P6.55 Take x-axis up the hill

$$\sum F_x = ma_x: \quad +T\sin\theta - mg\sin\phi = ma$$
$$a = \frac{T}{m}\sin\theta - g\sin\phi$$
$$\sum F_y = ma_y: \quad +T\cos\theta - mg\cos\phi = 0$$
$$T = \frac{mg\cos\phi}{\cos\theta}$$
$$a = \frac{g\cos\phi\sin\theta}{\cos\theta} - g\sin\phi$$
$$a = \boxed{g(\cos\phi\tan\theta - \sin\phi)}$$

P6.60 For the block to remain stationary, $\sum F_y = 0$ and $\sum F_x = ma_r$.

$$n_1 = (m_p + m_b)g \text{ so } f \le \mu_{s1}n_1 = \mu_{s1}(m_p + m_b)g.$$

At the point of slipping, the required centripetal force equals the maximum friction force:

$$\therefore (m_p + m_b)\frac{v_{\text{max}}^2}{r} = \mu_{s1}(m_p + m_b)g$$

or $v_{\text{max}} = \sqrt{\mu_{s1}rg} = \sqrt{(0.750)(0.120)(9.80)} = 0.939 \text{ m/s}$.

For the penny to remain stationary on the block:

$$\sum F_y = 0 \Rightarrow n_2 - m_p g = 0 \text{ or } n_2 = m_p g$$

and $\sum F_x = ma_r \Rightarrow f_p = m_p\dfrac{v^2}{r}$.

When the penny is about to slip on the block, $f_p = f_{p,\text{max}} = \mu_{s2}n_2$

or $\mu_{s2}m_p g = m_p\dfrac{v_{\text{max}}^2}{r}$

$$v_{\text{max}} = \sqrt{\mu_{s2}rg} = \sqrt{(0.520)(0.120)(9.80)} = 0.782 \text{ m/s}$$

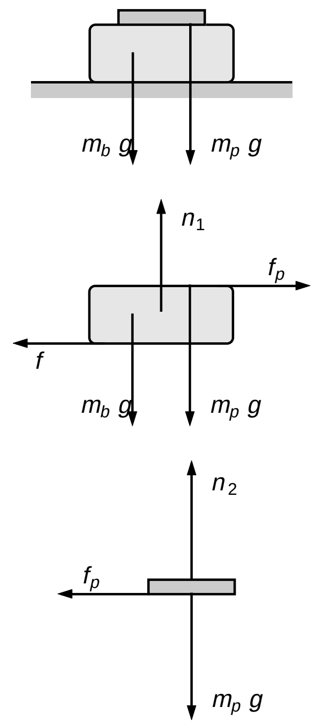

FIG. P6.60

This is less than the maximum speed for the block, so the penny slips before the block starts to slip. The maximum rotation frequency is

$$\text{Max rpm} = \frac{v_{\text{max}}}{2\pi r} = (0.782 \text{ m/s})\left[\frac{1 \text{ rev}}{2\pi(0.120 \text{ m})}\right]\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = \boxed{62.2 \text{ rev/min}}.$$

P6.61 $v=\dfrac{2\pi r}{T}=\dfrac{2\pi(9.00\text{ m})}{(15.0\text{ s})}=3.77\text{ m/s}$

(a) $a_r=\dfrac{v^2}{r}=\boxed{1.58\text{ m/s}^2}$

(b) $F_{\text{low}}=m(g+a_r)=\boxed{455\text{ N}}$

(c) $F_{\text{high}}=m(g-a_r)=\boxed{328\text{ N}}$

(d) $F_{\text{mid}}=m\sqrt{g^2+a_r^2}=\boxed{397\text{ N upward and}}$ at $\theta=\tan^{-1}\dfrac{a_r}{g}=\tan^{-1}\dfrac{1.58}{9.8}=\boxed{9.15°\text{ inward}}$.

P6.63 (a) The mass at the end of the chain is in vertical equilibrium. Thus $T\cos\theta=mg$.

Horizontally $T\sin\theta=ma_r=\dfrac{mv^2}{r}$

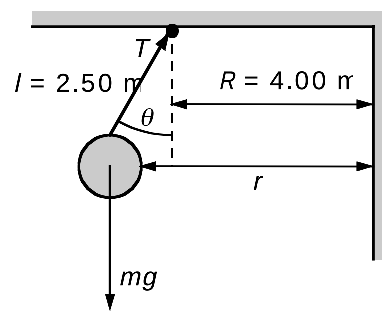

FIG. P6.63

$$r=(2.50\sin\theta+4.00)\text{ m}$$
$$r=(2.50\sin 28.0°+4.00)\text{ m}=5.17\text{ m}$$

Then $a_r=\dfrac{v^2}{5.17\text{ m}}$.

By division $\tan\theta=\dfrac{a_r}{g}=\dfrac{v^2}{5.17\,g}$

$$v^2=5.17g\tan\theta=(5.17)(9.80)(\tan 28.0°)\text{ m}^2/\text{s}^2$$
$$v=\boxed{5.19\text{ m/s}}$$

(b) $T\cos\theta=mg$

$$T=\frac{mg}{\cos\theta}=\frac{(50.0\text{ kg})(9.80\text{ m/s}^2)}{\cos 28.0°}=\boxed{555\text{ N}}$$

P6.70 $v=\left(\dfrac{mg}{b}\right)\left[1-\exp\left(\dfrac{-bt}{m}\right)\right]$ where $\exp(x)=e^x$ is the exponential function.

At $t\to\infty$, $v\to v_T=\dfrac{mg}{b}$

At $t=5.54\text{ s}$

$$0.500v_T=v_T\left[1-\exp\left(\frac{-b(5.54\text{ s})}{9.00\text{ kg}}\right)\right]$$

$$\exp\left(\frac{-b(5.54\text{ s})}{9.00\text{ kg}}\right)=0.500;$$

$$\frac{-b(5.54\text{ s})}{9.00\text{ kg}}=\ln 0.500=-0.693;$$

$$b=\frac{(9.00\text{ kg})(0.693)}{5.54\text{ s}}=1.13\text{ m/s}$$

continued on next page

(a) $v_T = \frac{mg}{b}$ $v_T = \frac{(9.00\text{ kg})(9.80\text{ m/s}^2)}{1.13\text{ kg/s}} = \boxed{78.3\text{ m/s}}$

(b) $0.750 v_T = v_T\left[1 - \exp\left(\frac{-1.13t}{9.00\text{ s}}\right)\right]$ $\exp\left(\frac{-1.13t}{9.00\text{ s}}\right) = 0.250$

$$t = \frac{9.00(\ln 0.250)}{-1.13}\text{ s} = \boxed{11.1\text{ s}}$$

(c) $\frac{dx}{dt} = \left(\frac{mg}{b}\right)\left[1 - \exp\left(-\frac{bt}{m}\right)\right]$; $\int_{x_0}^{x} dx = \int_0^t \left(\frac{mg}{b}\right)\left[1 - \exp\left(\frac{-bt}{m}\right)\right]dt$

$$x - x_0 = \frac{mgt}{b} + \left(\frac{m^2 g}{b^2}\right)\exp\left(\frac{-bt}{m}\right)\Bigg|_0^t = \frac{mgt}{b} + \left(\frac{m^2 g}{b^2}\right)\left[\exp\left(\frac{-bt}{m}\right) - 1\right]$$

At $t = 5.54$ s,

$$x = 9.00\text{ kg}(9.80\text{ m/s}^2)\frac{5.54\text{ s}}{1.13\text{ kg/s}} + \left(\frac{(9.00\text{ kg})^2(9.80\text{ m/s}^2)}{(1.13\text{ m/s})^2}\right)\left[\exp(-0.693) - 1\right]$$

$$x = 434\text{ m} + 626\text{ m}(-0.500) = \boxed{121\text{ m}}$$

Chapter 7: Energy and Energy Transfer

SOLUTIONS TO PROBLEMS

P7.9 (a) $\mathbf{A} = 3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}$

$\mathbf{B} = 4.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}}$ $\qquad \theta = \cos^{-1}\dfrac{\mathbf{A}\cdot\mathbf{B}}{AB} = \cos^{-1}\dfrac{12.0 + 8.00}{\sqrt{(13.0)(32.0)}} = \boxed{11.3°}$

(b) $\mathbf{B} = 3.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}} + 2.00\hat{\mathbf{k}}$

$\mathbf{A} = -2.00\hat{\mathbf{i}} + 4.00\hat{\mathbf{j}}$ $\qquad \cos\theta = \dfrac{\mathbf{A}\cdot\mathbf{B}}{AB} = \dfrac{-6.00 - 16.0}{\sqrt{(20.0)(29.0)}}$ $\qquad \theta = \boxed{156°}$

(c) $\mathbf{A} = \hat{\mathbf{i}} - 2.00\hat{\mathbf{j}} + 2.00\hat{\mathbf{k}}$

$\mathbf{B} = 3.00\hat{\mathbf{j}} + 4.00\hat{\mathbf{k}}$ $\qquad \theta = \cos^{-1}\left(\dfrac{\mathbf{A}\cdot\mathbf{B}}{AB}\right) = \cos^{-1}\left(\dfrac{-6.00 + 8.00}{\sqrt{9.00}\cdot\sqrt{25.0}}\right) = \boxed{82.3°}$

P7.10 $\mathbf{A} - \mathbf{B} = \left(3.00\hat{\mathbf{i}} + \hat{\mathbf{j}} - \hat{\mathbf{k}}\right) - \left(-\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}} + 5.00\hat{\mathbf{k}}\right)$

$\mathbf{A} - \mathbf{B} = 4.00\hat{\mathbf{i}} - \hat{\mathbf{j}} - 6.00\hat{\mathbf{k}}$

$\mathbf{C}\cdot(\mathbf{A} - \mathbf{B}) = \left(2.00\hat{\mathbf{j}} - 3.00\hat{\mathbf{k}}\right)\cdot\left(4.00\hat{\mathbf{i}} - \hat{\mathbf{j}} - 6.00\hat{\mathbf{k}}\right) = 0 + (-2.00) + (+18.0) = \boxed{16.0}$

P7.16 (a) Spring constant is given by $F = kx$

$$k = \frac{F}{x} = \frac{(230\text{ N})}{(0.400\text{ m})} = \boxed{575\text{ N/m}}$$

(b) Work $= F_{\text{avg}}x = \dfrac{1}{2}(230\text{ N})(0.400\text{ m}) = \boxed{46.0\text{ J}}$

P7.34 $\sum F_y = ma_y$: $\qquad n + (70.0\text{ N})\sin 20.0° - 147\text{ N} = 0$

$n = 123\text{ N}$

$f_k = \mu_k n = 0.300(123\text{ N}) = 36.9\text{ N}$

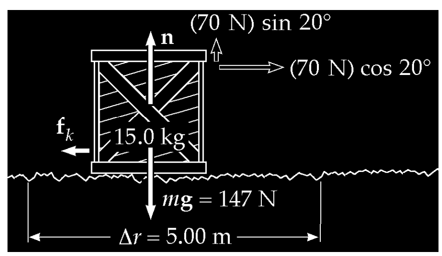

FIG. P7.34

(a) $W = F\Delta r\cos\theta = (70.0\text{ N})(5.00\text{ m})\cos 20.0° = \boxed{329\text{ J}}$

(b) $W = F\Delta r\cos\theta = (123\text{ N})(5.00\text{ m})\cos 90.0° = \boxed{0\text{ J}}$

(c) $W = F\Delta r\cos\theta = (147\text{ N})(5.00\text{ m})\cos 90.0° = \boxed{0}$

(d) $\Delta E_{\text{int}} = F\Delta x = (36.9\text{ N})(5.00\text{ m}) = \boxed{185\text{ J}}$

(e) $\Delta K = K_f - K_i = \sum W - \Delta E_{\text{int}} = 329\text{ J} - 185\text{ J} = \boxed{+144\text{ J}}$

***P7.36** $\mathcal{P}_{\text{av}} = \dfrac{W}{\Delta t} = \dfrac{K_f}{\Delta t} = \dfrac{mv^2}{2\Delta t} = \dfrac{0.875\text{ kg}(0.620\text{ m/s})^2}{2\left(21\times 10^{-3}\text{ s}\right)} = \boxed{8.01\text{ W}}$