Work

$$\boxed{W = \vec{F}\,\vec{d} = Fd\cos(\theta)}$$

Unit: J

Power

$$\boxed{P = \frac{|W|}{\Delta t}}$$

Unit: J/s = W

Kinetic energy

$$\boxed{K = \frac{1}{2}mv^2}$$

Unit: J

Gravitational potential energy

$$\boxed{U = mgy}$$

Unit: J

U

Elastic potential energy

$$\boxed{U = \frac{1}{2}kx^2}$$

Unit: J

Conservation of mechanical energy

$U_g + U_e$

$$\boxed{E_{mec} = K + U} \qquad K_1 + U_1 = K_2 + U_2$$

Work done on a system (no friction involved)

$$W = \Delta E_{mec} = \Delta K + \Delta U$$

Unit: J

Work done on a system (friction involved)

$$W = \Delta E_{mec} + \Delta E_{thermal}$$

Unit: J

Work done by friction

$$|W_{friction}| = \Delta E_{thermal} = -\Delta E_{mec}$$

Unit: J

$$W_{friction} = \vec{F}\,\vec{d}$$

Center of mass

$$x_{com} = \frac{m_1x_1 + m_2x_2 + \cdots + m_nx_n}{m_1 + m_2 + \ \dots + m_n} = \frac{A_1x_1 + A_2x_2}{A_1 + A_2}$$

Unit: m

$$m = \rho \text{ x thickness x area}$$

Linear momentum

$$\vec{p} = m\,\vec{v}$$

Unit: kg m/s

Conservation of linear momentum

$$p = p'$$

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Impulse

$F = \frac{J}{\Delta t}$

$F = \frac{J}{\Delta t} = \frac{\Delta p}{\Delta t}$

$$J = F_{avg} \times \Delta t = \Delta p \qquad \boxed{\Delta\vec{p} = \vec{J}} \qquad \text{Unit: N.s}$$

$\hookrightarrow m\Delta v$ ||

Collision

- Elastic collision: p and K conserved

$K_i = K_f$

- Inelastic collision: only p conserved
  + Perfectly inelastic collision
  + Non-perfectly inelastic collision

→ Elastic or inelastic? $K_i = K_f$ → elastic
$K_i \neq K_f$ → inelastic

Angular position: θ Unit: rad (1 rev = 2π rad)

Angular velocity: ω Unit: rad/s

Angular acceleration: α Unit: rad/s^2

Period of revolution: $T = \dfrac{2\pi}{\omega}$ Unit: s

Tangential acceleration: $a_t = \alpha r$ Unit: m/s^2 a

$v = \omega R$

Radial acceleration: $a_r = \dfrac{v^2}{r} = \omega^2 r$ Unit: m/s^2

Rotational inertia: I Unit: kg.m^2

Torque: $\vec{\tau} = \vec{F}\,\vec{r}$ Unit: N.m

Angular momentum: $\vec{l} = \vec{p}\,\vec{r}$ Unit: kg m^2 s^{-1}

Translation	Rotation
x	θ
v	ω
a	α
$\vec{F} = m\,\vec{a}$	$\vec{\tau} = \vec{F}\,\vec{r} = I\,\alpha$
m	I $L = P$
$\vec{p} = m\,\vec{v}$ $P \to L$	$\vec{l} = \vec{p}\,\vec{r} = I\,\omega$
$\vec{W} = \vec{F}\,\vec{d}$	$\vec{W} = \vec{\tau}\,\vec{\varphi}$
$K = \frac{1}{2}mv^2$	$K = \frac{1}{2}I\omega^2$

(v) $\omega = \omega_o + \alpha t$

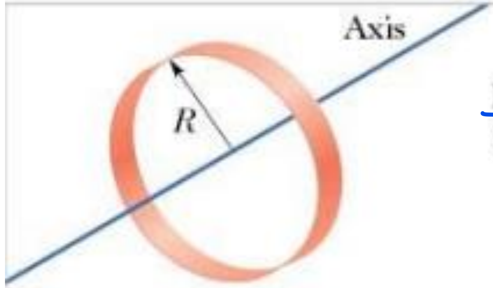
(x) $\theta = \theta_o + \omega_o t + \frac{1}{2}\alpha t^2$

(v) $\omega^2 - \omega_o^2 = 2\alpha(\theta - \theta o)$

F ~ $\vec{\tau} = \vec{F}\vec{r} = I\alpha$ L ~ $\vec{l} = \vec{p}\vec{r} = I\omega$ ~ P

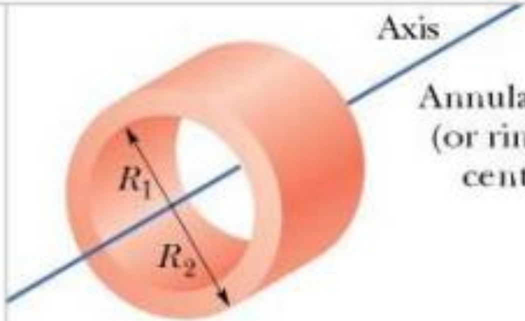
Rotational inertia (I)

- For a point mass: $I = mr^2$
- For a rigid body: depends on the shape



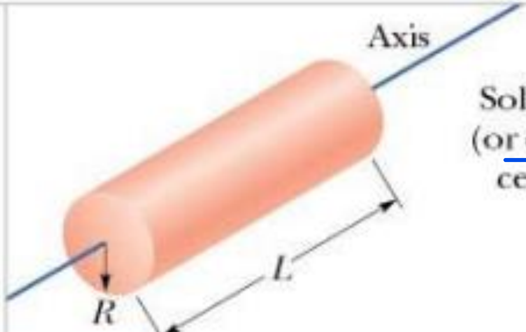
Hoop about central axis

$I = MR^2$ (a)



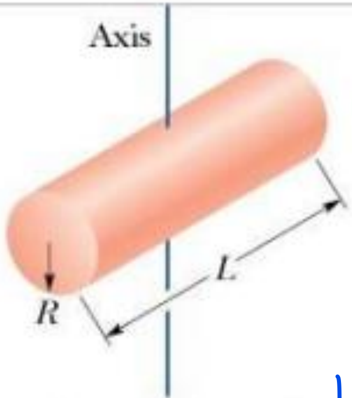
Annular cylinder (or ring) about central axis

$I = \frac{1}{2}M(R_1^2 + R_2^2)$ (b)



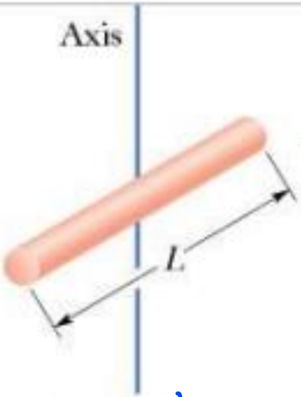
Solid cylinder (or disk) about central axis

$I = \frac{1}{2}MR^2$ (c)



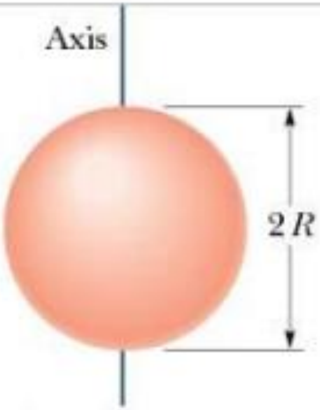
Solid cylinder (or disk) about central diameter

$I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$ (d)



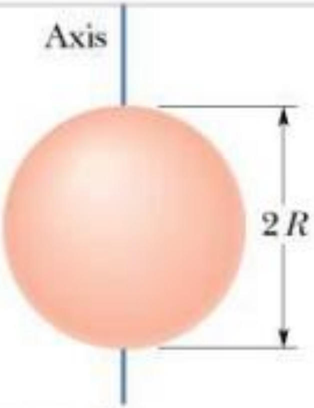
Thin rod about axis through center perpendicular to length

$I = \frac{1}{12}ML^2$ (e)



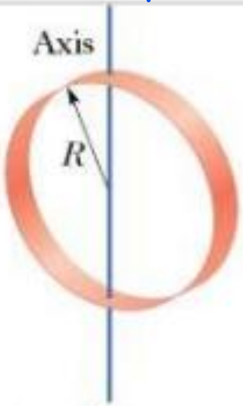
Solid sphere about any diameter

$I = \frac{2}{5}MR^2$ (f)



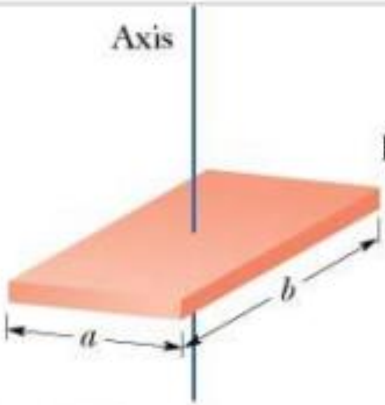
Thin spherical shell about any diameter

$I = \frac{2}{3}MR^2$ (g)



Hoop about any diameter

$I = \frac{1}{2}MR^2$ (h)



Slab about perpendicular axis through center

$I = \frac{1}{12}M(a^2 + b^2)$ (i)

Conservation of angular momentum: $I_i\omega_i = I_f\omega_f$

$L' = L = I\omega$

Rotational work

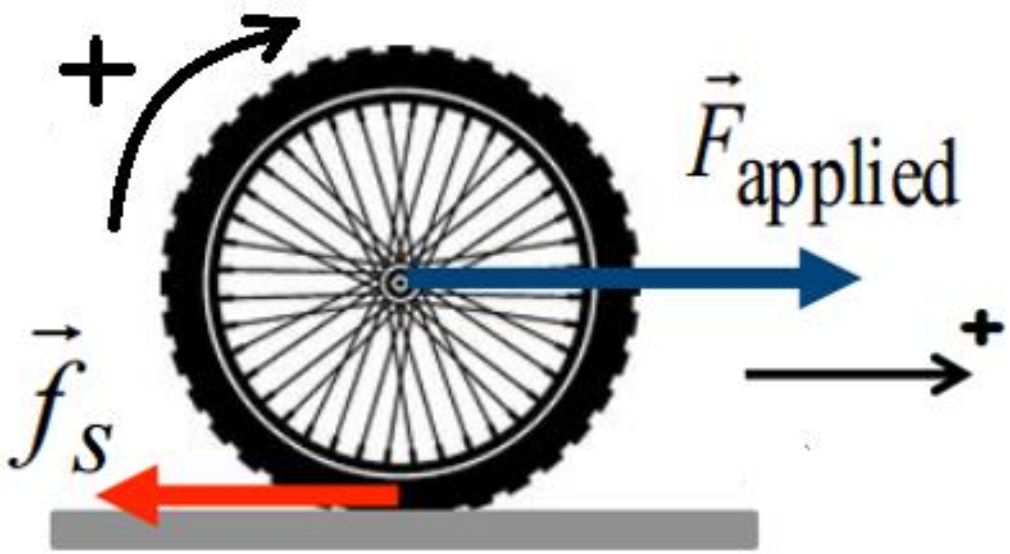
$$W = \Delta K = \frac{1}{2}I{\omega_f}^2 - \frac{1}{2}I{\omega_i}^2 = \tau\varphi$$

Rolling motion: Translational + Rotational

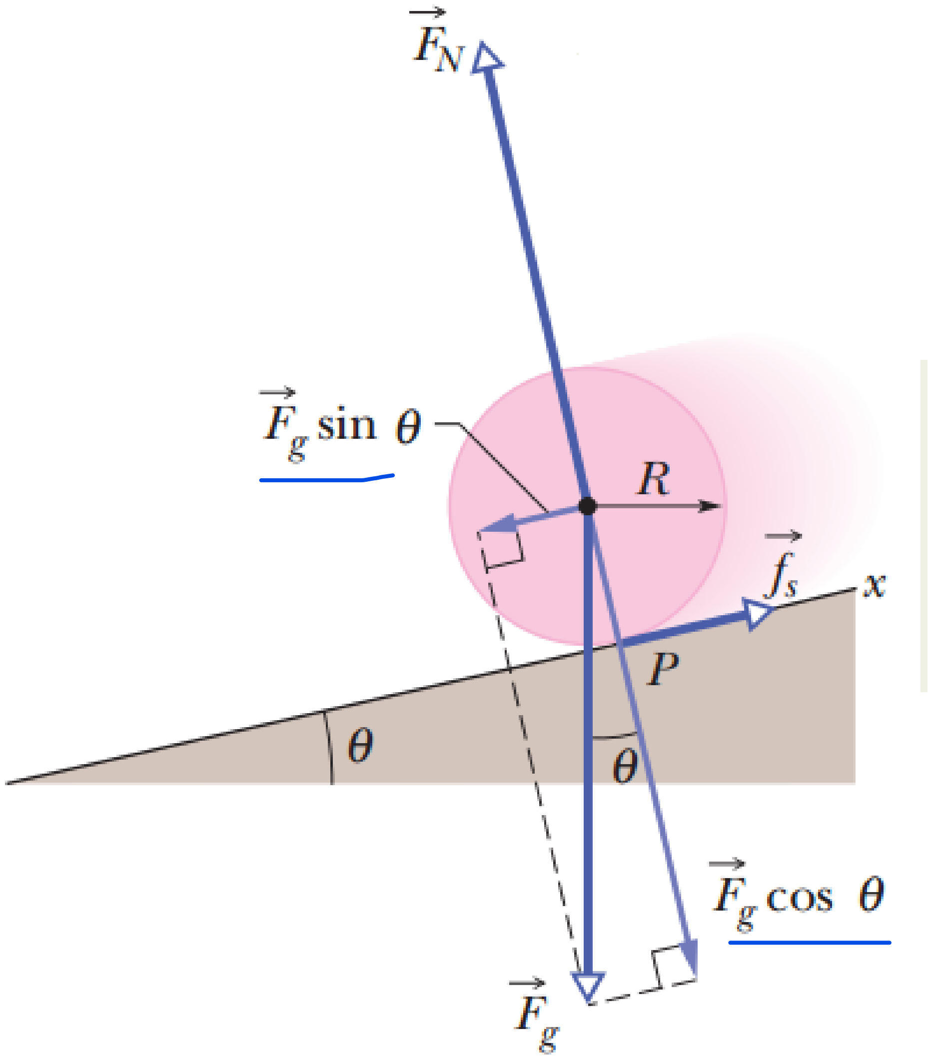
$v = \omega R$ $\qquad$ $a = \alpha R$ $\qquad$ $K = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$

$s = \theta R$

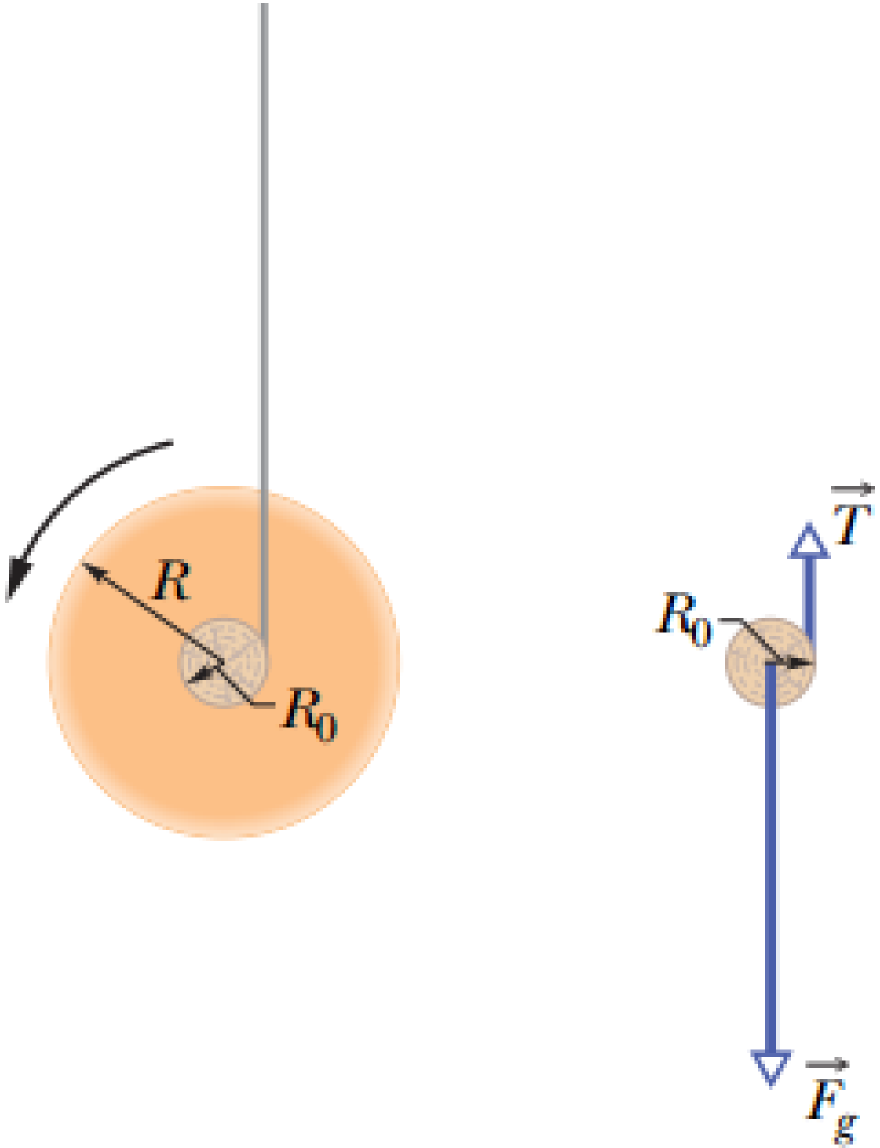
Rolling on horizontal surface



Rolling on an incline



The yo-yo



The pulley