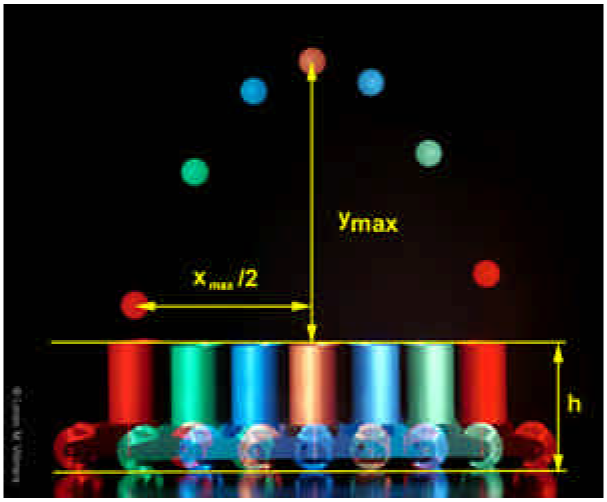
Ballistic Cart Analysis

It's necessary to make some decisions about what to measure. An annotated photo is used here in order to make the choices clear. However, a description in words or a labeled sketch are also acceptable.



The height of the cart from the bottom of the wheels to the top of the cannon was used to determine a scale factor. This distance on the photo was 3.4 cm, so the scale factor is 11/3.4 = 3.2 real to photo.

The height of the trajectory, y_{max}, was measured from the top of the cannon to the center of the topmost image of the ball. This assumes that the ball is launched as its center passes the top of the cannon. Different assumptions may be made as long as they're stated. After scaling, y_{max} = 0.24 m.

Half of the range was measured as the horizontal distance from the first image of the ball to the vertical line passing through the topmost image. After scaling, $x_{max}/2$ = 15 cm.

In the following analysis, +x is to the right and +y is up.

The vertical component of the launch velocity was found as follows.

$$v_y^{\,2} = v_{oy}^{\,2} + 2a_y y_o$$

Substituting $v_y = 0$ and solving for v_{oy},

$$\begin{aligned} v_{oy} &= \pm\sqrt{-2a_y y_o} \\ &= \pm\sqrt{-2(-9.8\,m/s^2)(0.24\,m)} \\ &= \pm 2.2\,m/s \end{aligned}$$

We select the positive root, since we know the velocity is positive.

We now solve for the time to reach the maximum height.

$$t_{max} = \frac{v_y - v_{oy}}{a_y}$$
$$= \frac{0 - 2.2 m/s}{-9.8 m/s^2}$$
$$= 0.22 s$$

There are 3 intervals of time in t_{max}, so the time between flashes is about 0.22/3 = 0.07 s. We chose to round, since 0.22 s is actually a fraction of a flash interval greater than 3 intervals.

The horizontal component of the launch velocity can now be found.

$$v_{ox} = \frac{x_{max}/2}{t_{max}}$$
$$= \frac{0.15 m}{0.22 s}$$
$$= 0.68 m/s$$

The magnitude of the launch velocity is then:

$$v_o = \sqrt{v_{ox}^2 + v_{oy}^2}$$
$$= \sqrt{(0.68 m/s)^2 + (2.2 m/s)^2}$$
$$= 2.3 m/s$$

As a check, we can find the angle of launch.

$$\theta = \arctan\left(\frac{2.3}{0.68}\right) = 73°$$.

This value is reasonable.