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**Kinematics:**  $v = v_0 + at$      $x = x_0 + v_0t + \frac{1}{2}at^2$      $v^2 = v_0^2 + 2a(x - x_0)$      $a_{rad} = \frac{v^2}{r}$   
 $T = \frac{2\pi r}{v}$      $\vec{v}_{P/A} = \vec{v}_{P/B} + \vec{v}_{B/A}$

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**Forces and Potentials:**  $\Sigma \vec{F} = m\vec{a}$      $f_s \leq \mu_s F_N$      $f_k = \mu_k F_N$      $U_g = mgy$   
 $F_s = -k(x - x_R)$      $U_s = \frac{1}{2}k(x - x_R)^2$      $\vec{F}_g = -\frac{GM_1M_2}{r^2}\hat{r}$      $U_g = -\frac{GM_1M_2}{r}$   
 $GMT^2 = 4\pi^2a^3$

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**Work-Energy:**  $W = \int_{r_1}^{r_2} \vec{F} \cdot d\vec{r}$      $W = \vec{F} \cdot \vec{r}$      $K_i + W_{tot} = K_f$      $P = \vec{F} \cdot \vec{v}$   
 $\Delta U_{AB} = -\int_A^B \vec{F} \cdot d\vec{r}$      $F_x = -\frac{dU}{dx}$

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**Systems of Particles:**  $\vec{p} = m\vec{v}$      $\vec{F} = \frac{d\vec{p}}{dt}$      $Mx_{cm} = m_1x_1 + m_2x_2 + \dots = \sum_i m_ix_i$   
 $\sum \vec{F}_{ext} = M\vec{a}_{cm}$      $v_{2f} - v_{1f} = -(v_{2i} - v_{1i})$

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**Rotation:**  $\theta = \theta_0 + \omega_0t + \frac{1}{2}\alpha t^2$      $\omega = \omega_0 + \alpha t$      $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$      $v = \omega r$   
 $a_{tan} = \alpha r$      $a_{rad} = \omega^2 r$      $\vec{L} = \vec{r} \times \vec{p}$  (particle)     $L = I\omega$  (rigid body)     $\vec{\tau} = \vec{r} \times \vec{F}$   
 $I = \sum_i m_ir_i^2$      $K = \frac{1}{2}I\omega^2$      $\sum \vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$      $\sum \tau_{ext} = I\alpha$      $I = I_{cm} + Md^2$   
 $K = \frac{1}{2}MV_{cm}^2 + \frac{1}{2}I_{cm}\omega^2$

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**Oscillations:**  $F = -kx$      $x = A \cos(\omega t + \phi)$      $\omega = 2\pi f$      $f = \frac{1}{T}$      $\omega = \sqrt{k/m}$   
 $\omega = \sqrt{g/L}$      $\omega = \sqrt{Mgd/I}$      $E = \frac{1}{2}kA^2$   
 $x = Ae^{-bt/(2m)} \cos(\omega't + \phi)$      $\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$

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**Waves:**  $y(x, t) = A \cos(kx - \omega t + \phi)$      $k = \frac{2\pi}{\lambda}$      $v = \lambda f = \frac{\omega}{k}$      $v = \sqrt{\frac{F_T}{\mu}}$      $\mu = \frac{M}{L}$   
 $v = \sqrt{\frac{\gamma RT}{M}}$      $P_{avg} = \frac{1}{2}\mu v \omega^2 A^2$      $I = \frac{P}{A}$      $y(x, t) = A_{sw} \sin(kx) \cos(\omega t)$      $f_n = n \frac{v}{2L}$   
 $f_n = n_{odd} \frac{v}{4L}$      $\phi = 2\pi \frac{\Delta r}{\lambda}$      $f_{beat} = |f_2 - f_1|$      $f_L = \left( \frac{v \pm v_L}{v \pm v_S} \right) f_S$

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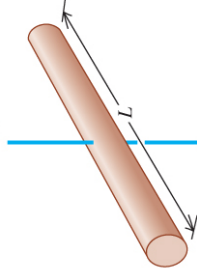
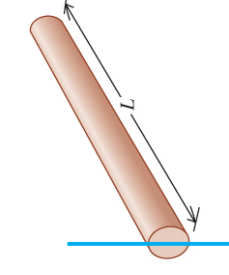
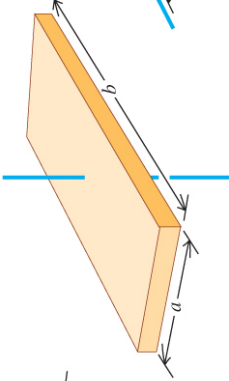
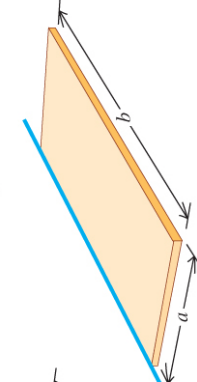
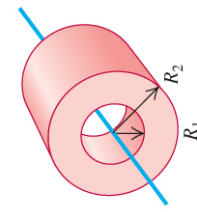
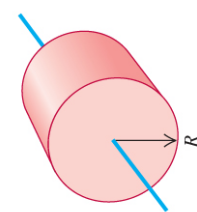
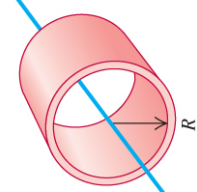
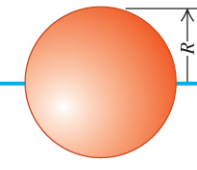
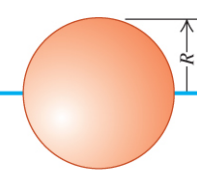
**Vectors:**  $A_x = A \cos \theta$      $A_y = A \sin \theta$      $A = \sqrt{A_x^2 + A_y^2}$      $\tan \theta = \frac{A_y}{A_x}$   
 $\vec{A} \cdot \vec{B} = AB \cos \phi_{AB}$      $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$      $\vec{A} \times \vec{B} = \hat{n} AB \sin \phi_{AB}$

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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  $x \ll 1$

**Constants:**  $g = 9.8 \text{ m/s}^2$       $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$       $R_{Earth} = 6.37 \times 10^6 \text{ m}$   
 $M_{Earth} = 5.98 \times 10^{24} \text{ kg}$       $M_{Sun} = 1.99 \times 10^{30} \text{ kg}$       $c = 2.998 \times 10^8 \text{ m/s}$   
 $v_{sound} = 343 \text{ m/s}$

**TABLE 9.2** Moments of Inertia of Various Bodies

<p>(a) Slender rod, axis through center</p> $I = \frac{1}{12}ML^2$ 	<p>(b) Slender rod, axis through one end</p> $I = \frac{1}{3}ML^2$ 	<p>(c) Rectangular plate, axis through center</p> $I = \frac{1}{12}M(a^2 + b^2)$ 	<p>(d) Thin rectangular plate, axis along edge</p> $I = \frac{1}{3}Ma^2$ 	<p>(e) Hollow cylinder</p> $I = \frac{1}{2}M(R_1^2 + R_2^2)$ 	<p>(f) Solid cylinder</p> $I = \frac{1}{2}MR^2$ 	<p>(g) Thin-walled hollow cylinder</p> $I = MR^2$ 	<p>(h) Solid sphere</p> $I = \frac{2}{5}MR^2$ 	<p>(i) Thin-walled hollow sphere</p> $I = \frac{2}{3}MR^2$ 
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