Introductory Mechanics Formulas

$$g = \frac{GM_\mathrm{E}}{R_\mathrm{E}^2} = 9.81\frac{\mathrm{m}}{\mathrm{s}^2} = 9.81\frac{\mathrm{N}}{\mathrm{kg}}\ ;\ R_\mathrm{E} = 6.4\times10^6\mathrm{m}\ ;\ M_\mathrm{E} = 6.0\times10^{24}\mathrm{kg}\ ;\ G = 6.67\times10^{-11}\ \mathrm{N\cdot m^2/kg^2}$$

Vector Principles

$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \Rightarrow (A_x, A_y, A_z)\ ;\ \Delta\vec{A} \equiv \vec{A}_\mathrm{final} - \vec{A}_\mathrm{initial}\ ;\ \vec{a}\cdot\vec{b} = ab\cos\theta\ ;\ |\vec{a}\times\vec{b}| = ab\sin\theta$$

Kinematics

$$\vec{r} = x\hat{i} + y\hat{j}\ ;\ \vec{v} \equiv \frac{d\vec{r}}{dt}\ ;\ \vec{a} \equiv \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}\ ;\ x(t) = x_0 + \int_0^t v(t')dt'\ ;\ v(t) = v_0 + \int_0^t a(t')dt'\ ;\ \vec{v}_\mathrm{av} \equiv \frac{\Delta\vec{r}}{\Delta t}\ ;\ \vec{a}_\mathrm{av} \equiv \frac{\Delta\vec{v}}{\Delta t}$$

Constant Acceleration Kinematics

$$\vec{v} = \vec{v}_0 + \vec{a}t\ ;\ \vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2\ ;\ \vec{r} = \vec{r}_0 + \frac{1}{2}(\vec{v}_0 + \vec{v})t\ ;\ x = x_0 + \frac{1}{2a}(v^2 - v_0^2)$$

Rotational Kinematics

$$\theta \equiv \frac{s}{r}\ ;\ \omega \equiv \frac{d\theta}{dt}\ ;\ \alpha \equiv \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}\ ;\ v_\mathrm{t} = \frac{ds}{dt} = \omega r\ ;\ a_\mathrm{t} = \frac{d^2s}{dt^2} = \alpha r\ ;\ \omega_\mathrm{av} \equiv \frac{\Delta\theta}{\Delta t}\ ;\ \alpha_\mathrm{av} \equiv \frac{\Delta\omega}{\Delta t}$$

Uniform Circular Motion

$$a_\mathrm{cent} = a_\mathrm{r} = \frac{v^2}{r} = \omega^2 r\ ;\ T = \frac{2\pi r}{v}$$

Simple Harmonic Motion

$$x(t) = A\cos(\omega t + \delta)\ ;\ f = \frac{1}{T}\ ;\ \omega = 2\pi f\ ;\ T_\mathrm{mass-spring} = 2\pi\sqrt{\frac{m}{k}}\ ;\ T_\mathrm{pend} = 2\pi\sqrt{\frac{L}{g}}\ ;\ T_\mathrm{phys-pend} = 2\pi\sqrt{\frac{I}{mgD}}$$

Dynamics, Friction & Gravity

$$\frac{\vec{F}_\mathrm{net}}{m} = \vec{a}\ ;\ \vec{F}_{AB} = -\vec{F}_{BA}\ ;\ |f_s| \le \mu_s N\ ;\ |f_k| = \mu_k N\ ;\ F^\mathrm{spring} = -kx\ ;\ \vec{F}_{ab}^\mathrm{grav} = -\frac{Gm_am_b}{r_{ab}^2}\hat{r}_{ab}\ ;\ F_\mathrm{earth,m}^\mathrm{grav} = w = gm$$

Work, Energy & Momentum

$$W_{\mathrm{by}\vec{\mathrm{F}}} = \int\vec{F}\cdot d\vec{s} = \int F_x dx + \int F_y dy + \int F_z dz\ ;\ K = \frac{1}{2}mv^2\ ;\ \Delta U = -W_\mathrm{BCF}\ ;\ F_\mathrm{int,cons} = -\frac{dU}{dx}$$

$$U_\mathrm{g} = -\frac{GMm}{r}\ ;\ U_\mathrm{g} = mgy\ ;\ U_\mathrm{sp} = \frac{1}{2}kx^2\ ;\ W_\mathrm{ext} = \Delta E_\mathrm{sys} = \Delta K + \Delta U_\mathrm{g} + \Delta U_\mathrm{sp} + \Delta E_\mathrm{chem} + \Delta E_\mathrm{therm}\ ;\ f\Delta s = \Delta E_\mathrm{therm}$$

$$P \equiv \frac{dW}{dt} = \vec{F}\cdot\vec{v}\ ;\ v_{2f} - v_{1f} = -(v_{2i} - v_{1i})\ ;\ \vec{p} = m\vec{v}\ ;\ \vec{I} = \int\vec{F}dt = \Delta\vec{p}\ ;\ \sum F_\mathrm{ext} = \frac{d\vec{P}}{dt}$$

Systems of Particles

$$\vec{r}_\mathrm{cm} = \frac{1}{M_\mathrm{tot}}\sum m_i\vec{r}_i \quad ; \quad \vec{r}_\mathrm{cm} = \frac{\int\vec{r}dm}{\int dm}$$

Rotational Dynamics

$$I = \sum m_i r_i^2\ ;\ I = \int r^2 dm\ ;\ I_\mathrm{p} = I_\mathrm{cm} + Mh^2\ ;\ K = \frac{1}{2}I\omega^2\ ;\ W_\mathrm{rot} = \int\tau d\theta = \Delta K_\mathrm{rot}\ ;\ P = \frac{dW}{dt} = \tau\omega\ ;\ \vec{L} = \vec{r}\times\vec{p}$$

$$\vec{\tau} = \vec{r}\times\vec{F}\ ;\ \tau = r_\perp F\ ;\ \sum\vec{\tau} = I\vec{\alpha}\ ;\ \sum\vec{\tau} = \frac{d\vec{L}}{dt}\ ;\ v_\mathrm{cm} = r\omega\ ;\ a_\mathrm{cm} = r\alpha\ ;\ \vec{L} = I\vec{\omega}$$

Moments of Inertia

cylindrical shell: $I_\mathrm{cm} = MR^2$; disk: $I_\mathrm{cm} = (1/2)MR^2$; rod: $I_\mathrm{cm} = (1/12)ML^2$;
solid sphere: $I_\mathrm{cm} = (2/5)MR^2$; hollow sphere: $I_\mathrm{cm} = (2/3)MR^2$

Waves

$$y(x,t) = A\sin(kx - \omega t)\ ;\ \omega = 2\pi f = \frac{2\pi}{T}\ ;\ k = \frac{2\pi}{\lambda}\ ;\ \frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}\ ;\ v_\mathrm{wave} = f\lambda = \frac{\omega}{k}\ ;\ v_\mathrm{wave\ on\ string} = \sqrt{\frac{F}{\mu}}$$

$$v_\mathrm{air} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}\ ;\ v_\mathrm{solid} = \sqrt{\frac{B}{\rho}}\ ;\ P_\mathrm{av} = \frac{1}{2}\mu\omega^2A^2v\ ;\ I_\mathrm{av} = \frac{P_\mathrm{av}}{4\pi r^2}\ ;$$

$$\beta = (10dB)\log_{10}\left(\frac{I}{I_0}\right)\ ;\ I_0 = 10^{-12}\frac{\mathrm{W}}{\mathrm{m}^2}\ ;\ y_\mathrm{sw} = A\sin(kx)\cos(\omega t)\ ;\ \Delta L_\mathrm{const} = m\lambda\ ;\ \Delta L_\mathrm{dest} = \left(m + \frac{1}{2}\right)\lambda$$

$$A\sin\theta_1 + A\sin\theta_2 = 2A\cos\left(\frac{\theta_1 - \theta_2}{2}\right)\sin\left(\frac{\theta_1 + \theta_2}{2}\right)\ ;\ A\sin\theta_1 - A\sin\theta_2 = 2A\cos\left(\frac{\theta_1 + \theta_2}{2}\right)\sin\left(\frac{\theta_1 - \theta_2}{2}\right)$$