Tennessee Operator Certification Formula Manual

Collection 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.

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Circumference and Perimeter

Circumference of a Circle = (3.14)(Diameter)

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

Area

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

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

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

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

Total Exterior Surface Area of a Cylinder, ft^2 =

$$\left(\text{end \#1 SA, ft}^2\right)+\left(\text{end \#2 SA, ft}^2\right)+[(3.14)(\text{Diameter, ft})(\text{Height, ft})]$$

Where SA = Surface Area

Area of a Rectangle*, ft^2 = (Length, ft)(Width, ft)

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

Volume

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

Volume of a Cylinder*, ft^3 = (0.785)(Diameter, ft)^2(Height, ft)

Volume of a Rectangular Tank*, ft^3 = (Length, ft)(Width, ft)(Height, ft)

Volume, gallons = $\left(\text{Volume, ft}^3\right)\left(7.48\ \text{gal/ft}^3\right)$

Velocity and Flow

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

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

Flow Through a Channel, ft^3/sec = (Width, ft)(Depth, ft)(Velocity, ft/sec)

Flow Through a Full Pipe, ft^3/sec = (0.785)(Diameter, ft)^2(Velocity, ft/sec)

Flow Through a Partially Full Pipe, ft^3/sec = (Factor from d/D table)(Diameter, ft)^2(Velocity, ft/sec)

See pg. 12 for depth/Diameter Table

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

Pounds (Feed Rate)

Mass*, lb = (Concentration, mg/L)(Volume, MG)(8.34 lb/gal)

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

Loading Rate*, lb/day = (Concentration, mg/L)(Flow, MGD)(8.34 lb/gal)

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

Dosage

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

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

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

Power

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

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

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

Cost, $/hour = (Motor Horsepower, hp)(0.746 kW/hp)(Cost, $/kW-hr)

Electromotive Force*, volts = (Current, amps)(Resistance, ohms)

$$\text{Horsepower} = \frac{(\text{EMF, volts})(\text{Amperage, amps})}{(746\ \text{watts/HP})}$$

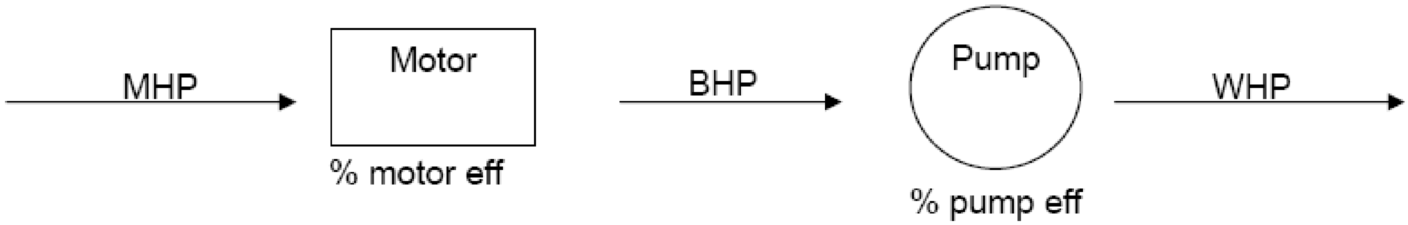
Power, watts (AC Circuit) = (Volts)(Amps)(Power Factor)

Power, watts (DC Circuit) = (Volts)(Amps)

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

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

Pumps and Motors



$$\text{Cycle Time, min} = \frac{\text{Storage Volume, gal}}{(\text{Pump Capacity, gpm} - \text{Wet Well Inflow, gpm})}$$

Horsepower

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

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

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

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

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

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

Efficiency

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

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

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

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

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

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

Pumps and Motors (continued)

Pumping Rate

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

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

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

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

Collection Systems Calculations

$$\text{Average} = \frac{(\text{Time \#1} + \text{Time \#2})}{2}$$

$$\text{Blower Capacity, ft}^3\text{/min} = \frac{(0.785)(\text{Manhole Diameter, ft})^2(\text{Manhole Depth, ft})}{\text{Time for Air Change, min}}$$

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

Force

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

$$\text{Force (cylinder), lbs} = (\text{Pressure, psi})(0.785)(\text{Diameter, in})^2$$

$$\text{Force (rectangle), lb} = (\text{Pressure, psi})(\text{Length, in})(\text{Width, in})$$

Leak Testing

$$\text{Leakage, gal} = (0.785)(\text{Manhole Diameter, ft})^2(\text{Water Drop, ft})(7.48\ \text{gal/ft}^3)$$

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

$$\text{Leakage, gal/hr} = \frac{\text{Leakage, gpd}}{24\ \text{hr/day}}$$

$$\text{Leakage, gal/day/inch} = \frac{\text{Leakage, gpd}}{\text{Sewer Diameter, in}}$$

$$\text{Leakage, gpd/inch/mile} = \frac{(\text{Leakage, gpd/in})(5280\ \text{ft/mi})}{\text{Pipe Length, ft}}$$

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

Chlorination

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

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

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

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

Chemical Feeders

$$\text{Chemical, lbs} = \frac{(\text{Water Volume, gal})(8.34\ \text{lb/gal})(\text{Desired Concentration, \%})}{(100\%\text{-desired concentration,\%})}$$

All percentages (%) should be entered in decimal form.

$$\text{Water Volume, gal} = \frac{(\text{Chemical, lbs})(100\%\text{-Desired Concentration, \%})}{(\text{Desired Concentration, \%})(8.34\ \text{lb/gal})}$$

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

Chemical Feed Pump Setting, mL/min =

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

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

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

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

Laboratory Calculations

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

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

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

Solution Preparation

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

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

Temperature

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

Temperature, °F = (°C)(1.8) + 32

Common Abbreviations

ac-ft = acre-feet
atm = atmospheres
BOD_5 = biochemical oxygen demand
˚C = Celsius
$CBOD_5$ = carbonaceous biochemical oxygen demand
CCSS = clarifier core suspended solids
cfs = cubic feet per second
cm = centimeters
COD = chemical oxygen demand
DO = dissolved oxygen
EMF = electromotive force
˚F = Fahrenheit
F/M Ratio = food to microorganism ratio
ft = feet
ft lb = foot-pound
g = grams
gal = gallons
gfd = gallons flux per day
gpcd = gallons per capita per day
gpd = gallons per day
gpg = grains per gallon
gpm = gallons per minute
hp = horsepower
hr = hours
in = inches
kg = kilograms
km = kilometers
kPa = kilopascals
kW = kilowatts
kWh = kilowatt-hours
L = liter
lb = pounds
m = meters
MCRT = mean cell residence time
MG = million gallons
mg = milligrams
MGD = million gallons per day
mi = mile
mL = milliliters
MLSS = mixed liquor suspended solids
MLVSS = mixed liquor volatile suspended solids
OCR = oxygen consumption rate
OUR = oxygen uptake rate
PE = population equivalent
ppb = parts per billion
ppm = parts per million
psi = pounds per square inch
Q = flow
RAS = return activated sludge
RBC = rotating biological contactor
RPM = revolutions per minute
$SBOD_5$ = soluble BOD
SDI = sludge density index
sec = second
SOUR = specific oxygen uptake rate
SRT = solids retention time
SS = settleable solids
SSV_{30} = settled sludge volume 30 minute
SVI = sludge volume index
TOC = total organic carbon
TS = total solids
TSS = total suspended solids
VS = volatile solids
VSS = volatile suspended solids
W = watts
WAS = waste activated sludge
yd = yards
yr = year

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

Area

1 ac	= 43,560 ft^2
1 m^2	= 1.19 yd^2
1 ft^2	= 144 in^2
π or pi	= 3.14

Volume

1 ac-ft	= 43,560 ft^3
1 ac-ft	= 325,828.8 gal
1 ft^3	= 7.48 gal
1 L	= 0.2642 gal
1 L	= 1,000 mL
1 gal	= 231 in^3
1 gal	= 0.1337 ft^3
1 gal	= 3.785 L
1 MG	= 1,000,000 gal
1 m^3	= 264 gal
1 yd^3	= 27 ft^3

Flow

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

Weight and Mass

1 ft^3 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

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
1 psi	= 33,000 ft•lb/min

Power

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

Population Equivalent

PE, hydraulic	= 100 gal/person/day
PE, organic	= 0.17 BOD/person/day

Metric Conversion Chart

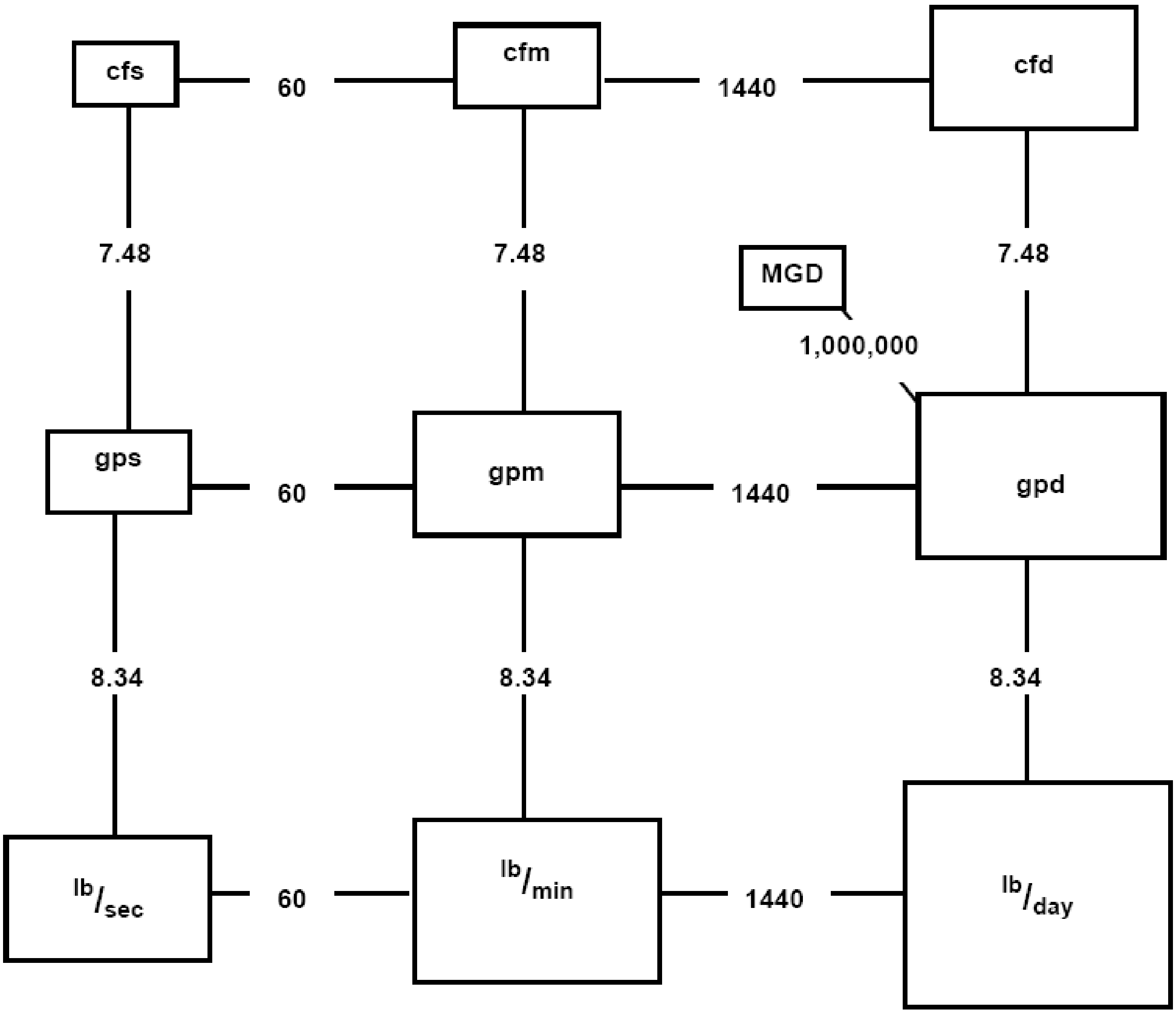
Primary Unit

kilo	hecto	deka	no	deci	centi	milli
(k)	(h)	(da)	prefix	(d)	(c)	(m)
1,000	100	10	1	0.1	0.01	0.001

↓

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.

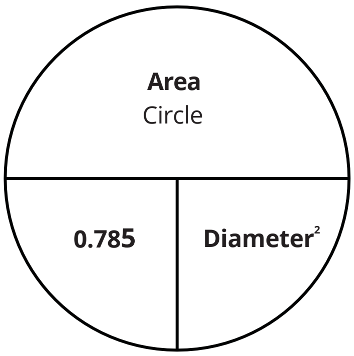
When moving from a **smaller box to a larger box, multiply** by the factor between them.

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

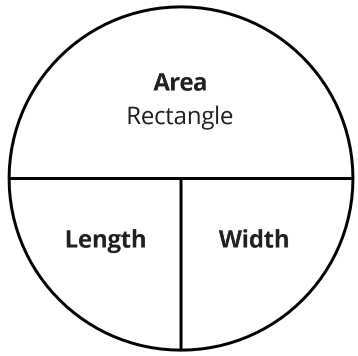
Pie Wheels

- 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. (m^2).

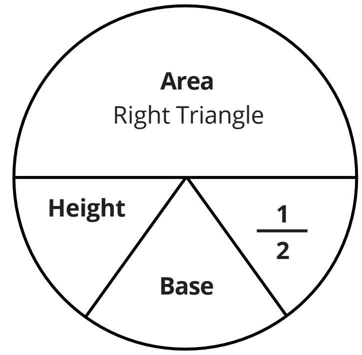
Area of Circle



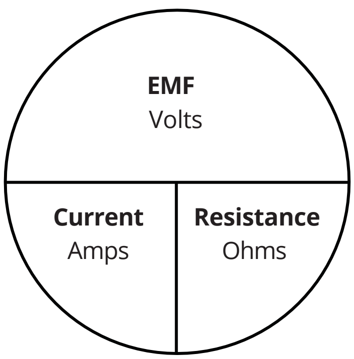
Area of Rectangle



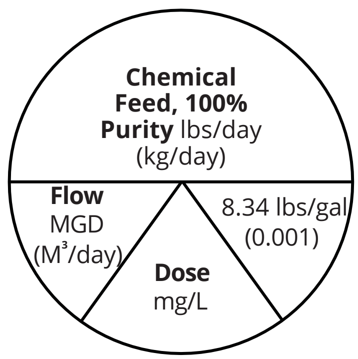
Area of Right Triangle



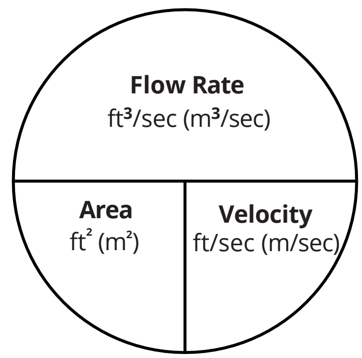
Electromotive Force (EMF), Volts



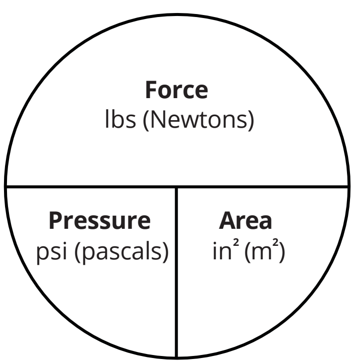
Feed Rate, lbs/day (kg/day)



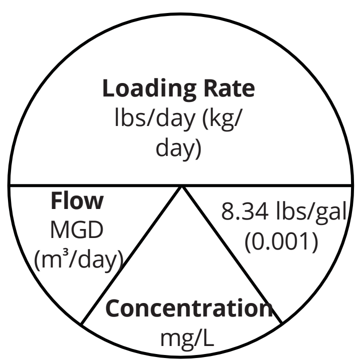
Flow Rate, ft^3/sec (m^3/sec)



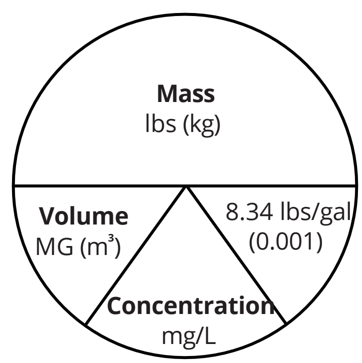
Force, lbs (Newtons)



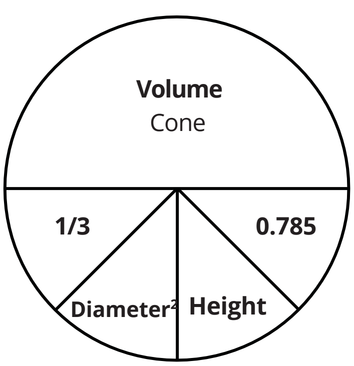
Loading Rate, lbs/day (kg/day)



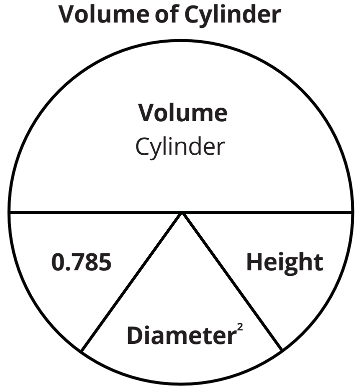
Mass, lbs (kg)



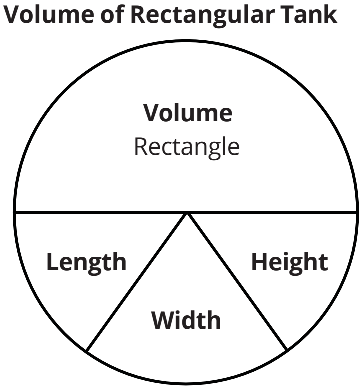
Volume of Cone



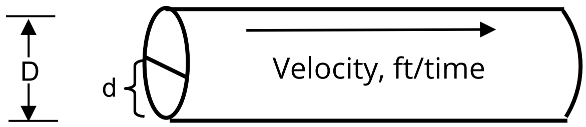
Volume of Cylinder



Volume of Rectangular Tank



Flow Through a Partially Full Pipe



Where D = diameter, and d = depth

Flow, cfs = (Area, ft^2)(Velocity, fps)

Flow, cfs = [(factor from $^{d}/_{D}$ table)(Diameter, ft)^2](Velocity, fps)

d, in / D, in	Factor	d, in / D, in	Factor	d, in / D, in	Factor	d, in / D, in	Factor
0.01	0.0013	0.26	0.1623	0.51	0.4027	0.76	0.6404
0.02	0.0037	0.27	0.1711	0.52	0.4127	0.77	0.6489
0.03	0.0069	0.28	0.1800	0.53	0.4227	0.78	0.6573
0.04	0.0105	0.29	0.1890	0.54	0.4327	0.79	0.6655
0.05	0.0147	0.30	0.1982	0.55	0.4426	0.80	0.6736
0.06	0.0192	0.31	0.2074	0.56	0.4526	0.81	0.6813
0.07	0.0242	0.32	0.2167	0.57	0.4625	0.82	0.6893
0.08	0.0294	0.33	0.2260	0.58	0.4724	0.83	0.6969
0.09	0.0350	0.34	0.2355	0.59	0.4822	0.84	0.7043
0.10	0.0409	0.35	0.2450	0.60	0.4920	0.85	0.7115
0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
0.12	0.0534	0.37	0.2642	0.62	0.5118	0.87	0.7254
0.13	0.0600	0.38	0.2739	0.63	0.5212	0.88	0.7320
0.14	0.0668	0.39	0.2836	0.64	0.5308	0.89	0.7384
0.15	0.0739	0.40	0.2934	0.65	0.5404	0.90	0.7445
0.16	0.0811	0.41	0.3032	0.66	0.5499	0.91	0.7504
0.17	0.0885	0.42	0.3130	0.67	0.5594	0.92	0.7560
0.18	0.0961	0.43	0.3229	0.68	0.5687	0.93	0.7612
0.19	0.1039	0.44	0.3328	0.69	0.5780	0.94	0.7662
0.20	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	0.46	0.3527	0.71	0.5964	0.96	0.7749
0.22	0.1281	0.47	0.3627	0.72	0.6054	0.97	0.7785
0.23	0.1365	0.48	0.3727	0.73	0.6143	0.98	0.7816
0.24	0.1449	0.49	0.3827	0.74	0.6231	0.99	0.7841
0.25	0.1535	0.50	0.3927	0.75	0.6318	1.00	0.7854