Homework Problem #48

Laith

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Problem

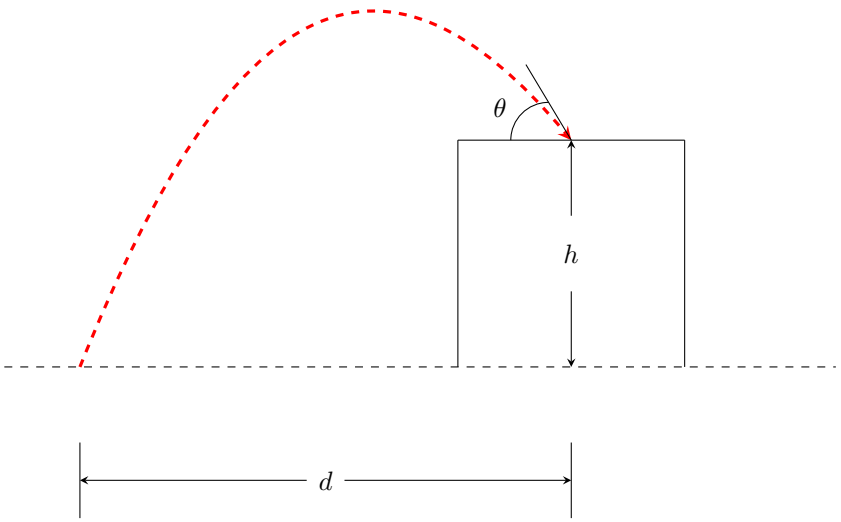
In Fig. 4-41, a ball is thrown up onto a roof, landing 4.00 s later at height $h = 20.0$ m above the release level. The ball's path just before landing is angled at $\theta = 60.0°$ with the roof.

(a) Find the horizontal distance d it travels. (See the hint to Problem 39.)

(b) What is the magnitude relative to the horizontal of the ball's initial velocity?

(c) What is the angle relative to the horizontal of the ball's initial velocity?

Figure 1: Figure 4-11



Solution

Part (a)

First we need to find the distance d. Since this distance is horizontal, we can define it as the function $\mathrm{y}(t)$. We can determine $\mathrm{y}(t)$ to be equal to $v_0 \cos(\theta)t$. We already know that our time will be $t = 0$ as that is when the ball is thrown. However, we do not know what our initial velocity v_0 is. We also can't solve for v_0 since $\mathrm{y}(t)$ and the angle at which the ball was thrown are also unknown. We do know that our height at $t = 4$ is 20 m and the ball lands with an angle of $\theta = 60°$. So, by defining our height as the function $\mathrm{z}(t)$, which will be equal to $v_0 \sin(\theta)t - \frac{1}{2}gt^2$, in which $\mathrm{z}(4) = 0$, we can solve for v_0 as that will be our only unknown, and then we can substitute v_0 to get distance.

$$\mathrm{z}(t) = v_0 \sin(\theta)t - \frac{1}{2}gt^2 \tag{1}$$

$$\mathrm{z}(4) = v_0 \sin(60)(4) - \frac{1}{\cancel{2}}(\cancel{10}^{5})(4)^2 \tag{2}$$

$$h = v_0 \frac{\sqrt{3}}{\cancel{2}_{1}}(\cancel{4}^{2}) - 5(16) \tag{3}$$

$$20 = v_0 2\sqrt{3} - 80 \Rightarrow 100 = v_0 2\sqrt{3} \tag{4}$$

$$\Rightarrow v_0 = \frac{10\sqrt{3}}{3} = \frac{10}{3}\sqrt{3} \tag{5}$$

We find that our initial velocity is $\frac{10}{3}\sqrt{3}$ m/s and we can now substitute this back into our equation for distance:

$$\mathrm{y}(t) = v_0 \cos(\theta)t \tag{6}$$

$$\mathrm{y}(4) = (\frac{10}{3}\sqrt{3}) \cos(60)(4) \tag{7}$$

$$d = (\frac{10}{3}\sqrt{3})(\frac{1}{\cancel{2}})(\cancel{4}^{2}) \tag{8}$$

$$d = 2(\frac{10}{3}\sqrt{3}) = \frac{20}{3}\sqrt{3} \tag{9}$$

Our answer:

$$\boxed{d = \frac{20}{3}\sqrt{3}\,\mathrm{m}}$$