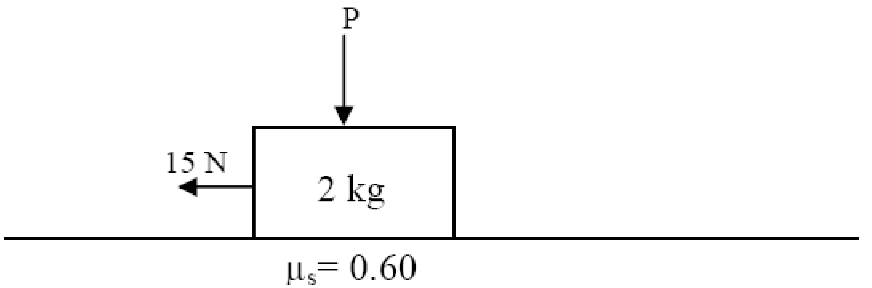
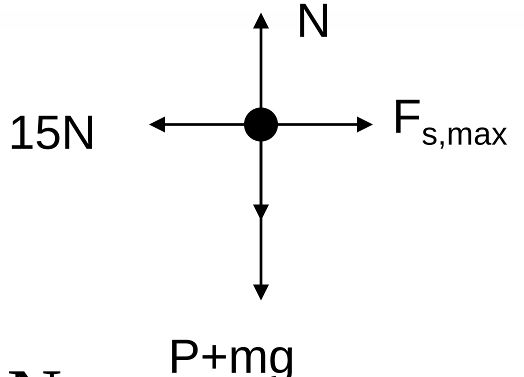
Selected Problems from Chapter 6

1) A 2.0 kg block is initially at rest on a horizontal surface. A 15 N horizontal force and a vertical force P are applied to the block as shown Fig . If the coefficient of static friction for the block and the surface is 0.60, what is the magnitude of force P that makes the block start moving?

A1 5.4 N
A2 25 N
A3 19.6 N
A4 44.6 N
A5 0 N



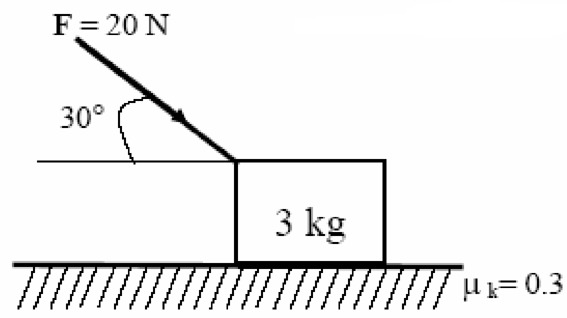


$$f_{s,\max} = 15 = \mu_s N \Rightarrow N = \frac{15}{0.60} = 25\ \mathrm{N}$$

$$N = P + mg \Rightarrow P = N - mg = 25 - 2.0 \times 9.80 = 5.4\ \mathrm{N}$$

2) A 3.0 kg block is pushed across a horizontal surface by a force F=20 N making an angle of 30 degrees with the horizontal (Fig). If the coefficient of kinetic friction between the block and the surface is 0.3, what is the magnitude of the acceleration of the block?

A1 1.8 m/s**2
A2 2.8 m/s**2
A3 3.3 m/s**2
A4 5.4 m/s**2
A5 2.5 m/s**2



$$F_x = F\cos 30^o = 17.3 \text{ N}$$
$$F_y = F\sin 30^o = 10 \text{ N}$$

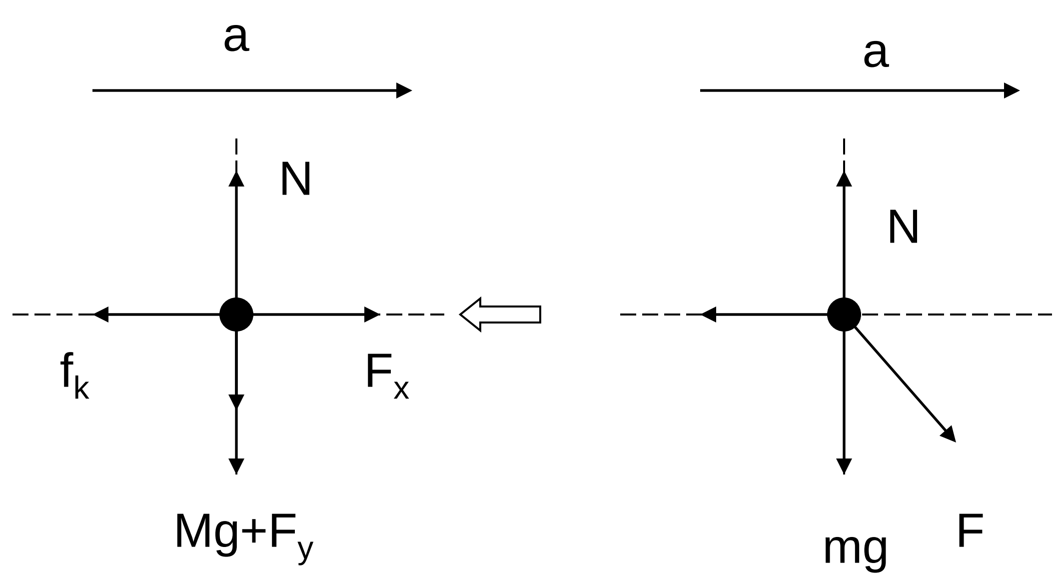
on the y-axis:

mg= 3.0×9.80=29.4 N

$$N = mg + F_y = 29.4 + 10 = 39.4 \text{ N}$$

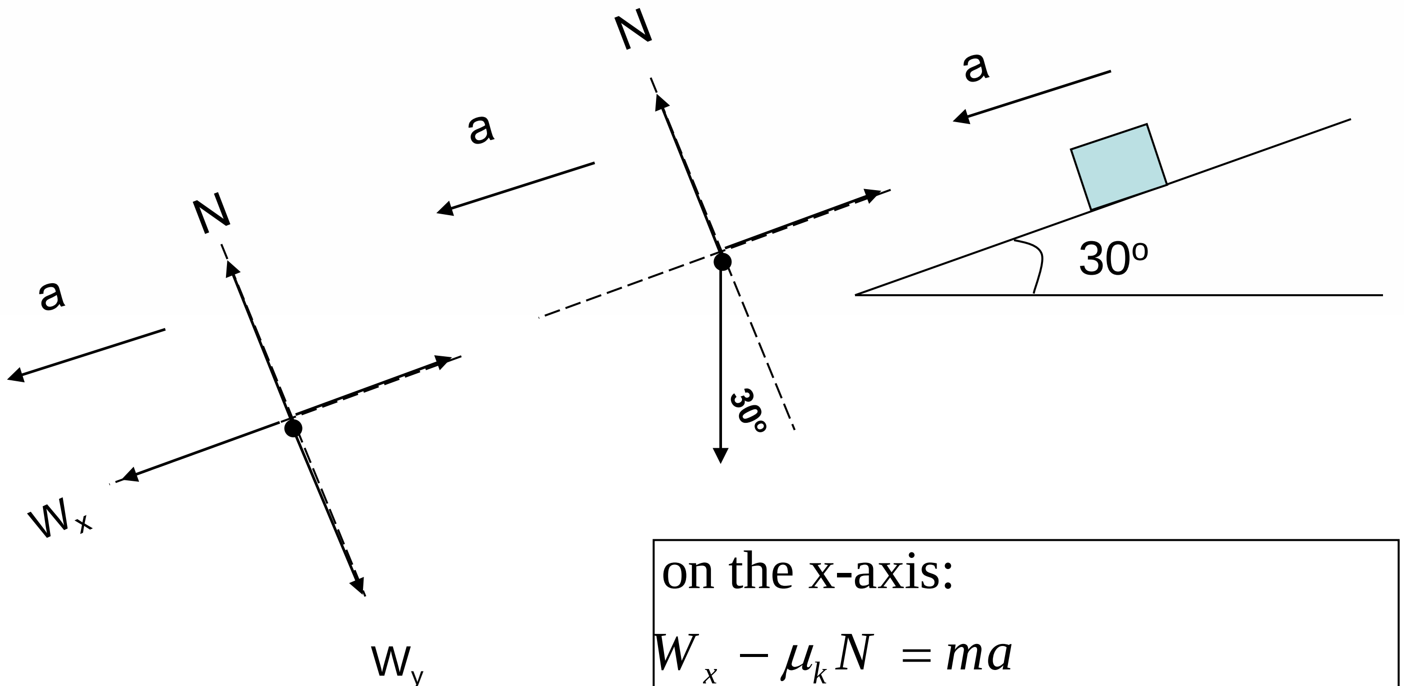
on the x-axis:

$$F_x - f_k = ma$$
$$17.3 - \mu_k N = ma$$
$$a = \frac{17.3 - \mu_k N}{m} = \frac{17.3 - 0.3 \times 39.4}{3.0} = 1.8 \text{ m/s}^2$$



3) A box slides down a 30 degree incline with an acceleration = 3.2 m/s**2. Find the coefficient of kinetic friction between the box and the incline.

A1 0.20
A2 0.25
A3 0.15
A4 0.30
A5 0.62



on the x-axis:

$$W_x - \mu_k N = ma$$

$$\mu_k = \frac{W_x - ma}{N} = \frac{mg\sin 30^o - ma}{mg\cos 30^o}$$

$$= \frac{g\sin 30^o - a}{g\cos 30^o}$$

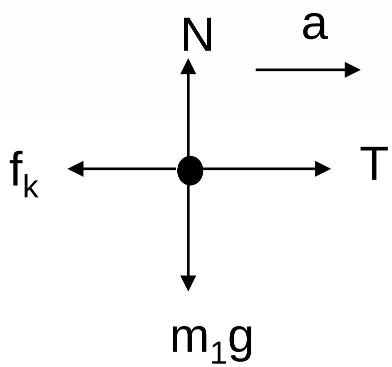
$$W_x = mg\sin 30^o$$
$$W_y = mg\cos 30^o$$

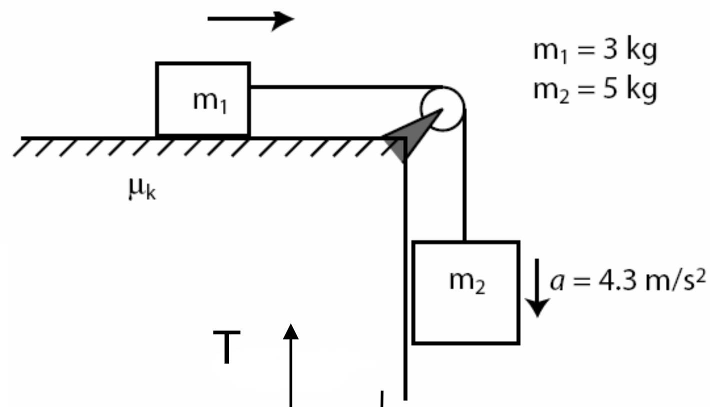
on the y-axis:

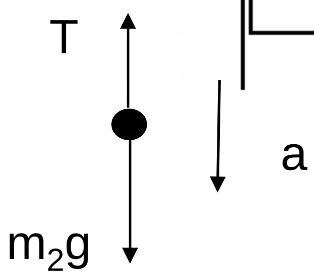
$$N = W_y$$

4) A block (m1= 3.0 kg) on a rough horizontal plane is connected to a second block (m2=5.0 kg) by a cord over a massless pulley. Calculate the coefficient of kinetic friction between the block m1 and the table if the acceleration of the descending block m2 is 4.3 m/s**2 (see Fig.)

A1 0.50
A2 0.25
A3 0.35
A4 0.75
A5 0.65







$$N = mg, \quad f_k = \mu_k N = \mu_k m_1 g$$

$$T - f_k = m_1 a$$
$$T - \mu_k m_1 g = m_1 a$$
$$\mu_k = \frac{T - m_1 a}{m_1 g} \quad (1)$$

$$m_2 g - T = m_2 a$$
$$T = m_2(g - a) \quad (2)$$

from (1) & (2)

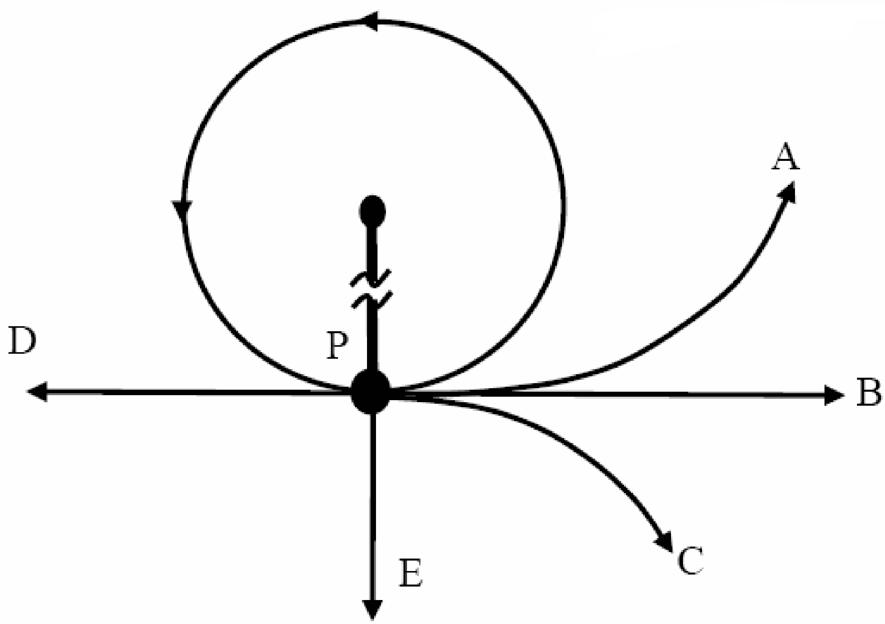
$$\mu_k = \frac{m_2(g-a) - m_1 a}{m_1 g} = \frac{m_2 g - a(m_2 - m_1)}{m_1 g}$$

5) An object moving in a circle at constant speed:

A1 has an acceleration of constant magnitude.
A2 has a constant acceleration.
A3 has a constant velocity .
A4 is held to its path by centrifugal force (a force directed
A4 away from the center .)
A5 has an acceleration that is tangent to the circle.

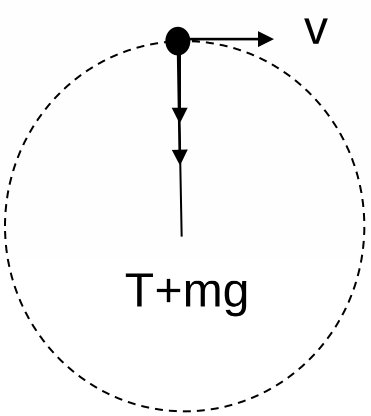
6) A block attached to a string, rotates counter-clockwise in a circle on a smooth horizontal surface. The string breaks at point P (Fig.). What path will the block follow?

A1 path B
A2 path A
A3 path C
A4 path D
A5 path E



7) One end of a 1.0-m string is fixed, the other end is attached to a 1.0-kg stone. The stone swings in a vertical circle, and has a speed of 5.0 m/s at the top of the circle. The tension in the string at this point is approximately:

A1 15 N
A2 11 N
A3 28 N
A4 31 N
A5 10 N



$$T + mg = \frac{mv^2}{R}$$

$$T = \frac{mv^2}{R} - mg = m\left(\frac{v^2}{R} - g\right)$$

8) Find the minimum coefficient of static friction between the tyres of a car and a level road if the car is to make a circular turn of radius 90 m at a speed of 60 km/h.

A1 0.315
A2 0.521
A3 0.423
A4 0.214
A5 0.125

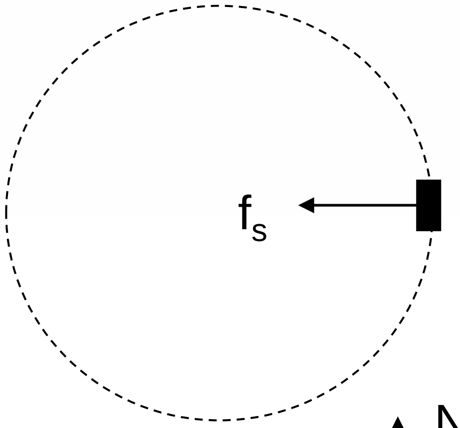
$$f_s = \frac{mv^2}{R}$$

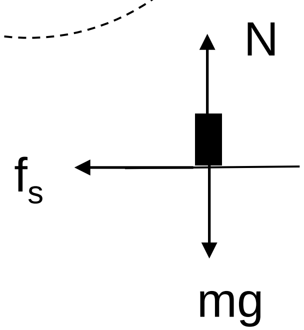
$$f_{s,\max} = \mu_s N = \mu_s mg$$

at slipping $(f_s = f_{s,\max})$

$$\mu_s mg = \frac{mv^2}{R}$$

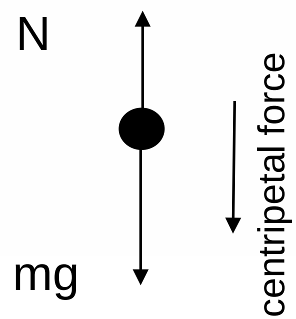
$$\mu_s = \frac{v^2}{gR}$$

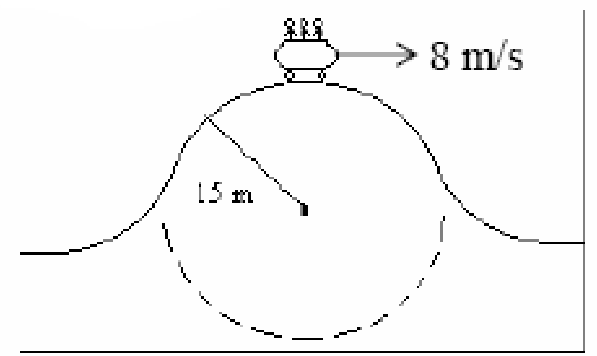




9) A roller-coaster car has a mass of 500 kg when fully loaded with passengers. The car passes over a hill of radius 15 m (Fig). At the top of the hill, the car has a speed of 8 m/s. What is the force of the track on the car at the top of the hill?

A1 2800 N up
A2 7000 N down
A3 7000 N up
A4 2800 N down
A5 0 N





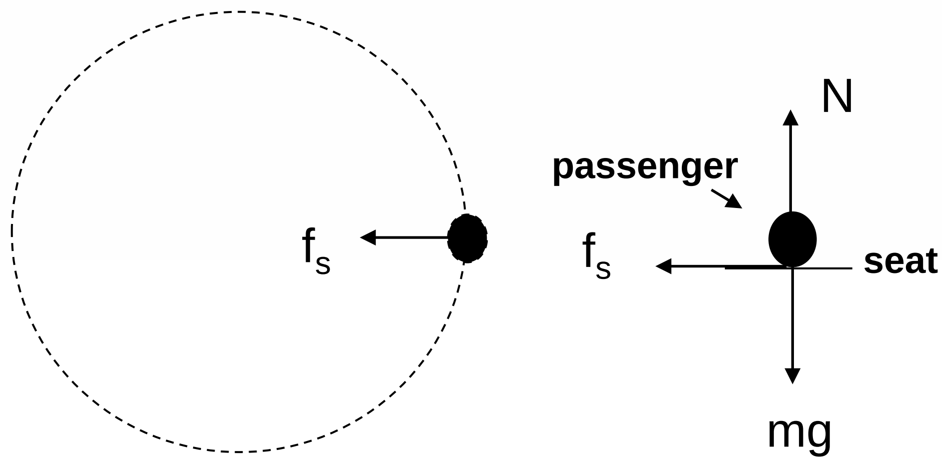
$$mg - N = \frac{mv^2}{R}$$

$$N = mg - \frac{mv^2}{R}$$

$$= \mathrm{m}(g - \frac{v^2}{R})$$

10) A car is rounding a flat curve of radius R=220 m with speed v = 94 km/h. What is the magnitude of the force exerted by the seat on the passenger whose mass m is 85 kg.

A1 263 N
A2 325 N
A3 455 N
A4 650 N
A5 100 N



$$f_s = \frac{mv^2}{R}$$

•7 A 3.5 kg block is pushed along a horizontal floor by a force $\vec{F}$ of magnitude 15 N at an angle $\theta = 40°$ with the horizontal (Fig. 6-20). The coefficient of kinetic friction between the block and the floor is 0.25. Calculate the magnitudes of (a) the frictional force on the block from the floor and (b) the block's acceleration.

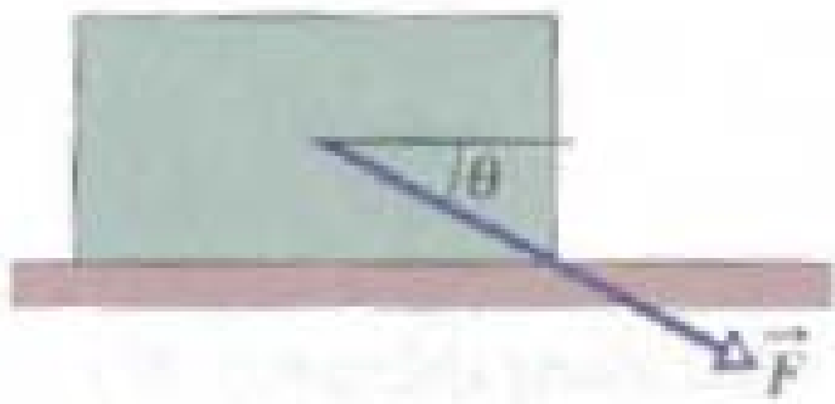


Fig. 6-20 Problem 7.

7. We choose $+x$ horizontally rightwards and $+y$ upwards and observe that the 15 N force has components $F_x = F\cos\theta$ and $F_y = -F\sin\theta$.

(a) We apply Newton's second law to the y axis:

$$F_N - F\sin\theta - mg = 0 \Rightarrow F_N = (15)\sin 40° + (3.5)(9.8) = 44\text{ N}.$$

With $\mu_k = 0.25$, Eq. 6-2 leads to $f_k = 11$ N.

(b) We apply Newton's second law to the x axis:

$$F\cos\theta - f_k = ma \quad \Rightarrow \quad a = \frac{(15)\cos 40° - 11}{3.5} = 0.14\text{ m/s}^2 .$$

Since the result is positive-valued, then the block is accelerating in the $+x$ (rightward) direction.

•13 A 68 kg crate is dragged across a floor by pulling on a rope attached to the crate and inclined 15° above the horizontal. (a) If the coefficient of static friction is 0.50, what minimum force magnitude is required from the rope to start the crate moving? (b) If $\mu_k = 0.35$, what is the magnitude of the initial acceleration of the crate? SSM

13. (a) The free-body diagram for the crate is shown below. $\vec{T}$ is the tension force of the rope on the crate, $\vec{F}_N$ is the normal force of the floor on the crate, $m\vec{g}$ is the force of gravity, and $\vec{f}$ is the force of friction. We take the $+x$ direction to be horizontal to the right and the $+y$ direction to be up. We assume the crate is motionless. The equations for the x and the y components of the force according to Newton's second law are:

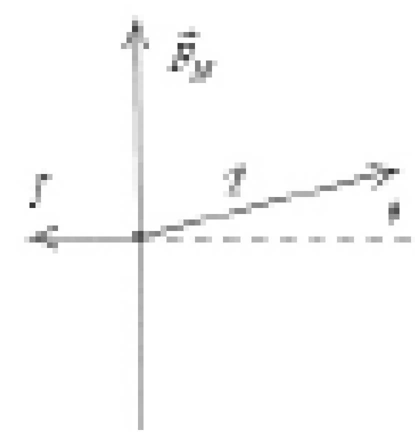
$$T\cos\theta - f = 0$$
$$T\sin\theta + F_N - mg = 0$$

where $\theta = 15°$ is the angle between the rope and the horizontal. The first equation gives $f = T\cos\theta$ and the second gives $F_N = mg - T\sin\theta$. If the crate is to remain at rest, f must be less than $\mu_s F_N$, or $T\cos\theta < \mu_s(mg - T\sin\theta)$. When the tension force is sufficient to just start the crate moving, we must have

$$T\cos\theta = \mu_s(mg - T\sin\theta).$$

We solve for the tension:

$$\begin{aligned} T &= \frac{\mu_s mg}{\cos\theta + \mu_s\sin\theta} \\ &= \frac{(0.50)(68)(9.8)}{\cos 15° + 0.50\sin 15°} \\ &= 304 = 3.0\times10^2\ \text{N}. \end{aligned}$$



(b) The second law equations for the moving crate are

$$T\cos\theta - f = ma$$
$$F_N + T\sin\theta - mg = 0.$$

Now $f = \mu_k F_N$, and the second equation gives $F_N = mg - T\sin\theta$, which yields $f = \mu_k(mg - T\sin\theta)$. This expression is substituted for f in the first equation to obtain

$$T\cos\theta - \mu_k(mg - T\sin\theta) = ma,$$

so the acceleration is

$$a = \frac{T(\cos\theta + \mu_k\sin\theta)}{m} - \mu_k g.$$

Numerically, it is given by

$$a = \frac{(304\ \text{N})(\cos 15^\circ + 0.35\sin 15^\circ)}{68\ \text{kg}} - (0.35)(9.8\ \text{m/s}^2) = 1.3\ \text{m/s}^2.$$

**21 Block B in Fig. 6-30 weighs 711 N. The coefficient of static friction between block and table is 0.25; angle θ is 30°; assume that the cord between B and the knot is horizontal. Find the maximum weight of block A for which the system will be stationary. SSM WWW

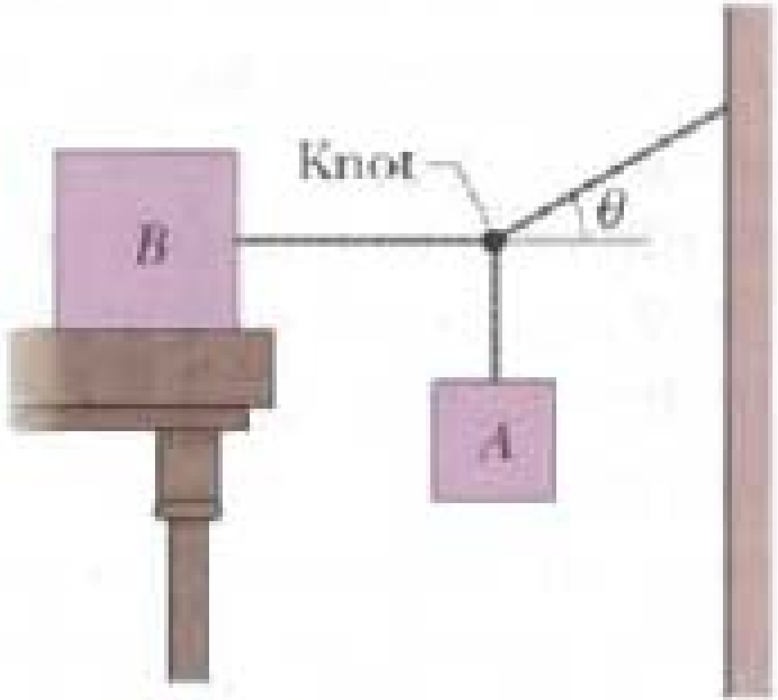
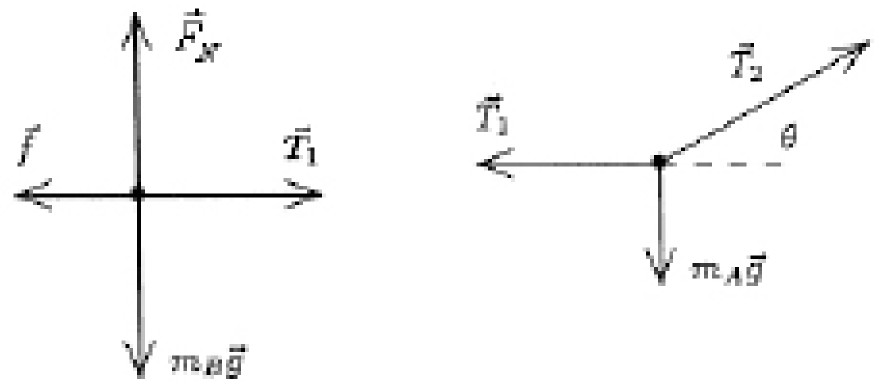


Fig. 6-30 Problem 21.

21. The free-body diagrams for block B and for the knot just above block A are shown next. $\vec{T}_1$ is the tension force of the rope pulling on block B or pulling on the knot (as the case may be), $\vec{T}_2$ is the tension force exerted by the second rope (at angle $\theta = 30°$) on the knot, $\vec{f}$ is the force of static friction exerted by the horizontal surface on block B, $\vec{F}_N$ is normal force exerted by the surface on block B, W_A is the weight of block A (W_A is the magnitude of $m_A\vec{g}$), and W_B is the weight of block B ($W_B = 711$ N is the magnitude of $m_B\vec{g}$).



For each object we take $+x$ horizontally rightward and $+y$ upward. Applying Newton's second law in the x and y directions for block B and then doing the same for the knot results in four equations:

$$\begin{aligned} T_1 - f_{s,\max} &= 0 \\ F_N - W_B &= 0 \\ T_2 \cos\theta - T_1 &= 0 \\ T_2 \sin\theta - W_A &= 0 \end{aligned}$$

where we assume the static friction to be at its maximum value (permitting us to use Eq. 6-1). Solving these equations with $\mu_s = 0.25$, we obtain $W_A = 103 \text{ N} \approx 1.0\times10^2 \text{ N}$.

••43 A circular-motion addict of mass 80 kg rides a Ferris wheel around in a vertical circle of radius 10 m at a constant speed of 6.1 m/s. (a) What is the period of the motion? What is the magnitude of the normal force on the addict from the seat when both go through (b) the highest point of the circular path and (c) the lowest point?

43. (a) Eq. 4-35 gives $T = 2\pi(10)/6.1 = 10$ s.

(b) The situation is similar to that of Sample Problem 6-7 but with the normal force direction reversed. Adapting Eq. 6-19, we find

$$F_N = m(g - v^2/R) = 486 \text{ N} \approx 4.9 \times 10^2 \text{ N}.$$

(c) Now we reverse both the normal force direction and the acceleration direction (from what is shown in Sample Problem 6-7) and adapt Eq. 6-19 accordingly. Thus we obtain

$$F_N = m(g + v^2/R) = 1081 \text{ N} \approx 1.1 \text{ kN}.$$

••47 An airplane is flying in a horizontal circle at a speed of 480 km/h (Fig. 6-39). If its wings are tilted at angle $\theta = 40°$ to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface. SSM WWW

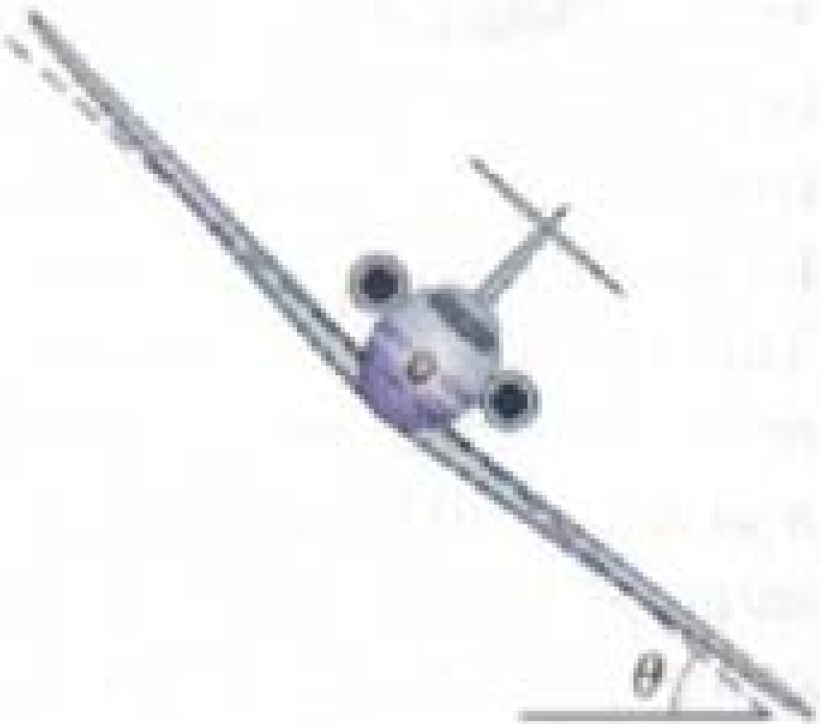


Fig. 6-39 Problem 47.

47. The free-body diagram (for the airplane of mass m) is shown below. We note that $\vec{F}_\ell$ is the force of aerodynamic lift and $\vec{a}$ points rightwards in the figure. We also note that $|\vec{a}| = v^2/R$ where $v = 480$ km/h $= 133$ m/s.

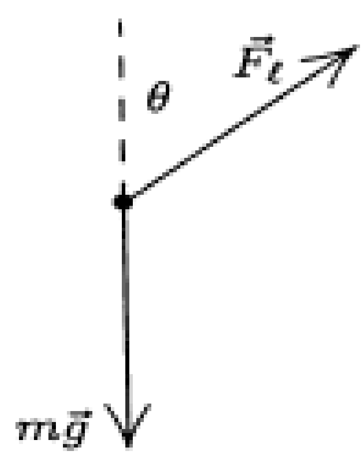
Applying Newton's law to the axes of the problem (+x rightward and +y upward) we obtain

$$\vec{F}_\ell \sin\theta = m\frac{v^2}{R}$$
$$\vec{F}_\ell \cos\theta = mg$$

where $\theta = 40°$. Eliminating mass from these equations leads to

$$\tan\theta = \frac{v^2}{gR}$$

which yields $R = v^2/g \tan\,\theta = 2.2 \times 10^3$ m.



**49 A puck of mass $m = 1.50$ kg slides in a circle of radius $r = 20.0$ cm on a frictionless table while attached to a hanging cylinder of mass $M = 2.50$ kg by a cord through a hole in the table (Fig. 6-41). What speed keeps the cylinder at rest? SSM

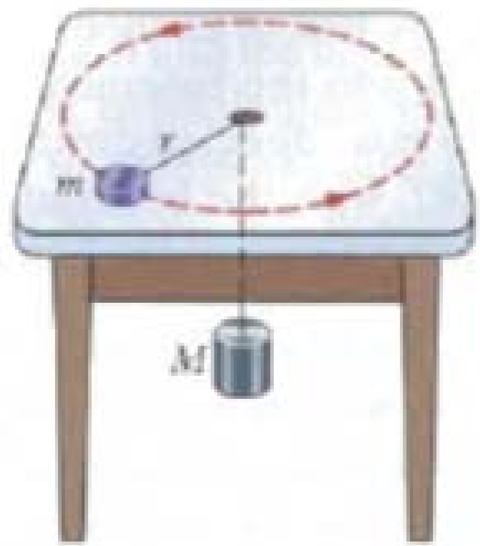


Fig. 6-41 Problem 49.

49. For the puck to remain at rest the magnitude of the tension force T of the cord must equal the gravitational force Mg on the cylinder. The tension force supplies the centripetal force that keeps the puck in its circular orbit, so $T = mv^2/r$. Thus $Mg = mv^2/r$. We solve for the speed:

$$v = \sqrt{\frac{Mgr}{m}} = \sqrt{\frac{(2.50)(9.80)(0.200)}{1.50}} = 1.81 \text{ m/s}.$$

89 In Fig. 6-57, a stuntman drives a car (without negative lift) over the top of a hill, the cross section of which can be approximated by a circle of radius $R = 250$ m. What is the greatest speed at which he can drive without the car leaving the road at the top of the hill?

Fig. 6-57 Problem 89.

89. At the top of the hill the vertical forces on the car are the upward normal force exerted by the ground and the downward pull of gravity. Designating $+y$ downward, we have

$$mg - F_N = \frac{mv^2}{R}$$

from Newton's second law. To find the greatest speed without leaving the hill, we set $F_N = 0$ and solve for v:

$$v = \sqrt{gR} = \sqrt{(9.8)(250)} = 49.5 \text{ m/s} = 49.5(3600/1000) \text{ km/h} = 178 \text{ km/h}.$$