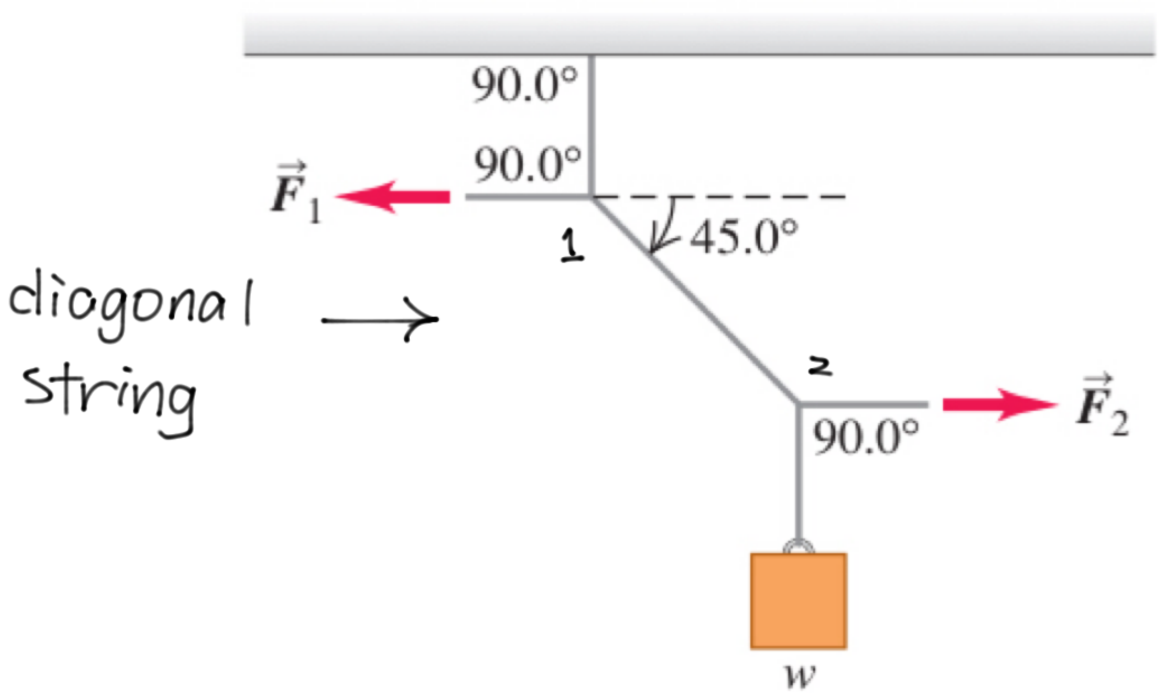
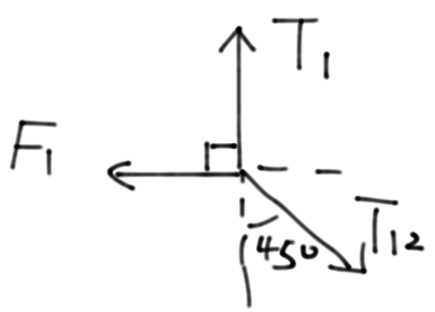
5.10 •• In Fig. E5.10 the weight w is 60.0 N. (a) What is the tension in the diagonal string? (b) Find the magnitudes of the horizontal forces $\vec{F}_1$ and $\vec{F}_2$ that must be applied to hold the system in the position shown.

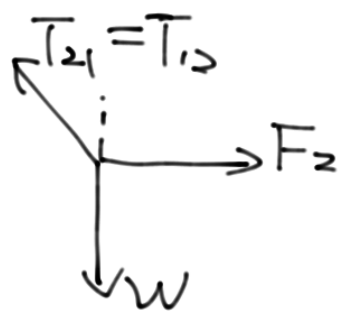
Figure **E5.10**



Point 1

Point 2





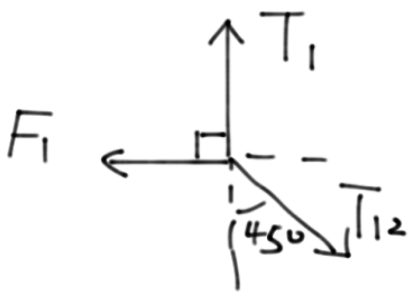
x: $F_2 = T_{12} \cdot \sin 45°$

y: $w = T_{12} \cdot \cos 45°$

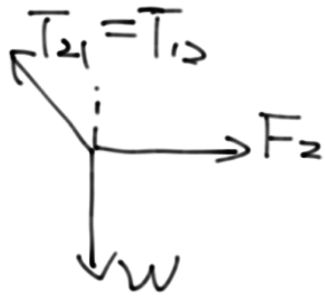
x: $F_1 = T_{12} \cdot \sin 45°$

y: $T_1 = T_{12} \cdot \cos 45°$

Point 1



Point 2



$x: \; F_1 = T_{12} \cdot \sin 45°$ ①

$y: \; T_1 = T_{12} \cdot \cos 45°$ ②

$x: \; F_2 = T_{12} \cdot \sin 45°$ ③

$y: \; W = T_{12} \cdot \cos 45°$ ④

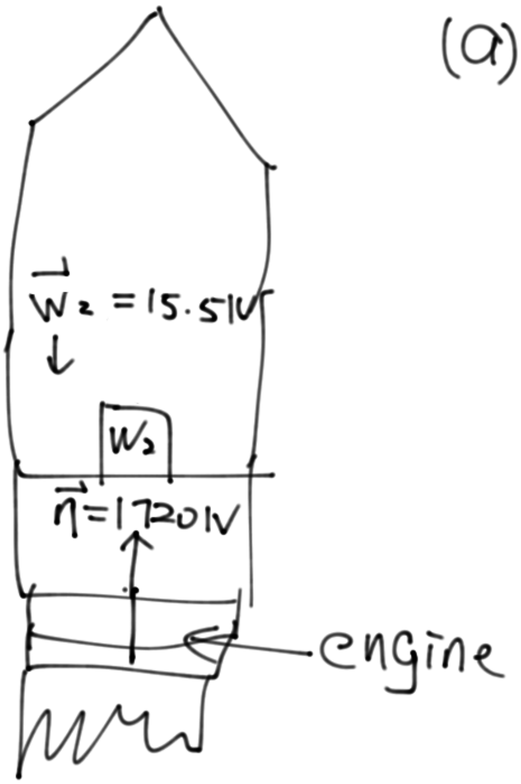
We only know W, so start from it ④

$$T_{12} = \frac{W}{\cos 45°} = 60\sqrt{2} \text{ N}$$

(b) From ①. $F_1 = T_{12} \cdot \sin 45° = 60 \text{N}$

② $F_2 = 60 \text{N}$

5.12 •• A 125-kg (including all the contents) rocket has an engine that produces a constant vertical force (the *thrust*) of 1720 N. Inside this rocket, a 15.5-N electrical power supply rests on the floor. (a) Find the acceleration of the rocket. (b) When it has reached an altitude of 120 m, how hard does the floor push on the power supply? (*Hint:* Start with a free-body diagram for the power supply.)



(a) For the rocket

$$\Sigma\vec{F} = \vec{n} - mg \cdot \hat{i}$$
$$= 1720 - 1225\,N\,\hat{i}$$
$$= 495N \cdot \hat{i}$$

$$\vec{a} = \frac{\Sigma\vec{F}}{m} = \frac{495N}{125\,kg} \cdot \hat{i}$$
$$= 3.96\ m/s^2\ \hat{i}$$

$\vec{a} \uparrow$ same $\vec{a}$!

(b)

$\vec{W}_2 = 15.5N(-\hat{i})$

$$\left.\begin{aligned} \Sigma\vec{F} &= m\vec{a} = \frac{W_2}{g} \cdot \vec{a} \\ \Sigma\vec{F} &= \vec{n} + \vec{W}_2 = (n - W_2)\hat{i} \end{aligned}\right] \Rightarrow$$

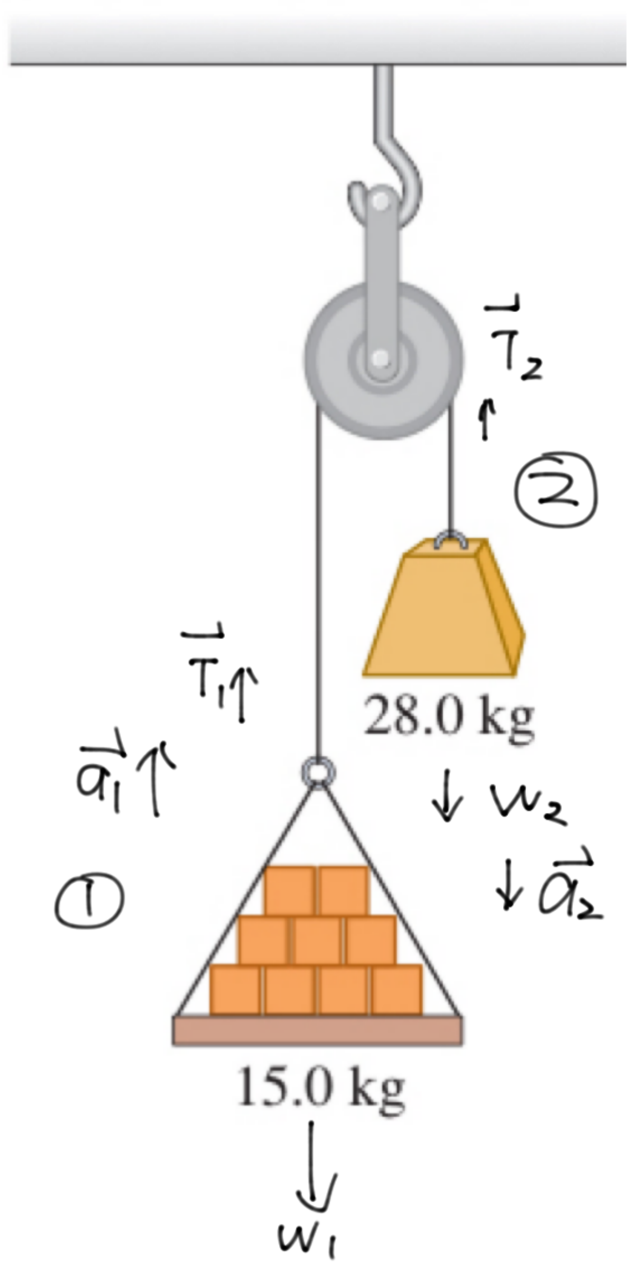
$$\Rightarrow (n - W_2)\hat{i} = \frac{W_2}{g} a\ \hat{i}$$

$$\Rightarrow n = W_2 + W_2\left(\frac{a}{g}\right) = 15.5N \cdot \left(1 + \frac{3.96}{9.8}\right)$$
$$= 21.7N$$

$\vec{n} = 21.7N\,\hat{i}$

5.15 •• **Atwood's Machine.** A 15.0-kg load of bricks hangs from one end of a rope that passes over a small, frictionless pulley. A 28.0-kg counterweight is suspended from the other end of the rope, as shown in Fig. E5.15. The system is released from rest. (a) Draw two free-body diagrams, one for the load of bricks and one for the counterweight. (b) What is the magnitude of the upward acceleration of the load of bricks? (c) What is the tension in the rope while the load is moving? How does the tension compare to the weight of the load of bricks? To the weight of the counterweight?

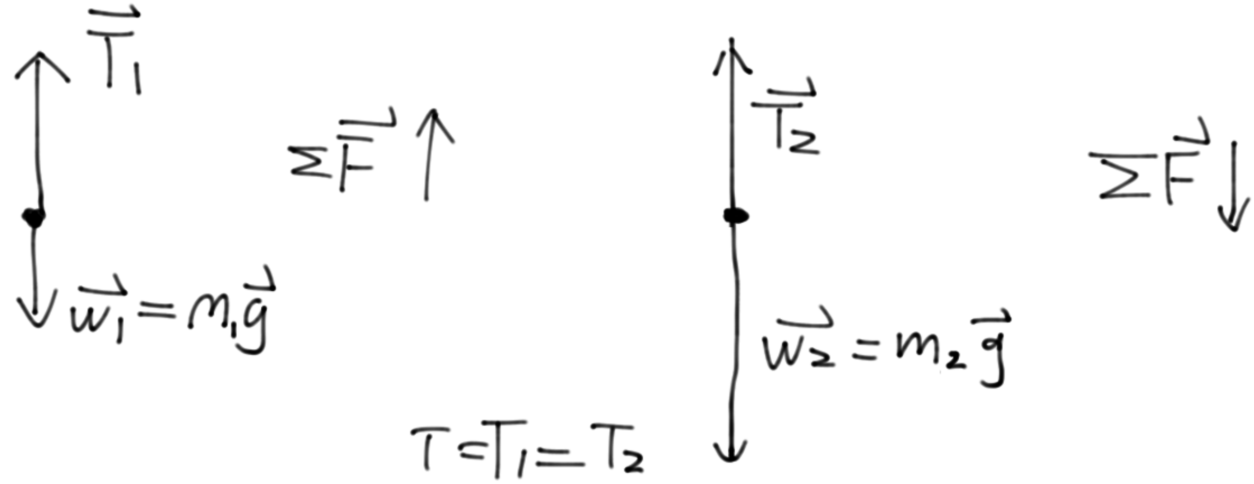
Figure **E5.15**



Implied Constraints:

1 $|\vec{T_1}| = |\vec{T_2}|$

2 $|\vec{a_1}| = |\vec{a_2}|$ length of the rope is constant



$T=T_1=T_2$

① $T_1-m_1g=m_1a$ $\qquad$ $m_2g-T_2=m_2a$ ②

①+②

$$(T-m_1g)+(m_2g-T)=m_1a+m_2a$$

$$(m_2-m_1)g=(m_1+m_2)a \Rightarrow a=\frac{m_2-m_1}{m_2+m_1}g$$

$$a=\frac{28-15}{28+15}\cdot 9.8\,m/s^2=2.96\ m/s^2$$

$\hat{i}\uparrow$

(a) $\vec{a_1}=2.96\,m/s^2\,\hat{i}$

$\vec{a_2}=-2.96\,m/s^2\,\hat{i}$

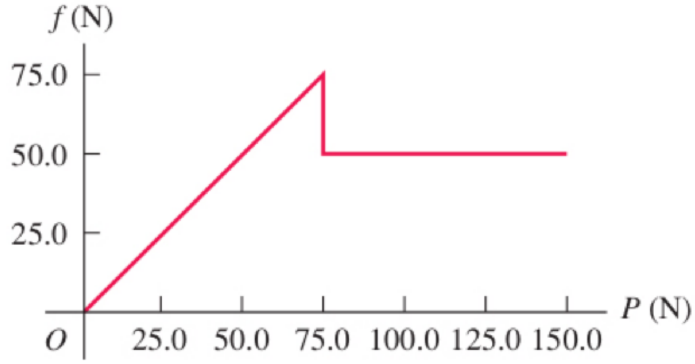
(b) $T=m_1g+m_1a$ from ①

$=15\,kg\,(9.8+2.96)\,m/s^2$

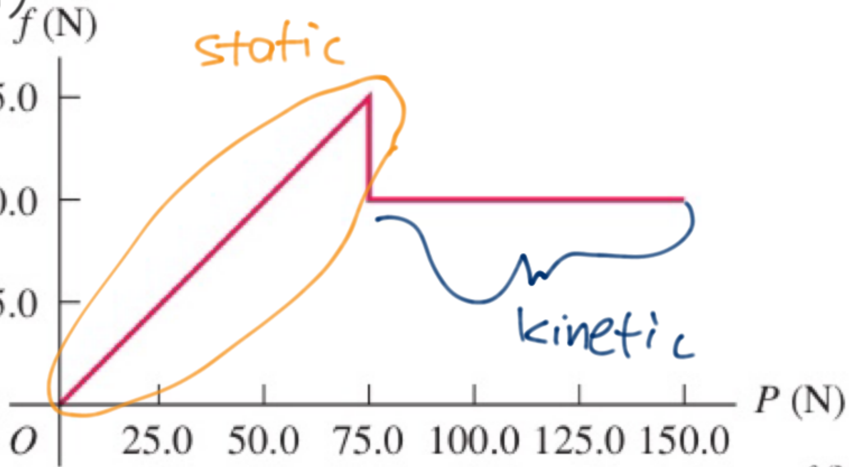
$=191.0\ N$

5.26 • In a laboratory experiment on friction, a 135-N block resting on a rough horizontal table is pulled by a horizontal wire. The pull gradually increases until the block begins to move and continues to increase thereafter. Figure E5.26 shows a graph of the friction force on this block as a function of the pull. (a) Identify the regions of the graph where static and kinetic friction occur. (b) Find the coefficients of static and kinetic friction between the block and the table. (c) Why does the graph slant upward in the first part but then level out? (d) What would the graph look like if a 135-N brick were placed on the box, and what would the coefficients of friction be in that case?

Figure **E5.26**



(a)



(b) $f_{static} \leq \mu_s n$

for static friction

$f_{static,\,max} = 75N$

$= \mu_s n.$

$n = 135N$

so $\mu_s = \frac{f_{static,\,max}}{n}$

$= 0.56$

$\mu_k = \frac{f_k}{n} = \frac{50N}{135N} = 0.37$

(c) static part :

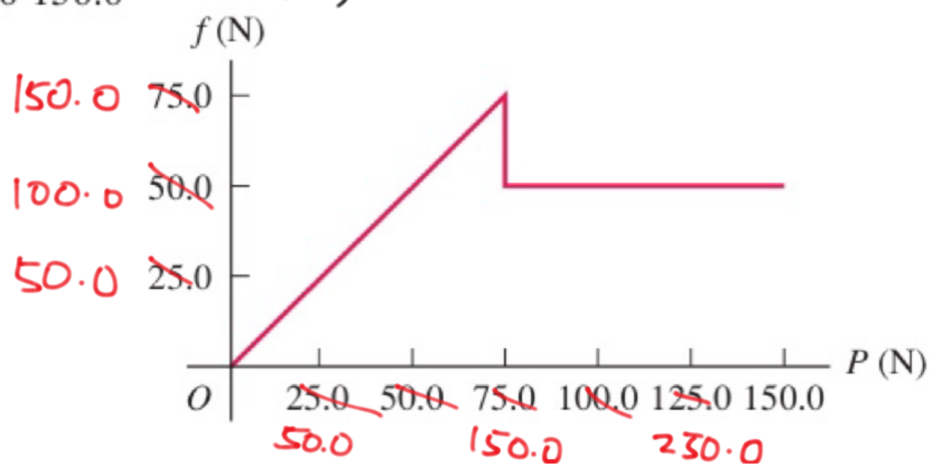
No motion $\Sigma \vec{F} = 0$

$P = f$ must hold

kinetic part :

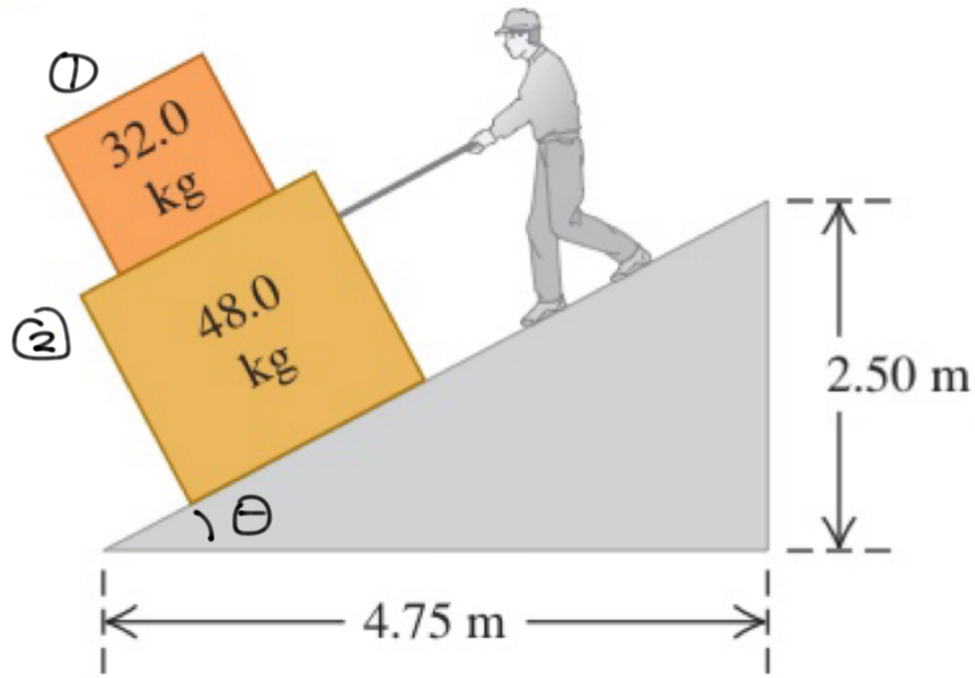
f_k is a constant

(d) μ_K, μ_s unchanged



5.31 •• You are lowering two boxes, one on top of the other, down the ramp shown in Fig. E5.31 by pulling on a rope parallel to the surface of the ramp. Both boxes move together at a constant speed of 15.0 cm/s. The coefficient of kinetic friction between the ramp and the lower box is 0.444, and the coefficient of static friction between the two boxes is 0.800. (a) What force do you need to exert to accomplish this? (b) What are the magnitude and direction of the friction force on the upper box?

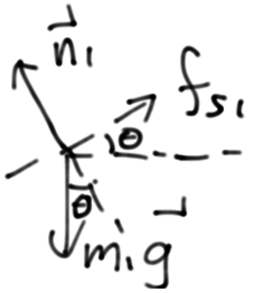
Figure **E5.31**



$\tan\theta = \frac{2.5m}{4.75m} = 0.5263 \qquad \theta = 27.76^\circ$

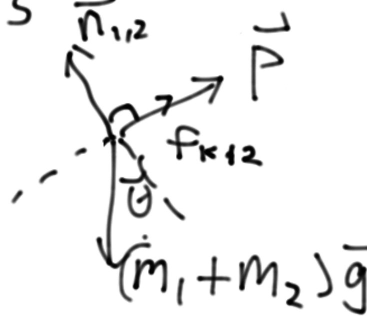
$\sin\theta = 0.466 \qquad \cos\theta = 0.885$

①



①② moving together.

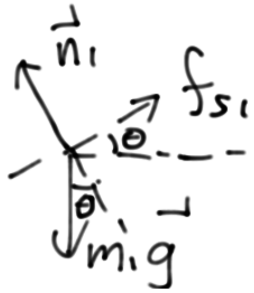
①+②



$m_1 = 32.0\,kg$

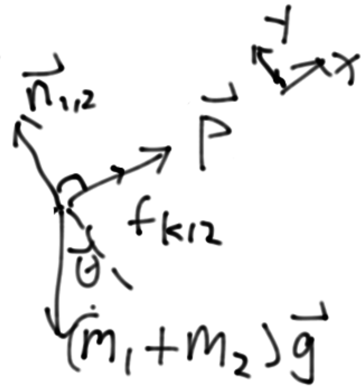
$\tan\theta = \frac{2.5\,m}{4.75\,m} = 0.5263 \qquad \theta = 27.76^\circ$

$\sin\theta = 0.466 \qquad \cos\theta = 0.885$

① 

①② moving together.

$m_1 = 32.0\,kg$

①+② 

$m_2 = 48.0\,kg$

For ①+②

Along x: $\quad P + f_{k12} = (m_1+m_2)g\cdot\sin\theta \qquad$ ①

Along y: $\quad n_{12} = (m_1+m_2)\cdot\cos\theta\, g \qquad$ ②

which are unknown? what is missing?

$f_{k12} = \mu_k \cdot n_{12} \quad$ ③ $\qquad \mu_k = 0.444$

②+③: $\quad = \mu_k (m_1+m_2)\cos\theta\, g$

Plug f_{k12} in ①

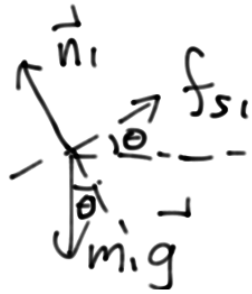
$$P = (m_1+m_2)g\sin\theta - \underbrace{(m_1+m_2)g\cdot\mu_k\cdot\cos\theta}_{f_{k12}}$$

$$= (m_1+m_2)g\,(\sin\theta - \mu_k\cdot\cos\theta)$$

$$= 80.0\,kg \cdot 9.8\,m/s^2\,(0.466 - 0.444\times 0.885)$$

$$= 57.3\,N$$

①



①② moving together.

$\cos\theta = 0.885$
$\sin\theta = 0.466$

$m_1 = 32.0\,kg$

①+② moving together so between them, there is STATIC Friction

$$n_1 = m_1 g \cdot \cos\theta$$

$$f_{s_1} = m_1 g \cdot \sin\theta \quad \text{so}$$

$$f_{s_1} = 32.0\,kg \cdot 9.8\,m/s^2 \cdot 0.466$$

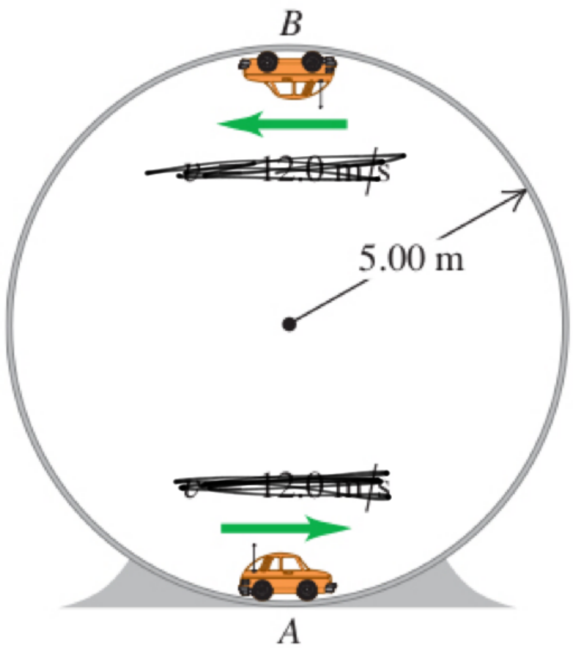
$$= 146.1\,N$$

Section 5.4 Dynamics of Circular Motion

5.42 •• A small car with mass 0.800 kg travels at constant speed on the inside of a track that is a vertical circle with radius 5.00 m (Fig. E5.42). If the normal force exerted by the track on the car when it is at the top of the track (point *B*) is 6.00 N, what is the normal force on the car when it is at the bottom of the track (point *A*)?

5.43 •• A machine part consists of a thin 40.0-cm-long bar with small 1.15-kg masses fastened by screws to its ends. The

Figure **E5.42**



Uniform circular motion

$F_{total} = m\frac{v^2}{R} = m a_{rad}$

$\boxed{\text{magnitude of } a_{rad} \text{ is the same}}$

Point A:

$\vec{n}_A$, $m\vec{g}$

$|\Sigma \vec{F}_A| = |\vec{n}_A| - |m\vec{g}|$

$\vec{a}_A = \frac{v^2}{R}\hat{i}$

$\Sigma \vec{F}_A = m\vec{a}_A$

$n_A - mg = m\frac{v^2}{R}$

Part B:

$|\Sigma \vec{F}_B| = |\vec{n}_B| + |m\vec{g}|$

$m\vec{g}$, $\vec{n}_B$

$\vec{a}_B = \frac{v^2}{R}\cdot(-\hat{i})$

$\Sigma \vec{F}_B = m\vec{a}_B$

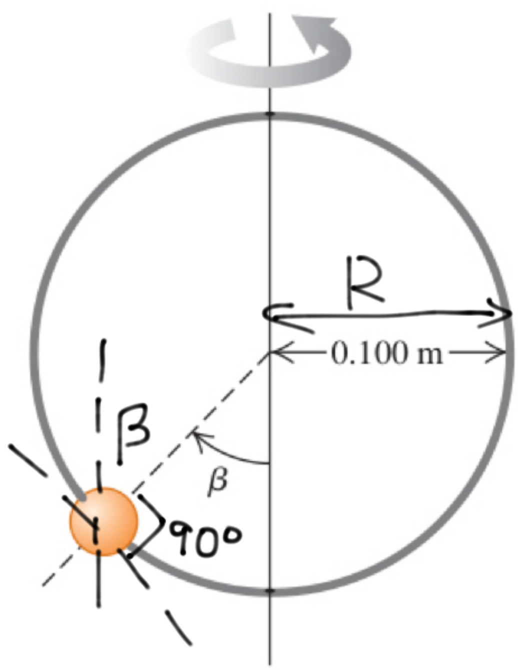
$\underbrace{n_B}_{6.0N} + \underbrace{m}_{0.8kg}g = m\frac{v^2}{R}$

$n_A - mg = n_B + mg$

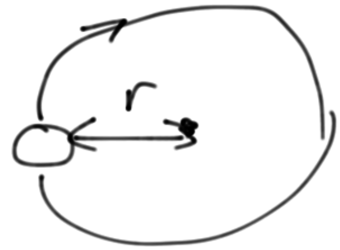
$n_A = 2mg + n_B = 2 \times 0.8\,kg \times 9.8\,m/s^2 + 6.0N = 21.68N$

5.119 •• A small bead can slide without friction on a circular hoop that is in a vertical plane and has a radius of 0.100 m. The hoop rotates at a constant rate of 4.00 rev/s about a vertical diameter (Fig. P5.119). (a) Find the angle β at which the bead is in vertical equilibrium. (Of course, it has a radial acceleration toward the axis.) (b) Is it possible for the bead to "ride" at the same elevation as the center of the hoop? (c) What will happen if the hoop rotates at 1.00 rev/s?

Figure **P5.119**



Top down view



$r = R \cdot \sin\beta$

$v = 2\pi \underline{freq.}\, r$

4 rev/s

$|\Sigma \vec{F}| = m\frac{v^2}{r}$

$\rightarrow$ axis of rotation

$$n \cdot \sin\beta = m\frac{v^2}{r} = \frac{m\,(2\pi\, freq\, r)^2}{r}$$

$$= 4\pi^2 freq^2\, m\, r$$

$r = R \cdot \sin\beta$ $\quad = 4\pi^2 \sin\beta\, mR\, freq^2$

$$n = 4\pi^2\, mR \cdot freq^2$$

Along axis

$mg = n \cdot \cos\beta$

$$\cos\beta = \frac{mg}{n} = \frac{g}{4\pi^2 R\, freq^2}.$$

$$\cos\beta = \frac{mg}{n} = \frac{g}{4\pi^2 R\, freq^2}$$

(a) when $freq = 4\ rev/s$

$$\cos\beta = \frac{9.8\ m/s^2}{4\times 3.14^2 \times (0.1\,m)\times(4/s)^2} = 0.155$$

$$\beta = \arccos(0.155) = 81.1^\circ$$

(b) That means $\beta = 90^\circ$ or $\cos\beta = 0$

But $\cos\beta = \dfrac{g}{4\pi^2 R\cdot freq^2} > 0$

(c) when $freq_2 = 1.0\ rev/s$

$$\cos\beta_2 = \frac{g}{4\pi^2 R\cdot freq_2^2} = 16\times 0.155 > 1$$

β_2 has no solution !

Rethink our assumptions

$\beta = 0$

What is the minimum β for $\beta > 0$?

$$\cos\beta = 1 = \frac{g}{4\pi^2 R\,\text{freq}^2}$$

$$\Rightarrow \text{freq} = \sqrt{\frac{g}{4\pi^2 R}}$$

$$= \sqrt{\frac{9.8\,m/s^2}{4 \times 3.14^2 \times 0.1\,m}}$$

$$= 1.576\ \text{rev/s}$$