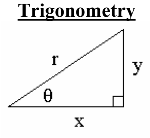
Useful Formulae and Constants

Trigonometry



$$\sin\theta = \frac{y}{r} \qquad \cos\theta = \frac{x}{r}$$

$$\tan\theta = \frac{y}{x}$$

$$\sin^2\theta + \cos^2\theta = 1$$

$$\sin 2\theta = 2\sin\theta\cos\theta$$

$$\cos 2\theta = \cos^2\theta - \sin^2\theta$$

$$x^2 + y^2 = r^2$$

Quadratic Formula

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Circle

$$A = \pi r^2$$

$$C = 2\pi r$$

Sphere

$$A = 4\pi r^2$$

$$V = \frac{4}{3}\pi r^3$$

Units

$$1 \text{ in} = 2.54 \text{ cm}$$

$$1 \text{ mile} = 1.61 \text{ km}$$

$$1 \text{ liter} = 1000 \text{ cm}^3$$

One-Dimensional Motion

$$\bar{v} = \frac{v_1 + v_0}{2} = \frac{\Delta x}{\Delta t}$$

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

$$v(t) = v_0 + at$$

$$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

Forces

$$\sum \mathbf{F} = m\mathbf{a}$$

$$F_{kf} = \mu_k F_n \qquad F_{sf} \le \mu_s F_n$$

$$F_s = -kx$$

Uniform Circular Motion

$$a_c = \frac{v^2}{r}$$

$$v = \frac{2\pi r}{T} \qquad T = \frac{1}{f}$$

Gravity

$$F = G\frac{m_1 m_2}{r^2}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right)R^3$$

$$G = 6.67 \times 10^{-11}\,\frac{\text{Nm}^2}{\text{kg}^2}$$

$$g = 9.80\,\frac{\text{m}}{\text{s}^2}$$

Useful Formulae and Constants

Work, Energy, and Power

$$W = \vec{F} \bullet \vec{d} = Fd\cos\theta$$

$$KE = \frac{1}{2}mv^2$$

$$PE_{grav} = mgy \text{ (near surface)}$$

$$PE_{elastic} = \frac{1}{2}kx^2$$

$$W_{NC} = \Delta KE + \Delta PE$$

$$P = \frac{\text{Work}}{\text{Time}} = \frac{W}{\Delta t} = \vec{F} \bullet \vec{v}$$

Momentum and Impulse

$$\mathbf{p} = m\mathbf{v}$$

$$J = \Delta \text{p} = \text{F}\Delta t = \int \vec{F}dt$$

Conservation of Momentum

$$m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = m_1\mathbf{v}_1' + m_2\mathbf{v}_2'$$

1-Dimensional Elastic Collision

$$v_1 - v_2 = -(v_1' - v_2')$$

Rotational Kinematics

$$1\text{ rev} = 2\pi \text{ rad} = 360^0$$

$$\bar{\omega} = \frac{\Delta\theta}{\Delta t}, \qquad \bar{\alpha} = \frac{\Delta\omega}{\Delta t}$$

$$s = \theta r, \quad v = \omega r, \quad a_T = \alpha r$$

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

Rotational Dynamics

Torque: $\tau = \vec{r} \times \vec{F}$

magnitude: $\tau = rF\sin\theta$

direction: right-hand rule

$$I = \sum m_i r_i^2, \; I = \int r^2 dm$$

$$L = I\omega$$

$$KE_{rot} = 1/2 I\omega^2$$

$$I_{rod} = mr^2/12$$

Useful Formulae and Constants

Center of Mass

$$x_{CM} = \frac{\sum m_i x_i}{\sum m_i}$$

Static Equilibrium

$$\Sigma F = 0 \qquad \Sigma \tau = 0$$

Fluids

$$\rho = m/V \qquad SG = \rho / \rho_{water}$$

$$P = F / A$$

$$P = P_0 + \rho g h$$

$$P_G = P - P_0$$

$$P_0 = 1\text{atm} = 1.013 \times 10^5 \text{ Pa}$$

$$F_{Bouyant} = \rho_{fluid} \cdot V_{displaced} \cdot g$$

$$Av = \text{constant}$$

$$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

Constants

Water:

$$c_W = 4190 J/(kg\,^oC)$$

$$c_I = 2100 J/(kg\,^oC)$$

$$L_f = 334 \bullet (10)^3 J/kg$$

$$L_v = 2256 \bullet (10)^3 J/kg$$

Standard P and T:

$$P = P_{atm}$$

$$T = 0^o C = 273 K$$

$$P_m = \frac{m}{L} \ldots\ldots\ldots\ldots\ldots\ldots$$

$$P_{ABCD} = P_A P_B P_C P_D \ldots\ldots\ldots\ldots$$

$$W_{AB} = \frac{(A+B)!}{A!B!} \ldots\ldots\ldots\ldots$$

$$\bar{x} = \langle x \rangle = \sum_{i=1}^{N} x_i P_i \ldots\ldots\ldots\ldots$$

$$\bar{f} = \langle f(x) \rangle = \sum_{i=1}^{N} f(x_i) P_i \ldots\ldots\ldots\ldots$$

$$\sigma = \sqrt{\left\langle \left(x - \bar{x}\right)^2 \right\rangle} = \sqrt{\sum^{N} x_i^2 P_i - \left(\bar{x}\right)^2}.$$

$$w = \frac{n!}{R!(n-r)!}$$

Useful Formulae and Constant

Temperature

$$T_C = \frac{5}{9}\left(T_F - 32\right) \qquad T_K = T_C + 273$$

$$\langle x^2 \rangle \propto t \ldots\ldots\ldots\ldots \Delta x_{RMS} = \sqrt{2Dt}$$

$$\lambda = \frac{1}{4\sqrt{2}\pi (N/V) r^2}$$

Idea Gas Law

$$\langle KE \rangle = \frac{1}{2} m \langle v^2 \rangle = \frac{3}{2} kT$$

$$v_{rms} = \sqrt{(v^2)_{ave}} = \sqrt{3kT/m}$$

$$PV = nRT = NkT$$

$$n = N / N_A \qquad m = nM$$

$$R = 8.315 \text{ J/(mol} \cdot \text{K)}$$

$$k = 1.38 \times 10^{-23} \text{ J/K}$$

$$N_A = 6.02 \times 10^{23} \text{ /mol}$$

$$P_0 = 1\text{atm} = 1.013 \times 10^5 \text{ Pa}$$

Heat

specific heat $Q = mc\Delta T$

latent heat $Q = mL$

$$1 \text{ cal} = 4.186 \text{ J}$$

$$1 amu = 1.66 x 10^{-27} kg$$

$$H = \frac{dQ}{dt} = kA\frac{T_H - T_L}{L} \qquad H = e\sigma A T^4$$

$$\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4)$$

Thermodynamics

internal energy $\Delta U = nC_V \Delta T$

first law $\Delta E = Q + W$

$$W = \int_{V_A}^{V_B} PdV$$

$$C_P = C_V + R, \qquad \gamma = C_P / C_V$$

Ideal, monotonic gas: $C_V = (3/2)R$
Ideal, diatomic gas: $C_V = (5/2)R$
Ideal monotonic solid: $C_V = 3R$

Isothermal process (constant T)
Isobaric process (constant P)
Isochoric process (constant V)
Adiabatic process (Q=0,
PV^{γ}=const, $TV^{\gamma-1}$ = diff const)
Free expansion (Q=0, W=0)

heat engine $Q_H = Q_C + W$

efficiency $\eta \equiv \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$

CoP $K \equiv \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$

$$W = k_B T \ln\left(V_f / V_i\right)$$

Entropy $\Delta S = \int \frac{dQ}{T}, \qquad S = k \ln w$