Pressures and Densities

Pressure $= \dfrac{\text{force}}{\text{area}}$

1 column of water 1 foot deep = 62.4 pounds per square foot, or 0.433 pounds per square inch. 1 column of water 1 centimeter deep = 1 gram per square centimeter.

Specific gravity (liquid) = number of times a substance is as heavy as an equal body of water, or specific gravity (liquid) = $\dfrac{\text{weight of liquid}}{\text{weight of equal volume of water}}$

Density $= \dfrac{\text{weight}}{\text{volume}}$

Pressure = depth x density, or force per unit area. An increase in pressure is transmitted equally through the liquid.

Specific gravity (solid) = $\dfrac{\text{weight of body}}{\text{weight of equal volume of water}}$

or specific gravity (solid) = $\dfrac{\text{weight of body}}{\text{loss of weight in water}}$

One cubic yard of air weighs about 2 pounds. Atmospheric pressure at sea level = about 15 pounds per square inch.

Velocities and Energies

Velocity $= \dfrac{\text{distance}}{\text{time}}$

Acceleration $= \dfrac{\text{change of velocity}}{\text{time}}$

Acceleration of gravity = 32 feet per second

Centripetal force = $\dfrac{\text{weight}}{\text{acceleration of gravity}} \times \dfrac{(\text{velocity})^2}{\text{radius}}$ seconds

Potential energy = weight of body x elevation

Kinetic energy = $\dfrac{1}{2} \dfrac{\text{weight}}{\text{acceleration of gravity}} \times (\text{velocity})^2 ac$

Momentum = mass of body x its velocity

Mass $= \dfrac{\text{weight}}{\text{acceleration of gravity}} \sqrt{\dfrac{L}{G}}$

Period of pendulum: $T = 2\pi$

Wave velocity = wave frequency x wave length, or $v = nx1$

Speed of sound: 1090 feet per second in air at 0 degrees Celsius. Velocity of sound increases 2 feet per second for each degree Celsius rise in temperature above zero degrees Celsius.

Electricity

1 ampere = 1 coulomb per second

1 volt = 1 joule per coulomb

Ohm's Law: Current $= \dfrac{\text{potential difference}}{\text{resistance}}$

or **amperes (I)** $= \dfrac{\text{volts or E}}{\text{ohms}} \quad \dfrac{E}{R}$

Ampere = electric current **Volt** = potential difference **Ohm** = electrical resistance

One volt potential difference will drive 1 ampere through a resistance of 1 ohm.

The resistance of conductor can be calculated by the formula:

$R = \dfrac{kl}{d2}$ (Where l is length, d is diameter, and k is constant)

The combined resistance of conductors connected in parallel is

$\dfrac{1}{Rc} = \dfrac{1}{R1} + \dfrac{1}{R2} + \dfrac{1}{R3}$

1 watt is the power of a current on 1 ampere when the potential difference is 1 volt.

To compute electric power: P (power in watts) = V (voltage in volts) x l (current in amperes), or P = V x I.

To compute the heat (H), produced by a current (I), through a resistance (R), in a time (t), use the equation: $H = I_2 \times R \times t \times 0.24$ cal/watt-sec.

Light and Lenses

1 foot-candle: the illumination of any point on a surface 1 foot from a standard candle.

Illumination(ft-c) $= \dfrac{\text{intensity (candles)}}{\text{distance in feet2}}$

Velocity of light = 186,000 miles per sec.

Index of refraction $= \dfrac{\text{velocity of light in air}}{\text{velocity of light in the substance}}$

Lens image equation: $\dfrac{1}{D_0} \times \dfrac{1}{D1\ f} = \dfrac{1}{}$

Magnification $= \dfrac{\text{image length}}{\text{object length}}$ or $\dfrac{\text{image distance}}{\text{object distance}}$

Heat

To convert Fahrenheit to Celsius: subtract 32 from F, then multiply by $\frac{5}{9}$, written $C = \frac{5}{9} (F-32)$. NOTE: Centigrade is now referred to as Celsius. (NOTE: 212°F = 100°C). To convert Celsius to Fahrenheit: multiply C by $\frac{9}{5}$, then add 32, written $F = (\frac{9}{5} C) + 32$.

To convert Celsius to Absolute or Kelvin scale: add 273 to C.

To convert Fahrenheit to Absolute or Kelvin scale: first convert F to C, then add 273.

Boyle's Law: $p_1 \times V_1 = p_2 \times V_2$ at constant temperature. Zero degrees Kelvin is the lowest possible temperature.

In Kelvin Absolute temperature scale: water boils at 373K, freezes at 273K.

Charles' Law: $\dfrac{V_1}{V_2} = \dfrac{T_1}{T_2}$ at constant pressure

Combination of Charles' and Boyle's Laws:

$$\frac{V_1 p_1}{T_1} = \frac{V_2 p_2}{T_2}$$

When heated through one degree Celsius, any gas expands $\dfrac{1}{273}$ of its volume at 0 degrees Celsius if the pressure remains constant. One BTU is the heat required to raise the temperature of 1 pound of water through 1 degree Fahrenheit.

One calorie: the heat required to raise the temperature of 1 gram of water through 1 degree Celsius.

Specific Heat: heat required to raise the temperature of a unit mass of that substance through 1 degree. If H is total heat and M is mass, $H = M \times s \times (t_2 - t_1)$.

Heat of melting or heat of fusion, L, is the quantity of heat needed to melt one unit weight of substance without changing its temperature, or $H = M \times L$.

0 calories of heat is required to melt 1 gram of ice without raising its temperature.

Boiling point of liquid: that temperature at which the vapor pressure is equal to the pressure above the liquid.

0.427 kilogram-meter (kg-m) = 1 calorie

$$\frac{\text{Work}}{\text{mechanical equivalent of heat}}$$

Horsepower

1 horsepower = 550 ft-lb sec

$$\text{Horsepower} = \frac{\text{force (lb) x distance (ft)}}{\text{550 ft-lb sec x time (sec)}}$$

$$\text{Friction Constant} = \frac{\text{friction force}}{\text{weight}}$$

Work = force x distance moved

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

1 watt = 10,200 gram-centimeters per sec.

1 kilowatt is 1000 watts

1 kilowatt is approximately $1\frac{1}{3}$ horsepower

Dyne is absolute metric unit of force. **Erg** is its unit of work.

1 Erg = force of 1 dyne acting through 1 centimeter

1 Joule = 10,000,000 ergs, or about $\frac{3}{4}$ foot pounds

The law of work when friction is neglected: effort force x effort distance = resistance force x resistance distance Mechanical advantage of a machine =

$$\frac{\text{resistance force}}{\text{effort force}}$$

When friction is zero, mechanical advantage of a machine:

$$\frac{\text{effort distance}}{\text{resistance distance}}$$

Mechanical advantage of a lever = $\dfrac{\text{effort arm}}{\text{resistance arm}}$

Moment of force = force x lever arm
Frictionless mechanical advantage of an inclined plane

plane = $\dfrac{\text{length}}{\text{height}}$

Frictionless mechanical advantage of a wheel and axle:

$$\frac{\text{circumference of wheel}}{\text{circumference of axle}}$$

Conversion Tables

Engineering Constants and Conversions

Power

Physical Quantity…		Multiply By…	To Convert To…	
British Thermal Units/Hour	(BTU/hr)	0.393×10^{-3}	Horsepower	(Hp)
British Thermal Units/Hour	(BTU/hr)	0.2931	Joules/Second	(J/s)
British Thermal Units/Hour	(BTU/hr)	0.2931	Watts	(W)
Horsepower	(Hp)	0.746	Kilowatts	(KW)
Horsepower	(Hp)	2544.4	British Thermal Units/Hour	(BTU/hr)
Horsepower	(Hp)	746.0	Joules/Second	(J/s)
Joules/Second	(J/s)	1.0	Watts	(W)
Joules/Second	(J/s)	0.001341	Horsepower	(Hp)
Joules/Second	(J/s)	3.412	British Thermal Units/Hour	(BTU/hr)
Kilowatts	(KW)	1.341	Horsepower	(Hp)
Kilowatts	(KW)	1000.0	Joules/Second	(J/s)
Kilowatts	(KW)	3412.0	British Thermal Units/Hour	(BTU/hr)
Watts	(W)	0.001	Kilowatts	(KW)
Watts	(W)	0.001341	Horsepower	(Hp)
Watts	(W)	1.0	Joules/Second	(J/s)
Watts	(W)	3.412	British Thermal Units/Hour	(BTU/hr)

Area

Physical Quantity…		Multiply By…	To Convert To…	
Square Centimeters	(cm^2)	0.155	Square Inches	(in^2)
Square Feet	(ft^2)	0.0929	Square Meters	(m^2)
Square Inches	(in^2)	6.452	Square Centimeters	(cm^2)
Square Meters	(m^2)	10.76	Square Feet	(ft^2)
Square Millimeters	(mm^2)	0.00155	Square Inches	(in^2)

Volume

Physical Quantity…		Multiply By…	To Convert To…	
Cubic Centimeters	(cm^3)	0.061	Cubic Inches	(in^3)
Cubic Feet	(ft^3)	0.02832	Cubic Meters	(m^3)
Cubic Feet	(ft^3)	1728.0	Cubic Inches	(in^3)
Cubic Feet	(ft^3)	7.481	Cubic Gallons	(gal^3)
Cubic Inches	(in^3)	16.387	Cubic Centimeters	(cm^3)
Cubic Meters	(m^3)	1000.0	Liters	(l)
Cubic Meters	(m^3)	264.18	Gallons	(gal)
Cubic Meters	(m^3)	35.31	Cubic Feet	(ft^3)
Cubic Millimeters	(mm^3)	61×10^{-6}	Cubic Inches	(in^3)
Gallons	(gal)	231.0	Cubic Inches	(in^3)
Gallons	(gal)	3.7854	Liters	(l)
Liters	(l)	0.2642	Gallons	(gal)
Liters	(l)	1000.0	Milliliters	(ml)
Milliliters	(ml)	0.061	Cubic Inches	(in^3)

Density

Physical Quantity…		Multiply By…	To Convert To…	
Grams/Cubic Centimeter	(g/cm^3)	1000.0	Kilograms/Cubic Meter	(kg/cm^3)
Grams/Cubic Centimeter	(g/cm^3)	0.03613	Pounds/Cubic Inch	(lb/in^3)
Kilograms/Cubic Meter	(kg/m^3)	0.06243	Pounds/Cubic Foot	(lb/ft^3)
Kilograms/Cubic Meter	(kg/m^3)	0.001	Grams/Cubic Centimeter	(g/cm^3)
Pounds/Cubic Foot	(lb/ft^3)	16.018	Kilograms/Cubic Centimeter	(kg/cm^3)
Pounds/Cubic Inch	(lb/in^3)	0.5787×10^{-3}	Pounds/Cubic Foot	(lb/ft^3)
Pounds/Cubic Inch	(lb/in^3)	27.68	Grams/Cubic Centimeter	(g/cm^3)

Engineering Constants and Conversions (Continued)

Speed/Velocity

Physical Quantity…		Multiply By…	To Convert To…	
Centimeters/Second	(cm/s)	0.03281	Feet/Second	(fps)
Feet/Minute	(fpm)	0.011364	Miles/Hour	(mph)
Feet/Second	(fps)	0.3048	Meters/Second	(m/s)
Meters/Second	(m/s)	3.281	Feet/Second	(fps)
Miles/Hour	(mph)	1.609	Kilometers/Hour	(km/hr)
Miles/Hour	(mph)	88.0	Feet/Minute	(fpm)

Volumetric Flow Rate

Physical Quantity…		Multiply By…	To Convert To…	
Cubic Centimeters/Second	(cm^3/s)	60×10^{-6}	Cubic Meters/Minute	(m^3/min)
Cubic Feet/Hour	(ft^3/hr)	0.12468	Gallons/Minute	(gpm)
Cubic Meters/Minute	(m^3/min)	264.18	Gallons/Minute	(gpm)
Gallons/Minute	(gpm)	0.06308	Liters/Second	(l/s)
Gallons/Minute	(gpm)	.22713	Cubic Meters/Hour	(m^3/hr)

Mass

Physical Quantity…		Multiply By…	To Convert To…	
Gram	(g)	0.03527	Ounces	(oz)
Kilogram	(kg)	2.205	Pounds	(lb)
Metric Ton		1000.0	Kilograms	(kg)
Metric Ton		2205	Pounds	(lb)
Ounces	(oz)	28.35	Grams	(g)
Pound	(lb)	0.4536	Kilograms	(kg)
Pound	(lb)	453.6	Grams	(g)
Ton		907.18	Kilograms	(kg)

Pressure

Physical Quantity…		Multiply By…	To Convert To…	
Atmospheres	(atm)	1.01325	Bar	
Atmospheres	(atm)	10,332.3	Kilograms/Square Meter	(kg/m^2)
Atmospheres	(atm)	101,325.0	Kilopascals	(KPa)
Atmospheres	(atm)	14.696	Pounds/Square Inch	(psi)
Atmospheres	(atm)	29.921	Inches Mercury	(in Hg)
Atmospheres	(atm)	33.934	Feet of Water	(ft H$_2$O)
Atmospheres	(atm)	760.0	Millimeters Mercury	(mm Hg)
Atmospheres	(atm)	760.0	Torr	
Bar		14.504	Pounds/Square Inch	(psi)
Pounds/Square Inch	(psi)	703.07	Kilograms/Square Meter	(kg/m^2)
Pounds/Square Inch	(psi)	0.0703	Kilograms/Square Centimeter	(kg/cm^2)

Length

Physical Quantity…		Multiply By…	To Convert To…	
Centimeters	(cm)	0.3937	Inches	(in)
Feet	(ft)	0.3048	Meters	(m)
Inches	(in)	2.54	Centimeters	(cm)
Kilometers	(km)	0.6215	Miles	(mi)
Meters	(m)	3.281	Feet	(ft)
Miles	(mi)	1.609	Kilometers	(km)
Pounds/Cubic Inch	(P/in^3)	0.03937	Inches	(in)

Units and Conversion Factors

Linear Measure

Symbol	Unit	Inches Per Unit	Feet Per Unit	Yards Per Unit	Miles Per Unit	Centimeters Per Unit	Meters Per Unit	Kilometers Per Unit
in	Linear inch	1	0.0833	0.027778	—	2.54	0.0254	—
ft	Linear foot	12	1	0.3333	—	30.480	0.3048	—
yd	Linear yard	36	3	1	—	91.44	0.9144	—
mi	Linear mile	63360	5280	1760	1	—	1609.34	1.609
cm	Centimeter	0.3937	0.0328	0.010936	—	1	0.01	—
m	Meter	39.37	3.2808	1.093613	—	100	1	.001
km	Kilometer	39370	3280.8	1093.613	.6214	—	1000	1

e.g. 1 meter = 3.2808 ft, so 300 meters would be (300 m) (3.2808 ft/m) = 984.24 ft

Square Measure

Symbol	Unit	Square Inches Per Unit	Square Feet Per Unit	Square Yards Per Unit	Acres Per Unit	Square Centimeters Per Unit	Square Meters Per Unit	Hectares Per Unit
in^2	Square inch	1	0.006944	0.0007716	—	6.4516	0.000645	—
ft^2	Square foot	144	1	0.111111	—	929.034	0.0929	—
yd^2	Square yard	1296	9	1	—	8361.274	0.836127	—
—	^{1} Acre	—	43560	4840	1	—	4047	0.4047
cm^2	Sq. Centimeter	.15500	0.0010764	0.00011960	—	1	0.0001	—
m^2	Square meter	1550.0031	10.76391	1.195990	—	10000	1	0.0001
—	Hectares	—	—	11954.8	2.47	—	1000	1

1) 640 Acres = 1 square mile
e.g. 1 square meter = 1.195990 square yards so 30 square meters would be (30 m2) (1.195990 yd^2/m^2) = 35.88 yd^2

Cubic Measure

Symbol	Unit	Cubic Inches Per Unit	Cubic Feet Per Unit	Cubic Yards Per Unit	Cubic Centimeters Per Unit	Cubic Meters Per Unit
cu in	Cubic inch	1	.0005787	.00002143	16.387064	.000016387
cu ft	Cubic foot	1728	1	.037037	28316.847	.018317
cu yard	Cubic yard	46656	27	1	764554.9	.7646
cu cm or cm^3	Cu Centimeter	0.0610237	.0000353	.000001308	1	.000001
cu m or m^3	Cubic meter	61023.74	35.31467	1.307951	1,000,000	1

e.g. 1 m^3 = 1.307951cu yds, so 3 cubic meters would be (3 m^3) (1.307942 cu yd/m^3) = 3.923853 cu yd

Liquid Measure

Symbol	Unit	Fluid Ounces Per Unit	Pints Per Unit	Quarts Per Unit	Gallons Per Unit	Liters Per Unit
fl oz	Fluid Ounces	1	.0625	.03125	.0078125	.02957
—	Pint	16	1	.5	.125	.4732
l.qt	Quart	32	2	1	.25	.9464
gal	Gallons	128	8	4	1	3.7854
l	Liter	33.814	2.1134	1.0567	.26417	1

e.g. 1 Liter = .26418 gallons, so 4 liters would be (4l) (.26418 gal/l) = 1.05672 gal

Weights

Symbol	Unit	Grain Units	Grams Per Unit	Troy Ounces Per Unit	Avoirdupois Ounces Per Unit	Troy Pounds Per Unit	Avoirdupois Pounds Per Unit	Kilograms Per Unit	Metric Tons Per Unit	Avoirdupois Tons Per Unit	Per Unit
gr	Grain	1	.0648	.002083	.002286	.0001736	.0001429	—	—	—	
g	Gram	15.4324	1	.032151	.035274	.002679	.002205	.001	—	—	
oz. t.	Ounce Troy	480	31.1035	1	1.09715	.083333	.068571	.031103	—	—	
oz. av.	Ounce Av.	437.5	28.3495	.911458	1	.075955	.0625	.028350	—	—	
lb. t.	Pound Troy	5760	373.242	12	13.1657	1	.822857	.37324	.000373	.000411	
lb. av.	Pound Av.	7000	453.59	14.5833	16	1.215278	1	.45359	.000454	.00050	
kg	Kilograms	—	1000	32.1507	35.274	2.67923	2.20462	1	.001	.001102	
—	Ton Metric	—	—	32150.7	35274	2679.23	2204.62	1000	1	1.10231	
—	Ton Av.	—	—	29166.7	32000	2430.56	2000	907.185	.907185	1	

e.g. 1 gram = .032151 troy ounces, so 40 grams would be (40 g) (.032151 oz.t./g) = 1.28604 oz.t.

Fractions to Decimals to Millimeters

Fraction	Decimal	mm	Fraction	Decimal	mm
1/64	0.0156	0.3969	33/64	0.5156	13.0969
1/32	0.0312	0.7938	17/32	0.5312	13.4938
3/64	0.0469	1.1906	35/64	0.5469	13.8906
1/16	0.0625	1.5875	9/16	0.5625	14.2875
5/64	0.0781	1.9844	37/64	0.5781	14.6844
3/32	0.0938	2.3812	19/32	0.5938	15.0812
7/64	0.1094	2.7781	39/64	0.6094	15.4781
1/8	0.1250	3.1750	5/8	0.6250	15.8750
9/64	0.1406	3.5719	41/64	0.6406	16.2719
5/32	0.1562	3.9688	21/32	0.6562	16.6688
11/64	0.1719	4.3656	43/64	0.6719	17.0656
3/16	0.1875	4.7625	11/16	0.6875	17.4625
13/64	0.2031	5.1594	45/64	0.7031	17.8594
7/32	0.2188	5.5562	23/32	0.7188	18.2562
15/64	0.2344	5.9531	47/64	0.7344	18.6531
1/4	0.2500	6.3500	3/4	0.7500	19.0500
17/64	0.2656	6.7469	49/64	0.7656	19.4469
9/32	0.2812	7.1438	25/32	0.7812	19.8438
19/64	0.2969	7.5406	51/64	0.7969	20.2406
5/16	0.3125	7.9375	13/16	0.8125	20.6375
21/64	0.3281	8.3344	53/64	0.8281	21.0344
11/32	0.3438	8.7312	27/32	0.8438	21.4312
23/64	0.3594	9.1281	55/64	0.8594	21.8281
3/8	0.3750	9.5250	7/8	0.8750	22.2250
25/64	0.3906	9.9219	57/64	0.8906	22.6219
13/32	0.4062	10.3188	29/32	0.9062	23.0188
27/64	0.4219	10.7156	59/64	0.9219	23.4156
7/16	0.4375	11.1125	15/16	0.9375	23.8125
29/64	0.4531	11.5094	61/64	0.9531	24.2094
15/32	0.4688	11.9062	31/32	0.9688	24.6062
31/64	0.4844	12.3031	63/64	0.9844	25.0031
1/2	0.5000	12.7000	1	1.0000	25.4000

Decimals to Millimeters

Decimal	mm	Decimal	mm
0.001	0.0254	0.500	12.700
0.002	0.0508	0.510	12.9540
0.003	0.0762	0.520	13.2080
0.004	0.1016	0.530	13.4620
0.005	0.1270	0.540	13.7160
0.006	0.1524	0.550	13.9700
0.007	0.1778	0.560	14.2240
0.008	0.2032	0.570	14.4780
0.009	0.2286	0.580	14.7320
0.010	0.2540	0.590	14.9860
0.020	0.5080		
0.030	0.7620		
0.040	1.0160	0.600	15.2400
0.050	1.2700	0.610	15.4940
0.060	1.5240	0.620	15.7480
0.070	1.7780	0.630	16.0020
0.080	2.0320	0.640	16.2560
0.090	2.2860	0.650	16.5100
		0.660	16.7640
0.100	2.5400	0.670	17.0180
0.110	2.7940	0.680	17.2720
0.120	3.0480	0.690	17.5260
0.130	3.3020		
0.140	3.5560		
0.150	3.8100		
0.160	4.0640	0.700	17.7800
0.170	4.3180	0.710	18.0340
0.180	4.5720	0.720	18.2880
0.190	4.8260	0.730	18.5420
		0.740	18.7960
0.200	5.0800	0.750	19.0500
0.210	5.3340	0.760	19.3040
0.220	5.5880	0.770	19.5580
0.230	5.8420	0.780	19.8120
0.240	6.0960	0.790	20.0660
0.250	6.3500		
0.260	6.6040		
0.270	6.8580		
0.280	7.1120	0.800	20.3200
0.290	7.3660	0.810	20.5740
		0.820	20.8280
0.300	7.6200	0.830	21.0820
0.310	7.8740	0.840	21.3360
0.320	8.1280	0.850	21.5900
0.330	8.3820	0.860	21.8440
0.340	8.6360	0.870	22.0980
0.350	8.8900	0.880	22.3520
0.360	9.1440	0.890	22.6060
0.370	9.3980		
0.380	9.6520		
0.390	9.9060	0.900	22.8600
0.400	10.1600	0.910	23.1140
0.410	10.4140	0.920	23.3680
0.420	10.6680	0.930	23.6220
0.430	10.9220	0.940	23.8760
0.440	11.1760	0.950	23.1300
0.450	11.4300	0.960	24.3840
0.460	11.6840	0.970	24.6380
0.470	11.9380	0.980	24.8920
0.480	12.1920	0.990	25.1460
0.490	12.4460	1.000	25.4000