

Appendix A: Physical Constants and Conversion Factors

PHYSICAL CONSTANTS

Avogadro's number, $N_A = 6.023 \times 10^{26}$ molecules/kgmole
 Boltzmann's constant, $k = 1.381 \times 10^{-23}$ J/(molecule·K)
 Electron charge, $e = 1.602 \times 10^{-19}$ C
 Electron mass, $m_e = 9.110 \times 10^{-31}$ kg
 Faraday's constant, $F = 96,487$ kC/kgmole electrons = 96,487 kJ/(V·kgmole electrons)
 Gravitational acceleration (standard), $g = 32.174$ ft/s² = 9.807 m/s²
 Gravitational constant, $k_G = 6.67 \times 10^{-11}$ m³/(kg·s²)
 Newton's second law constant, $g_c = 32.174$ lbm·ft/(lbf·s²) = 1.0 kg·m/(N·s²)
 Planck's constant, $\hbar = 6.626 \times 10^{-34}$ J·s/molecule
 Stefan-Boltzmann constant, $\sigma = 0.1714 \times 10^{-8}$ Btu/(h·ft²·R⁴) = 5.670 × 10⁻⁸ W/(m²·k⁴)
 Universal gas constant $\mathfrak{R} = 1545.35$ ft·lbf/(lbmole·R) = 8314.3 J/(kgmole·K)
 = 8.3143 kJ/(kgmole·K) = 1.9858 Btu/(lbmole·R)
 = 1.9858 kcal/(kgmole·K) = 1.9858 cal/(gmole·K)
 = 0.08314 bar·m³/(kgmole·K) = 82.05 L·atm/(kgmole·K)
 Velocity of light in a vacuum, $c = 9.836 \times 10^8$ ft/s = 2.998 × 10⁸ m/s

UNIT DEFINITIONS

1 coulomb (C) = 1 A·s	1 ohm (Ω) = 1 V/A
1 dyne = 1 g·cm/s ²	1 pascal (Pa) = 1 N/m ²
1 erg = 1 dyne·cm	1 poundal = 1 lbm·ft/s ²
1 farad (F) = 1 C/V	1 siemens (S) = 1 A/V
1 henry (H) = 1 Wb/A	1 slug = 1 lbf·s ² /ft
1 hertz (Hz) = 1 cycle/s	1 tesla (T) = 1 Wb/m ²
1 joule (J) = 1 N·m	1 volt (V) = 1 W/A
1 lumen = 1 candela·steradian	1 watt (W) = 1 J/s
1 lux = 1 lumen/m ²	1 weber (Wb) = 1 V·s
1 newton (N) = 1 kg·m/s ²	

CONVERSION FACTORS

Length	Energy
1 m = 3.2808 ft = 39.37 in = 10 ² cm = 10 ¹⁰ Å	1 J = 1 N·m = 1 kg·m ² /s ² = 9.479 × 10 ⁻⁴ Btu
1 cm = 0.0328 ft = 0.394 in = 10 ⁻² m = 10 ⁸ Å	1 kJ = 1000 J = 0.9479 Btu = 238.9 cal
1 mm = 10 ⁻³ m = 10 ⁻¹ cm	1 Btu = 1055.0 J = 1.055 kJ = 778.16 ft·lbf = 252 cal
1 km = 1000 m = 0.6215 miles = 3281 ft	1 cal = 4.186 J = 3.968 × 10 ⁻³ Btu
1 in = 2.540 cm = 0.0254 m	1 Cal (in food value) = 1 kcal = 4186 J = 3.968 Btu
1 ft = 12 in = 0.3048 m	1 erg = 1 dyne·cm = 1 g·cm ² /s ² = 10 ⁻⁷ J
1 mile = 5280 ft = 1609.36 m = 1.609 km	1 eV = 1.602 × 10 ⁻¹⁹ J

(Continued)

CONVERSION FACTORS (Continued)

Area

$$1 \text{ m}^2 = 10^4 \text{ cm}^2 = 10.76 \text{ ft}^2 = 1550 \text{ in}^2$$

$$1 \text{ ft}^2 = 144 \text{ in}^2 = 0.0929 \text{ m}^2 = 929.05 \text{ cm}^2$$

$$1 \text{ cm}^2 = 10^{-4} \text{ m}^2 = 1.0764 \times 10^{-3} \text{ ft}^2 = 0.155 \text{ in}^2$$

$$1 \text{ in}^2 = 6.944 \times 10^{-3} \text{ ft}^2 = 6.4516 \times 10^{-4} \text{ m}^2 = 6.4516 \text{ cm}^2$$

Volume

$$1 \text{ m}^3 = 35.313 \text{ ft}^3 = 6.1023 \times 10^4 \text{ in}^3 = 1000 \text{ L} = 264.171 \text{ gal}$$

$$1 \text{ L} = 10^{-3} \text{ m}^3 = 0.0353 \text{ ft}^3 = 61.03 \text{ in}^3 = 0.2642 \text{ gal}$$

$$1 \text{ gal} = 231 \text{ in}^3 = 0.13368 \text{ ft}^3 = 3.785 \times 10^{-3} \text{ m}^3$$

$$1 \text{ ft}^3 = 1728 \text{ in}^3 = 28.3168 \text{ L} = 0.02832 \text{ m}^3 = 7.4805 \text{ gal}$$

$$1 \text{ in}^3 = 16.387 \text{ cm}^3 = 1.6387 \times 10^{-5} \text{ m}^3 = 4.329 \times 10^{-3} \text{ gal}$$

Mass

$$1 \text{ kg} = 1000 \text{ g} = 2.2046 \text{ lbm} = 0.0685 \text{ slug}$$

$$1 \text{ lbm} = 453.6 \text{ g} = 0.4536 \text{ kg} = 3.108 \times 10^{-2} \text{ slug}$$

$$1 \text{ slug} = 32.174 \text{ lbm} = 1.459 \times 10^4 \text{ g} = 14.594 \text{ kg}$$

Force

$$1 \text{ N} = 10^5 \text{ dyne} = 1 \text{ kg} \cdot \text{m}/\text{s}^2 = 0.225 \text{ lbf}$$

$$1 \text{ lbf} = 4.448 \text{ N} = 32.174 \text{ poundals}$$

$$1 \text{ poundal} = 0.138 \text{ N} = 3.108 \times 10^{-2} \text{ lbf}$$

Power

$$1 \text{ W} = 1 \text{ J}/\text{s} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^3 = 3.412 \text{ Btu}/\text{h} = 1.3405 \times 10^{-3} \text{ hp}$$

$$1 \text{ kW} = 1000 \text{ W} = 3412 \text{ Btu}/\text{h} = 737.3 \text{ ft} \cdot \text{lbf}/\text{s} = 1.3405 \text{ hp}$$

$$1 \text{ Btu}/\text{h} = 0.293 \text{ W} = 0.2161 \text{ ft} \cdot \text{lbf}/\text{s} = 3.9293 \times 10^{-4} \text{ hp}$$

$$1 \text{ hp} = 550 \text{ ft} \cdot \text{lbf}/\text{s} = 33000 \text{ ft} \cdot \text{lbf}/\text{min} = 2545 \text{ Btu}/\text{h} = 746 \text{ W}$$

Pressure

$$1 \text{ Pa} = 1 \text{ N}/\text{m}^2 = 1 \text{ kg}/(\text{m} \cdot \text{s}^2) = 1.4504 \times 10^{-4} \text{ lbf}/\text{in}^2$$

$$1 \text{ lbf}/\text{in}^2 = 6894.76 \text{ Pa} = 0.068 \text{ atm} = 2.036 \text{ in Hg}$$

$$1 \text{ atm} = 14.696 \text{ lbf}/\text{in}^2 = 1.01325 \times 10^5 \text{ Pa}$$

$$= 101.325 \text{ kPa} = 760 \text{ mm Hg}$$

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.987 \text{ atm} = 14.504 \text{ lbf}/\text{in}^2$$

$$1 \text{ dyne}/\text{cm}^2 = 0.1 \text{ Pa} = 10^{-6} \text{ bar} = 145.04 \times 10^{-7} \text{ lbf}/\text{in}^2$$

$$1 \text{ in Hg} = 3376.8 \text{ Pa} = 0.491 \text{ lbf}/\text{in}^2$$

$$1 \text{ in H}_2\text{O} = 248.8 \text{ Pa} = 0.0361 \text{ lbf}/\text{in}^2$$

MISCELLANEOUS UNIT CONVERSIONS

Specific Heat Units

$$1 \text{ Btu}/(\text{lbm} \cdot ^\circ\text{F}) = 1 \text{ Btu}/(\text{lbm} \cdot \text{R})$$

$$1 \text{ kJ}/(\text{kg} \cdot \text{K}) = 0.23884 \text{ Btu}/(\text{lbm} \cdot \text{R}) = 185.8 \text{ ft} \cdot \text{lbf}/(\text{lbm} \cdot \text{R})$$

$$1 \text{ Btu}/(\text{lbm} \cdot \text{R}) = 778.16 \text{ ft} \cdot \text{lbf}/(\text{lbm} \cdot \text{R}) = 4.186 \text{ kJ}/(\text{kg} \cdot \text{K})$$

Energy Density Units

$$1 \text{ kJ}/\text{kg} = 1000 \text{ m}^2/\text{s}^2 = 0.4299 \text{ Btu}/\text{lbm}$$

$$1 \text{ Btu}/\text{lbm} = 2.326 \text{ kJ}/\text{kg} = 2326 \text{ m}^2/\text{s}^2$$

Energy Flux

$$1 \text{ W}/\text{m}^2 = 0.317 \text{ Btu}/(\text{h} \cdot \text{ft}^2)$$

$$1 \text{ Btu}/(\text{h} \cdot \text{ft}^2) = 3.154 \text{ W}/\text{m}^2$$

Heat Transfer Coefficient

$$1 \text{ W}/(\text{m}^2 \cdot \text{K}) = 0.1761 \text{ Btu}/(\text{h} \cdot \text{ft}^2 \cdot \text{R})$$

$$1 \text{ Btu}/(\text{h} \cdot \text{ft}^2 \cdot \text{R}) = 5.679 \text{ W}/(\text{m}^2 \cdot \text{K})$$

Thermal Conductivity

$$1 \text{ W}/(\text{m} \cdot \text{K}) = 0.5778 \text{ Btu}/(\text{h} \cdot \text{ft} \cdot \text{R})$$

$$1 \text{ Btu}/(\text{h} \cdot \text{ft} \cdot \text{R}) = 1.731 \text{ W}/(\text{m} \cdot \text{K})$$

Temperature

$$T(^{\circ}\text{F}) = \frac{9}{5} T(^{\circ}\text{C}) + 32 = T(\text{R}) - 459.67$$

$$T(^{\circ}\text{C}) = \frac{5}{9} [T(^{\circ}\text{F}) - 32] = T(\text{K}) - 273.15$$

$$T(\text{R}) = \frac{9}{5} T(\text{K}) = (1.8)T(\text{K}) = T(^{\circ}\text{F}) + 459.67$$

$$T(\text{K}) = \frac{5}{9} T(\text{R}) = T(\text{R})/1.8 = T(^{\circ}\text{C}) + 273.15$$

Density

$$1 \text{ lbm}/\text{ft}^3 = 16.0187 \text{ kg}/\text{m}^3$$

$$1 \text{ kg}/\text{m}^3 = 0.062427 \text{ lbm}/\text{ft}^3 = 10^{-3} \text{ g}/\text{cm}^3$$

$$1 \text{ g}/\text{cm}^3 = 1 \text{ kg}/\text{L} = 62.4 \text{ lbm}/\text{ft}^3 = 10^3 \text{ kg}/\text{m}^3$$

Viscosity

$$1 \text{ Pa} \cdot \text{s} = 1 \text{ N} \cdot \text{s}/\text{m}^2 = 1 \text{ kg}/(\text{m} \cdot \text{s}) = 10 \text{ poise}$$

$$1 \text{ poise} = 1 \text{ dyne} \cdot \text{s}/\text{cm}^2 = 1 \text{ g}/(\text{cm} \cdot \text{s}) = 0.1 \text{ Pa} \cdot \text{s}$$

$$1 \text{ poise} = 2.09 \times 10^{-3} \text{ lbf} \cdot \text{s}/\text{ft}^2 = 6.72 \times 10^{-2} \text{ lbm}/(\text{ft} \cdot \text{s})$$

$$1 \text{ centipoise} = 0.01 \text{ poise} = 10^{-3} \text{ Pa} \cdot \text{s}$$

$$1 \text{ lbf} \cdot \text{s}/\text{ft}^2 = 1 \text{ slug}/(\text{ft} \cdot \text{s}) = 47.9 \text{ Pa} \cdot \text{s} = 479 \text{ poise}$$

$$1 \text{ stoke} = 1 \text{ cm}^2/\text{s} = 10^{-4} \text{ m}^2/\text{s} = 1.076 \times 10^{-3} \text{ ft}^2/\text{s}$$

$$1 \text{ centistoke} = 0.01 \text{ stoke} = 10^{-6} \text{ m}^2/\text{s} = 1.076 \times 10^{-5} \text{ ft}^2/\text{s}$$

$$1 \text{ m}^2/\text{s} = 10^4 \text{ stoke} = 10^6 \text{ centistoke} = 10.76 \text{ ft}^2/\text{s}$$