$$v_x = \frac{dx}{dt} \qquad v_{x,avg} = \frac{\Delta x}{\Delta t} \qquad \omega = \frac{d\theta}{dt} \qquad \omega_{avg} = \frac{\Delta\theta}{\Delta t}$$

$$a_x = \frac{dv_x}{dt} \qquad a_{x,avg} = \frac{\Delta v_x}{\Delta t} \qquad \alpha = \frac{d\omega}{dt} \qquad \alpha_{avg} = \frac{\Delta\omega}{\Delta t}$$

$$v_x = v_{x0} + a_x \Delta t \qquad \omega = \omega_0 + \alpha\,\Delta t$$

$$x = x_0 + v_{x0}\Delta t + \tfrac{1}{2} a_x (\Delta t)^2 \qquad \theta = \theta_0 + \omega_0 \Delta t + \tfrac{1}{2}\alpha\,(\Delta t)^2$$

$$v_x^{\,2} = v_{x0}^{\,2} + 2a_x \Delta x \qquad \omega^2 = \omega_0^{\,2} + 2\alpha\,\Delta\theta$$

Similar equations apply for motion along *y* and *z*.

$$a_{rad} = \frac{v^2}{R} = \omega^2 \mathrm{R} \qquad a_{tan} = \alpha\,\mathrm{R} \qquad v_{tan} = \omega\,\mathrm{R} \qquad s = \theta\,\mathrm{R}$$

$$\vec{F}_{net} = m\vec{a} \qquad \vec{\tau}_{net} = I\vec{\alpha}$$

$$w = mg \qquad \vec{F}_{spring} = -k(\Delta\vec{x}) \qquad \vec{\tau} = \vec{r} \times \vec{F}$$

$$f_s \le \mu_s n \qquad f_k = \mu_k n \qquad f_r = \mu_r n$$

where $|\tau| = lF = rF\sin\phi = rF_{\tan}$

$f_{drag} = kv$ (low speed) OR $f_{drag} = Dv^2$ (high speed)

$$I = \sum_i m_i r_i^2$$

$$\Delta K = W_{total} \qquad W_c = -\Delta U \qquad W_{NC} = -\Delta U_{\mathrm{int}} = \Delta E \quad \text{where } E = K + U$$

$$\Delta K + \Delta U + \Delta U_{\mathrm{int}} = 0 \qquad K_i + U_i + W_{NC} = K_f + U_f$$

$$K_{trans} = \tfrac{1}{2} m v^2 \qquad K_{rot} = \tfrac{1}{2} I\omega^2$$

$$W = \int_{s_i}^{s_f} \vec{F} \bullet d\vec{s} \qquad W = \int_{\theta_i}^{\theta_f} \tau_z\, d\theta$$

$P = \frac{dW}{dt} = \vec{F} \bullet \vec{v}$ (constant force) $\qquad P = \frac{dW}{dt} = \tau_z \omega_z$ (constant torque)

$$U_{\mathrm{g}} = mgy \qquad U_{elastic} = \tfrac{1}{2} k (\Delta x)^2 \qquad F_x(x) = \frac{-dU(x)}{dx}$$

$$\vec{p} = m\vec{v} \qquad \vec{L} = \vec{r} \times \vec{p} = \vec{r} \times m\vec{v} = I\vec{\omega}$$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt} \qquad \vec{\tau}_{net} = \frac{d\vec{L}}{dt}$$

$$\vec{J} = \int_{t_i}^{t_f} \vec{F}_{net}\, dt = \langle \vec{F}_{net} \rangle \Delta t = \Delta\vec{p}$$

$I\omega$ applies only for a rigid body around an axis of symmetry

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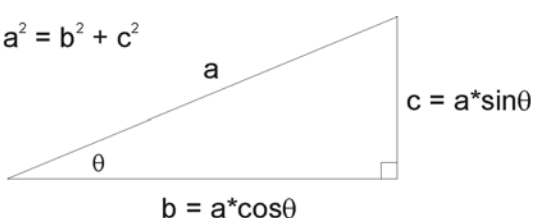
Useful Constants

$g = 9.8\ \mathrm{m/s^2}$

Algebra and trigonometry

$$ax^2 + bx + c = 0 \quad \Rightarrow \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Moments of Inertia

slender rod (length *L*), through center	$I = \frac{1}{12} ML^2$
slender rod (length *L*), through end	$I = \frac{1}{3} ML^2$
rectangular plate (*a* by *b*), through center	$I = \frac{1}{12} M(a^2 + b^2)$
rectangular plate (*a* by *b*), along edge *b*	$I = \frac{1}{3} Ma^2$
hollow cylinder (inner radius R_1, outer R_2)	$I = \frac{1}{2} M\left(R_1^2 + R_2^2\right)$
solid cylinder, (radius *R*)	$I = \frac{1}{2} MR^2$
thin-walled hollow cylinder, (radius *R*)	$I = MR^2$
solid sphere (radius *R*)	$I = \frac{2}{5} MR^2$
thin-walled hollow sphere (radius *R*)	$I = \frac{2}{3} MR^2$