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**Kinematics:**  $v_x = \frac{dx}{dt}$      $a_x = \frac{dv_x}{dt}$      $v_{xf} = v_{xi} + a_x \Delta t$      $x_f = x_i + v_{xi} \Delta t + \frac{1}{2} a_x \Delta t^2$   
 $v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$      $a_{rad} = \frac{v^2}{r}$      $\vec{v}_{PA} = \vec{v}_{PB} + \vec{v}_{BA}$      $T = \frac{2\pi r}{v}$      $f = 1/T$

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**Forces and Potentials:**  $\sum \vec{F}_i = m\vec{a}$      $f_s \leq \mu_s n$      $f_k = \mu_k n$      $F_s = -k(x - x_R)$   
 $F_g = \frac{GM_1 M_2}{r^2}$      $GMT^2 = 4\pi^2 r^3$

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**Rotation:**  $\omega = \frac{d\theta}{dt}$      $\alpha = \frac{d\omega}{dt}$      $v = \omega r$      $a_{tan} = \alpha r$      $a_{rad} = \omega^2 r$      $\omega = 2\pi f$   
 $\theta_f = \theta_i + \omega_i \Delta t + \frac{1}{2} \alpha \Delta t^2$      $\omega_f = \omega_i + \alpha \Delta t$      $\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$      $\tau = rF \sin \phi$   
 $I = \sum_i m_i r_i^2$      $Mx_{cg} = m_1 x_1 + m_2 x_2 + \dots = \sum_i m_i x_i$      $\sum \tau_{ext} = I\alpha$

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**Momentum:**  $\vec{p} = m\vec{v}$      $L = rp \sin \phi = r_{\perp} p$  (particle)     $L = I\omega$  (rigid body)

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**Work-Energy:**  $W = \vec{F} \cdot \vec{r}$      $P = \frac{\Delta E}{\Delta t}$      $U_g = mgy$      $U_s = \frac{1}{2} kx^2$      $K = \frac{1}{2} mv^2$   
 $K = \frac{1}{2} I\omega^2$      $K = \frac{1}{2} MV_{cm}^2 + \frac{1}{2} I_{cm} \omega^2$

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**Oscillations:**  $F = -kx$      $x = A \cos(2\pi ft + \phi)$      $\omega = 2\pi f$      $T = \frac{1}{f}$      $f = \frac{1}{2\pi} \sqrt{k/m}$   
 $f = \frac{1}{2\pi} \sqrt{g/L}$      $E = \frac{1}{2} kA^2$      $v_{max} = 2\pi f A$      $a_{max} = (2\pi f)^2 A$

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**Fluids:**  $\rho = M/V$      $p = F/A$      $p = p_{atm} + \rho gh$      $F_B = \rho_f V_{disp} g$      $A_1 v_1 = A_2 v_2$   
 $p_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$      $Q = v_{avg} A = \frac{(p_1 - p_2) \pi r^4}{8\eta L}$

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**Thermodynamics:**  $T_K = T_C + 273.15$      $E_{th} = \bar{K}_{tr} = \frac{3}{2} N k_B T$      $W = \int_{V_i}^{V_f} p dV$   
 $Q = nC_V \Delta T$      $Q = nC_p \Delta T$      $C_V = \frac{3}{2} R$      $C_p = C_V + R$      $Q = W + \Delta E_{th}$   
 $Q = mc\Delta T$      $Q = \pm mL$      $pV = nRT = Nk_B T$      $e = \frac{|W|}{|Q_H|}$      $e_{max} = 1 - \frac{T_C}{T_H}$   
 $COP = \frac{|Q_C|}{|W|}$      $COP_{max} = \frac{T_C}{T_H - T_C}$

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**Vectors:**  $A_x = A \cos \theta$      $A_y = A \sin \theta$      $A = \sqrt{A_x^2 + A_y^2}$      $\tan \theta = \frac{A_y}{A_x}$   
 $\vec{A} \cdot \vec{B} = AB \cos \phi_{AB}$      $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$      $\vec{A} \times \vec{B} = \hat{n} AB \sin \phi_{AB}$

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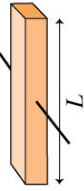
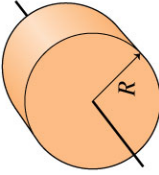
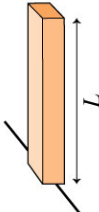
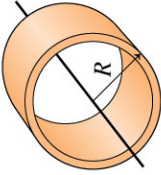
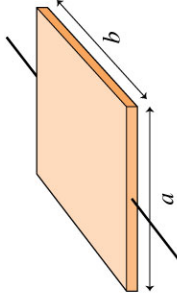
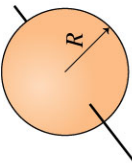
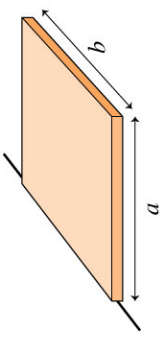
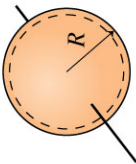
**Math:**  $ax^2 + bx + c = 0$      $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$      $(1+x)^n \approx 1 + nx$  for  $x \ll 1$   
 $A = 4\pi r^2$      $V = \frac{4}{3} \pi r^3$

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**Constants:**  $g = 9.8 \text{ m/s}^2$      $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$      $R_{Earth} = 6.37 \times 10^6 \text{ m}$   
 $M_{Earth} = 5.98 \times 10^{24} \text{ kg}$      $M_{Sun} = 1.99 \times 10^{30} \text{ kg}$      $c = 2.998 \times 10^8 \text{ m/s}$   
 $T_z = -273.15^\circ \text{C}$      $1 \text{ atm} = 1.013 \times 10^5 \text{ N/m}^2 = 101.3 \text{ kPa}$      $\rho_{water} = 1000 \text{ kg/m}^3$   
 $k_B = 1.38 \times 10^{-23} \text{ J/K}$      $N_A = 6.022 \times 10^{23}$      $R = 8.3145 \text{ J/mol} \cdot \text{K}$   
 $v_{sound} = 343 \text{ m/s}$      $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$

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**TABLE 7.1** Moments of inertia of objects with uniform density and total mass  $M$

Object and axis	Picture	$I$	Object and axis	Picture	$I$
Thin rod (of any cross section), about center		$\frac{1}{12}ML^2$	Cylinder or disk, about center		$\frac{1}{2}MR^2$
Thin rod (of any cross section), about end		$\frac{1}{3}ML^2$	Cylindrical hoop, about center		$MR^2$
Plane or slab, about center		$\frac{1}{12}Ma^2$	Solid sphere, about diameter		$\frac{2}{5}MR^2$
Plane or slab, about edge		$\frac{1}{3}Ma^2$	Spherical shell, about diameter		$\frac{2}{3}MR^2$