EXAMPLE 5–8 **Two components of acceleration.** A race car starts from rest in the pit area and accelerates at a uniform rate to a speed of 35 m/s in 11 s, moving on a circular track of radius 500 m. Assuming constant tangential acceleration, find (*a*) the tangential acceleration, and (*b*) the radial acceleration, at the instant when the speed is $v = 15\,\text{m/s}$.

APPROACH The tangential acceleration relates to the change in speed of the car, and can be calculated as $a_{\tan} = \Delta v/\Delta t$. The centripetal acceleration relates to the change in the *direction* of the velocity vector and is calculated using $a_{\text{R}} = v^2/r$.

SOLUTION (*a*) During the 11-s time interval, we assume the tangential acceleration $a_{\tan}$ is constant. Its magnitude is

$$a_{\tan} = \frac{\Delta v}{\Delta t} = \frac{(35\,\text{m/s} - 0\,\text{m/s})}{11\,\text{s}} = 3.2\,\text{m/s}^2.$$

(*b*) When $v = 15\,\text{m/s}$, the centripetal acceleration is

$$a_{\text{R}} = \frac{v^2}{r} = \frac{(15\,\text{m/s})^2}{(500\,\text{m})} = 0.45\,\text{m/s}^2.$$

EXERCISE F When the speed of the race car in Example 5–8 is 30 m/s, how are (*a*) $a_{\tan}$ and (*b*) a_{R} changed?

These concepts can be used for an object moving along any curved path, such as that shown in Fig. 5–16. We can treat any portion of the curve as an arc of a circle with a radius of curvature *r*. The velocity at any point is always tangent to the path. The acceleration can be written, in general, as a vector sum of two components: the tangential component $a_{\tan} = \Delta v/\Delta t$, and the radial (centripetal) component $a_{\text{R}} = v^2/r$.

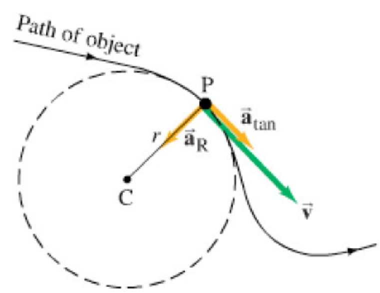

FIGURE 5–16 Object following a curved path (solid line). At point P the path has a radius of curvature *r*. The object has velocity $\vec{\mathbf{v}}$, tangential acceleration $\vec{\mathbf{a}}_{\tan}$ (the object is increasing in speed), and radial (centripetal) acceleration $\vec{\mathbf{a}}_{\text{R}}$ (magnitude $a_{\text{R}} = v^2/r$) which points toward the center of curvature C.

* 5–5 Centrifugation

PHYSICS APPLIED
Centrifuge

A useful device that nicely illustrates circular motion is the centrifuge, or the very high speed ultracentrifuge. These devices are used to sediment materials quickly or to separate materials. Test tubes are held in the centrifuge rotor, which is accelerated to very high rotational speeds: see Fig. 5–17, where one test tube is shown in two positions as the rotor turns. The small green dot represents a small particle, perhaps a macromolecule, in a fluid-filled test tube. When the tube is at position A and the rotor is turning, the particle has a tendency to move in a straight line in the direction of the dashed arrow. But the fluid, resisting the motion of the particles, exerts a centripetal force that keeps the particles moving nearly in a circle. Usually, the resistance of the fluid (a liquid, a gas, or a gel, depending on the application) does not quite equal mv^2/r, and the particles eventually reach the bottom of the tube. The purpose of a centrifuge is to provide an "effective gravity" much larger than normal gravity because of the high rotational speeds, thus causing more rapid sedimentation.