Answer on Question#54851 - Physics - Mechanics - Kinematics - Dynamics

You throw a ball from the balcony onto the court in the basketball arena. You release the ball at a height of $H_i = 6\text{m}$ above the court, with an initial velocity equal to $v = 9\frac{\text{m}}{\text{s}}$ at $\varphi = 33°$ above the horizontal. A friend of yours, standing on the court $L = 10\text{m}$ from the point directly beneath you, waits for a period of time after you release the ball and then begins to move directly away from you at an acceleration of $a = 3\frac{\text{m}}{\text{s}^2}$. (She can only do this for a short period of time!) If you throw the ball in a line with her, how long after you release the ball should she wait to start running directly away from you so that she'll catch the ball exactly $H_f = 1\text{m}$ above the floor of the court?

Solution:

To find the time the ball spent in the air it's useful to write the dependence of the ball's height h from time t ($t = 0\text{s}$ when the ball is released):

$$h(t) = H_i + v \cdot \sin\varphi \cdot t - \frac{gt^2}{2},$$

where $g = 9.8\frac{\text{m}}{\text{s}^2}$ – is the acceleration due to gravity. To find the time it spent in the air we should solve the previous equation for $h(t) = H_f$:

$$H_f = H_i + v \cdot \sin\varphi \cdot t - \frac{gt^2}{2}$$

$$1\text{m} = 6\text{m} + 9\frac{\text{m}}{\text{s}} \cdot \sin 33° \cdot t - \frac{9.8\frac{m}{s^2} \cdot t^2}{2}$$

$$5\text{m} + 4.9\frac{\text{m}}{\text{s}} \cdot t - 4.9\frac{m}{s^2} \cdot t^2 = 0$$

This equation has only one positive root

$$t = 1.6\text{s}$$

Since the horizontal speed of the ball is constant and equal to $v_h = v \cdot \cos\varphi = 9\frac{\text{m}}{\text{s}} \cdot \cos 33° = 7.5\frac{\text{m}}{\text{s}}$, the ball overcomes the distance

$$l_f = v_h \cdot t = 7.5\frac{\text{m}}{\text{s}} \cdot 1.6\text{s} = 12\text{m}$$

Therefore the friend should overcome the distance of $l_f - L = 12\text{m} - 10\text{m} = 2\text{m}$ to catch the ball. She will need some time τ to do this. This time is given by

$$\tau = \sqrt{\frac{2(l_f - L)}{a}} = \sqrt{\frac{2 \cdot 2\text{m}}{3\frac{\text{m}}{\text{s}^2}}} = 1.2\text{s}$$

Therefore after the ball was released she should wait for the following time

$$t - \tau = 1.6\text{s} - 1.2\text{s} = 0.4\text{s}$$

Answer: 0.4s.

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