

EXAMPLE 12.9

At any instant the horizontal position of the weather balloon in Fig. 12-18a is defined by $x = (8t)$ ft, where t is in seconds. If the equation of the path is $y = x^2/10$, determine the magnitude and direction of the velocity and the acceleration when $t = 2$ s.

SOLUTION

Velocity. The velocity component in the x direction is

$$v_x = \dot{x} = \frac{d}{dt}(8t) = 8 \text{ ft/s} \rightarrow$$

To find the relationship between the velocity components we will use the chain rule of calculus. When $t = 2$ s, $x = 8(2) = 16$ ft, Fig. 12-18a, and so

$$v_y = \dot{y} = \frac{d}{dt}(x^2/10) = 2x\dot{x}/10 = 2(16)(8)/10 = 25.6 \text{ ft/s} \uparrow$$

When $t = 2$ s, the magnitude of velocity is therefore

$$v = \sqrt{(8 \text{ ft/s})^2 + (25.6 \text{ ft/s})^2} = 26.8 \text{ ft/s} \quad \text{Ans.}$$

The direction is tangent to the path, Fig. 12-18b, where

$$\theta_v = \tan^{-1} \frac{v_y}{v_x} = \tan^{-1} \frac{25.6}{8} = 72.6^\circ \quad \text{Ans.}$$

Acceleration. The relationship between the acceleration components is determined using the chain rule. (See Appendix C.) We have

$$a_x = \dot{v}_x = \frac{d}{dt}(8) = 0$$

$$\begin{aligned} a_y = \dot{v}_y &= \frac{d}{dt}(2x\dot{x}/10) = 2(\dot{x}\dot{x}/10) + 2x(\ddot{x})/10 \\ &= 2(8)^2/10 + 2(16)(0)/10 = 12.8 \text{ ft/s}^2 \uparrow \end{aligned}$$

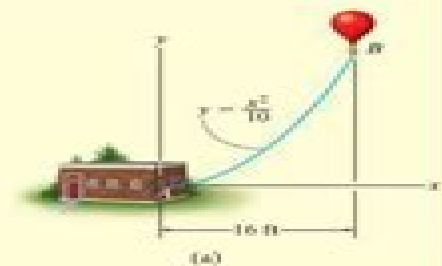
Thus,

$$a = \sqrt{(0)^2 + (12.8)^2} = 12.8 \text{ ft/s}^2 \quad \text{Ans.}$$

The direction of $\mathbf{a}$, as shown in Fig. 12-18c, is

$$\theta_a = \tan^{-1} \frac{12.8}{0} = 90^\circ \quad \text{Ans.}$$

NOTE: It is also possible to obtain v_y and a_y by first expressing $y = f(t) = (8t)^2/10 = 6.4t^2$ and then taking successive time derivatives.



(a)



(b)



Fig. 12-18

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