

108. We adopt the positive direction choices used in the textbook so that equations such as Eq. 4-22 are directly applicable. The coordinate origin is at the initial position for the football as it begins projectile motion in the sense of §4-5), and we let  $\theta_0$  be the angle of its initial velocity measured from the  $+x$  axis.

(a)  $x = 46$  m and  $y = -1.5$  m are the coordinates for the landing point; it lands at time  $t = 4.5$  s. Since  $x = v_{0x}t$ ,

$$v_{0x} = \frac{x}{t} = \frac{46 \text{ m}}{4.5 \text{ s}} = 10.2 \text{ m / s.}$$

Since  $y = v_{0y}t - \frac{1}{2}gt^2$ ,

$$v_{0y} = \frac{y + \frac{1}{2}gt^2}{t} = \frac{(-1.5 \text{ m}) + \frac{1}{2}(9.8 \text{ m/s}^2)(4.5 \text{ s})^2}{4.5 \text{ s}} = 21.7 \text{ m/s.}$$

The magnitude of the initial velocity is

$$v_0 = \sqrt{v_{0x}^2 + v_{0y}^2} = \sqrt{(10.2 \text{ m/s})^2 + (21.7 \text{ m/s})^2} = 24 \text{ m/s.}$$

(b) The initial angle satisfies  $\tan \theta_0 = v_{0y}/v_{0x}$ . Thus,  $\theta_0 = \tan^{-1}(21.7/10.2) = 65^\circ$ .