CAUTION

There is no real "centrifugal force"

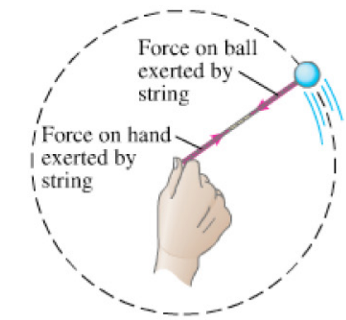
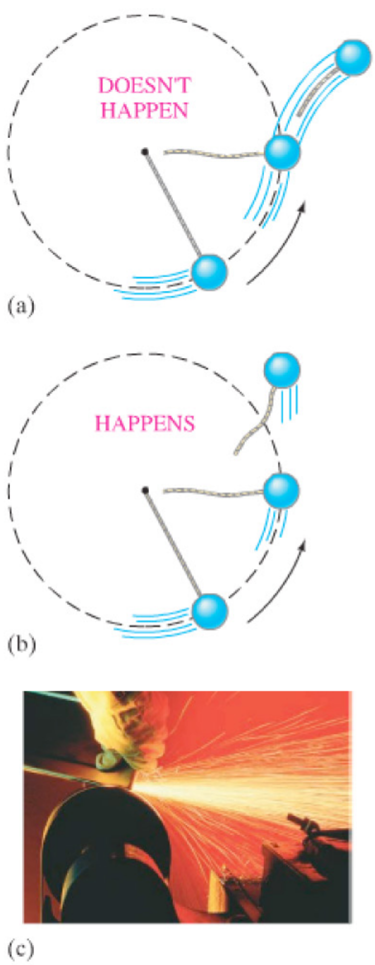


FIGURE 5–5 Swinging a ball on the end of a string.

There is a common misconception that an object moving in a circle has an outward force acting on it, a so-called centrifugal ("center-fleeing") force. This is incorrect: *there is no outward force* on the revolving object. Consider, for example, a person swinging a ball on the end of a string around her head (Fig. 5–5). If you have ever done this yourself, you know that you feel a force pulling outward on your hand. The misconception arises when this pull is interpreted as an outward "centrifugal" force pulling on the ball that is transmitted along the string to your hand. This is not what is happening at all. To keep the ball moving in a circle, you pull *inwardly* on the string, and the string exerts this force on the ball. The ball exerts an equal and opposite force on the string (Newton's third law), and *this* is the outward force your hand feels (see Fig. 5–5).

The force *on the ball* is the one exerted *inwardly* on it by you, via the string. To see even more convincing evidence that a "centrifugal force" does not act on the ball, consider what happens when you let go of the string. If a centrifugal force were acting, the ball would fly outward, as shown in Fig. 5–6a. But it doesn't; the ball flies off tangentially (Fig. 5–6b), in the direction of the velocity it had at the moment it was released, because the inward force no longer acts. Try it and see!

FIGURE 5–6 If centrifugal force existed, the revolving ball would fly outward as in (a) when released. In fact, it flies off tangentially as in (b). For example, in (c) sparks fly in straight lines tangentially from the edge of a rotating grinding wheel.



EXAMPLE 5–3 ESTIMATE Force on revolving ball (horizontal). Estimate the force a person must exert on a string attached to a 0.150-kg ball to make the ball revolve in a horizontal circle of radius 0.600 m. The ball makes 2.00 revolutions per second ($T = 0.500\,\mathrm{s}$), as in Example 5–1.

APPROACH First we need to draw the free-body diagram for the ball. The forces acting on the ball are the force of gravity, $m\vec{\mathbf{g}}$ downward, and the tension force $\vec{\mathbf{F}}_\mathrm{T}$ that the string exerts toward the hand at the center (which occurs because the person exerts that same force on the string). The free-body diagram for the ball is as shown in Fig. 5–7. The ball's weight complicates matters and makes it impossible to revolve a ball with the cord perfectly horizontal. We assume the weight is small, and put $\phi \approx 0$ in Fig. 5–7. Thus $\vec{\mathbf{F}}_\mathrm{T}$ will act nearly horizontally and, in any case, provides the force necessary to give the ball its centripetal acceleration.

SOLUTION We apply Newton's second law to the radial direction, which we assume is horizontal:

$$(\Sigma F)_\mathrm{R} = ma_\mathrm{R},$$

where $a_\mathrm{R} = v^2/r$ and $v = 2\pi r/T = 2\pi(0.600\,\mathrm{m})/(0.500\,\mathrm{s}) = 7.54\,\mathrm{m/s}$. Thus

$$F_\mathrm{T} = m\frac{v^2}{r} = (0.150\,\mathrm{kg})\frac{(7.54\,\mathrm{m/s})^2}{(0.600\,\mathrm{m})} \approx 14\,\mathrm{N}.$$

NOTE We keep only two significant figures in the answer because $mg = (0.150\,\mathrm{kg})(9.80\,\mathrm{m/s^2}) = 1.5\,\mathrm{N}$, being about $\frac{1}{10}$ of our result, is small but not so small as to justify stating a more precise answer since we ignored the effect of mg.

NOTE To include the effect of $m\vec{\mathbf{g}}$, resolve $\vec{\mathbf{F}}_\mathrm{T}$ in Fig. 5–7 into components, and set the horizontal component of $\vec{\mathbf{F}}_\mathrm{T}$ equal to mv^2/r and its vertical component equal to mg.

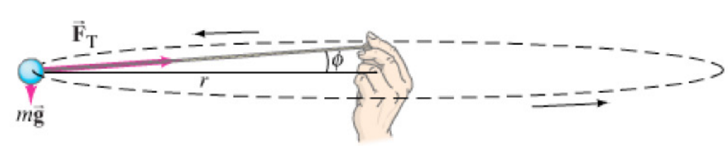


FIGURE 5–7 Example 5–3.