13-8

\[ T_2 \]

10
7

15

30° angle

\[ \Sigma F_y = T_1 \cos 30° - 5g = 0 \]
\[ \Sigma F_x = T_1 \sin 30° - \mu (10g) = 0 \]

\[ T_1 = \frac{5g}{\cos(30°)} \quad \mu = \frac{5g \tan(30°)}{10g} = 0.29 \]

13-36 a) Calculate torque about the "pin"

\[ \Sigma \tau = TL \sin \theta - mgx = 0 \]

\[ T = \frac{mg}{L \sin \theta} x \]

b) \[ F_x' - T \cos \theta = 0 \quad \text{...use } T \text{ from } (a) \]

\[ F_x = \frac{mg}{L \tan \theta} x \]

c) \[ F_y' + T \sin \theta - mg = 0 \quad \text{...use } T \text{ from } (a) \]

\[ F_y' = mg \left( 1 - \frac{x}{L} \right) \]
The figure shows all the forces. The roller has no friction, but the floor does. Both roller and floor exert normal forces perpendicular to contact plane.

For $\theta = 70^\circ$, $f_s$ is at its maximum value $f_{s,\text{max}}$

$f_{s,\text{max}} = \mu_s N$

Calculate torques about point on floor where ladder touches. Net torque = 0

$N_R \left( \frac{h}{\sin 70^\circ} \right) - W \cos 70^\circ \left( \frac{L}{2} \right) = 0$

$N_R \cos 70^\circ + N - W = 0$

$\mu_s N - N_R \sin 70^\circ = 0$

3 unknowns $(N_R, N, \mu)$

3 equations

Get $\mu_s = \frac{\cos 70^\circ (\sin 70^\circ)^2}{1 - (\cos 70^\circ)^2 \sin 70^\circ} = 0.34$
16-19

(a) From \( T = 2\pi \sqrt{\frac{m + M}{R}} \), we solve for \( M \) to get \( M = (k/4\pi^2)T^2 - m \).

(b) Since \( M = 0 \),

\[
m = \frac{kT^2}{4\pi^2} = \frac{(605.6 \text{ N/m})(0.90149 \text{ s})}{4\pi^2} = 12.47 \text{ kg}.
\]

(c) The mass of the astronaut is

\[
M = (k/4\pi^2)T^2 - m = \frac{(605.6 \text{ N/m})(2.08832 \text{ s})}{4\pi^2} - 12.47 \text{ kg} = 54.43 \text{ kg}.
\]

16-25

Since the maximum horizontal force exerted on the block of mass \( m \) is \( f_{\text{max}} = \mu mg \), the block is only capable of reaching a maximum acceleration \( a_m = f_{\text{max}}/m = \mu g \). Since \( m \) is in SHM, its actual maximum acceleration is \( a'_m = \omega^2 A = kA/(m + M) \). Thus the condition for \( m \) and \( M \) to be in contact is

\[
a'_m = \frac{kA}{m + M} \leq a_m = \mu g,
\]

or

\[
A \leq \frac{\mu g(m + M)}{k} = \frac{(0.40)(9.8 \text{ m/s}^2)(1.0 \text{ kg} + 10 \text{ kg})}{200 \text{ N/m}} = 0.22 \text{ m}.
\]

16-33

Consider a displacement \( x \) (say, to the right) of the mass \( m \). The force \( f_1 \) exerted by the left spring on the mass is \( f_1 = -kx \), while the force \( f_2 \) exerted by the right one is also \( f_2 = -kx \). Thus the net force on \( m \) is \( f_{\text{net}} = f_1 + f_2 = -2kx = -k_{\text{eff}}x \). So

\[
f = \frac{1}{2\pi} \sqrt{\frac{k_{\text{eff}}}{m}} = \frac{1}{2\pi} \sqrt{\frac{2k}{m}}.
\]
(a) Use $\frac{1}{2} kA^2 = \frac{1}{2}mv^2$ to find $k$:

$$k = m\left(\frac{v}{A}\right)^2 = (0.130 \text{ kg})\left(\frac{11.2 \times 10^3 \text{ m/s}}{1.50 \text{ m}}\right)^2 = 7.25 \times 10^8 \text{ N/m}.$$  

(b) The number of people required is

$$n = \frac{kA}{220 \text{ N}} = \frac{(7.25 \times 10^8 \text{ N/m})(1.50 \text{ m})}{220 \text{ N}} = 49,400.$$

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16-72

(a) The linear acceleration due to $F$ at point $O$ is given by $F = ma$, or $a = F/m$.

(b) The angular acceleration about point $C$ is

$$\alpha = \frac{\tau}{I} = \frac{F(L_0/6)}{mL_0^2/12} = \frac{2F}{mL_0}.$$

(c) The actual linear acceleration at point $O$ is given by

$$\alpha \frac{L_0}{2} = \frac{F}{m} = \frac{2F}{mL_0} = \frac{L_0}{2}.$$

Answer: $\frac{\alpha L_0}{2}$

(d) Since $a_0 = 0$, no force is felt at $O$, i.e. $P$ is indeed the "sweet spot."