UNIVERSITY PHYSICS

Chapter 6 APPLICATIONS OF NEWTON’S LAWS

PowerPoint Image Slideshow

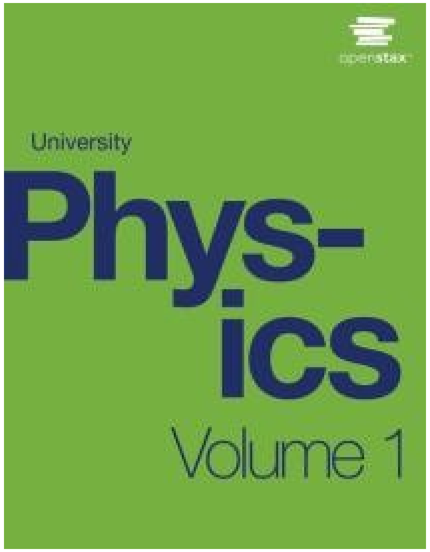
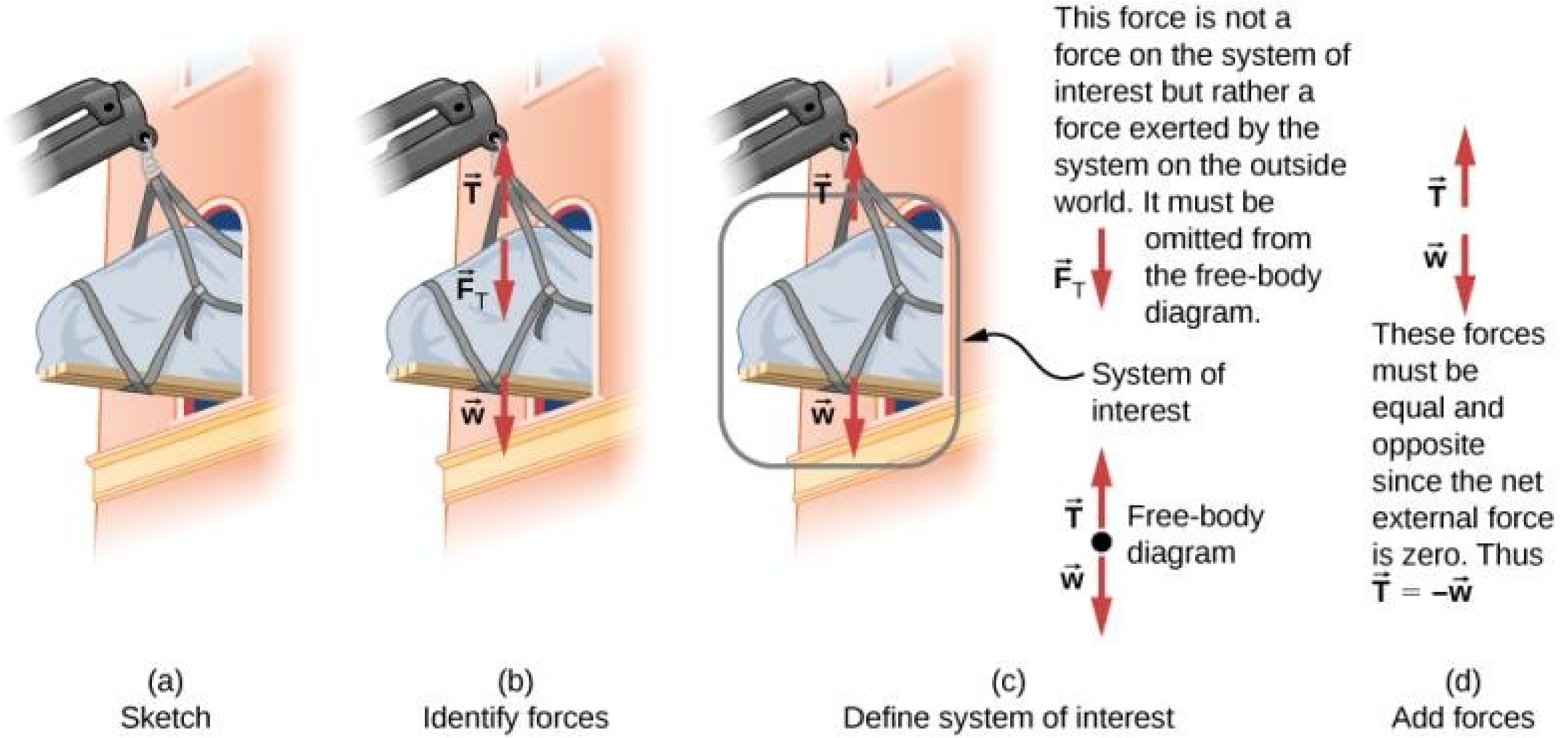


FIGURE 6.2



This force is not a force on the system of interest but rather a force exerted by the system on the outside world. It must be omitted from the free-body diagram.

System of interest

Free-body diagram

These forces must be equal and opposite since the net external force is zero. Thus $\vec{T} = -\vec{w}$

(a) Sketch

(b) Identify forces

(c) Define system of interest

(d) Add forces

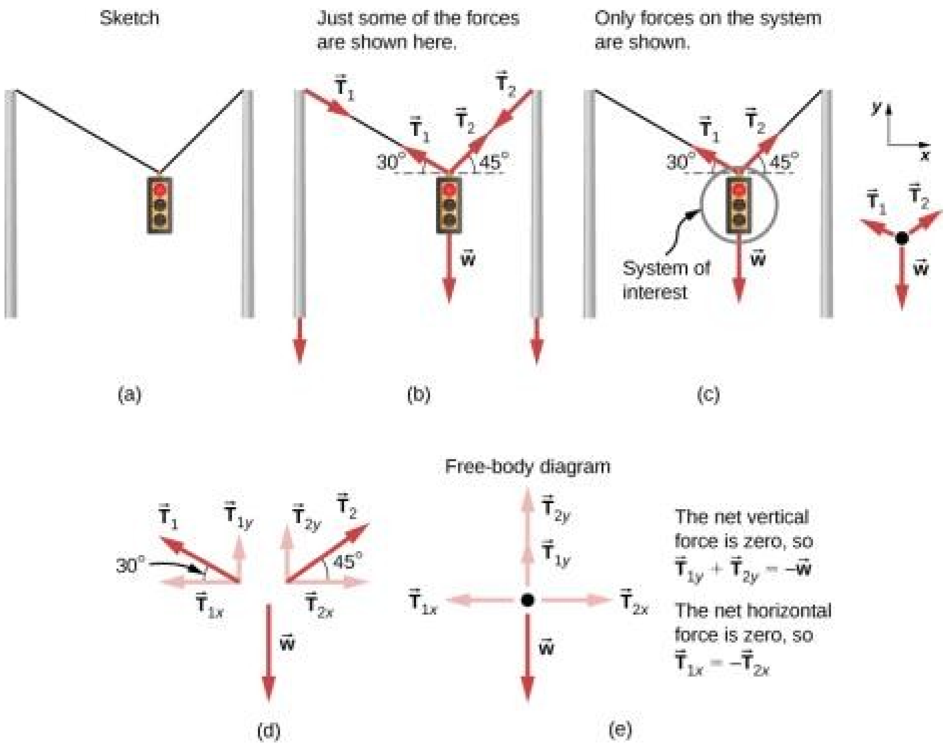
a) A grand piano is being lifted to a second-story apartment.

b) Arrows are used to represent all forces: is the tension in the rope above the piano, is the force that the piano exerts on the rope, and is the weight of the piano. All other forces, such as the nudge of a breeze, are assumed to be negligible.

c) Suppose we are given the piano’s mass and asked to find the tension in the rope. We then define the system of interest as shown and draw a free-body diagram. Now is no longer shown, because it is not a force acting on the system of interest; rather, acts on the outside world.

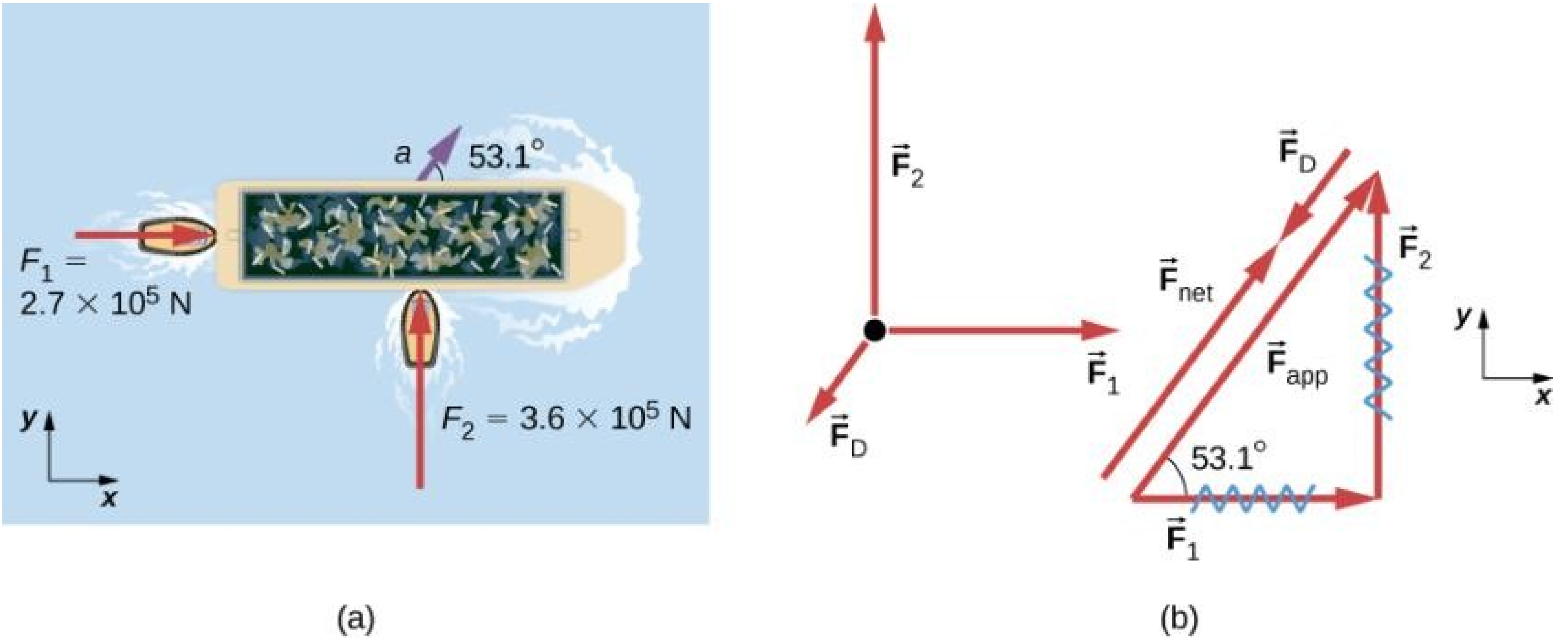
d) Showing only the arrows, the head-to-tail method of addition is used. It is apparent that if the piano is stationary, .

FIGURE 6.3



A traffic light is suspended from two wires. (b) Some of the forces involved. (c) Only forces acting on the system are shown here. The free-body diagram for the traffic light is also shown. (d) The forces projected onto vertical (*y*) and horizontal (*x*) axes. The horizontal components of the tensions must cancel, and the sum of the vertical components of the tensions must equal the weight of the traffic light. (e) The free-body diagram shows the vertical and horizontal forces acting on the traffic light.

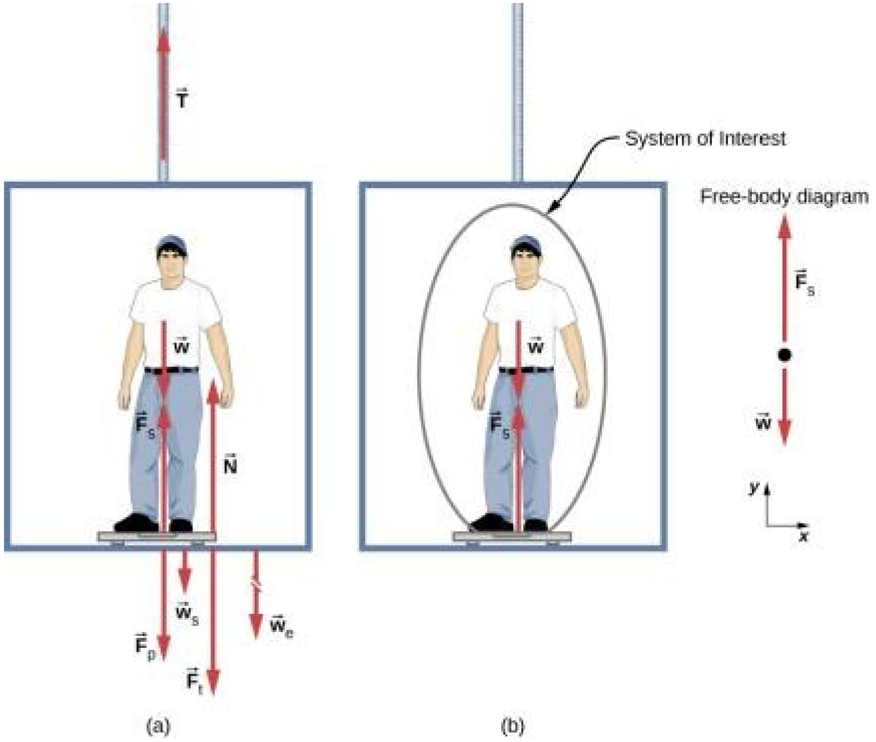
FIGURE 6.4



a) A view from above of two tugboats pushing on a barge.

b) The free-body diagram for the ship contains only forces acting in the plane of the water. It omits the two vertical forces—the weight of the barge and the buoyant force of the water supporting it cancel and are not shown. Note that is the total applied force of the tugboats.

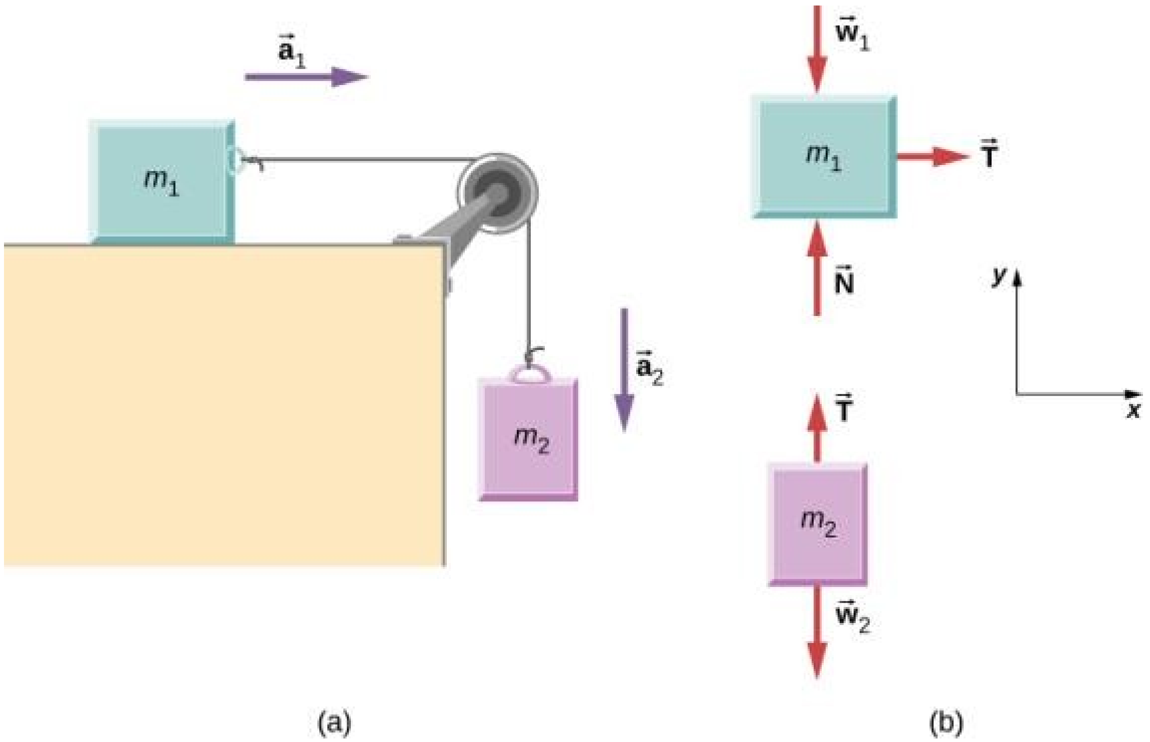
FIGURE 6.5



a) The various forces acting when a person stands on a bathroom scale in an elevator. The arrows are approximately correct for when the elevator is accelerating upward—broken arrows represent forces too large to be drawn to scale. is the tension in the supporting cable, is the weight of the person, is the weight of the scale, is the weight of the elevator, is the force of the scale on the person, is the force of the person on the scale, is the force of the scale on the floor of the elevator, and is the force of the floor upward on the scale.

b) The free-body diagram shows only the external forces acting on the designated system of interest—the person—and is the diagram we use for the solution of the problem.

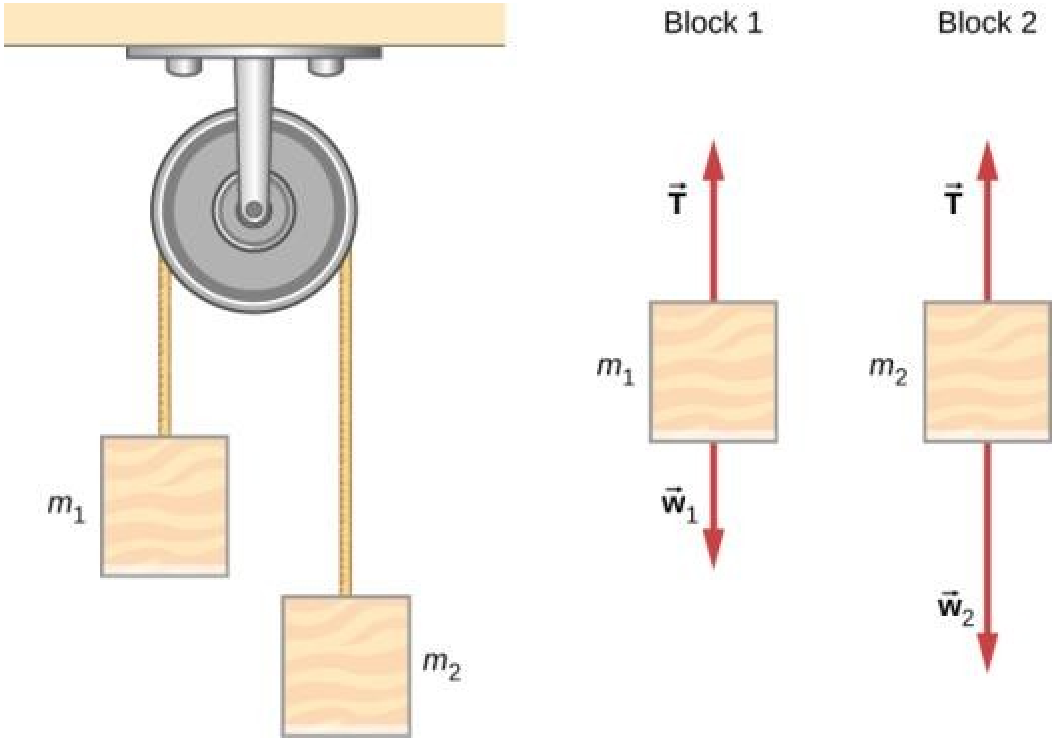
FIGURE 6.6



a) Block 1 is connected by a light string to block 2.

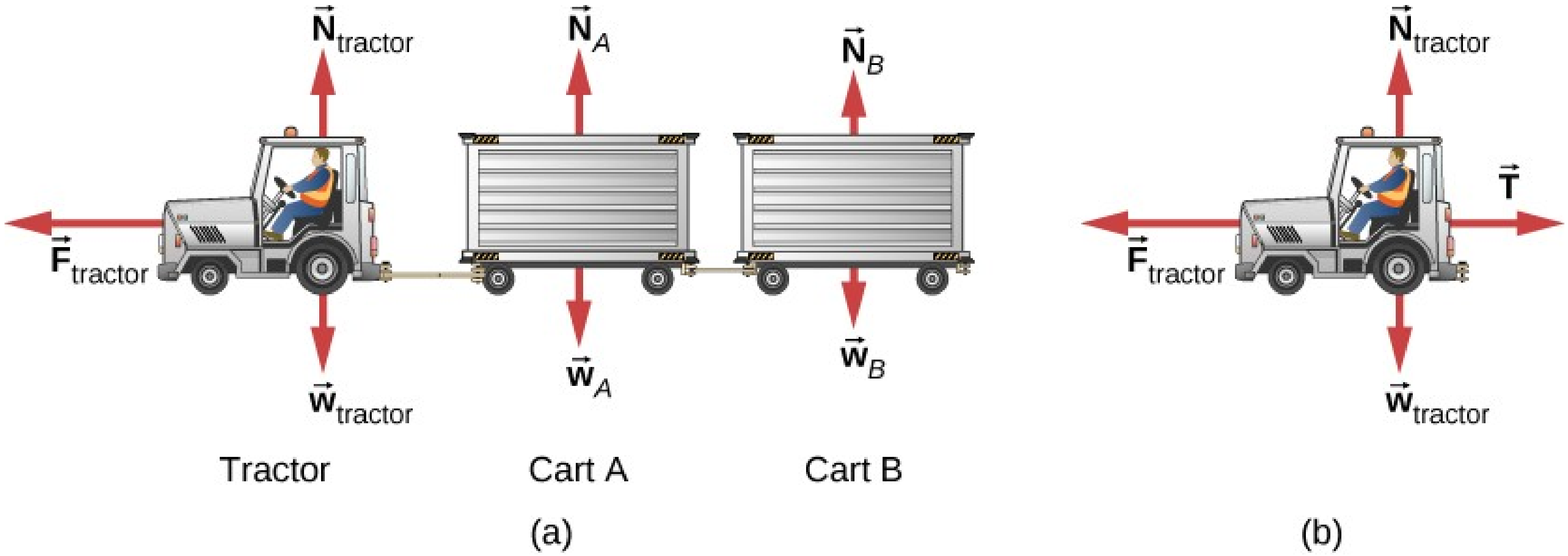
b) The free-body diagrams of the blocks.

FIGURE 6.7



An Atwood machine and free-body diagrams for each of the two blocks.

FIGURE 6.8

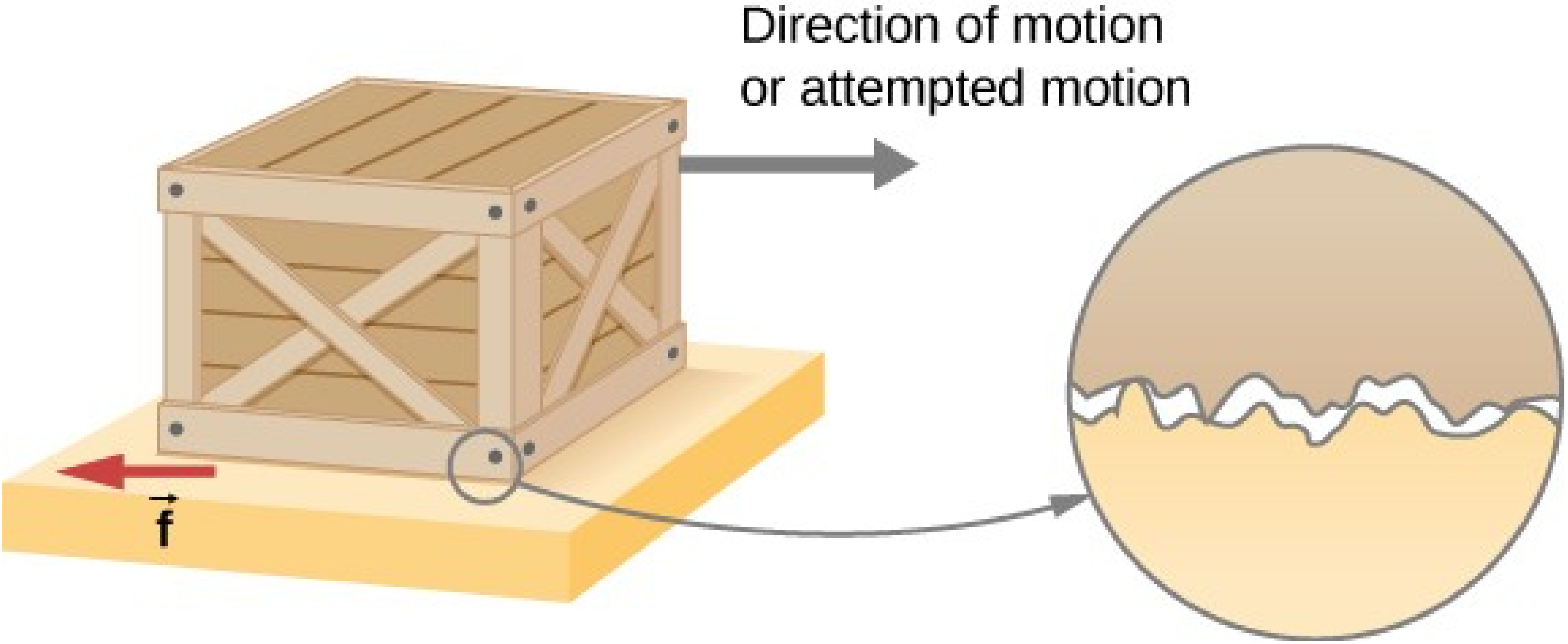


a) A free-body diagram is shown, which indicates all the external forces on the system consisting of the tractor and baggage carts for carrying airline luggage.

b) A free-body diagram of the tractor only is shown isolated in order to calculate the tension in the cable to the carts.

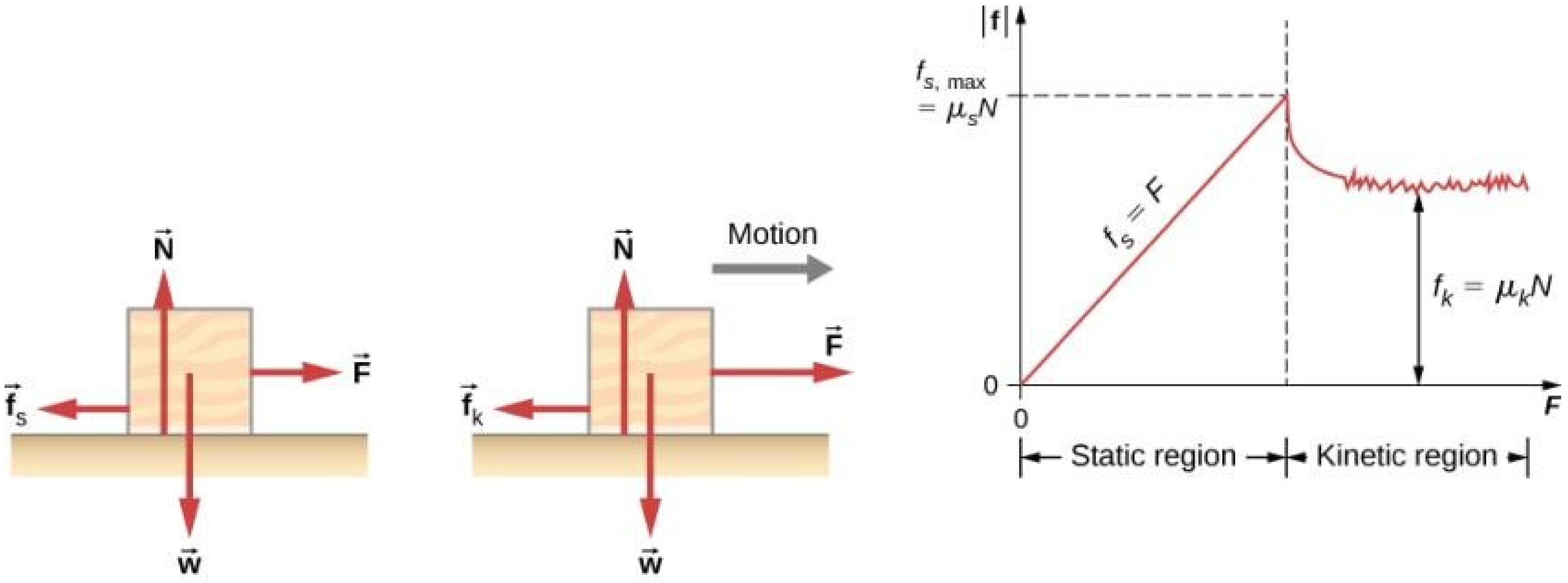
Friction & drag

FIGURE 6.10



Frictional forces, such as , always oppose motion or attempted motion between objects in contact. Friction arises in part because of the roughness of the surfaces in contact, as seen in the expanded view. For the object to move, it must rise to where the peaks of the top surface can skip along the bottom surface. Thus, a force is required just to set the object in motion. Some of the peaks will be broken off, also requiring a force to maintain motion. Much of the friction is actually due to attractive forces between molecules making up the two objects, so that even perfectly smooth surfaces are not friction-free. (In fact, perfectly smooth, clean surfaces of similar materials would adhere, forming a bond called a “cold weld.”)

FIGURE 6.11



(a)
Impending motion

(b)
Object moves

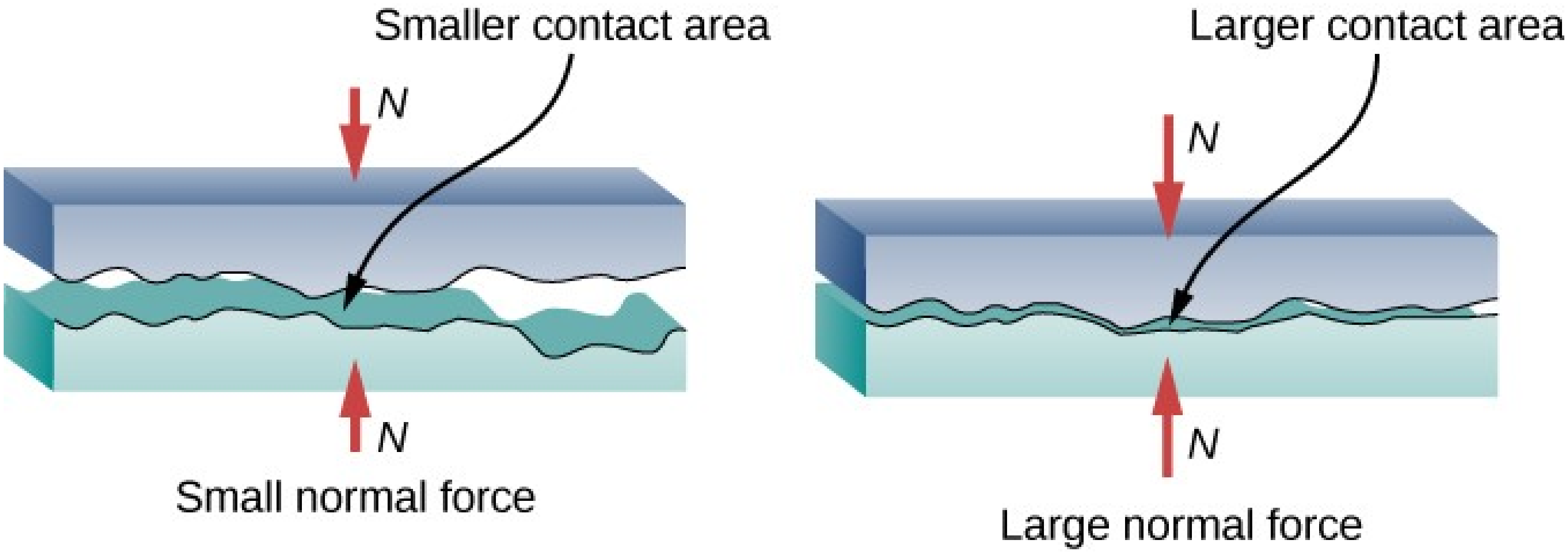
(c)

a) The force of friction between the block and the rough surface opposes the direction of the applied force . The magnitude of the static friction balances that of the applied force. This is shown in the left side of the graph in (c).

b) At some point, the magnitude of the applied force is greater than the force of kinetic friction, and the block moves to the right. This is shown in the right side of the graph.

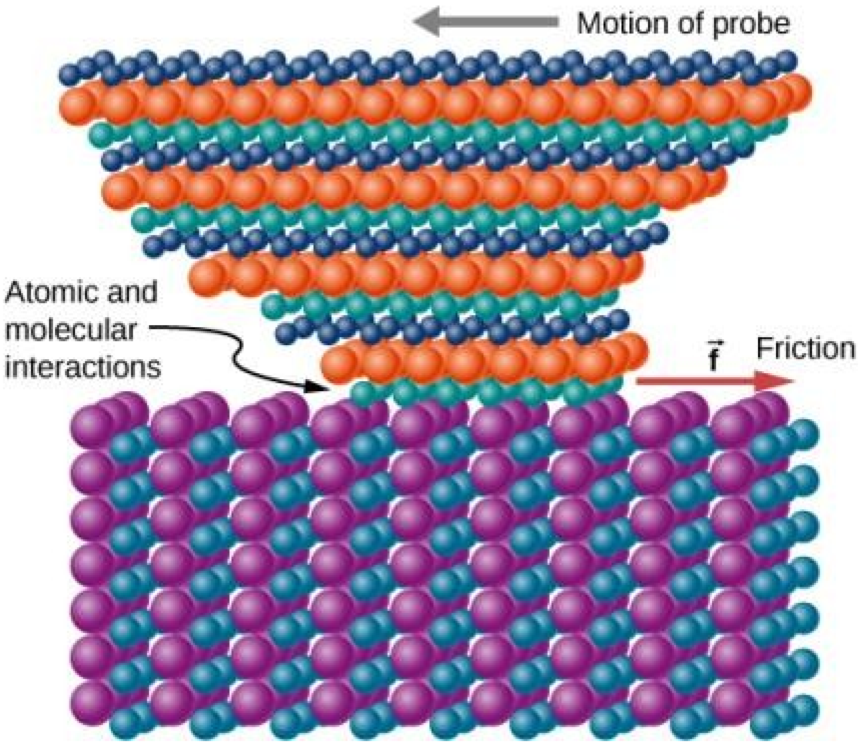
c) The graph of the frictional force versus the applied force; note that . This means that .

FIGURE 6.15



Two rough surfaces in contact have a much smaller area of actual contact than their total area. When the normal force is larger as a result of a larger applied force, the area of actual contact increases, as does friction.

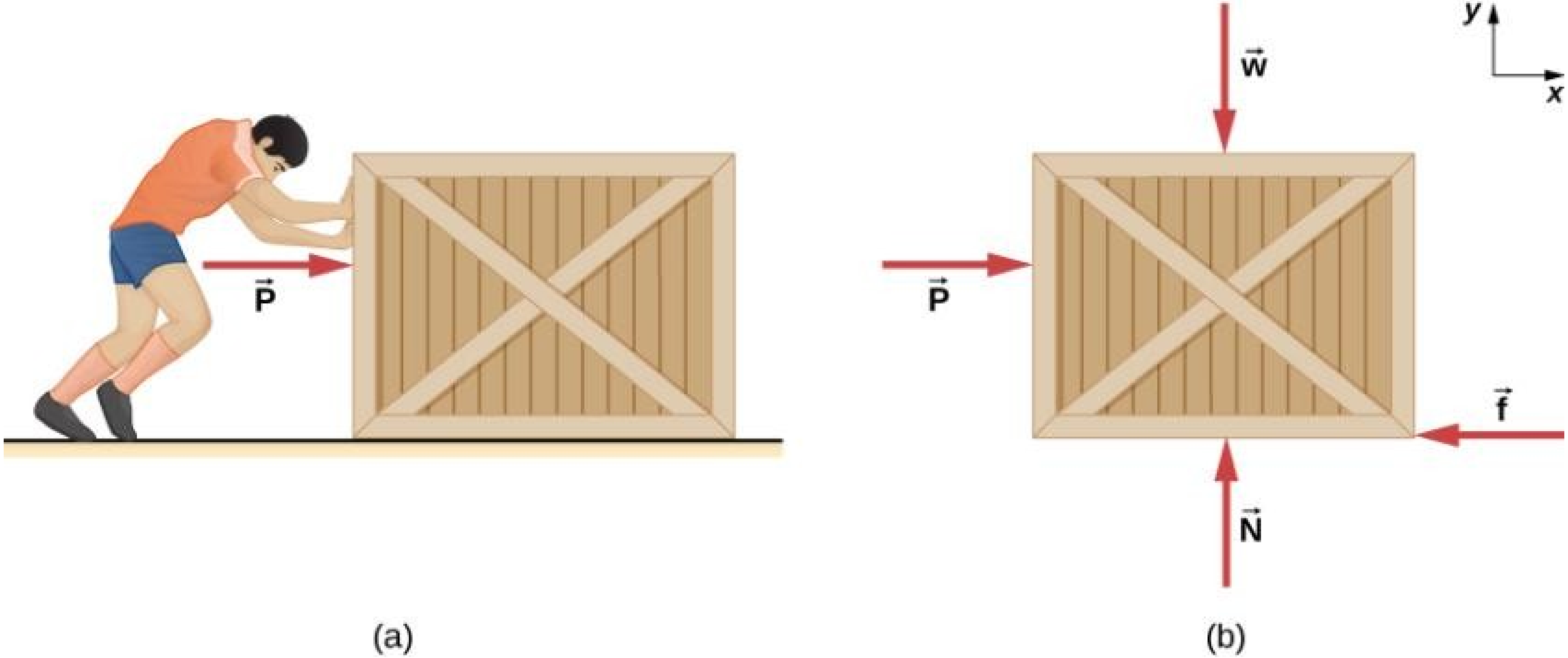
FIGURE 6.16



The tip of a probe is deformed sideways by frictional force as the probe is dragged across a surface. Measurements of how the force varies for different materials are yielding fundamental insights into the atomic nature of friction.

Examples

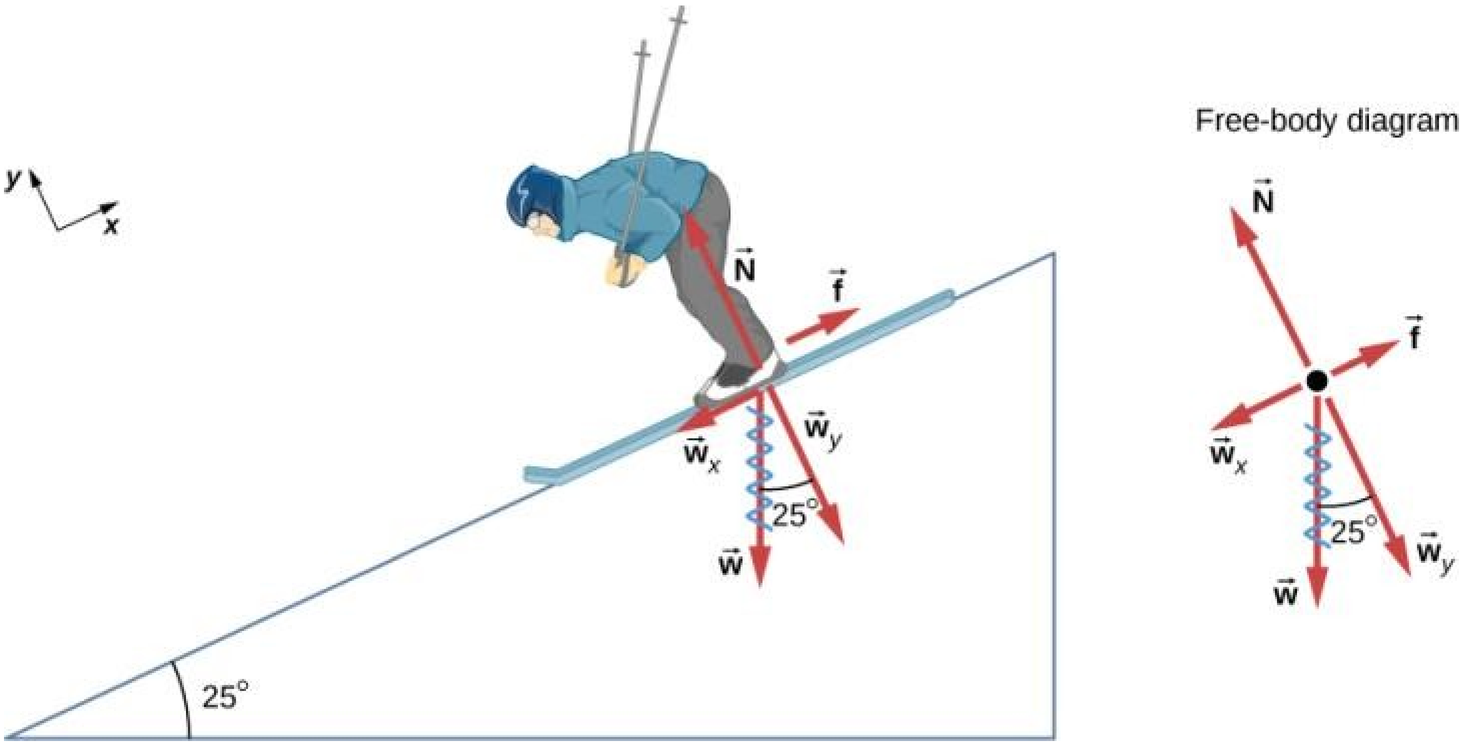
FIGURE 6.13



a) A crate on a horizontal surface is pushed with a force .

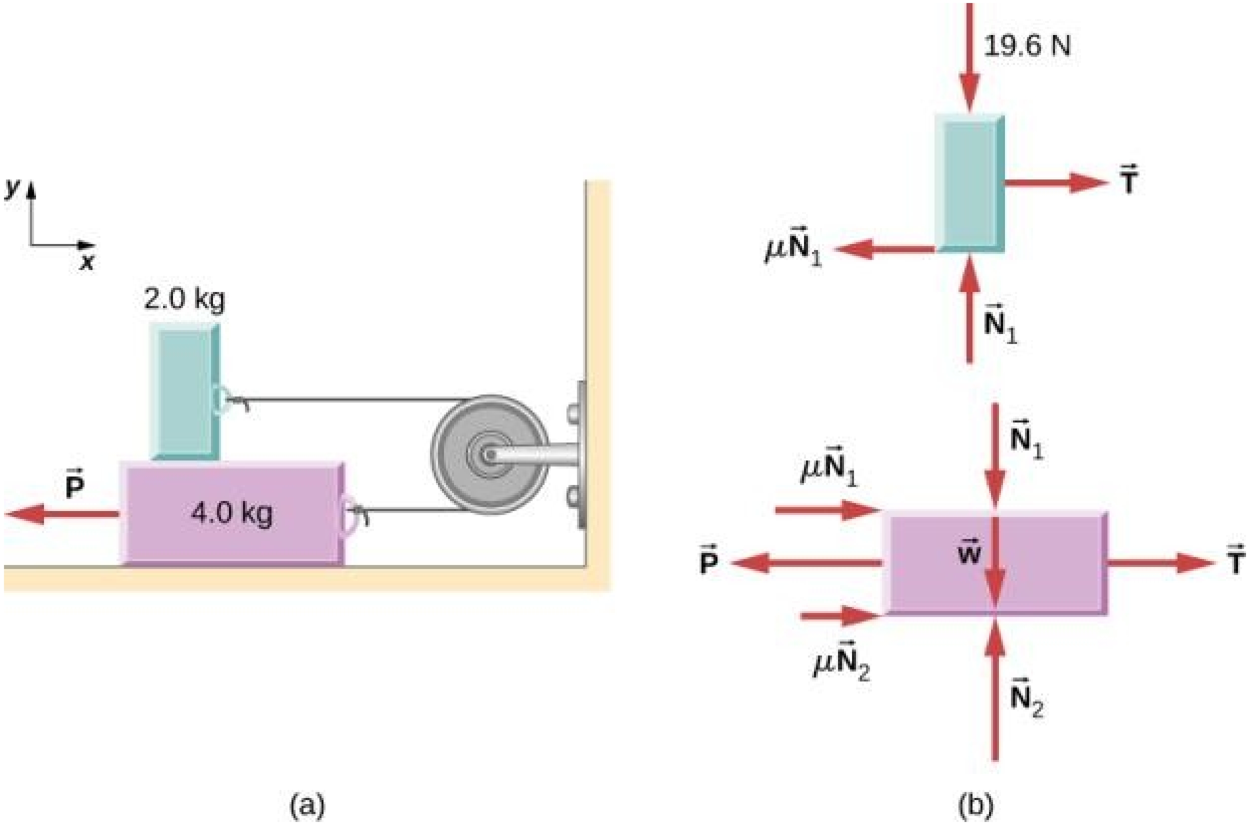
b) The forces on the crate. Here, may represent either the static or the kinetic frictional force.

FIGURE 6.14



The motion of the skier and friction are parallel to the slope, so it is most convenient to project all forces onto a coordinate system where one axis is parallel to the slope and the other is perpendicular (axes shown to left of skier). The normal force is perpendicular to the slope, and friction is parallel to the slope, but the skier’s weight has components along both axes, namely and . The normal force is equal in magnitude to , so there is no motion perpendicular to the slope. However, is less than in magnitude, so there is acceleration down the slope (along the *x*-axis).

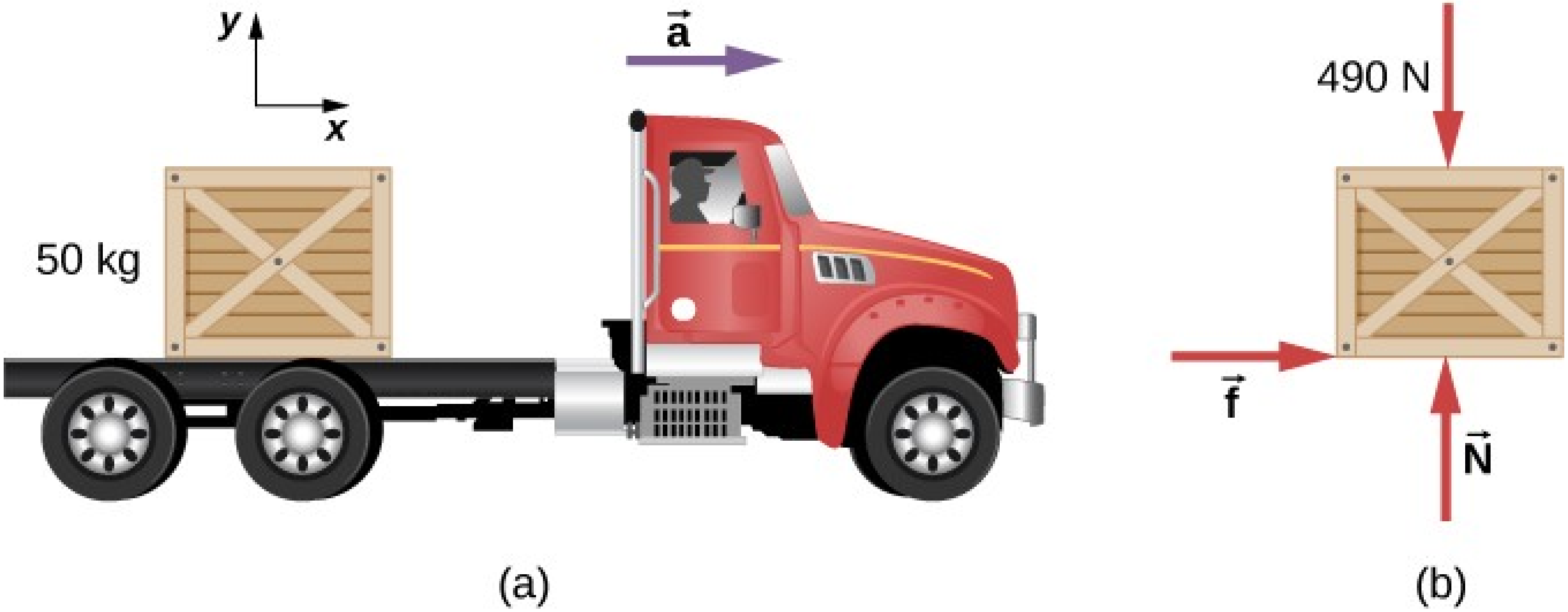
FIGURE 6.17



a) Each block moves at constant velocity.

b) Free-body diagrams for the blocks.

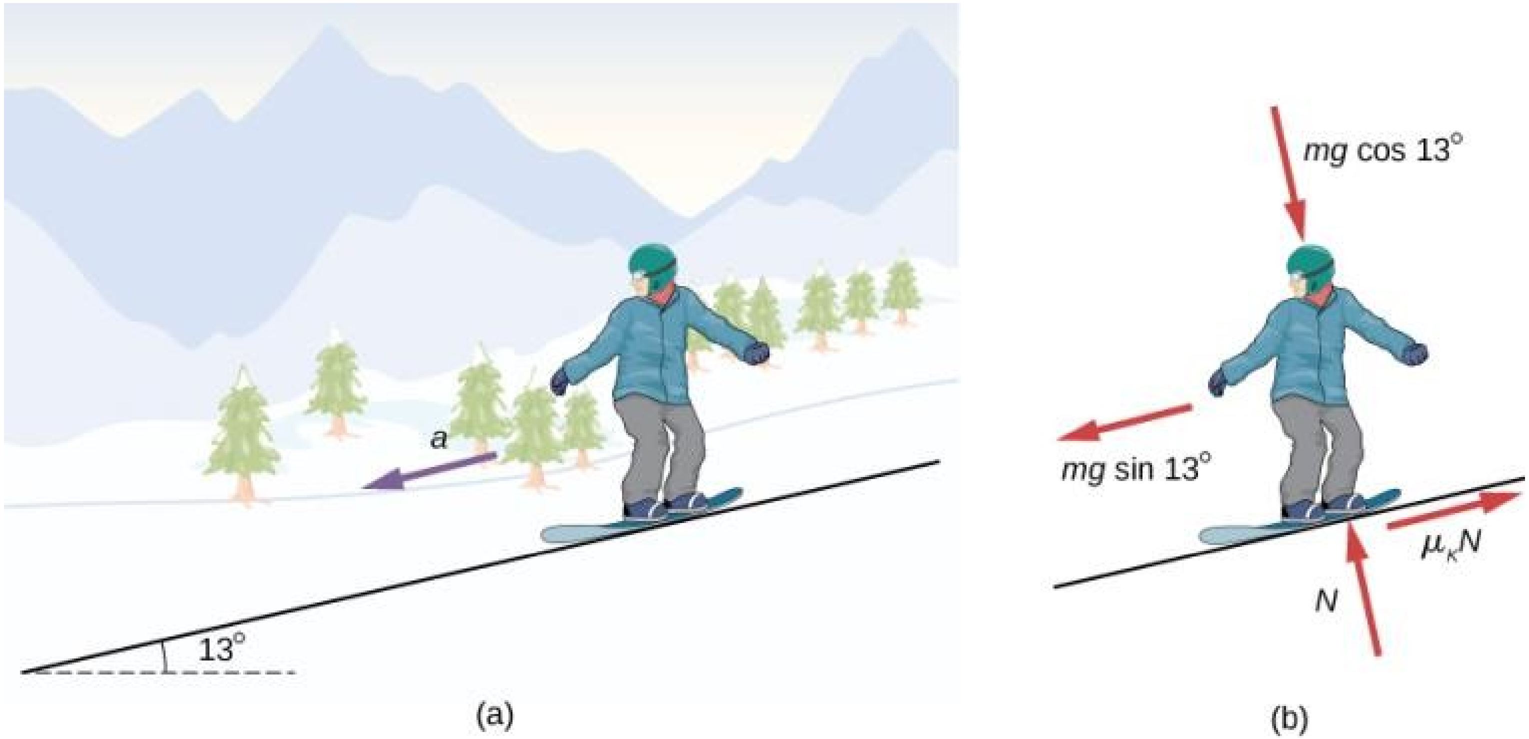
FIGURE 6.18



a) A crate rests on the bed of the truck that is accelerating forward.

b) The free-body diagram of the crate.

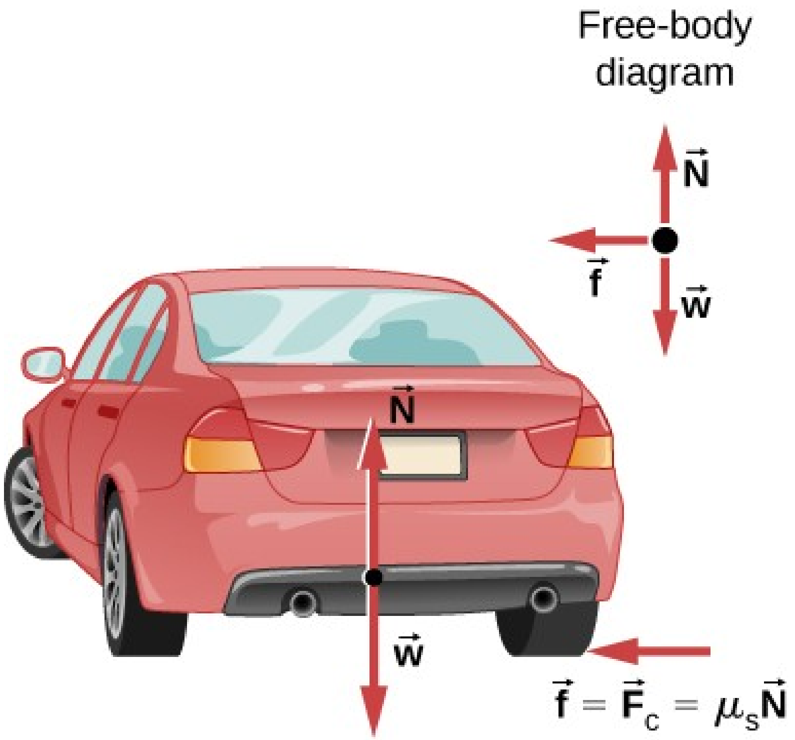
FIGURE 6.19



a) A snowboarder glides down a slope inclined at 13° to the horizontal.

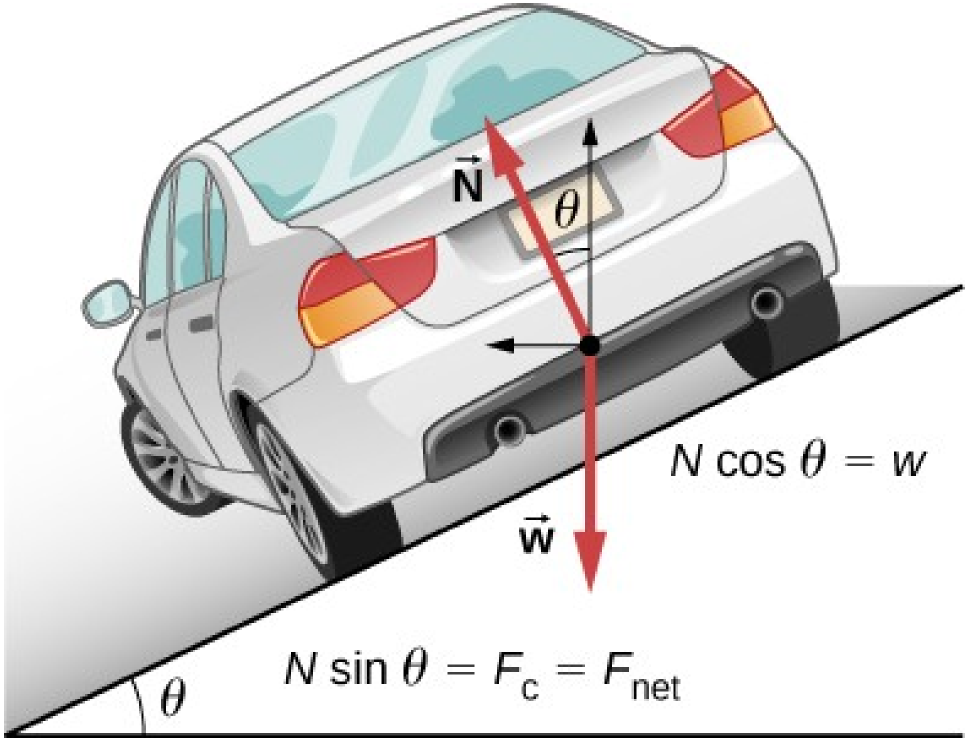
b) The free-body diagram of the snowboarder.

FIGURE 6.21



This car on level ground is moving away and turning to the left. The centripetal force causing the car to turn in a circular path is due to friction between the tires and the road. A minimum coefficient of friction is needed, or the car will move in a larger-radius curve and leave the roadway.

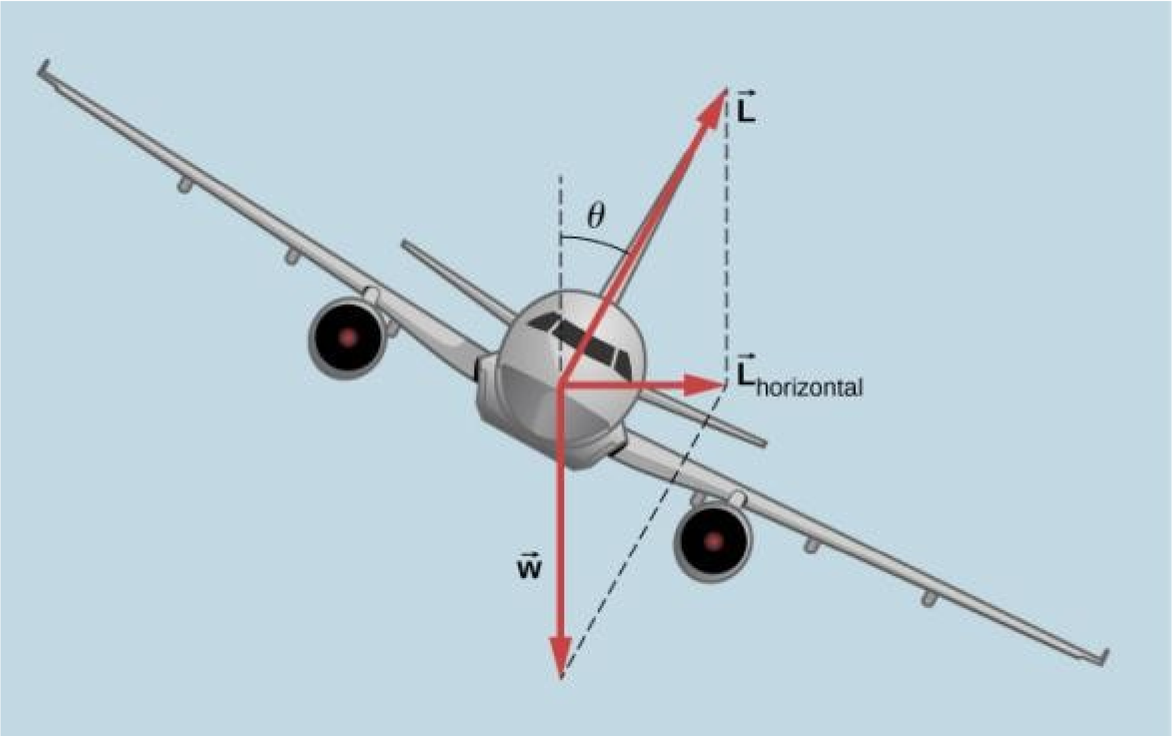
FIGURE 6.22



The car on this banked curve is moving away and turning to the left.

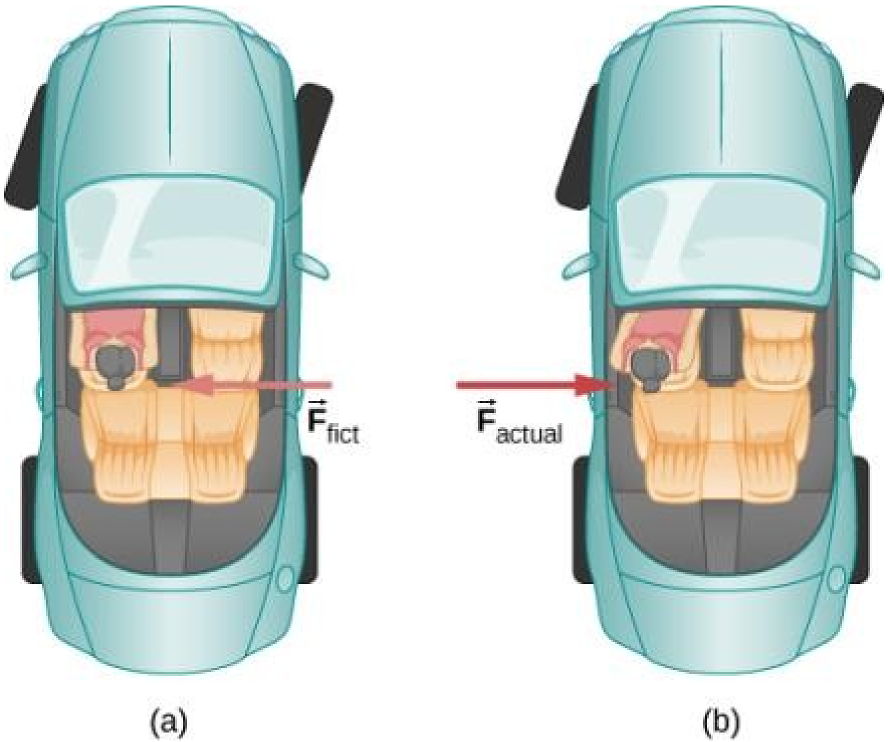
Moving reference frames

FIGURE 6.23



In a banked turn, the horizontal component of lift is unbalanced and accelerates the plane. The normal component of lift balances the plane's weight. The banking angle is given by . Compare the vector diagram with that shown in **Figure 6.22**.

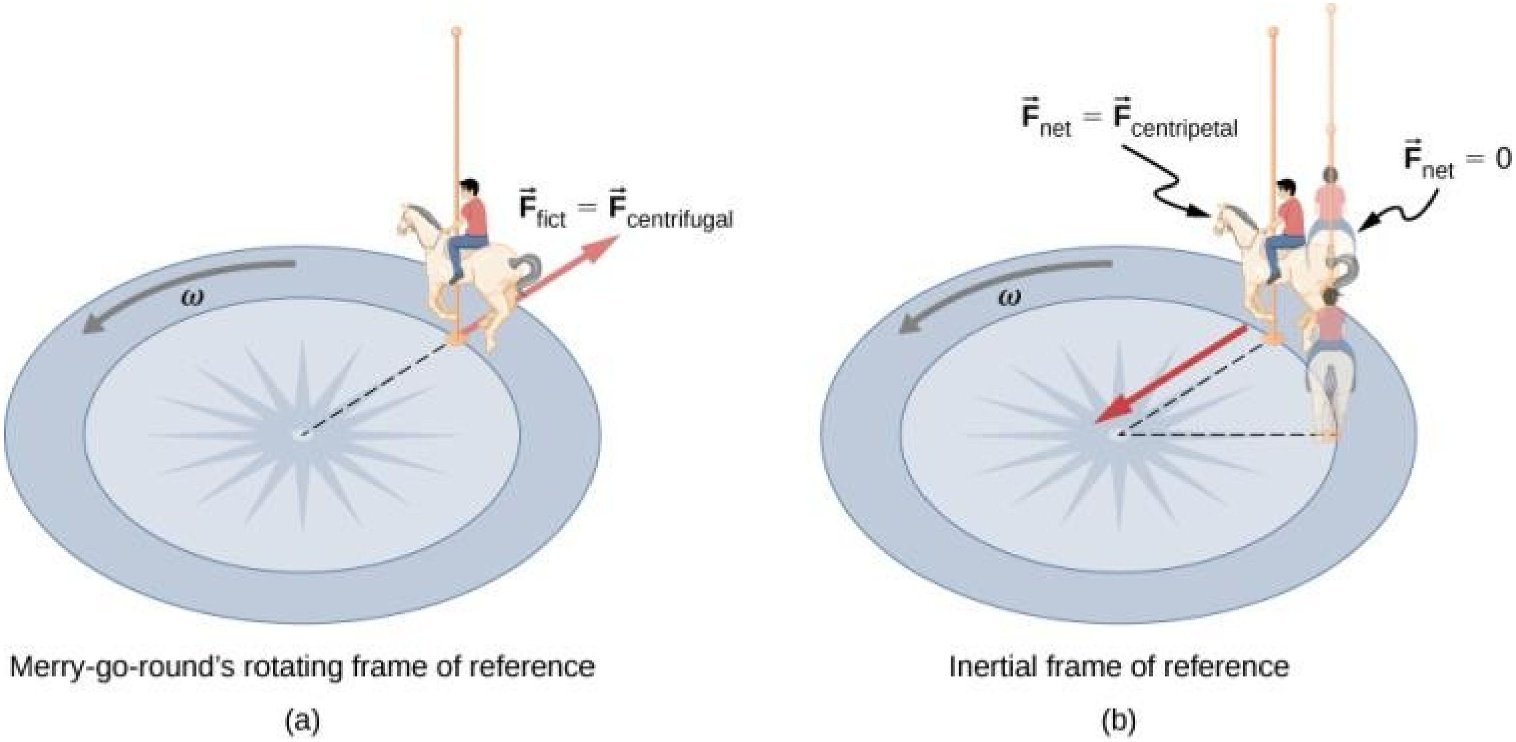
FIGURE 6.24



a) The car driver feels herself forced to the left relative to the car when she makes a right turn. This is an inertial force arising from the use of the car as a frame of reference.

b) In Earth’s frame of reference, the driver moves in a straight line, obeying Newton’s first law, and the car moves to the right. There is no force to the left on the driver relative to Earth. Instead, there is a force to the right on the car to make it turn.

FIGURE 6.25



Merry-go-round's rotating frame of reference

(a)

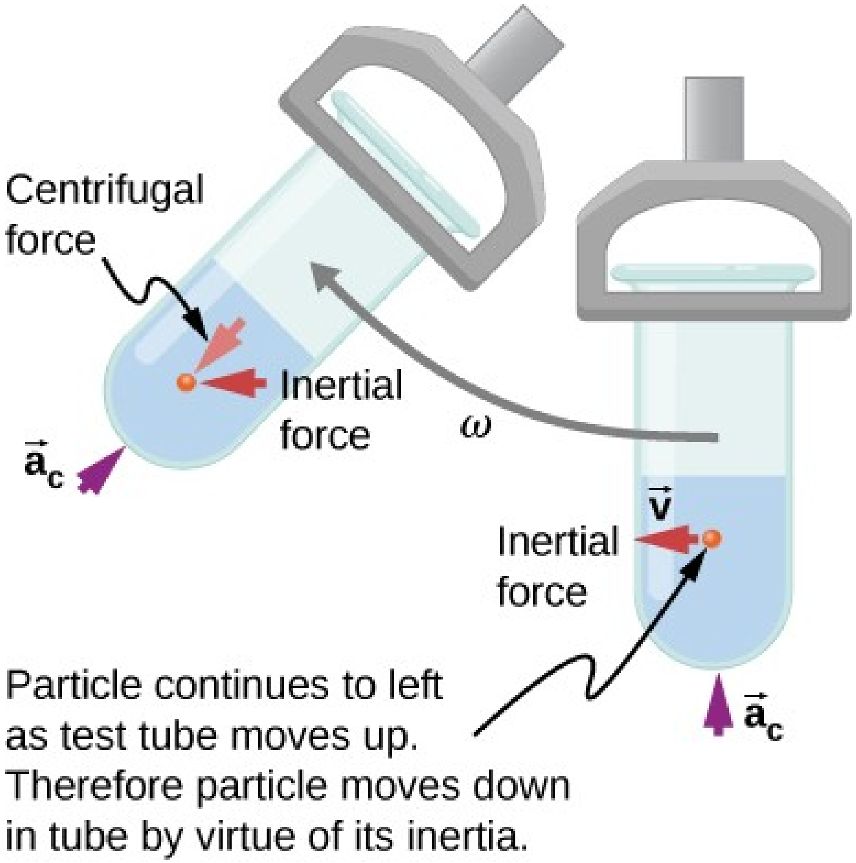
Inertial frame of reference

(b)

a) A rider on a merry-go-round feels as if he is being thrown off. This inertial force is sometimes mistakenly called the centrifugal force in an effort to explain the rider's motion in the rotating frame of reference.

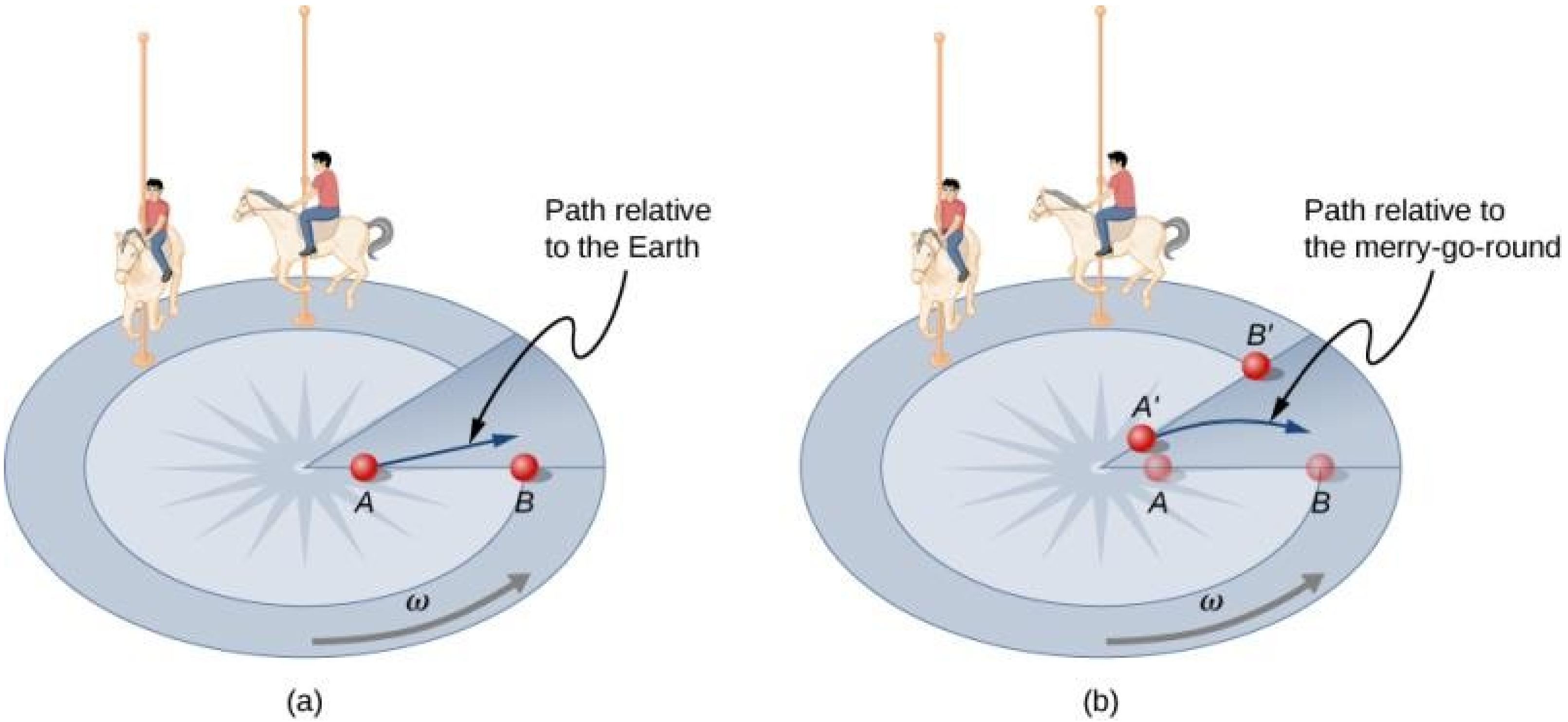
b) In an inertial frame of reference and according to Newton's laws, it is his inertia that carries him off (the unshaded rider has and heads in a straight line). A force, , is needed to cause a circular path.

FIGURE 6.26



Centrifuges use inertia to perform their task. Particles in the fluid sediment settle out because their inertia carries them away from the center of rotation. The large angular velocity of the centrifuge quickens the sedimentation. Ultimately, the particles come into contact with the test tube walls, which then supply the centripetal force needed to make them move in a circle of constant radius.

FIGURE 6.27



Looking down on the counterclockwise rotation of a merry-go-round, we see that a ball slid straight toward the edge follows a path curved to the right. The person slides the ball toward point *B*, starting at point *A*. Both points rotate to the shaded positions (*A*’ and *B*’) shown in the time that the ball follows the curved path in the rotating frame and a straight path in Earth’s frame.