

Important Prefixes: nano = 10^{-9} , micro = 10^{-6} , milli = 10^{-3} , kilo = 10^3 , mega = 10^6 , giga = 10^9

Physical Constants and Properties: $g = 9.81 \text{ m/s}^2$, $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$,

$$M_{\text{Earth}} = 5.97 \times 10^{24} \text{ kg}, \quad R_{\text{Earth}} = 6.37 \times 10^6 \text{ m}, \quad \rho_{\text{water}} = 1000 \text{ kg/m}^3, \quad \rho_{\text{seawater}} = 1030 \text{ kg/m}^3,$$

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}, \quad v_{\text{sound air } 20^\circ\text{C}} = 343 \text{ m/s}$$

Geometry: (circle circumference) = $2\pi r$, (circle area) = πr^2 , (cylinder volume) = $\pi r^2 h$,

$$(\text{sphere area}) = 4\pi r^2, \quad (\text{sphere volume}) = \frac{4}{3}\pi r^3$$

Vectors: $\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$, $|\vec{A}| = A = \sqrt{A_x^2 + A_y^2 + A_z^2}$, $\vec{A} \cdot \vec{B} = AB \cos \phi = A_x B_x + A_y B_y + A_z B_z$

$$|\vec{A} \times \vec{B}| = AB \sin \phi, \quad (\vec{A} \times \vec{B})_x = A_y B_z - A_z B_y, \quad (\vec{A} \times \vec{B})_y = A_z B_x - A_x B_z, \quad (\vec{A} \times \vec{B})_z = A_x B_y - A_y B_x$$

Calculus: $\frac{d}{dx}(uv) = \left(\frac{du}{dx}\right)v + u\left(\frac{dv}{dx}\right)$ (product rule), $\frac{df}{dx} = \frac{df}{du} \frac{du}{dx}$ (chain rule),

$$\frac{d}{dx}x^n = nx^{n-1}, \quad \frac{d}{dx}e^x = e^x, \quad \frac{d}{dx}\ln x = \frac{1}{x}, \quad \frac{d}{dx}\sin x = \cos x, \quad \frac{d}{dx}\cos x = -\sin x$$

$$\int x^n dx = \frac{1}{n+1}x^{n+1} \quad (n \neq -1), \quad \int e^x dx = e^x, \quad \int \frac{dx}{x} = \ln|x|, \quad \int \cos x dx = \sin x, \quad \int \sin x dx = -\cos x$$

Kinematics: $\Delta x = x_f - x_i$, $v_{\text{av } x} = \frac{\Delta x}{\Delta t}$, $v_x = \frac{dx}{dt}$, $\Delta x = \int_{t_i}^{t_f} v_x dt$, $\text{speed}_{\text{av}} = \frac{s}{\Delta t}$, $a_{\text{av } x} = \frac{\Delta v_x}{\Delta t}$,

$$a_x = \frac{dv_x}{dt}, \quad \Delta v_x = \int_{t_i}^{t_f} a_x dt, \quad v_x = v_{0x} + a_x t, \quad x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2, \quad v_x^2 = v_{0x}^2 + 2a_x \Delta x,$$

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}, \quad \vec{v} = \frac{d\vec{r}}{dt}, \quad \vec{a} = \frac{d\vec{v}}{dt}, \quad \vec{v} = \vec{v}_0 + \vec{a}t, \quad \vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2, \quad \vec{v}_{\text{AB}} = -\vec{v}_{\text{BA}},$$

$$\vec{v}_{\text{PB}} = \vec{v}_{\text{PA}} + \vec{v}_{\text{AB}}, \quad v = \frac{2\pi r}{T}, \quad a_c = \frac{v^2}{r}, \quad a_t = \frac{dv}{dt}$$

Forces: $\vec{F}_{\text{net}} = m\vec{a}$, $\vec{F}_{\text{BA}} = -\vec{F}_{\text{AB}}$, $\vec{F}_g = m\vec{g}$, $F_x = -kx$, $f_s \leq f_{s \text{ max}}$, $f_{s \text{ max}} = \mu_s F_n$,

$$f_k = \mu_k F_n, \quad f_r = \mu_r F_n, \quad F_d = bv^n, \quad v_T = \left(\frac{mg}{b}\right)^{1/n}, \quad F_{\text{net } c} = m a_c = \frac{mv^2}{r}, \quad F_{\text{net } t} = m a_t,$$

$$M\vec{r}_{\text{cm}} = m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots, \quad M\vec{v}_{\text{cm}} = m_1\vec{v}_1 + m_2\vec{v}_2 + \cdots, \quad M\vec{a}_{\text{cm}} = m_1\vec{a}_1 + m_2\vec{a}_2 + \cdots,$$

$$M\vec{r}_{\text{cm}} = \int \vec{r} dm, \quad \vec{F}_{\text{net ext}} = \sum_i \vec{F}_{i \text{ ext}} = M\vec{a}_{\text{cm}}$$

Energy: $W = \int_i^f \vec{F} \cdot d\vec{\ell} = \int_i^f F_{\parallel} d\ell$, $W = \vec{F} \cdot \vec{\ell} = F_{\parallel} \ell = F \ell_{\parallel} = F \ell \cos \theta$, $W = F_x \Delta x = F |\Delta x| \cos \theta$,

$$W = \int_{x_i}^{x_f} F_x dx, \quad K = \frac{1}{2}mv^2, \quad W_{\text{total}} = \Delta K, \quad P_{\text{av}} = \frac{W}{\Delta t}, \quad P = \frac{dW}{dt} = \vec{F} \cdot \vec{v}, \quad \Delta U = -W = -\int_i^f \vec{F} \cdot d\vec{\ell},$$

$$U_g = U_0 + mgy, \quad U_{\text{spring}} = \frac{1}{2}kx^2, \quad F_x = -\frac{dU}{dx}, \quad E_{\text{mech}} = K_{\text{sys}} + U_{\text{sys}}, \quad K_f + U_f = K_i + U_i,$$

$$W_{\text{ext}} = \Delta E_{\text{mech}} - W_{\text{nc}}, \quad W_{\text{ext}} = \Delta E_{\text{sys}} = \Delta E_{\text{mech}} + \Delta E_{\text{therm}} + \Delta E_{\text{chem}} + \Delta E_{\text{other}}, \quad \Delta E_{\text{therm}} = f_k s_{\text{rel}}$$

Momentum: $\vec{p} = m\vec{v}, \quad K = \frac{p^2}{2m}, \quad \vec{F}_{\text{net}} = \frac{d\vec{p}}{dt}, \quad \vec{P}_{\text{sys}} = M\vec{v}_{\text{cm}}, \quad \vec{F}_{\text{net ext}} = \frac{d\vec{P}_{\text{sys}}}{dt}, \quad \vec{I} = \int_{t_i}^{t_f} \vec{F} dt,$

$$\vec{I} = \vec{F}_{\text{av}} \Delta t, \quad \vec{I}_{\text{net}} = \int_{t_i}^{t_f} \vec{F}_{\text{net}} dt = \Delta \vec{p}, \quad \vec{P}_{\text{sys f}} = \vec{P}_{\text{sys i}} \quad (\text{isolated system})$$

Rotation: $s = r\theta, \quad \omega = \frac{d\theta}{dt} = \frac{2\pi}{T} = 2\pi f, \quad v_t = r\omega, \quad \alpha = \frac{d\omega}{dt}, \quad a_t = r\alpha, \quad \omega = \omega_0 + \alpha t,$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2, \quad \omega^2 = \omega_0^2 + 2\alpha\Delta\theta, \quad I = \int r^2 dm, \quad dm = \lambda dx, \quad I_{\text{particle}} = mr^2, \quad I_{\text{hoop}} = MR^2,$$

$$I_{\text{rod center}} = \frac{1}{12}ML^2, \quad I_{\text{rod end}} = \frac{1}{3}ML^2, \quad I_{\text{disk}} = \frac{1}{2}MR^2, \quad I_{\text{solid sphere}} = \frac{2}{5}MR^2,$$

$$I_{\text{spherical shell}} = \frac{2}{3}MR^2, \quad I = I_{\text{cm}} + Mh_{\text{axis} \rightarrow \text{cm}}^2, \quad K_{\text{rot}} = \frac{1}{2}I\omega^2, \quad \tau = F_t r = rF \sin \phi = F\ell, \quad \tau_{\text{net ext}} = I\alpha,$$

$$W = \int_{\theta_i}^{\theta_f} \tau d\theta, \quad P = \tau\omega, \quad K_{\text{roll}} = \frac{1}{2}I_{\text{cm}}\omega^2 + \frac{1}{2}Mv_{\text{cm}}^2, \quad v_{\text{cm}} = \omega R, \quad a_{\text{cm}} = \alpha R, \quad \vec{\tau} = \vec{r} \times \vec{F},$$

$$\vec{L}_{\text{particle}} = \vec{r} \times \vec{p}, \quad |\vec{L}_{\text{particle}}| = rp \sin \phi, \quad \vec{L}_{\text{rigid body}} = I\vec{\omega}, \quad \vec{\tau}_{\text{net ext}} = \frac{d\vec{L}_{\text{sys}}}{dt}, \quad \vec{L}_i = \vec{L}_f \quad (\text{isolated system})$$

Gravitation: $\vec{F} = -\frac{Gm_1 m_2}{r_{12}^2} \hat{r}_{12}, \quad U = -\frac{GMm}{r}, \quad T^2 = \frac{4\pi^2}{GM} r^3$

Fluids: $\rho_{\text{av}} = \frac{m}{V}, \quad P = \frac{F}{A}, \quad P = P_{\text{gauge}} + P_{\text{at}}, \quad P = P_0 + \rho g \Delta h, \quad B = \rho_{\text{fluid}} V_{\text{fluid}} g$

Oscillations: $x = A \cos(\omega t + \delta), \quad \omega = \frac{2\pi}{T} = 2\pi f, \quad \omega = \sqrt{\frac{k}{m}}, \quad \omega = \sqrt{\frac{g}{L}}, \quad \omega = \sqrt{\frac{MgD}{I}},$

$$E = K + U = \frac{1}{2}kA^2 = \frac{1}{2}mv_{\text{max}}^2,$$

Waves: $v_{\text{string}} = \sqrt{\frac{F_T}{\mu}}, \quad v_{\text{sound}} = \sqrt{\frac{B}{\rho}}, \quad \mu = \frac{M}{L}, \quad y(x, t) = A \sin(kx \pm \omega t + \delta), \quad k = \frac{2\pi}{\lambda},$

$$v = \frac{\lambda}{T} = \lambda f = \frac{\omega}{k}, \quad P_{\text{av}} = \frac{1}{2}\mu v \omega^2 A^2, \quad I = \frac{P_{\text{av}}}{A} = \frac{P_{\text{av}}}{4\pi r^2} \quad (\text{spherical wave}), \quad f_r = \left(\frac{v \pm u_r}{v \mp u_s} \right) f_s,$$

$$y = y_1 + y_2 = y_0 \sin(kx - \omega t) + y_0 \sin(kx - \omega t + \delta) = [2y_0 \cos(\frac{1}{2}\delta)] \sin(kx - \omega t + \frac{1}{2}\delta), \quad f_{\text{beat}} = \Delta f,$$

$$\delta = k\Delta x = 2\pi \frac{\Delta x}{\lambda}, \quad L = n \frac{\lambda_n}{2} \quad \text{for } n = 1, 2, 3, \dots, \quad f_n = \frac{v}{\lambda_n} = n \frac{v}{\lambda_1} = n \frac{v}{2L} = n f_1 \quad \text{for } n = 1, 2, 3, \dots,$$

$$L = n \frac{\lambda_n}{4} \quad \text{for } n = 1, 3, 5, \dots, \quad f_n = \frac{v}{\lambda_n} = n \frac{v}{\lambda_1} = n \frac{v}{4L} = n f_1 \quad \text{for } n = 1, 3, 5, \dots,$$

$$y_n(x, t) = A_n \sin(k_n x) \cos(\omega_n t + \delta_n)$$