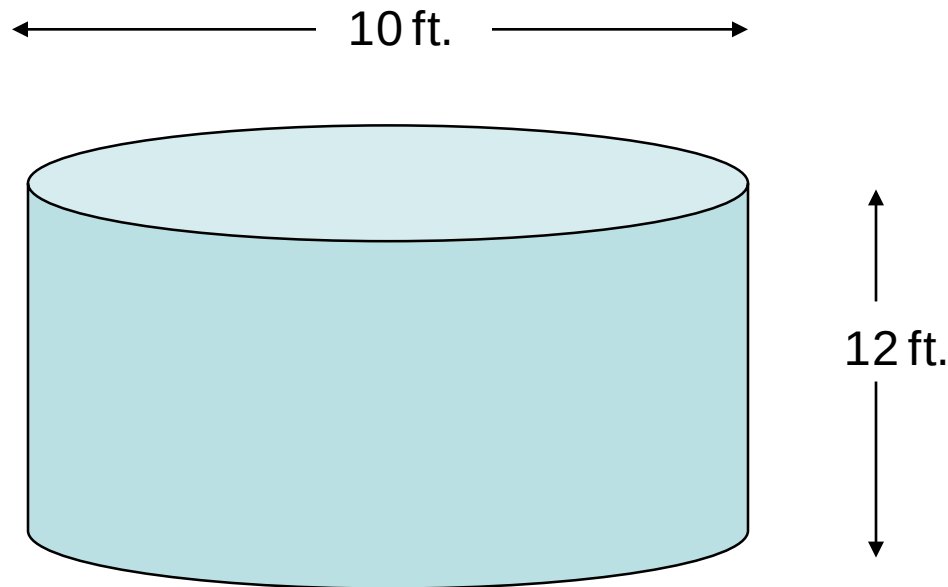


Volume Calculation

- Volume measurements define the amount of space that an object occupies.
- Some U.S. units of Volume:
 1. Cubic inches = in^3
 2. Cubic feet = ft^3
 3. Cubic yards = yds^3
 4. Gallons per cu.ft. = 7.48 gals.
- 5. Cylinder = $0.7854 \times (d^2) \times (3^{\text{rd}} \text{ dimension})$
- 6. Cylinder = $3.14 \times (r^2) \times (3^{\text{rd}} \text{ dimension})$

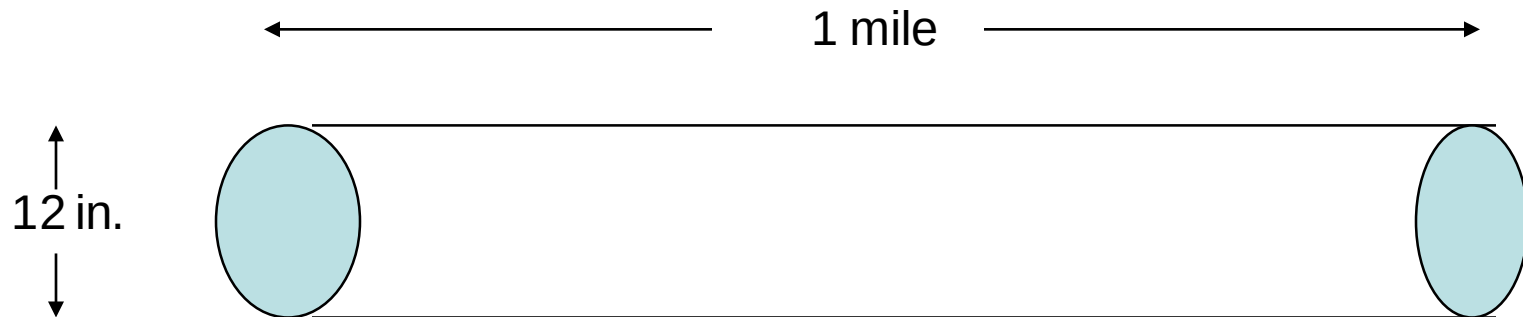
Problem # 4

- What is the volume of a tank which has a diameter of 10 ft. and a height of 12 ft.?
- Hint: (the 3rd dimension is the height of the tank)



Problem # 5

- What is the volume of a 1 mile long 12 inch diameter pipe?



Solution to # 5

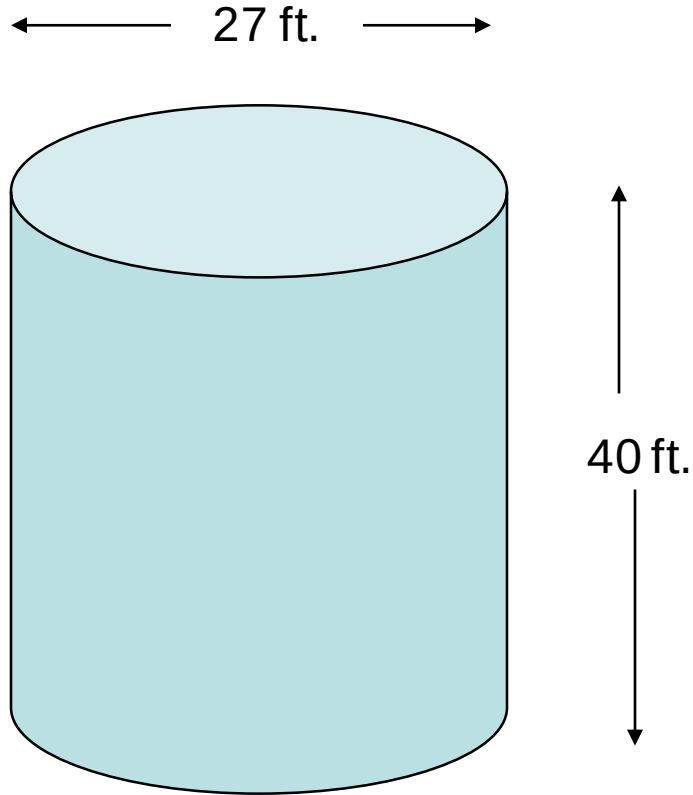
- Volume = $.7854 \times (d^2) \times (3^{\text{rd}} \text{ dimension})$
- Volume = $.7854 \times 1\text{ft.} \times 1\text{ft.} \times 5280\text{ft.}$
- Volume = 4146.9 ft.^3 or 4146.9 cu.ft.

(Problem # 6)

- How many gallons can the pipe describe in problem # 5 hold if both ends were sealed?
- Hint: $1 \text{ cu.ft.} = 7.48 \text{ gals.}$

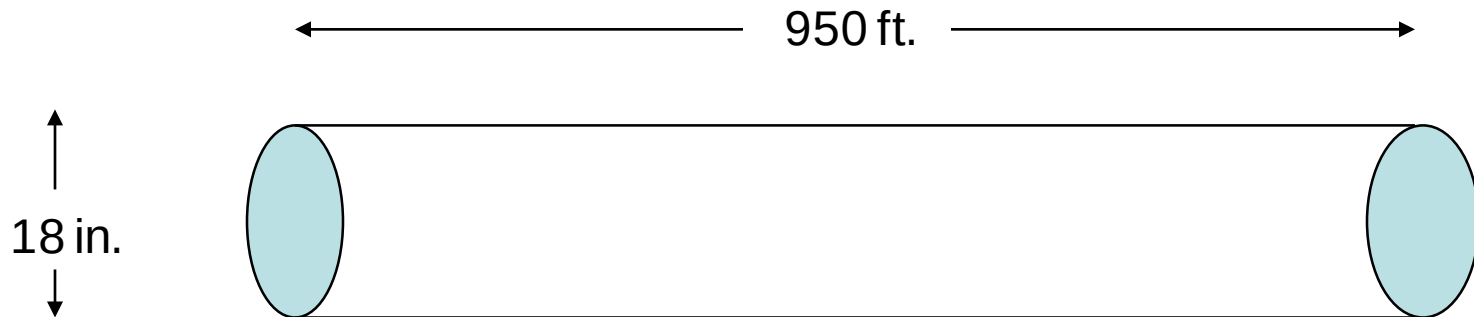
Problem # 7

- How many gallons of water will a storage tank hold if it has a 27ft. Diameter and 40ft. Depth?



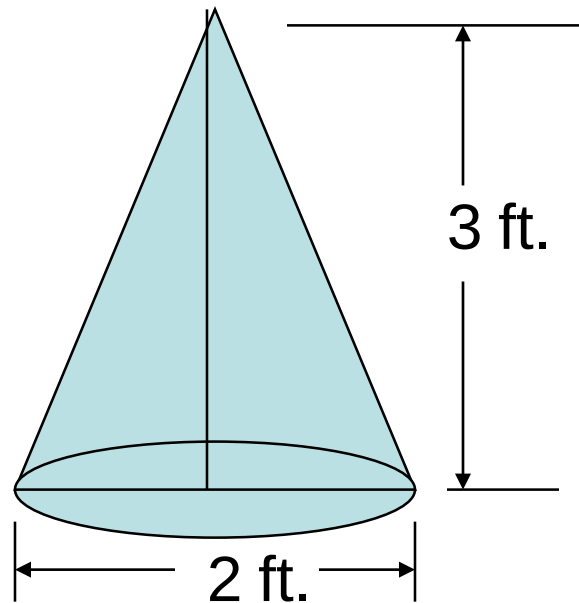
Problem # 8

- How many gallons water will be required to fill a 950 ft. long pipe and 18 in. diameter?



CONE

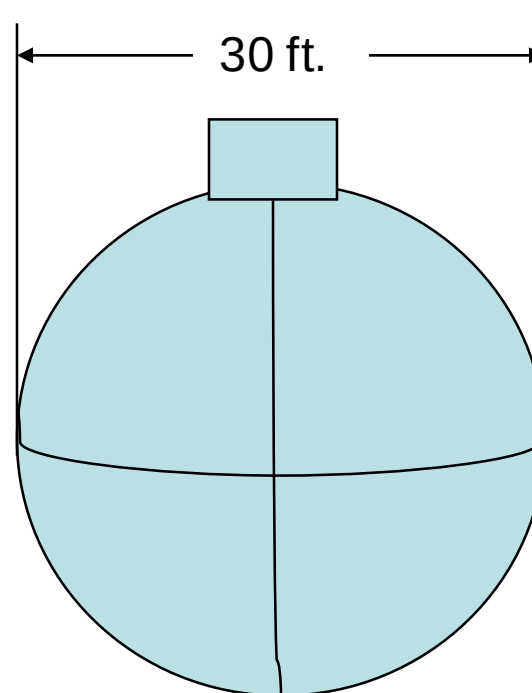
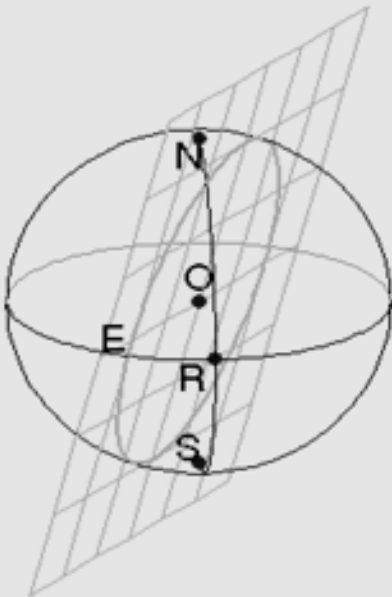
- Calculate the volume of a cone with the dimensions shown on the diagram.
- = Volume of a cone = $\frac{1}{3}$ (volume of a cylinder)
- or
- $= (0.7854) (D^2) (\text{Third dimension})$
3
- $= (0.7854) (2 \text{ ft.}) (2 \text{ ft.}) (3 \text{ ft.})$
3
- = 3.14 cu. ft.



Problem # 9

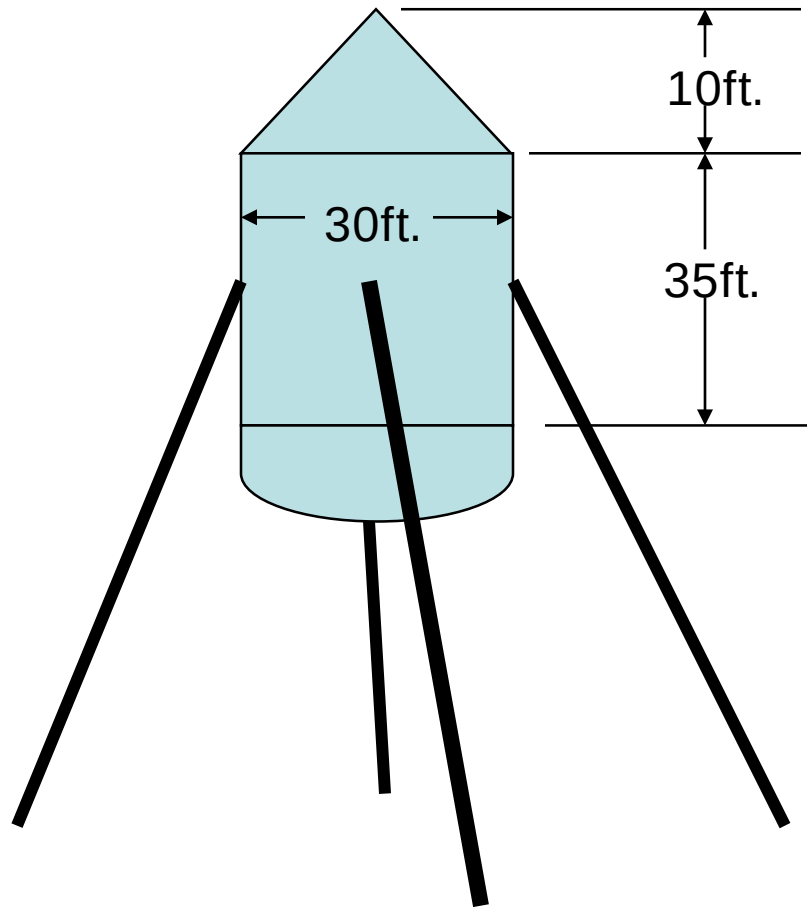
- If a spherical tank is 30ft. in diameter, how many gallons of water are required to fill it?
- Formula: $(\underline{3.14}) \times \text{Diameter}^3 \times 7.48\text{gls/cuft}$

(6)



Problem # 10

- How many gallons of water can this reservoir hold if filled?

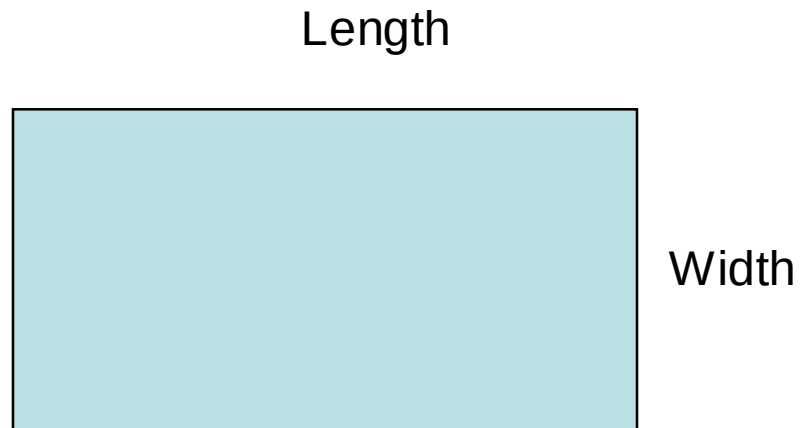


Solution to # 10

- As you can see you have three distinct shapes. Cone, cylinder, & hemisphere. In this case the volumes can be calculated separately, then added together to the total volume.
- Cone= $\frac{0.7854 \times D^2 \times H \times 7.48 \text{ gls/cuft}}{3}$
- Cylinder= $0.7854 \times D^2 \times H \times 7.48 \text{ gls/cuft}$
- Hemisphere= $\frac{3.14 \times D^3 \times 7.48 \text{ gls/cuft}}{2}$

- Rectangle:

$$\text{Area} = \text{Width} \times \text{Length}$$



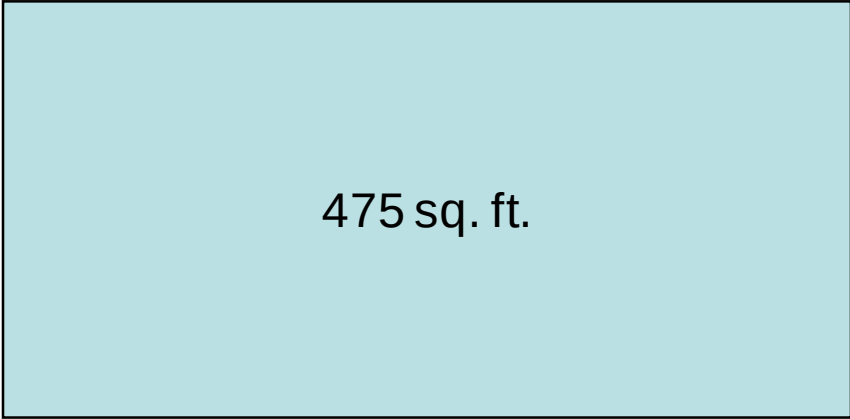
Rectangular Area

- Problem # 11 A
- There is a room which needs carpeting. If the room measures 25 ft. by 19 ft. how much carpet is needed to cover the floor?



11 B

- If one roll of carpet covers 80 ft.², how many rolls of carpet are needed?



475 sq. ft.

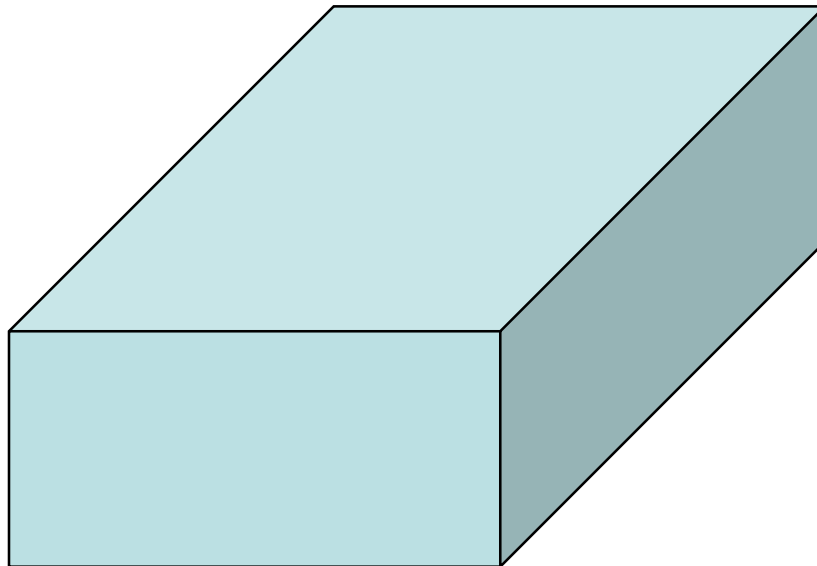
Problem # 12

- A sedimentation tank is 75 ft. long and 35 ft. wide. What is the surface area of the water tank?



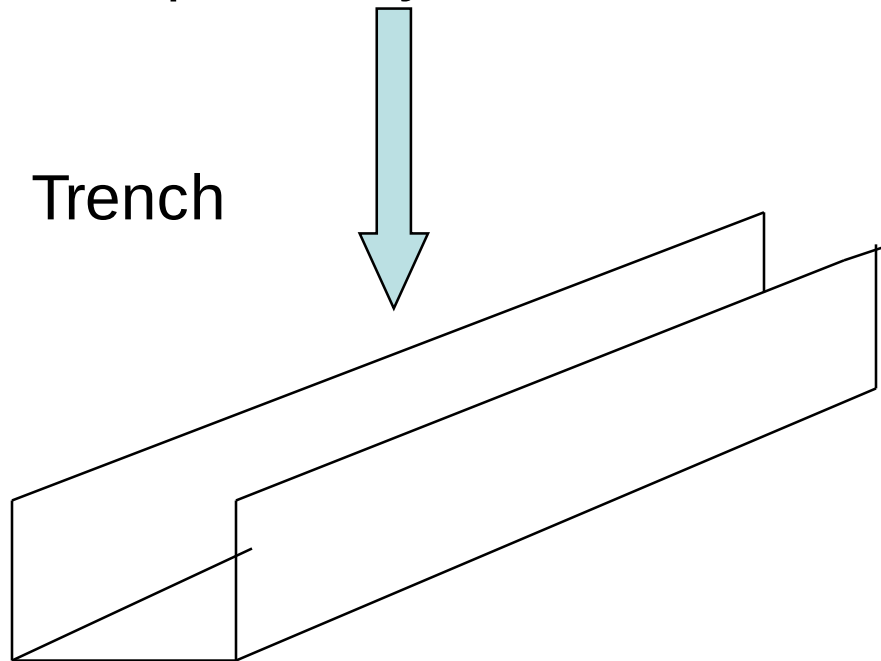
Rectangular Volume

- Problem # 13
- Calculate the volume of a tank that is 35 ft. long, 22 ft. wide and 11 ft. deep.
- $\text{Volume} = L \times W \times H$



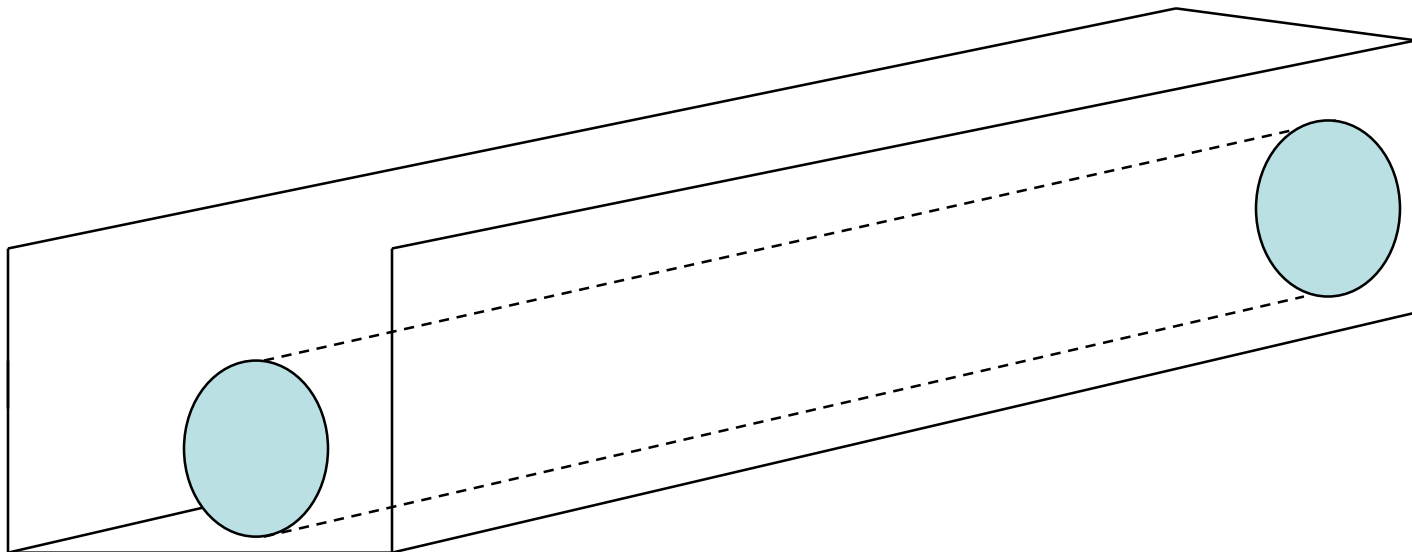
Problem # 14

- How many cubic yards of backfill would be required fill a 3,500 ft. trench, which is 4.5 ft. wide and 6 ft. deep?
- (Hint) 27ft.^3 per 1cu.yd.



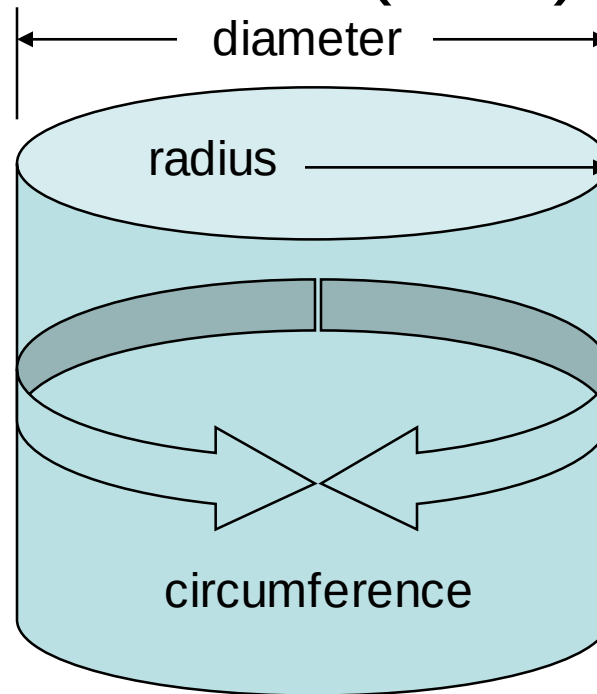
Problem # 15 A

- How many cubic yards of backfill would be required to fill a 5,500 ft. trench that is 6 ft. wide and 8 ft. in depth, after a 36 inch diameter water main pipe has been laid in the trench at the same distance?



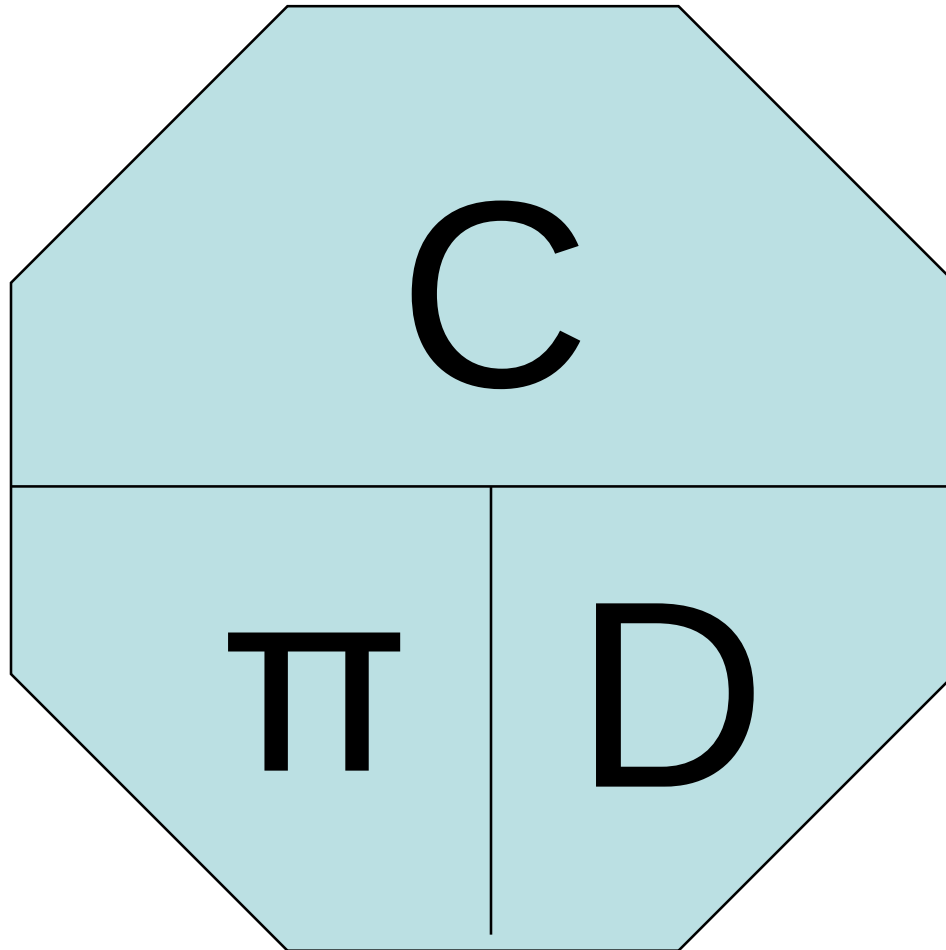
Circumference of a Circle

- The circumference of a circle is the length or distance around the edge of the circle.
- Circumference = π or (3.14) x (diameter)



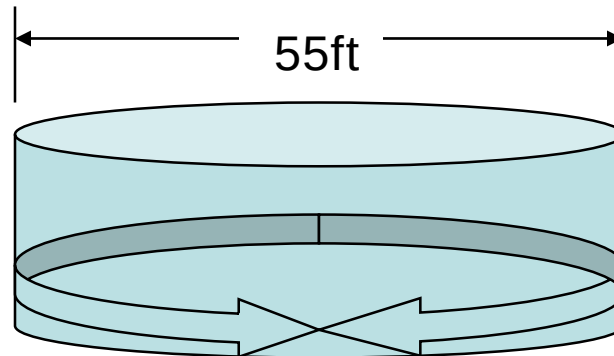
Circumference of a Circle

Shortcut Calculation



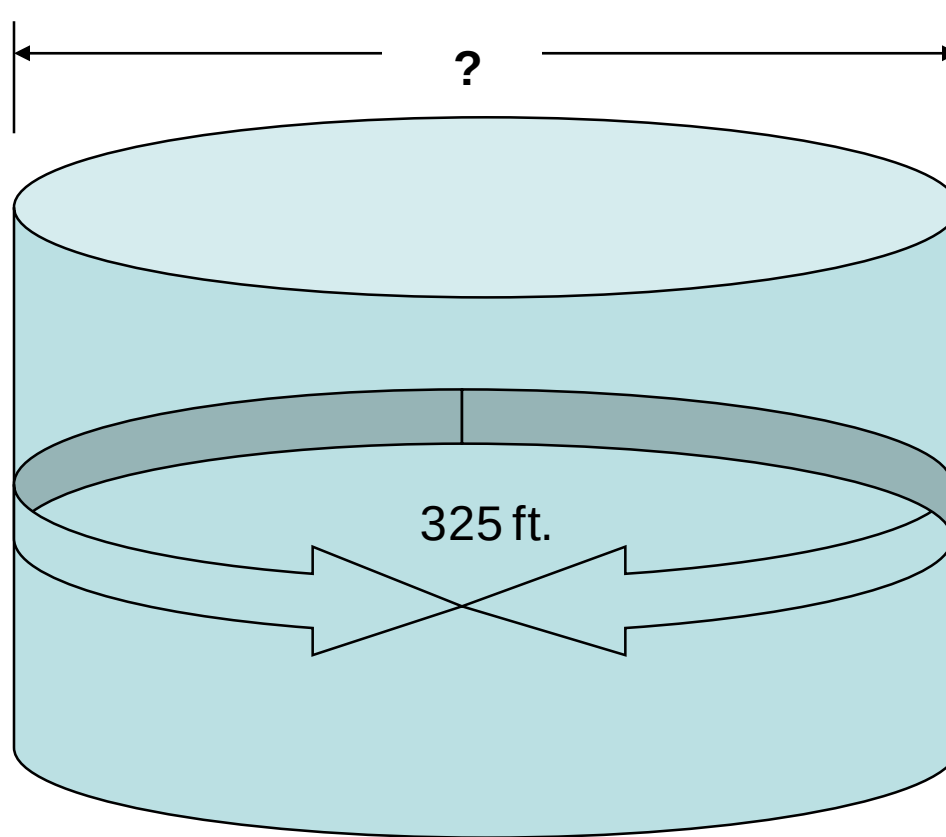
Problem # 16

- A circular tank has a diameter of 55 ft., what is the circumference of the tank?
- Circ. = $3.14 \times \text{diameter}$
- Circ. =



Problem # 17

- The circumference of a tank is 325 ft., what is the diameter of the tank?

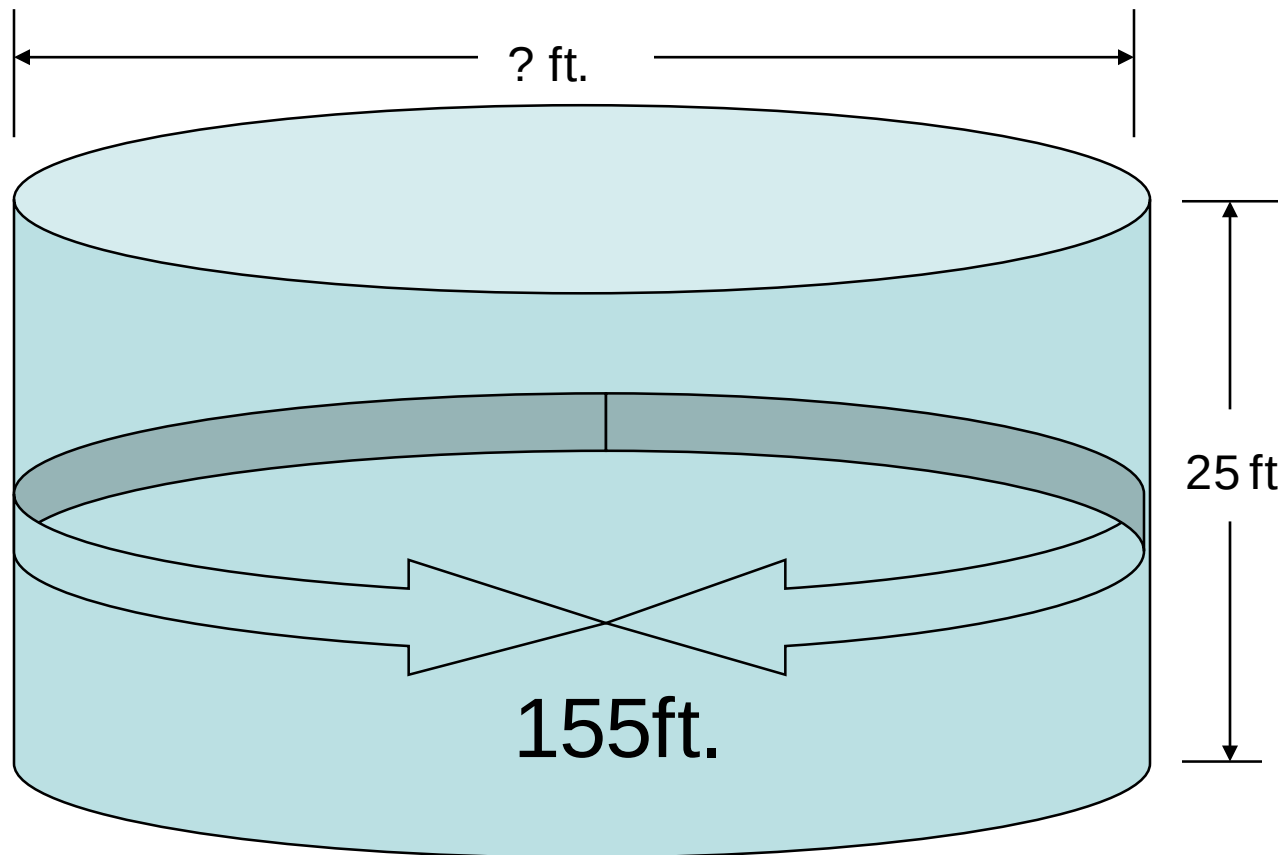


Problem # 18

- How many gallons of paint are required to paint the outside top and the outside of the tank? The tank circumference is 155 ft. and has a sidewall depth of 25 ft.
- 1 gallon of paint will cover 225 ft.²
- Area of tank top =
- Area of tank side =
- Total area =
- Amount of paint =

Solution to # 18

- Draw it out

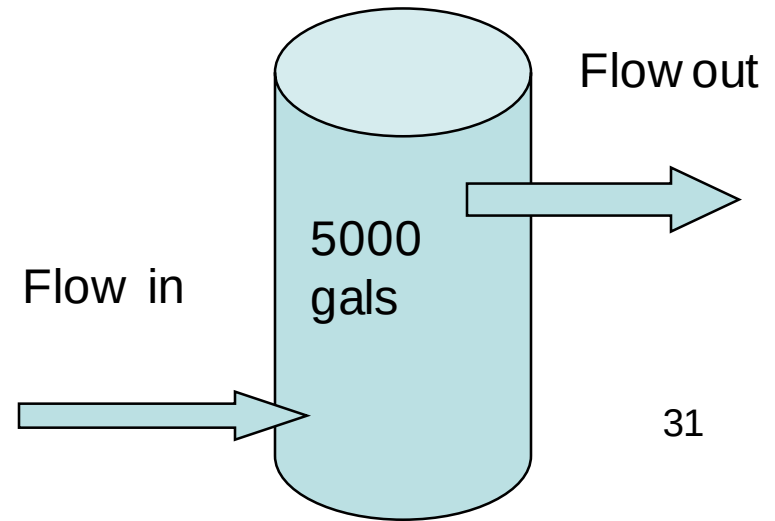


Calculating Detention Time (DT)

- Use – detention time is the amount of time that a fluid stays in a container.
- Units – detention time is expressed in units of time. The most common are; seconds, minutes, hours and days.
- Calculations – detention time is to divide the volume of the container by the flow rate.
- Volume units – are gallons or sometimes cubic feet.
- Time units – will be whatever units are used to express the flow; $GPM = DT(\text{min})$,
 $GPD = DT(\text{days})$

Detention Time (DT)

- $DT = \frac{\text{volume of tank}}{\text{flow, gals/time}}$
- A chlorine contact chamber holds 5,000 gals. It is desired to have a contact time (CT) of 30 minutes in the chamber. What is the maximum flow rate that can pass through this chamber at this DT?
- $DT = \frac{\text{Vol.}}{\text{flow}}$ (place the known values in the equation)
- $30 \text{ min} = \frac{5000 \text{ gals.}}{\text{gal/min}}$
- Rearrange the equation
- $GPM = \frac{5000 \text{ gals.}}{30 \text{ min}}$ or 166.66 gpm

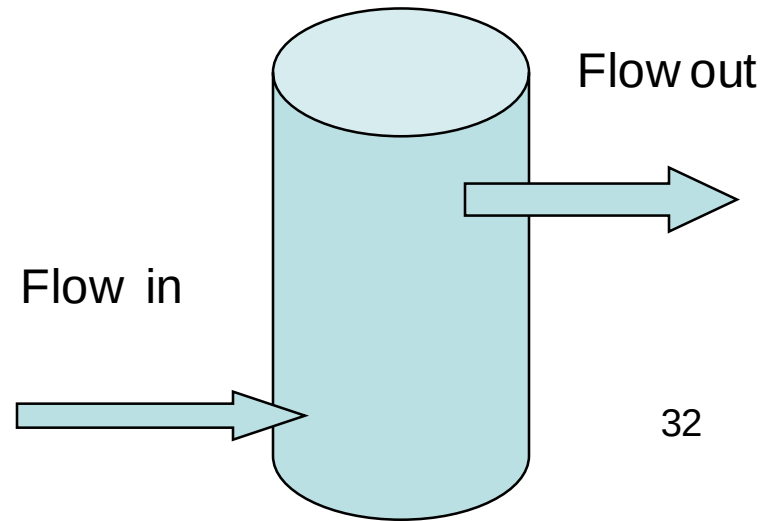


Detention Time (DT)

- $DT = \frac{\text{volume of tank}}{\text{flow, gals/time}}$
- A water storage tank holds 15,000 gals. It is desired to have a contact time (CT) of 20 minutes in the chamber. What is the maximum flow rate that can pass through this tank at this DT?
- $DT = \frac{\text{Vol.}}{\text{flow}}$ (place the known values in the equation)
- $20 \text{ min} = \frac{15,000 \text{ gals.}}{\text{gal/min}}$

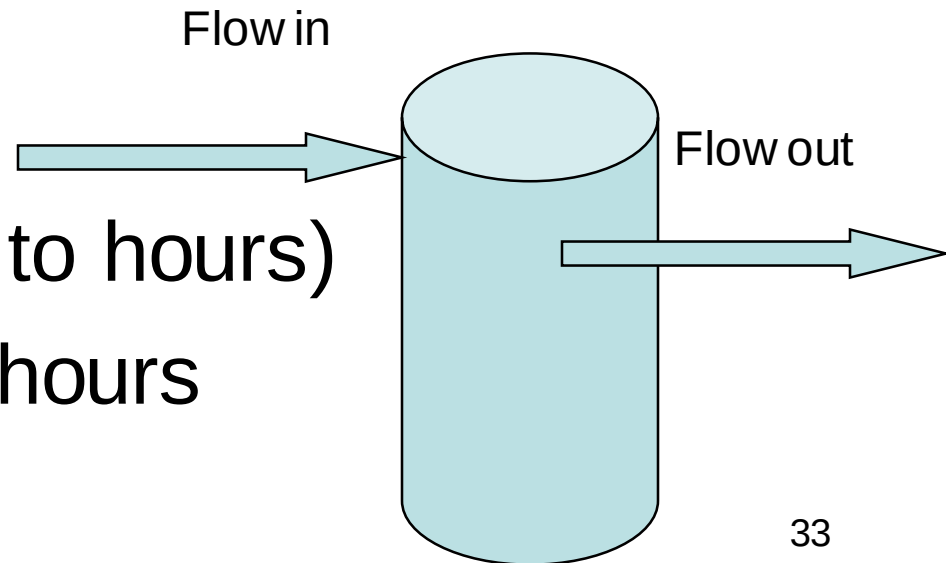
Rearrange the equation

- $GPM = \frac{15,000 \text{ gals.}}{20 \text{ min}}$ or 750 gpm



Detention Time (DT)

- $DT = \frac{\text{volume of tank}}{\text{flow rate, gals/time}}$
- Find the detention time in a 50,000 gal. reservoir if the flow rate is 100 gpm.
- Convert minute to hours
- $DT = \frac{50,000 \text{ gals.}}{100 \text{ gal/min}}$
- $DT = 500 \text{ min. (convert to hours)}$
- $GPM = \frac{500 \text{ min}}{60 \text{ min/hour}} = 8.33 \text{ hours}$



DT # 19

- A water reservoir that is 20ft. Diameter and a depth of 16ft. needs to be filled up. If the well is pumping at 200 gpm, how long will it take to fill in minutes? And convert to hours.

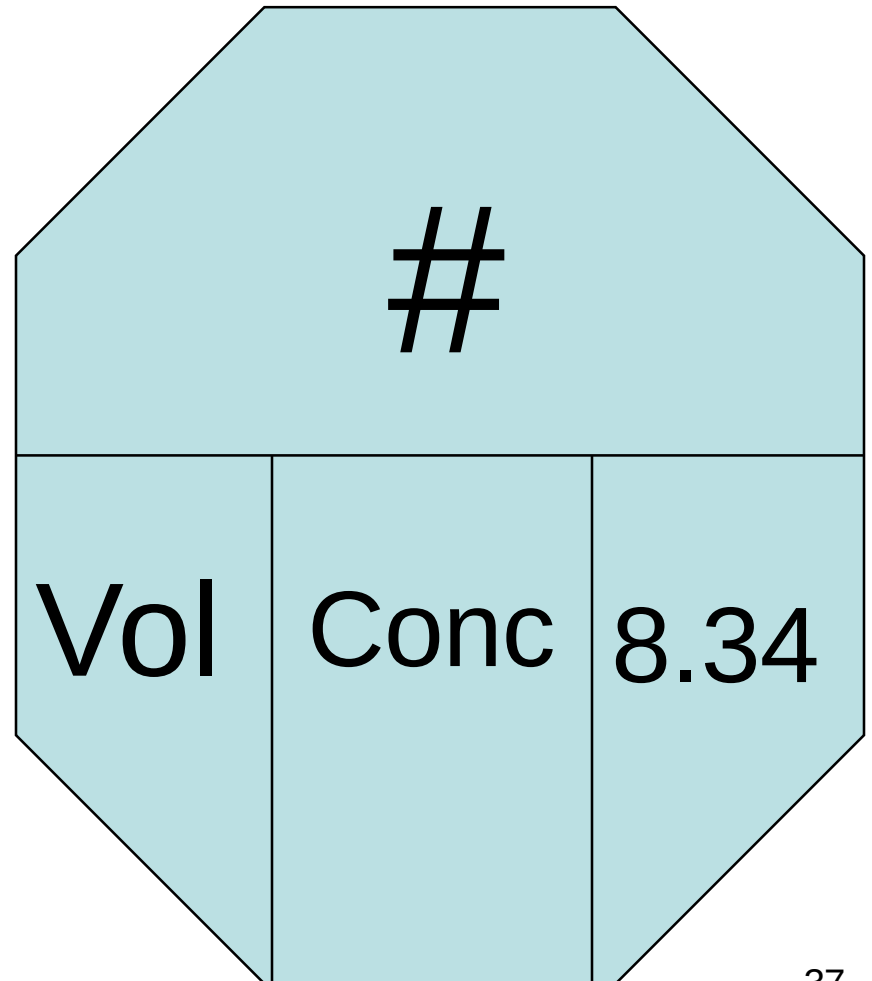
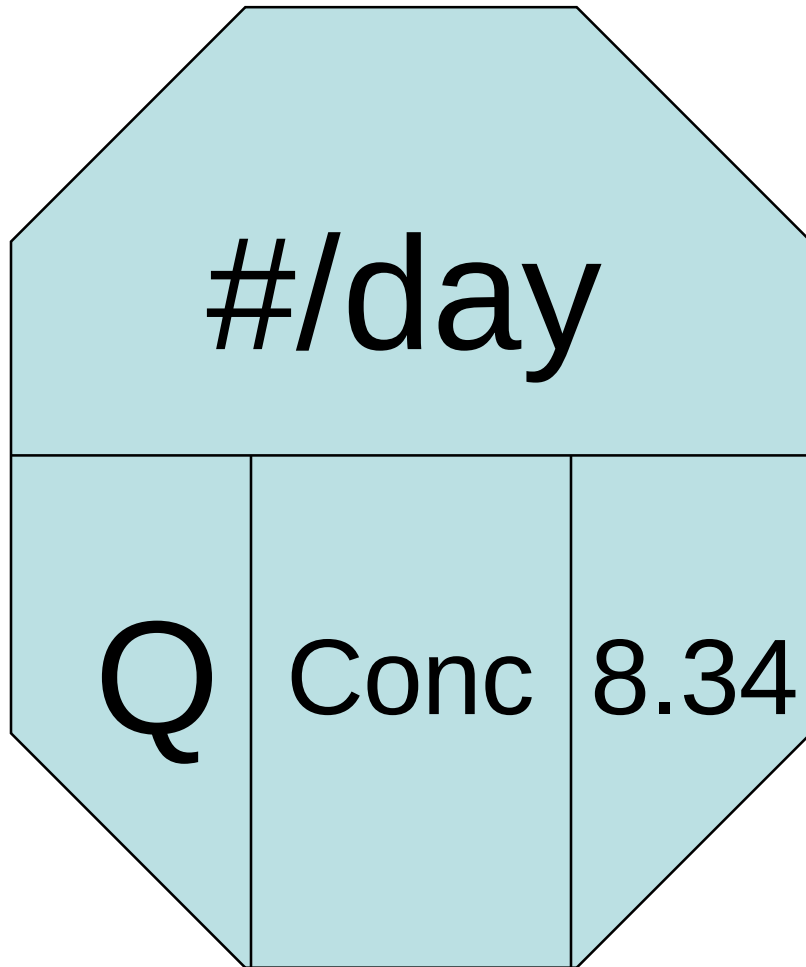
Chemical Dosage

- One of the more common uses of mathematics in water treatment practice is chemical dosage calculation. As a basic or intermediate level operator, there are generally the following types of dosage formulas you might need to know:
- Milligrams-per-litre to pounds-per-day
- Milligrams-per-litre to percent
- Feed rate
- Chlorine dosage / demand / residual
- Solution dilution

Milligrams-per-litre to Pounds-per-day

- Continuous feed for water supply
 $\text{\#/day} = Q, \text{ MGD} \times \text{dose, mg/L} \times 8.34 \text{ lb/gal}$
- One-time feed for tank, pipe, well
 $\# = \text{Vol, Mgal} \times \text{dose, mg/L} \times 8.34 \text{ lb/gal}$
- Problem # 20:
- The Cl_2 dosage rate at a water treatment plant is 1.5 mg/L. The flow rate is 1.5 MGD. How many pounds per day of Cl_2 are required?

Concentration to Mass Shortcut Calculations

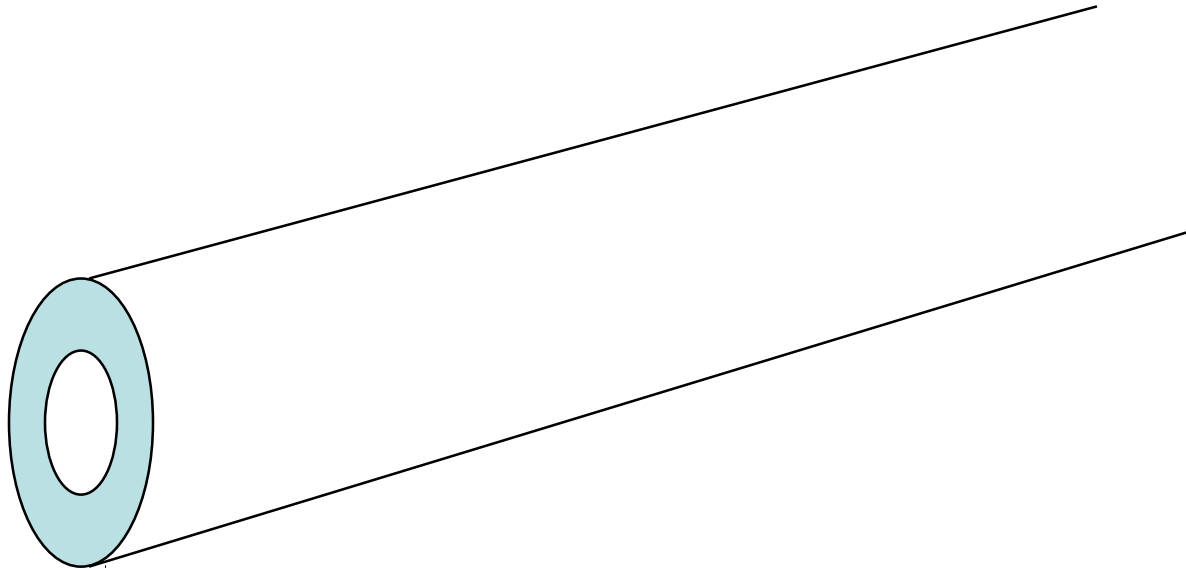


Solution to # 20

- $\text{mg/L} \times \text{MGD} \times 8.34 \text{ lbs./gal.} = \text{lbs/day}$
- Problem # 21:
- A water supply has a flow of 750,000 gal/day. If sodium hypochlorite with 12% available Cl_2 is used, how many pounds of sodium hypochlorite is required to maintain a dosage of 3 mg/L?

Problem # 21

- How many pounds of Cl_2 are required to disinfect 3600 ft. long by 10inch diameter C900 pipe if 50 mg/L is required?
- (Hint) Must find the volume of the pipe and then do the dosage formula.



Problem # 22

- A pump discharges 400gpm. What chlorine feed rate (pounds-per-day) is required to provide a dosage of 2.5 mg/L?
- Hint: there's 1440 min/day

Problem # 23

- How many lbs/day of hypochlorite (70% available Cl_2) are required for disinfection in a plant where the flow rate is 1.25mgd and the chlorine dosage is 2.5mg/L?
- Hint: convert % to decimal; always move two places to the left.

LMI Calculating Required Output

- Set-up & Installation

$$\frac{\text{Desired (mg/L) X GPM (Max Flow of Well Pump)}}{\% \text{ Concentration of Chemical (Use \% Whole Number)}} \times .006 \text{ (Constance Convert to GPH)}$$

= Required Pump Output in GPH

- Calculating output %

$$\frac{\text{Required Pump Output}}{\text{Maximum Output of Pump}} = \% \text{ Output Required from Pump}$$

- Calculating % Speed & % Stoke


 % Output Required from Pump (Square Root)
 = % Speed & % Stroke

Diaphragm Chemical Pump Calculation

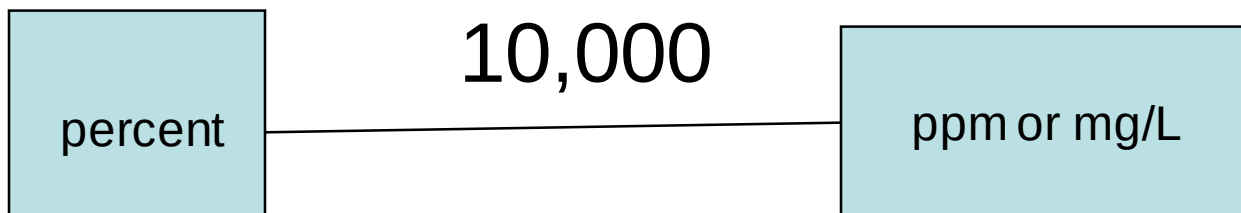
- Well submersible pump is pumping at 100 gpm (max flow) and is using 10% sodium hypochlorite for disinfection. The desired Cl_2 residual dosage is 0.5 mg/L, the max output is 0.42 GPH. What is the pump stroke and speed setting?

Diaphragm Chem. Pump Calculation

- Well submersible pump is pumping at 225 gpm (max flow) and is using 12% sodium hypochlorite for disinfection. The desired Cl_2 residual dosage is 0.5 mg/L, the max output is 1.0 GPH. What is the pump stroke and speed setting?

Mg/L to Percent

- A concentration or dosage expressed as mg/L can also be expressed as %(decimal). Mg/L are approximately equal to ppm, and % means parts per hundred.
- $\text{Mg/L} = \text{ppm} = \text{parts} \quad 1,000,000$
- $\% = \text{parts per hundred} = \text{parts} \quad 100$
- Because $1,000,000 \div 100 = 10,000$, converting from ppm (or mg/L) to % (decimal) is accomplished by dividing by 10,000.



Problem # 24, 25 & 26

- A chemical is to be dosed at 25mg/L. Express the dosage as %.
- Express 120 ppm as %.
- HTH used for disinfection has concentration of 65%. Express the concentration as mg/L. Be careful with this one!

Percent Strength

1. The percent strength of a solution can be expressed as percent-by weight.
 2. % strength (by Wt.) = $\frac{\text{Wt. of Solute}}{\text{Wt. of Solution}} \times 100\%$
 - Solute = Wt. of Chemical
 - Solution = the combined Wt. of Solute and Solvent
-
- If 25 lbs. of chemical is added to 400 lbs. of water, what is the percent strength of the solution by weight?
 - Wt. of Solution = Wt. of Solute + Wt. of Solvent
 - = 25 lbs. + 400 lbs.
 - = 425 lbs.

Percent Strength

- % Strength (by Wt.) = $\frac{\text{Wt. of Solute}}{\text{Wt. of Solution}} \times 100\%$
 $= \frac{25 \text{ lbs.}}{425 \text{ lbs.}} \times 100\%$
 $= 0.059 \times 100\%$
 $= 5.9 \%$

Percent Strength

- If 40 lbs. chemical is added to 120 gals. of water, what is the percent strength of the solution by weight?

1. % strength (by Wt.) = $\frac{\text{Wt. of Solute}}{\text{Wt. of Solution}} \times 100\%$

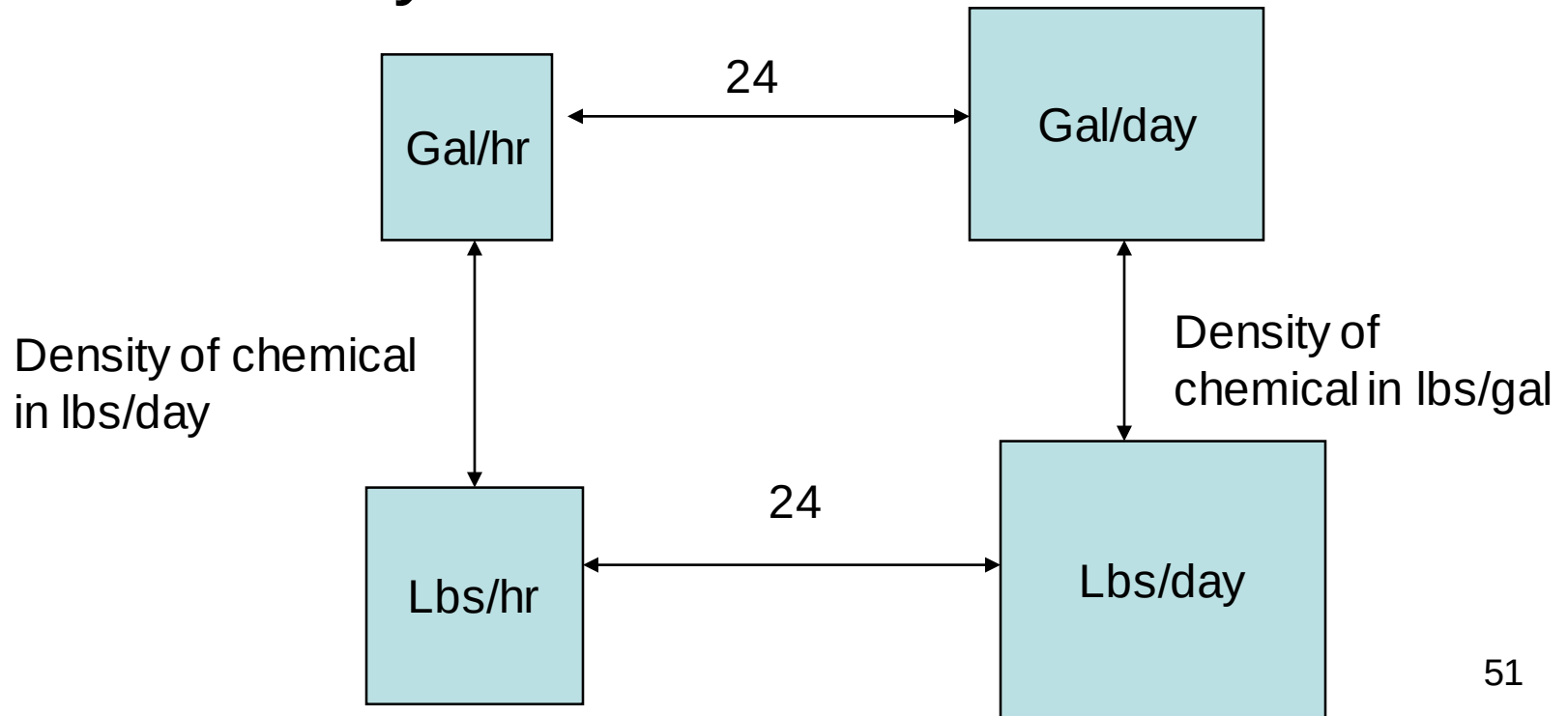
- Solute = Wt. of Chemical
- Solution = the combined Wt. of Solute and Solvent
- Convert 120 gals. of water to pounds of water.
- $(120 \text{ lbs.}) (8.334 \text{ lbs/gal}) = 1001 \text{ lbs.}$
- $\text{Wt. of Solution} = \text{Wt. of Solute} + \text{Wt. of Solvent}$
- $\quad \quad \quad = \quad 40 \text{ lbs.} \quad + \quad 1001 \text{ lbs.}$
- $\quad \quad \quad = \quad \quad \quad 1041 \text{ lbs.}$

Percent Strength

- % Strength (by Wt.) = $\frac{\text{Wt. of Solute}}{\text{Wt. of Solution}} \times 100\%$
 $= \frac{40 \text{ lbs.}}{1001 \text{ lbs.}} \times 100\%$
 $= 0.038 \times 100\%$
 $= 3.8 \%$

Feed Rate Conversion

- gal/hr to gal/day
- gal/hr to lbs/day
- lbs/hr to lbs/day
- lbs/hr to lbs/day



Problems # 27, 28

- #27- The feed rate for a chemical is 230 lbs/day. What is the feed rate expressed in lbs/hr?
- #28- A chemical has a density of 11.58 lbs/gal. The desired feed rate for the chemical is 0.6 gal/hr. How many lbs/day is this?

Solution to #27 & 28

- #27- multiply #/day by day/24 hr
- #28- converting from gal/hr to lbs/day, you are moving from a smaller box to a larger box and then to a still larger box. Therefore, multiplication by the density of the chemical and 24 is indicated.
- $0.6\text{gal/hr} \times (\text{density of chemical, lbs/gal}) \times 24 = \text{lb/day}$

Chlorine Dosage/Demand/Residual

- The Cl_2 requirement or Cl_2 dosage is the sum of the Cl_2 demand and the desired Cl_2 residual.
- $\text{dosage (mg/L)} = \text{demand (mg/L)} + \text{residual (mg/L)}$
- Problem # 29
- A sample of water is tested and found to have a Cl_2 demand of 6mg/L. The desired Cl_2 residual is 0.2mg/L. How many pounds of Cl_2 will be required daily to chlorinate a flow of 2.5mgd?

Problem # 30

- The Cl_2 demand of a water sample is 5.5mg/L. A Cl_2 residual of 0.3mg/L is desired. How many pounds of Cl_2 will be required daily for a flow of 3.5mgd?

Flow Rates

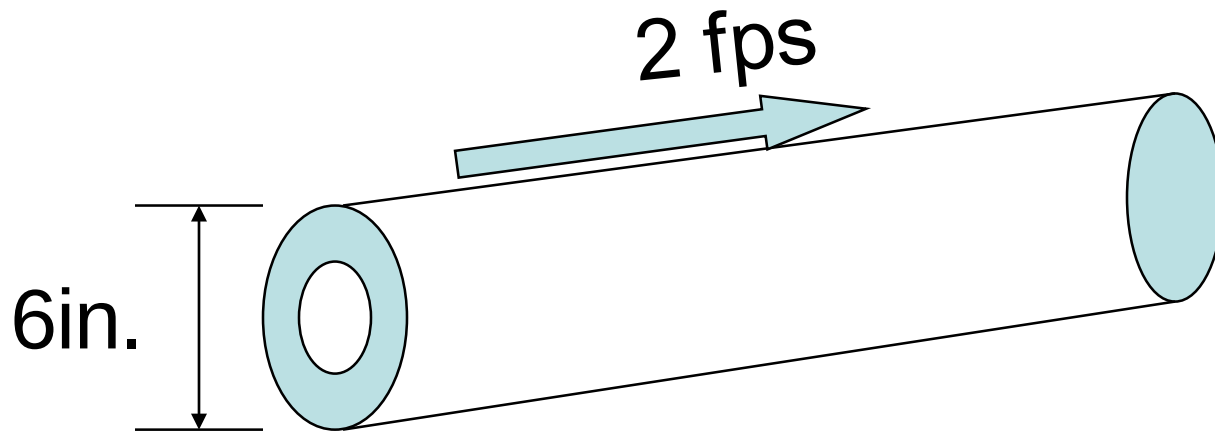
- Flow is express in;
- Gallons per minute (gpm)
- Cubic feet per second (cfs)
- Gallons per day (gpd)
- Million gallons per day (mgd)
- Conversion;
- $1 \text{ cfs} = 448 \text{ gpm}$
- $1 \text{ gpm} = 1440 \text{ gpd}$
- $\text{mgd} = \text{gpd} \div 1,000,000$

Flow Rates

- Flow in a pipeline, channel or stream at a particular moment depends on the cross-sectional area and the velocity of water moving through it & is found using the equation:
- $Q = A \times V$
- Q = flow rate, cu.ft. per time; sec, min, hour
- A = area, in square feet
- V = velocity, feet per time; sec, min, hours
- If a circular pipe is flowing full (most situations) the resulting flow rate is expressed as
- $\text{cuft/time} = 0.7854 \times D^2(\text{ft}^2) \times \text{ft/time}$

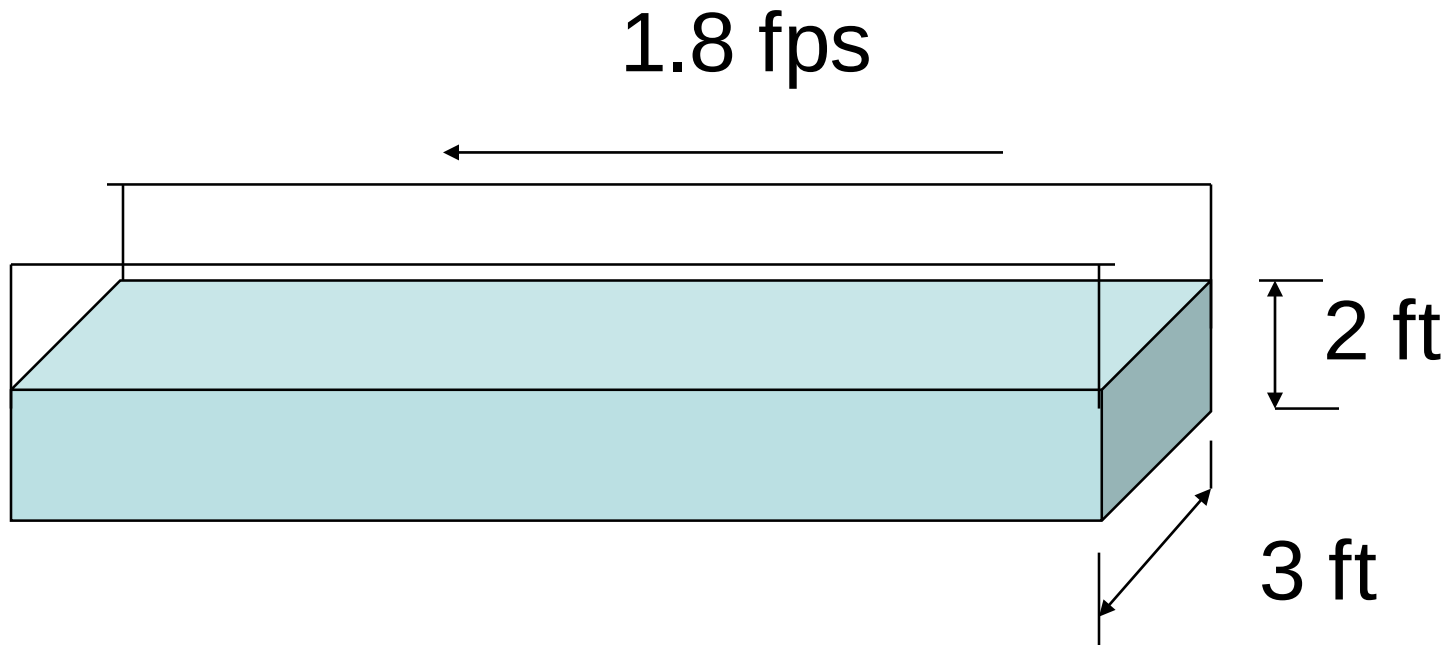
Problem # 31

- Find the flow in cfs in a 6 inch pipe, if the velocity is 2 feet per second.
- Don't forget to convert inches to feet
- Also find the cross sectional area of the pipe



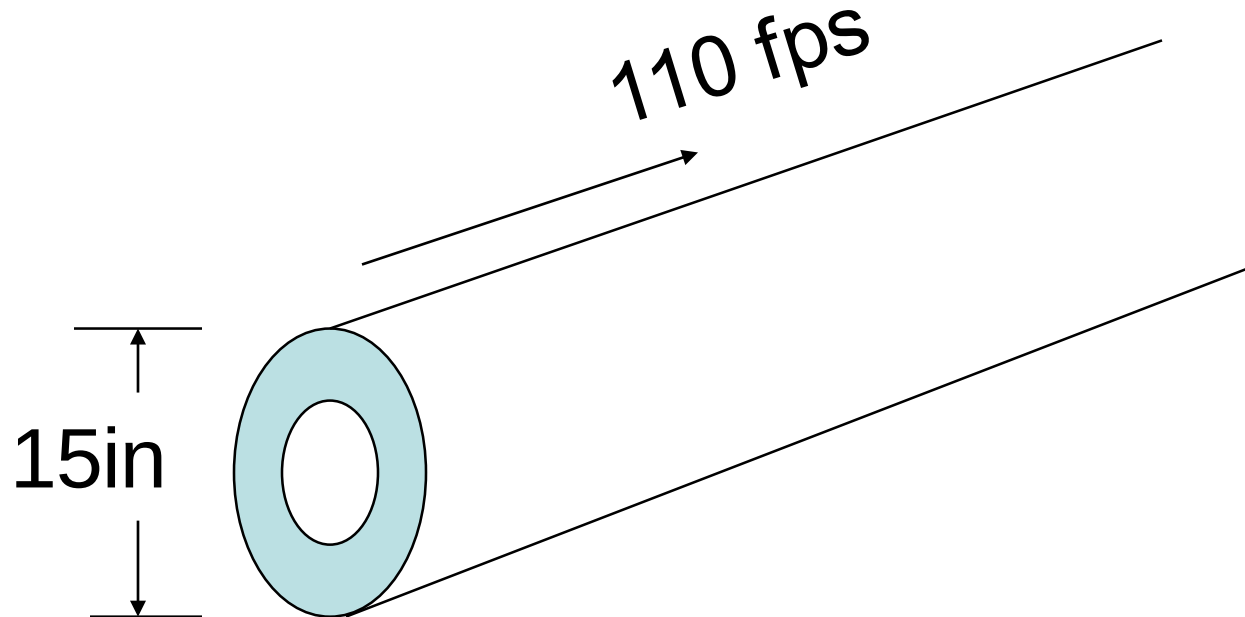
Problem # 32

- A channel is 3 ft. deep with water flowing at a depth of 2 ft. The velocity in the channel is found to be 1.8 fps. What is the cubic feet per second flow rate in the channel?



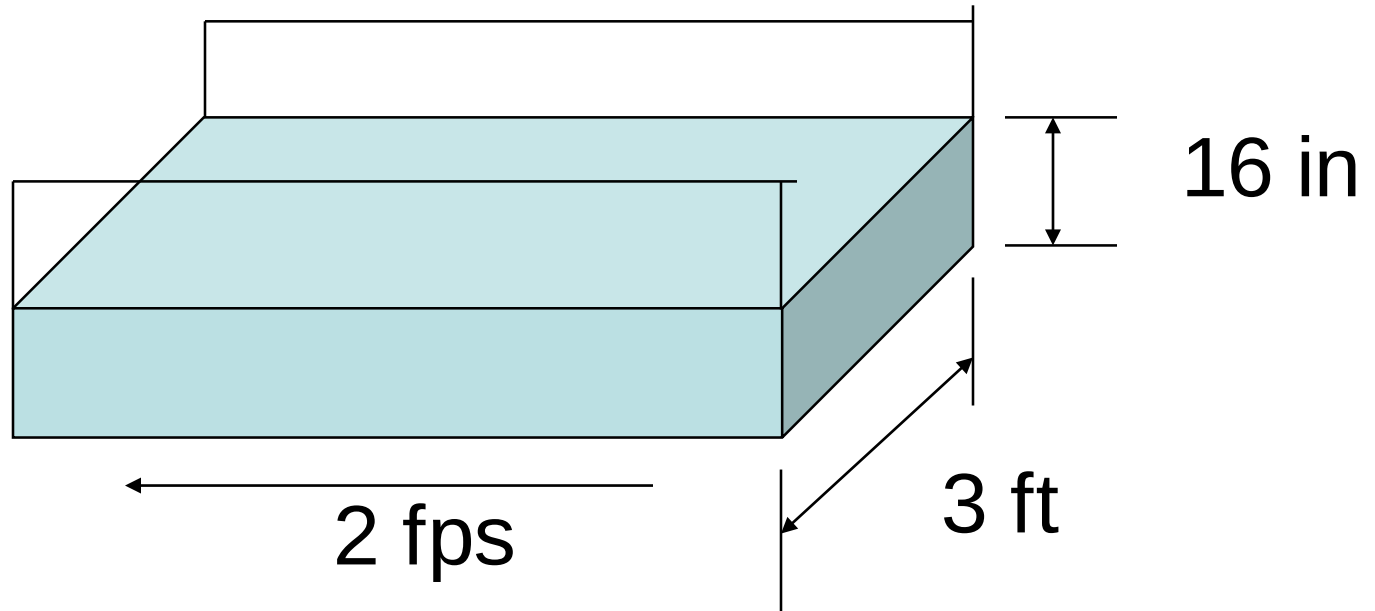
Problem # 33

- A 15 in. diameter pipe is flowing full. What is the gallons per minute flow rate in the pipe if the velocity is 110 fps?



Problem # 34

- What is the MGD flow rate through a channel that is 3 ft. wide with the water flowing at a depth of 16 in. at a velocity of 2 fps?



Problem # 35

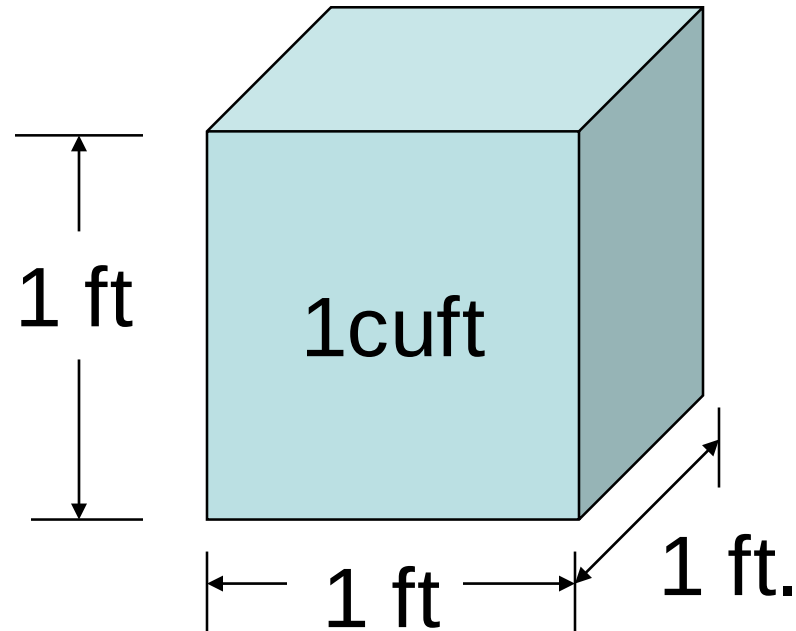
- a.) change 212 F to C
- b.) change 70 F to C
- c.) change 140 F to C
- d.) change 20 C to F
- e.) change 85 C to F
- f.) change 4 C to F

Pressure & Head Calculation

- Pressure is the weight per unit area
- Pounds per square inch, lbs/in^2
- Pounds per square foot, lbs/ft^2
- Pressure on the bottom of a container is not related to the volume of the container, nor the size of the bottom.
- Pressure is dependant on the height of the fluid in the container.
- The height of the fluid in a container is referred to as Head. Head is a direct measurement in feet & directly related to pressure.

Relationship between Feet & Head

- Weight of Water is 62.4 pounds per cu.ft.
- $7.48 \text{ gal/cuft} \times 8.34 \text{ lbs/gal} = 62.4 \text{ lbs/cuft}$



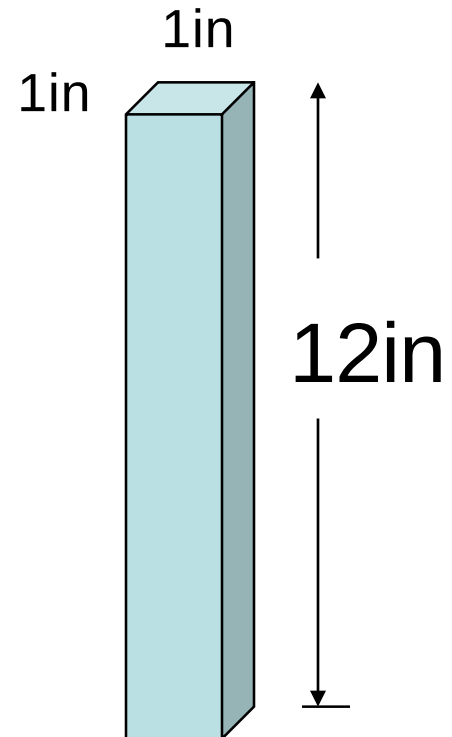
Pressure & Head

- Imagine a cube of water 1ft x 1ft x 1ft. Then, the surface area of any one side of the cube will contain 144 in.² (12in x 12in = 144 in²). The cube will also contain 144 columns of water one foot tall & one inch square.

$$\begin{aligned}\text{Weight} &= 62.4\text{lbs}/144\text{in}^2 \\ &= 0.433\text{lbs}/\text{in}^2 \text{ or} \\ &= 0.433 \text{ psi}\end{aligned}$$

$$\begin{aligned}\text{Therefore, 1 Feet of head} \\ &= 1\text{ft} \quad 0.433\text{psi} \\ &= 2.31 \text{ ft/psi}\end{aligned}$$

$$\begin{aligned}\text{So,} \quad 1\text{ft} &= 0.433 \text{ psi, and} \\ 1\text{psi} &= 2.31 \text{ feet}\end{aligned}$$



Problem # 36

- Convert 40 psi to feet of head
- 40 psi $0.433 \text{ psi/ft} = 92.37 \text{ feet of head}$
- 40 psi x $2.31 \text{ feet/psi} = 92.4 \text{ feet}$

Problem # 37, a, b & c

- Convert a pressure of 45 psi to feet of head
- Convert 12 psi to feet
- Convert 85 psi to feet

Problem # 38

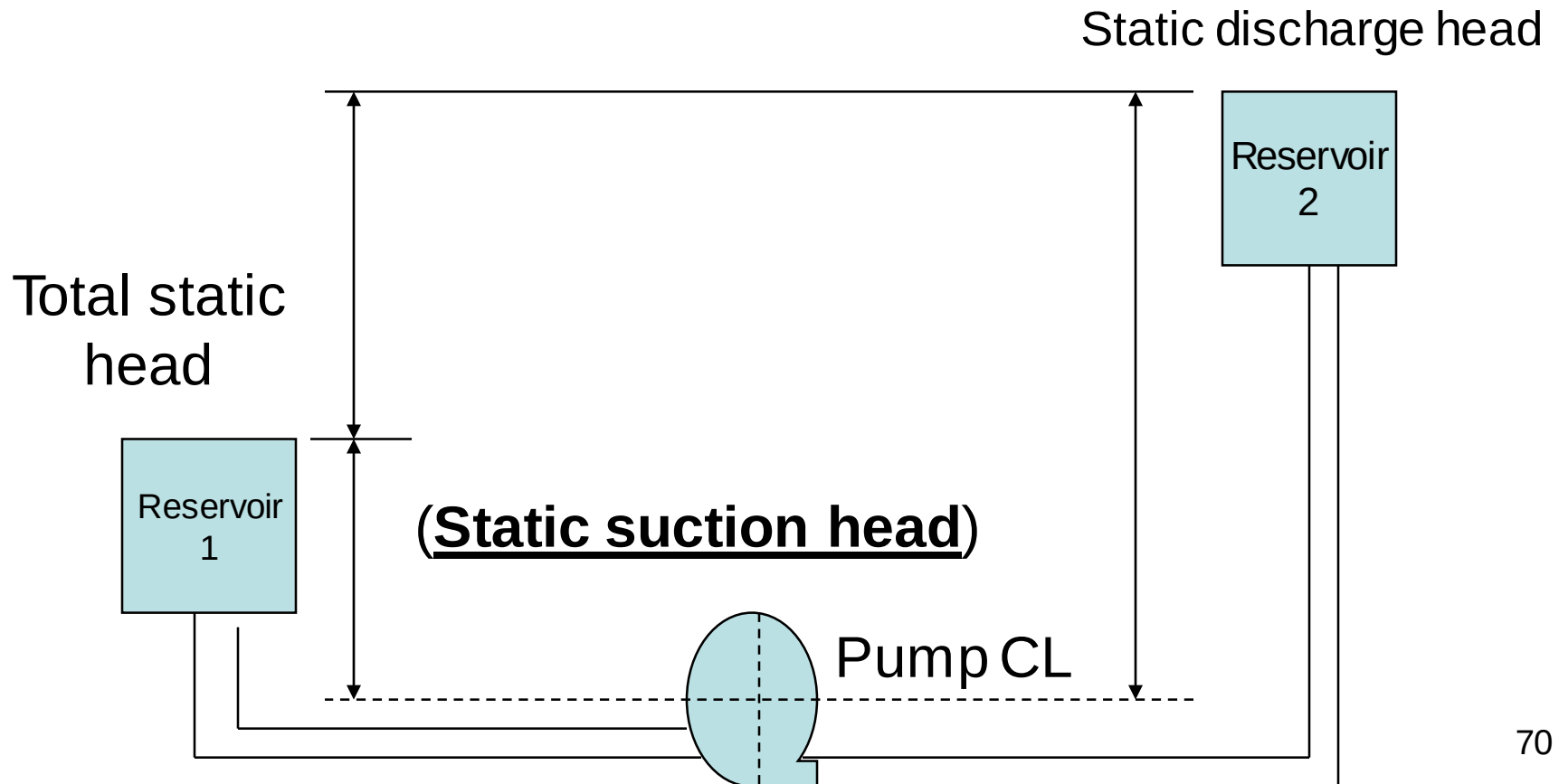
- It is 112 feet in elevation between the top of the reservoir and the watering point.
What will the static pressure (psi) be at the watering point?

Problem # 39

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

Static Head

- In a system where the reservoir feeding the pump is higher than the pump, the difference in elevation between the pump centerline and the free water surface of the reservoir feeding the pump is called?

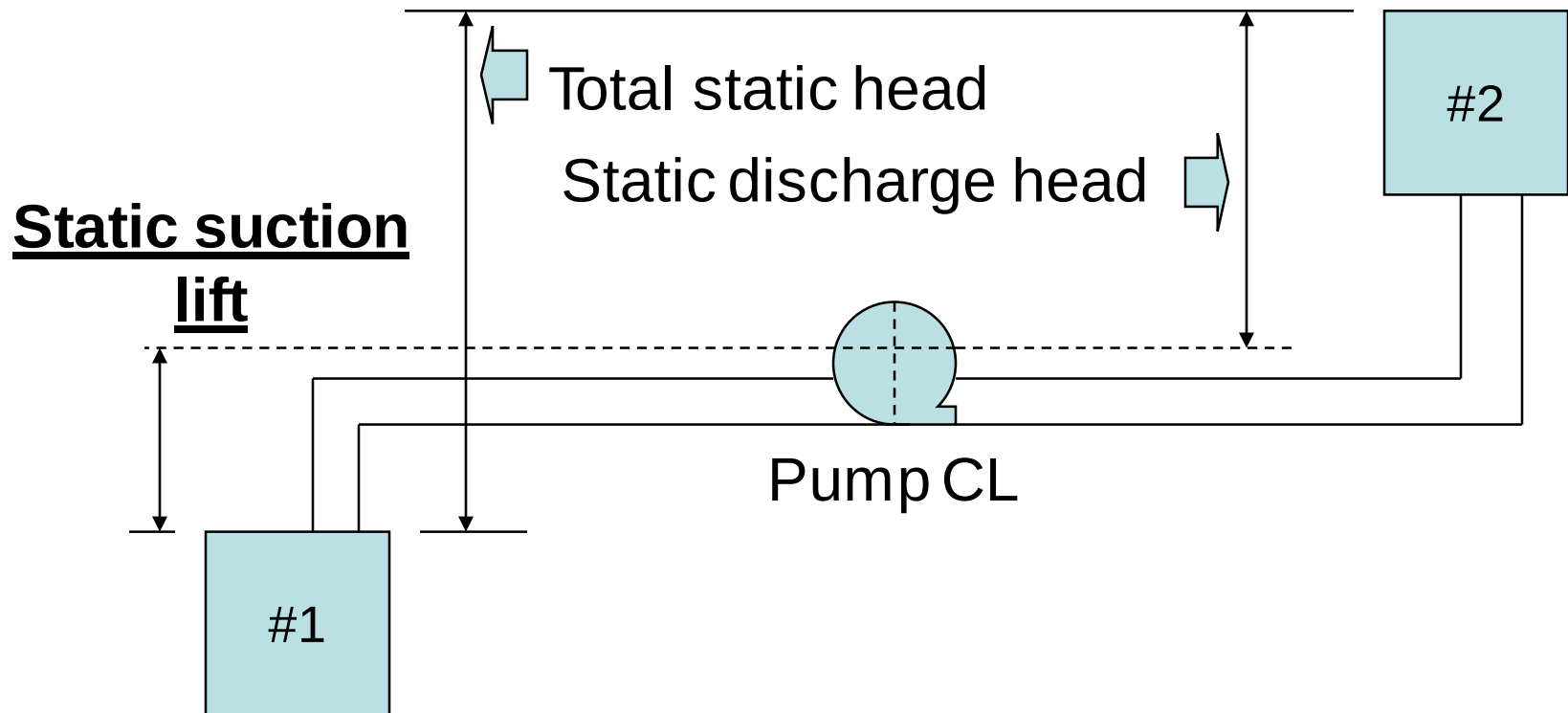


Static head

- Static Discharge Head is defined as the difference in height between the pump centerline and the level of the free water surface on the discharge side of the pump.
- Total Static Head is the total height that the pump must lift the water when moving it from reservoir #1 to reservoir #2.

Static Head

- In a system where the reservoir feeding the pump is lower than the pump, the difference in elevation between the centerline and the free water surface of the reservoir feeding the pump is called?



Problem # 40

- Locate, label and calculate (in feet):
- Static suction head
- Static discharge head
- Total static head

