Joint Workshop

Math for Operators - *Morning*

A Necessary Skill for Water & Wastewater Operators

Reading Process & Instrumentation Diagrams - *Afternoon*

Following the lines of monitoring and control

American Water Works Association
Pacific Northwest Section

PNWS-AWWA
Training
Coordination
Committee

Version 1.1 – March 2019

Prepared for Pacific Northwest Section AWWA

Math for Operators:

Content & Goals

To review basic math skills and to practice those skills on practical problems

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Content & Goals:

- To enhance and reinforce the math skills for operators

Outline:

- **Workshop topics**
  - **Math Basics**
  - **Aids to Navigation**
  - **Units of Measure**
  - **Algebra**
  - **Trigonometry**
  - **Conversion Factors**
  - **Practical Applications**
  - **Examples – *2nd hour***
  - **Problem Solving Practice – 3rd hour**

Safety

The cornerstone of everything we do

Safety – Mission Critical

There are many hazards associated with water operations. Some examples include;

- Confined spaces
- Trenching & excavation
- Electrical
- Vehicles & equipment
- Chemicals
- Ergonomic

"If you're not doing the job safely, you are not doing it right."

Photo from Tualatin Valley Water District

Protecting Yourself and Others

Rules to live by:

1. **You** are responsible for your safety and the safety of others
2. Follow the rules
3. If you're not trained for it; Don't do it
4. Work smarter, not harder
5. Don't take short cuts
6. Practice good housekeeping
7. Be Prepared
8. Be a safety advocate

Photo from Tualatin Valley Water District

"It's better to take a minute to save your life than to lose your life in a minute."

Personal Protection Equipment - PPE

Includes but is not limited to:

- Safety Glasses/Shield
- Hard Hat
- Hearing Protection
- Visible Safety Shirt/Jacket
- Protective Toe Footwear
- Gloves
- Gas Monitors
- Harness
- Radio/Flashlight
- *Mask*
- *Hand sanitizer*

Graphic from Whitney Equipment Company, Inc.

811 – Call Before You Dig – *it's the law*

Utility Notification Center

- Each state operates its own 811 center
  - ID – 811 or 1-800-342-1585 (Boise) & 1-866-729-5140 (CdA)
  - OR – 811 or 1-800-332-2344
  - WA – 811 or 1-800-424-5555
  - Or on-line
- Open 24/7
- May be regional within a state
- 2 days advanced notice is required
- https://youtu.be/ZH7cXJ2PpdY

Graphic from Tualatin Valley Water District

PNWS Training-in-a-Box (TIAB)

- Workshop curricula prepared by the Section's Training Coordination Committee to increase the quality and consistency of training in PNWS and to increase distribution of that training throughout the Section
- Current programs:
  - Pump Station O&M
  - Basic Waterworks
  - Emergency Preparedness
  - Water Storage Basics
  - Math for Operators / P&IDs
  - Groundwater Basics
- Upcoming programs:
  - Chemistry for Operators
  - Chemical Feed & Storage Systems

American Water Works Association
Pacific Northwest Section
Northwest Washington Subsection

Questions, Comments and Suggestions?

American Water Works Association
Pacific Northwest Section

PNWS-AWWA
Training
Coordination
Committee

Prepared for the Pacific Northwest Section - AWWA

Math for Operators

If you can't do the numbers, you can't make the water (or clean the wastewater!)

Version 1.0 & May 2019

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Math Basics

You can't run the place without it!

Math Basics - ***Real*** *Basics*

1 + 1 = 2

2 * 2 = 4

The numbers by themselves are generally not useful until we attach units to them so we know what we are measuring

We will assume you have basic math (arithmetic) skills; + - x & /

Math Basics – Adding Units of Measure

1 foot + 1 inch ≠ 2

Math Basics – When adding and subtracting must be the SAME units

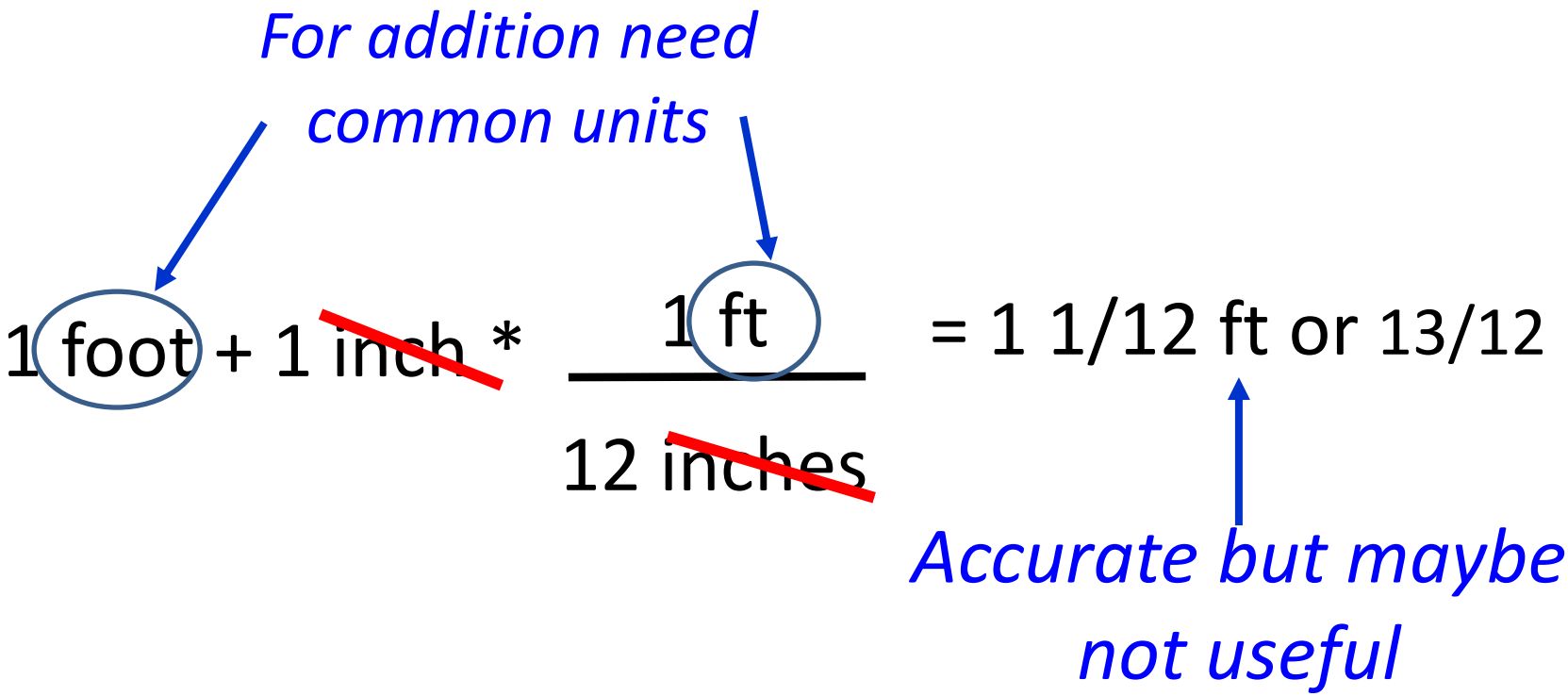
1 foot + 1 inch ≠ 2

~~*1 foot + (1 inch * (12 inches/foot))=*~~

1 foot + (1 ~~inch~~ * (1 foot/12 ~~inches~~))=

Convert to a common unit of measure, in this case feet

Closer Look – Keeping track of UNITS



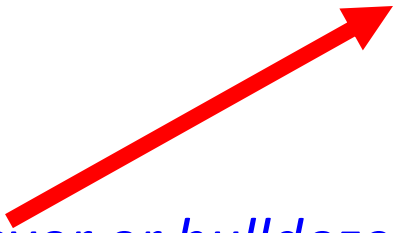
Unit Basics – It makes a difference what you want to do

1 foot + 1 inch ≠ 2

1 foot + 1 inch * (1 foot/12 inches)=

1 foot + 1/12 foot = 1-1/12 feet

1 foot + .083 foot = 1.083 feet



Useful for a surveyor or bulldozer operator, or for measuring liquid depth

Unit Basics 2

$$1 \text{ foot} + 1 \text{ inch} \neq 2$$

$$1 \text{ foot} * (12 \text{ inches/foot}) + 1 \text{ inch} =$$

$$12 \text{ inches} + 1 \text{ inch} = 13 \text{ inches}$$

Useful for a plumber or carpenter

Our choice of units has a lot to do with who we are and what we need to do with the "answer"

Math Basics – Short Cuts

Exponents

$2 * 2 = 4$

$2^2 = 4$

Whole number exponents used area and volume formulas

You can often do these by hand or in your head.

$3^2 = 3 * 3 = 9$

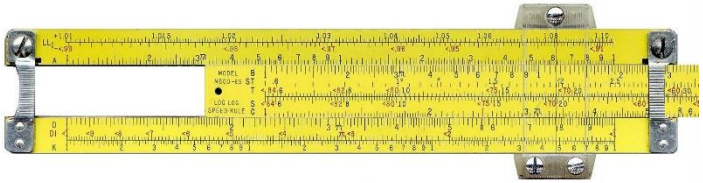
Fractional exponents used in friction formulas and other equations

$30^{1.85} = 540.35$

For this one you need your calculator, a computer, a slide rule, or log tables.

FOUR-PLACE COMMON LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1 2 3 4 5 6 7 8 9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4 8 12 17 21 25 29 33 37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4 8 11 15 19 23 26 30 34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3 7 10 14 17 21 24 28 31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3 6 10 13 16 19 23 26 29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3 6 9 12 15 18 21 24 27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3 6 8 11 14 17 20 22 25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3 5 8 11 13 16 18 21 24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2 5 7 10 12 15 17 20 22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2 5 7 9 12 14 16 19 21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2 4 7 9 11 13 16 18 20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2 4 6 8 11 13 15 17 19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2 4 6 8 10 12 14 16 18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2 4 6 8 10 12 14 15 17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2 4 6 7 9 11 13 15 17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2 4 5 7 9 11 12 14 16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2 3 5 7 9 10 12 14 15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2 3 5 7 8 10 11 13 15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2 3 5 6 8 9 11 13 14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2 3 5 6 8 9 11 12 14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1 3 4 6 7 9 10 12 13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1 3 4 6 7 9 10 11 13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1 3 4 6 7 8 10 11 12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1 3 4 5 7 8 9 11 12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1 3 4 5 6 8 9 10 12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1 3 4 5 6 8 9 10 11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1 2 4 5 6 7 9 10 11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1 2 4 5 6 7 8 10 11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1 2 3 5 6 7 8 9 10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1 2 3 5 6 7 8 9 10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1 2 3 4 5 7 8 9 10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1 2 3 4 5 6 8 9 10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1 2 3 4 5 6 7 8 9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1 2 3 4 5 6 7 8 9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1 2 3 4 5 6 7 8 9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1 2 3 4 5 6 7 8 9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1 2 3 4 5 6 7 8 9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1 2 3 4 5 6 7 7 8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1 2 3 4 5 5 6 7 8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1 2 3 4 4 5 6 7 8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1 2 3 4 4 5 6 7 8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1 2 3 3 4 5 6 7 8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1 2 3 3 4 5 6 7 8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1 2 2 3 4 5 6 7 7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1 2 2 3 4 5 6 6 7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1 2 2 3 4 5 6 6 7
N	0	1	2	3	4	5	6	7	8	9	1 2 3 4 5 6 7 8 9



Images from International Slide Rule Museum, coolstuff4891.blogspot.com+, & Abelard.com

Math Basics – Short Cuts

Then how do the units follow?

$2 * 2 = 2^2 = 4$

$ft * ft = ft^2$

$3^3 = 3 * 3 * 3 = 27$

$ft * ft * ft = ft^3$

Math Basics – 2 & 3 dimensions

$2 * 2 = 4$

$2^2 = 4$

$ft * ft = ft^2$

AREA

$3^3 = 3 * 3 * 3 = 27$

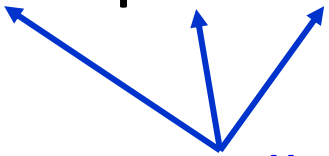
$ft * ft * ft = ft^3$

Volume

Math Basics – Multiplication & Division

2 ft * 2 ft = 4 Square Feet (ft^2)

ft^2 = sq ft = sf



All abbreviations are used

Math Basics – Multiplication & Division

2 ft * 2 inches = 4 foot-inch

Correct
But not a useable term

Math Basics – Multiplication & Division

2 acre * 2 feet = 4 acre-feet

Very correct!
Is a common term for lake & large reservoir volume

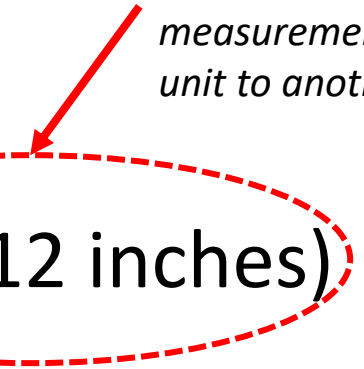
Not all mixed units are wrong

(So how big is an acre you ask? 43,560 sf or a square 208.71 feet on a side)

Math Basics – Multiplication & Division

Calculating areas

This is a conversion factor. It allows us to convert a measurement in one type of unit to another type of unit.



=2 ft * 2 inches

=2 ft * 2 inches * (1 foot/12 inches)

= 2 ft * 2/12 ft

= 4/12 ft^2

= 0.33 ft^2 (or 1/3 ft^2)

Math Basics – Multiplication & Division

But what if we want sq. in. instead of sq. ft.?

=2 ft * 2 inches

=(2 ft * (12 inches/1 foot)) * 2 inches

= 24 inches * 2 inches

= 48 inches^2

Same relationship, only inverted

Math Basics – Multiplication & Division

Calculating flow rates

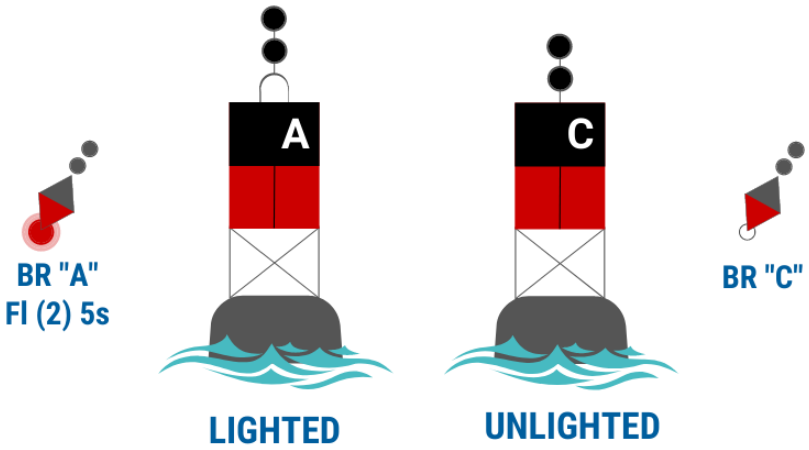
$$= \frac{200 \text{ gallons}}{20 \text{ minutes}}$$

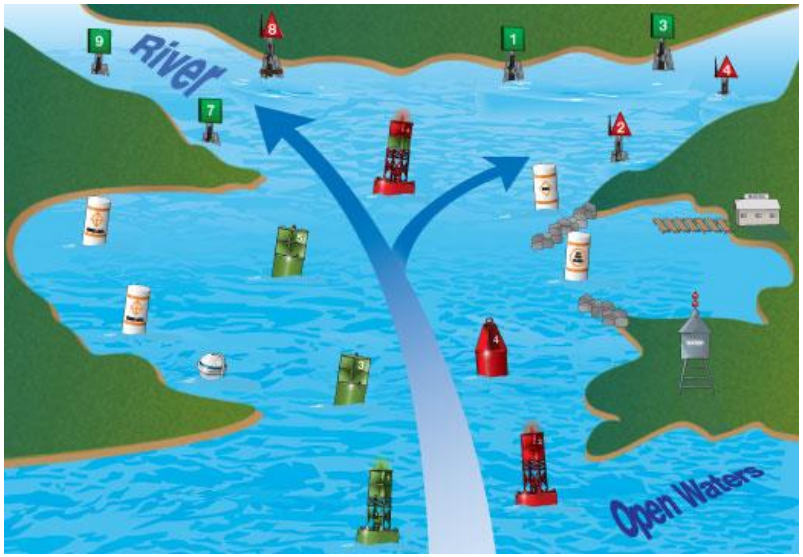
= 10 gallons per minute (gpm)

gpm is one of many terms of flow measurement

Aids to Navigation

Resources that will come in handy





Graphics from BoatUS Foundation & Boat ED

Aids to Navigation - Handout

Formula/Conversion Table

Water Treatment, Distribution, & Water Laboratory Exams

Alkalinity, mg/L as $CaCO_3$ = $\frac{(\text{Titrant Volume, mL})(\text{Acid Normali}}{\text{Sample Volume, mL}}$

Amps = $\frac{\text{Volts}}{\text{Ohms}}$

Area of Circle* = $(0.785)(\text{Diameter}^2)$

Area of Circle = $(3.14)(\text{Radius}^2)$

Area of Cone (lateral area) = $(3.14)(\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$

Area of Cone (total surface area) = $(3.14)(\text{Radius})(\text{Radius} + \sqrt{\text{Radi}}$

Area of Cylinder (total exterior surface area) = [End #1 SA] + [E

Where SA = surface

Area of Rectangle* = (Length)(Width)

Area of Right Triangle* = $\frac{(\text{Base})(\text{Height})}{2}$

Average (arithmetic mean) = $\frac{\text{Sum of All Terms}}{\text{Number of Terms}}$

Average (geometric mean) = $[(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$ *The n*

Blending = $(V_1)(C_1) + (V_2)(C_2) = (V_3)(C_3)$ *Where V = volume or*

Formula/Conversion Table

Wastewater Treatment, Collection, Industrial Waste, & Wastewater Laboratory Exams

Alkalinity, mg/L as $CaCO_3$ = $\frac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50{,}000)}{\text{Sample Volume, mL}}$

Amps = $\frac{\text{Volts}}{\text{Ohms}}$

Area of Circle* = $(0.785)(\text{Diameter}^2)$

Area of Circle = $(3.14)(\text{Radius}^2)$

Area of Cone (lateral area) = $(3.14)(\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$

Area of Cone (total surface area) = $(3.14)(\text{Radius})(\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2})$

Area of Cylinder (total exterior surface area) = [End #1 SA] + [End #2 SA] + [(3.14)(Diameter)(Height or Depth)]

Where SA = surface area

Area of Rectangle* = (Length)(Width)

Area of Right Triangle* = $\frac{(\text{Base})(\text{Height})}{2}$

Average (arithmetic mean) = $\frac{\text{Sum of All Terms}}{\text{Number of Terms}}$

Average (geometric mean) = $[(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$ *The nth root of the product of n numbers*

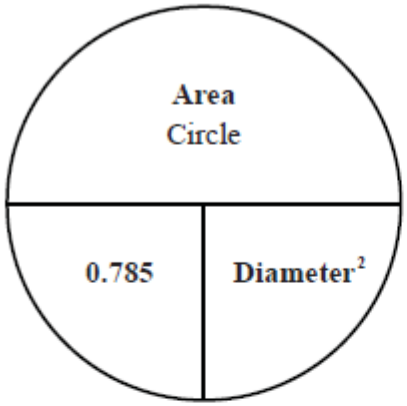
Biochemical Oxygen Demand (seeded), mg/L = $\frac{[(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L}) - \text{Seed Correction Factor, mg/L})][300\text{ mL}]}{\text{mL of Sample}}$

Biochemical Oxygen Demand (unseeded), mg/L = $\frac{[(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})][300\text{ mL}]}{\text{mL of Sample}}$

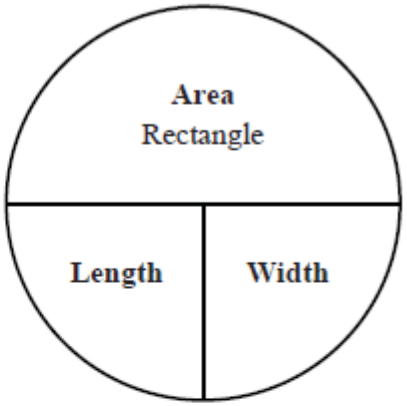
Graphics from ABC Professional Operators

Aids to Navigation – Handout2

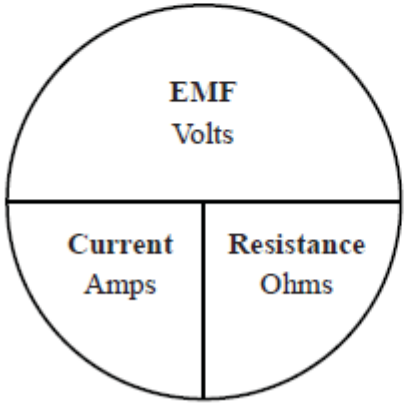
Area of Circle



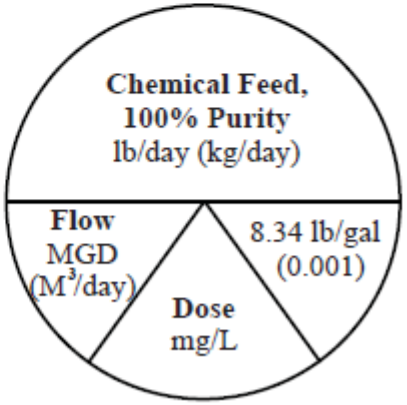
Area of Rectangle



Electromotive Force (EMF), Volts



Feed Rate, lb/day (kg/day)



Force, lb (Newtons)

Loading Rate, lb/day (kg/day)

Graphics from ABC Professional Operators

Abbreviations

C	Celsius
cfs	cubic feet per second
cm	centimeters
DO	dissolved oxygen
EMF	electromotive force
F	Fahrenheit
ft	feet
ft lb	foot-pound
g	grams
gal	US gallons
gfd	US gallons flux per day
gpcd	US gallons per capita per day
gpd	US gallons per day
gpg	grains per US gallon
gpm	US gallons per minute
hp	horsepower
hr	hours
in	inches
kg	kilograms
km	kilometers
kPa	kilopascals
kW	kilowatts
kWh	kilowatt-hours
L	liters
lb	pounds
Lpcd	liters per capita per day
Lpd	liters per day

Conversion Factors

1 acre	= 43,560 ft^2
	= 4,046.9 m^2
1 acre foot of water	= 326,000 gal
1 cubic foot of water	= 7.48 gal
	= 62.4 lb
1 cubic foot per second	= 0.646 MGD
	= 448.8 gpm
1 cubic meter of water	= 1,000 kg
	= 1,000 L
	= 264 gal
1 foot	= 0.305 m
1 foot of water	= 0.433 psi
1 gallon (US)	= 3.785 L
	= 8.34 lb of water

Units of Measure

Tracking what we count

Time for an Example

A 20-foot diameter tank, with 10,000 gallons of water (4.25 feet water depth) is drained in 2 hours using a pump. What is average flow rate in gpm?

Graphics from Pioneer Water Storage Tank

Time for an Example

A 20-foot diameter tank, with 10,000 gallons of water (4.25 feet water depth) is drained in 2 hours using a pump. What is average flow rate in gpm?

$$\frac{10{,}000 \text{ gallons} * 1 \text{ hour}}{2 \text{ hours} * 60 \text{ minutes}}$$

Change units from what you are given to what you need

Time for an Example

A 20-foot diameter tank, with 10,000 gallons of water (4.25 feet water depth) is drained in 2 hours using a pump. What is average flow rate in gpm?

$$\frac{10{,}000 \text{ gallons} * 1 \text{ hour}}{2 \text{ hours} * 60 \text{ minutes}} = 83.3 \text{ gpm}$$

Average flow rate. Why is this likely not the continuous flow rate beginning to end?

Time for an Example

Same flow, different units

10,000 gallons / 7.48 gallons / cu ft

= 1,336.89 cu ft

$$= \frac{1{,}336.89\ ft^3}{2\ hrs \times 60\ min./\ hr \times 60\ sec./\ min.}$$

= 0.186 cubic feet per second (cfs)

Volume per unit of time

Time for an Example

Could we go from gpm to cfs another way?

10,000 gallons / 120 minutes = 83.3 gpm

From the info we have this is the quickest way to get volume / unit time

83.3 gpm x conversion factor ⇨ ?cfs

Look in our aids and tables to find a conversion factor that fits

83.3 ~~gpm~~ x 0.002228 cfs / ~~gpm~~

= 0.186 cubic feet per second (cfs)

Time for Another Example

Different starting information

$$= \frac{200 \text{ cu ft}}{20 \text{ seconds}}$$

= 10 cubic feet per second (cfs)

Volume per unit of time

Percentage, Fraction & Decimal

If the Mariners went 1 for 4 on recent road trip … demonstrate winning

As a fraction

As a decimal

As a percentage

Percentage, Fraction & Decimal

If the Mariners went 1 for 4 on recent road trip … demonstrate winning

$\frac{1}{4}$ Fraction

0.25 Decimal

25% Percentage

Algebra

Just who is "X" and what do they want?

First We Need to Understand Math Order of Operations

- The order in which operations should be done is abbreviated as PEMDAS
  - **P**arentheses **()**
  - **E**xponents **^**
  - **M**ultiplication & **D**ivision (from left to right) *** /**
  - **A**ddition & **S**ubtraction (from left to right) **+ -**
    - **"Please Excuse My Dear Aunt Sally"**
  - $Q=((w_1+w_2)/2*d)*C/n*R^{2/3}*S^{1/2}$

    (Manning's Equation for a trapezoidal channel)

Algebra – Solving for X (and sometimes half of the rest of the alphabet)

Addition

$$X + 3 = 12$$

Looking to isolate X on one side of the equation

$$X + 3 \mathbf{- 3} = 12 \mathbf{- 3}$$

$$X = 9$$

Subtract 3 from each side of the equal sign

Algebra – Solving for X

Subtraction

$$X - 3 = 12$$

$$X - 3 \mathbf{+ 3} = 12 \mathbf{+ 3}$$

$$X = 15$$

Again we are looking to isolate X on one side of the equation

Add 3 from each side of the equal sign

Algebra – Solving for X

$$3 * X = 12$$

Multiplication

$$\frac{3 * X}{3} = \frac{12}{3}$$

$$\frac{3*X}{3} = \frac{12}{3}$$

$$X = 4$$

Divide each side by 3

Algebra – Solving for X

$$X / 3 = 12$$

Division

$$\frac{X * \mathbf{3}}{3} = 12 * \mathbf{3}$$

$$\frac{X * \cancel{\mathbf{3}}}{\cancel{\mathbf{3}}} = 12 * \mathbf{3}$$

$$X = 36$$

Multiply each side by 3

Algebra – Solving for X

$$36 / X = 12$$

$$\frac{36 * X}{X * 12} = \frac{12 * X}{12}$$

$$\frac{36 * \cancel{X}}{\cancel{X} * 12} = \frac{\cancel{12} * X}{\cancel{12}}$$

$$X = 3$$

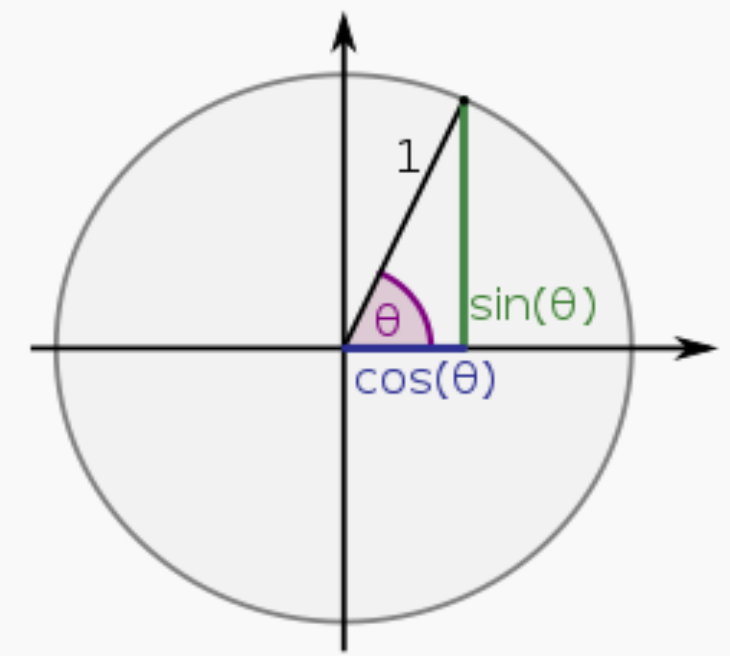
Multiply each side by X to bring X to the numerator and divide each side by 12 to isolate X on one side of the equation

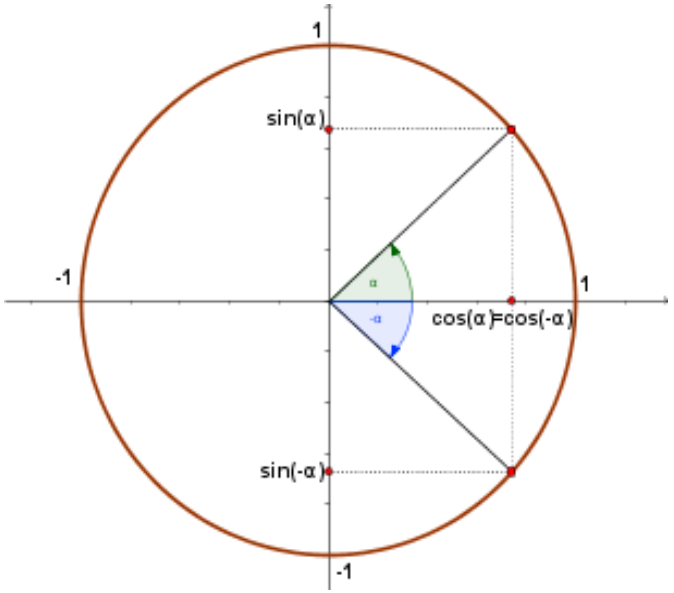
Trigonometry

It's all about relationships!

Trigonometry

- From Greek trigonon "triangle" + metron "measure"
- New terms
  - Angle (theta, θ)
  - Sine
  - Cosine
  - Tangent





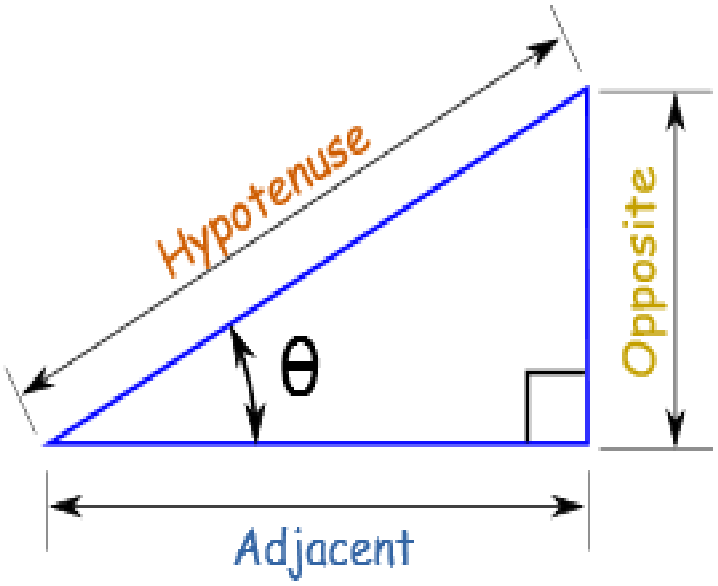
Graphics from Wikepedia & MathPortal.org

How are They Defined?

$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

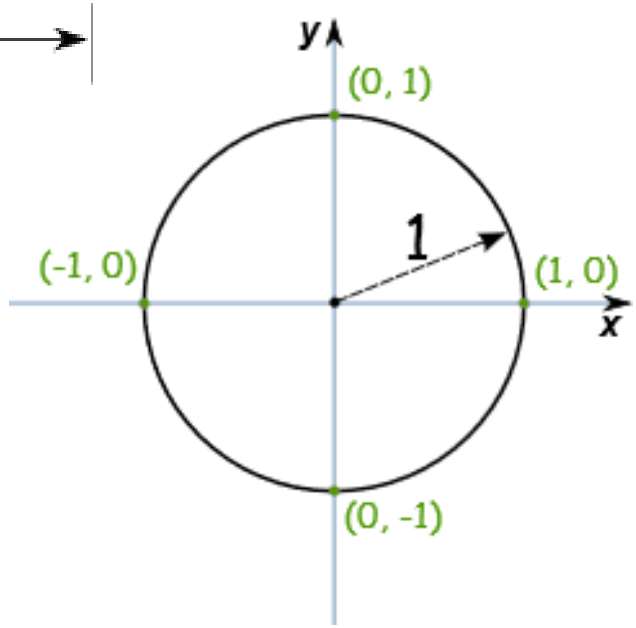
$$\cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\tan\theta = \frac{\text{Opposite}}{\text{Adjacent}}$$



Angle	Degrees	Radians
Right Angle	90°	π/2
Straight Angle	180°	π
Full Rotation	360°	2π

Graphics from Mathisfun.com



Conversion Factors

It's all about tracking units!

Conversion Factors are Your Friend!

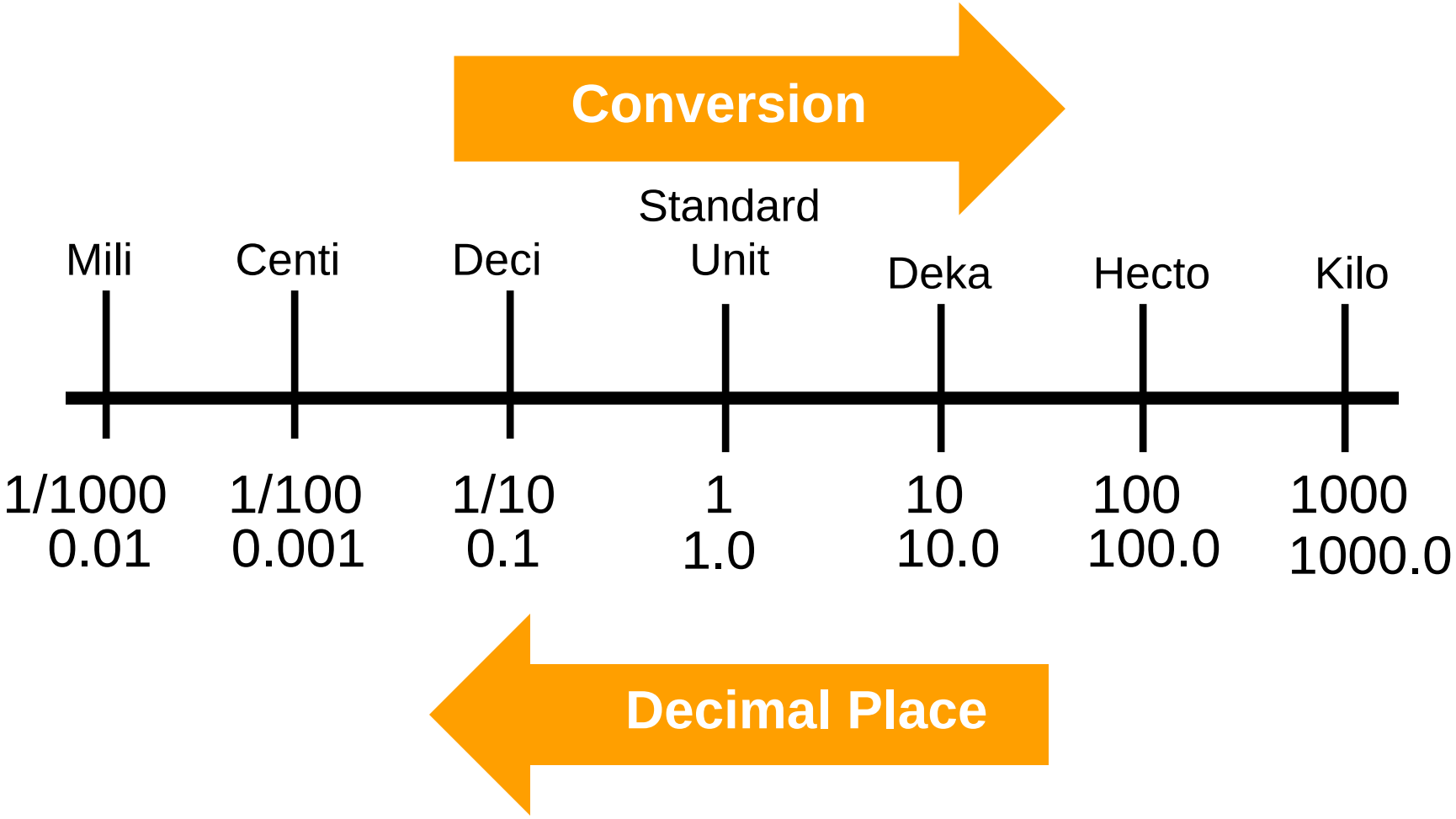
Most all of water and wastewater math is about converting from one set of units to another.

Conversion Factors are Your Friend!

1 foot of water = 0.433 psi
1 psi = 2.31 feet of water (head)
1 cubic foot = 7.48 gallons
1 gallon water = 8.34 pounds

Memorize these (and other) conversion factors!

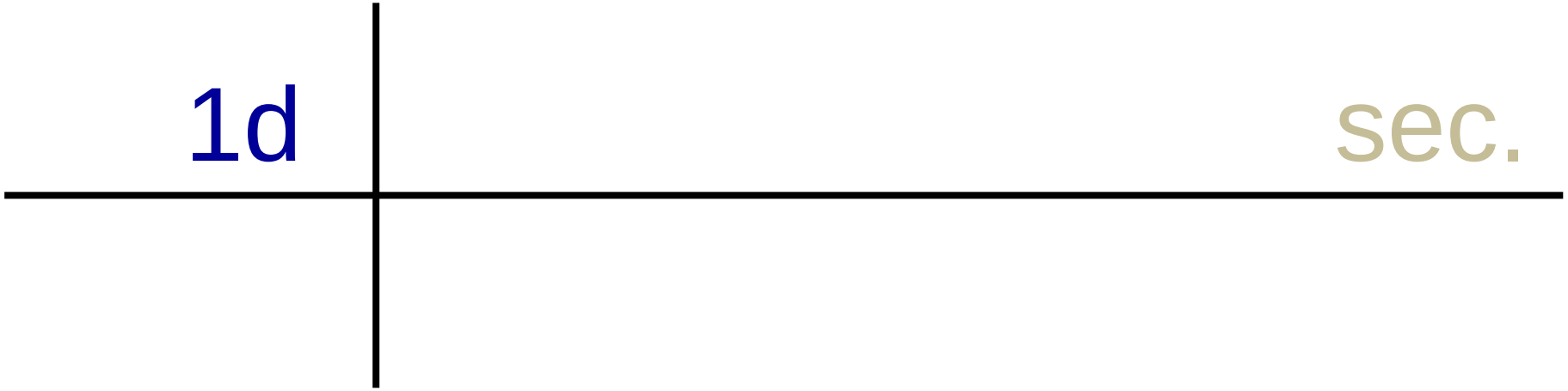
Conversion Factors are Your Friends!



Time Conversion Example

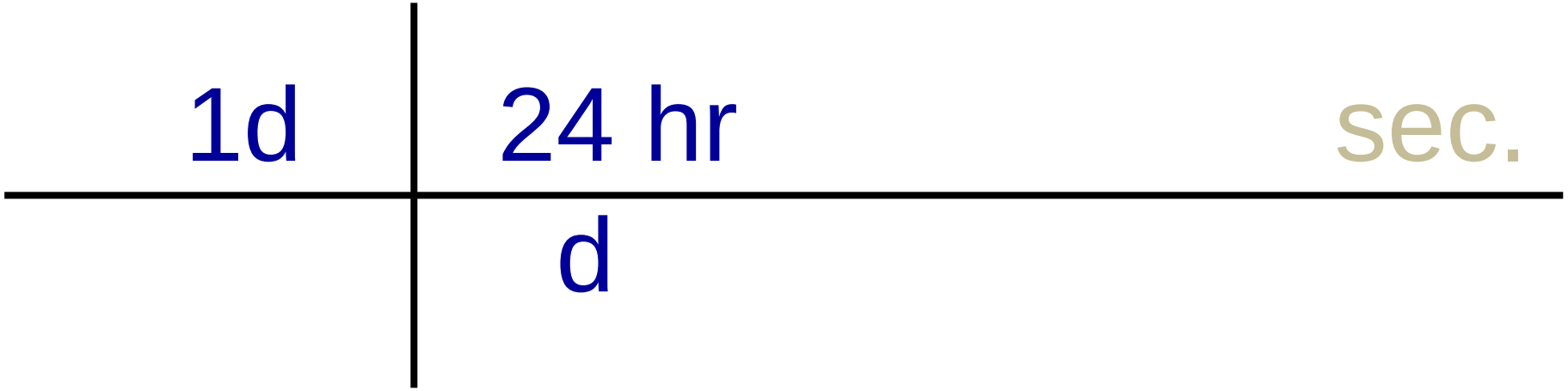
Determine how many seconds are in a day.

Starting Point



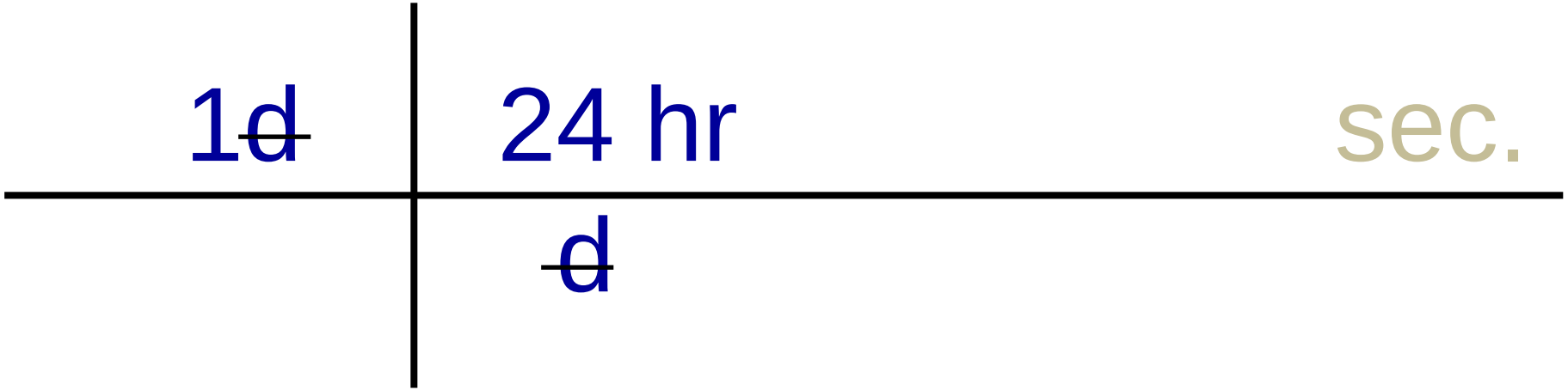
Start with 1 day and head towards seconds, one unit of measure at a time.

One Step at a Time Days to Hours



24 hour per day

One Step at a Time



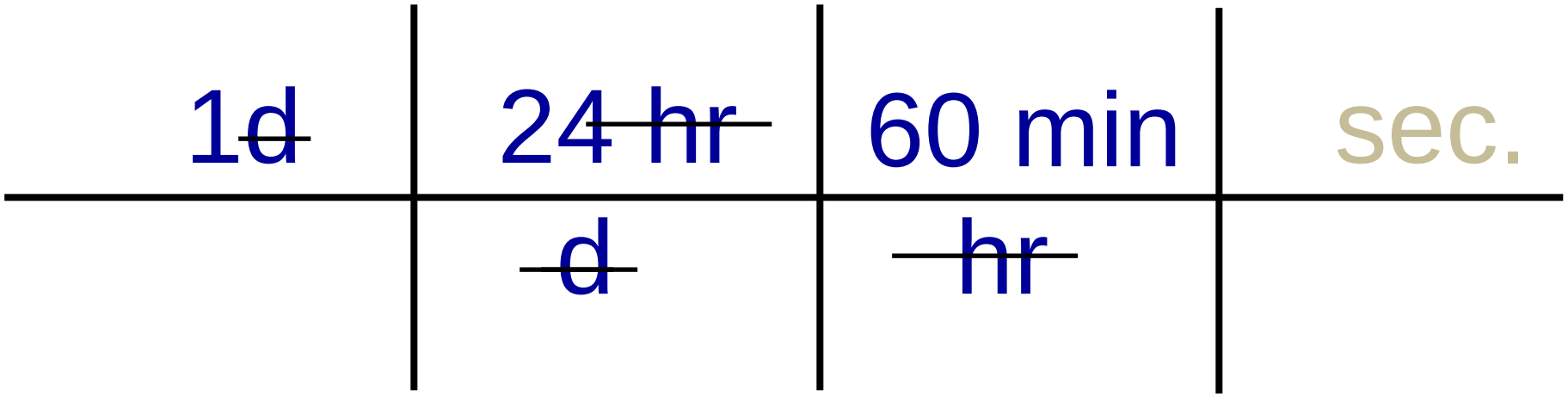
Days cancel out

One Step at a Time – Hours to Minutes

$$\frac{1\,\cancel{d}}{} \quad \frac{24\ hr}{\cancel{d}} \quad \frac{60\ min}{hr}$$

60 minutes per hour

One Step at a Time – Hours to Minutes



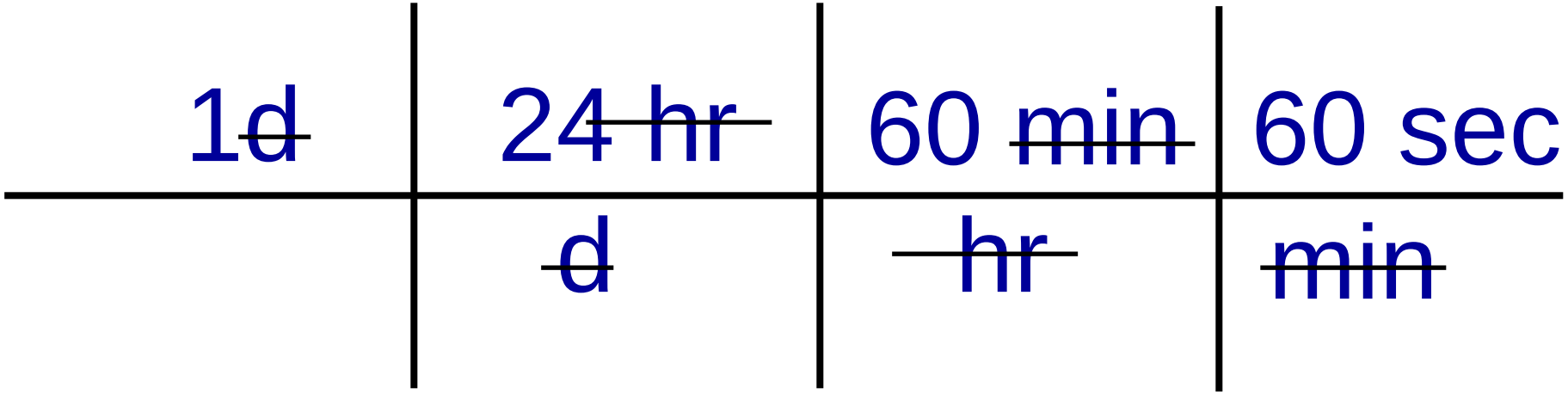
Hours cancel

One Step at a Time – Minutes to Seconds

$$\frac{1\,\cancel{d}}{} \quad \frac{24\,\cancel{hr}}{\cancel{d}} \quad \frac{60\ min}{\cancel{hr}} \quad \frac{60\ sec}{min}$$

60 Seconds per minute

One Step at a Time



Minutes cancel

Now do the Math

Multiply
1 x 24 x 60 x 60 =
86,400 seconds in 1 day

Keeping Track of the Units

1 foot of water = 0.433 psi

What is the pressure of 3 feet of water?

Keeping Track of the Units

1 foot of water = 0.433 psi

$$3 \text{ feet of water} * \frac{0.433 \text{ psi}}{1 \text{ foot of water}}$$

Keeping Track of the Units

1 foot of water = 0.433 psi

$$\frac{3 \text{ feet of water} * \quad 0.433 \text{ psi}}{1 \text{ foot of water}}$$

= 1.3 psi

Keeping Track of Units

1 foot of water = 0.433 psi

If the pressure is 3 psi what is that in feet of water?

Keeping Track of Units

1 foot of water = 0.433 psi

$$\frac{3\ \text{psi} * 1\ \text{foot of water}}{0.433\ \text{psi}}$$

= 6.9 feet of water

Keeping Track of Units

1 cubic foot = 7.48 gallons

How many cubic feet in 100 gallons?

Keeping Track of Units

1 cubic foot = 7.48 gallons

$$100 \text{ gallons} * \frac{1 \text{ cubic foot}}{7.48 \text{ gallons}}$$

Keeping Track of Units

1 cubic foot = 7.48 gallons

$$100 \text{ gallons} * \frac{1 \text{ cubic foot}}{7.48 \text{ gallons}}$$

= 13.4 cubic feet (ft^3)

Keeping Track of Units

1 cubic foot = 7.48 gallons

How many gallons in 100 cubic feet?

Keeping Track of Units

1 cubic foot = 7.48 gallons

$$100 \text{ cubic feet} * \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

Keeping Track of Units

1 cubic foot = 7.48 gallons

$$100 \text{ cubic feet} * \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

=748 gallons

Keeping Track of Units

1 gallon water = 8.34 pounds

How many gallons in 100 pounds of water?

Keeping Track of Units

1 gallon water = 8.34 pounds

$$100 \text{ pounds} * \frac{1 \text{ gallon water}}{8.34 \text{ pounds}}$$

Keeping Track of Units

1 gallon water = 8.34 pounds

$$100 \text{ pounds} * \frac{1 \text{ gallon water}}{8.34 \text{ pounds}}$$

= 12 gallons

Keeping Track of Units

1 gallon water = 8.34 pounds

How many pounds in 100 gallons of water?

Keeping Track of Units

1 gallon water = 8.34 pounds

$$100 \text{ gallons} * \frac{8.34 \text{ pounds}}{1 \text{ gallon water}}$$

Keeping Track of Units

1 gallon water = 8.34 pounds

$$100 \text{ gallons} * \frac{8.34 \text{ pounds}}{1 \text{ gallon water}}$$

= 834 pounds

Examples

Let's try out the process

Problem

How many gallons in a ton of water?

Problem – Changing Units

How many gallons in a ton of water?

1 gallon water = 8.34 pounds
1 ton = 2000 pounds

Problem

How many gallons in a ton of water?

$$1 \text{ ton} * \frac{2000 \text{ pounds}}{1 \text{ ton}} * \frac{1 \text{ gallon water}}{8.34 \text{ pounds}}$$

Problem

How many gallons in a ton of water?

$$1\ \cancel{\text{ton}} * \frac{2000\ \text{pounds}}{1\ \cancel{\text{ton}}} * \frac{1\ \text{gallon water}}{8.34\ \text{pounds}}$$

Problem

How many gallons in a ton of water?

$$1\ \cancel{\text{ton}} * \frac{2000\ \cancel{\text{pounds}}}{1\ \cancel{\text{ton}}} * \frac{1\ \text{gallon water}}{8.34\ \cancel{\text{pounds}}}$$

$$= 239.8\ \text{gallons}$$

Problem

How many cubic feet in a ton of water?

Problem

How many cubic feet in a ton of water?

$$1 \text{ ton} * \frac{2000 \text{ pounds}}{1 \text{ ton}} * \frac{1 \text{ gallon water}}{8.34 \text{ pounds}} * \frac{1 \text{ cubic foot}}{7.48 \text{ gallons}}$$

Problem

How many cubic feet in a ton of water?

$$1\ \text{ton} * \frac{2000\ \text{pounds}}{1\ \text{ton}} * \frac{1\ \text{gallon water}}{8.34\ \text{pounds}} * \frac{1\ \text{cubic foot}}{7.48\ \text{gallons}}$$

= 32.1 cubic feet

Problem – Short cut if you know the conversion factor

How many cubic feet in a ton of water?

$$1\ \text{ton} * \frac{2000\ \text{pounds}}{1\ \text{ton}} * \frac{1\ \text{cubic foot}}{62.4\ \text{pounds}}$$

= 32.1 cubic feet

Significant Figures & Rounding – The Result

Significant figures –
How many # after the decimal point?

Usually one significant figure after the decimal point is sufficient or 3 numbers

So instead of 11.99034325234
It would be 12.0

11.09 would be 11.1
11.04 would be 11.0

Significant Figures & Rounding – The Calculation

Generally, let the calculator or computer carry whatever they have. If you have to write down a number as part of an interim step, Use the roundoff rules

Practical Applications

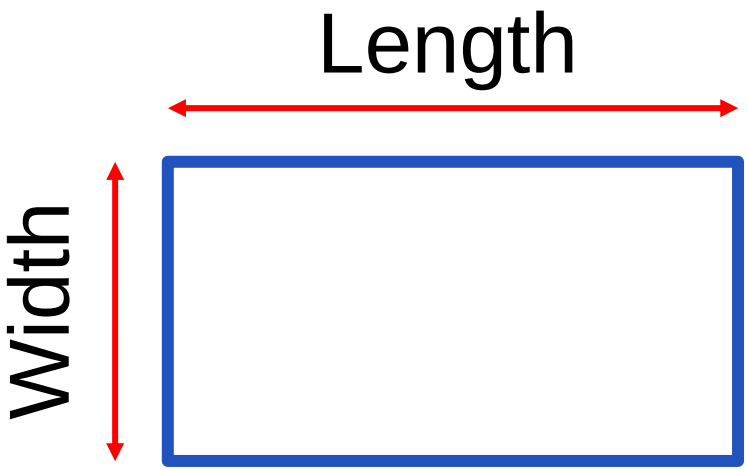
How do we use this ability?

Distance, Area and Volumes

Distance is one dimension (i.e. ft, meters)
Areas are two dimensions (i.e. ft^2, SY, acres)
Volumes are three dimensions (i.e. ft^3, CM)

Other Volumes: Gallons, Liters, acre-ft

Area – Squares / Rectangles

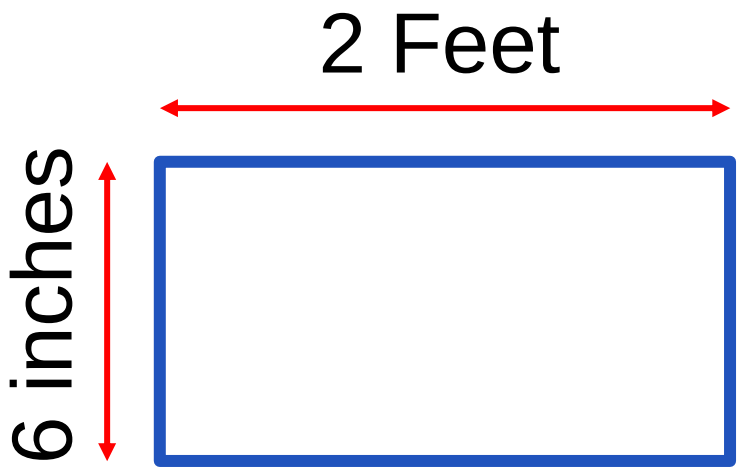


Area = length * width

Area = dimension^1 * dimension^1

Note 1 – Dimensions need to be the same units of measure

Area

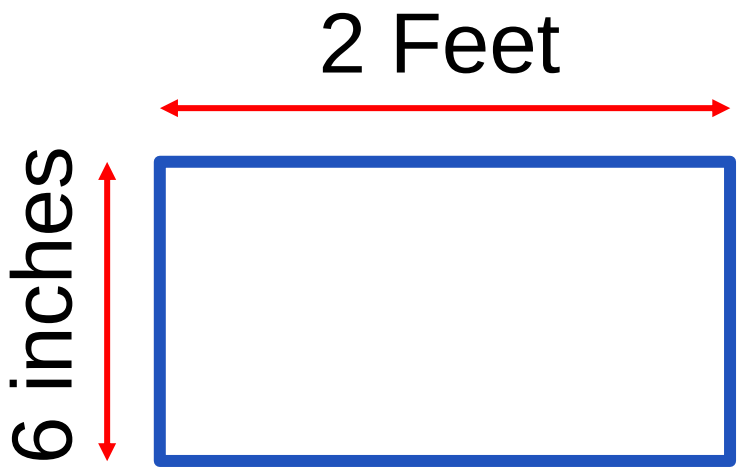


What is the area?

Area = length * width

Area = dimension * dimension

Area



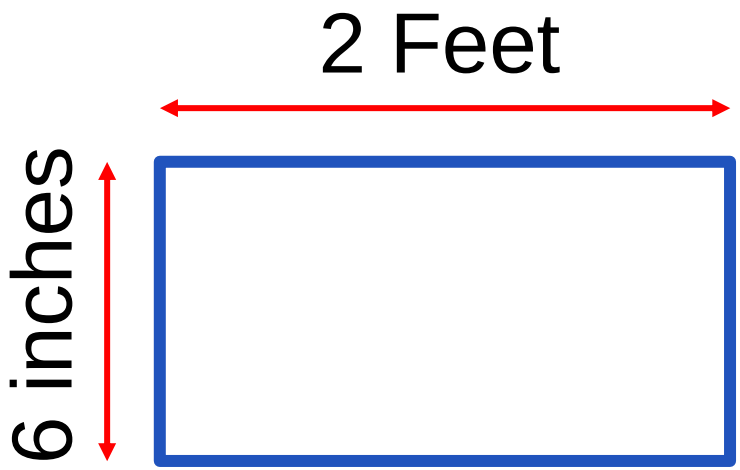
What is the area?

First get all the dimensions in the same units

$$\text{Area} = \text{length} * \text{width}$$

$$\text{Area} = 2 \text{ feet} * \frac{6 \text{ inches} * 1 \text{ foot}}{12 \text{ inches}}$$

Area



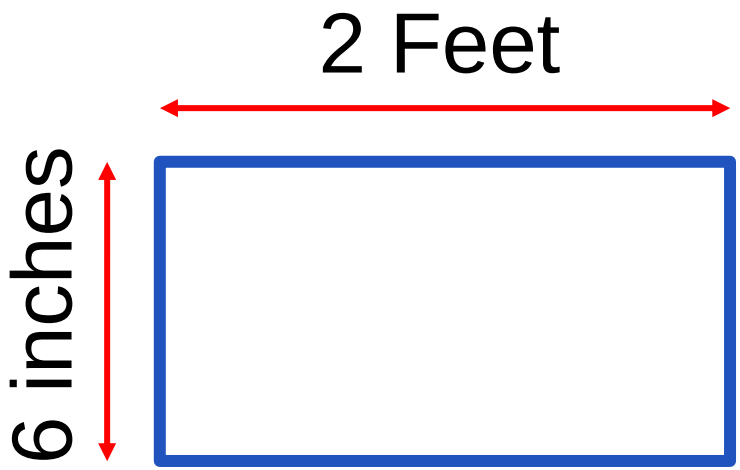
What is the area?

Area = length * width

$$\text{Area} = 2 \text{ feet} * \frac{6 \text{ inches} * 1 \text{ foot}}{12 \text{ inches}}$$

Area= 1 sq ft

Area



What is the area?

What if we need the area in square inches?

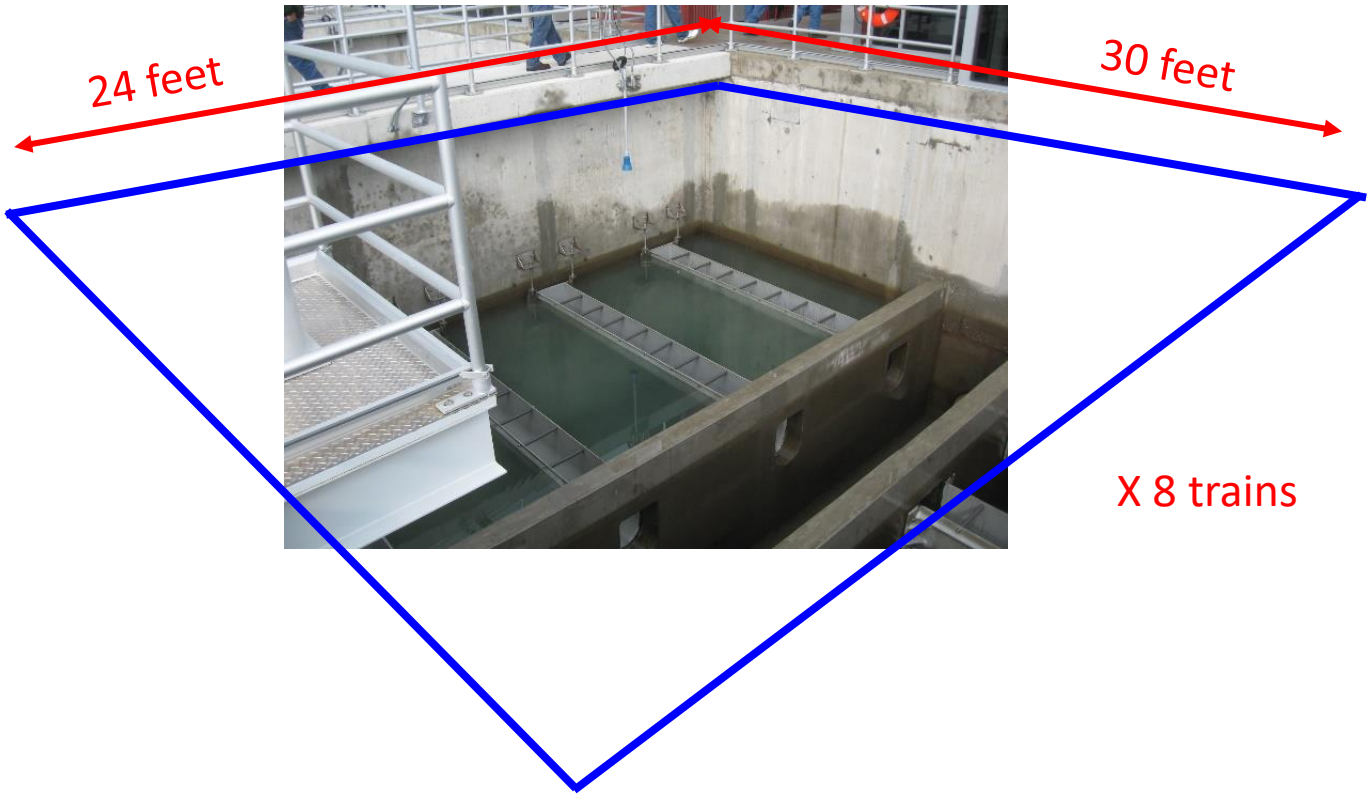
Area = length * width

$$\text{Area} = 2\ \text{feet} * \frac{12\ \text{inches}}{1\ \text{foot}} * 6\ \text{inches}$$

Area= 144 sq in

Practical Application

You are going to cover your sand filters and the sales rep wants to know the area so he can get you a price. There are 8 trains, each 24 feet wide by 30 feet long.



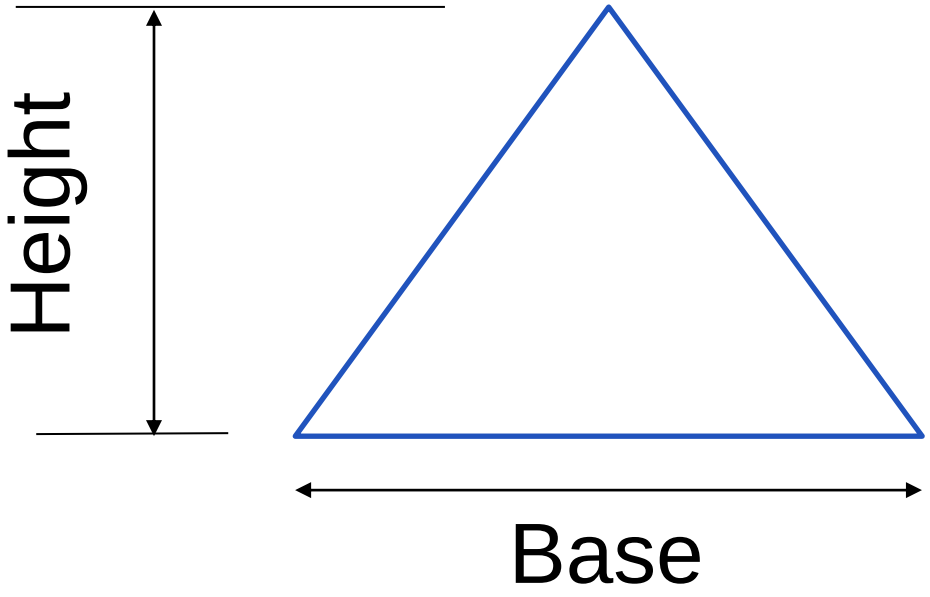
Practical Application - Area

You are going to cover your sand filters and the sales rep wants to know the area so he can get you a price. There are eight trains, each 24 feet wide by 30 feet long.

Area = 8 basins * 24 ft * 30 ft

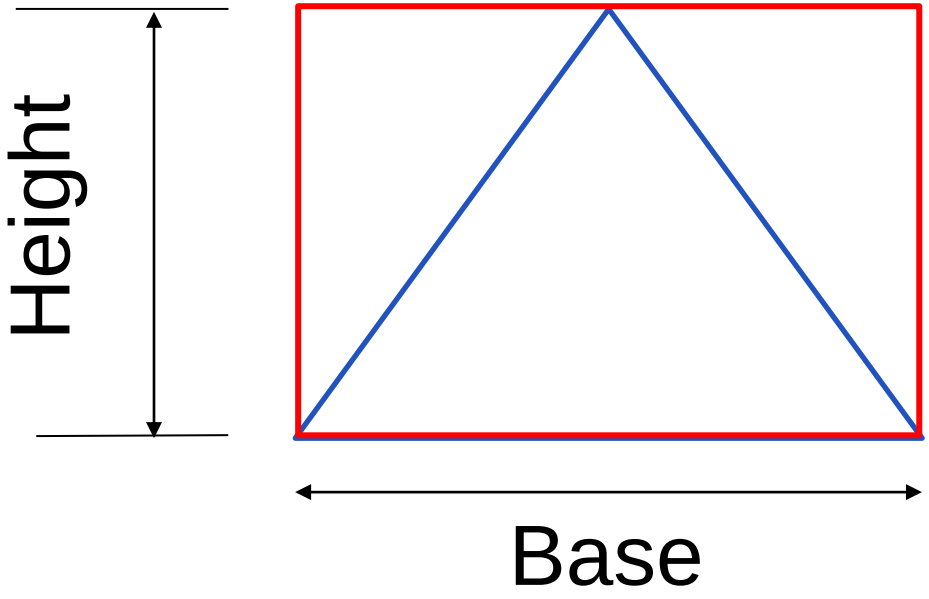
Area = 5,760 sq ft

Area - Triangles



Area = (1/2) * base * height

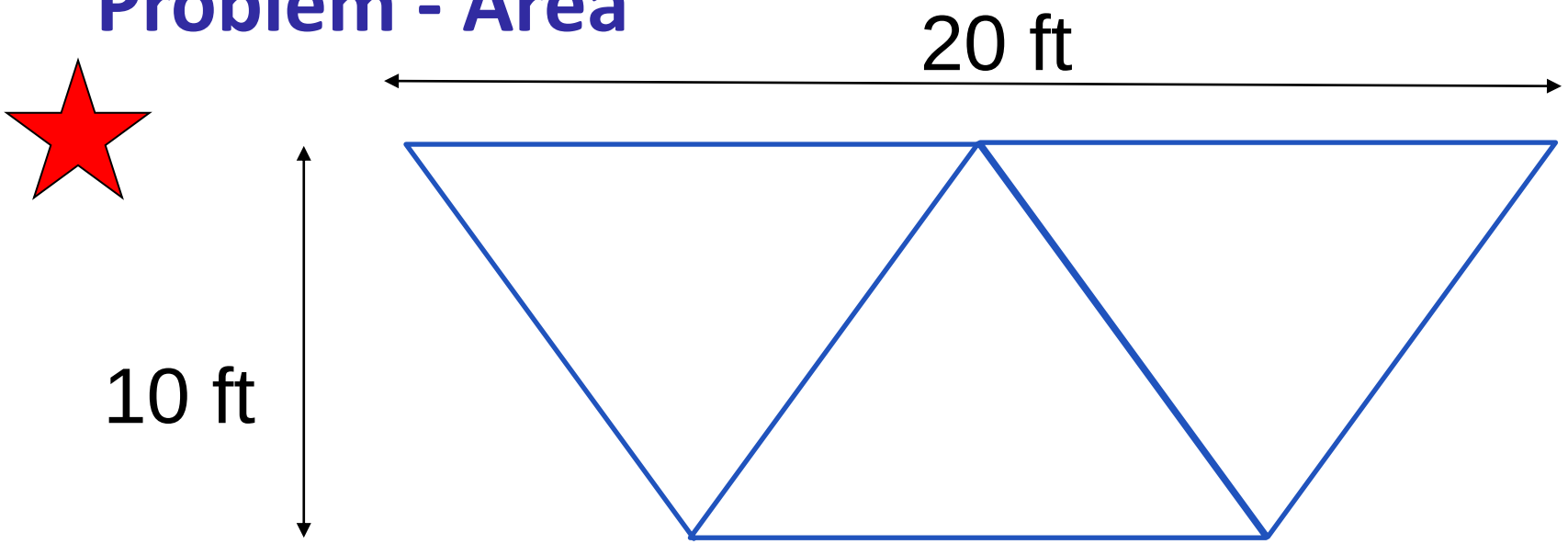
Area



Area = (1/2)*base * height

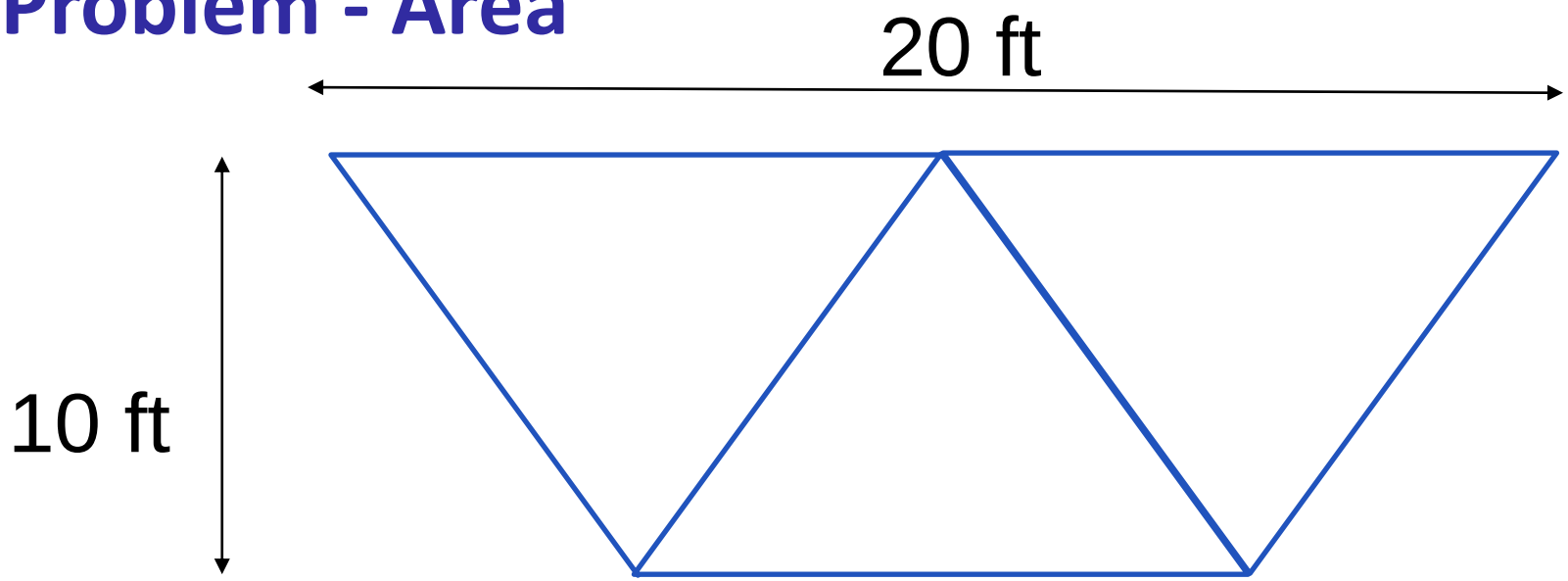
Triangle is ½ of rectangle!

Problem - Area



You are covering a truss with a banner for City Celebration. They want to cover the truss. How big?

Problem - Area



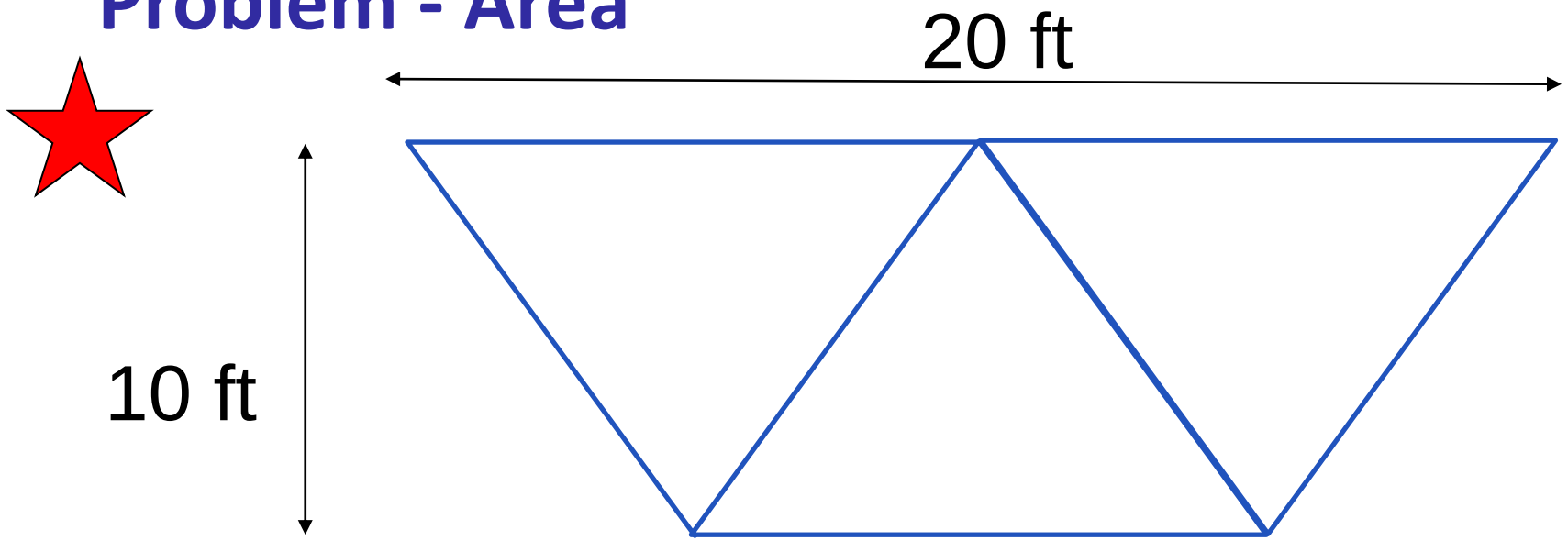
You are covering a truss with a banner for City Celebration. They want to cover the truss. How big will the banner be?

Area = 3 triangles

= 3 * ½ * 10 ft * 10 ft

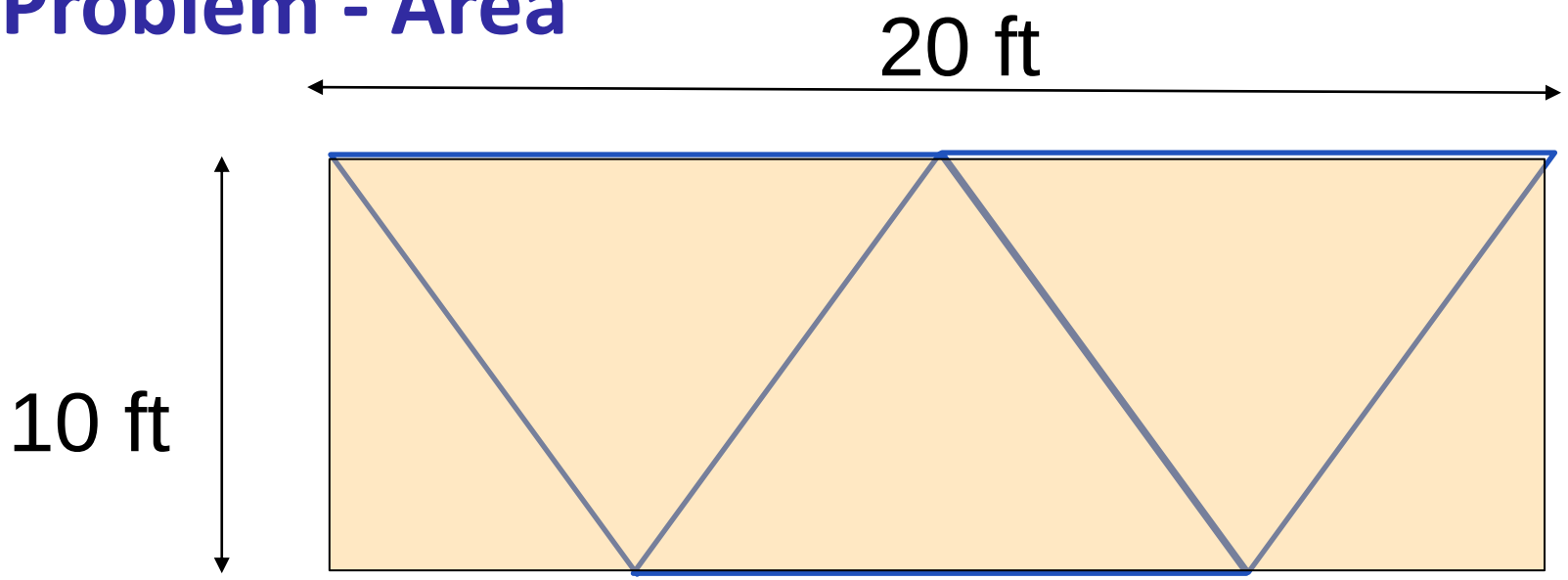
= 150 sq ft

Problem - Area



Opps! Change of plan, the City Manager now wants a rectangular banner – how big will it be?

Problem - Area



The City Manager wants rectangular banner – how big?

Area = 20 ft * 10 ft = 200 sq ft

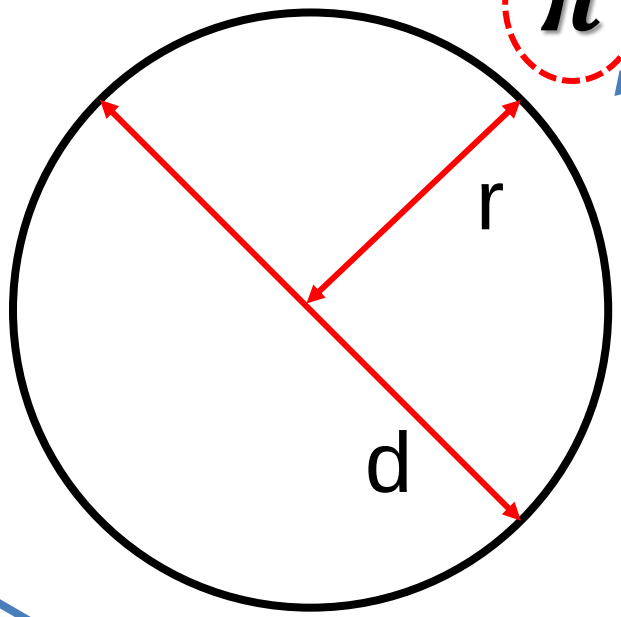
Area - Circles

$\pi = 3.14$

Area of a circle

$$A = \pi r^2$$

$$A = \pi(d^2/4)$$



What is this symbol? It's all Greek to me!

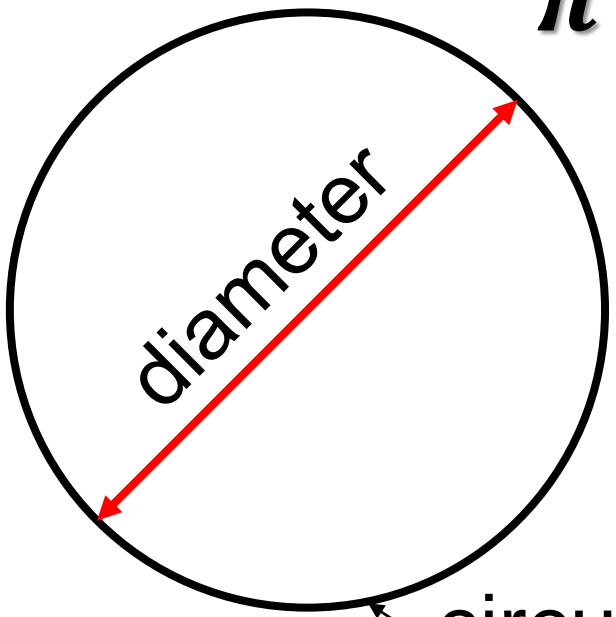
$$A = 0.785 * d^2$$

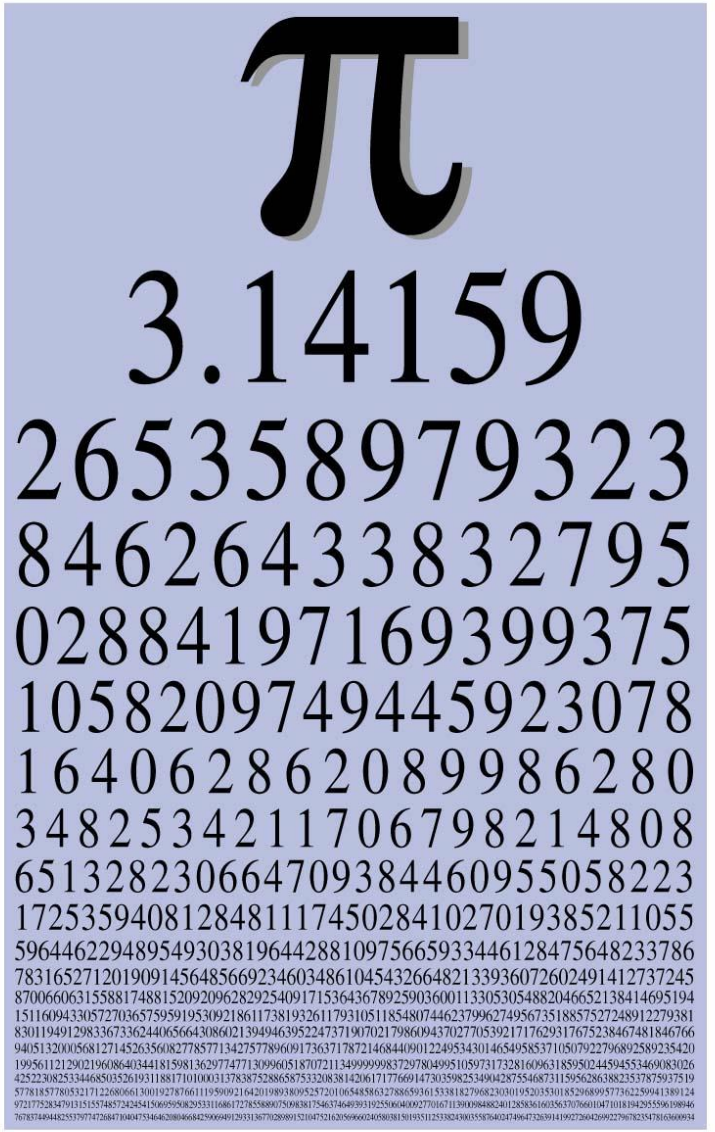
Or use a constant

The Magical World of Pi

Pi is a name given to the ratio of the circumference of a circle to the diameter.

$$\pi = 3.14$$



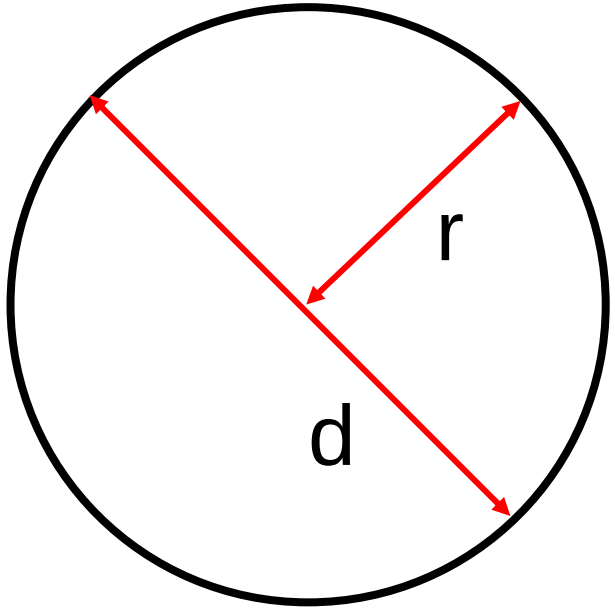


The Magical World of Pi

Circumference = $2 * \pi * r$

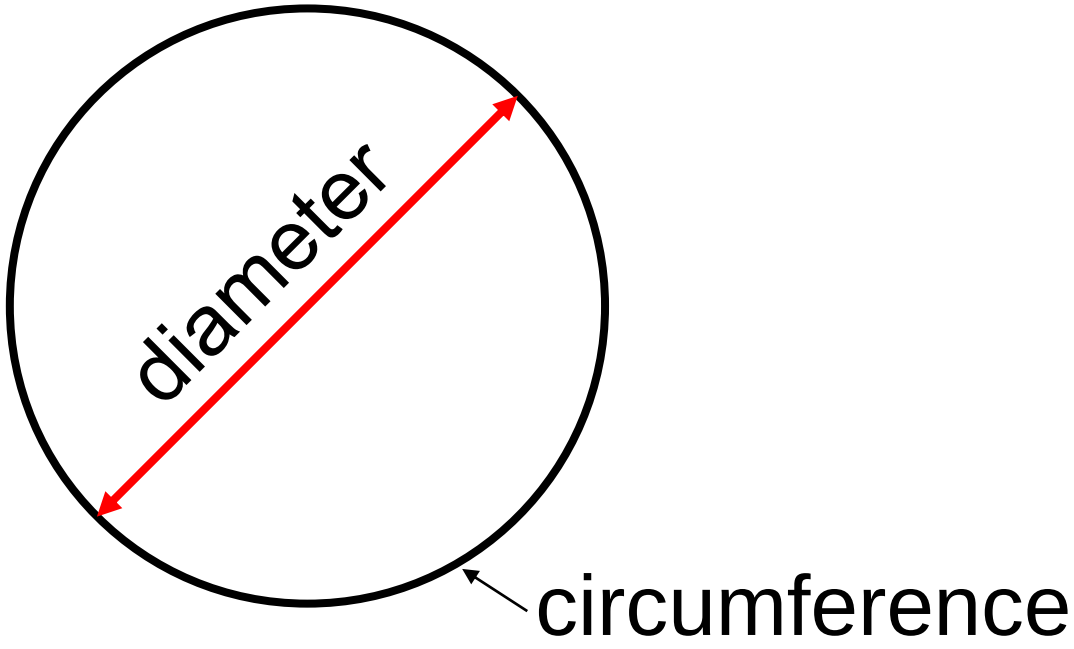
Diameter = $2 * r$

$$\frac{2 * \pi * r}{2 * r} = \pi$$



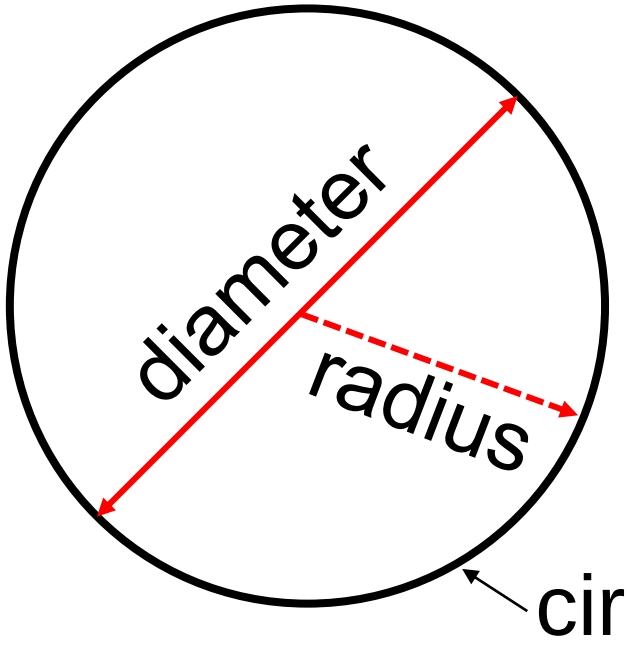
Practical Use of Pi (π)

The diameter of the circular clarifier is 100 feet. What is the weir length (the circumference)?



Practical Use of Pi (π)

The diameter of the circular clarifier is 100 feet.
What is the weir length?



Circumference = 2 π r

Diameter (d) = 2 r

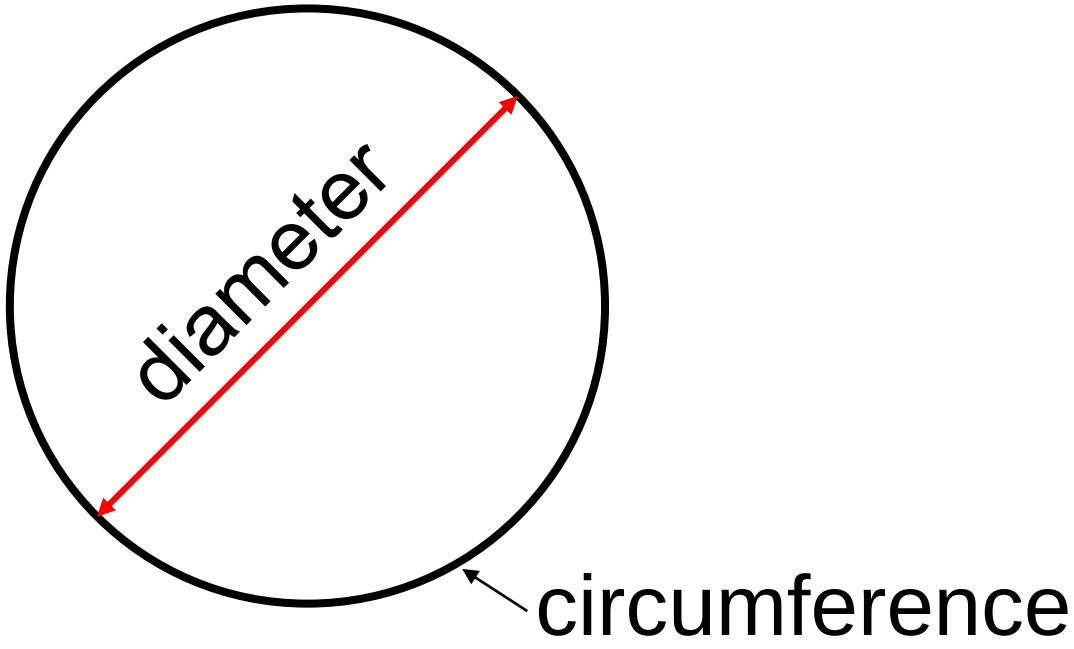
Circumference = π d

100 feet * π =

= 314 feet

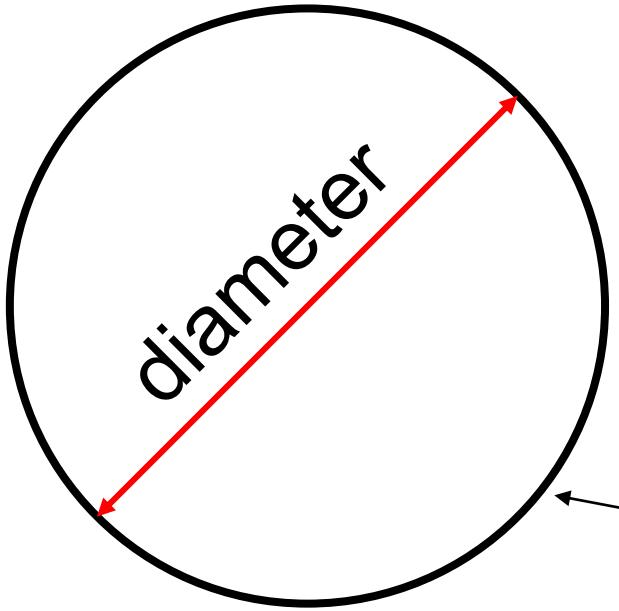
Practical Use of Pi (π) – Back to Area

The diameter of the circular clarifier is 100 feet. What is the surface area?



Practical Use of Pi (π)

The diameter of the circular clarifier is 100 feet. What is the surface area?



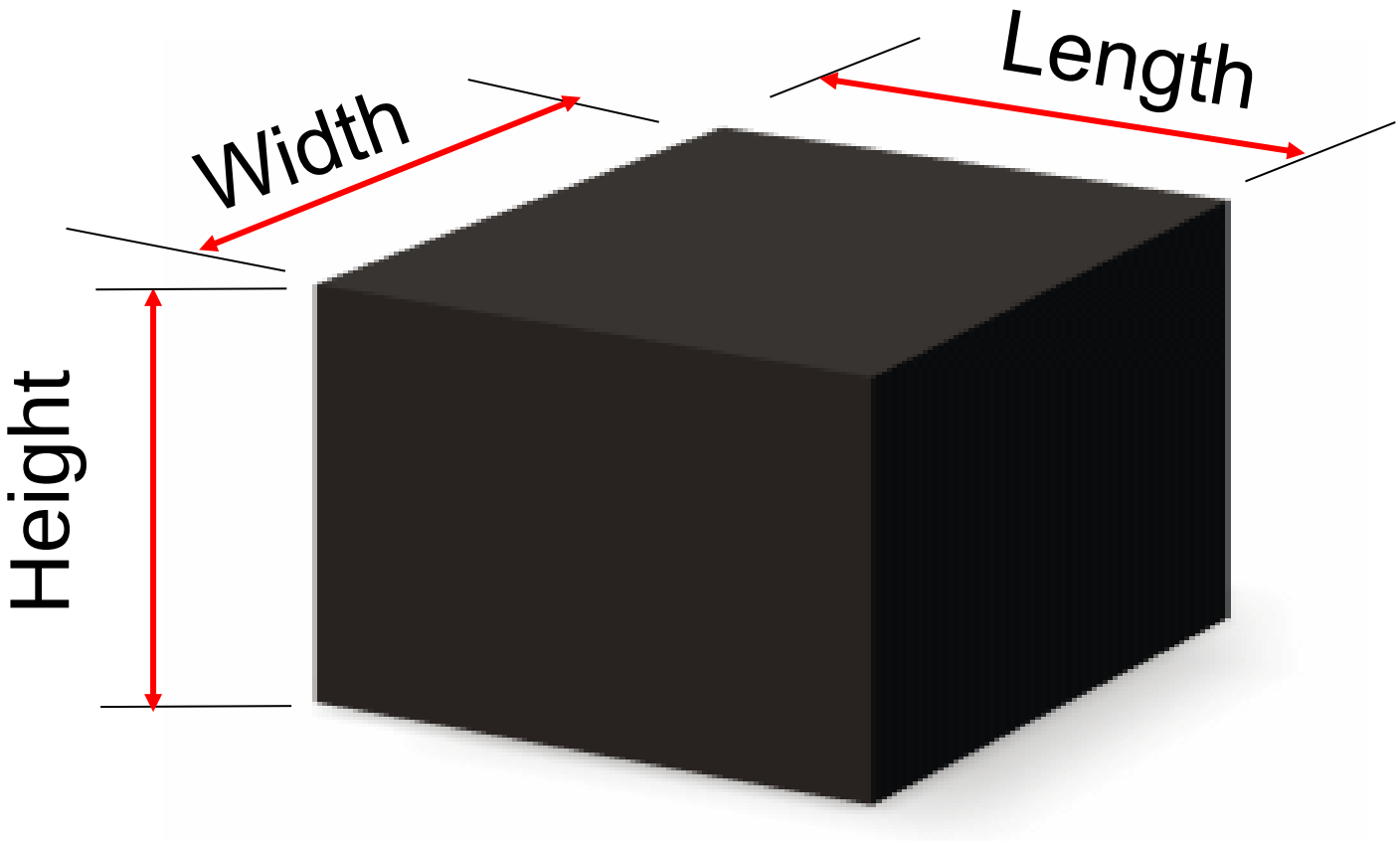
$$\text{Area} = 0.785 * d^2$$

$$\text{Area} = 0.785 * (100 \text{ feet})^2$$

$$\text{Area} = 7{,}850 \text{ sq ft}$$

Volume

Volume = length * width * height



Volumes – Practical Question

What is the volume of water in a rectangular basin with following characteristics? Answer in **gallons**.

- Length 200 **feet**
- Width 50 **feet**
- Total Depth 20 **feet**
- Freeboard is 3 **feet**

Desired answer needs to be gallons (volume). Basin dimensions are in feet (length)

Depth of water = 20 feet – 3 feet

Volume = length * width * depth

Volume = 200 ft * 50 ft * 17 feet

Volume = 170,000 cu ft

Volumes – Practical Question

What is the volume of water in a rectangular basin with following characteristics? Answer in gallons.

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 3 feet

Change cubic feet to gallons – keep the units straight!

$$\text{Volume} = 170{,}000 \text{ cu ft} * \frac{7.48 \text{ gallons}}{1 \text{ cu ft}}$$

Volumes – Practical Question

What is the volume of water in a rectangular basin with following characteristics? Answer in gallons.

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 3 feet

Change cubic feet to gallons – keep the units straight!

$$\text{Volume} = 170{,}000 \text{ cu ft} * \frac{7.48 \text{ gallons}}{1 \text{ cu ft}}$$

Volume = 1,271,600 gallons or 1.27×10^6

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

What is the water depth (height)?

= 20 feet – 1 meter

Mixed units! Get all dimensions in one measurement unit

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

What is the water depth (height)?

$$= 20 \text{ feet} - 1 \text{ meter} \frac{* 3.28 \text{ feet}}{1 \text{ meter}}$$

Change meters to feet

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

What is the water depth (height)?

$$= 20 \text{ feet} - 1 \text{ meter} \times \frac{3.28 \text{ feet}}{1 \text{ meter}}$$

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

What is the water depth (height)?

= 20 feet – 3.28 feet

= 16.72 feet

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

With all measurements in feet, now calculate the volume in cubic feet

$$\text{Vol} = 50 \text{ ft} * 200 \text{ ft} * 16.72 \text{ ft}$$
$$= 167{,}200 \text{ ft}^3$$

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

Now change cubic feet to gallons

$$\text{Vol} = 167{,}200 \text{ ft}^3$$

$$167{,}200 \text{ cubic feet} * \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

Now change gallons to million gallons

$$\text{Vol} = 1{,}250{,}656 \text{ gallons}$$

$$\text{Vol} = \frac{1{,}250{,}656 \text{ gallons} * 1 \text{ MG}}{1{,}000{,}000 \text{ gal}}$$

Volumes – Practical Question

What is the volume of the water in the rectangular basin with following characteristics? Answer in MG (million gallons)

- Length 200 feet
- Width 50 feet
- Total Depth 20 feet
- Freeboard is 1 meter

Round off the answer

Vol = 1,250,656 gallons

$$\text{Vol} = \frac{1{,}250{,}656 \text{ gallons} * 1 \text{ MG}}{1{,}000{,}000 \text{ gallons}} = \underline{\mathbf{1.25 \text{ MG}}}$$

Volume –Tank Example (Cylinder)

Volume = Area x Height

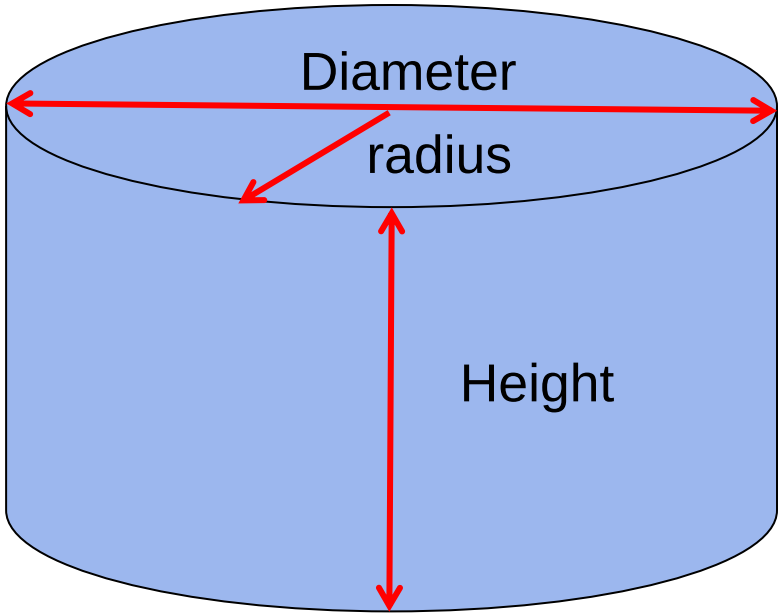
π = pi = 3.14

r = radius

D = Dia. = Diameter

2 * r = Dia.

Tank



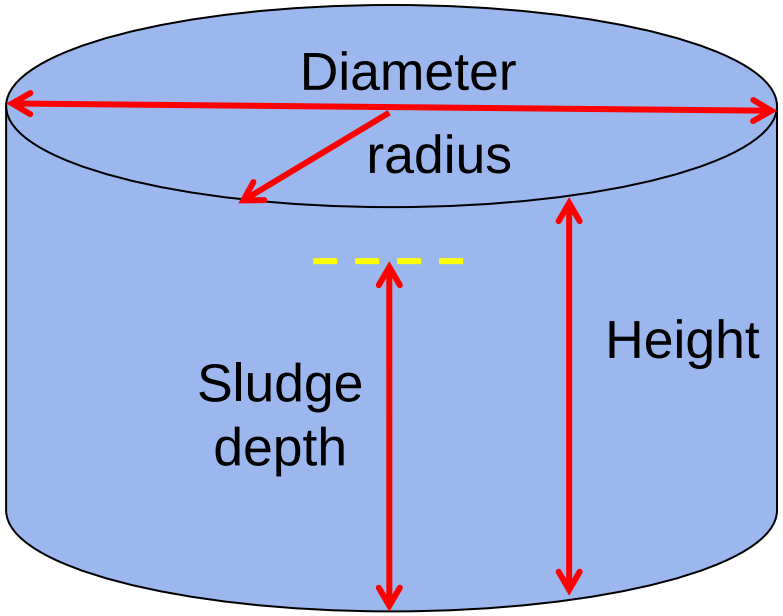
Vol = 3.14 * r^2 *height

= .785 * d^2 * height

Volume –Tank Example

What is volume of sludge holding tank in gallons?
Diameter = 100 feet
Height = 24 feet
Sludge depth = 20 feet

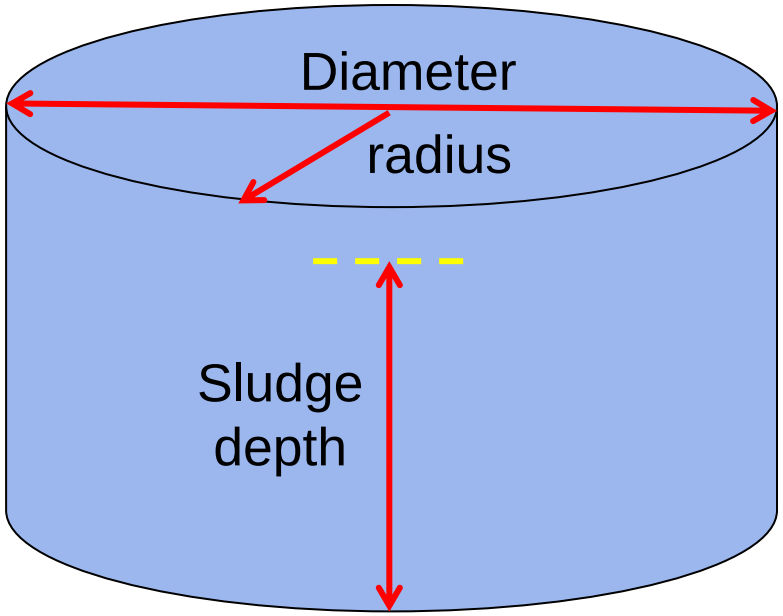
Tank



Volume –Tank Example

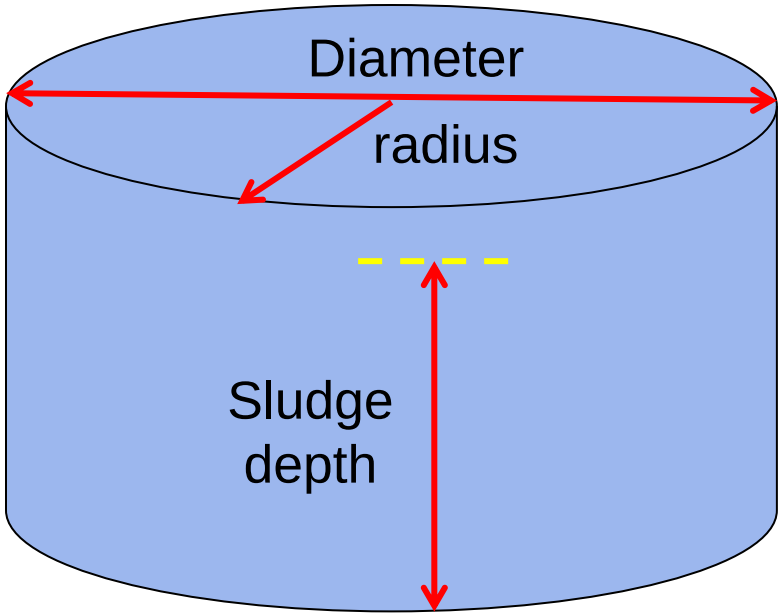
What is volume of sludge holding tank in gallons?
Diameter = 100 feet
Height = 24 feet

Tank



$$\text{Vol} = 0.785 * d^2 * \text{height}$$
$$= 0.785 * (100\ \text{ft})^2 * 20\ \text{ft}$$
$$= 157{,}000\ \text{ft}^3$$

Volume –Tank Example

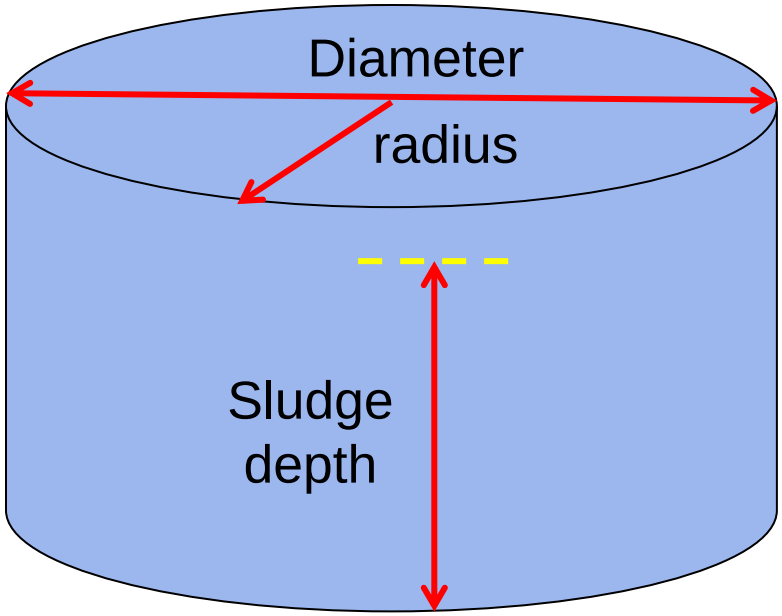


What is volume of sludge holding tank in gallons?
Diameter = 100 ft
Sludge depth = 20 ft

Vol = 157,000 ft^3

$$157{,}000 \text{ cubic feet} * \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

Volume –Tank Example



What is volume of sludge holding tank in gallons?

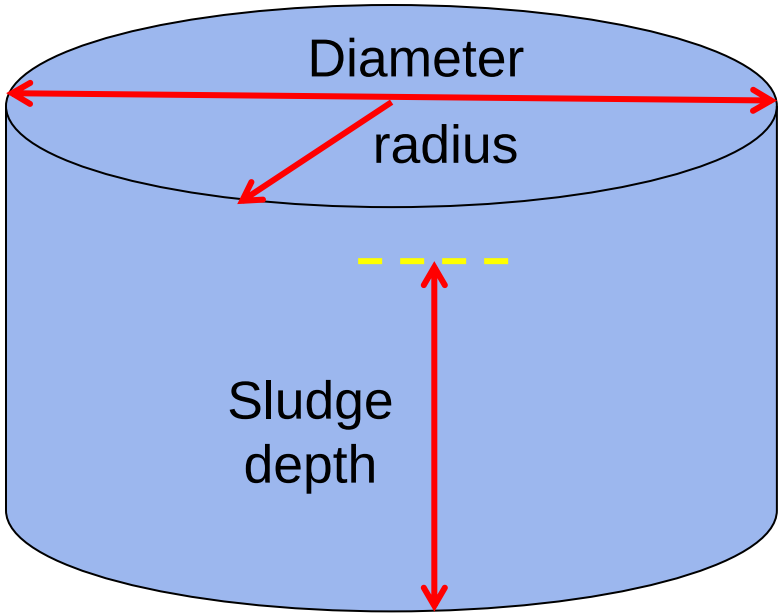
Diameter = 100 ft

Sludge depth = 20 ft

Vol = 157,000 ft^3

$$157{,}000 \text{ ~~cubic feet~~} * \frac{7.48 \text{ gallons}}{1 \text{ ~~cubic foot~~}}$$

Volume –Tank Example



What is volume of sludge holding tank in gallons?

Diameter = 100 ft

Height = 20 ft

Vol = 157,000 ft^3 * 7.48

1,174,360 gallons

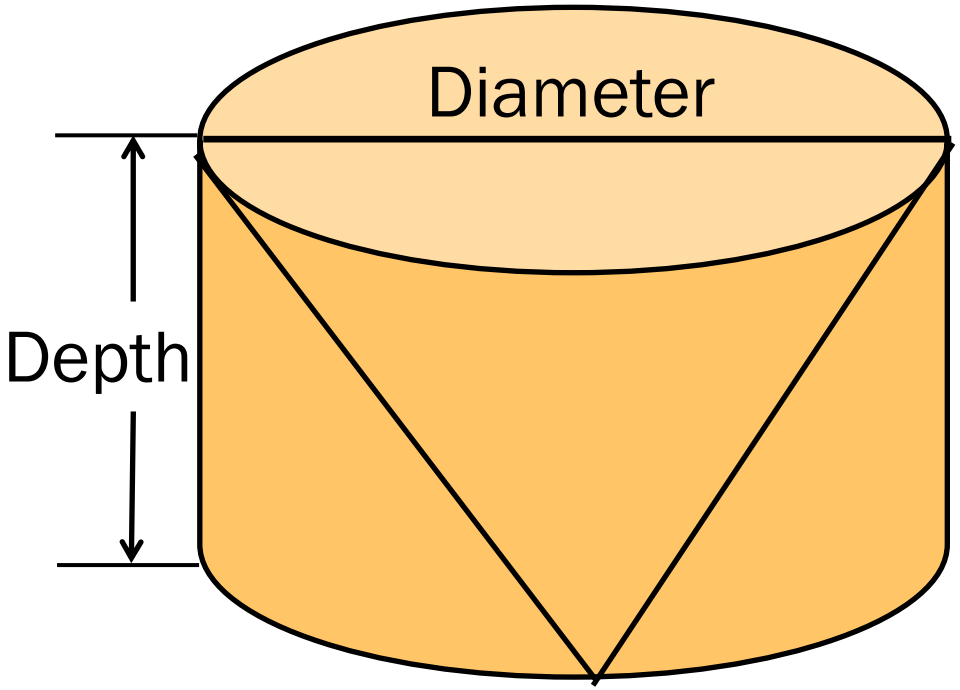
or

1.17 MG

Divide by 1,000,000 and round off

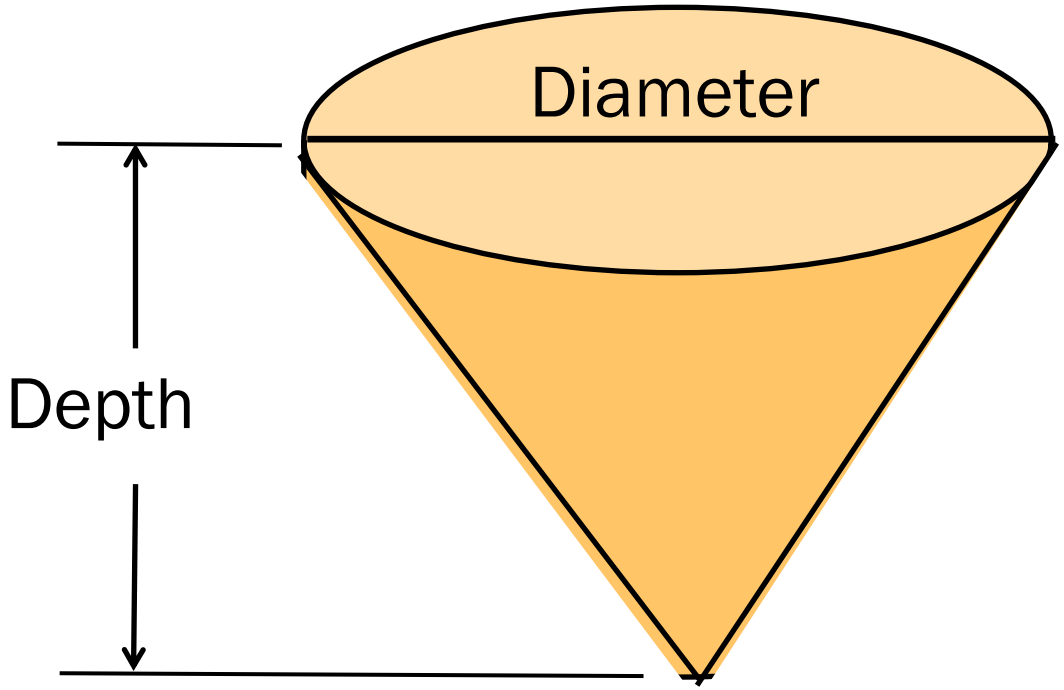
Volume of a Cone

1/3 the volume of a cylinder.



Practical Application

What is the water volume (gallons) of the grit chamber if it is 10 feet deep with a diameter of 5 feet?



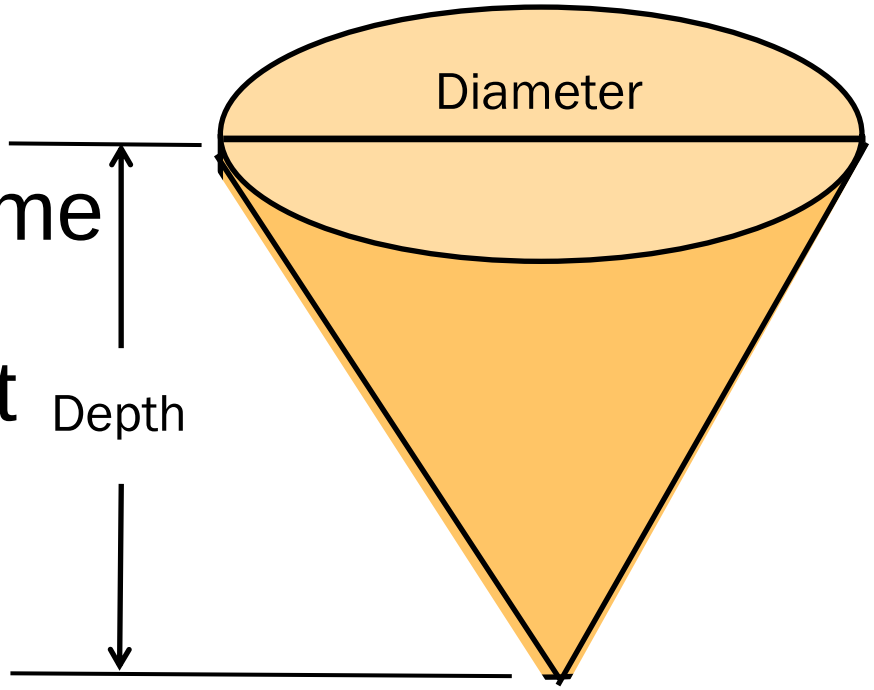
Practical Application

What is the water volume (gallons) of the grit chamber if it is 10 feet deep with a diameter of 5 feet?

Cone = 1/3* Cylinder Volume

Cylinder= $0.785*(5ft)^2*10ft$

Cylinder = 196 cu ft



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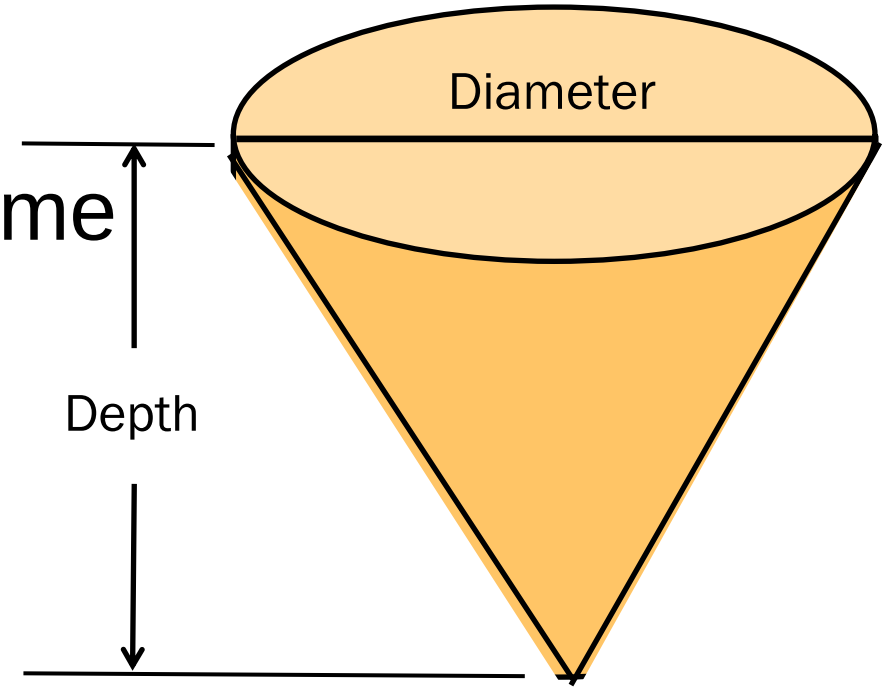


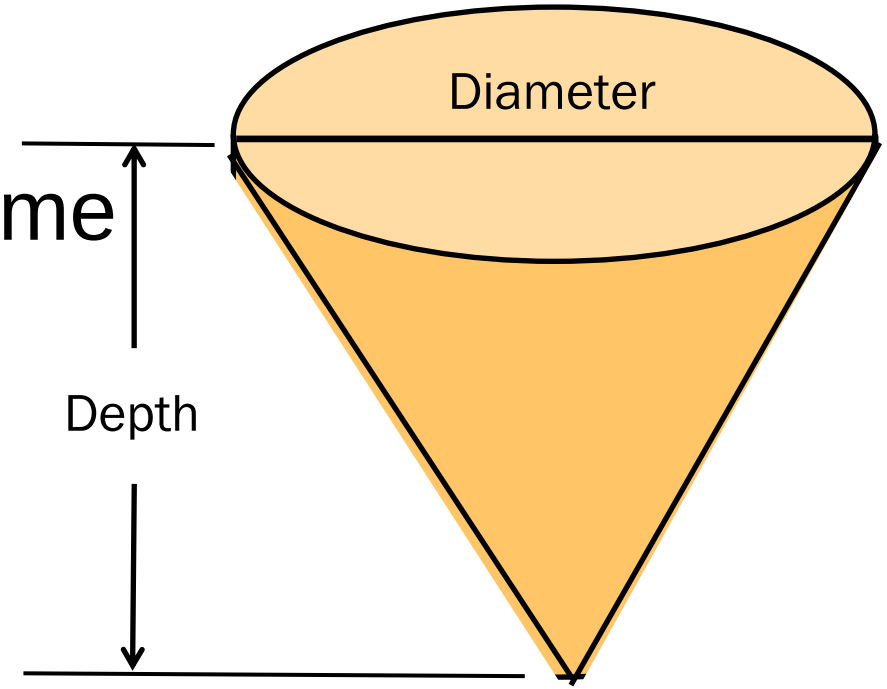
Cone = 1/3* Cylinder Volume

Cylinder = 196 cu ft

$$\frac{196 \text{ cu ft} * 7.48 \text{ gallons}}{1 \text{ cu ft}}$$

Practical Application

What is the water volume (gallons) of the grit chamber if it is 10 feet deep with a diameter of 5 feet?



Cone = 1/3* Cylinder Volume

Tank = 196 cu ft

$$\frac{196 \text{ cu ft} * 7.48 \text{ gallons}}{1 \text{ cu ft}}$$

Cylinder = 1,466 gallons

Practical Application

What is the water volume (gallons) of the grit chamber if it is 10 feet deep with a diameter of 5 feet?

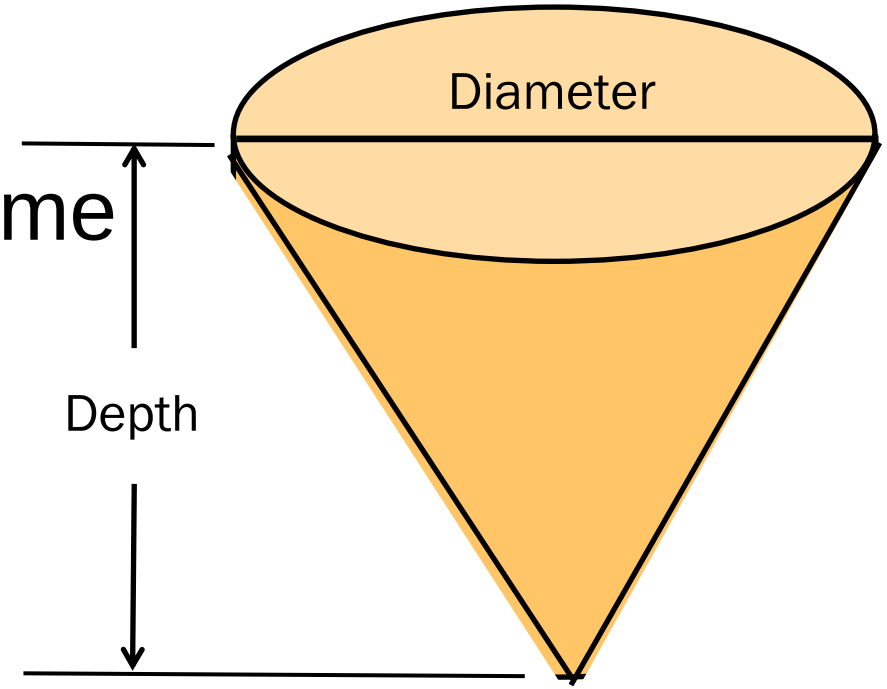
Cone = 1/3* Cylinder Volume

Cylinder = 196 cu ft

Cylinder = 1466 gallons

Cone = 1/3 * 1466 gal

Cone = 489 gal

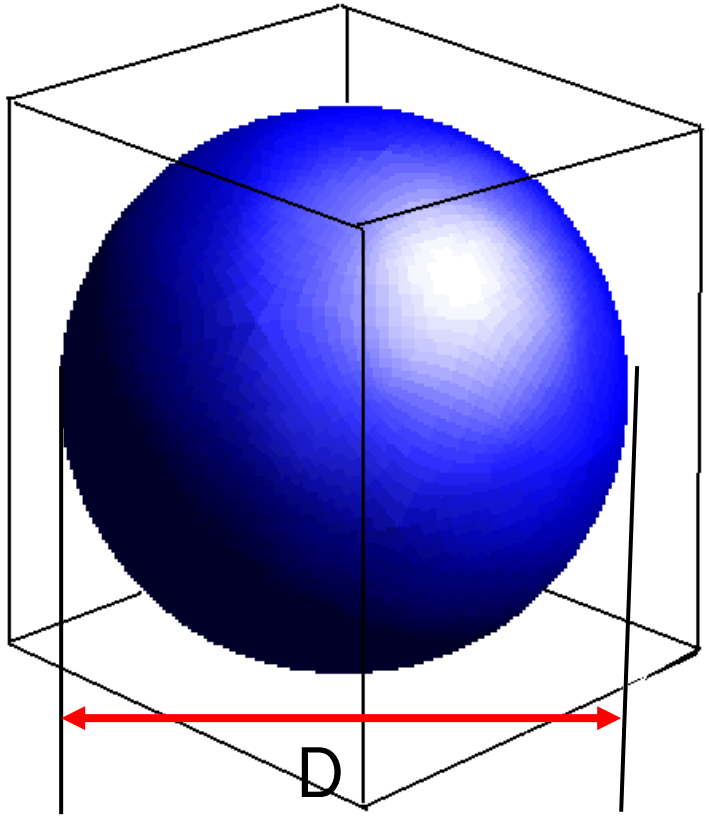


Practical Application – What About Rounding?

- Tank 1,174,360 gallons or 1.17 MG
  - 1.2 MG “nominal”
- Cone 489 gallons
  - 500 “nominal” gallons
- It all depends on the use

Volume of a Sphere

3/4 the volume of a cube with the same dimensions



Practical Application – Sphere Volume

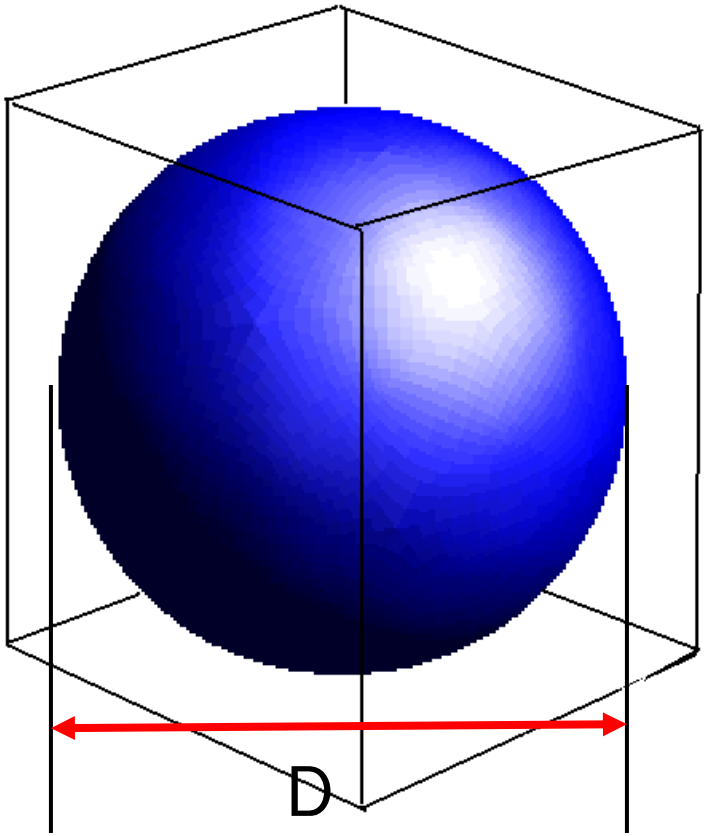
What is the volume of the gas holding sphere if the diameter is 50 feet?

Sphere volume =
¾ * cube volume

Volume =
¾ * 50 ft * 50 ft * 50 ft

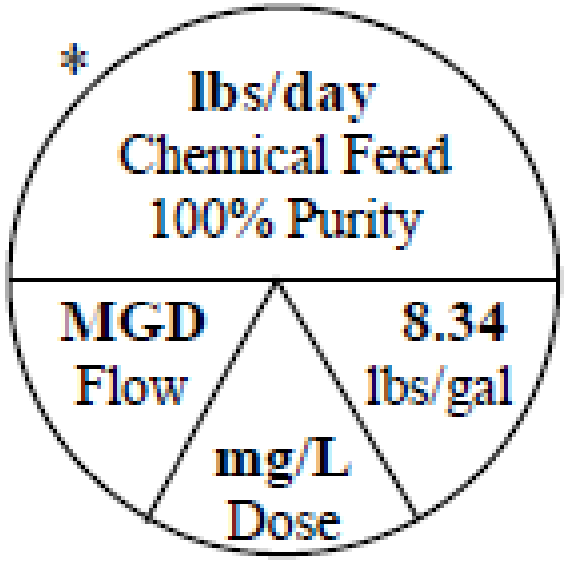
$= 0.75 * 50^3$ ft

Volume = 93,750 cubic feet

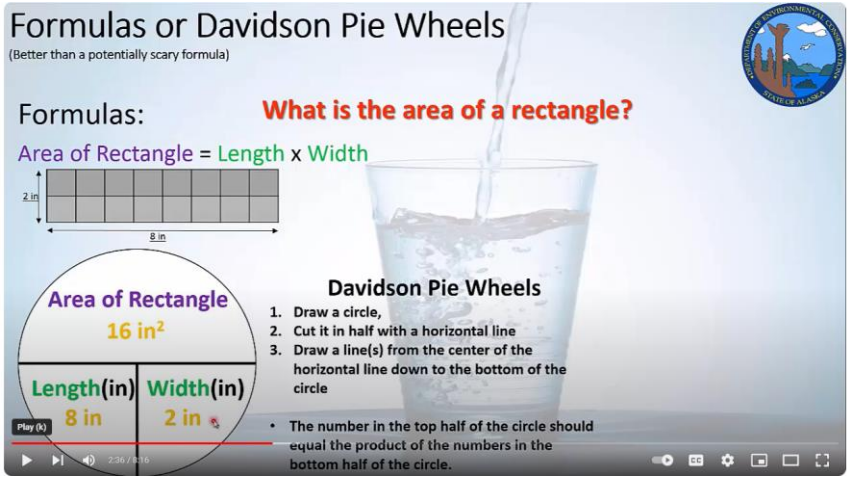


Calculation Wheels – Refer to ABC Handout

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



YouTube Links:
https://www.youtube.com/watch?v=FIH0pkvmuPA



Can also be used without rate or flow
Feed in pounds, Volume in MG

Time Out - Percentages

If something is 56%, what is the mathematical (decimal) way to show that number?

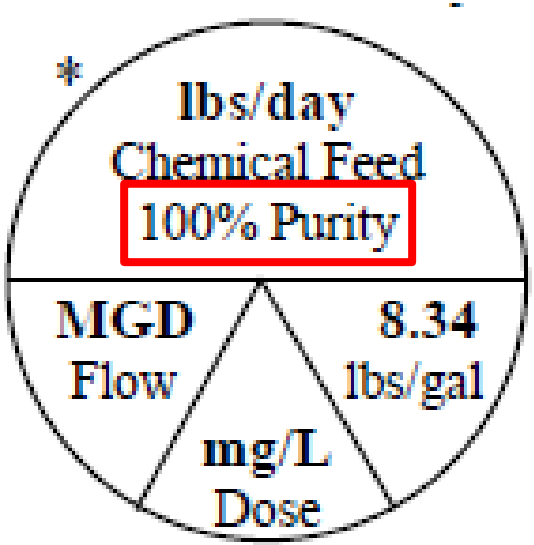
56% = ?

Time Out - Percentages

If something is 56%, what is mathematical (decimal) way to show number?

$$56\% = \frac{56}{100} = 0.56$$

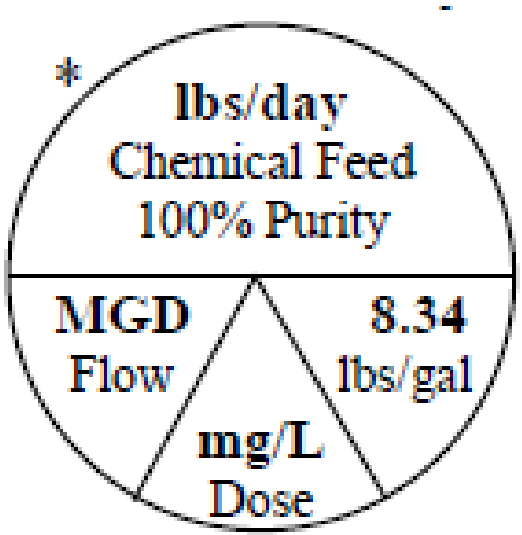
Back to the Calculation Wheels



$$\text{Feed lbs/day} = \frac{\text{Flow MGD} * \text{Dose mg/l} * 8.34 \text{ lbs/gal}}{\text{Purity decimal percentage}}$$

This is where that algebra stuff comes into play

Back to the Calculation Wheels

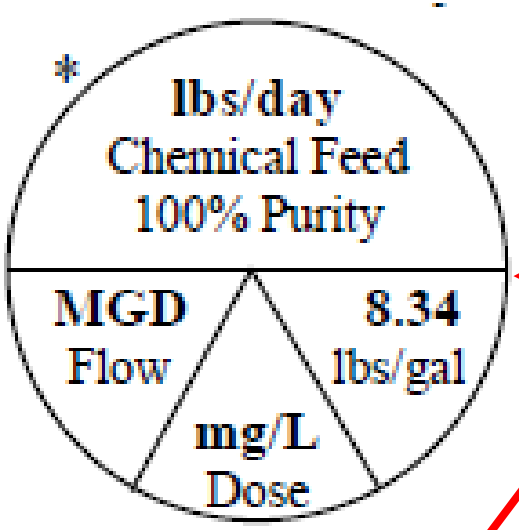


What if you know feed, but not flow?

$$\frac{\text{Feed lbs/day}}{\text{Dose mg/l} * 8.34 \text{ lbs/gal}} = \frac{\text{Flow MGD} * \text{Dose mg/l} * 8.34 \text{ lbs/gal}}{\text{Dose mg/l} * 8.34 \text{ lbs/gal}}$$

Rearrange the equation to isolate flow on one side

Back to the Calculation Wheels



Division Line

$$\frac{\text{Feed lbs/day}}{\text{Dose mg/l} * 8.34 \text{ lbs/gal}} = \frac{\text{Flow MGD} * \text{Dose mg/l} * 8.34 \text{ lbs/gal}}{\text{Dose mg/l} * 8.34 \text{ lbs/gal}}$$

Make sure the units are correct

Questions, Comments and Suggestions?

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Operator Worked Problems

Let's see if any of this stuff sunk in!

Set A

Version1.0 & October 2020

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Segment Outline

Topics:

- Area & Volume
- Pressure
- Flow Rate
- Chemical & Process

Volume & Area

How big? How Much?

Question V1.1:

How many gallons are in 28.65 acre-feet?

A 9,354,282 gallons

B 9,322,137 gallons

C 9,355,000 gallons

D 9,763,599 gallons

Question V1.1:

How many gallons are in 28.65 acre-feet?

28.65 ac-ft x 43,560 cf / ac-ft = 1,247,994 cf

1,247,994 cf x 7.48 gallons / cf = 9,334,995 gal

C ~9,355,000 gallons

Question V1.2:

A trench that averages 4.2 ft wide and 5.4 ft in depth is dug for the purpose of installing a 24-in. diameter pipeline. If the trench is 1,287 ft long, how much soil in cubic feet will be put in the trench after the pipe is in place, assuming that the only soil left over is that which the pipe now occupies?

A 1,300 cu ft

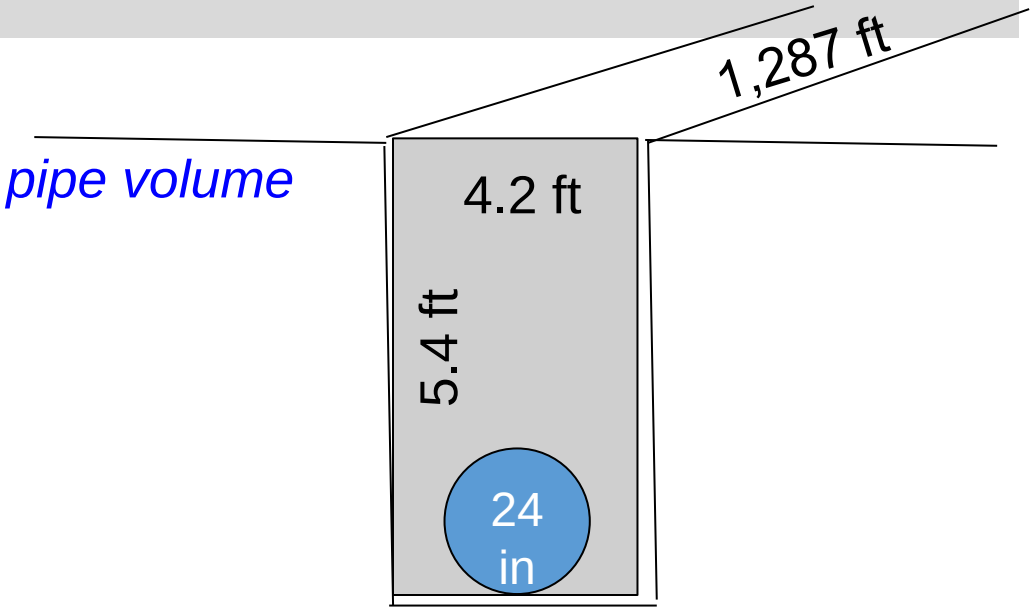
B 4,000 cu ft

C 25,000 cu ft

D 29,000 cu ft

Question V1.2:

A trench that averages 4.2 ft wide and 5.4 ft in depth is dug for the purpose of installing a 24-in. diameter pipeline. If the trench is 1,287 ft long, how much soil in cubic feet will be put in the trench after the pipe is in place, assuming that the only soil left over is that which the pipe now occupies?



Soil volume = trench volume – pipe volume

Area of trench = w x d

= 4.2 ft x 5.4 ft

= 22.7 sq ft

Area of pipe = .785 d^2

= 0.785 x (24 in/12 in/ft)^2

= 3.14 sq ft

Question V1.2:

A trench that averages 4.2 ft wide and 5.4 ft in depth is dug for the purpose of installing a 24-in. diameter pipeline. If the trench is 1,287 ft long, how much soil in cubic feet will be put in the trench after the pipe is in place, assuming that the only soil left over is that which the pipe now occupies?

Area of backfill = trench area – pipe area

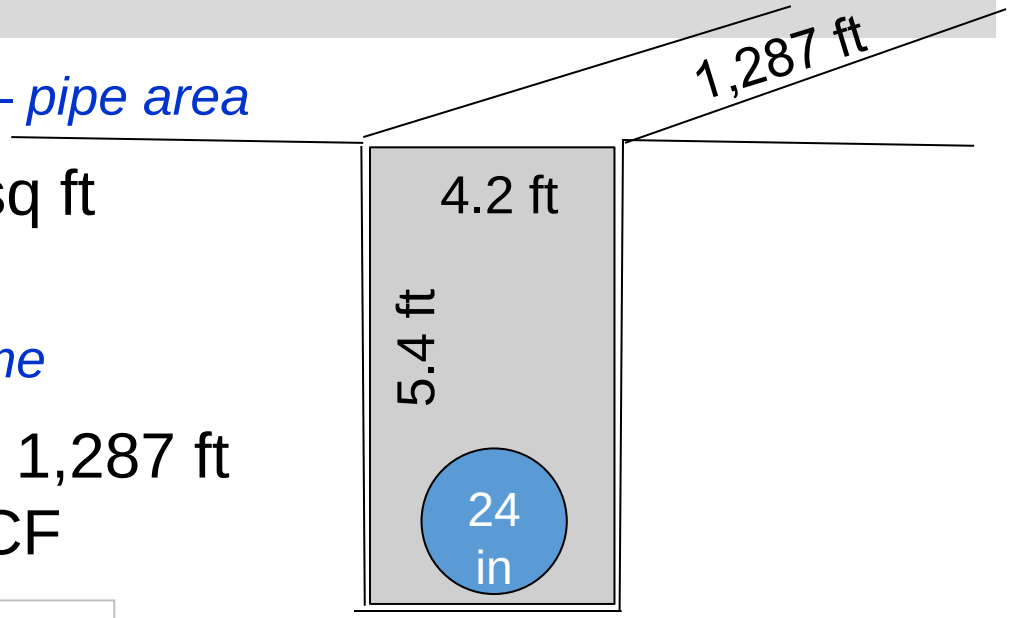
= 22.7 sq ft – 3.14 sq ft
= 19.56 sq ft

Area x length = Volume

Volume = 19.56 sq feet x 1,287 ft
= 25,173 cu.ft. or CF

~25,000 cu ft

Assumes excavation is used as pipe bedding!



Soil volume typically expressed as cubic yards. 9 CF = 1 CY
25,173 CF / 9 CF / CY = 2,797 CY

W & WW

Question V1.3:

How many gallons are in a pipe that is 18-inches in diameter and 1,165 ft long

A 2,060 gallons

B 10,300 gallons

C 15,400 gallons

D 17,200 gallons

Question V1.3:

How many gallons are in a pipe that is 18-inches in diameter and 1,165 ft long

18 inches / 12 inches/ft = 1.5 ft

1.5^2 x Pi / 4 = 1.767 sf

1.767 sf x 1,165 ft = 2,058.7 cf

2,058.7 cf x 7.48 gallons/cf = 15,399.2 gal.

C ~15,400 gallons

Question V1.4:

A process chemical tank is 4 ft inside diameter and 10 ft tall. The level is measured in % with 0 being empty and 100% 1 ft below the rim. The tank is refilled anytime the level drops below 20%. If the level is 18.5% how many gallons to refill to 100%?

A 940 gallons

B 690 gallons

C 850 gallons

D 92.2 gallons

Question V1.4:

W & WW

A process chemical tank is 4 ft inside diameter and 10 ft tall. The level is measured in % with 0 being empty and 100% 1 ft below the rim. The tank is refilled anytime the level drops below 20%. If the level is 18.5% how many gallons to refill to 100%?

Useable depth = 10ft – 1ft = 9 ft

Volume/ft = 4ft^2 x Pi / 4 x 7.48 gal/ft^3 = 94 gal/ft

Full tank volume = 94 gal/ft x 9 ft = 846 gallons

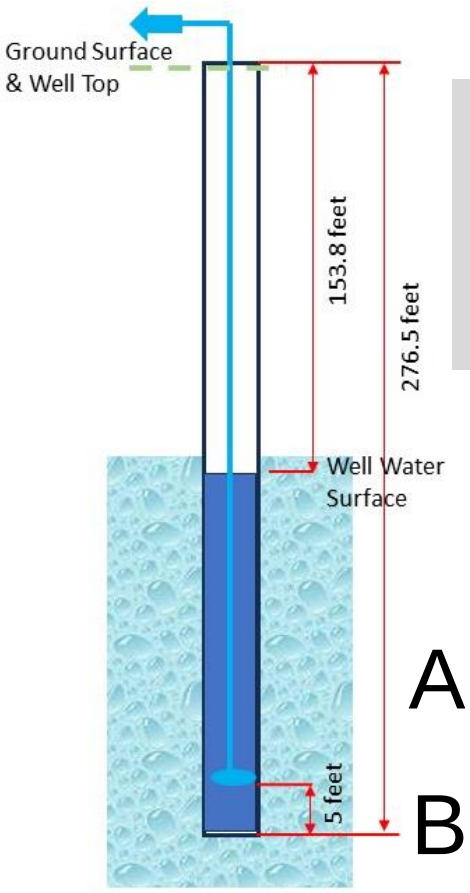
846 gallons x 0.815% = 689.5

D ~690 gallons

Pressure

Can you handle the pressure?

Question P1.1:



A well has a depth of 276.5 ft. If the water depth is 153.8 ft., what is the pressure in psi, 5 feet above the bottom (disregard atmospheric pressure)?

A 42 psi

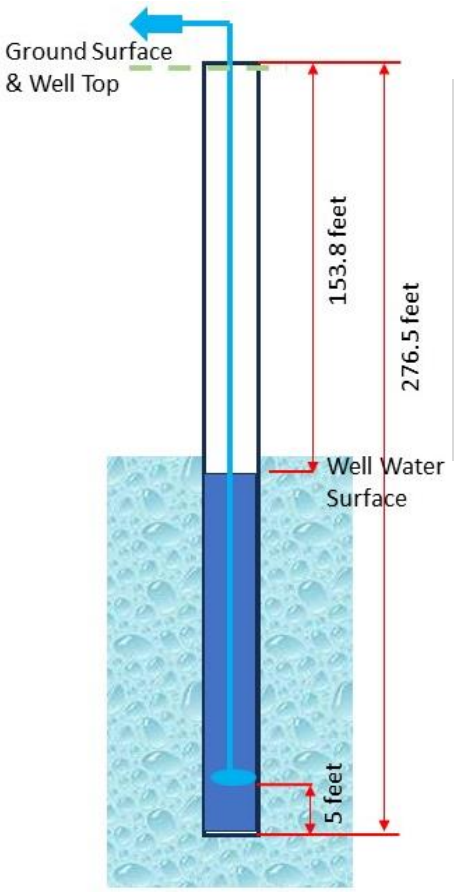
B 46 psi

C 48 psi

D 51 psi

Question P1.1:

W



A well has a depth of 276.5 ft. If the water depth is 153.8 ft. below grade, what is the pressure in psi 5 feet above the bottom of the well (disregard atmospheric pressure)?

276.5 ft - 153.8 ft = 122.7 ft depth of water

122.7 ft – 5.0 ft = 117.7 ft

117.7 ft / 2.3104 ft / psi = 50.944

D ~51 psi

Graphic from Alabama News Center

Question: P1.2

Your utility wants to build a new elevated tank (ground elev. 100) to serve a new large development (elev. 84). What is the minimum WS if the pressure at the edge of the zone is to be 65 psi and the average head loss between the tank and the end of the zone is 12 ft at design flow?

A 153.0 ft

B 145.0 ft

C 238.4 ft

D 230.4 ft

Question: P1.2

Water tank minimum water surface

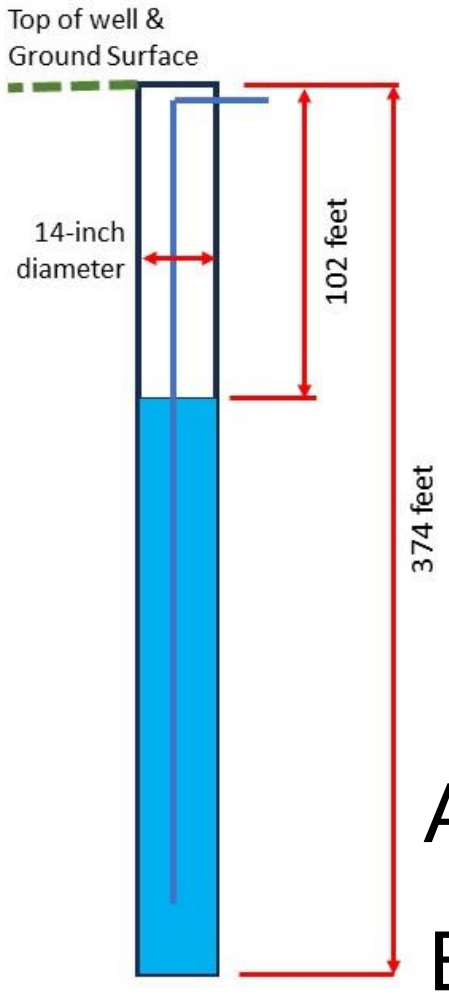
Change pressure from psi to feet

65 psi * 2.314 ft / psi = 150.4 ft

Start at the end and work to the tank

84 ft + 16 ft (delta elev.) – 12 ft (hl) + 150.4 ft (system pressure) = 238.4 ft

C **238.4 ft**



Question P1.3:

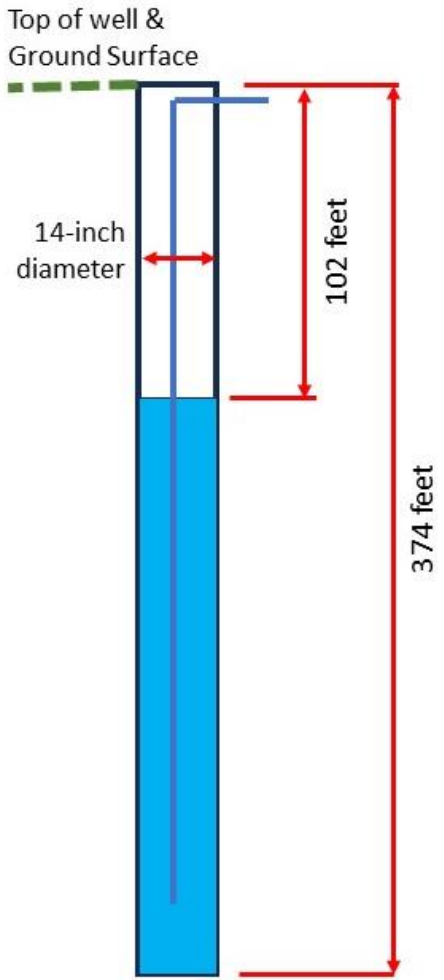
A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many pounds of calcium hypochlorite (65% available chlorine) are required?

A 0.9 lb

B 1.4 lb

C 10.5 lb

D 44.6 lb



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A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many pounds of calcium hypochlorite (65% available chlorine) are required?

First calculate the volume of water in the well, in gallons

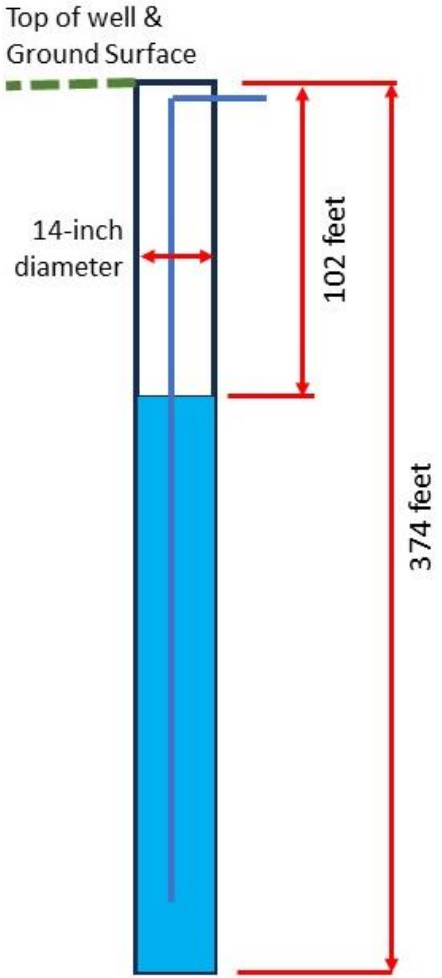
Water volume = X-sectional area x depth

Step 1 – well casing x-section area

$$\text{X-section area} = (0.785 \times \text{dia}^2)$$

$$\text{X-section area} = (0.785 \times (14 \text{ in.} / 12 \text{ in./ft.})^2)$$

$$\text{X-section area} = 0.785 \times 1.167 \text{ ft.}^2 = \underline{\mathbf{1.07 \text{ sq. ft}}}$$



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Step 2 – depth of the water in the well

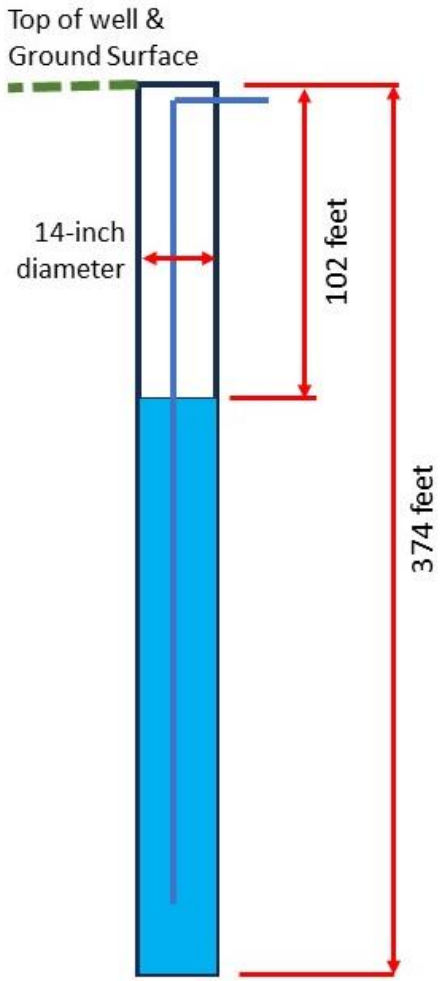
Water depth = 374 ft -102 ft.

Water depth = **272 ft.**

Step 3 – Water volume in cu. ft.

X-section area x depth = 1.07 sq. ft x 272 ft

Water volume = **290 cu ft. or $ft.^3$**



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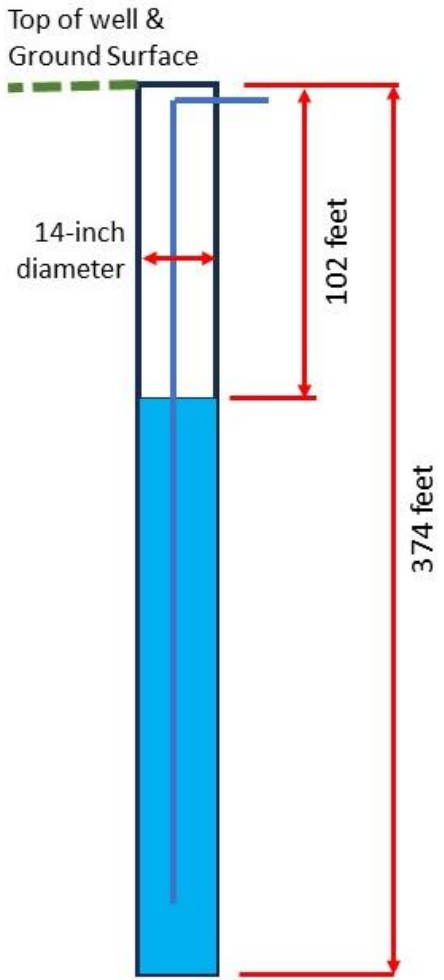
A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many pounds of calcium hypochlorite (65% available chlorine) are required?

Step 4 – calculate volume in gallons

290 cu. ft. x 7.48 gal. / cu. ft. = **2,174 gal.**

Step 5 - change gallons to million gallons

2,174 gallons / 1,000,000 gal = **0.002174 MG**



Question P1.3:

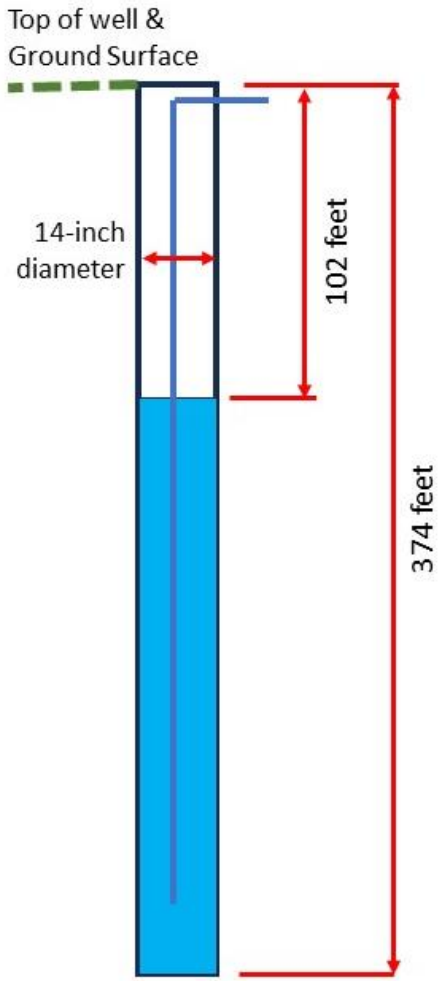
A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many **pounds** of calcium hypochlorite (65% available chlorine) are required?

Step 6 - calculate the dose of calcium hypochlorite required

Pounds CL = Dose x Volume x 8.34 / % purity

ose is in mg/l, Volume is in MG – do we have some unit issues to work out?

Not in this case – mg/l is parts per million, pounds per MG x unit weight of water provides the same ppm comparison



Question P1.3:

A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many **pounds** of calcium hypochlorite (65% available chlorine) are required?

Step 6 – continued

$$\text{Pounds CL} = \text{Dose} \times \text{Volume} \times 8.34 / \%\ \text{purity}$$

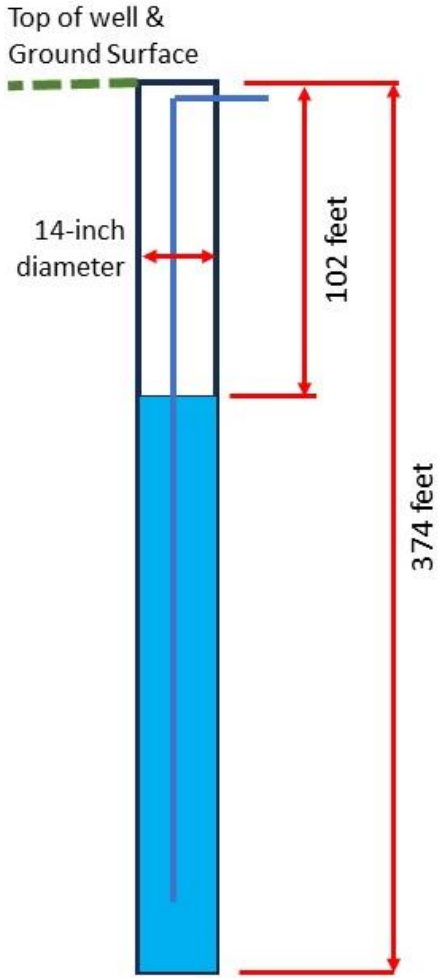
$$\text{Pounds CL} = \frac{(50\ \text{ppm} \times 0.00274\ \text{MG} \times 8.34\ \text{lb./gal.})}{65\%}$$

Dimensionless

$$\frac{\text{Parts}}{\text{million}} \times \text{million gallons} \times \text{lbs} \times \frac{1}{\text{gallons}} \quad \frac{1}{0.65}$$

Dimensionless

$$\text{Pounds CL} = 1.39\ \text{pound}$$



Question P1.3:

A well that is 374 ft in depth and 14 in. in diameter requires disinfection. Depth to water from top of casing is 102 ft. If the desired dose is 50 mg/L, how many pounds of calcium hypochlorite (65% available chlorine) are required?

3 **1.4 lb**

Flow Rate

How much & how fast?

Question Q1.1:

The level in a storage tank rises 3.1 ft. in 4.5 hours. If the tank has a diameter of 225 ft. and the plant is producing 32.4 mgd, what is the average discharge rate of the treated water discharge pumps in gallons per minute?

A 3,408 gpm

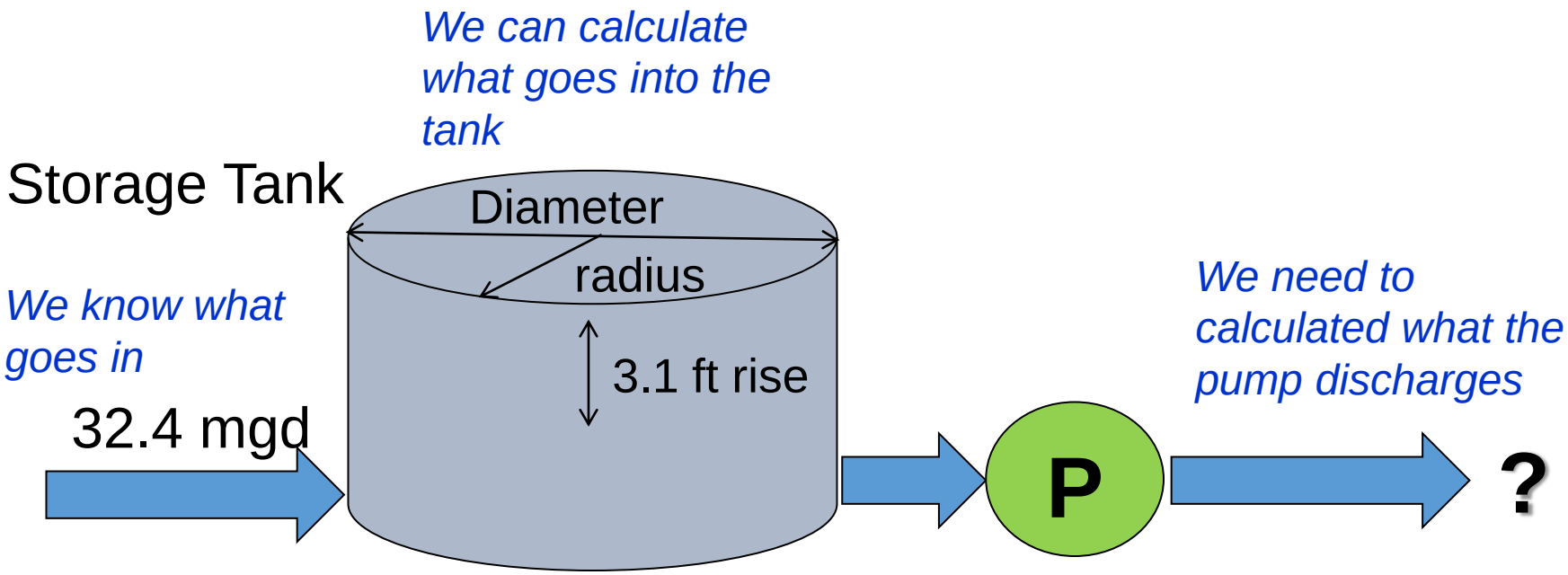
B 15,336 gpm

C 19,088 gpm

D 22,518 gpm

Question Q1.1:

The level in a storage tank rises 3.1 ft. in 4.5 hours. If the tank has a diameter of 225 ft. and the plant is producing 32.4 mgd, what is the average discharge rate of the treated water discharge pumps in gallons per minute?



Question Q1.1:
Solve for Discharge Pumping Rate:

First determine storage used

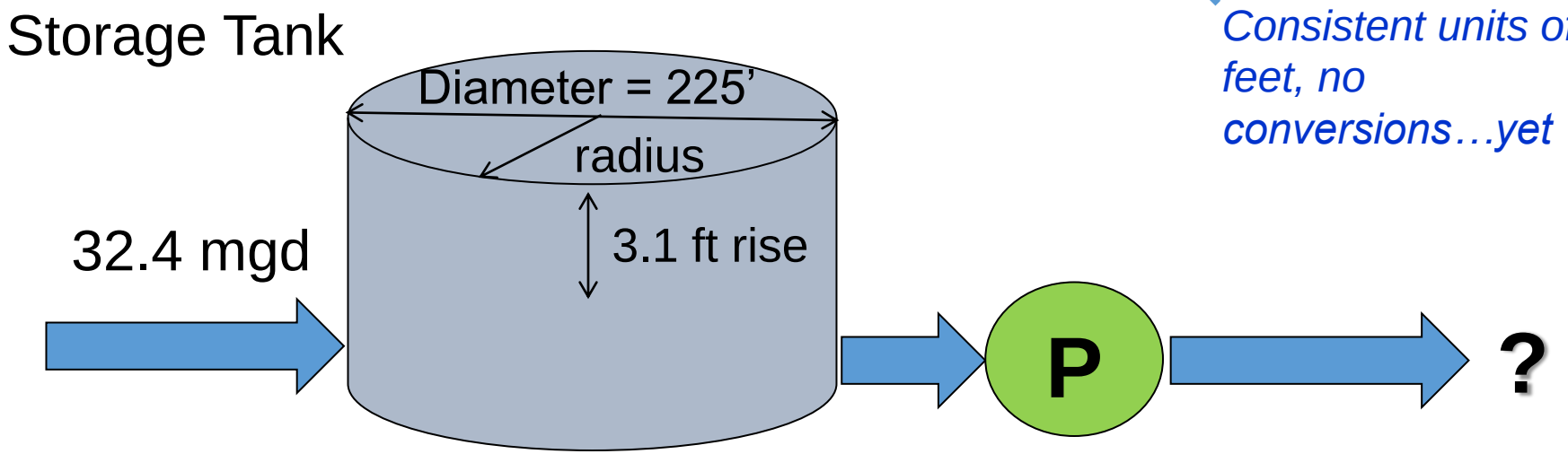
Storage = volume of rise

Storage = 0.785 x $(dia)^2$ x height of rise

Storage = 0.785 x $(225ft)^2$ x 3.1 ft

= 123,195 cu.ft

Consistent units of feet, no conversions…yet

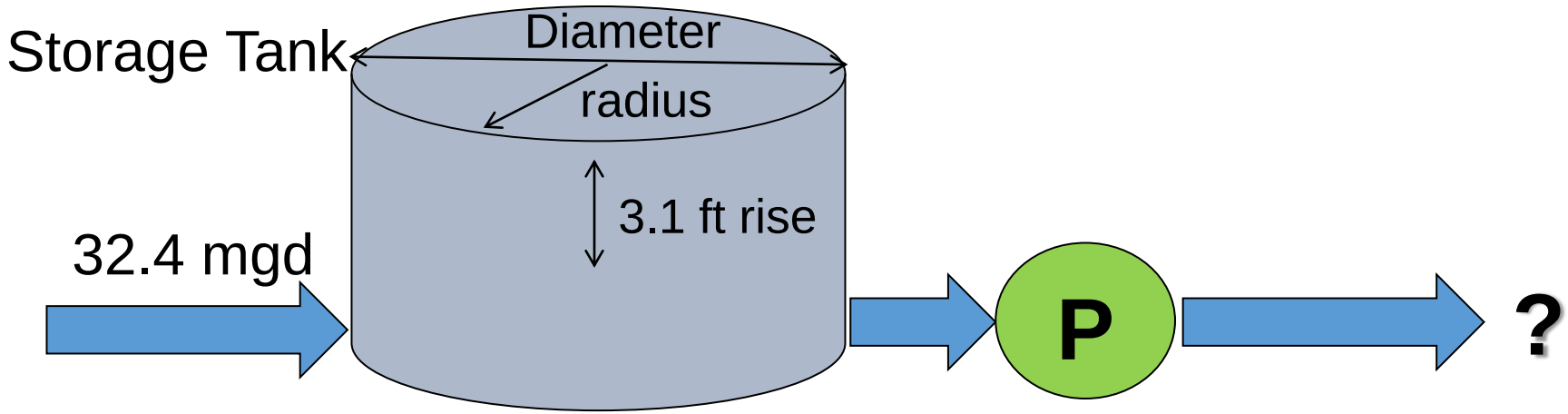


Question Q1.1:
Solve for Discharge Pumping Rate:

Now convert storage in cubic feet to gallons

123,195 cu.ft x 7.48 gal/cu.ft

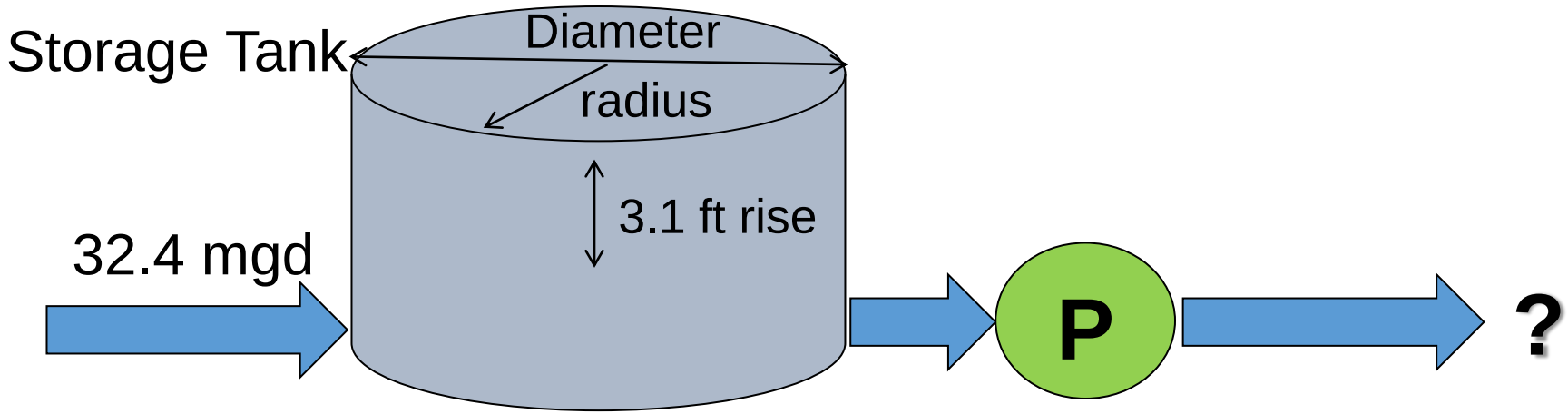
123,195 cu.ft. x 7.48 gal/cu.ft. = 921,498 gal



Question Q1.1:
Solve for Discharge Pumping Rate:

Calculate gallons per minute from daily flow

$$\frac{32.4\ \text{mg}}{\text{day}} \times \frac{1{,}000{,}000\ \text{gal}}{\text{mg}} \times \frac{\text{day}}{24\ \text{hr}} \times \frac{\text{hr}}{60\ \text{min}}$$

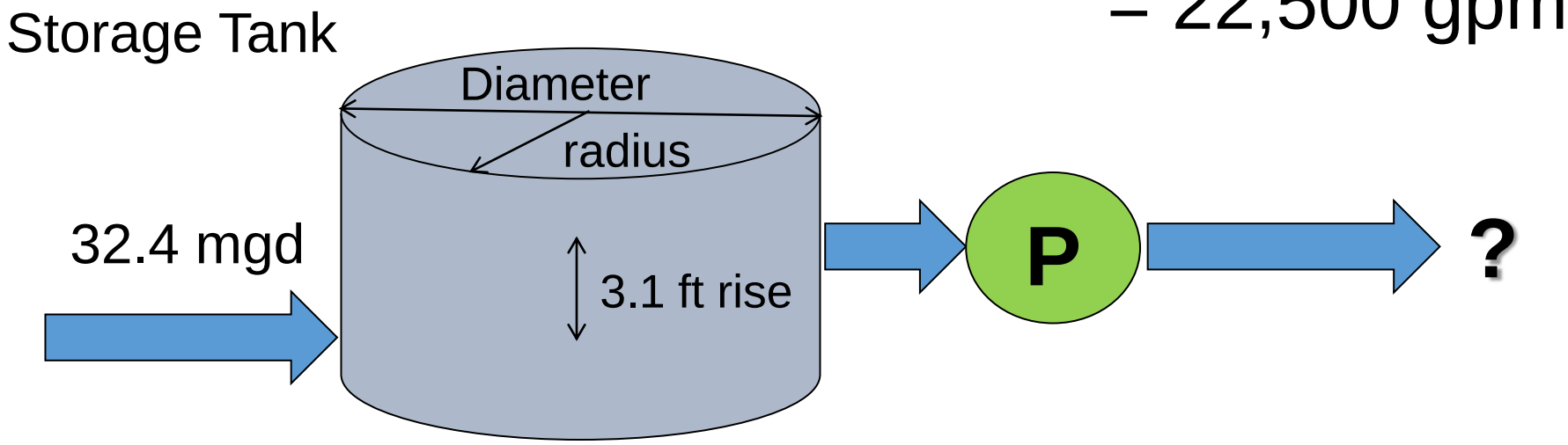


Question Q1.1:
Solve for Discharge Pumping Rate:

Working through the math and units

$$\frac{32.4\ \frac{mg}{d} \quad 1{,}000{,}000\ gal \quad d \quad hr}{d \quad mg \quad 24\ hr \quad 60\ min}$$

$$= 22{,}500\ gpm$$



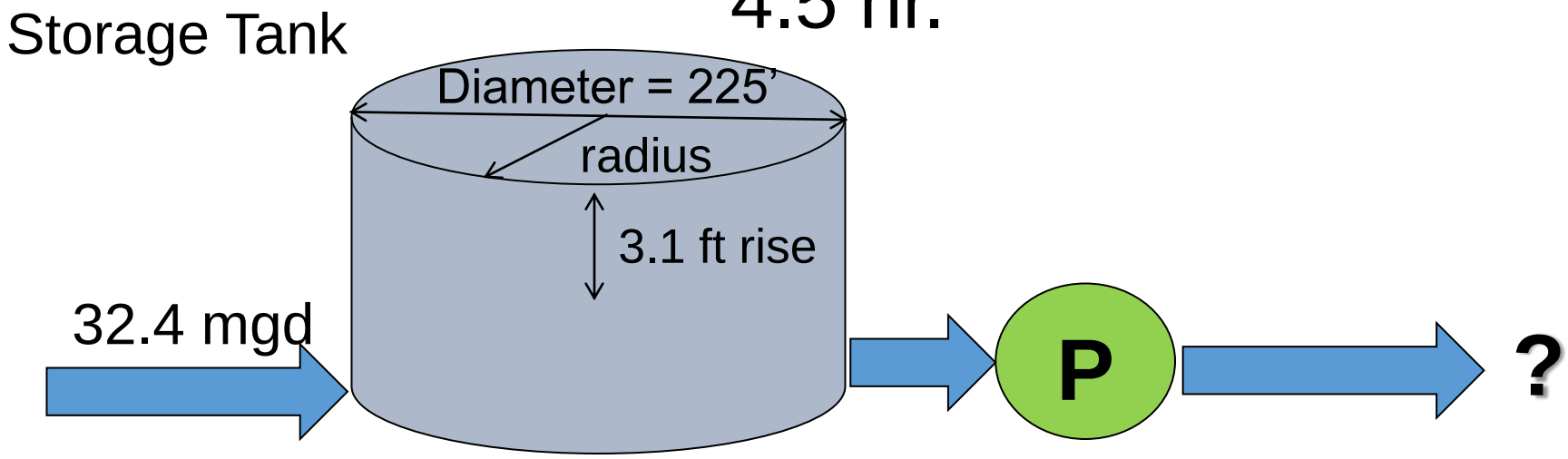
Question Q1.1:
Solve for Discharge Pumping Rate:

Determine reservoir inflow or storage rate

Storage volume = 921,498 gal

Storage rate = storage volume / time

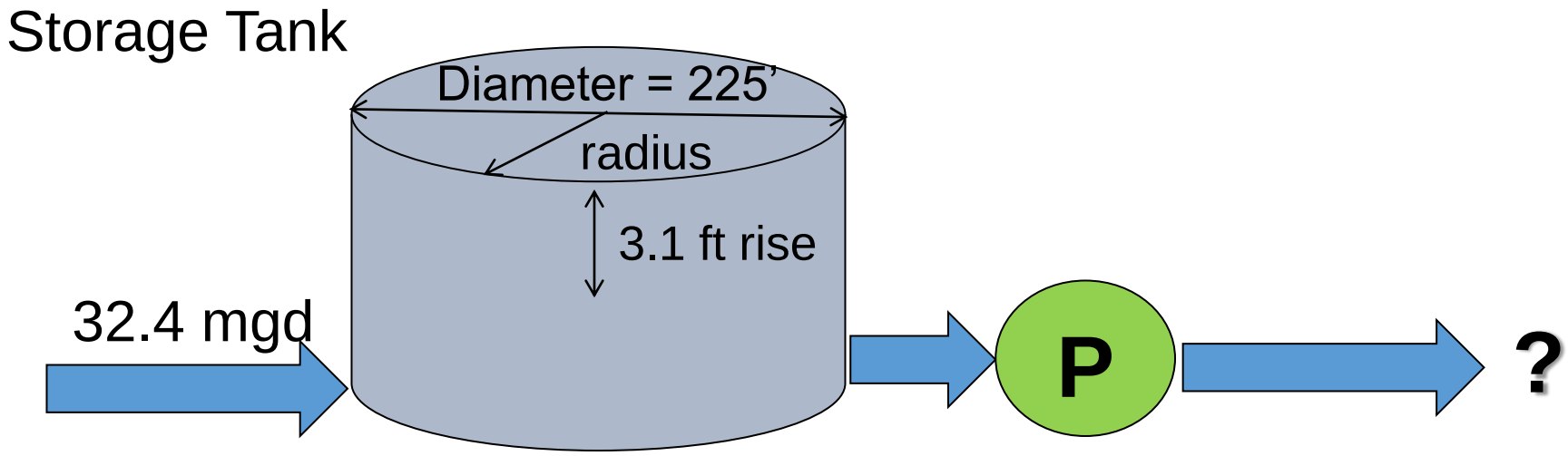
$$\text{Storage rate} = \frac{921{,}498 \text{ gal}}{4.5 \text{ hr.}} = 204{,}777 \text{ gal/hr.}$$



Question Q1.1:
Solve for Discharge Pumping Rate:

Convert gallons per hour to gpm

$$\frac{204{,}777 \text{ gal}}{\cancel{\text{hr}}} \times \frac{1 \text{ } \cancel{\text{hr}}}{60 \text{ min}} = 3{,}412 \text{ gpm}$$

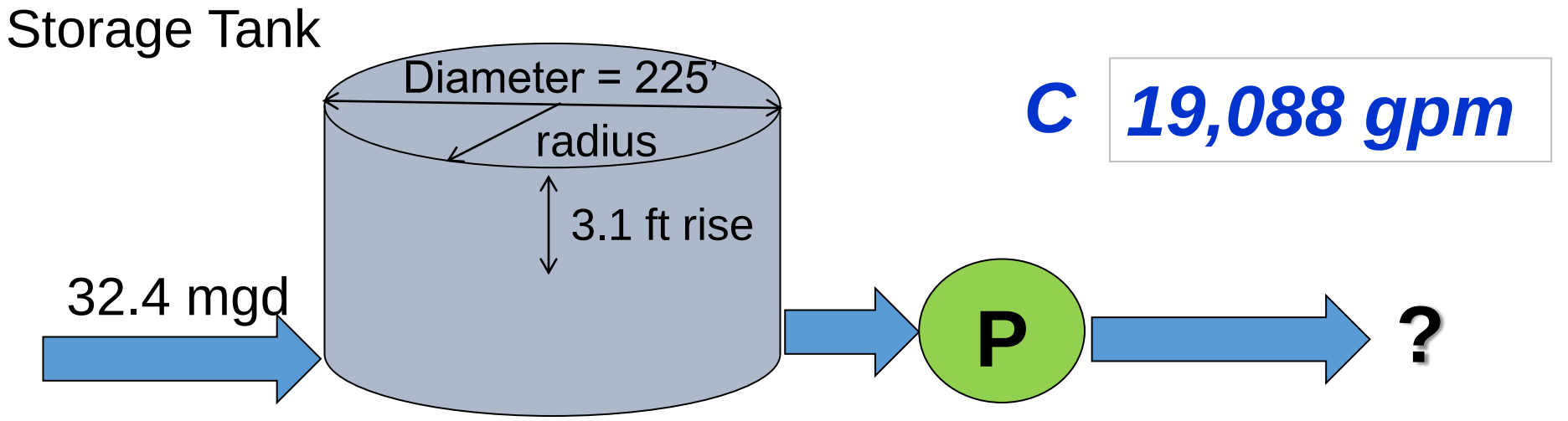


Question Q1.1:
Solve for Discharge Pumping Rate:

Pumping rate = Production minus storage

Discharge rate = 22,500 gpm – 3412 gpm
= 19,088 gpm

(Same units, no canceling)



C ***19,088 gpm***

Question Q1.2:

A 6-in. pipeline needs to be flushed. If the desired length of pipeline to be flushed is 316 ft, how many minutes will it take to flush the line at 31 gpm?

A 10 minutes

B 15 minutes

C 30 minutes

D 60 minutes

Question Q1.2:

A 6-in. pipeline needs to be flushed. If the desired length of pipeline to be flushed is 316 ft, how many minutes will it take to flush the line at 31 gpm?

First determine the volume of the pipe:

Volume of pipeline = x-section area x length

$= (0.785 \times (6 \text{ in}/12 \text{ in/ft.})^2) \times 316 \text{ feet} = 62 \text{ cu.ft.}$

62 cu.ft. x 7.48 gal/cu.ft. = 464 gal.

Question Q1.2:

A 6-in. pipeline needs to be flushed. If the desired length of pipeline to be flushed is 316 ft, how many minutes will it take to flush the line at 31 gpm?

Next determine the time required to flush:

Minutes to flush = volume of pipe/flush rate

= 464 gal / 31 gpm

= 15 min

B 15 minutes

Question Q1.4:

If a 6-in. force main has a metered flow of 200,000 gpd, what is the velocity of the fluid through the force main?

A 1.6 ft/sec

B 2.5 ft/sec

C 3.1 ft/sec

D 3.9 ft/sec

Question Q1.4:

If a 6-in. force main has a metered flow of 200,000 gpd, what is the velocity of the fluid through the force main

Flow = Velocity x Area

Area = 0.785 x dia^2

Area = 0.785 x $(6in / 12in/ft)^2$ = 0.196 sq ft

Flow (in cfs) = 200,000 gpd

24 hr/day * 60 min/hr * 60 min/sec

Flow = 0.2 mgd x 1.55 cfs/mgd = 0.31 cfs

(assumes constant flow)

Question Q1.4:

If a 6-in. force main has a metered flow of 200,000 gpd, what is the velocity of the fluid through the force main

Velocity = Flow/Area

– Rearrange the equation to isolate what you want to calculate

Velocity = 0.31 cfs/ 0.196 sq ft = **1.6 ft/sec**

A 1.6 ft/sec

Question Q1.5:

If a pump discharges 10,350 gallons in 3 hours 45 minutes, what is the pump flow rate in gpm?

A 43 gpm

B 44 gpm

C 45 gpm

D 46 gpm

Question Q1.5:

If a pump discharges 10,350 gallons in 3 hours 45 minutes, what is the pump flow rate in gpm?

Time in minutes = 3 hr x 60 min/hr + 45 min. = 225 min.

Q = 10,350 gal / 225 min. = 46 gpm

D 46 gpm

W & WW

Question Q1.6:

A filter has a surface area of 920 sf. What is the filtration rate in gpm/sf if the filter receives a flow of 4,875 gpm?

A 2.4 gpm/sf

B 4.8 gpm/sf

C 5.3 gpm/sf

D 9.2 gpm/sf

Question Q1.6:

A filter has a surface area of 920 sf. What is the filtration rate in gpm/sf if the filter receives a flow of 4,875 gpm?

4,875 gpm / 920 sf = 5.29891 gpm/sf

C **~5.3 gpm/sf**

Treatment Process & Chemical Dosing

Tracking the treatment

Question T1.1:

A system uses 250 gal of 15% hypochlorite solution each day. The system operator receives a call from his/her chemical supplier saying that the 15% hypochlorite solution will no longer be available but is being replaced with a 10% hypochlorite solution. In order to keep the dosage the same, how much of the 10% solution will the operator need to feed every day?

A 150 gal

C 250 gal

B 375 gal

D 420 gal

Question T1.1:

A system uses 250 gal of 15% hypochlorite solution each day. The system operator receives a call from his/her chemical supplier saying that the 15% hypochlorite solution will no longer be available but is being replaced with a 10% hypochlorite solution. In order to keep the dosage the same, how much of the 10% solution will the operator need to feed every day?

First determine the volume of 100% hypo

Dosage of hypo = 250 gal x 15%

Dosage of hypo = 250 gal x .15 = 37.5 gal

Question T1.1:

A system uses 250 gal of 15% hypochlorite solution each day. The system operator receives a call from his/her chemical supplier saying that the 15% hypochlorite solution will no longer be available but is being replaced with a 10% hypochlorite solution. In order to keep the dosage the same, how much of the 10% solution will the operator need to feed every day?

Next calculate the volume of the new more dilute solution

Dosage of hypo = 37.5 gal New solution = 10% hypo

$$\text{New solution} = \frac{37.5 \text{ gal}}{0.10} = 375 \text{ gallons}$$

W & WW

Question T1.2:

Determine the specific gravity (SG) of an unknown liquid if the density of the liquid is 70.9 lb/ft^3

A 1.05 SG

B 1.14 SG

C 1.18 SG

D 1.21 SG

Question T1.2:

Determine the specific gravity (SG) of an unknown liquid if the density of the liquid is 70.9 lb/ft^3.
Note - *SG is a ratio & dimensionless*

$70.9\ lb/ft^3 / 62.4\ lb/ft^3 = 1.1362$ SG

B ~1.14 SG

W & WW

Question T1.3:

Determine the percentage strength of a solution mixture if 875 lb of a 49.6% strength solution is mixed with 293 lb of a 17.2% solution.

A 41.5%

B 42.4%

C 43%

D 43.1%

Question T1.3:

Determine the percentage strength of a solution mixture if 875 lb of a 49.6% strength solution is mixed with 293 lb of a 17.2% solution.

875 lb + 293 lb = 1,168 lb total solution weight

((875 lb x 0.496) + (293 lb x 0.172)) / 1,168 lb =

= 0.41472 x 100 = 41.472%

A ~41.5%

Question T1.4:

W

An 84 ft diameter tank that's 24.25 ft high at the overflow requires disinfection at a dosage of 50 mg/l. How much 12.5% sodium hypochlorite that weighs 9.59 lb/gallon is required?

A 310 gallons

B 350 gallons

C 380 gallons

D 410 gallons

Question T1.4:

W

84 ft diameter tank x 24.25 ft high
Disinfection of 50 mg/l.
12.5% sodium hypochlorite @ 9.59 lb/gallon

$84^{\wedge 2}$ ft^2 x Pi / 4 x 24.25 ft = 134,390 ft^3

134,390 ft^3 x 7.48 gal/ft^3 = 1.005 x10^6 gallons

50 mg / L / 12.5% = 400 mg / L hypo reqd

400mg/L x10^{-6} kg/mg x 2.2lb/kg = 8.82 x 10^{-4} lb/L

8.82 x 10^{-4} lb/L x 3.7854 L/gal / 9.59 lb/gal =

3.81x10^6 L x x 3.7854 L/gal 8.82x10^{-4} lb/L =

B **350 gallons**

W & WW

Question T1.5:

Your group uses 80 units of an item per week. You are required to have a 10 week reserve of the item on hand at all times, and it requires 4 weeks to obtain a new supply. What is the minimum reorder point?

A 320 units

B 800 units

C 1,120 units

D 2,240 units

Question T1.5:

W & WW

Your group uses 80 units of an item per week. You are required to have a 10 week reserve of the item on hand at all times, and it requires 4 weeks to obtain a new supply. What is the minimum reorder point?

Q_W = 80 units

Q_M = 80 units x 10 weeks = 800 units

Q_{ST} = 80 units x 4 weeks = 320 units

Q_R = 800 units + 320 units = 1,120 units

C 1,120 units

Question T1.6:

What percentage is 34,411 of 74,818?

A	34.411%
B	45.993%
C	74.818%
D	217.42%

Question T1.6:

W & WW

What percentage is 34,411 of 74,818?

34,411 / 74,818 = 0.459929

0.459929 x 100 = 45.993%

B 45.993% **~ 46%**

W & WW

Question T1.7:

The iron content of raw water is 1.81 mg/l. What is the % removal if the finished water contains 0.11 mg/l?

A	17%
B	20%
C	60%
D	94%

Question T1.7:

W & WW

The iron content of raw water is 1.81 mg/l. What is the % removal if the finished water contains 0.11 mg/l?

Iron removed (weight) = 1.81 mg/l – 0.11 mg/l = 1.7 mg/l

Iron removed % = 1.70 mg/l / 1.81 mg/l = 0.93923 (dimensionless ratio)

0.93923 x 100 = 93.926%

D **~94%**

Questions were taken from the following:
(with some modifications)

Operator Certification Study Guide – *A Guide to Preparing for Water Treatment and Distribution Operator Certification Exams,* Fifth Edition. Written by John Giorgi, Prepared by the Association of Boards of Certification. American Water Works Association, 2003

WEF/ABC Wastewater Operators' – *Guide to Preparing for the Certification Examination.* Water Environment Federation, 2002

WEF/ABC Collection Systems Operators' – *Guide to Preparing for the Certification Examination.* Water Environment Federation, 2002

OpFlow Certification Corner – *Monthly publication from AWWA*

Questions, Comments and Suggestions?

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Example Problems

Let's work through some practical examples

Version 1.0 & October 2020

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Segment topics:

- Length, area & volumes
- Pressure
- Rates of flow & velocity
- Chemicals & Process

Length, Area & Volumes

Get out your pencils, paper & calculators

Question:

Your new WTP will have 8 filter beds and you are planning on 7 being in service at any time. The flow rate is 8 gal/sf/min for clean bed and 6.5 for a bed that is ready for backwashing. If the beds will be close to square, what are the plan dimensions for a capacity of 40.0 mgd?

Photo from City of Lynden, WA

Question:

Filter Area

Average capacity = (8.0 + 6.5)/2 = 7.25gal/sf/min

7.25 g/sf/min x 60 min/hr * 24 hr/d = 10,440 gal/sf/day

10,440 gal/day x (1 MG / 1,000,000 gal = 0.010440 MG/sf/day

Area required = 40.0 mgd / 0.01044 MG/sf/d = 3,831 sf

Area required / filter bed = 3,831 sf / 7 = 547 ft^2 / bay

Rough dimensions = $(547\ sf)^{0.5}$ = 23.4 ft / side

~ **24 ft * 24 ft = 576 sf** (multiples of 4 ft wide forms)

or **20 ft * 28 ft = 560 sf** (multiples of 4 ft wide forms)

Question:

Your new reservoir is to have a active storage capacity of 1 MG and a pressure range of 25 psi. What is the diameter of the reservoir?

Graphic from City of Troutdale, OR

Question:

Tank diameter

Height range 25 psi x 2.31 ft/psi = 57.75 ft

Volume 1,000,000 gal./ 7.48 gal./ ft^3 = 133,690 ft^3

133,690 ft^3 / 57.75 ft = 2,415 ft^2 = tank area

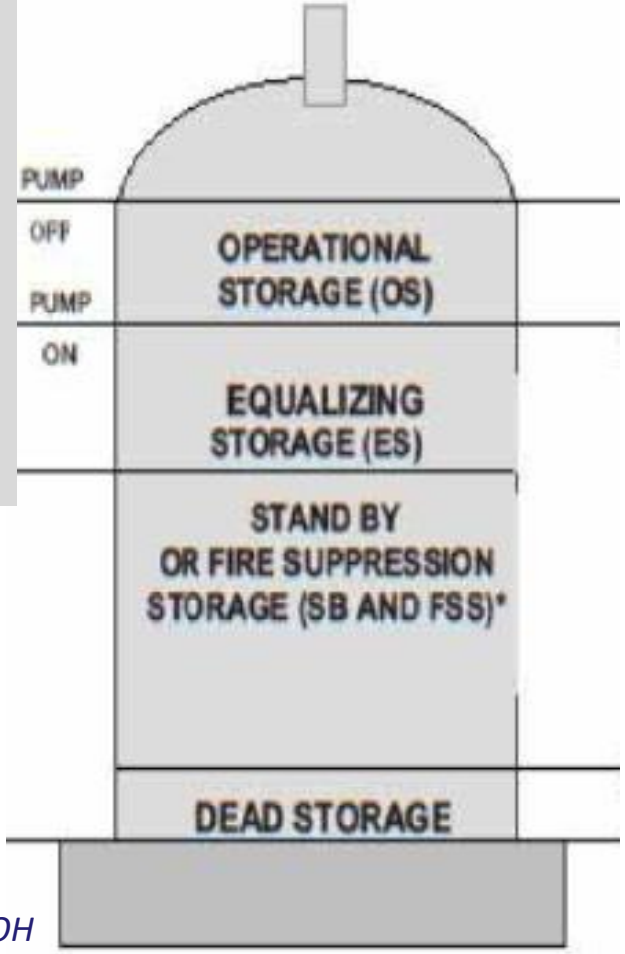
Area = D^2 x PI / 4 rearranged D = $(area * 4 / PI)^{0.5}$

$(2,415 * 4 / 3.14159)^{0.5}$ = 54.29 ft inside diameter

~55 ft

Question:

You've been given a screaming good deal for a new water tank but the Canadian contractor wants to do the job in metric units. You need 500,000 gallons of storage (operational + equalizing + standby). The proposed tanks is 12 meters in diameter x 20 meters to the overflow. Is the tank big enough? If yes, what is the volume of the dead storage?



Graphic from WSDOH

Question:

Is the tank big enough?

Area = 12^2 * 3.14159 / 4 = 113.10 m^2

Volume = 113.10 m2 x 20 m = 2,262 m^3

Volume conversion 264.172 gallons / m^3

2,263 ~~m^3~~ x 264.172 gallons / ~~m^3~~

597,543 gallons – **YES** big enough

597,543 gal. – 500,000 gal. = 97,543 gal excess

Question:

A lime tank is a cone at the bottom and cylindrical at the top. The cylinder portion is 28 feet tall. The cone has a minimum diameter of 2 feet and is 12 feet tall. What is the volume of the tank in cubic feet to 3 significant figures?

Question:

A lime tank is a cone at the bottom and cylindrical at the top. The cylinder portion is 28 feet tall. The cone has a minimum diameter of 2 feet and is 12 feet tall. What is the volume of the tank in cubic feet to 3 significant figures?

Cylinder volume = Π x d^2 / 4 x H

Cone volume = (d_1^2 + d_2^2) / 2 x Π/4 x H

Π x 15^2 / 4 x 28 + (15^2+2^2)/2 x Π/4 X H

6,030 ft3

Question:

Convert 16,912,000 liters to acre-feet

Photo from the Town of Friday Harbor

Question:

Convert 16,912,000 liters to acre-feet

Liters → gallons → cubic feet → acre-feet

16,912,000 liters x 0.2642 gal/liter = 4,468,150 gal

4,468,150 gallons / 7.48 gallons/cf = 597,346 cf

597,346 cf / 43,560 cf/acre-feet = 13.7138 acre-ft

13.7 acre-feet

Question:

A new section of pipe is 16” in diameter and 550 feet long. How many gallons does the pipe contain? And why do we care?

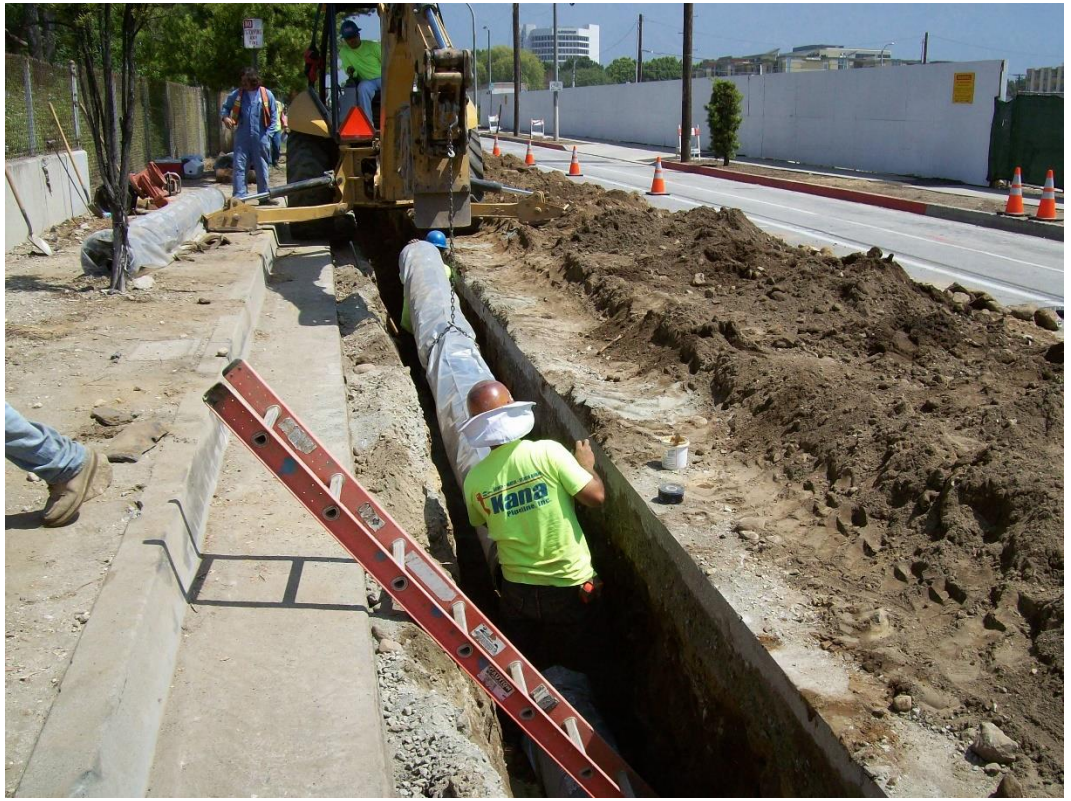


Photo from Kana Pipeline, Inc.

Question:

A pipe is 16” in diameter and 550 feet long. How many gallons does the pipe contain?

$1.33\ ft^2 \times PI / 4 \times 1\ ft = 1.39\ ft^3 / ft$

$1.39\ ft^3 / ft \times 550\ ft = 764.11\ ft^3$

$764.11\ ft^3 \times 7.48\ gal. / ft^3 = 5{,}715.5\ gallons$

5,715.5 gallons – *round off to 5,720 gallons*

Question:

What is the diameter of a tank with a circumference of 408.2 ft?

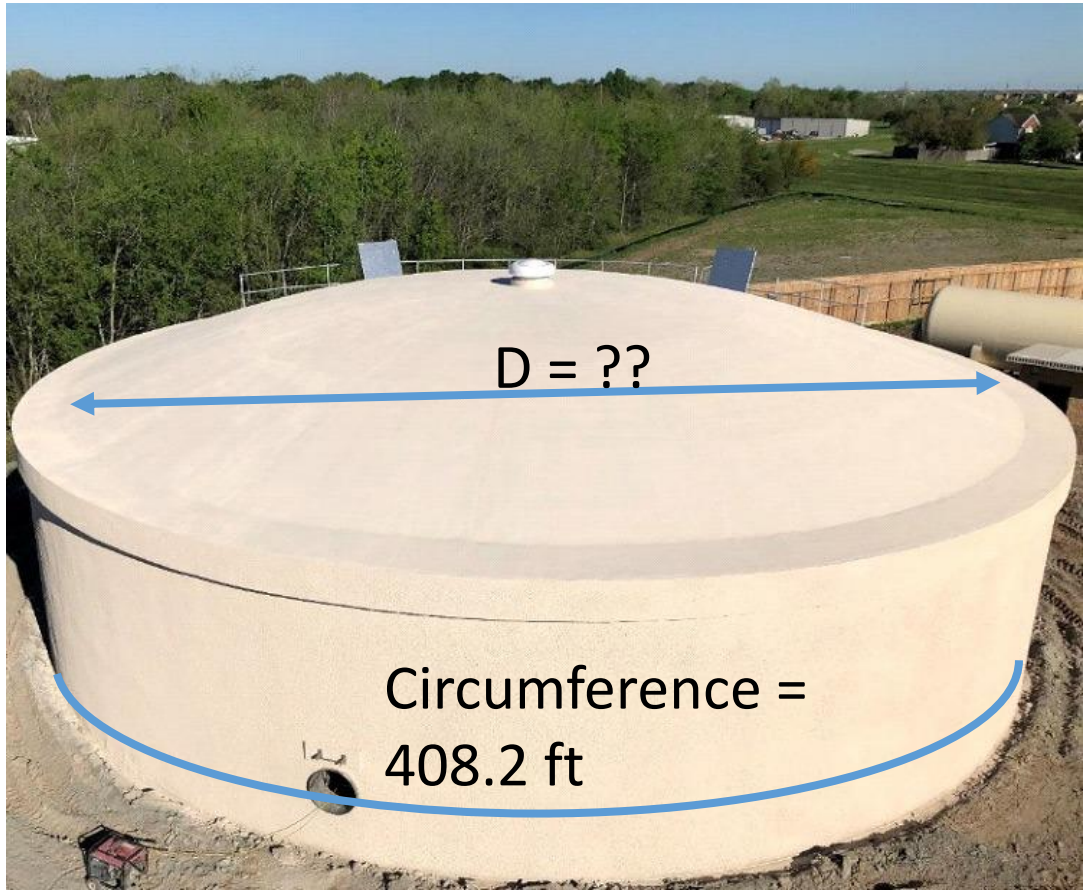


Photo from DN Tanks

Question:

What is the diameter of a tank with a circumference of 408.2 ft?

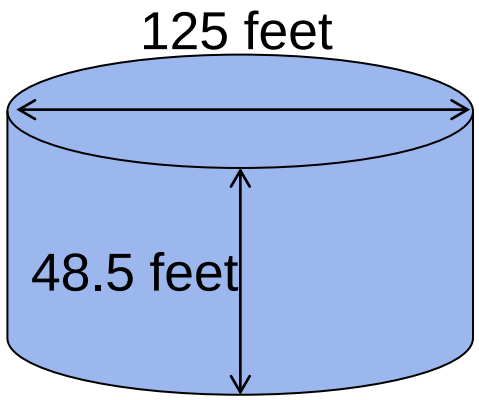
408.2 feet / pi = 408.2 feet / 3.14159 =

= 129.93 feet in diameter

~130 feet

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Top = Area 1

Area 1 = $0.785*dia^2$

Area 1 = $0.785 \times (125\ ft)^2$

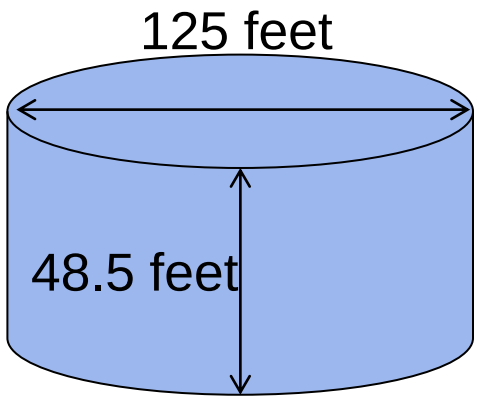
Area 1 = 12,265 sq ft

Top & Bottom = 2 x 12,265 sq ft

Top & Bottom = 24,530 sq ft

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Cylinder wall = Area 2

Area 2 = circumference x ht

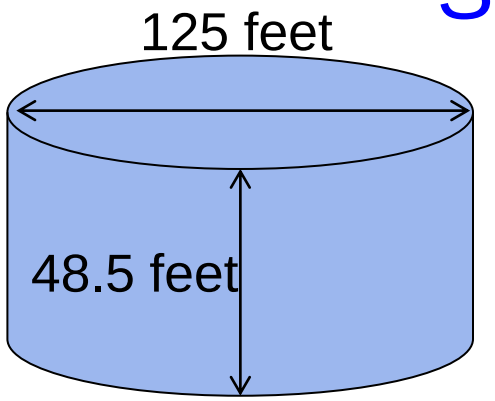
Area 2 = Π x diameter x ht

Area 2 = 3.14 x 125 x 48.5

Area 2 = 19,036 sq ft

Question:

What is the internal surface area of a cylindrical tank (bottom, top, and the cylinder wall), if it is 125.0 ft in diameter and 48.5 ft high



Surface area = 2 x Area1 + Area2

= 24,530 sq ft +19,036 sq ft

= 43,566 sq ft

43,600 sq ft

Pressure

Often the limiting factor

Question:

What is the pounds per square inch pressure at the bottom of a tank, if the water level is 38.29 ft.?

Photo from City of Marysville

Question:

What is the pounds per square inch pressure at the bottom of a tank, if the water level is 38.29 ft.?

1 foot of water = 0.433 psi

38.29 ft * 0.433 psi / ft water = 16.6 psi

16.6 psi ~ 17 psi

Question:

The pressure at a fire hydrant is 171 feet. What is the pressure in pounds per square inch (psi)?

Photo from City of Palm Springs

Question:

The pressure at a fire hydrant is 171 feet. What is the pressure in pounds per square inch (psi)?

= 171 ft / 2.31 psi/ ft

74 psi

Question:

What is the pressure head at a fire hydrant in feet, if the pressure gauge reads 121 psi

Photo by Jeff Lundt

Question:

What is the pressure head at a fire hydrant in feet, if the pressure gauge reads 121 psi

1 foot of water = 0.433 psi

121 psi / 0.433 psi / ft water = 279.45 ft

~280 ft

Question:

Determine the pressure in psi at the bottom of an alum storage tank if the tank's level is 8.95 feet and alum density is 11.32 lb / gallon

Photo from DN Tanks

Question:

Determine the pressure in psi at the bottom of an alum storage tank if the tank's level is 8.95 feet and alum density is 11.32 lb / gallon

Pressure is the weight of the fluid above the point of measurement

11.32 lb/gallon x 7.48 gallons/cf = 84.67 lb/cf

8.95 feet x 84.67 lb/cf = 757.8 lb/sf

757.8 lb/sf / 144 in^2/sf = 5.2625 lb/in^2 or psi

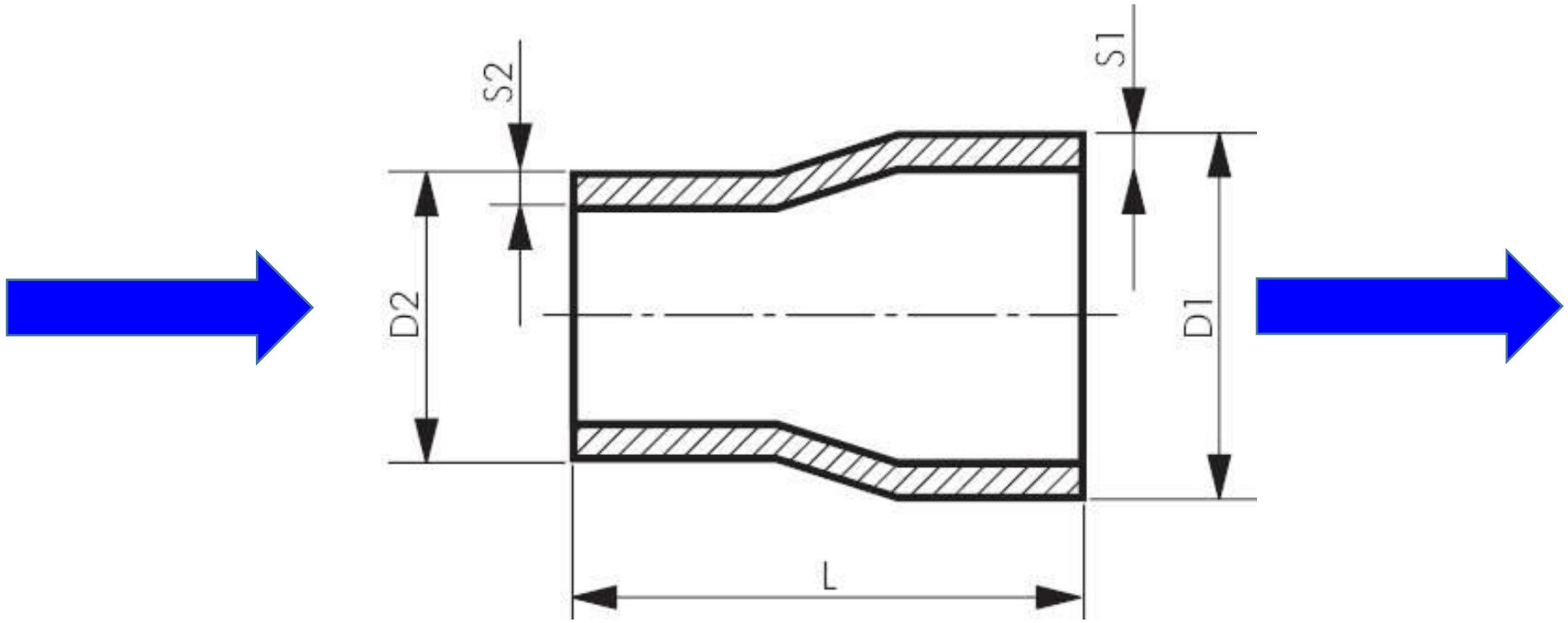
5.26 psi

Rates of Velocity & Flow

How fast?

Question:

Water flows at a velocity of 3.75 fps in a 10-in. diameter pipe. If the pipe changes from the 10-in. to a 12-in. pipe, what will the velocity be in the 12-in. pipe?



Question:

Water flows at a velocity of 3.75 fps in a 10-in. diameter pipe. If the pipe changes from the 10-in. to a 12-in. pipe, what will the velocity be in the 12-in. pipe?

Use the ratio of the areas (w/o pi & constant)

$10^2 / 12^2 = 100 / 144 = 0.694$

3.75 fps x 0.694 = 2.60 fps

2.6 fps

Question:

Water is flowing in a pipeline at a rate of 2.65 cu/ft per sec. What is the flow rate in gallons per min.?

Question:

Water is flowing in a pipeline at a rate of 2.65 cu.ft. per sec. What is the flow rate in gallons per min.?

2.65 cfs x 7.48 gal/cf x 60 sec/min. =
1,189.3 gpm

1,190 gpm

Question:

An 18-inch diameter distribution pipe delivers 988,000 gallons in 24 hours. What is the average velocity during the 24 hour period in feet / second?

Photo from 123RF.com

Question:

An 18-inch diameter distribution pipe delivers 988,000 gallons in 24 hours. What is the average flow during the 24 hour period in feet / second?

$(18 \text{ inches} / 12 \text{ inch / ft})^2 \times PI / 4 = 1.77 \text{ sf}$

$24 \text{ hr} \times 60 \text{ min / hr} \times 60 \text{ sec / min} = 86{,}400 \text{ sec}$

$988{,}000 \text{ gal} / 7.48 \text{ ft}^3 / \text{gal} = 132{,}085.6 \text{ ft}^3$

$132{,}085.6 \text{ ft}^3 / 1.77 \text{ sf} / 86{,}400 \text{ sec} =$

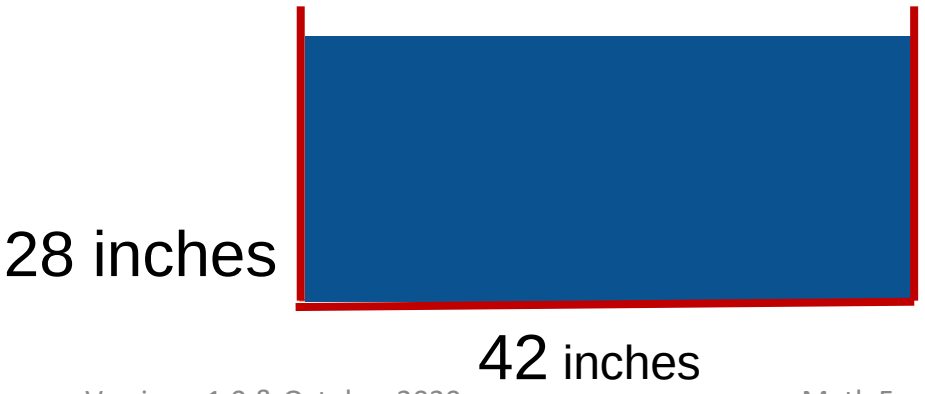
0.87 ft / sec

Question:

A rectangular section channel is 42” wide and the water is a depth of 28”. You toss a float in and determine that it travels 30 feet in 15 seconds. What is the flow rate in ft^3/sec? gpm?

Dimensions in inches, change to feet

Flow = Velocity x Area



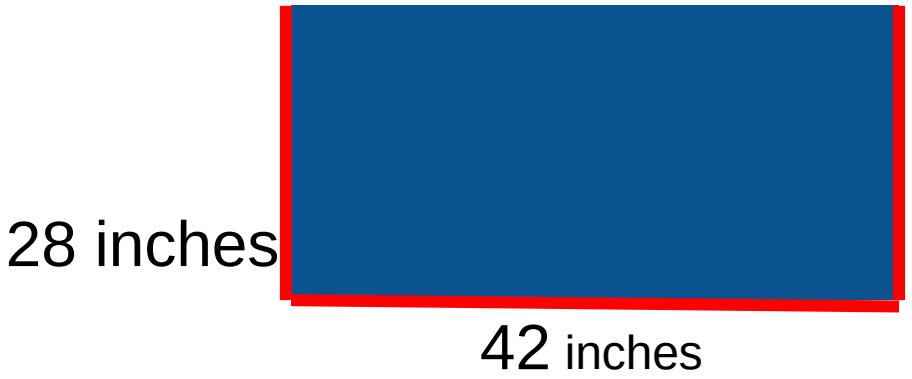
$$\text{Width} = \frac{42 \text{ in} \mid 1 \text{ ft}}{\mid 12 \text{ in}} = 3.5 \text{ ft}$$

$$\text{Depth} = \frac{28 \text{ in} \mid 1 \text{ ft}}{\mid 12 \text{ in}} = 2.3 \text{ ft}$$

Question:

A channel is 42” wide and the water is a depth of 28”. You toss a float in and determine that it travels 30 feet in 15 seconds. What is the flow rate in ft^3/sec? gpm?

Flow = Velocity x Area



Area = 2.3 ft x 3.5 ft

Area = 8.05 sq ft

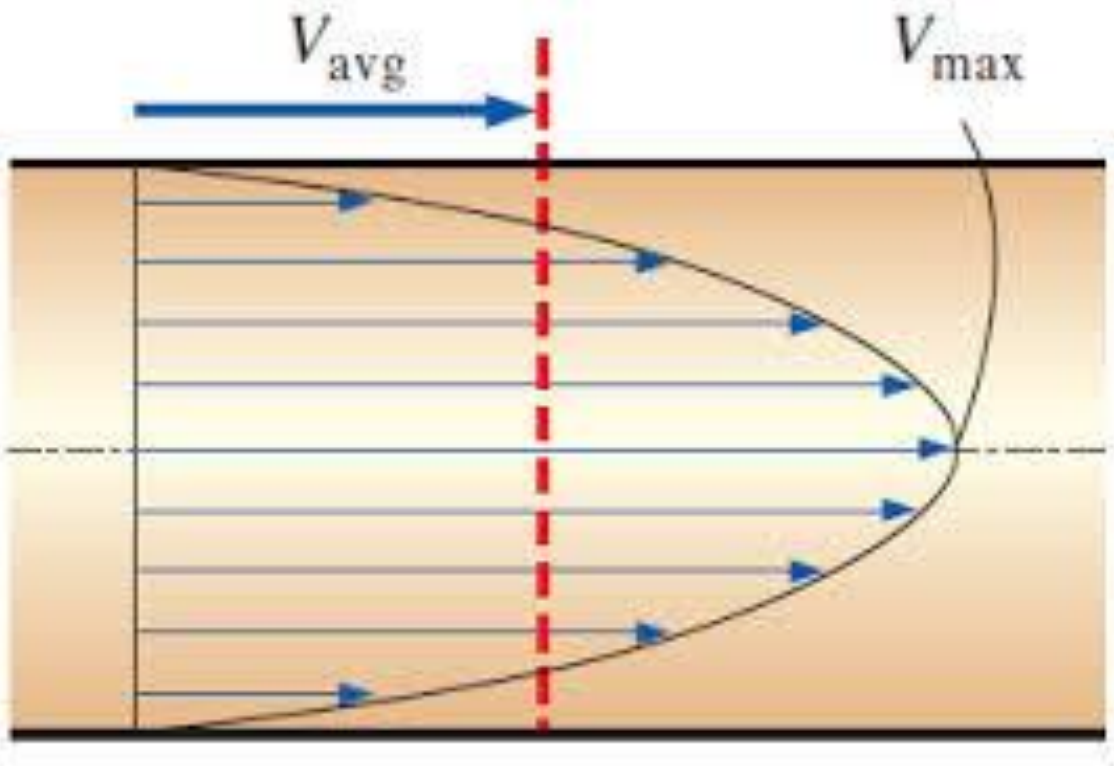
$$\text{Velocity} = \frac{30 \text{ feet}}{15 \text{ seconds}} = 2 \text{ fps}$$

Flow = 2 fps x 8.05 sq ft

Flow rate = 16.1 cfs

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?



Graphic from drive.uqu.edu.sa

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

600 gpm = Velocity x $(.67\ ft)^2$ x .785

8 inches = 8/12 foot
= .67 foot

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

$600\ gpm = Velocity \times (.67\ ft)^2 \times .785$

$$\frac{600\ gpm}{(.67\ ft)^2 \times .785} = \frac{Velocity \times (.67\ ft)^2 \times .785}{(.67\ ft)^2 \times .785}$$

8 inches = 8/12 foot
= .67 foot

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

Flow (Q) = Velocity x Area

$$600\ \text{gpm} = \text{Velocity} \times (.67\ \text{ft})^2 \times .785$$

$$\frac{600\ \text{gpm}}{(.67\ \text{ft})^2 \times .785} = \frac{\text{Velocity} \times (.67\ \text{ft})^2 \times .785}{(.67\ \text{ft})^2 \times .785}$$

$$\frac{600\ \text{gal}}{\text{min}} \left| \frac{1\ \text{cu ft}}{7.48\ \text{gal}} \right. = 80.2\ \text{cfm}$$

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

$$\text{Flow (Q)} = \text{Velocity} \times \text{Area}$$

$$600 \text{ gpm} = \text{Velocity} \times (.67 \text{ ft})^2 \times .785$$

$$\frac{600 \text{ gpm}}{(.67 \text{ ft})^2 \times .785} = \frac{\text{Velocity} \times (.67 \text{ ft})^2 \times .785}{(.67 \text{ ft})^2 \times .785}$$

$$\frac{600 \text{ gal}}{\text{min}} \Big| \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = 80.2 \text{ cfm} \Rightarrow \frac{80.2 \text{ cu ft}}{\text{min}} \Big| \frac{1 \text{ min}}{60 \text{ sec}} = 1.3 \text{ cfs}$$

Question:

An 8-inch diameter pipe is flowing full at 600 gpm, what is the velocity in ft/sec?

$$\text{Flow (Q)} = \text{Velocity} \times \text{Area}$$

$$600 \text{ gpm} = \text{Velocity} \times (.67 \text{ ft})^2 \times .785$$

$$\frac{600 \text{ gpm}}{(.67 \text{ ft})^2 \times .785} = \frac{\text{Velocity} \times (.67 \text{ ft})^2 \times .785}{(.67 \text{ ft})^2 \times .785}$$

$$\frac{600 \text{ gal}}{\text{min}} \Big| \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = 80.2 \text{ cfm}$$

$$\frac{80.2 \text{ cu ft}}{\text{min}} \Big| \frac{1 \text{ min}}{60 \text{ sec}} = 1.3 \text{ cfs}$$

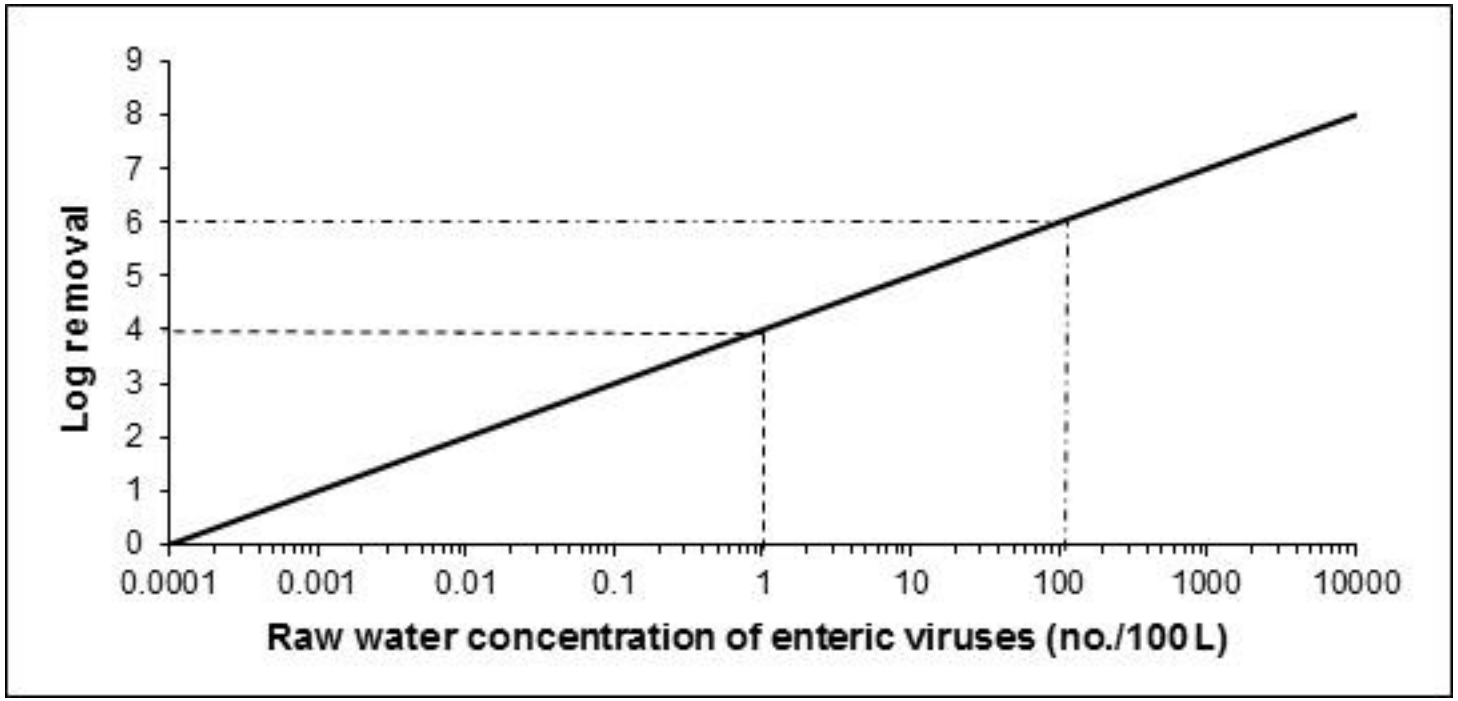
$$\frac{1.3 \text{ cfs}}{(0.67 \text{ ft})^2 \times 0.785} = \text{Velocity} = \mathbf{3.7 \text{ ft/sec}}$$

Chemicals & Process

More of the same but with a twist

Question:

Calculate the log removal for a water treatment plant if the samples show a raw water coliform count of 295/100 ml (through extrapolation) and the finished water shows 2/100 ml?



Graphic from Health Canada

Question:

Calculate the log removal for a water treatment plant if the samples show a raw water coliform count of 295/100 ml (through extrapolation) and the finished water shows 2/100 ml?

295 / 2 = 147.5

Log10 (147.5) = 2.1688 ~ 2.2

2.2 log removal

Question:

A 10 foot inside diameter chemical tank drops 4.31 inches in exactly 3 hours. What's the pumping rate for the chemical in gpm?

Photo from City of Anacortes

Question:

A 10 foot inside diameter chemical tank drops 4.31 inches in exactly 3 hours. What's the pumping rate for the chemical in gpm?

10 ft^2 x Π /4 = 78.53 sf

4.31 inches / 12 inches / ft = 0.3592 ft

78.53 sf x 0.3592 ft x 7.48 gal / ft^3 = 210.98 gal.

210.98 gal / 3 hr / 60 min./hr = 1.17 gpm

1.17 gpm

Question:

How many pounds per day of 65% calcium hypochlorite are required for maintaining a 2.5 mg/l dosage for a 2,575 gpm treatment plant?

Photo from Kemcore

Question:

How many pounds per day of 65% calcium hypochlorite are required for maintaining a 2.5 mg/l dosage for a 2,575 gpm treatment plant?

2.5 mg / L / 0.65% = 3.85 mg calcium hypo / L

3.85 mg/ L / 1000 mg / g / 1000 g / kg x 2.2 lb / kg / 0.264 L / gallon = 3.45×10^{-5} lb / gallon

2,575 gpm x 60 min/hr x 24 hr/day = 3.71×10^{6} gpd

3.71×10^{6} gpd x 3.45×10^{-5} lb / gallon

120 lb / day

Question:

Determine the percent mineral rejection from a reverse osmosis plant if the feedwater contains 1,230 mg/l total dissolved solids (TDS) and the product water contains 135 mg/l TDS.

Photo from Seattle Yacht Club, Henry Island

Question:

Determine the percent mineral rejection from a reverse osmosis plant if the feedwater contains 1,230 mg/l total dissolved solids (TDS) and the product water contains 135 mg/l TDS.

$$(1 - (135\text{mg/l} / 1{,}230\text{ mg/l})) = 0.8902 \times 100$$
$$= 89.02\%$$

Note all the units are the same and cancel (mg/l) so we get a unitless number as a ratio and assign % to it.

~89 percent

Question:

How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

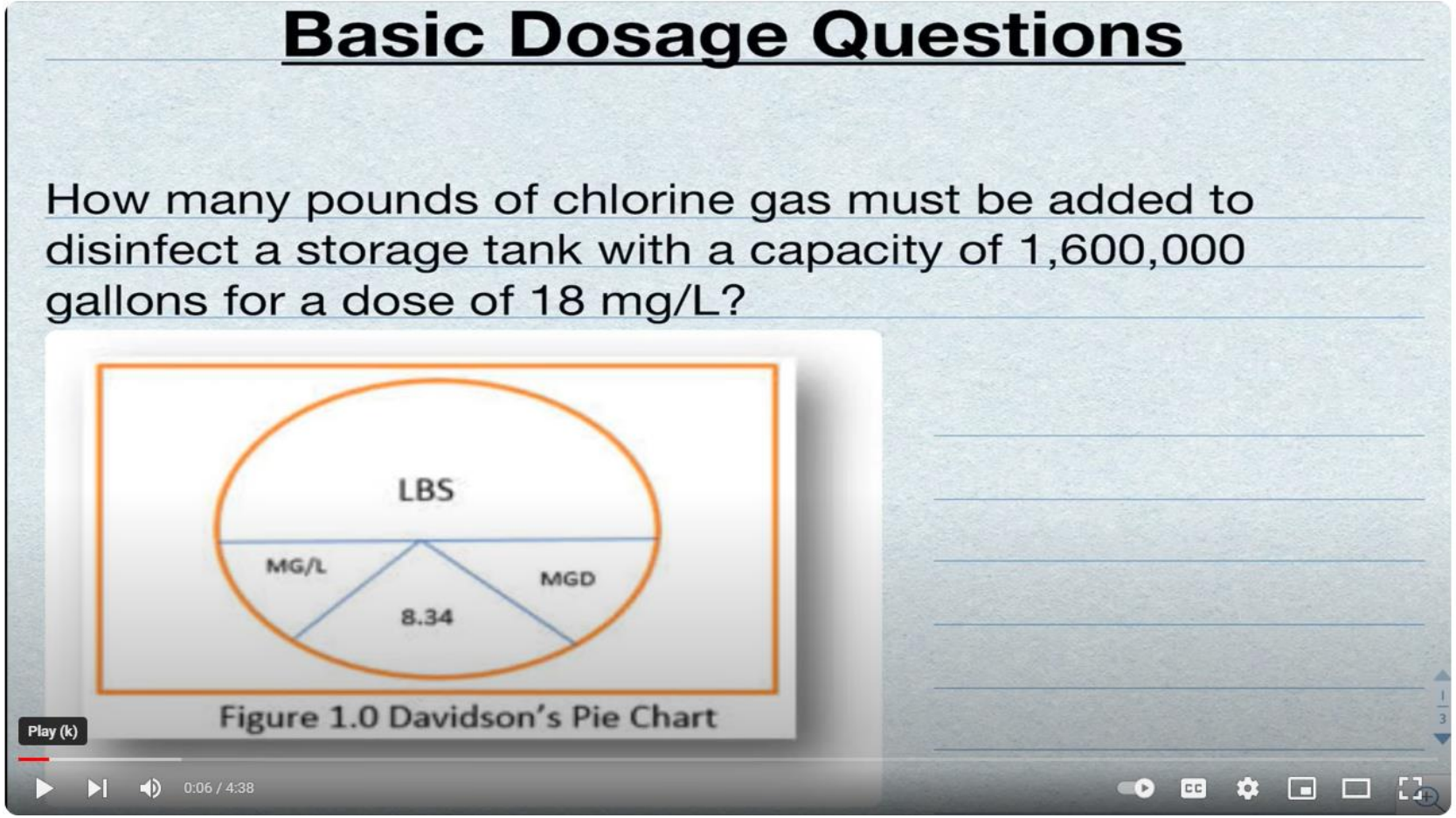
Photo from City of Anacortes

Davidson Pie Chart Examples – Chemical Dosing

YouTube Link:

[Water Math: Basic Dosage Questions For Treatment (youtube.com)]

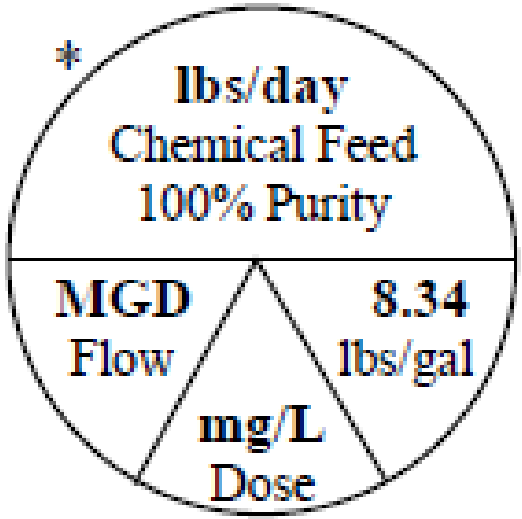
[Water Math: Advanced Dosage Questions For Treatment (youtube.com)]



Question:

How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



Pounds =

$$\frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{1.0\ \text{purity}}$$

Answer is 67 lb

Answer Time!

Question:

A 1.81 MG reservoir is being disinfected with a chlorine dosage of 9.75 mg/l. If the sodium hypochlorite is 11.5% available chlorine, how many pounds are needed?

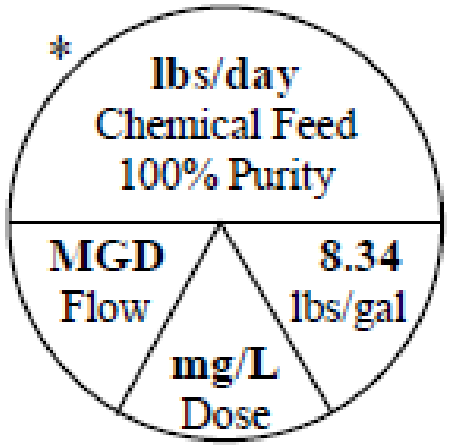
Photos from Roche Harbor & Silver Lake Water & Sewer District

Question:

A 1.81 MG reservoir is being disinfected with a chlorine dosage of 9.75 mg/l. If the sodium hypochlorite is 11.5% available chlorine, how many pounds are needed?

Use the wheel!

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34 \text{ lbs/gal})}{(\text{Purity, decimal percentage})}$$



$$= \frac{1.81 \text{ MG} \times 9.75 \text{ mg/l} \times 8.34 \text{ lb/gallons}}{0.115 \text{ (Purity in decimal)}}$$

$$= 1280 \text{ lbs}$$

Question:

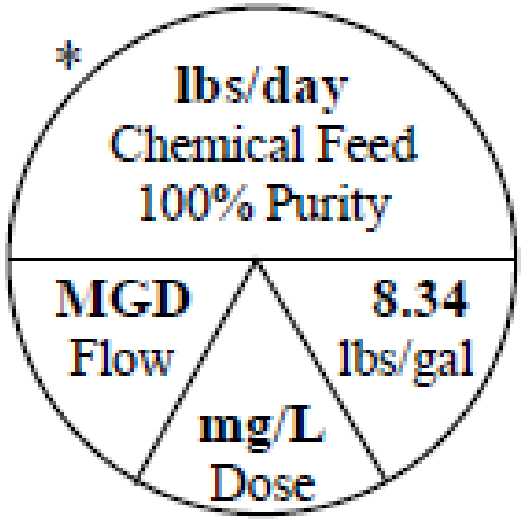
How many pounds of 12.5% sodium hypochlorite is necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

Photo from City of Marysville

Question:

How many pounds of 12.5% sodium hypochlorite is necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\,\text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



$$\text{Pounds} = \frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{0.125\ \text{purity}}$$

Answer is 534 lb (533.76)

Question:

How many pounds of 0.8% onsite generated sodium hypochlorite are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L?

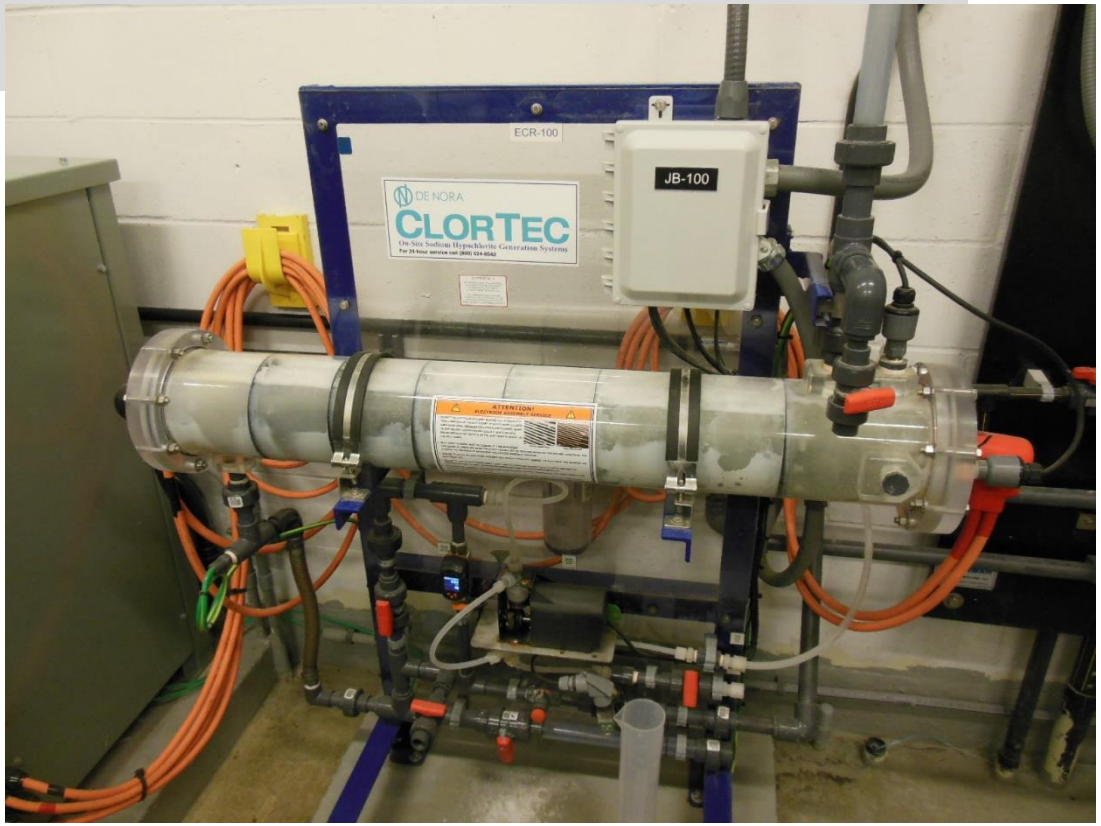
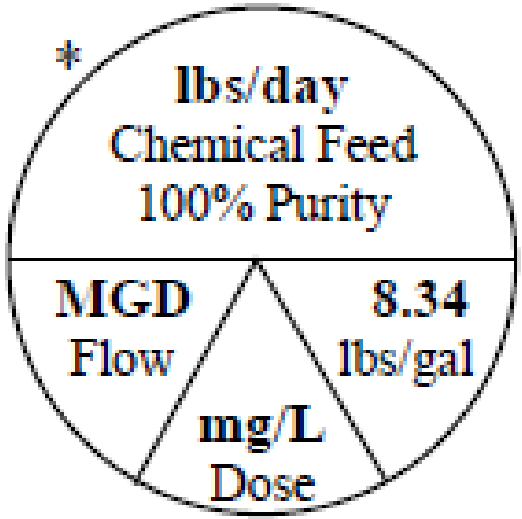


Photo from City of Marysville

Question:

How many pounds of chlorine gas are necessary to treat 4,000,000 gallons of water at a dosage of 2 mg/L

$$\text{Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gal})}{(\text{Purity, decimal percentage})}$$



Pounds =

$$\frac{4\ \text{MG} * 2\ \text{mg/l} * 8.34\ \text{lbs/gal}}{0.008\ \text{purity}}$$

Answer is 8,340 lb (= 1,115 gallons)

Questions, Comments and Suggestions?

American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA