A man is riding on a flatcar traveling at a constant speed of 9.10 m/s (Fig. 3.49). He wishes to throw a ball through a stationary hoop 4.90 m above the height of his hands in such a manner that the ball will move horizontally as it passes through the hoop. He throws the ball with a speed of 10.8 m/s with respect to himself.

a) What must the vertical component of the initial velocity of the ball be? b) How many seconds after he releases the ball will it pass through the hoop? c) At what horizontal distance in front of the hoop must he release the ball? d) When the ball leaves the man’s hands, what is the direction of its velocity relative to the frame of reference of the flatcar? Relative to the frame of reference of an observer standing on the ground?

\[
\begin{align*}
X & : \quad a_x = 0 \\
v_x & = v_{0x} \\
x & = v_{0x} t \\
y & = a_y = -g \\
v_y & = v_{0y} - gt \\
y & = v_{0y} t - \frac{gt^2}{2} \\
v_y & = v_{0y}^2 - 2gy \\
x_0 = y_0 = 0 \text{ at launch point}
\end{align*}
\]

\[
\begin{align*}
4.90 \text{ m} & \\
v_0 = 10.8 \text{ m/s} & \\
v = 9.10 \text{ m/s}
\end{align*}
\]

**Figure 3.49 Challenge Problem 3.86.**

**a) Want** \( v_y = 0 \) \( \text{when} \ y = 4.90 \text{ m} \)

\[
v_y^2 = v_{0y}^2 - 2gy \quad \Rightarrow \quad v_{0y} = \sqrt{2gy}
\]

\[
v_{0y} = \sqrt{2 \times 9.80 \times 4.90} = \sqrt{2 \times 9.80 \times 4.90} = 9.80 \text{ m/s}
\]

**b) The time from launch to passing through the hoop is time when** \( v_y = 0 \)

\[
v_y = v_{0y} - gt \quad \Rightarrow \quad t = \frac{v_{0y} - v_y}{-g} = \frac{9.80 - 0}{9.80}
\]

\[
t = 1.00 \text{ s}
\]

**c) The speed** \( v_0 = 10.8 \text{ m/s} \) is the magnitude of the velocity imparted to the ball by the thrower as measured in the thrower/flatcar frame. The thrower/flatcar frame is moving with an \( x \) velocity of \( v = 9.10 \text{ m/s} \) with respect to Earth.
We first obtain $V_{ox}$, the initial x velocity of the ball in the thrower/railcar frame.

$$V_0^2 = V_{ox}^2 + V_{oy}^2$$

$$\Rightarrow V_{ox} = \sqrt{V_0^2 - V_{oy}^2} = \sqrt{10.8^2 - 9.80^2}$$

$$V_{ox} = 4.54 \text{ m/s}$$

This, as well as $V = 9.10 \text{ m/s}$, are constant. So the constant x velocity (Earth frame) of the ball is

$$V_x = V_{ox} + V = 4.54 + 9.10$$

$$= 13.64 \text{ m/s}$$

In time $t = 1.00 \text{ s}$, the ball moves in x-direction, $d_x = V_x t = 13.64 \times 1.00 = 13.6 \text{ m}$

The ball is released this distance in front of the hoop.

d.) The angle $\theta_0$, viewed in the thrower/railcar frame is

$$\theta_0 = \tan^{-1}\left(\frac{V_{oy}}{V_{ox}}\right) = \tan^{-1}\left(\frac{9.80}{4.54}\right)$$

$$= 65.1^\circ$$

The same angle $\theta_0$, viewed in the Earth frame is

$$\theta_0 = \tan^{-1}\left(\frac{V_{oy}}{V_x}\right) = \tan^{-1}\left(\frac{9.80}{13.64}\right)$$

$$= 35.7^\circ$$