Kinematics
$\vec{v} = \vec{v}_0 + \vec{a}t$
$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$
$v^2 = v_0^2 + 2a\left(x - x_0\right)$
$g = 9.81\ \mathrm{m/s}^2 = 32.2\ \mathrm{ft/s}^2$
$\vec{V}_{\mathrm{A,B}} = \vec{V}_{\mathrm{A,C}} + \vec{V}_{\mathrm{C,B}}$

Uniform Circular Motion
$a = v^2/r$
$v = \omega r$
$\omega = 2\pi/T = 2\pi f$

Dynamics
$\vec{F}_{\mathrm{net}} = m\vec{a} = d\vec{p}/dt$
$\vec{F}_{\mathrm{A,B}} = -\vec{F}_{\mathrm{B,A}}$
$F = mg$ (near Earth's surface)
$F_{12} = Gm_1m_2/r^2$ (in general)
$F_{\mathrm{spring}} = -k\Delta x$

Friction
$f = \mu_{\mathrm{k}}N$ (kinetic)
$f \le \mu_{\mathrm{s}}N$ (static)

Work & Kinetic Energy
$W = \int \vec{F}\cdot d\vec{l}$
$W = \vec{F}\cdot\vec{\Delta r} = F\,\Delta r\cos\theta$ (constant force)
$W_{\mathrm{grav}} = -mg\Delta y$
$W_{\mathrm{spring}} = -k\left(x_2^2 - x_1^2\right)/2$
$K = mv^2/2$
$W_{\mathrm{net}} = \Delta K$

Potential Energy
$U_{\mathrm{grav}} = mgy$ (near Earth's surface)
$U_{\mathrm{grav}} = -GMm/r$ (in general)
$U_{\mathrm{spring}} = kx^2/2$
$\Delta E = \Delta K + \Delta U = W_{\mathrm{nc}}$

Power
$P = dW/dt$
$P = \vec{F}\cdot\vec{v}$

System of Particles
$\vec{R}_{\mathrm{CM}} = \sum m_i\vec{r}_i/\sum m_i$
$\vec{V}_{\mathrm{CM}} = \sum m_i\vec{v}_i/\sum m_i$
$\vec{A}_{\mathrm{CM}} = \sum m_i\vec{a}_i/\sum m_i$
$\vec{P} = \sum m_i\vec{v}_i$
$\sum\vec{F}_{\mathrm{ext}} = M\vec{A}_{\mathrm{CM}} = d\vec{P}/dt$

Impulse
$\vec{I} = \int\vec{F}\,dt$
$\Delta\vec{P} = \vec{F}_{\mathrm{avg}}\Delta t$

Collisions
If $\sum\vec{F}_{\mathrm{ext}} = 0$ in some direction, then $\vec{P}_{\mathrm{before}} = \vec{P}_{\mathrm{after}}$ in this direction:
$\sum m_i\vec{v}_i$ (before) $= \sum m_i\vec{v}_i$ (after)

<u>In addition, if the collision is elastic:</u>

- $E_{\mathrm{before}} = E_{\mathrm{after}}$
- *Rate of approach = Rate of recession*
- *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational Kinematics
$s = R\theta,\ v = R\omega,\ a = R\alpha$
$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
$\omega = \omega_0 + \alpha t$
$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Rotational Dynamics
$I = \sum m_i r_i^2$
$I_{\mathrm{parallel}} = I_{\mathrm{CM}} + MD^2$
$I_{\mathrm{disk}} = I_{\mathrm{cylinder}} = \frac{1}{2}MR^2$
$I_{\mathrm{hoop}} = MR^2$
$I_{\text{solid-sphere}} = \frac{2}{5}MR^2$
$I_{\text{spherical-shell}} = \frac{2}{3}MR^2$
$I_{\text{rod-cm}} = \frac{1}{12}ML^2$
$I_{\text{rod-end}} = \frac{1}{3}ML^2$
$\tau = I\alpha$ (rotation about a fixed axis)
$\tau = \vec{r}\times\vec{F},\ |\tau| = rF\sin\phi$

Work & Energy
$K_{\mathrm{rotation}} = \frac{1}{2}I\omega^2$
$K_{\mathrm{translation}} = \frac{1}{2}MV_{\mathrm{CM}}^2$
$K_{\mathrm{total}} = K_{\mathrm{rotation}} + K_{\mathrm{translation}}$
$W = \tau\theta$

Statics
$\sum\vec{F} = 0,\ \sum\tau = 0$ (about any axis)

Angular Momentum
$\vec{L} = \vec{r}\times\vec{p}$
$L_z = I\omega_z$
$\vec{L}_{\mathrm{total}} = \vec{L}_{\mathrm{CM}} + \vec{L}^*$
$\tau_{\mathrm{ext}} = d\vec{L}/dt$
$\tau_{\mathrm{cm}} = d\vec{L}^*/dt$
$\Omega_{\mathrm{precession}} = \tau/L$

Simple Harmonic Motion
$d^2x/dt^2 = -\omega^2 x$ (differential equation for SHM)
$x\left(t\right) = A\cos\left(\omega t + \phi\right)$
$b\left(t\right) = -\omega A\sin\left(\omega t + \phi\right)$
$a\left(t\right) = -\omega^2 A\cos\left(\omega t + \phi\right)$
$\omega^2 = k/m$ (mass on spring)
$\omega^2 = g/L$ (simple pendulum)
$\omega^2 = mgR_{\mathrm{CM}}/I$ (physical pendulum)
$\omega^2 = \kappa/I$ (torsion pendulum)

General Harmonic Transverse Waves
$y\left(x,t\right) = A\cos\left(kx - \omega t\right)$
$k = 2\pi/\lambda,\ \omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

Waves on a String
$V^2 = \dfrac{F}{\mu} = \dfrac{\text{(tension)}}{\text{(mass per unit length)}}$
$\overline{P} = \frac{1}{2}\mu v\omega^2A^2$
$\dfrac{d\overline{E}}{dx} = \frac{1}{2}\mu v\omega^2A^2$
$\dfrac{d^2y}{dx^2} = \dfrac{1}{v^2}\dfrac{d^2y}{dt^2}$ (wave equation)

Fluids
$\rho = \dfrac{m}{V}$
$p = \dfrac{F}{A}$
$A_1v_1 = A_2v_2$
$P_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2$
$F_{\mathrm{B}} = \rho_{\mathrm{liquid}}gV_{\mathrm{liquid}}$
$F_2 = F_1\dfrac{A_2}{A_1}$

Uncertainties
$\delta = \dfrac{\sigma}{\sqrt{N}}$
$t' = \dfrac{|\mu_{\mathrm{A}} - \mu_{\mathrm{B}}|}{\sqrt{\delta_{\mathrm{A}}^2 + \delta_{\mathrm{B}}^2}}$