31. 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) \( x = 46 \text{ m} \) and \( y = -1.5 \text{ m} \) are the coordinates for the landing point; it lands at time \( t = 4.5 \text{ s} \). 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 \( \tan \theta_0 = \frac{v_{0y}}{v_{0x}} \). Thus, \( \theta_0 = \tan^{-1}(21.7/10.2) = 64.8^\circ \).