1D motion:

$$V_{ave} = \frac{\Delta x}{\Delta t}, \quad V_{inst} = \frac{dx}{dt}, \quad a_{ave} = \frac{\Delta v}{\Delta t}, \quad a_{inst} = \frac{dv}{dt}$$

Kinematics:

$$V = V_0 + at, \quad x - x_0 = V_0 t + \frac{at^2}{2}, \quad x - x_0 = \frac{V - V_0}{2} t, \quad V^2 = V_0{}^2 + 2a(x - x_0), \quad x - x_0 = Vt - \frac{at^2}{2}$$

(linear variables)

$$\omega = \omega_0 + \alpha t, \quad \theta - \theta_0 = \omega_0 t + \frac{\alpha t^2}{2}, \quad \theta - \theta_0 = \frac{\omega - \omega_0}{2} t, \quad \omega^2 = \omega_0{}^2 + 2\alpha(x - x_0), \quad \theta - \theta_0 = \omega t - \frac{\alpha t^2}{2}$$

(rotational variables)

$$h = \frac{v_0^2 \sin^2\theta}{2g} \quad t = \frac{2v_0 \sin\theta}{g} \quad R = \frac{v_0^2 \sin 2\theta}{g}$$

(projectiles)

$$V_{\min} = \sqrt{\frac{gd}{2}\frac{1}{\sin\theta}}$$

(speed for projectile hitting a target)

Circles and such (kinematics):

$$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = \omega^2 r, \quad v = \omega r, \quad \omega = \frac{2\pi}{T}$$

(UCM)

$$\vec{a} = \vec{a_c} + \vec{a_t}$$

(curvilinear motion)

Forces:

$$F_{net} = ma, \quad F_{k\,or\,s} = \mu_{k\,or\,s} N, \quad F_c = \frac{mv^2}{r}, \quad F_g = mg = \frac{GMm}{r^2}$$

$$\vec{F} = \vec{F_c} + \vec{F_t}$$

(curvilinear)

$$\vec{F} = \vec{F} + \vec{F_i}$$

(accelerated frames)

$$F_N = mg + ma$$

(apparent weight elevator)

$$F_c = F_{gapparent}$$

(artificial gravity)

$$R = \frac{C\rho A v^2}{2}$$

(drag force for large objects, high v)

$$R = -bv$$

(small objects small v)

$$v_t = \sqrt{\frac{2mg}{C\rho A}}$$

(terminal speed falling body)

$$F = -kx$$
(spring force)

Work/energy:

$$W = dF\cos\theta = \vec{F} \bullet \vec{d} = \int_{x_i}^{x_f} F(x)dx \qquad W = \int_{\vec{r}_i}^{\vec{r}_f} \vec{F} \bullet d\vec{r}$$
(1- or 2-D work) (varying force) (3-D work, varying force)

$$W = \Delta E \qquad E_k = \frac{mv^2}{2} \qquad E_g = mgh \qquad v = \sqrt{2gh}$$
(velocity at end of fall)

$$E_s = \frac{kx^2}{2}$$

Linear Momentum, Collisions:

$$p = mv, \quad F = \frac{dp}{dt}, \quad I = \Delta p = \int_{t_i}^{t_f} F\,dt, \quad I = f\Delta t, \quad p_{1i} + p_{2i} = p_{1f} + p_{2f}$$

$$v = \frac{m_1 v_{0_1} + m_2 v_{0_2}}{m_t}$$
In 2- or 3-D, use conservation (and if elastic, energy) and derive

(perfectly inelastic collision, 2D)

$$v_1 = (\frac{m_1 - m_2}{m_t})v_{0_1} + (\frac{2m_2}{m_t})v_{0_2}, \quad v_2 = (\frac{2m_1}{m_t})v_{0_1} + (\frac{m_2 - m_1}{m_t})v_{0_2}$$
(elastic head-on collisions, 2D)

$$x_c = \frac{m_1 x_1 + m_2 x_2 + ... + m_n x_n}{m_1 + m_2 + ... + m_n} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i} \qquad y_c = \frac{m_1 y_1 + m_2 y_2 + ... + m_n y_n}{m_1 + m_2 + ... + m_n} = \frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i}$$
(center of mass - just use one in 1-D, use both in 2-D, do one for z in 3-D)

$$v = v_{ex}\ln(\frac{m_0}{m}), \quad v = v_{ex}\ln(\frac{m_0}{m}) - gt$$
(Rocket launch, rocket launch with gravity)

Rotation of rigid bodies:

$$\omega = \frac{d\theta}{dt}, \quad \alpha = \frac{d\omega}{dt} \qquad v_t = r\omega, \quad a_t = r\alpha, \quad a_r = r\omega^2$$

$$I = \sum m_i r_i^2, \quad I = \int r^2\, dm, \quad I_{homogenous\,body} = \int \rho r^2\, dV, \quad I = I_{cm} + MD^2$$

(moments of inertia) (parallel axis theorem)

$$E_{k\,(rotational)} = \frac{I\omega^2}{2}$$

$$\tau = rF\sin\theta = Fd = \vec{F} \times \vec{r}$$

(torque -> d is the moment arm (rsinθ))

**Moments of inertia for specific shapes:**

rod, axis through an end:

$$I = \frac{ML^2}{3}$$

rod, axis through centre:

$$I = \frac{ML^2}{12}$$

Rectangular plane, axis through centre

$$I = \frac{M(a^2 + b^2)}{12}$$

Thin rectangular plane, axis along edge: (a is the side perpendicular to the axis)

$$I = \frac{Ma^2}{3}$$

Hollow cylinder:

$$I = \frac{M(R_1^{\,2} + R_2^{\,2})}{2}$$

Solid cylinder:

$$I = \frac{MR^2}{2}$$

Thin walled hollow cylinder:

$$I = MR^2$$

Solid sphere:

$$I = \frac{2}{5}MR^2$$

Thin walled hollow sphere:

$$I = \frac{2}{3}MR^2$$

**Formulae for specific problem types:**

Unbanked curves (friction provides Fc):

$$\mu mg > \frac{mv^2}{r} \quad v < \sqrt{r\mu g}$$

Frictionless banked curves:

$$v = \sqrt{rg\tan\theta}$$

Banked curves with friction:

V max:

$$v = \sqrt{\frac{rg\left(\sin\theta + \mu_s\cos\theta\right)}{\cos\theta - \mu_s\sin\theta}} = \sqrt{\frac{rg\left(\tan\theta + \mu_s\right)}{1 - \mu_s\tan\theta}}$$

V min:

$$v = \sqrt{\frac{rg\left(\sin\theta - \mu_s\cos\theta\right)}{\cos\theta + \mu_s\sin\theta}} = \sqrt{\frac{rg\left(\tan\theta - \mu_s\right)}{1 + \mu_s\tan\theta}}$$

Coriolis effect:

$$a_{cor} = 2\omega v, \; a_{cor} = 2\omega^2 R\cos\lambda = \frac{2v^2}{R\cos\lambda}$$

(Coriolis acceleration in general, Coriolis acceleration on earth)

Foucault pendulum:

$$T(\lambda) = \frac{2\pi}{\omega\sin\lambda}$$