

## Chapters 4, 5, and 6

**4.67** A boy whirls a stone in a horizontal circle of radius 1.5m and at height 2.0 m above level ground. The string breaks and the stone flies off horizontally and strikes the ground after traveling a horizontal distance of 10.0 m. What is the magnitude of the centripetal acceleration of the stone while in circular motion?

Since we have the radius of the circle, all we need to compute the centripetal acceleration, all we need is the magnitude of the velocity  $v$ , since  $a_c = \frac{v^2}{r}$ . To compute the  $v$ , we consider the projectile motion portion of the problem. Since the stone was launched horizontally, the  $v$  that we need is the initial  $x$  velocity as there was no initial  $y$  velocity.

$$\begin{array}{ll} x_i = 0 & y_i = 2.0m \\ x_f = 10.0m & y_f = 0 \\ v_{ix} = ? & v_{iy} = 0m/s \\ v_{fx} = v_{ix} & v_{fy} = ? \\ a_x = 0 & a_y = -g \\ & t = ? \end{array}$$

We now compute how long it was in the air

$$\begin{aligned} y_f &= y_i + v_{iy}t + \frac{1}{2}at^2 \\ 0 &= y_i + 0 - \frac{1}{2}gt^2 \\ t &= \sqrt{\frac{2y_i}{g}} = 0.639 \text{ sec} \end{aligned}$$

Now that we know the time, we can find the horizontal velocity

$$\begin{aligned} x_f &= x_i + v_{ix}t + \frac{1}{2}a_x t^2 \\ x_f &= 0 + v_{ix}t + 0 \\ v_{ix} &= \frac{x_f}{t} = \frac{10.0m}{0.639s} = 15.65m/s \end{aligned}$$

The magnitude of the velocity of the whirling stone is now

$$v = \sqrt{15.65^2 + 0^2} = 15.65 \text{ m/s}$$

$$a_c = \frac{v^2}{r} = \frac{(15.65 \text{ m/s})^2}{1.5 \text{ m}}$$

$$= 163.3 \text{ m/s}^2$$

4.75

4.76

**5.2** Two horizontal forces act on a 2 kg chopping block that can slide over a frictionless kitchen counter, which lies in an xy plane. One force is

$$\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$$

Find the acceleration of the chopping block in unit-vector notation when the other force is

(a)  $\vec{F}_2 = (-3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$ , (b)  $\vec{F}_1 = (-3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$ , (c)  $\vec{F}_1 = (3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$

a) Compute the net force

$$\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$$

$$\vec{F}_2 = (-3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 = 0$$

$$\vec{a} = 0$$

b) Compute the net force

$$\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$$

$$\vec{F}_2 = (-3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 = (8.0 \text{ N})\hat{j}$$

$$\vec{a} = \frac{(8.0 \text{ N})}{2 \text{ kg}}\hat{j} = (4 \text{ m/s}^2)\hat{j}$$

c) Compute the net force

$$\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$$

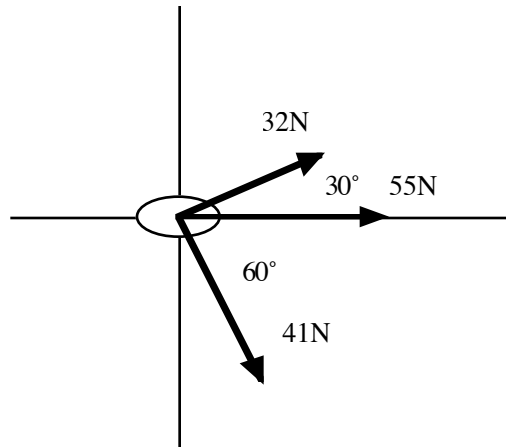
$$\vec{F}_2 = (3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 = (6.0 \text{ N})\hat{i}$$

$$\vec{a} = \frac{6.0 \text{ N}}{2 \text{ kg}}\hat{i} = (3 \text{ m/s}^2)\hat{i}$$

**5.7** Three astronauts, propelled by jet backpacks, push and guide a 120 kg asteroid toward a processing dock, exerting the forces shown in Fig. 5-30. What is the asteroid's acceleration (a) in

unit vector notation and as (b) a magnitude and (c) a direction.



a) We begin this problem by writing out each force in component form and then writing the net force.

$$\begin{aligned}\vec{F}_1 &= 32 \cos 30^\circ \hat{i} + 32 \sin 30^\circ \hat{j} \\ \vec{F}_2 &= 55 \hat{i} + 0 \hat{j} \\ \vec{F}_3 &= 41 \cos 60^\circ \hat{i} - 41 \sin 60^\circ \hat{j} \\ \vec{F}_{net} &= (32 \cos 30^\circ + 55 + 41 \cos 60^\circ) \hat{i} + (32 \sin 30^\circ + 0 - 41 \sin 60^\circ) \hat{j} \\ &= 118.22 \hat{i} - 19.51 \hat{j}\end{aligned}$$

Now that we know the net force, we can find the acceleration.

$$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{118.22 \hat{i} - 19.51 \hat{j} \text{ N}}{120 \text{ kg}} = 0.985 \hat{i} - 0.163 \hat{j}$$

The magnitude and direction are:

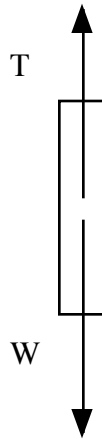
$$\begin{aligned}|\vec{a}| &= \sqrt{0.985^2 + 0.163^2} = 0.998 \text{ m / s}^2 \\ \tan \theta &= \frac{-0.163}{0.985} \Rightarrow \theta = -9.4^\circ\end{aligned}$$

## 5.10

**5.13** (a) An 11.0 kg salami is supported by a cord that runs to a spring which is supported by a cord hung from the ceiling (Fig 5.34a). What is the reading on the scale, which is marked in weight units? (b) In Fig 5-34b the salami is supported by a cord that runs around a pulley to a scale. The opposite end of the scale is attached by a cord to a wall. What is the reading on the scale? (c) In Fig 5-34c the wall has been replaced by a second 11 kg salami and the assembly is stationary. What is the reading on the scale?

The scale measures the tension in the cord. In each of these scenarios, the forces acting on the

right sausage are as shown below.



In all three cases, the sausage is not accelerating, which means that the net force is zero. We can easily solve for the tension  $T$ .

$$\begin{aligned}0 &= T - W \\T &= W \\&= 11\text{kg} \cdot 9.8\text{m} / \text{s}^2 \\&= 107.8\text{N}\end{aligned}$$

The tension is the same in each case because it is exactly balancing the weight. How the rope is attached is not important.

## 5.15

**5.23 Sunjamming.** A “sun yacht” is a spacecraft with a large sail that is pushed by sunlight. Although such a push is tiny in everyday circumstances, it can be large enough to send the spacecraft outward from the Sun on a cost free but slow trip. Suppose that the spacecraft has a mass of 900kg and receives a push of 20N. (a) What is the magnitude of the resulting acceleration? If the craft starts from rest, (b) how far will it travel in 1 day and (c) how fast will it be moving

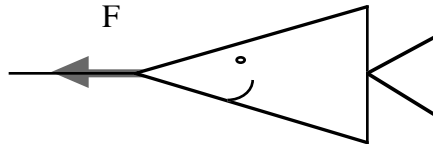
We begin by finding the acceleration.

$$a = \frac{F_{net}}{m} = \frac{20\text{N}}{900\text{kg}} = 0.022\text{m} / \text{s}^2$$

Given this acceleration, we can find the distance and speed after one day.

$$\begin{aligned}
 x_i &= 0 \\
 x_f &=? \\
 v_i &= 0 \\
 a &= 0.022 \text{ m/s}^2 \\
 t &= 86,400 \text{ s} \\
 x_f &= x_i + v_i t + \frac{1}{2} a t^2 \\
 &= 0 + 0 + \frac{1}{2} \cdot 0.022 \text{ m/s}^2 \cdot (86,400 \text{ s})^2 \\
 &= 8.2 \times 10^7 \text{ m} \\
 v_f &= v_i + a t \\
 &= 0 + 0.022 \text{ m/s}^2 \cdot (86,400 \text{ s}) \\
 &= 1900.8 \text{ m/s}
 \end{aligned}$$

**5.24** The tension at which a fishing line snaps is commonly called the line’s “strength.” What minimum strength is need for a line that is to stop a salmon of weight 85N in 11 cm if the fish is initially drifting at 2.8 m/s? Assume a constant deceleration.



We first calculate the acceleration that the fish experiences. After we know the acceleration, we can find the force.

$$\begin{aligned}
 x_i &= 0 \\
 x_f &= 0.11 \text{ m} \\
 v_i &= 2.8 \text{ m/s} \\
 v_f &= 0 \\
 m &= \frac{W}{g} = \frac{85 \text{ N}}{9.8 \text{ m/s}^2} = 8.67 \text{ kg}
 \end{aligned}$$

$$\begin{aligned}
 v_f^2 &= v_i^2 + 2 a (x_f - x_i) \\
 a &= \frac{v_f^2 - v_i^2}{2 (x_f - x_i)} = \frac{v_f^2 - v_i^2}{2 (x_f - x_i)} = \frac{0^2 - (2.8 \text{ m/s})^2}{2 (0.11 \text{ m} - 0)} \\
 &= -35.64 \text{ m/s}^2
 \end{aligned}$$

$$\begin{aligned}
 |F| &= m |a| \\
 &= 8.67 \text{ kg} \cdot 35.64 \text{ m/s}^2 \\
 &= 309 \text{ N}
 \end{aligned}$$

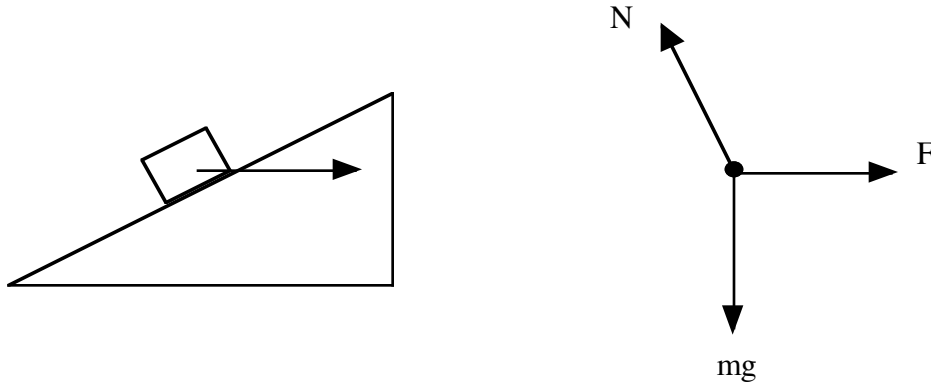
**5.26.** A car traveling at 53 km/h hits a bridge abutment. A passenger in the care moves forward a distance of 65 cm (with respect to the road) while being brought to rest by an inflated air bag. What magnitude of force (assumed constant) acts on the passenger's upper torso, which has a mass of 41 kg.

To find the force, we need to know the acceleration that the passenger experienced.

$$\begin{aligned}
 x_f - x_i &= 0.65m & v_f^2 &= v_i^2 + 2a(x_f - x_i) \\
 v_i &= \frac{53km}{h} \cdot \frac{1000m}{1km} \cdot \frac{1h}{3600s} = 14.72m/s & a &= \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{0^2 - 14.72^2}{2 \cdot 0.65m} = 166.7m/s^2 \\
 v_f &= 0 & F_{net} &= ma = 41kg \cdot 166.7m/s^2 = 6834.7N
 \end{aligned}$$

...Ouch!

**5.32.** A 100 kg crate is pushed at constant speed up the frictionless 30° ramp as shown. What horizontal force F is required? (b) What force is exerted by the ramp on the crate?



We use a standard (not rotated) x-y cord system. Since the mass is moving with constant speed, we know that the net force is zero. We write the forces in the vertical and horizontal directions.

$$0 = N \cos \theta - mg$$

$$0 = F - N \sin \theta$$

We now solve for F and N

$$N = \frac{mg}{\cos \theta}$$

$$F = N \sin \theta$$

$$= \frac{mg}{\cos \theta} \sin \theta$$

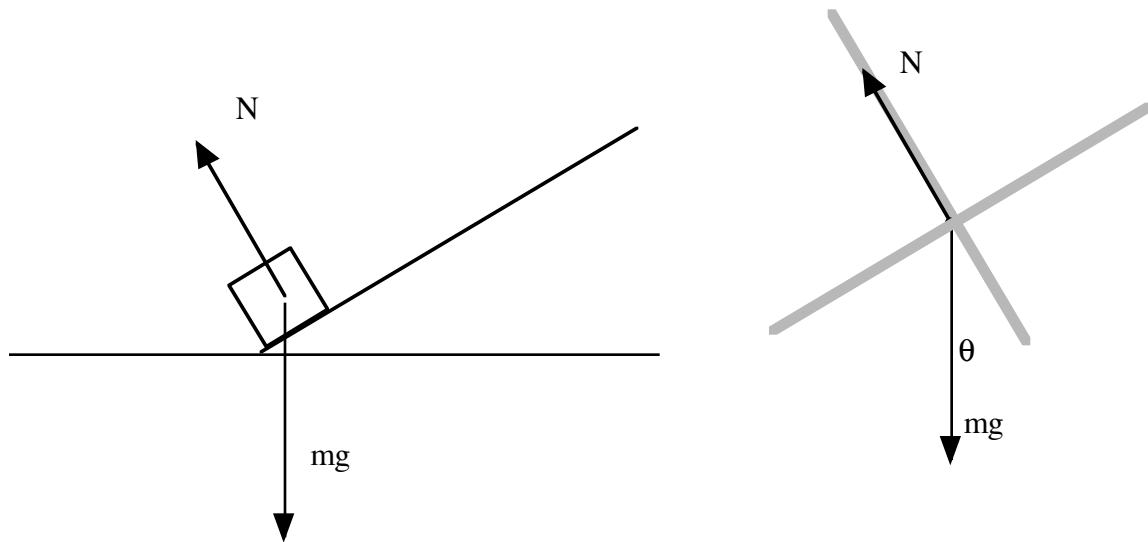
$$= mg \tan \theta$$

$$= 100kg \cdot 9.8m/s^2 \cdot \tan 30 = 565.8N$$

$$N = \frac{mg}{\cos \theta} = \frac{100kg \cdot 9.8m/s^2}{\cos 30} = 1131.6N$$

**5.35** A block is projected up a frictionless inclined plain with an initial speed  $v_0 = 3.5\text{m/s}$ . The angle of incline is 32 degrees. (a) How far up the incline does the block go? (b) How long does it take to get there? (c) What is its speed when it gets back down to the bottom

We begin by drawing the free body diagram of the forces on the mass as it slides up the incline.



We begin by computing the acceleration due to the forces that we have drawn.

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

$$ma = -mg \sin \theta$$

$$ma = -mg \sin \theta$$

$$a = -g \sin \theta$$

We can now compute the distance from the givens

$$v_i = 3.5\text{m/s}$$

$$v_f = 0$$

$$a = -g \sin \theta = -5.19\text{m/s}^2$$

$$v_f^2 = v_i^2 + 2a(x_f - x_i)$$

$$x_f - x_i = \frac{v_f^2 - v_i^2}{2a} = \frac{-v_i^2}{2a} = \frac{-(3.5\text{m/s})^2}{2 \cdot (-5.19\text{m/s}^2)}$$

$$= 1.18\text{m}$$

We can easily compute the time

$$v_i = 3.5 \text{ m/s}$$

$$v_f = 0$$

$$a = -g \sin \theta = -5.19 \text{ m/s}^2$$

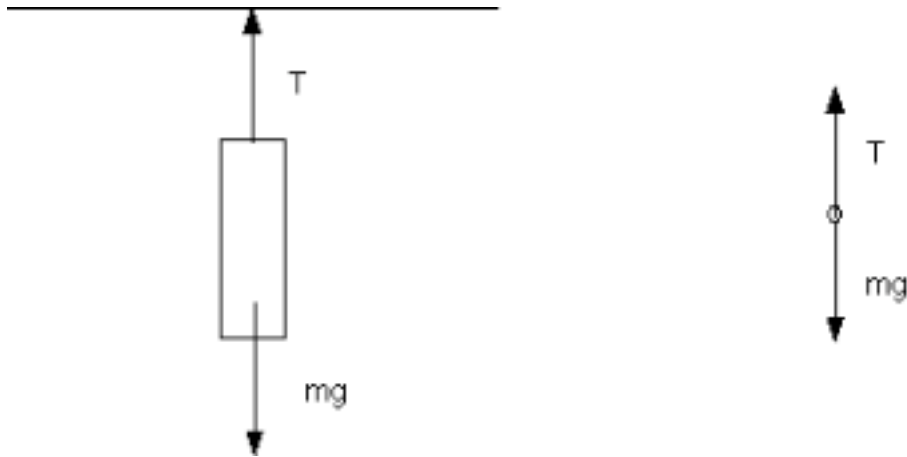
$$v_f = v_i + at$$

$$0 = v_i + at$$

$$t = -\frac{v_i}{a} = -\frac{3.5 \text{ m/s}}{-5.19 \text{ m/s}^2} = 0.674 \text{ s}$$

The magnitude of the speed on the downward trip is 3.5 since the path is symmetric.

**5.42** A lamp hangs vertically from a cord in a descending elevator that decelerates at  $2.4 \text{ m/s}^2$ . (a) If the tension in the cord is 89 N, what is the lamp's mass? (b) What is the cord's tension when the elevator ascends with an upward acceleration of  $2.4 \text{ m/s}^2$ .



a) Since the lamp is descending and decelerating, it is accelerating upward at  $2.4 \text{ m/s}^2$ . We can write the net force.

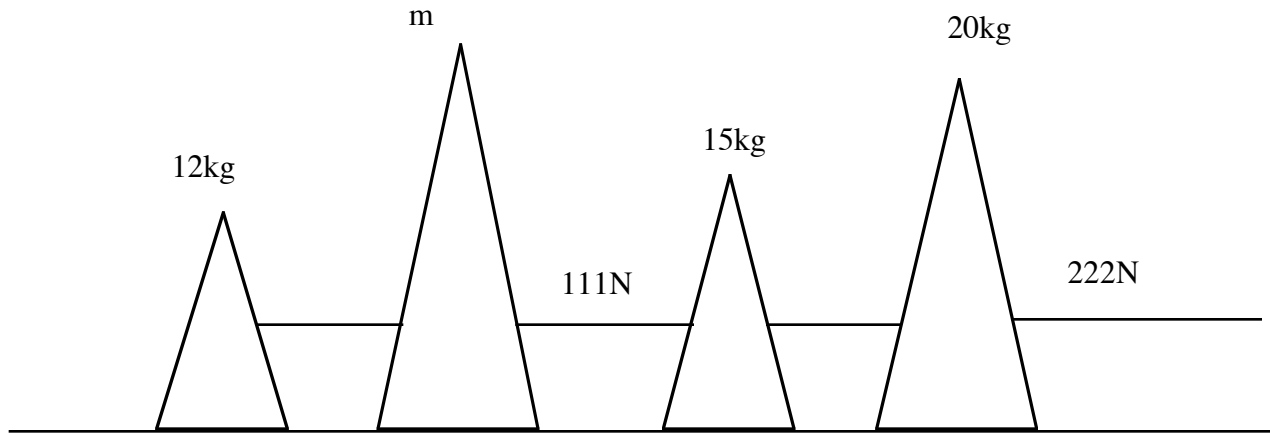
$$F_{net} = ma = T - mg$$

$$ma + mg = T$$

$$m = \frac{T}{a + g} = \frac{89 \text{ N}}{(2.4 + 9.8) \text{ m/s}^2} = 7.29 \text{ kg}$$

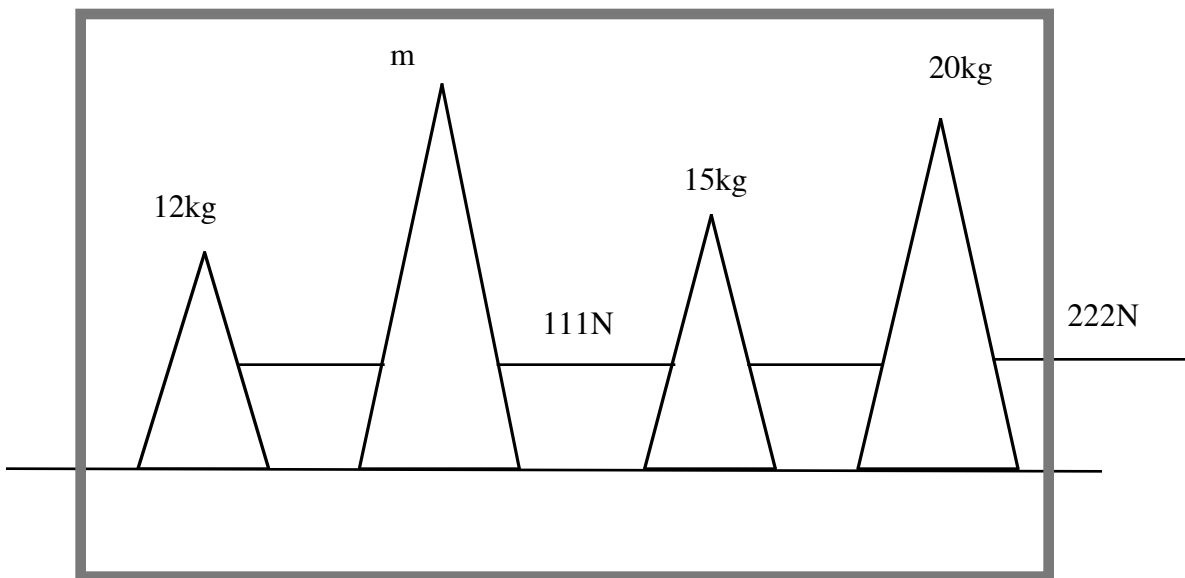
b) If the elevator is accelerating upward at  $2.4 \text{ m/s}^2$ , the tension is the same as in part a.

**5.50** The figure shows four penguins that are being playfully pulled along very slippery (frictionless) ice by a curator. The masses of three penguins and the tension in two of the cords are given. Find the penguin mass that is not given.



In this problem, we need to think about what mass is being accelerated. We can break this system of masses up in different ways. No matter how we break up our masses for calculation, all of them must have the same acceleration.

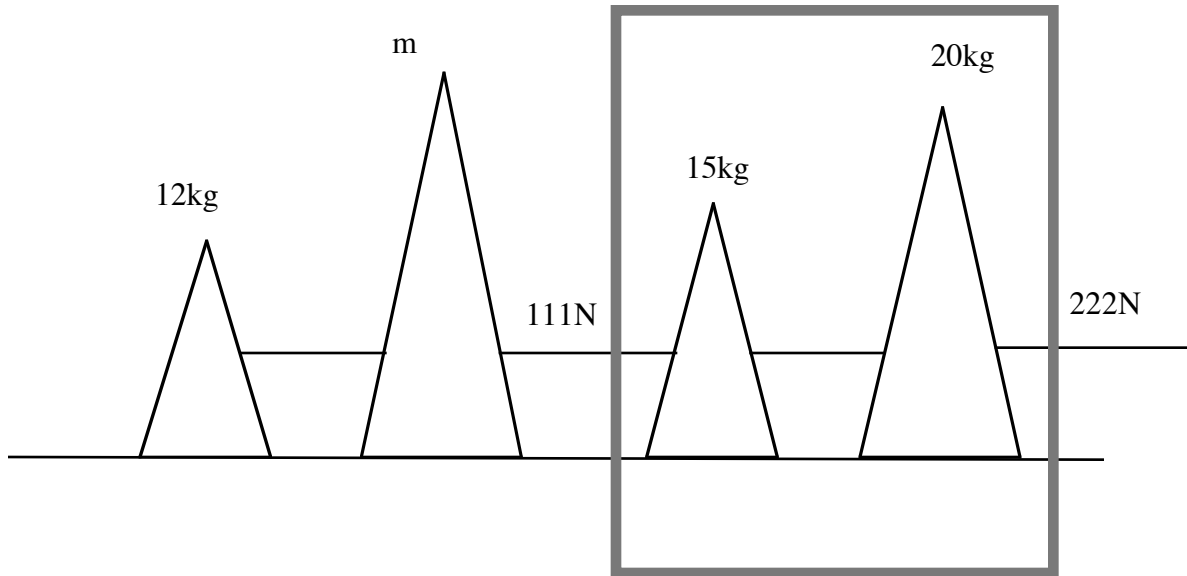
We begin by considering the entire set of penguins as a single mass. In this case the 222 N is the only external force that acts on the entire mass of penguins...



We can write  $ma$ , the net force.

$$(12kg + m + 15kg + 20kg) a = 222N$$

We now consider the force on just the two right most penguins...



We write the net force on these masses

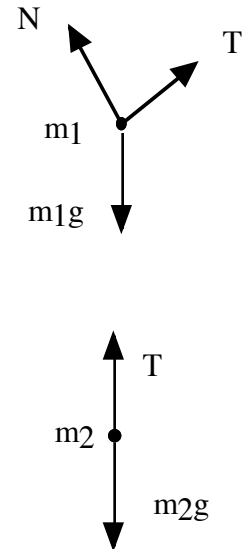
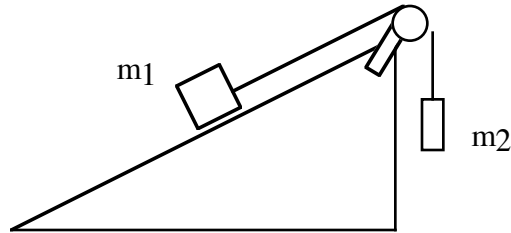
$$(15\text{kg} + 20\text{kg}) a = 222\text{N} - 111\text{N}$$

In this second case, we can solve for a. We then use that a to find the missing mass.

$$\begin{aligned}
 (12\text{kg} + m + 15\text{kg} + 20\text{kg}) a &= 222\text{N} \\
 (m + 47\text{kg}) a &= 222\text{N} \\
 ma &= 222\text{N} - 47\text{kg} \cdot a \\
 m &= \frac{222\text{N}}{a} - 47\text{kg} \\
 &= \frac{222\text{N}}{3.12\text{m/s}^2} - 47\text{kg} \\
 &= 24.15\text{kg}
 \end{aligned}$$

**5.59** A block of mass  $m_1 = 3.70\text{kg}$  on a frictionless inclined plane of angle  $30^\circ$  is connected by a cord over a massless frictionless pulley to a second block of mass  $m_2 = 2.3\text{kg}$  hanging vertically. What are (a) the magnitude of the acceleration of each block and (b) the direction of the acceleration of  $m_2$ ? (c) What is the tension in the cord?

The free-body diagram and forces are shown below.



We will call forces that drive the pulley clockwise positive. First we compute the net force on  $m_2$ .

$$m_2 a = m_2 g - T$$

We now write the forces on  $m_1$  in the vertical direction:

$$0 = N - m_1 g \cos \theta$$

$$N = m_1 g \cos \theta$$

and in the horizontal direction...

$$m_1 a = T - m_1 g \sin \theta$$

We now combine the equations to find the acceleration

$$T = m_2 g - m_2 a$$

$$m_1 a = (m_2 g - m_2 a) - m_1 g \sin \theta$$

$$a = \frac{m_2 g - m_1 g \sin \theta}{m_1 + m_2}$$

$$= \frac{2.3 \text{ kg} \cdot 9.8 \text{ m/s}^2 - 3.7 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot \sin 30}{2.3 \text{ kg} + 3.7 \text{ kg}}$$

$$= 0.735 \text{ m/s}^2$$

The mass  $m_2$  is downward since downward was defined as positive in this case.

$$T = m_2 g - m_2 a$$

$$= 2.3 \text{ kg} \cdot 9.8 \text{ m/s}^2 - 3.7 \text{ kg} \cdot 0.735 \text{ m/s}^2$$

$$= 19.82 \text{ N}$$

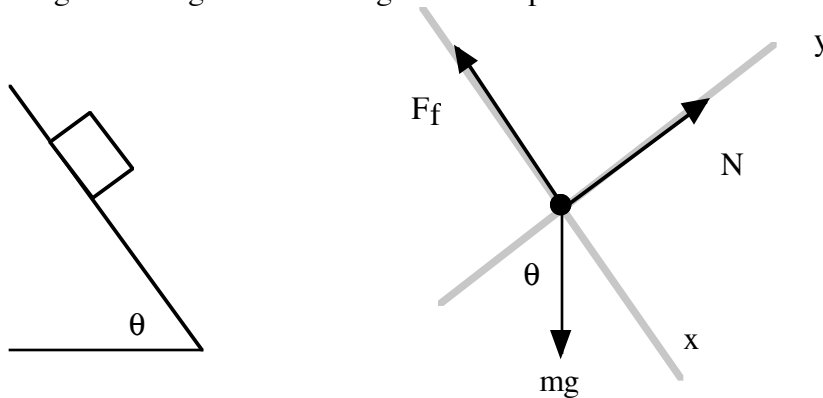
**6.2.** The mysterious sliding stones. Along the remote Racetrack Playa in Death Valley California, stones sometimes gouge out prominent trails in the desert floor, as if they had been migrating. For years, curiosity mounted about why the stones moved. One explanation was that strong winds during the occasional rainstorms would drag the rough stones over ground softened by rain. When the desert dried out, the trails behind the stones were hard-baked in place. According to measurements, the coefficient of kinetic friction between the stones and the wet playa ground is about 0.80. What horizontal force is needed on a stone of typical mass 20kg to maintain the stones motion once a gust has started it moving?.

The force of the wind must at least equal the force of friction. In this problem, the Normal force is equal to the weight, as in the previous problem.

$$\begin{aligned}
 F_{wind} &= \mu N \\
 &= \mu mg \\
 &= 0.80 \cdot 20\text{kg} \cdot 9.8\text{m/s}^2 \\
 &= 156.8\text{N}
 \end{aligned}$$

**6.6** A pig slides down a 35degree incline in twice the time it would take to slide down a frictionless incline. What is the coefficient of kinetic friction between the pig and the incline?

We begin by drawing force diagrams assuming friction is present.



$$\begin{aligned}
 0 &= N - mg \cos \theta \\
 N &= mg \cos \theta
 \end{aligned}$$

$$\begin{aligned}
 F_{net-x} &= ma = mg \sin \theta - F_f \\
 ma &= mg \sin \theta - F_f \\
 &= mg \sin \theta - \mu N \\
 &= mg \sin \theta - \mu mg \cos \theta \\
 a_f &= g(\sin \theta - \mu \cos \theta)
 \end{aligned}$$

We can easily calculate the no friction case by setting the coefficient of friction to zero.

$$a_{nf} = g \sin \theta$$

We now need to find the relationship between time and acceleration for sliding a fixed distance d.

$$x_f - x_i = d$$

$$v_i = 0$$

$$x_f = x_i + v_i t + \frac{1}{2} a t^2$$

$$x_f - x_i = v_i t + \frac{1}{2} a t^2$$

$$d = 0 + \frac{1}{2} a t^2$$

$$t = \sqrt{\frac{2d}{a}}$$

$$t_f = \sqrt{\frac{2d}{a_f}}$$

$$t_{nf} = \sqrt{\frac{2d}{a_{nf}}}$$

We know that the time with friction is twice the time without friction

$$t_f = 2t_{nf}$$

$$\sqrt{\frac{2d}{a_f}} = 2 \sqrt{\frac{2d}{a_{nf}}}$$

$$\frac{2d}{a_f} = 4 \cdot \frac{2d}{a_{nf}}$$

$$a_{nf} = 4 \cdot a_f$$

$$g \sin \theta = 4 \cdot g(\sin \theta - \mu \cos \theta)$$

$$4\mu \cos \theta = 3 \sin \theta$$

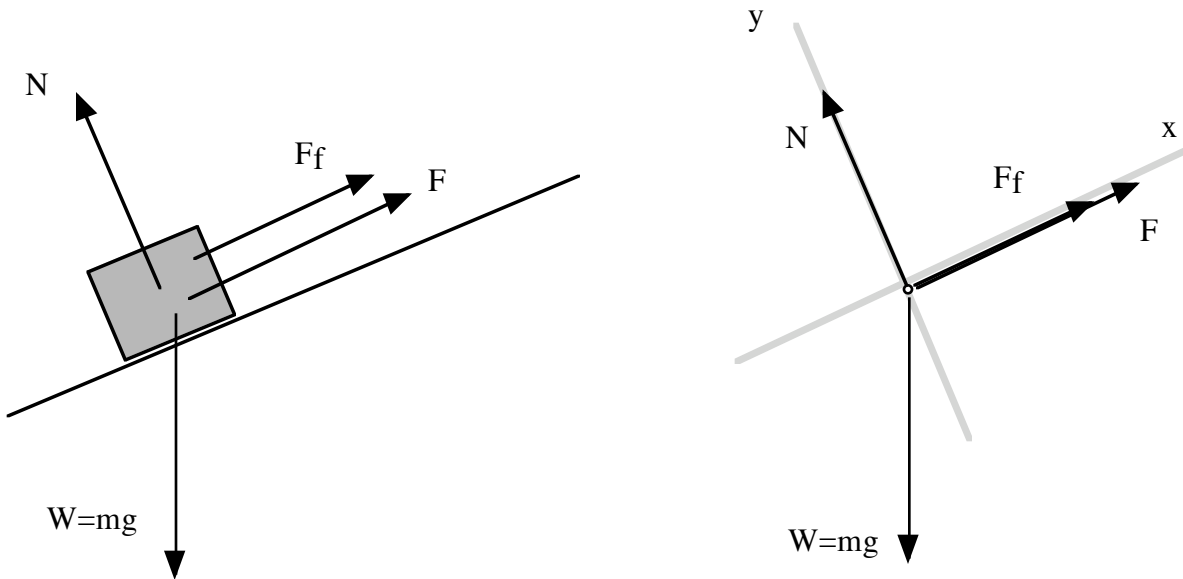
$$\mu = \frac{3}{4} \tan \theta$$

$$= \frac{3}{4} \tan 35$$

$$\mu = .525$$

**6.20** A loaded penguin sled weight 80N rests on a plane inclined at 20 degrees to the horizontal. Between the sled and the plane, the coefficient of static friction is 0.25, and the coefficient of kinetic friction is 0.15. (a) What is the minimum magnitude of the force F, parallel to the plane, that will prevent the sled from slipping down the plane. (b) What is the minimum magnitude F that will start the sled moving up the plane? (c) What value F is required to move the sled with constant velocity up the incline.

a) We begin by drawing the forces. Since the motion would be downward if  $F$  is too small, we draw Friction as pointing UP the incline for part a.



We now write the forces in component form. Since the sled is not to move, the net force will be zero.

*y - direction*

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

*x - direction*

$$0 = F + F_f - mg \sin \theta$$

$$F = mg \sin \theta - F_f$$

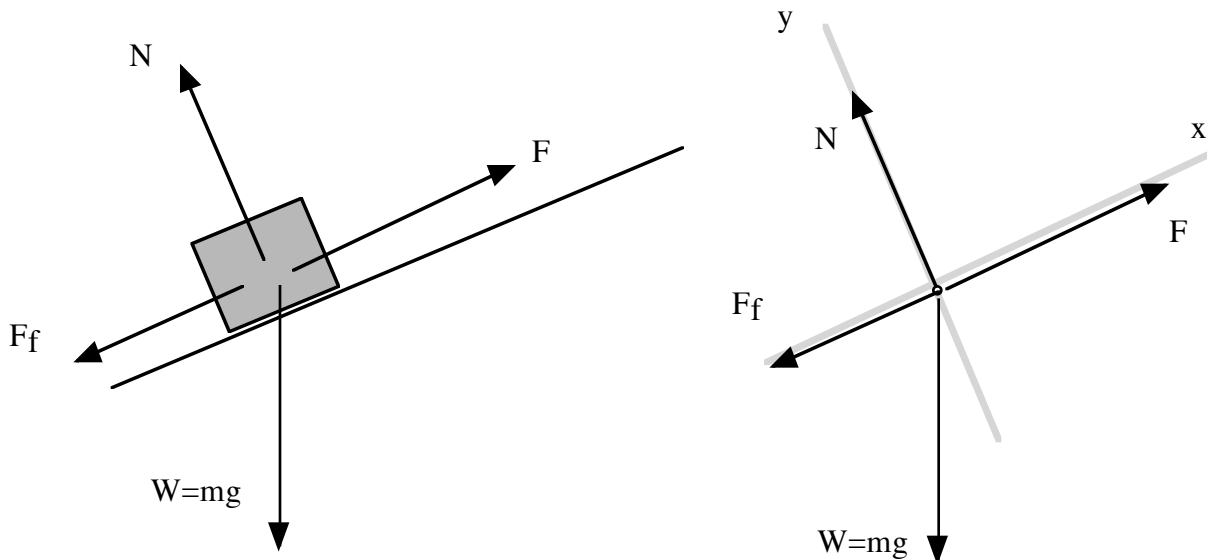
$$= mg \sin \theta - \mu N$$

$$= mg \sin \theta - \mu_s mg \cos \theta$$

$$= 80N \sin 20 - 0.25 \cdot 80N \cdot \cos 20$$

$$= 8.57N$$

b) In this section, we wish to get the block moving. The drawing will change, because the frictional force acts downward as it opposes the upward motion



*y* - direction

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

*x* - direction

$$0 = F - F_f - mg \sin \theta$$

$$F = mg \sin \theta + F_f$$

$$= mg \sin \theta + \mu N$$

$$= mg \sin \theta + \mu_s mg \cos \theta$$

$$= 80N \sin 20 + 0.25 \cdot 80N \cdot \cos 20$$

$$= 46.2N$$

c) The drawing for c is the same as for b), but since the sled is now moving with constant speed (not just starting) we need use the kinetic coefficient of friction.

*y* - direction

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

*x* - direction

$$0 = F - F_f - mg \sin \theta$$

$$F = mg \sin \theta + F_f$$

$$= mg \sin \theta + \mu N$$

$$= mg \sin \theta + \mu_k mg \cos \theta$$

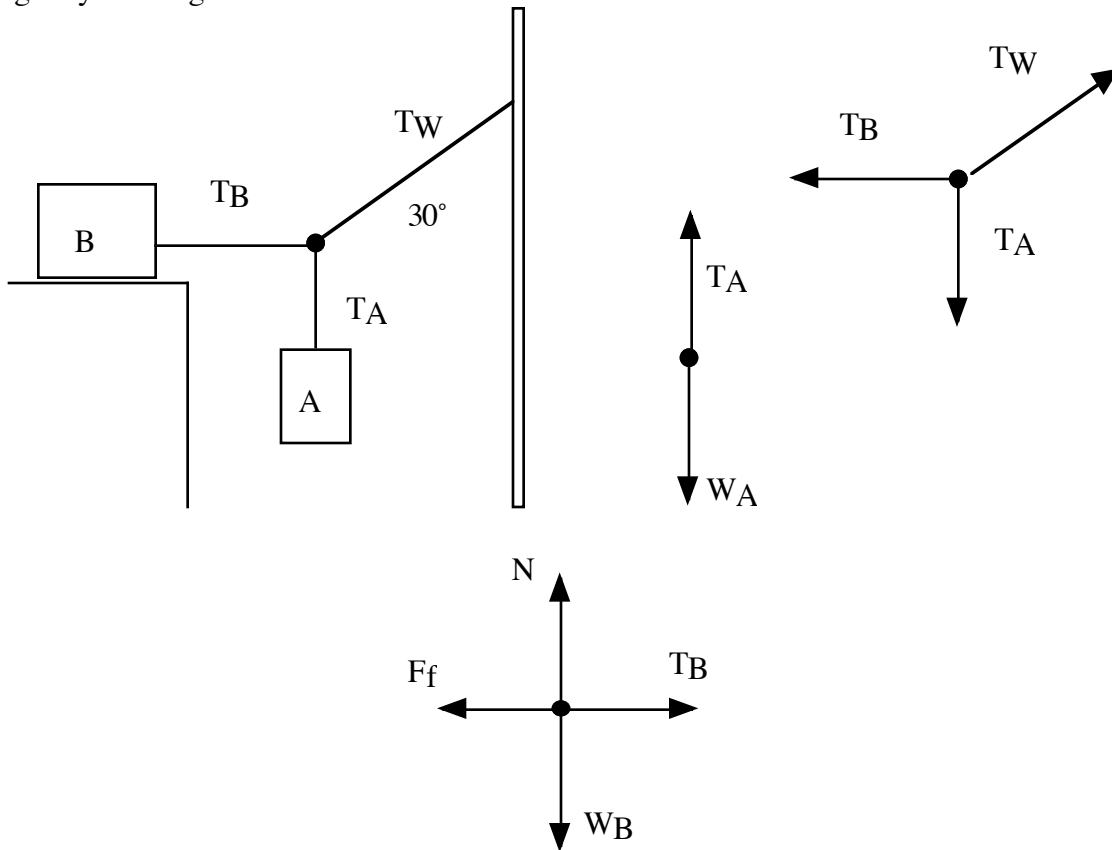
$$= 80N \sin 20 + 0.15 \cdot 80N \cdot \cos 20$$

$$= 38.6N$$

**6.23.** Block B in the figure weighs 711N. The coefficient of static friction between block and horizontal surface is 0.25. Find the maximum weight block A for which the system will be stationary.

This problem is a classic “statics” problem where the net force on the two blocks and the knot.

We begin by drawing the forces on the two blocks and on the knot.



The forces on A allow us to find the tension  $T_A$ .

$$0 = T_A - W_A$$

$$T_A = W_A$$

Now we write forces on the knot

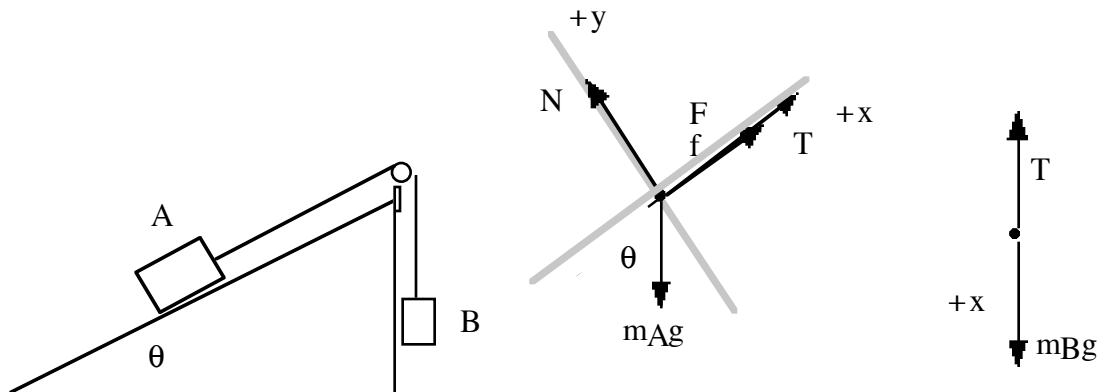
|   |                         |                                       |
|---|-------------------------|---------------------------------------|
|   | <i>y - direction</i>    | <i>x - direction</i>                  |
|   | $0 = T_w \sin 30 - T_A$ | $0 = T_w \cos 30 - T_B$               |
|   |                         | $T_B = T_w \cos 30$                   |
| $T_w = \frac{T_A}{\sin 30} = \frac{W_A}{\sin 30}$ |                         | $= \frac{W_A}{\sin 30} \cdot \cos 30$ |
|   |                         | $T_B = W_A \cot 30$                   |

and on B. We then substitute and solve for the weight of A.

$$\begin{array}{l}
 \text{y-direction} \\
 0 = N - W_B \\
 N = W_B
 \end{array}
 \qquad
 \begin{array}{l}
 \text{x-direction} \\
 0 = T_B - F_f \\
 T_B = F_f \\
 W_A \cot 30 = \mu N \\
 W_A = \frac{\mu N}{\cot 30} \\
 = \mu W_B \tan 30 \\
 = 0.25 \cdot 711N \cdot \tan 30 \\
 = 102.6N
 \end{array}$$

**6.30** Two blocks are connected over a pulley as shown in Fig. 6-31. The mass of block A is 10kg and the coefficient of kinetic friction is 0.20. The angle is  $30^\circ$ . Block A slides down the incline at constant speed. What is the mass of block B?

We begin, as always by drawing the forces.



Since the speed is constant, we know that the net force is zero. We write the forces and then solve. We will take forces that spin the pulley in the clockwise direction as positive.

$$\begin{array}{l}
 0 = N - m_A g \cos \theta \\
 N = m_A g \cos \theta
 \end{array}
 \qquad
 \begin{array}{l}
 0 = T + F_f - m_A g \sin \theta \\
 = T + \mu N - m_A g \sin \theta \\
 T = -\mu m_A g \cos \theta + m_A g \sin \theta
 \end{array}
 \qquad
 \begin{array}{l}
 0 = m_B g - T \\
 m_B g = T \\
 = -\mu m_A g \cos \theta + m_A g \sin \theta \\
 m_B = -\mu m_A \cos \theta + m_A \sin \theta \\
 = m_A (-\mu \cos \theta + \sin \theta) \\
 = 10\text{kg} \cdot (-0.2 \cdot \cos 30 + \sin 30) \\
 = 3.27\text{kg}
 \end{array}$$

**6.36.** The terminal speed of a sky diver in the spread-eagle position is 160 km/h. In the nosedive position, the terminal speed is 310 km/hr. Assuming that  $C$  does not change from one position to another, find the ration of the effective cross-sectional area  $A$  in the slower position to that in the faster position.

Terminal velocity occurs when the drag force equals the weight. In both positions, the drag -force equals the weight of the sky diver. This means that the Drag forces in both positions equal each other.

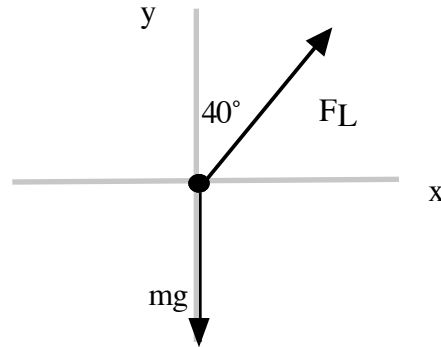
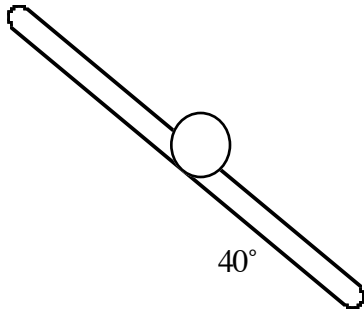
$$\begin{aligned}
 D_s &= D_n \\
 \frac{1}{2}C\rho A_s v_s^2 &= \frac{1}{2}C\rho A_n v_n^2 \\
 A_s v_s^2 &= A_n v_n^2 \\
 \frac{A_s}{A_n} &= \frac{v_n^2}{v_s^2} = \frac{(310 \text{ km / h})^2}{(160 \text{ km / h})^2} \\
 &= 3.76
 \end{aligned}$$

**6.41** What is the smallest radius of an unbanked (flat) track around which a bicyclist can travel if her speed is 29km/h and the coefficient of static friction is 0.32.

This is a centripetal force problem. The net inward force is the centripetal force. In this case, only friction contributes to the centripetal force. The normal force is just the biker's weight.

$$\begin{aligned}
 v &= \frac{29 \text{ km}}{\text{h}} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{1 \text{ h}}{3600 \text{ s}} = 8.06 \text{ m / s} \\
 \frac{mv^2}{r} &= \mu N \\
 \frac{mv^2}{r} &= \mu m g \\
 r &= \frac{v^2}{\mu g} = \frac{(8.06 \text{ m / s})^2}{0.32 \cdot 9.8 \text{ m / s}^2} = 20.7 \text{ m}
 \end{aligned}$$

**6.53.** An airplane is flying in a horizontal circle at a speed of 480 km/h. If the wings of the plane are tilted  $40^\circ$  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.



We write the forces and set the net inward force equal to the centripetal force.  $480 \text{ km/h} = 133.3 \text{ m/s}$ .

$$F_{\text{net-in}} = ma = m \frac{v^2}{r} = F_L \sin 40$$

$$m \frac{v^2}{r} = \left( \frac{mg}{\cos 40} \right) \cdot \sin 40$$

$$\frac{v^2}{r} = g \tan 40$$

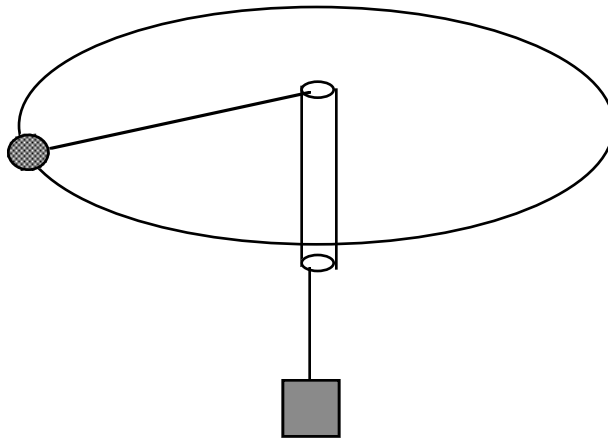
$$r = \frac{v^2}{g \tan 40} = \frac{(133.3 \text{ m/s})^2}{9.8 \text{ m/s}^2 \cdot \tan 40} = 2160.8 \text{ m}$$

$$0 = F_L \cos 40 - mg$$

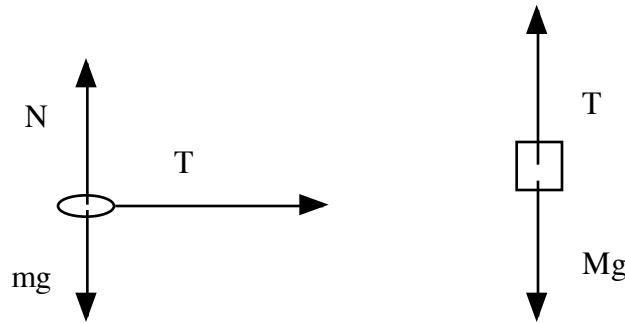
$$F_L \cos 40 = mg$$

$$F_L = \frac{mg}{\cos 40}$$

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



We write out the forces on each mass. The hanging mass does not accelerate. The orbiting mass experiences a net inward force that is the centripetal force.



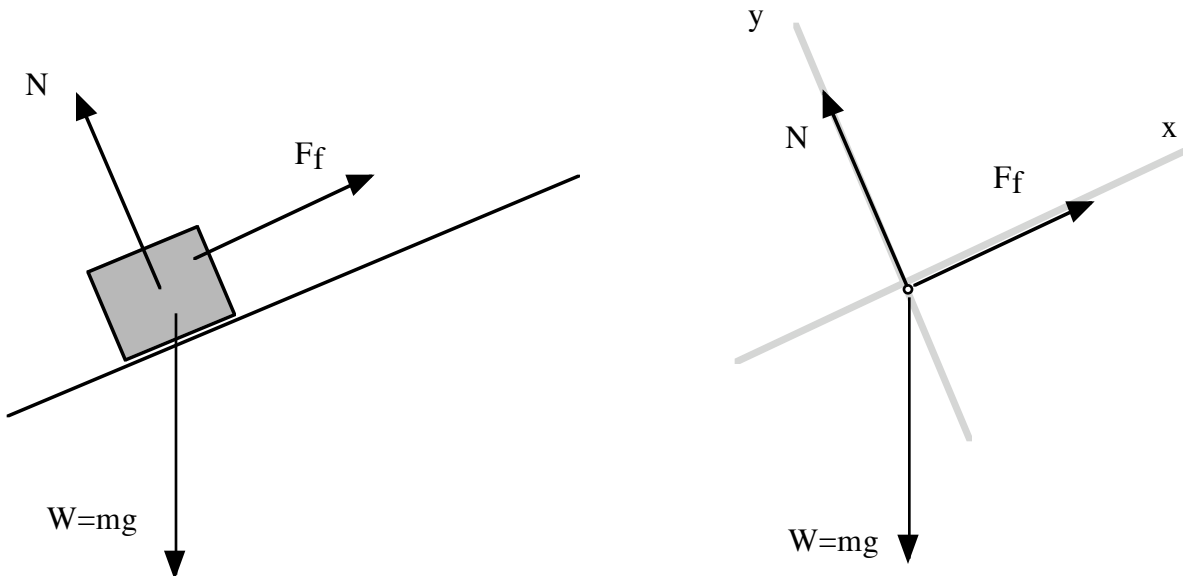
We write out the forces and solve for  $v$ .

$$\frac{mv^2}{r} = T \qquad 0 = T - Mg \qquad v = \sqrt{\frac{rT}{m}} = \sqrt{\frac{rMg}{m}} = \sqrt{\frac{0.2 \cdot 2.5 \cdot 9.8}{1.5}}$$

$$v = \sqrt{\frac{rT}{m}} \qquad T = Mg \qquad = 1.81 \text{ m/s}$$

**6.63** In the figure, the coefficient of kinetic friction between the block and the plane is 0.20, and the angle is 60 degrees. What are the (a) magnitude of  $a$  and the direction of the block's acceleration if the block is sliding down the plane. What are (c)  $a$  and (d) direction if the block is sliding up the incline.

a) We begin by drawing the forces. Since the motion is downward we draw Friction as pointing UP the incline for part a.

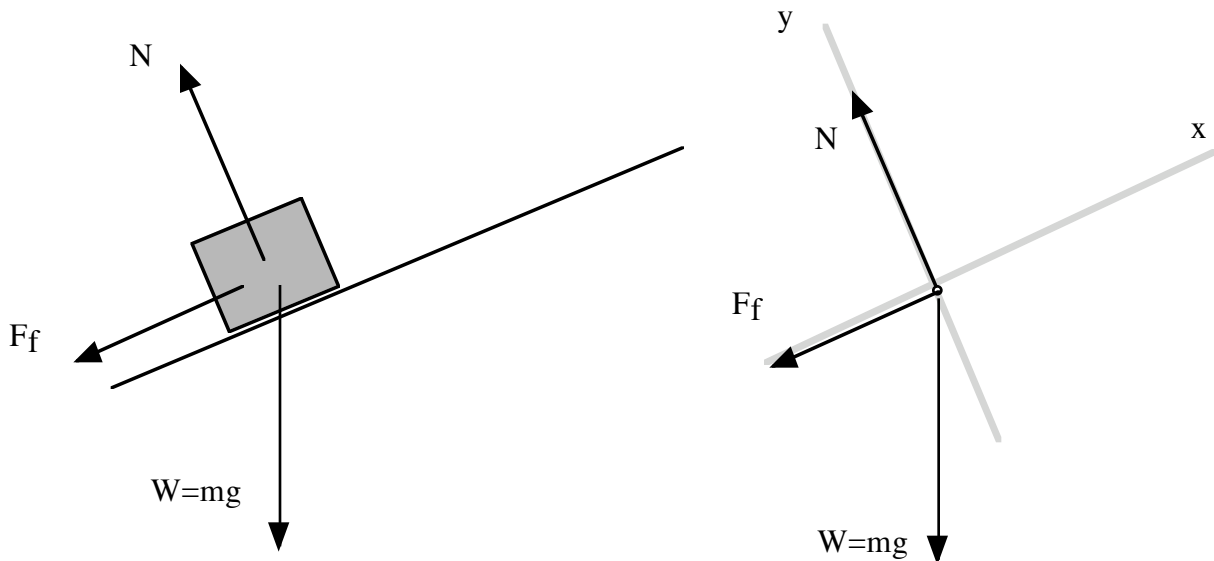


We now write the forces in component form.

$$\begin{aligned}
 & y\text{-direction} \\
 & 0 = N - mg \cos \theta \\
 & N = mg \cos \theta
 \end{aligned}$$

$$\begin{aligned}
 & x\text{-direction} \\
 ma &= F_f - mg \sin \theta \\
 &= F_f - mg \sin \theta \\
 &= \mu N - mg \sin \theta \\
 &= -\mu_s mg \cos \theta - mg \sin \theta \\
 a &= \mu_s g \cos \theta - g \sin \theta \\
 &= -7.51 \text{ m/s}^2
 \end{aligned}$$

c, d) In this section, the block moves up the incline. The drawing will change, because the frictional force acts downward as it opposes the upward motion



$$\begin{aligned}
 & y\text{-direction} \\
 & 0 = N - mg \cos \theta \\
 & N = mg \cos \theta
 \end{aligned}$$

$$\begin{aligned}
 & x\text{-direction} \\
 ma &= -F_f - mg \sin \theta \\
 &= -mg \sin \theta - F_f \\
 &= -mg \sin \theta - \mu N \\
 &= -mg \sin \theta - \mu_s mg \cos \theta \\
 a &= -g \sin \theta - \mu_s g \cos \theta \\
 &= -9.46 \text{ m/s}^2
 \end{aligned}$$

*y* - direction  
 $0 = N - mg \cos \theta$   
 $N = mg \cos \theta$

*x* - direction  
 $0 = F - F_f - mg \sin \theta$   
 $F = mg \sin \theta + F_f$   
 $= mg \sin \theta + \mu N$   
 $= mg \sin \theta + \mu_k mg \cos \theta$   
 $= 80N \sin 20 + 0.15 \cdot 80N \cdot \cos 20$   
 $= 38.6N$