

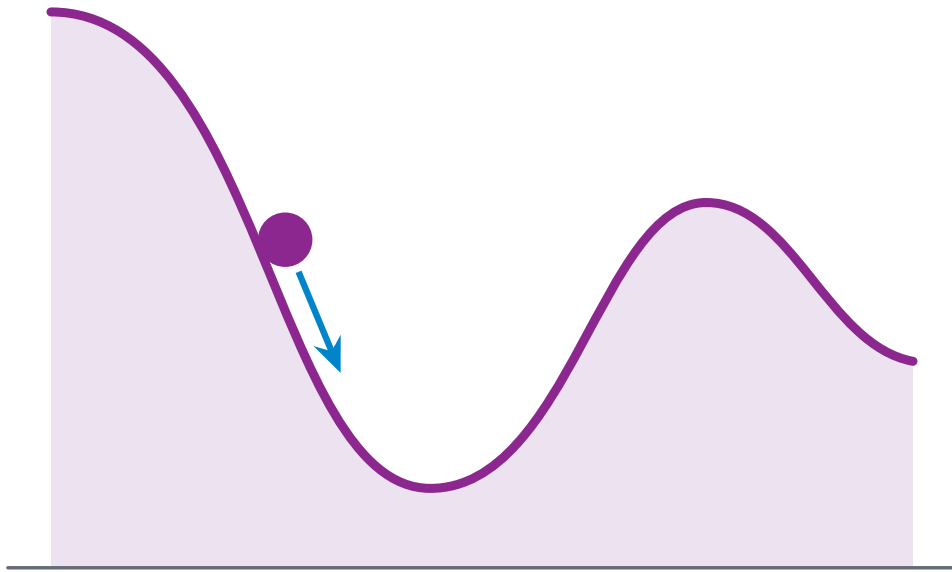
# GENERAL PHYSICS 1

## MECHANICS

### WORKBOOK

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13 chapters · 180 problems · step-by-step solutions



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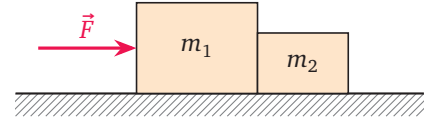
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## Connected objects

5.4

☆☆☆ Solution → p. 125

Two blocks in contact,  $m_1 = 4.00$  kg and  $m_2 = 2.00$  kg, on a frictionless horizontal floor are pushed by a horizontal force of 18.0 N applied to  $m_1$  from the left.



- Find the acceleration of the blocks.
- Find the contact force the blocks exert on each other.
- What would the contact force be if the same force were applied to  $m_2$  from the right? Why is the result different?

Grid area for solution to problem 5.4.

5.5

☆☆☆ Solution → p. 125

Two bodies of masses  $m$  and  $2m$  are hung from the ends of a string passing over a fixed pulley and the system is released. What is the tension  $T$  in the string?

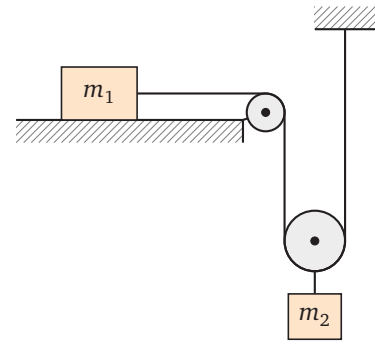
- A)  $mg$       B)  $\frac{4}{3}mg$       C)  $\frac{3}{2}mg$       D)  $2mg$       E)  $3mg$

Grid area for solution to problem 5.5.

## 5.6

★★★ Solution → p. 125

In the arrangement shown in the figure, the block of mass  $m_1 = 2.00 \text{ kg}$  is on a frictionless horizontal table. The string attached to the block passes over a fixed pulley at the edge of the table and under a movable pulley; the other end of the string is attached to the ceiling. A body of mass  $m_2 = 3.00 \text{ kg}$  hangs from the movable pulley.



- Find the relation between the acceleration  $a_1$  of  $m_1$  and the acceleration  $a_2$  of  $m_2$ .
- Find  $a_1$ ,  $a_2$  and the tension in the string.

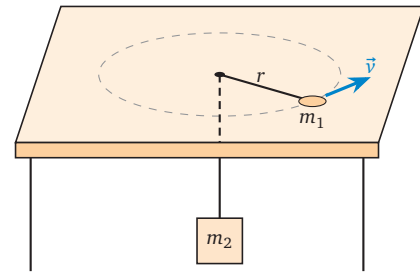
## Dynamics of circular motion

## 5.15

☆☆☆ Solution → p. 128

A disk of mass  $m_1 = 0.200$  kg on a frictionless horizontal table is connected by a string passing through a small hole at the center of the table to a body of mass  $m_2 = 0.500$  kg hanging beneath the table. While the disk moves uniformly in a circular path of radius  $r = 0.500$  m, the hanging body remains motionless.

- Find the tension in the string.
- Find the speed of the disk and its period of revolution.

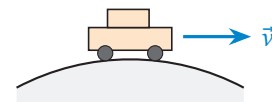


5.16

☆☆☆ Solution → p. 128

A 1200 kg car passes the top of a circular hump of radius 40.0 m at a speed of 12.0 m/s.

- Find the normal force the road exerts on the car at the top. Does the driver feel lighter or heavier?
- What is the maximum speed at which the car stays in contact with the road at the top?

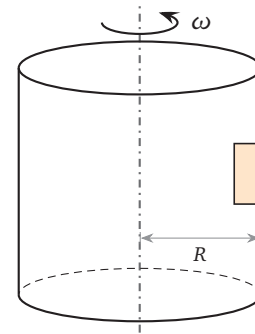


## 5.17

★★★ Solution → p. 128

In the amusement-park “rotor” ride, passengers stand with their backs against the inner wall of a cylinder of radius 2.50 m with a vertical axis. When the cylinder spins fast enough, the floor drops away and the passengers stay pinned to the wall. Between a passenger and the wall  $\mu_s = 0.400$ .

- What is the minimum angular speed of the cylinder so that the passengers do not slip?
- How long does one full revolution take in this case?
- Does the result depend on the mass of the passenger?

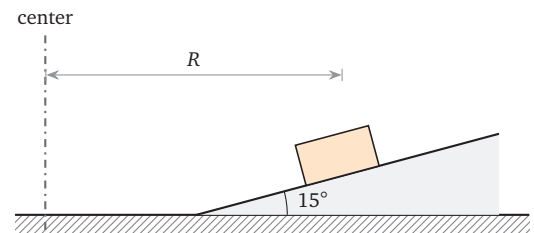


## 5.18

★★★ Solution → p. 128

A curve of radius 80.0 m is banked at an angle of  $15.0^\circ$ .

- At what speed could the curve be taken safely if there were no friction?
- If  $\mu_s = 0.300$  between the tires and the road, what is the maximum speed at which the curve can be taken without slipping? Why is there no minimum speed in this case?
- In rain  $\mu_s$  drops to 0.100. Find the range of safe speeds.



against the surface; the normal force increases by this amount. For the same reason only the part  $F \cos 25^\circ$  of the horizontal force balances the component of the weight along the incline; therefore the horizontal force must be larger.

**ANSWER** a. 36.6 N b. 86.5 N c. 33.1 N, 71.1 N

### 5.4

← Problem p. 44

a. The two blocks move together; for the system

$$a = \frac{F}{m_1 + m_2} = \frac{18.0}{6.00} = 3.00 \text{ m/s}^2.$$

b. The only horizontal force on  $m_2$  is the contact force  $P$ :

$$P = m_2 a = (2.00)(3.00) = 6.00 \text{ N}.$$

(Check for  $m_1$ :  $F - P = m_1 a$ ,  $18.0 - 6.00 = 12.0 = (4.00)(3.00)$ .)

c. The acceleration does not change. This time the contact force accelerates only  $m_1$ :  $P' = m_1 a = 12.0 \text{ N}$ . The contact force is the force that accelerates the mass in front of the pushed block; the larger the mass in front, the larger the contact force.

**ANSWER** a.  $3.00 \text{ m/s}^2$  b. 6.00 N c. 12.0 N

### 5.5

← Problem p. 44

The heavier body accelerates downward, the lighter body upward; the magnitudes of the accelerations are the same ( $a$ ).

$$2m : 2mg - T = 2ma$$

$$m : T - mg = ma$$

Adding gives  $mg = 3ma$ , so  $a = g/3$ . Hence  $T = mg + ma = \frac{4}{3}mg$ .

Shortcut: since the lighter body accelerates upward,  $T > mg$ ; since the heavier body accelerates downward,  $T < 2mg$ . Only B lies in this range.

**ANSWER** B

### 5.6

← Problem p. 45

a. The length of the string is fixed. If the block moves a distance  $\Delta x$  toward the pulley, this length of string is shared between the two segments of the movable pulley; each segment of the pulley lengthens by  $\Delta y$ :  $\Delta x = 2\Delta y$ . Differentiating twice with respect to time,

$$a_1 = 2a_2.$$

b. The tension is  $T$  everywhere in the string. Two string segments pull the movable pulley upward.

$$m_1 : T = m_1 a_1 = 2m_1 a_2$$

$$m_2 : m_2 g - 2T = m_2 a_2$$

Substituting the first into the second,  $m_2 g - 4m_1 a_2 = m_2 a_2$ :

$$a_2 = \frac{m_2 g}{m_2 + 4m_1} = \frac{(3.00)(9.80)}{3.00 + 8.00} = 2.67 \text{ m/s}^2,$$

$$a_1 = 2a_2 = 5.35 \text{ m/s}^2, \quad T = m_1 a_1 = 10.7 \text{ N}.$$

Check:  $m_2 g - 2T = 29.4 - 21.4 = 8.0 \text{ N} = m_2 a_2$ .

**ANSWER** a.  $a_1 = 2a_2$  b.  $a_1 = 5.35 \text{ m/s}^2$ ,  
 $a_2 = 2.67 \text{ m/s}^2$ ,  $T = 10.7 \text{ N}$

### 5.7

← Problem p. 46

The maximum static friction is  $f_{s,\max} = \mu_s mg = (0.500)(98.0) = 49.0 \text{ N}$ . The applied 20.0 N is smaller than this; the box does not move. Static friction grows just enough to maintain equilibrium:  $f_s = 20.0 \text{ N}$ .

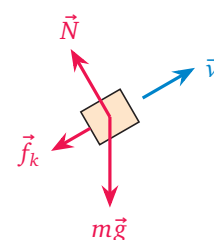
39.2 N is the kinetic friction (invalid, since the box does not slide); 49.0 N is the upper limit of static friction and does not always take that value.

**ANSWER** B

### 5.8

← Problem p. 46

The  $x$  axis is up along the incline. The normal force is  $N = mg \cos 30^\circ$  and the kinetic friction is  $f_k = \mu_k mg \cos 30^\circ$ ; friction always opposes the motion.



c. For  $v = 0.90 v_t$ ,  $e^{-t/\tau} = 0.10$ :

$$t = \tau \ln 10 = (0.102)(2.303) = 0.235 \text{ s.}$$

For the distance, integrate  $v(t)$ :

$$\begin{aligned} x(t) &= v_t [t - \tau(1 - e^{-t/\tau})] \\ &= 1.00 [0.235 - 0.102(0.90)] = 0.143 \text{ m.} \end{aligned}$$

**ANSWER** a. 1.00 m/s b.  $v = v_t(1 - e^{-t/\tau})$ ,  
 $\tau = 0.102 \text{ s}$  c. 0.235 s, 14.3 cm

**5.15**

← Problem p. 51

a. The hanging body is in equilibrium:  $T = m_2 g = (0.500)(9.80) = 4.90 \text{ N}$ .

b. The tension in the string provides the centripetal force on the disk:

$$\begin{aligned} T &= m_1 \frac{v^2}{r} \Rightarrow v = \sqrt{\frac{Tr}{m_1}}, \\ v &= \sqrt{\frac{(4.90)(0.500)}{0.200}} = 3.50 \text{ m/s,} \\ T_{\text{period}} &= \frac{2\pi r}{v} = \frac{2\pi(0.500)}{3.50} = 0.898 \text{ s.} \end{aligned}$$

**ANSWER** a. 4.90 N b. 3.50 m/s, 0.898 s

**5.16**

← Problem p. 51

At the top the center is below; the net force must be  $mv^2/R$  directed downward.

a.  $mg - N = m \frac{v^2}{R}$ :

$$\begin{aligned} N &= m \left( g - \frac{v^2}{R} \right) = 1200 \left( 9.80 - \frac{144}{40.0} \right) \\ &= 7.44 \times 10^3 \text{ N.} \end{aligned}$$

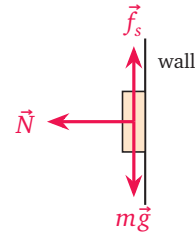
This is only 63% of the weight ( $1.18 \times 10^4 \text{ N}$ ); the driver feels lighter.

b. At the moment contact is lost  $N = 0$ :  $mg = mv^2/R$ ,  
 so  $v_{\text{max}} = \sqrt{gR} = \sqrt{(9.80)(40.0)} = 19.8 \text{ m/s}$ .

**ANSWER** a.  $7.44 \times 10^3 \text{ N}$ ; lighter b. 19.8 m/s

**5.17**

← Problem p. 52



The normal force of the wall points toward the center and provides the centripetal force; static friction supports the weight.

radial:  $N = m\omega^2 R$

vertical:  $f_s = mg \leq \mu_s N = \mu_s m\omega^2 R$

a.  $\omega_{\min} = \sqrt{\frac{g}{\mu_s R}} = \sqrt{\frac{9.80}{(0.400)(2.50)}} = 3.13 \text{ rad/s}$ .

b.  $T = 2\pi/\omega = 2.01 \text{ s}$  (about 30 revolutions per minute).

c.  $m$  cancels; heavy and light passengers alike stay in place at the same angular speed.

**ANSWER** a. 3.13 rad/s b. 2.01 s c. no

**5.18**

← Problem p. 52

The net force is horizontal, directed toward the center of the curve, with magnitude  $mv^2/R$ . The normal force is perpendicular to the road and friction is along the road.

a. Frictionless:  $N \cos \theta = mg$ ,  $N \sin \theta = mv^2/R$ .

Dividing,

$$v_0 = \sqrt{gR \tan \theta} = \sqrt{(9.80)(80.0)(0.268)} = 14.5 \text{ m/s.}$$

b. At the maximum speed the vehicle tends to slide outward; friction points *down* the slope (toward the center) and takes its maximum value,  $f = \mu_s N$ .

