Math for Operators

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

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American Water Works Association
Pacific Northwest Section

Prepared by the Training Coordination Committee, PNWS-AWWA

Acknowledgements:

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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**

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

For addition need common units

$$1\ \text{foot} + 1\ \text{inch} * \frac{1\ \text{ft}}{12\ \text{inches}} = 1\ 1/12\ \text{ft or } 13/12$$

Accurate but maybe not useful

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 foot + 1 inch ≠ 2

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

12 inches + 1 inch = 13 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.

$3^2 = 3 * 3 = 9$

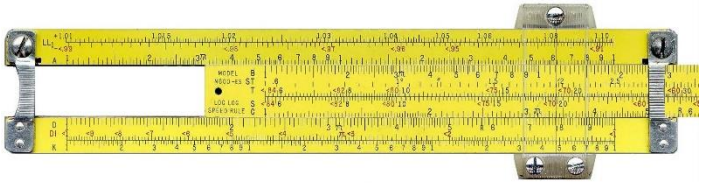
Fractional exponents used in friction formulas and other equations

$30^{1.85} = 540.35$

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

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

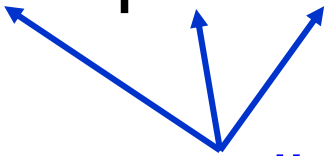
$ft * ft * ft = ft^3$

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 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

=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

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

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

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?

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?

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

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
  - Parentheses **()**
  - Exponents **^**
  - Multiplication & Division (from left to right) *** /**
  - Addition & Subtraction (from left to right) **+ -**

  - **"Please Excuse My Dear Aunt Sally"**

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

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

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

$$X = 4$$

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

$$36 / X = 12$$

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

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

$$X = 3$$

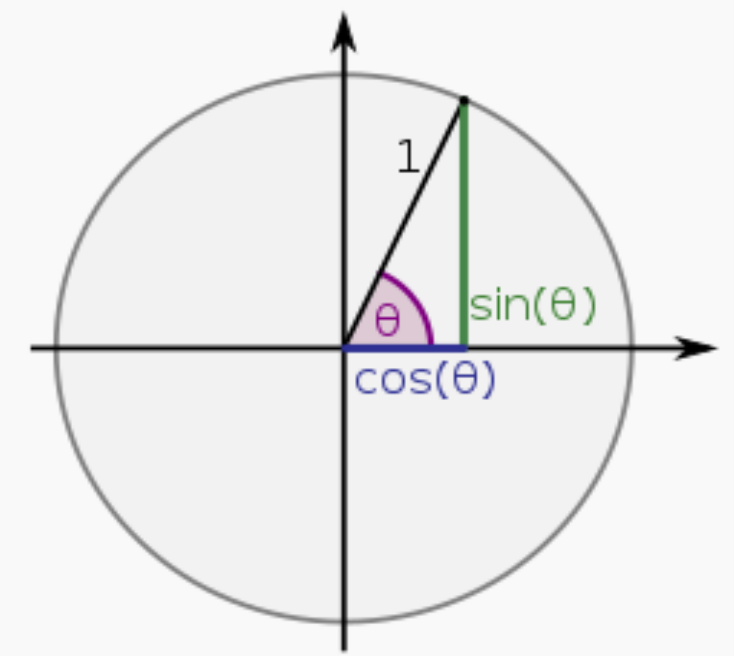
Multiply each side by X to bring X to the numerator and divide each side by 12 to isolate X on one side of the equation

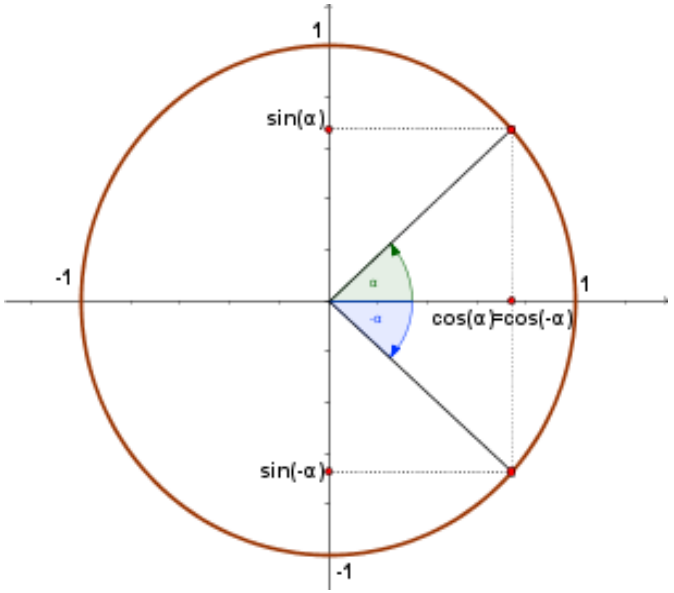
Trigonometry

It's all about relationships!

Trigonometry

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





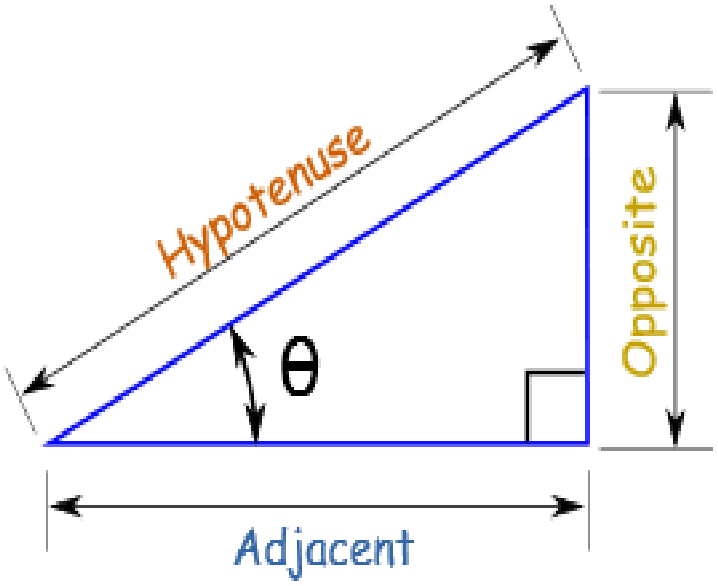
Graphics from Wikepedia & MathPortal.org

How are They Defined?

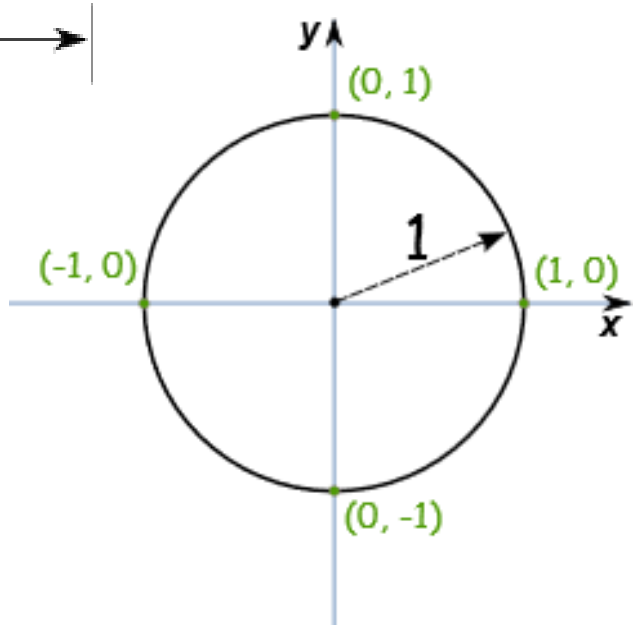
$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

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

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



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!

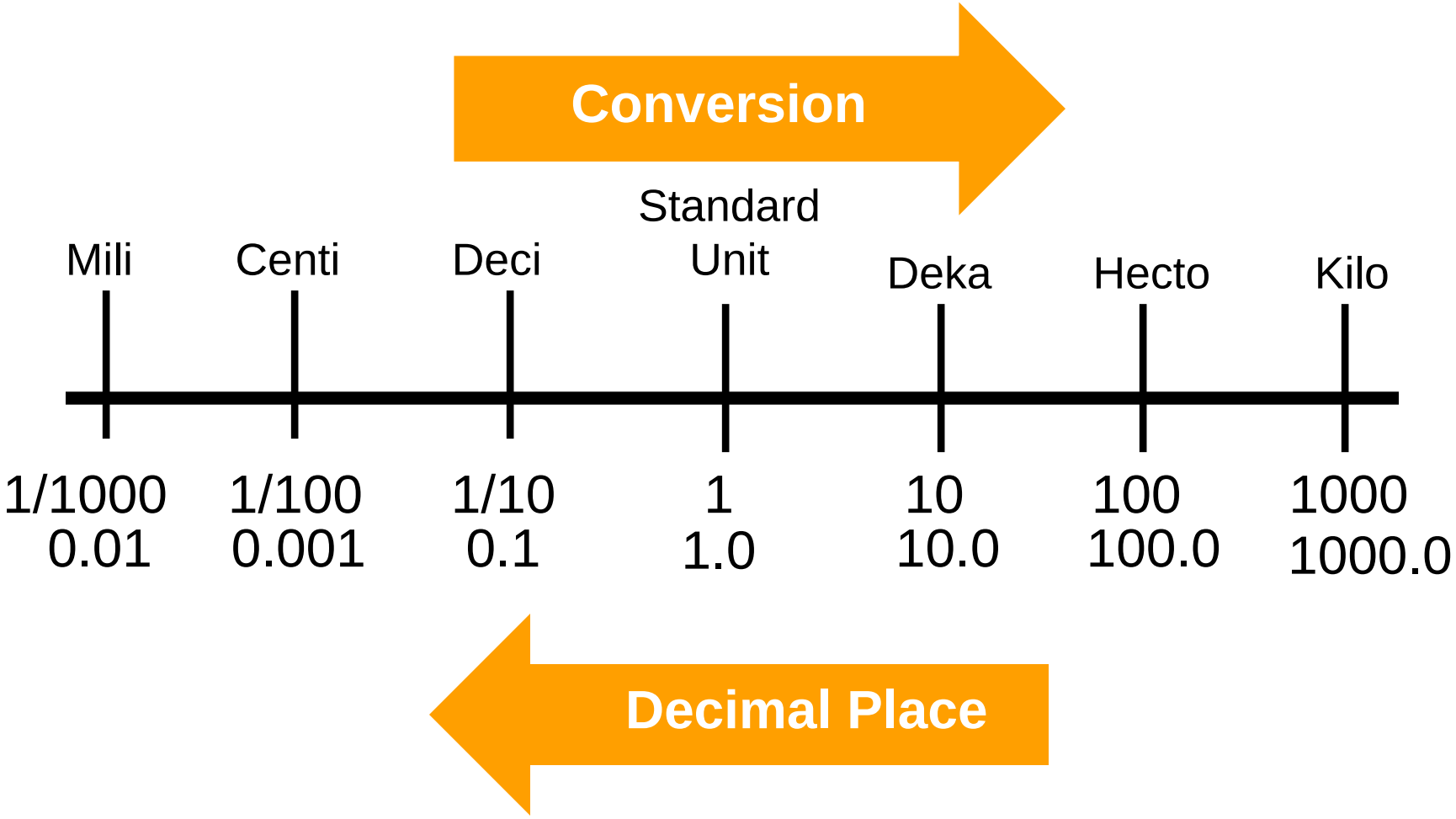
Most all of water and wastewater math is about converting from one set of units to another.

Conversion Factors are Your Friend!

1 foot of water = 0.433 psi
1 cubic foot = 7.48 gallons
1 gallon water = 8.34 pounds

Memorize these (and other) conversion factors!

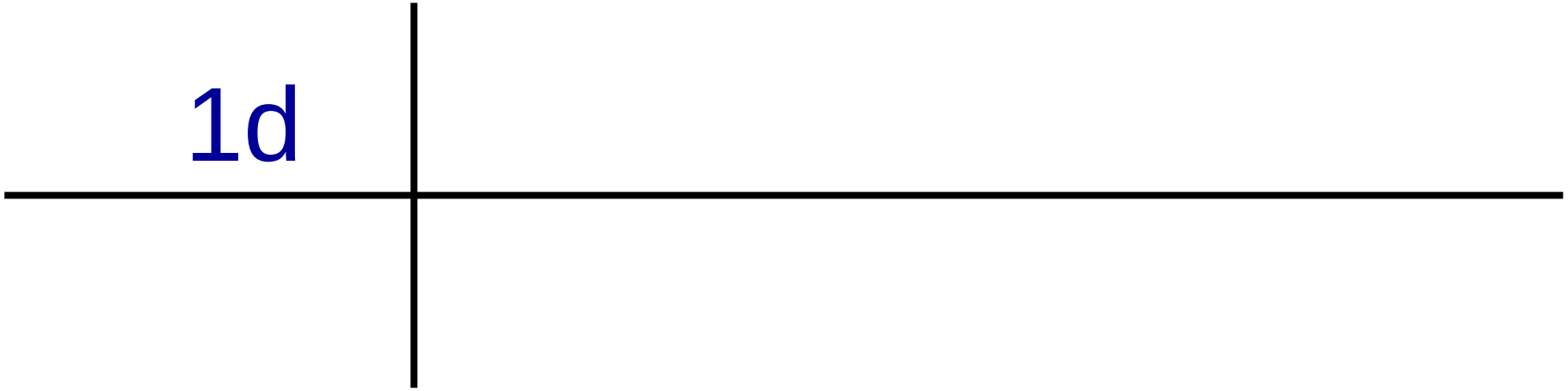
Conversion Factors are Your Friends!



Time Conversion Example

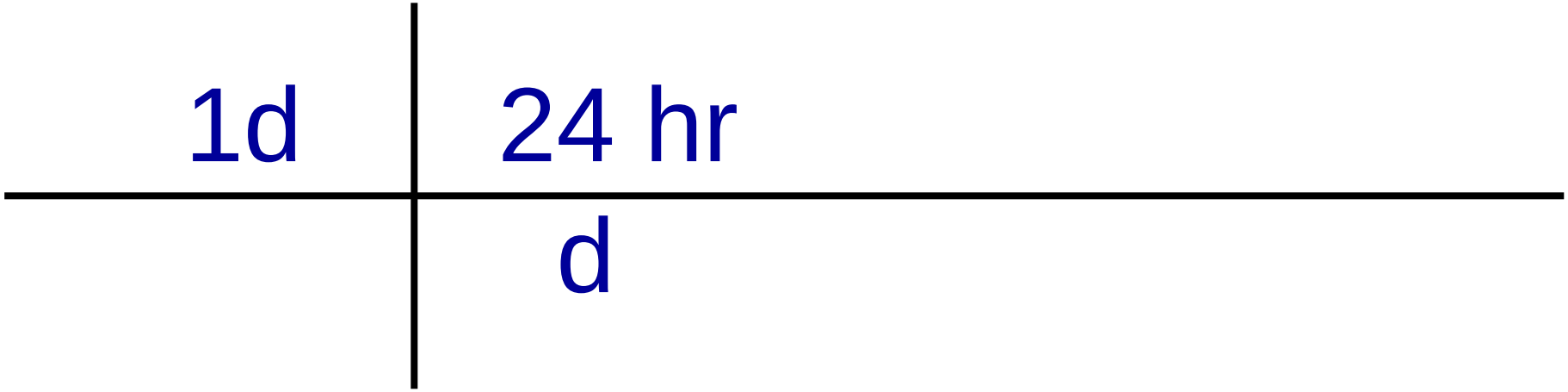
Determine how many seconds are in a day.

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

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

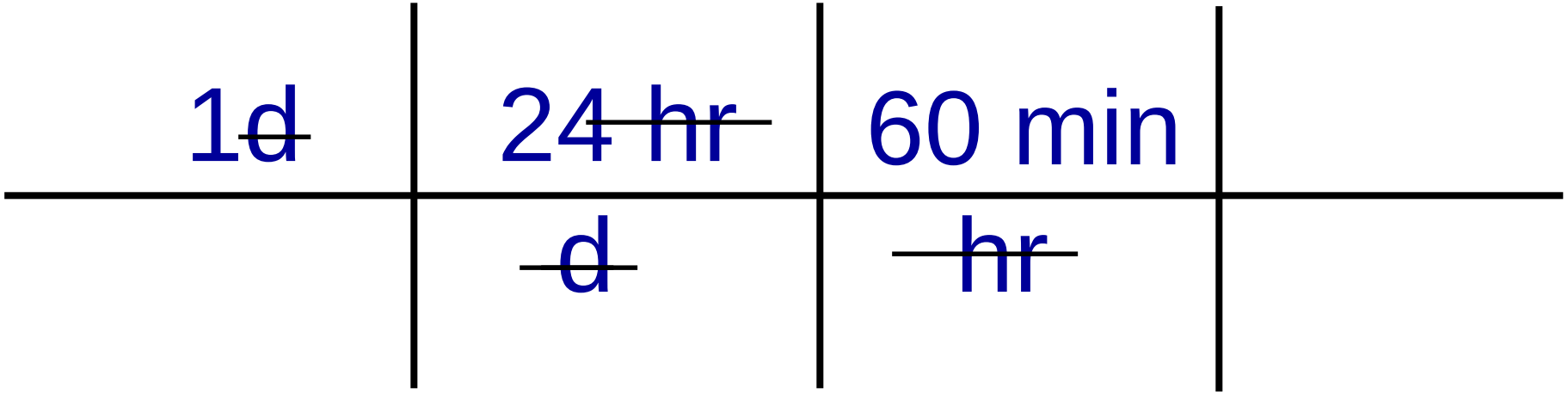
Days cancel out

One Step at a Time – Hours to Minutes

$$\frac{1\,\cancel{d}}{\cancel{d}} \left| \frac{24\ hr}{} \right| \frac{60\ min}{hr}$$

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

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

Minutes cancel

Now do the Math

Multiply
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

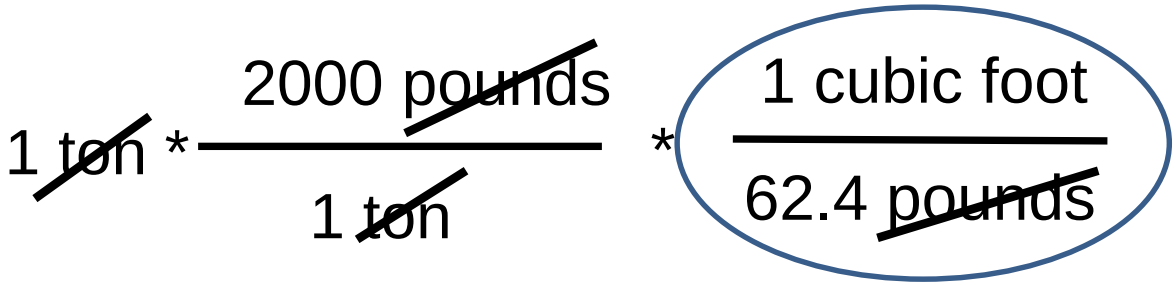
How many cubic feet in a ton of water?

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

= 32.1 cubic feet

Problem – Short cut if you know the conversion factor

How many cubic feet in a ton of water?



= 32.1 cubic feet

Significant Figures & Rounding

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

Practical Applications

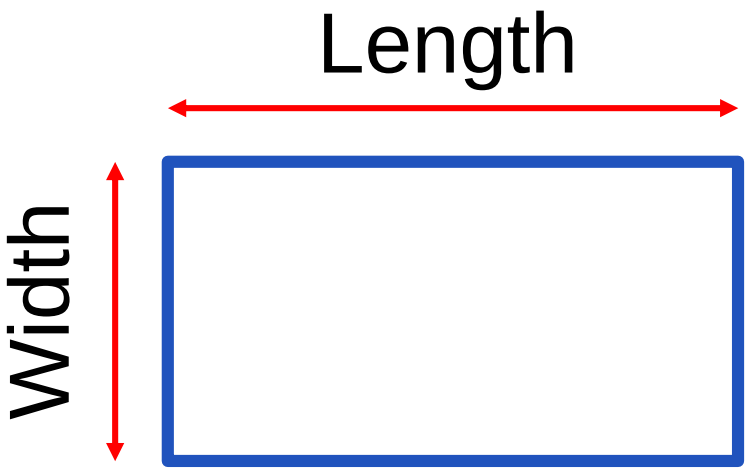
How do we use this ability?

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

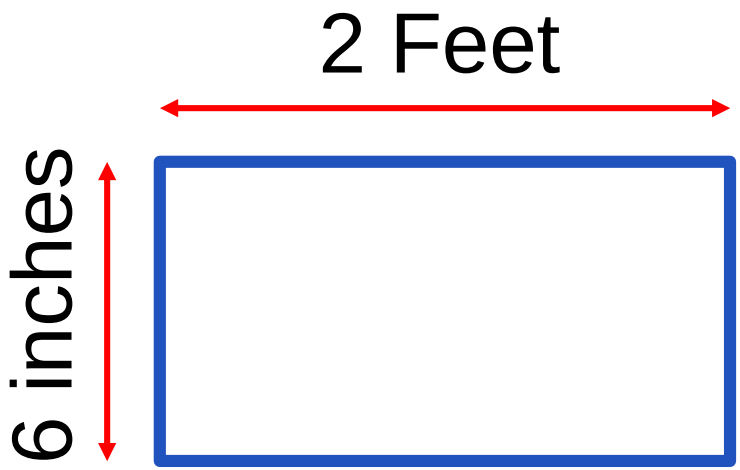


Area = length * width

Area = dimension^1 * dimension^1

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

Area

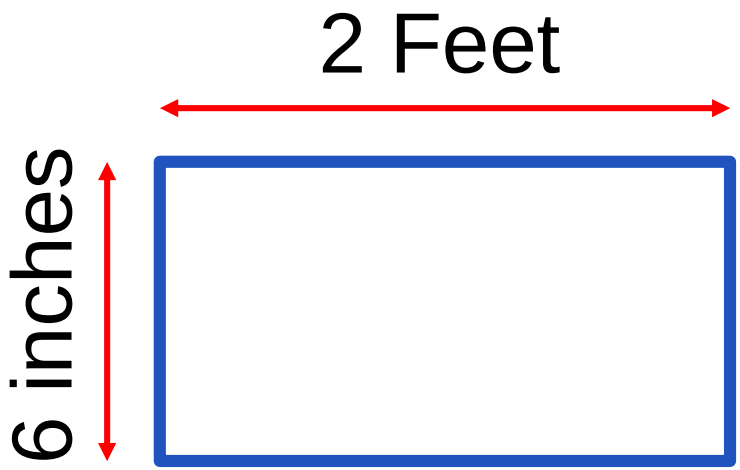


What is the area?

Area = length * width

Area = dimension * dimension

Area



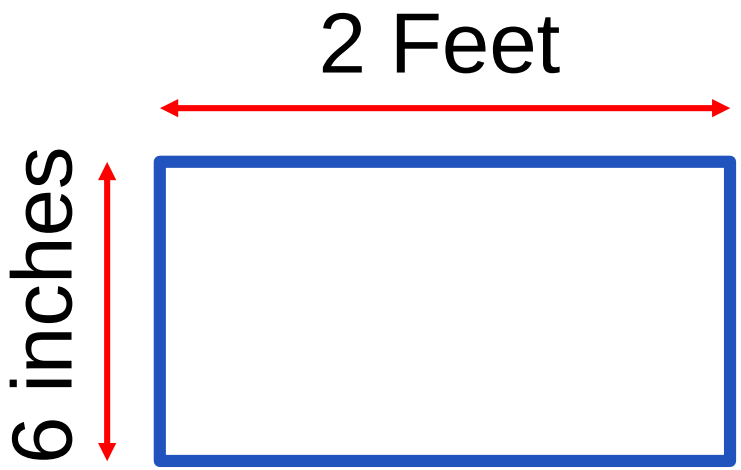
What is the area?

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



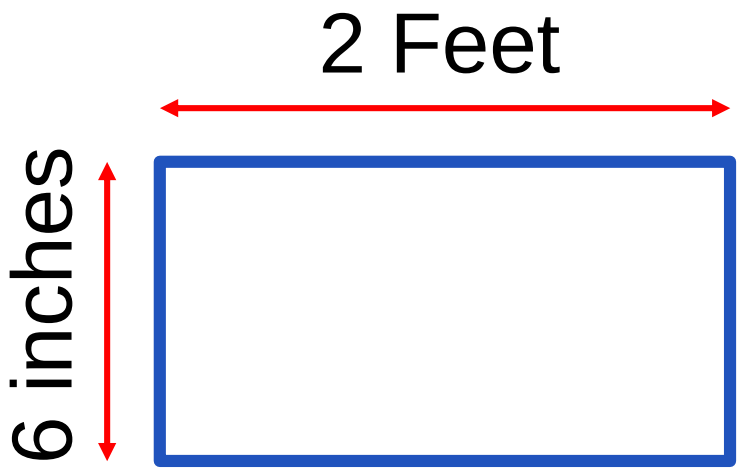
What is the area?

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?

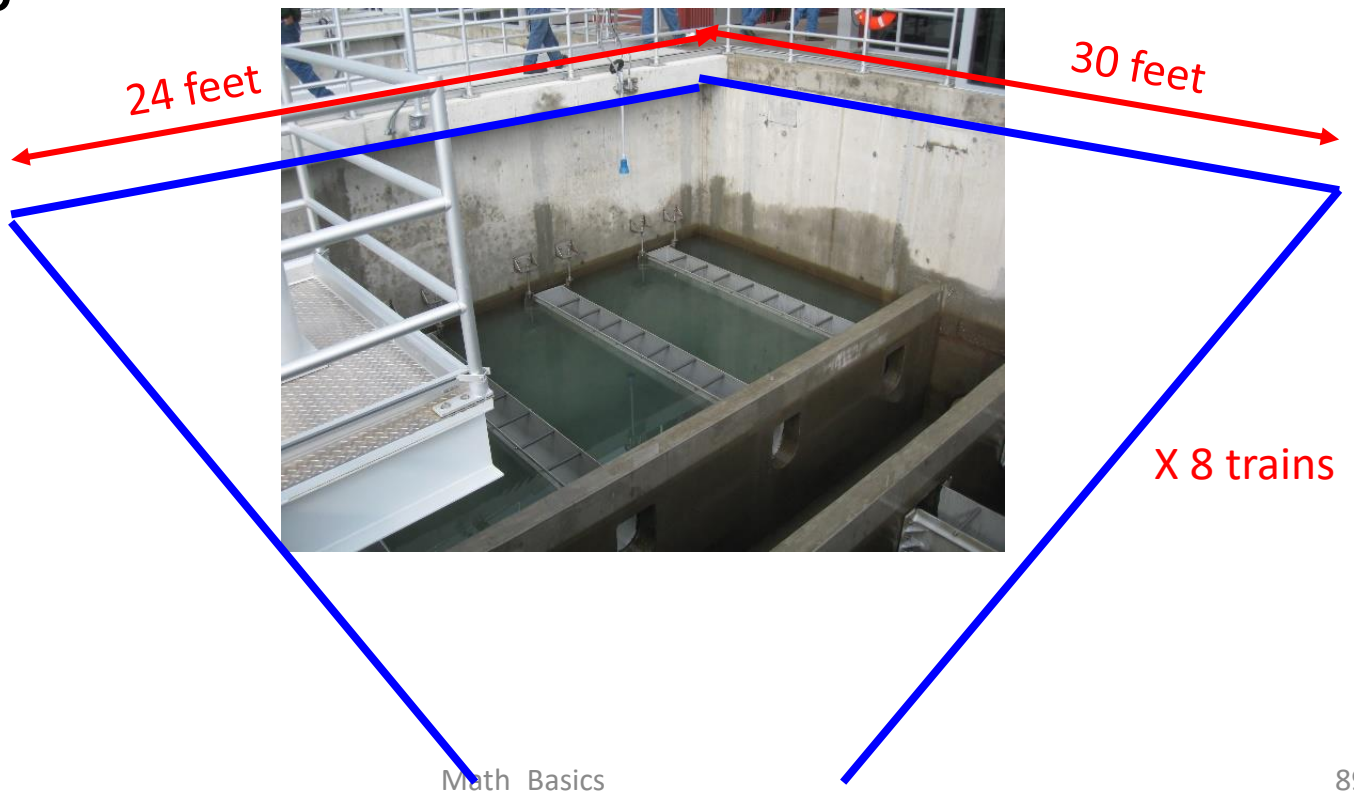
Area = length * width

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

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. The trains are 30 feet long.



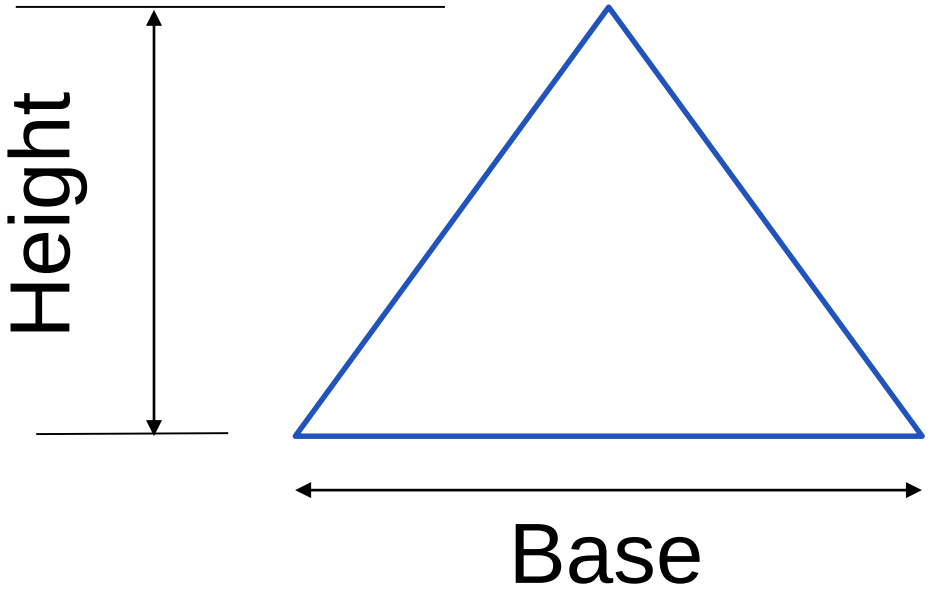
Practical Application - Area

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. The trains are 30 feet long.

Area = 8 basins * 24 ft * 30 ft

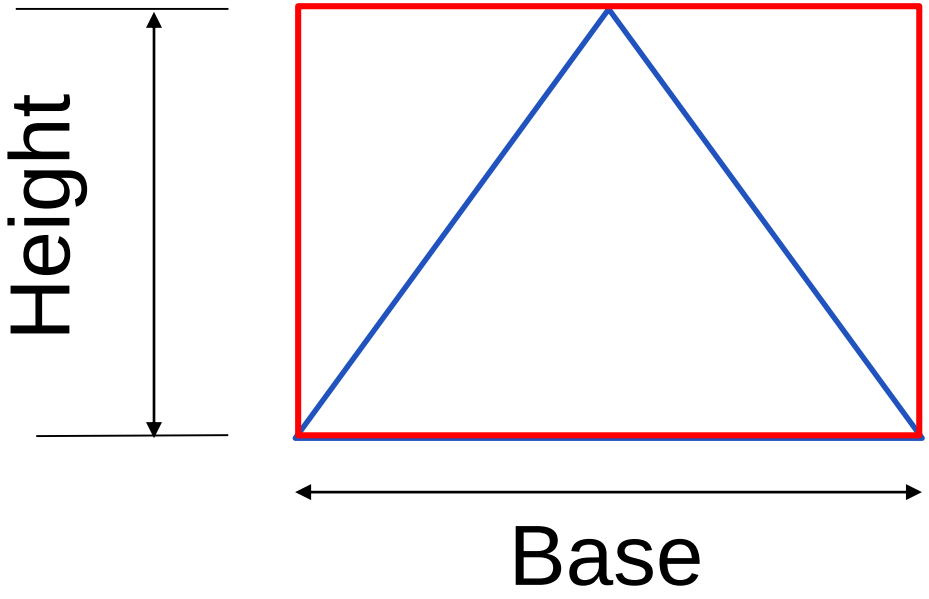
Area = 5,760 sq ft

Area - Triangles



Area = (1/2) * base * height

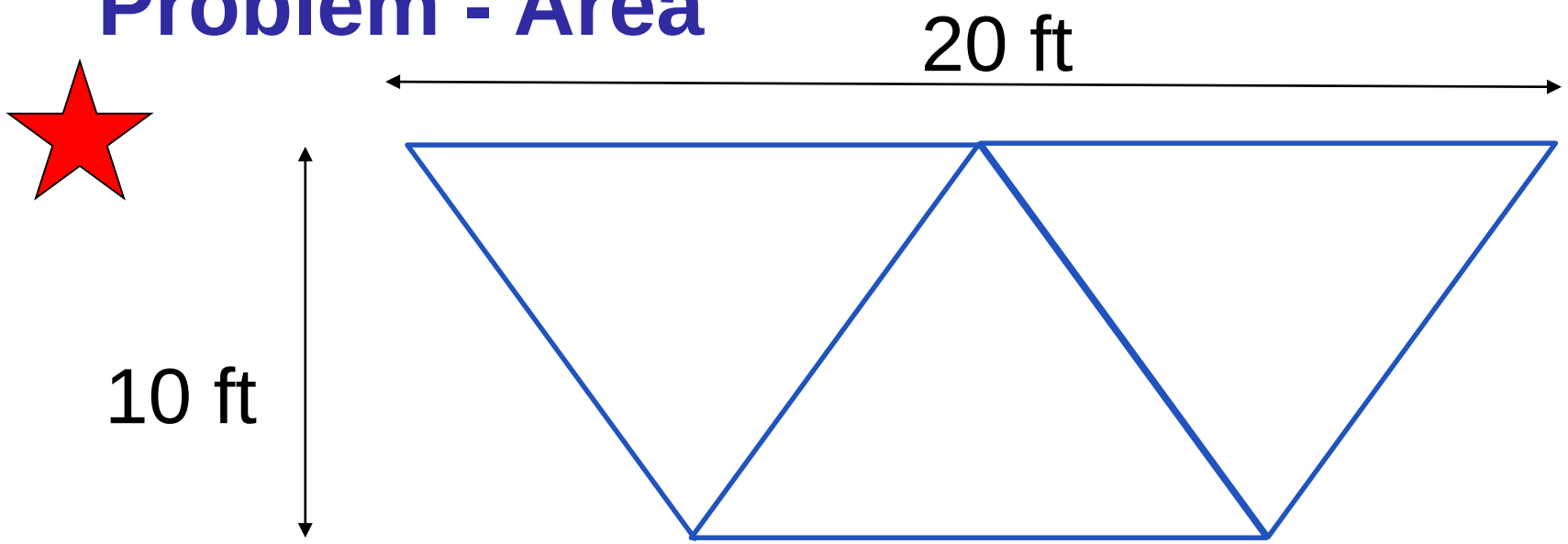
Area



Area = (1/2)*base * height

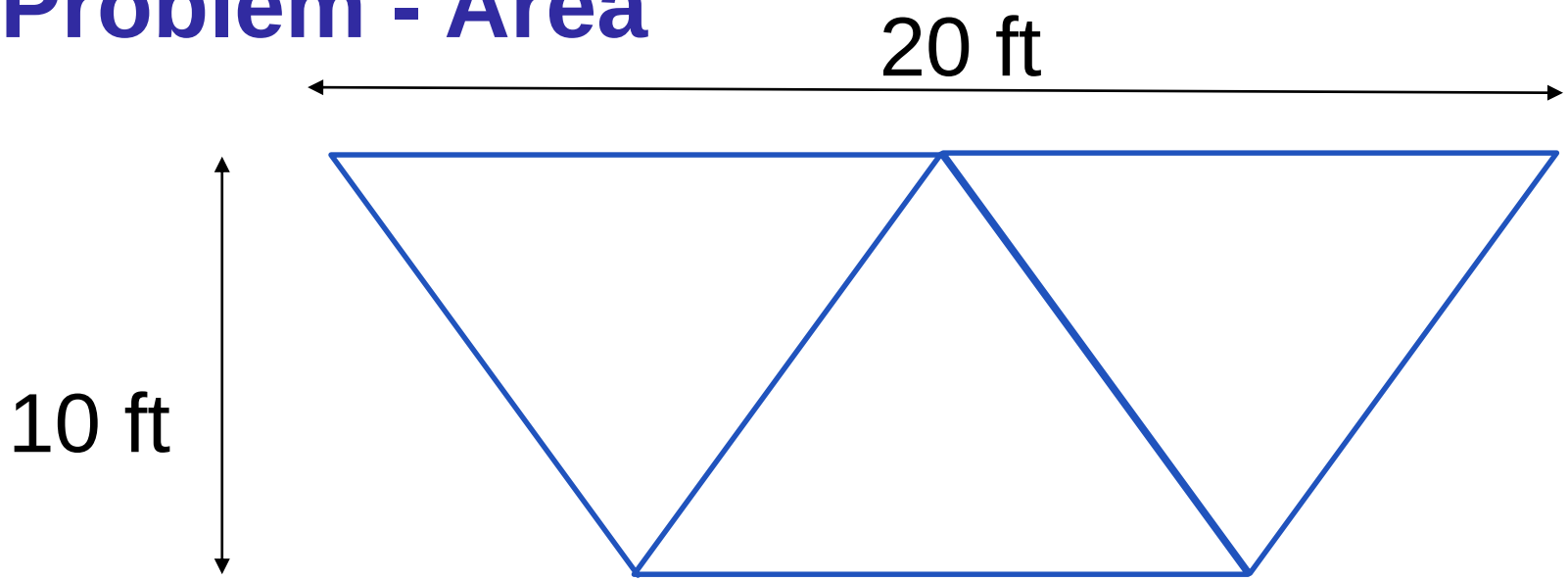
Triangle is ½ of rectangle!

Problem - Area



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

Problem - Area



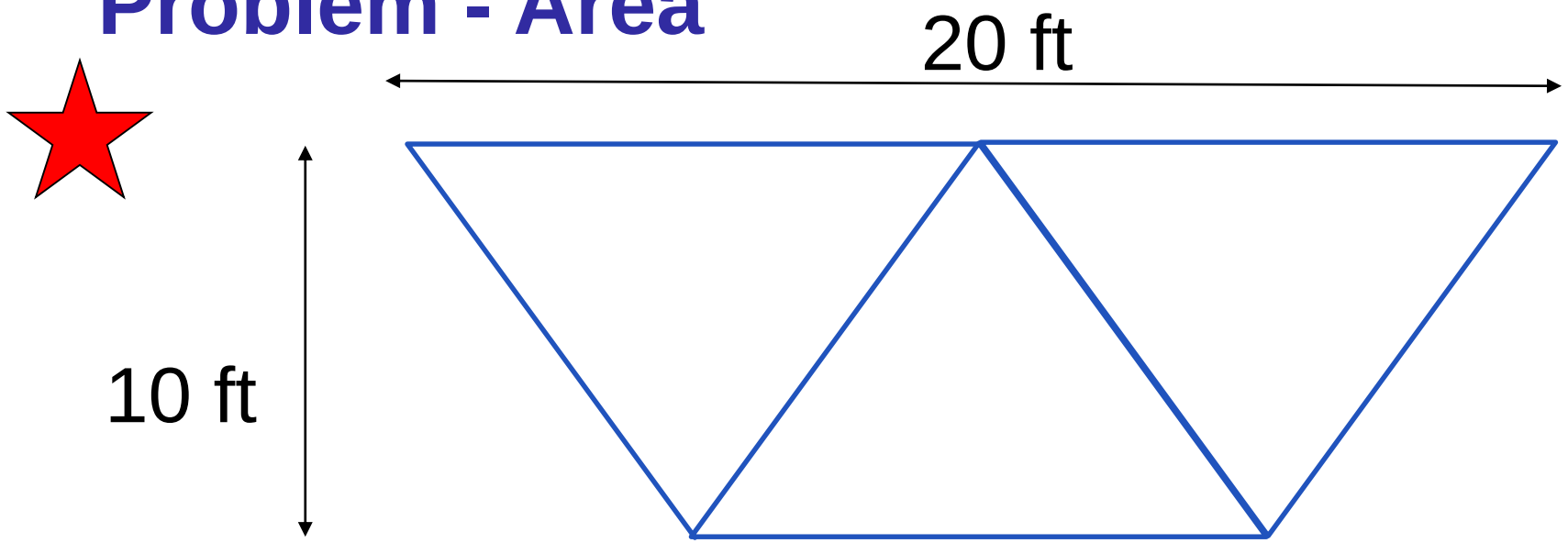
You are covering a truss with a banner for City Celebration. They want to cover the truss. How big will the banner be?

Area = 3 triangles

= 3 * ½ * 10 ft * 10 ft

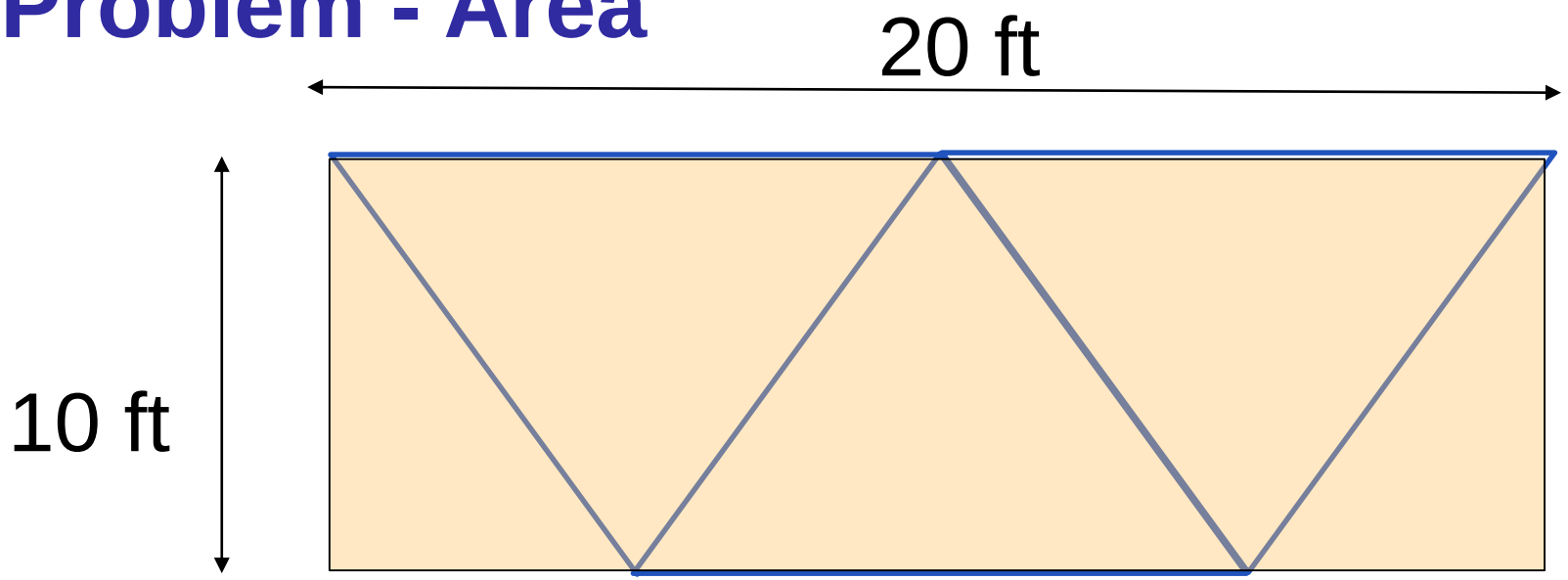
= 150 sq ft

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

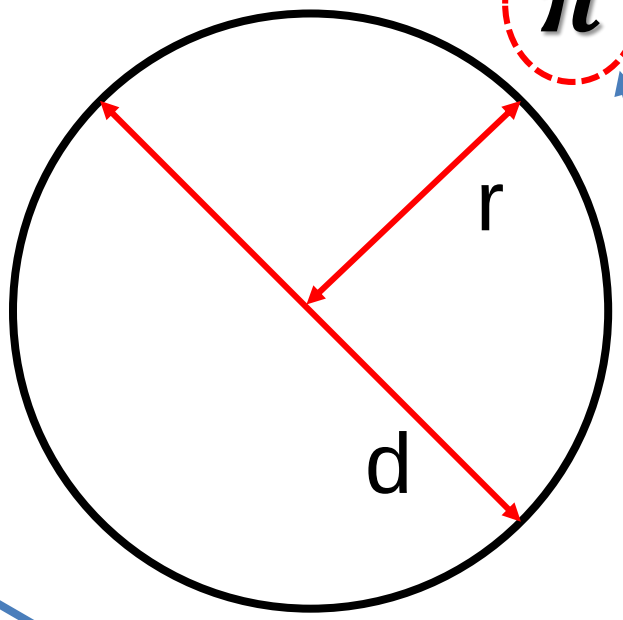
Area - Circles

$\pi = 3.14$

Area of a circle

$$A = \pi r^2$$

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



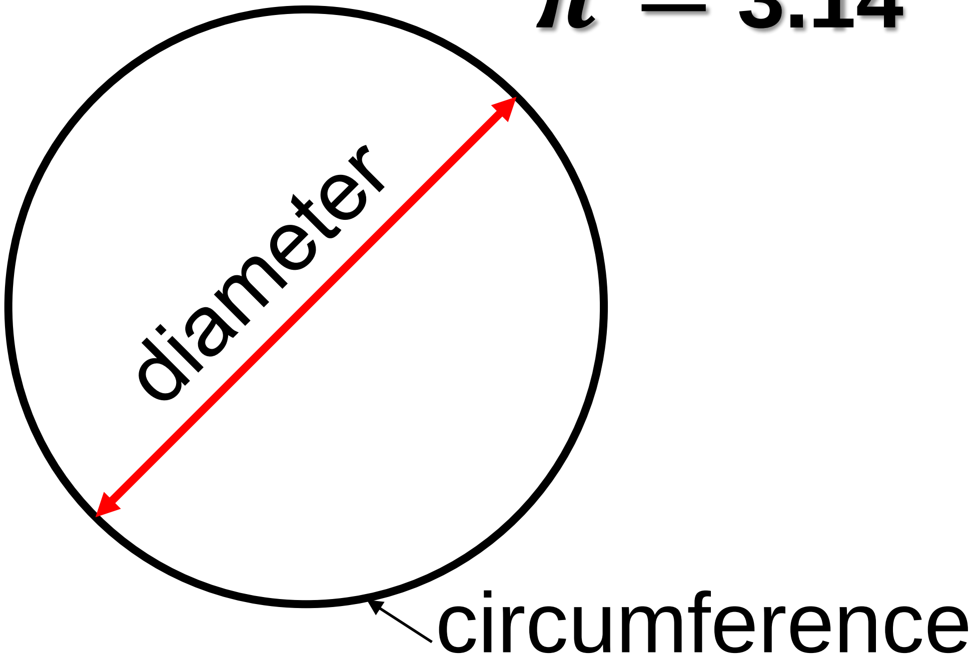
What is this symbol? It's all Greek to me!

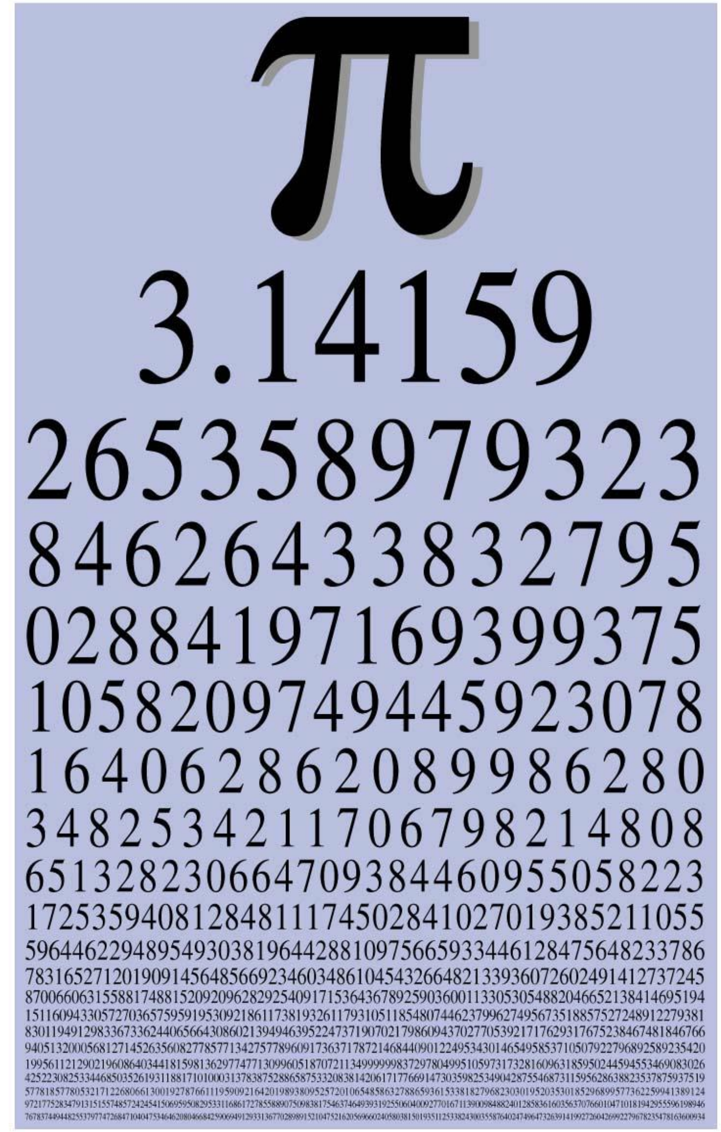
$$A = 0.785 * d^2$$

The Magical World of Pi

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

$\pi = 3.14$



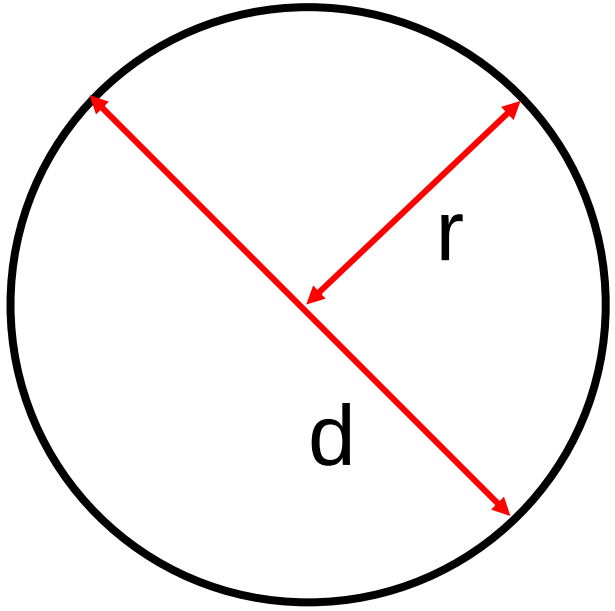


The Magical World of Pi

Circumference = $2 * \pi * r$

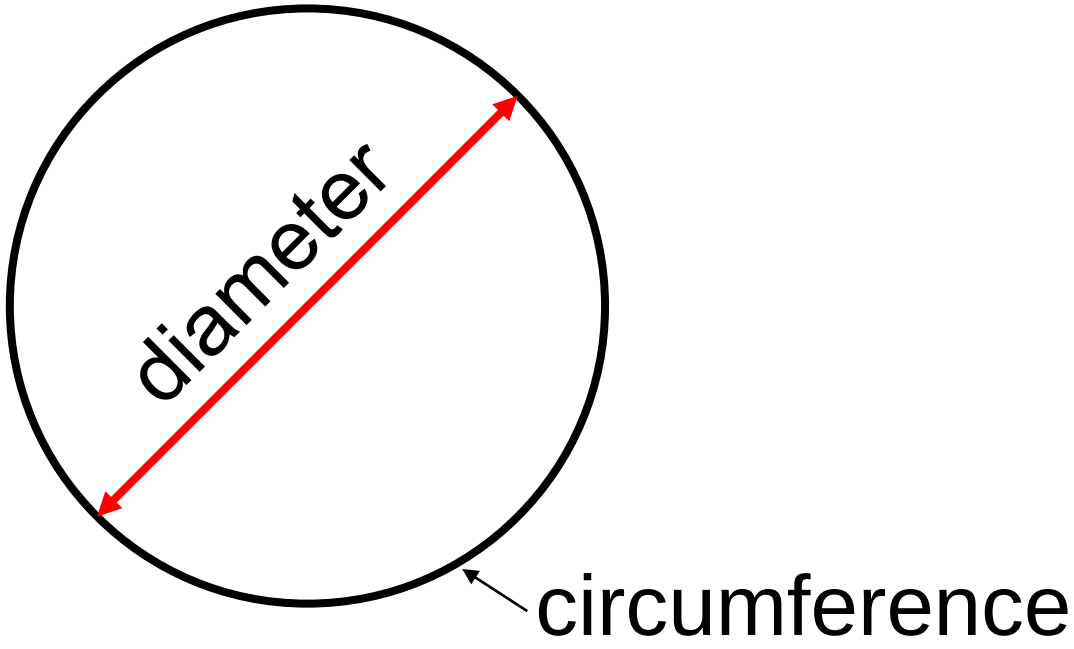
Diameter = $2 * r$

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



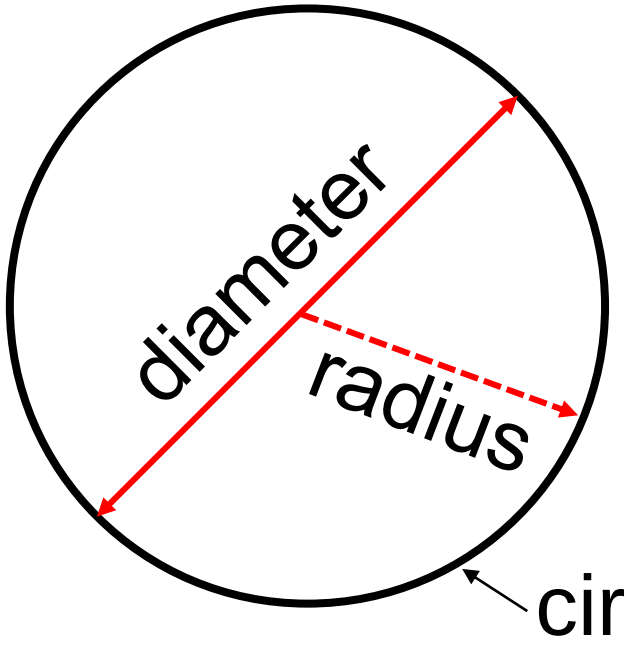
Practical Use of Pi (π)

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

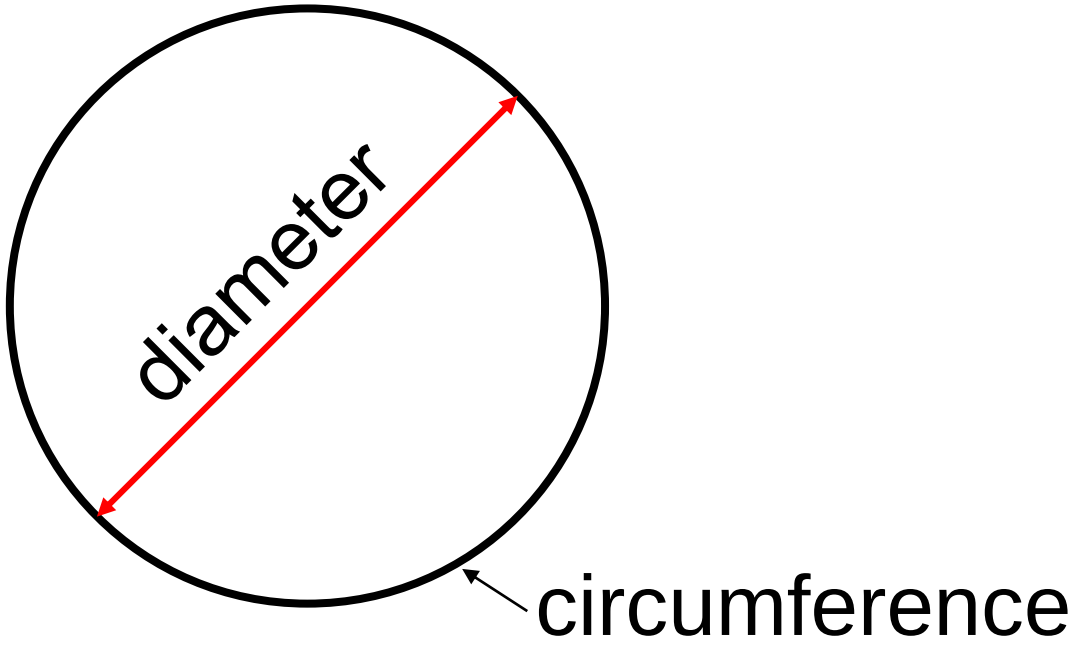
Circumference = π d

100 feet * π =

= 314 feet

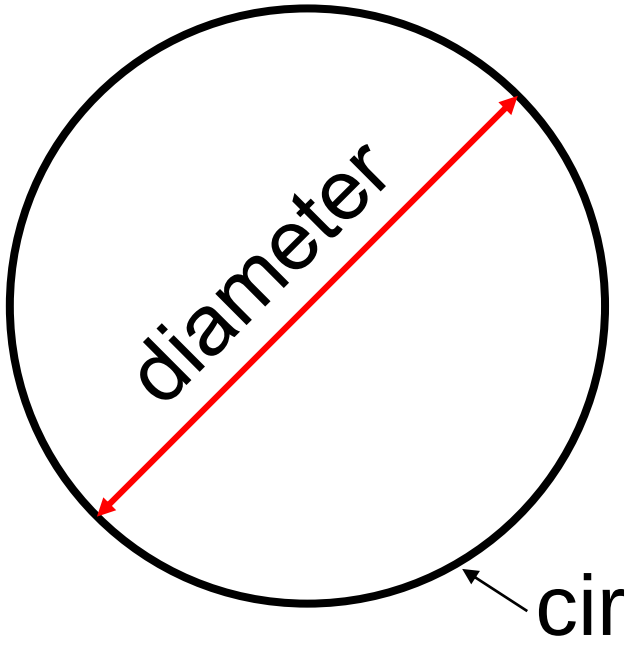
Practical Use of Pi (π) – Back to Area

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?



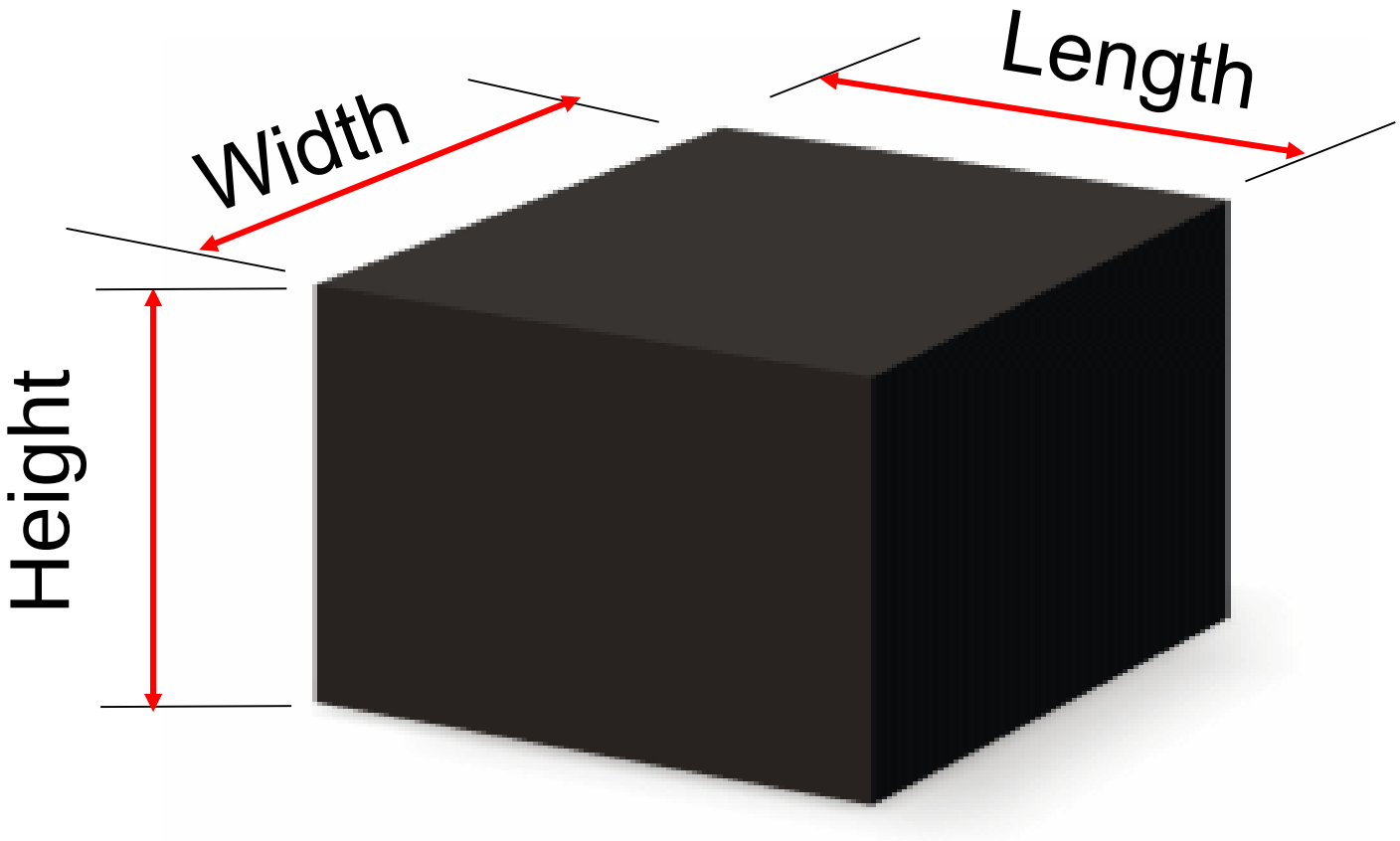
$$\text{Area} = 0.785 * d^2$$

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

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

Volume

Volume = length * width * height



Volumes – Practical Question

What is the volume of water in a the 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 the 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 the 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 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 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 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)?

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

Volumes – Practical Question

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

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

Vol = 1,250,656 gallons

Round off the answer

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

Volume –Tank Example (Cylinder)

Volume = Area x Height

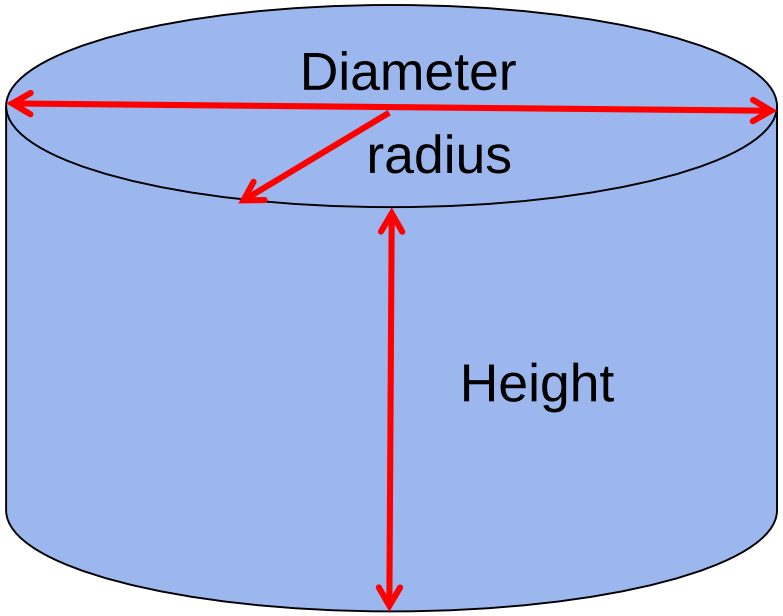
π = pi = 3.14

r = radius

D = Dia. = Diameter

2 * r = Dia.

Tank



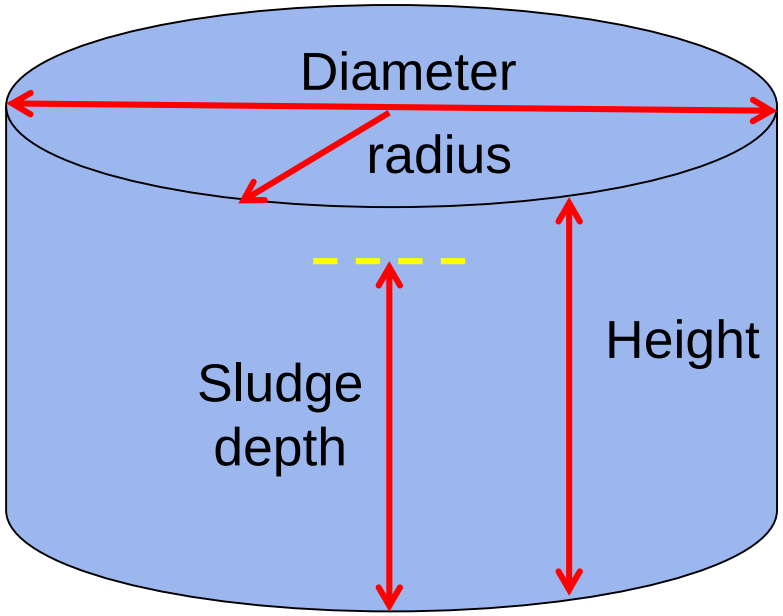
Vol = 3.14 * r^2 *height

= .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

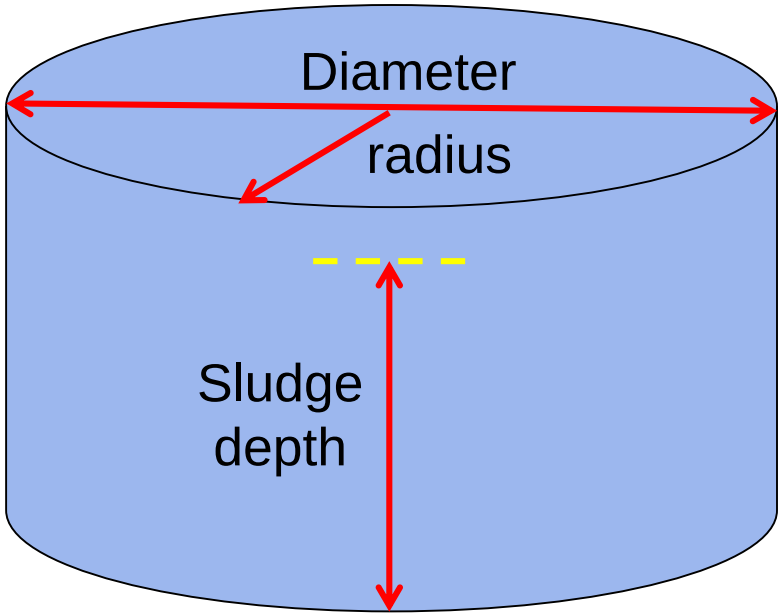
Tank



Volume –Tank Example

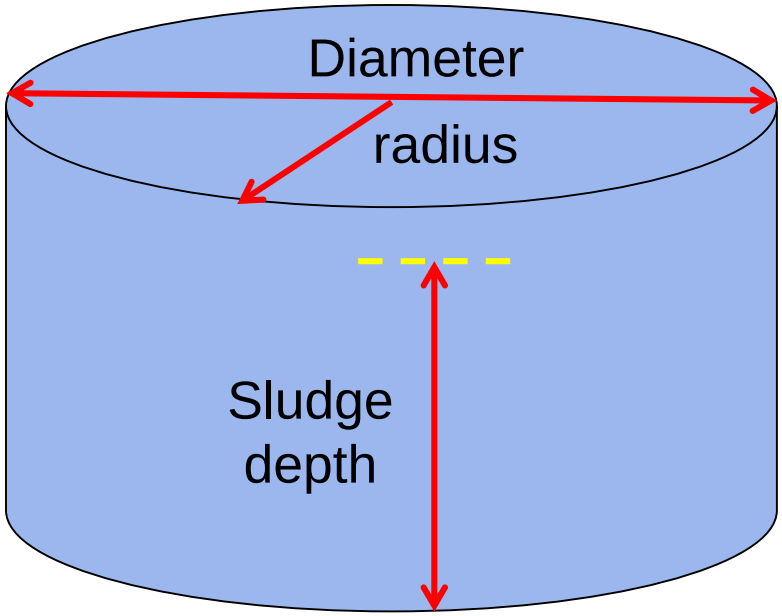
What is volume of sludge holding tank in gallons?
Diameter = 100 feet
Height = 100 feet

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?

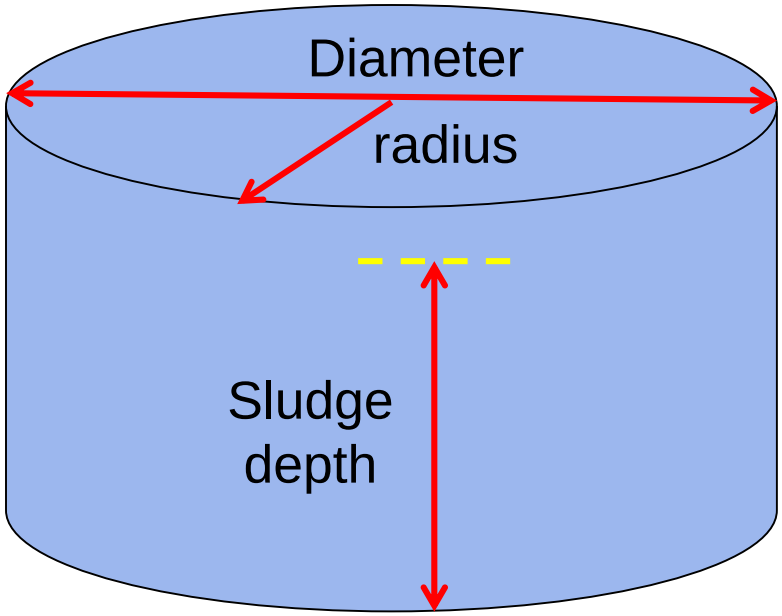
Diameter = 100 ft

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?

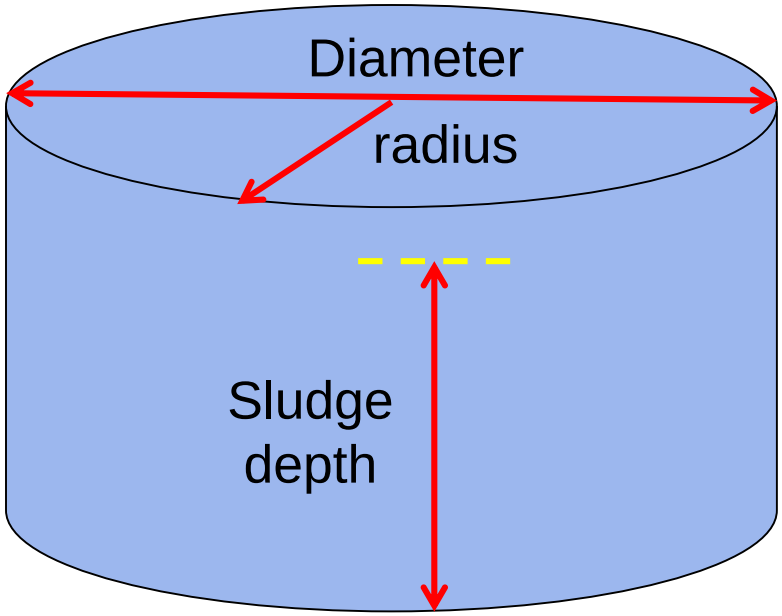
Diameter = 100 ft

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

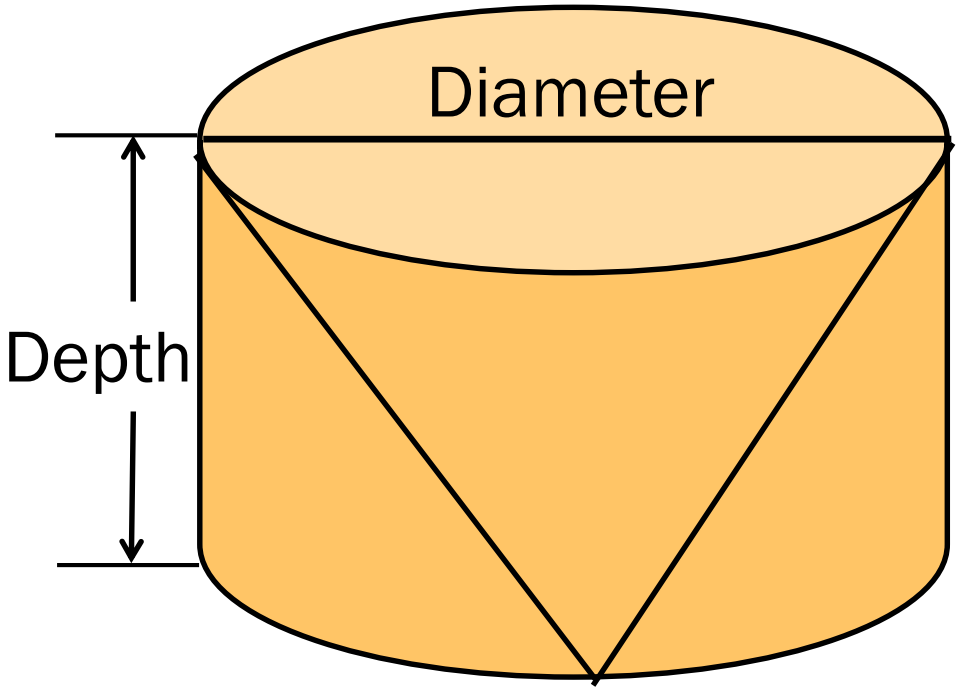
or

1.17 MG

Divide by 1,000,000 and round off

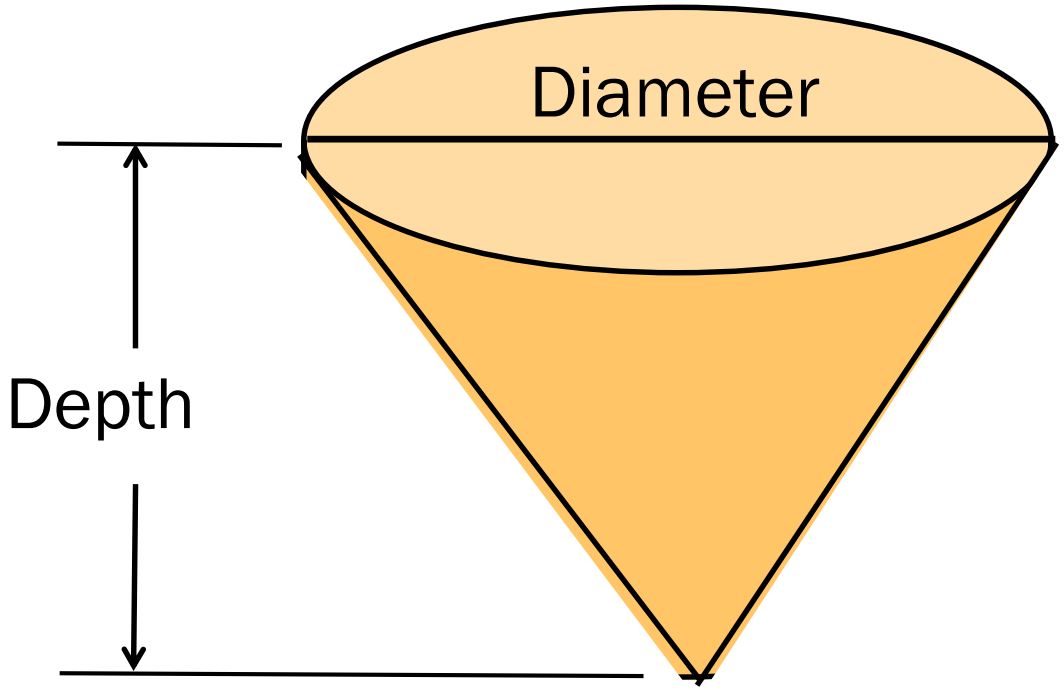
Volume of a Cone

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?



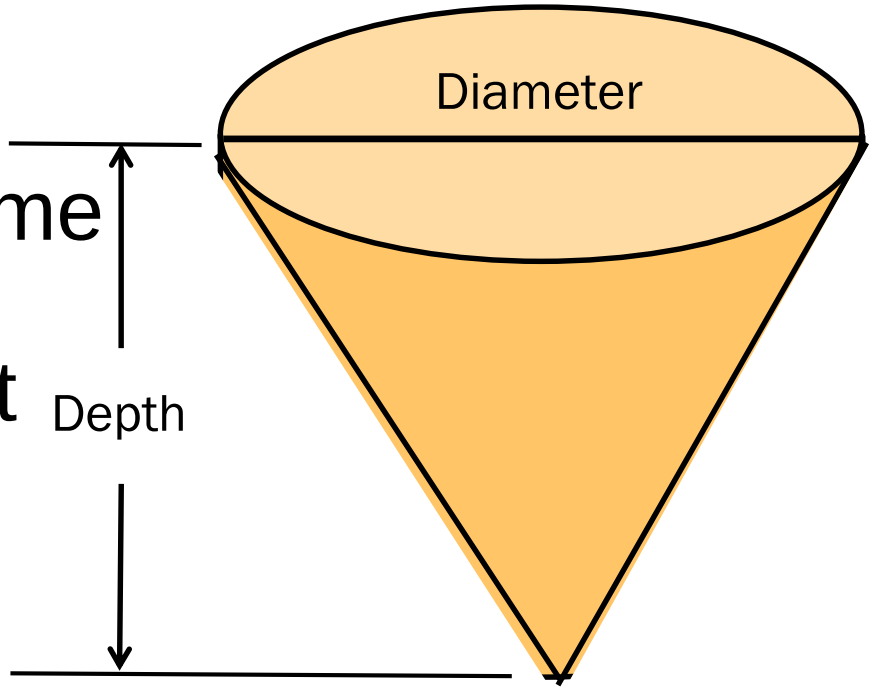
Practical Application

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

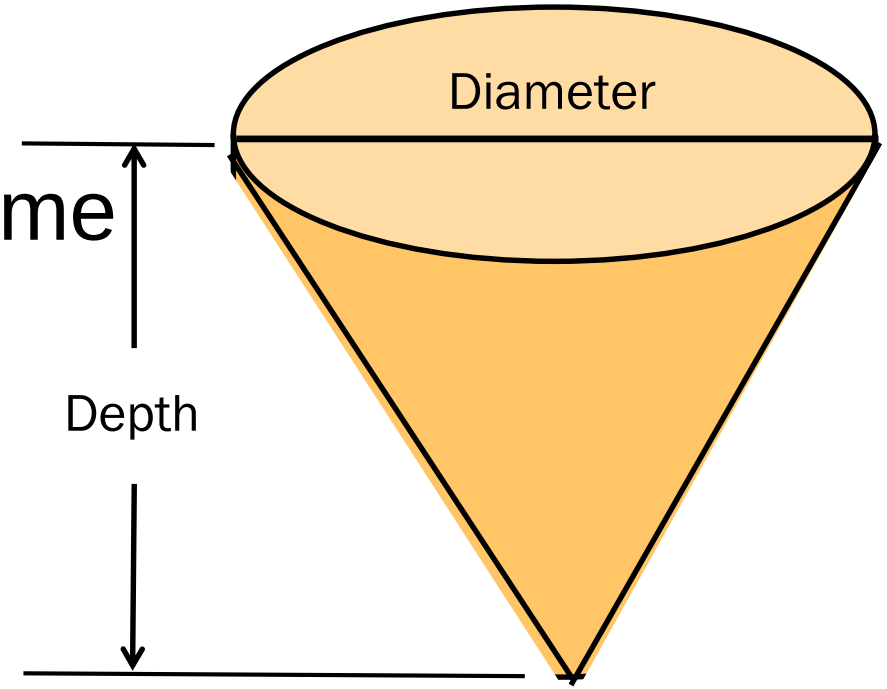
Cylinder= $0.785*(5ft)^2*10ft$

Cylinder = 196 cu ft



Practical Application

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



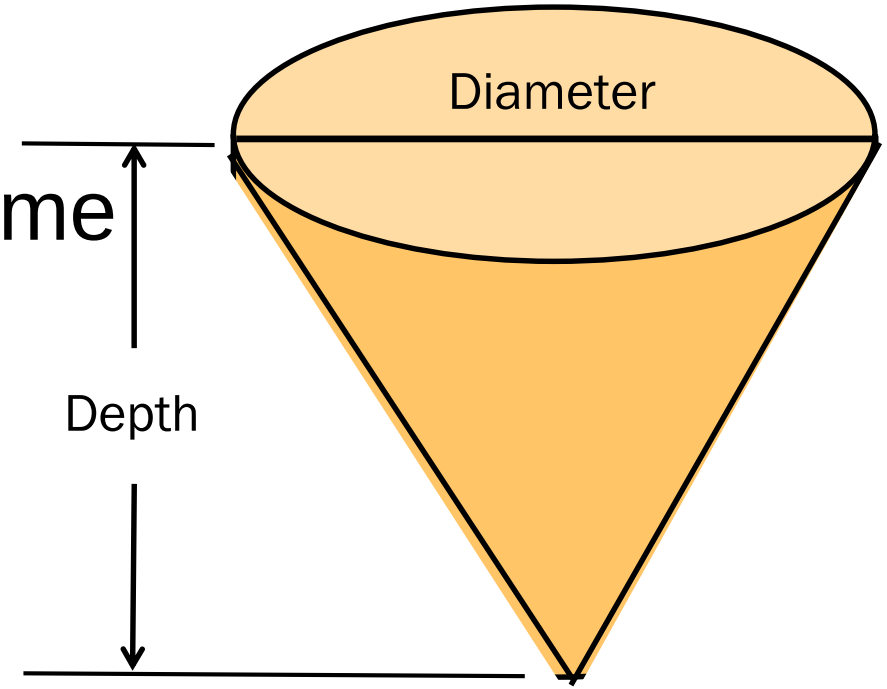
Cone = 1/3* Cylinder Volume

Cylinder = 196 cu ft

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

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?

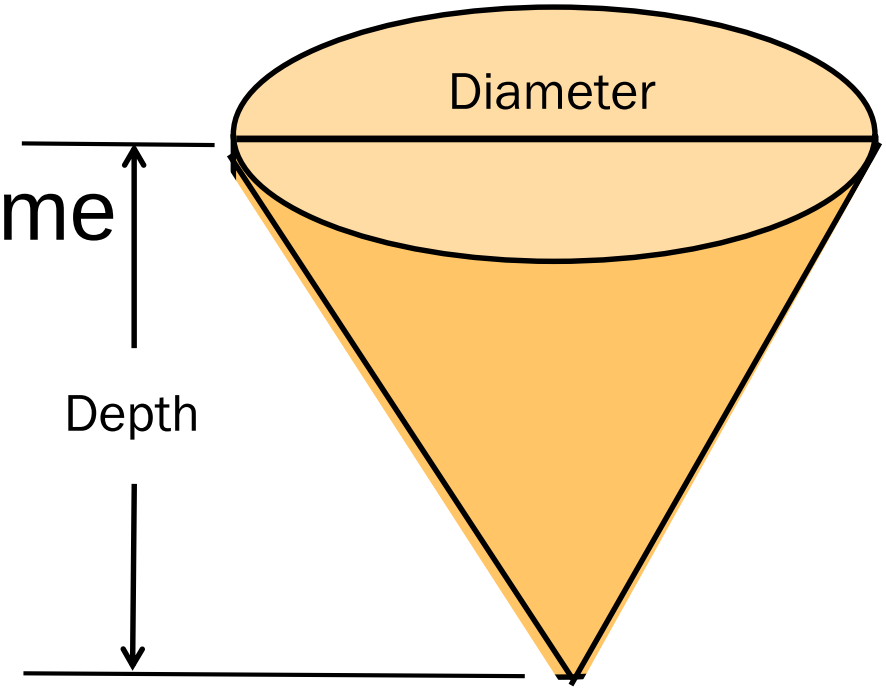
Cone = 1/3* Cylinder Volume

Cylinder = 196 cu ft

Cylinder = 1466 gallons

Cone = 1/3 * 1466 gal

Cone = 489 gal

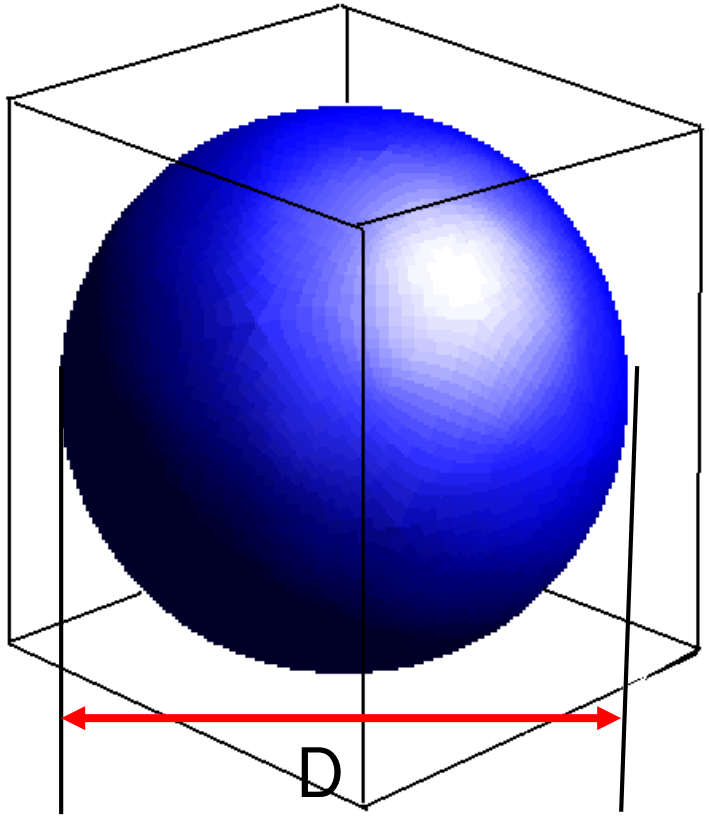


Practical Application – What About Rounding?

- 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

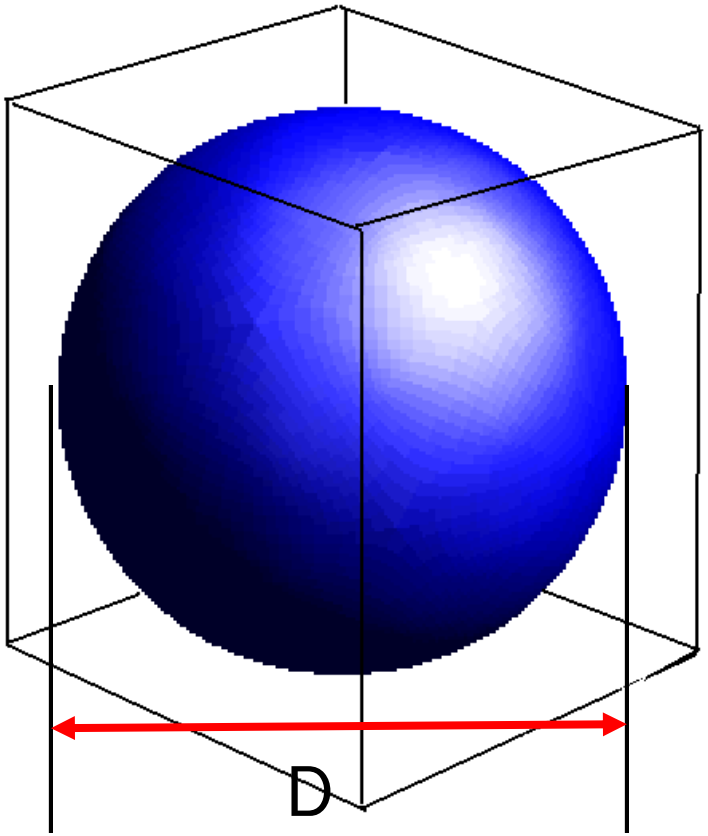
What is the volume of the gas holding sphere if the diameter is 50 feet?

Sphere volume =
¾ * cube volume

Volume =
¾ * 50 ft * 50 ft * 50 ft

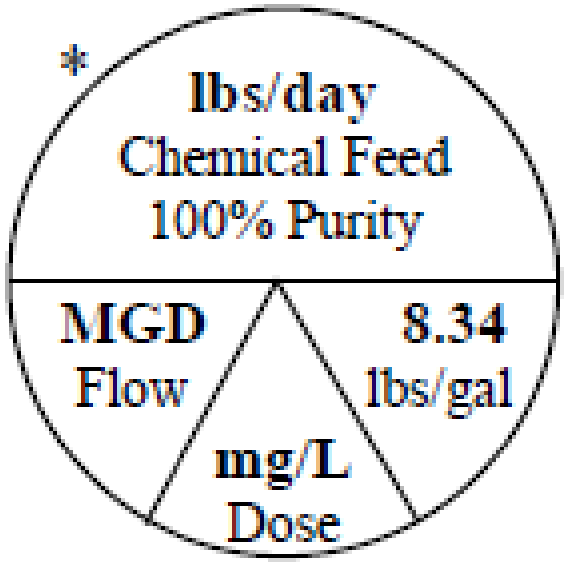
$= 0.75 * 50^3$ ft

Volume = 93,750 cubic feet



Calculation Wheels – Refer to ABC Handout

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



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?

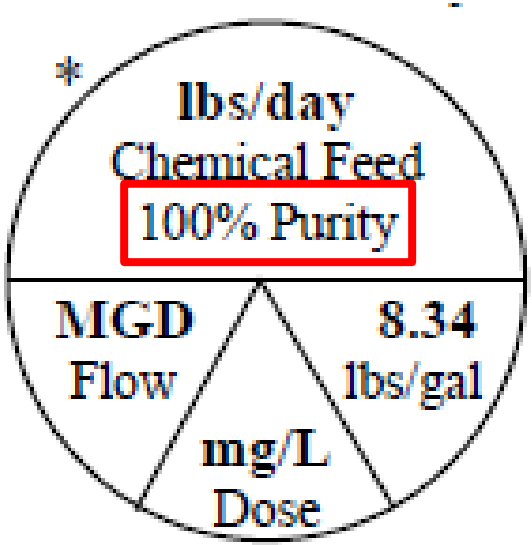
56% = ?

Time Out - Percentages

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

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

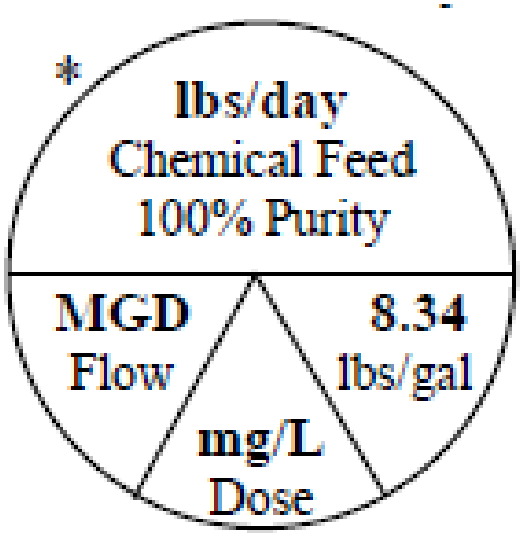
Back to the Calculation Wheels



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

This is where that algebra stuff comes into play

Back to the Calculation Wheels

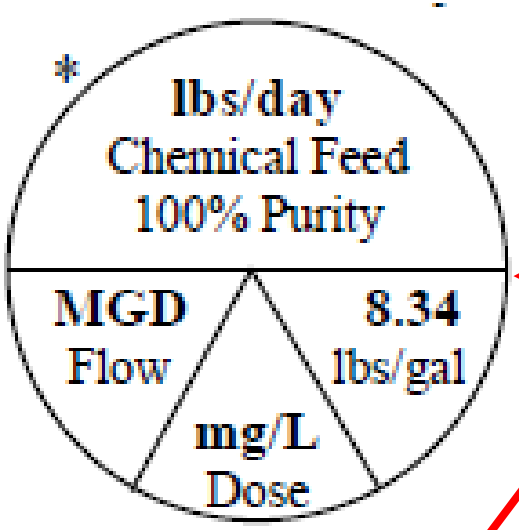


What if you know feed, but not flow?

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

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

Section title

subtitle

Header

- Tier 1 info
  - Tier 2 info
    - Tier 3 info

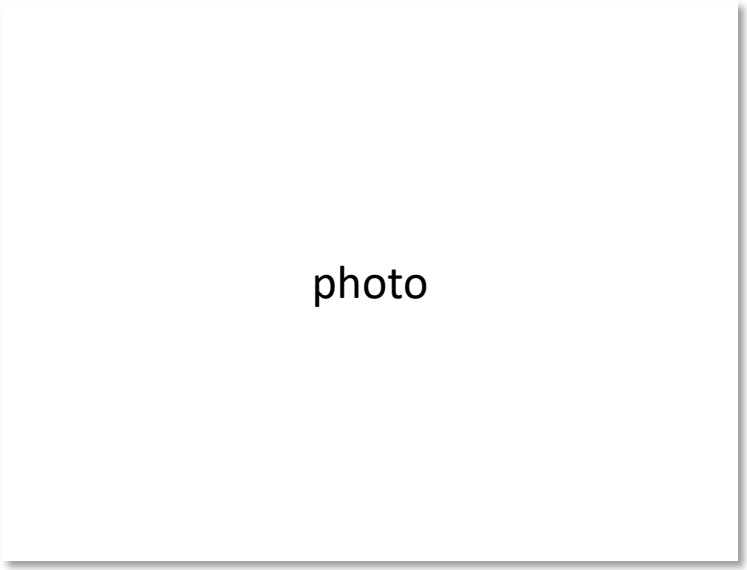


Photo caption

Optional text here

Header

- Tier 1 info
  - Tier 2 info
    - Tier 3 info

Photo caption

Optional text here

Header

Case A

- info

Case B

- info

Header

	Col 1	Col 2	Col 3	Col 4
This	X	X	X	X
That	X	X	X	X
The	X	X	X	X
Other	X	X	X	X
Thing	X	X	X	X

Optional text here