



Tennessee Operator Certification Formula Manual

Distribution Systems Formulas & Conversions

Prepared by the Fleming Training Center



About This Manual

This publication is provided by the Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), as an official resource for examinees participating in the State of Tennessee's operator certification program. It may be used during certification exams and is intended to support operators in understanding and applying essential mathematical formulas and conversions in the field.

This manual was collaboratively developed and reviewed by:

- **Fleming Training Center (FTC)** – content development and formatting
- **Water Professionals International (WPI)** – foundational formula reference materials
- **Tennessee Association of Utility Districts (TAUD)** – editorial review and industry input

This resource is intended to reflect Tennessee's commitment to operator preparedness and professional excellence. While based on national standards, the formatting and presentation have been tailored to meet the needs of Tennessee operators and exam settings.

Document Revision History

<u>Revision</u>	<u>Date</u>	<u>Brief Summary of Change</u>
0	10/2025	Initial Issue
1	1/2026	Revised Chemical Feed Pump, mL/min

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Distribution Systems Formulas & Conversions

Circumference and Perimeter

Circumference of a Circle = (3.14)(Diameter)

Perimeter, ft = (2)(Length, ft) + (2)(Width, ft)

Area

Area of a Circle*, ft² = (0.785)(Diameter, ft)²

Area of a Circle, ft² = (3.14)(Radius, ft)²

Area of a Rectangle*, ft² = (Length, ft)(Width, ft)

Area of a Right Triangle*, ft² = $\frac{[(\text{Base, ft})(\text{Height, ft})]}{2}$

Lateral Surface Area of a Cone, ft² = (3.14)(Radius, ft)($\sqrt{(\text{Radius, ft})^2 + (\text{Height, ft})^2}$)

Total Surface Area of a Cone, ft² = (3.14)(Radius, ft) (Radius, ft + $\sqrt{(\text{Radius, ft})^2 + (\text{Height, ft})^2}$)

Total Exterior Surface Area of a Cylinder, ft² =
(end #1 SA, ft²) + (end #2 SA, ft²) + [(3.14)(Diameter, ft)(Height, ft)]
Where SA = Surface Area of a Circle

Volume

Volume of a Cone*, ft³ = (1/3)(0.785)(Diameter, ft)²(Height, ft)

Volume of a Cylinder*, ft³ = (0.785)(Diameter, ft)²(Height, ft)

Volume of a Rectangular Tank*, ft³ = (Length, ft)(Width, ft)(Height, ft)

Volume, gallons = (Volume, ft³) (7.48 gal/ft³)

Velocity

Velocity, ft/sec = $\frac{\text{Distance, ft}}{\text{Time, sec}}$

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

*Pie Wheel Format for this equation is available at the end of this document

Distribution Systems Formulas & Conversions

Flow

$$\text{Flow}^*, \text{ft}^3/\text{sec} = (\text{Area, ft}^2)(\text{Velocity, ft/sec})$$

$$\text{Flow Through a Channel, ft}^3/\text{sec} = (\text{Width, ft})(\text{Depth, ft})(\text{Velocity, ft/sec})$$

$$\text{Flow Through a Full Pipeline, ft}^3/\text{sec} = (0.785)(\text{Diameter, ft})^2(\text{Velocity, ft/sec})$$

$$\text{Flow Through a Cone, ft}^3/\text{sec} = (1/3)(0.785)(\text{Diameter, ft})^2(\text{Velocity, ft/sec})$$

Pounds (Feed Rate)

$$\text{Mass}^*, \text{lb} = (\text{Concentration, mg/L})(\text{Volume, MG})(8.34 \text{ lb/gal})$$

$$\text{Mass, lb} = \frac{(\text{Concentration, mg/L})(\text{Volume, MG})(8.34 \text{ lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

$$\text{Loading Rate}^*, \text{lb/day} = (\text{Concentration, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})$$

$$\text{Feed Rate}^*, \text{lb/day} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

Dosage

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})}{(\text{Flow, MGD})(8.34 \text{ lb/gal})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Flow, MGD})(8.34 \text{ lb/gal})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Volume, MG})(8.34 \text{ lb/gal})}$$

Solution Preparation

$$\text{Three Normal Equation } (C_1 \times V_1) + (C_2 \times V_2) = (C_3 \times V_3)$$

$$\text{Two Normal Equation (Dilution) } (C_1 \times V_1) = (C_2 \times V_2)$$

Where C = Concentration or Normality
and V = Volume
Units must be compatible

*Pie Wheel Format for this equation is available at the end of this document

Distribution Systems Formulas & Conversions

Chemical Feeders

$$\text{Chemical Feed Pump Setting, \% stroke} = \frac{\text{Desired flow}}{\text{Maximum flow}} \times 100\%$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Dose, mg/L})(\text{Flow, MGD})(3.785 \text{ L/gal})(1,000,000 \text{ gal/MG})}{(\text{Chemical Density, mg/mL})(\text{Active Chemical, \% expressed as a decimal})(1440 \text{ min/day})}$$

$$\text{Dosage, mg/L} = \frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as decimal})}{(\text{Flow, MGD})(8.34 \text{ lb/gal})}$$

$$\text{Feed Rate*}, \text{ lb/day} = \frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$$

$$\text{Solution Feeder Setting, gpd} = \frac{(\text{Dose, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Solution Concentration, lb/gal}}$$

$$\text{Specific Gravity} = \frac{\text{Density of substance, lb/gal}}{8.34 \text{ lb/gal}}$$

Distribution Systems Calculations

$$\text{Force*}, \text{ lbs} = (\text{Pressure, psi}) (\text{Area, in}^2)$$

$$\text{Leakage, gpd} = \frac{\text{Volume, gal}}{\text{Time, days}}$$

$$\text{Slope, \%} = \frac{\text{Drop or Rise, ft}}{\text{Distance, ft}} \times 100\%$$

$$\text{Water Use, gpcd} = \frac{\text{Volume of Water Produced, gpd}}{\text{Population Served, capita}}$$

Operations Calculations

$$\text{Water Flow from Hydrant, gpm} = (27)(\text{Nozzle ID, in})^2(\sqrt{\text{pitot pressure, psig}})$$

$$\text{Meter Accuracy, \%} = \frac{\text{Volume of Water Registered, gal}}{\text{Actual Volume, gal}} \times 100\%$$

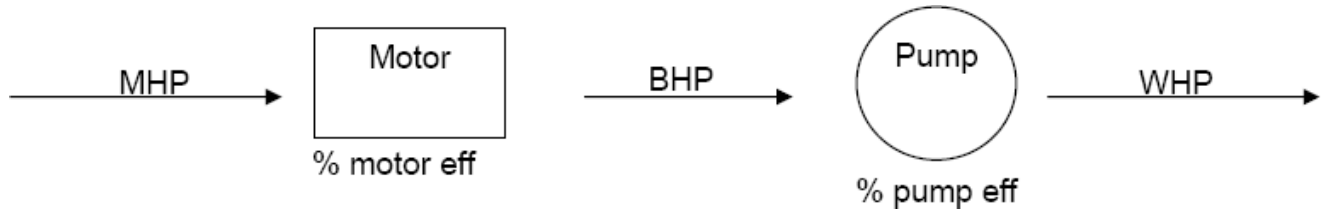
$$\text{Pressure, lb/ft}^2 = (62.4 \text{ lb/ft}^3)(\text{Water Column Height, ft})$$

$$\text{Uplift Force, lbs} = (62.4 \text{ lb/ft}^3)(\text{Volume, ft}^3)$$

$$\text{Leak Test Allowance, gal/hr} = \frac{(\text{Pipe Length, ft})(\text{Pipe Diameter, in})(\sqrt{\text{Average Test Pressure, psig}})}{148,000}$$

*Pie Wheel Format for this equation is available at the end of this document

Pumps and Motors



Horsepower

$$\text{Water Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)}$$

$$\text{Brake Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Pump Efficiency, \% expressed as a decimal})}$$

$$\text{Brake Horsepower, hp} = \frac{\text{Water Horsepower, hp}}{\text{Pump Efficiency, \% expressed as a decimal}}$$

$$\text{Motor Horsepower, hp} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Pump Efficiency, \% as a decimal})(\text{Motor Efficiency, \% as a decimal})}$$

$$\text{Motor Horsepower, hp} = \frac{\text{Water Horsepower, hp}}{(\text{Pump Efficiency, \% as a decimal})(\text{Motor Efficiency, \% as a decimal})}$$

$$\text{Motor Horsepower, hp} = \frac{\text{Brake Horsepower, hp}}{\text{Motor Efficiency, \% expressed as a decimal}}$$

Efficiency

$$\text{Efficiency, \%} = \frac{\text{Horsepower Output, hp}}{\text{Horsepower Supplied, hp}} \times 100\%$$

$$\text{Motor Efficiency, \%} = \frac{\text{Brake Horsepower, hp}}{\text{Motor Horsepower, hp}} \times 100\%$$

$$\text{Pump Efficiency, \%} = \frac{\text{Water Horsepower, hp}}{\text{Brake Horsepower, hp}} \times 100\%$$

$$\text{Wire-to-Water Efficiency, \%} = (\text{Pump Efficiency, \% as a decimal})(\text{Motor Efficiency, \% as a decimal})(100\%)$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, hp}}{\text{Motor Horsepower, hp}} \times 100\%$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Flow, gpm})(\text{Total Dynamic Head, ft})(0.746 \text{ kW/hp})}{(3,960)(\text{Electrical Demand, kW})} \times 100\%$$

Pumps and Motors (continued)

Pumping Rate

$$\text{Pumping Rate, gpm} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$\text{Pumping Rate of a Rectangular Tank, gpm} = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})(7.48 \text{ gal/ft}^3)}{\text{Time, min}}$$

$$\text{Pumping Rate of a Cylindrical Tank, gpm} = \frac{(0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48 \text{ gal/ft}^3)}{\text{Time, min}}$$

$$\text{Pumping Rate of a Conical Tank, gpm} = \frac{(1/3)(0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(7.48 \text{ gal/ft}^3)}{\text{Time, min}}$$

$$\text{Time to Fill, min} = \frac{\text{Tank Volume, gal}}{\text{Flow Rate, gal/min}}$$

Power

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

$$\text{Amps (Single-Phase)} = \frac{(746 \text{ watts/HP})(\text{Horsepower})}{(\text{Volts})(\text{Efficiency, \% as a decimal})(\text{Power Factor})}$$

$$\text{Amps (Three-Phase)} = \frac{(746 \text{ watts/HP})(\text{Horsepower})}{(1.732)(\text{Volts})(\text{Efficiency, \% as a decimal})(\text{Power Factor})}$$

$$\text{Electromotive Force*}, \text{ volts} = (\text{Current, amps})(\text{Resistance, ohms})$$

$$\text{Horsepower} = \frac{(\text{Volts})(\text{Amps})}{(746 \text{ watts/HP})}$$

$$\text{Power, watts (AC Circuit)} = (\text{Volts})(\text{Amps})(\text{Power Factor})$$

$$\text{Power, watts (DC Circuit)} = (\text{Volts})(\text{Amps})$$

$$\text{Power Factor} = \frac{\text{Power, watts}}{(\text{EMF, volts})(\text{Amperage, amps})}$$

$$\text{Cost, \$/hour} = (\text{Motor Horsepower, hp})(0.746 \text{ kW/hp})(\text{Cost, \$/kW-hr})$$

*Pie Wheel Format for this equation is available at the end of this document

Distribution Systems Formulas & Conversions

Chlorination

CT Calculation = (Disinfectant Residual Concentration, mg/L)(Time, min)

Chlorine Demand, mg/L = Chlorine Dose, mg/L - Chlorine Residual, mg/L

Chlorine Dose, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

Dosage, mg/L = $\frac{(\text{Feed Rate, lb/day})(\text{Chemical Purity, \% expressed as a decimal})}{(\text{Flow, MGD})(8.34 \text{ lb/gal})}$

Feed Rate, lb/day = $\frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Chemical Purity, \% expressed as a decimal}}$

Hypochlorite Feed Rate, gpd = $\frac{(\text{Dosage, mg/L})(\text{Flow, MGD})(8.34 \text{ lb/gal})}{(\text{Chemical Purity, \% expressed as a decimal})(\text{Solution Density, lb/gal})}$

Bleach, gal (dilution) = $\frac{(\text{Desired Concentration, \% expressed as a decimal})(\text{Desired Volume, gal})}{\text{Available Chlorine from Bleach, \% expressed as a decimal}}$

HTH, lbs = $\frac{(\text{Desired Concentration, \% expressed as a decimal})(\text{Desired Volume, gal})(8.34 \text{ lb/gal})}{\text{Available Chlorine from HTH, \% expressed as a decimal}}$

Laboratory Calculations

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

Composite Sample Single Portion = $\frac{(\text{Instantaneous Flow})(\text{Total Sample Volume})}{(\text{Number of Portions})(\text{Average Flow})}$

Temperature

Temperature, °C = $\frac{(^{\circ}\text{F} - 32)}{1.8}$

Temperature, °F = (°C)(1.8) + 32

Well Formulas

Well Yield, gal/min = $\frac{\text{Volume, gal}}{\text{Time, min}}$

Drawdown, ft = Pumping Water Level, ft - Static Water Level, ft

Specific Capacity, gpm/ft = $\frac{\text{Well Yield, gal/min}}{\text{Drawdown, ft}}$

Common Abbreviations

ac-ft = acre-feet	kWh = kilowatt-hours
C = Celsius	lb = pounds
cfs = cubic feet per second	LSI = Langelier Saturation Index
cm = centimeters	m = meters
DO = dissolved oxygen	mg = milligrams
Eff = efficiency	MG = million gallons
EMF = electromotive force	MGD = million gallons per day
F = Fahrenheit	min = minutes
ft = feet	mL = milliliters
ft lb = foot-pound	ppb = parts per billion
g = grams	ppm = parts per million
gal = gallons	psi = pounds per square inch
gfd = gallons flux per day	Q = flow
gpcd = gallons per capita per day	RPM = revolutions per minute
gpd = gallons per day	SDI = sludge density index
gpg = grains per gallon	sec = second
gpm = gallons per minute	SS = settleable solids
hp = horsepower	TOC = total organic carbon
hr = hours	TSS = total suspended solids
in = inches	W = watts
kg = kilograms	yd = yards
km = kilometers	yr = year
kPa = kilopascals	
kW = kilowatts	

Unit Conversion Factors

Linear

1 ft = 0.305 m
 1 ft = 12 in
 1 in = 2.54 cm
 1 yd = 3 ft
 1 mi = 5,280 ft

Weight and Mass

1 ft³ of water = 62.4 lb
 1 g = 1,000 mg
 1 gal of water = 8.34 lb
 1 kg = 1,000 g
 1 kg = 2.2 lbs
 1 lb = 0.454 kg
 1 lb = 453.6 g
 1 metric ton = 2,205 lb
 1 mg/L = 0.0584 gpg
 1 gpg = 17.118 mg/L
 1 ton = 2,000 lb
 1% = 10,000 mg/L

Area

1 ac = 43,560 ft²
 1 ac = 0.405 Hectare
 1 m² = 1.19 yd²
 1 ft² = 144 in²
 1 Hectare = 2.47 ac
 π or pi = 3.14

Pressure and Head

1 atm = 33.9 ft of water
 1 atm = 14.7 psi
 1 ft of water = 0.433 psi
 1 psi = 2.31 ft of water

Volume

1 ac-ft = 43,560 ft³
 1 ac-ft = 325,828.8 gal
 1 ft³ = 7.48 gal
 1 L = 0.2642 gal
 1 L = 1,000 mL
 1 gal = 231 in³
 1 gal = 0.1337 ft³
 1 gal = 3.785 L
 1 MG = 1,000,000 gal
 1 m³ = 264 gal
 1 yd³ = 27 ft³

Power

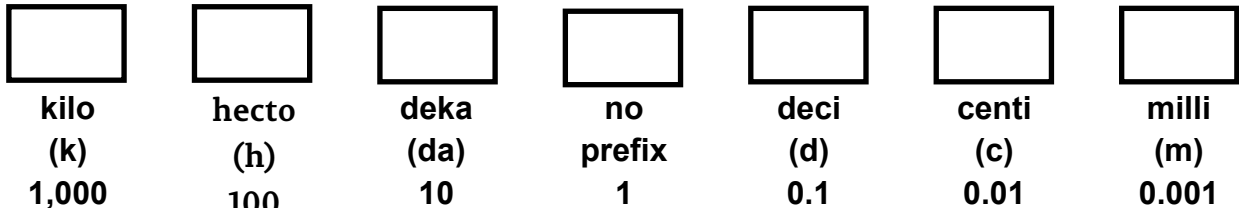
1 hp = 0.746 kW
 1 hp = 746 W
 1 hp = 33,000 ft•lb/min
 1 kW = 1,000 W

Flow

1 cfs = 0.6463 MGD
 1 cfs = 448.8 gpm
 1 MGD = 694.44 gpm
 1 MGD = 1.55 cfs

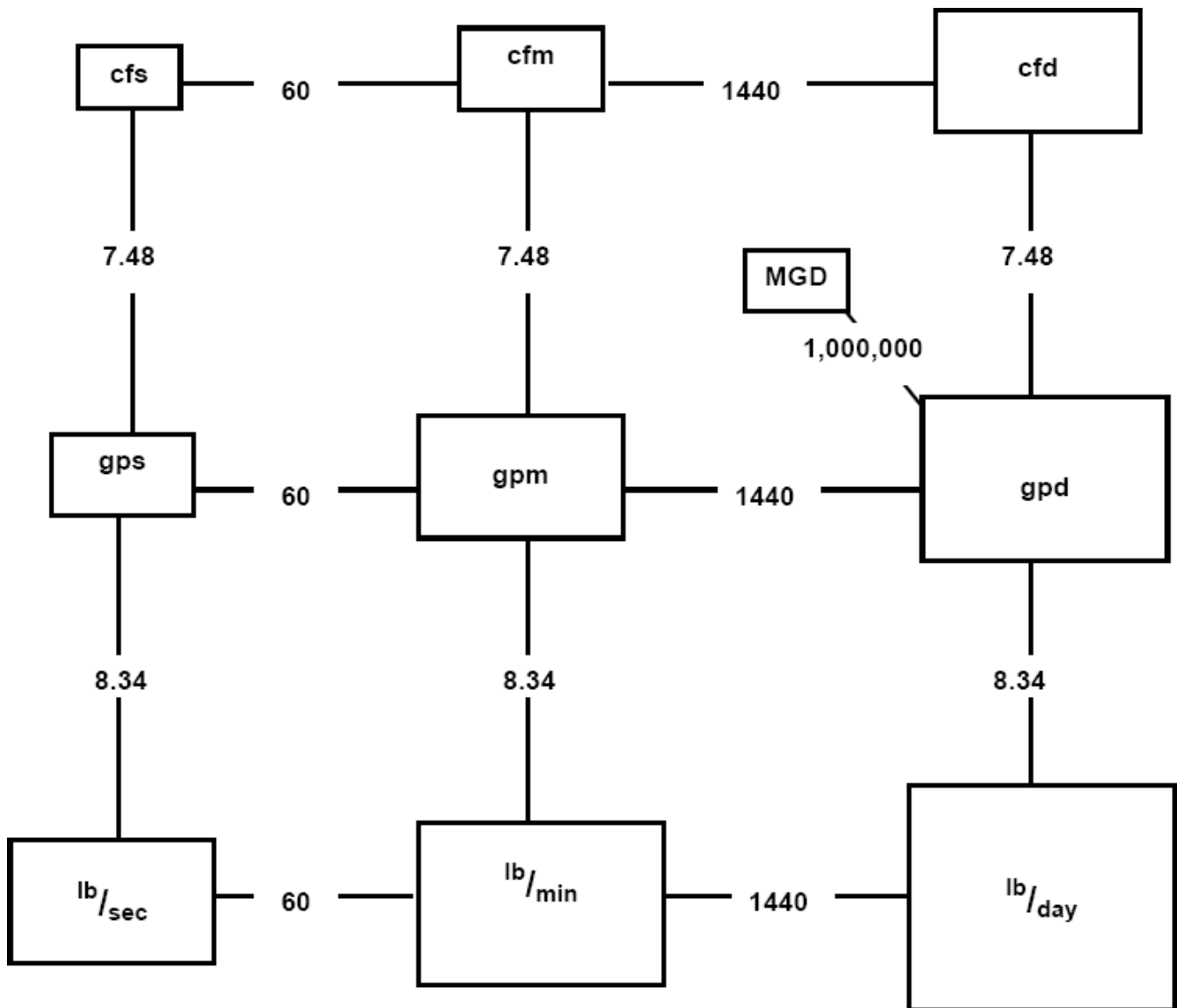
Metric Conversion Chart

Primary Unit



meter (m) - linear measurement
liter (L) - volume measurement
gram (g) - weight measurement

Flow Conversion Chart



To use this diagram: First, find the box that coincides with the beginning units (i.e. gpm). Then, find the box that coincides with the desired ending units (i.e. cfs). The numbers between the starting point and ending point are the conversion factors.

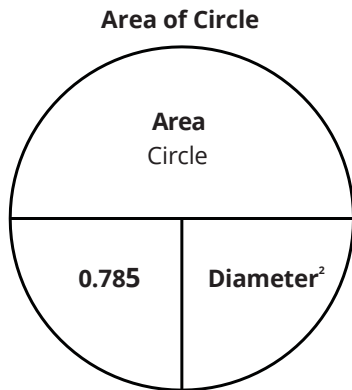
When moving from a **smaller box to a larger box, multiply** by the factor between them.

When moving from a **larger box to a smaller box, divide** by the factor between them.

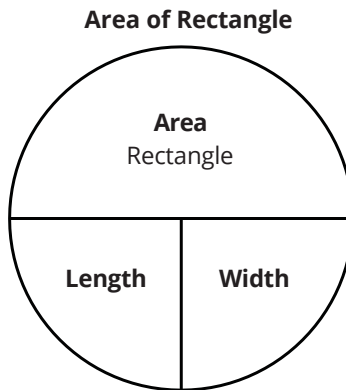
Distribution Systems Formulas & Conversions

Pie Wheels

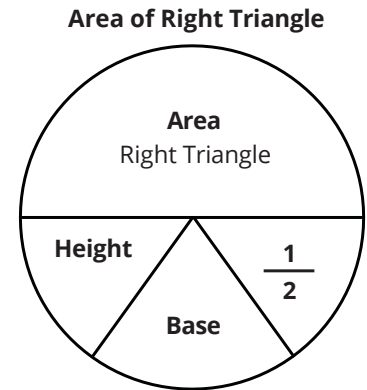
- To find the quantity above the horizontal line: multiply the pie wedges below the line together.
- To solve for one of the pie wedges below the horizontal line: cover that pie wedge, then divide the remaining pie wedge(s) into the quantity above the horizontal line.
- Given units must match the units shown in the pie wheel.
- When US and metric units or values differ, the metric is shown in parentheses, e.g. (m²).



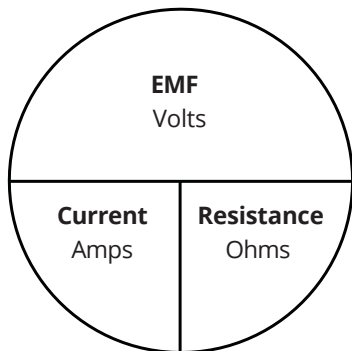
Electromotive Force (EMF), Volts



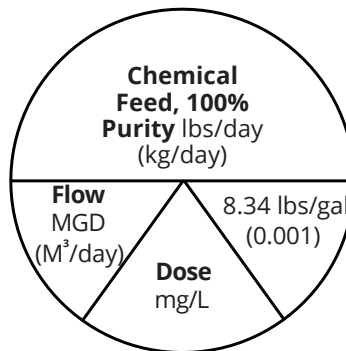
Feed Rate, lbs/day (kg/day)



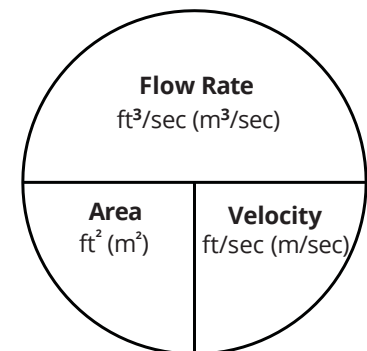
Flow Rate, ft³/sec (m³/sec)



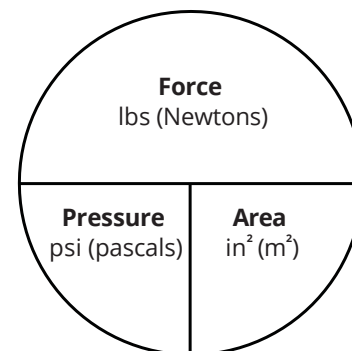
Force, lbs (Newtons)



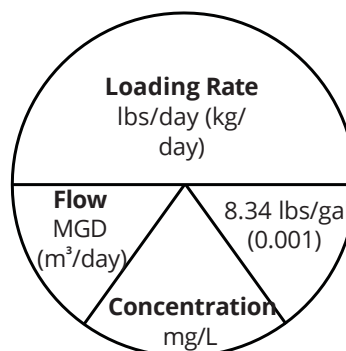
Loading Rate, lbs/day (kg/day)



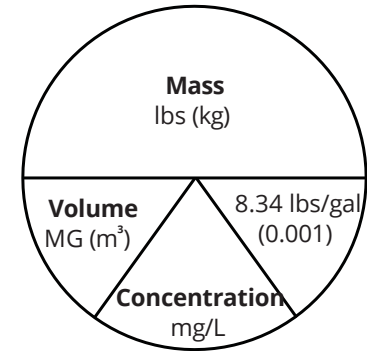
Mass, lbs (kg)



Volume of Cone



Volume of Cylinder



Volume of Rectangular Tank

