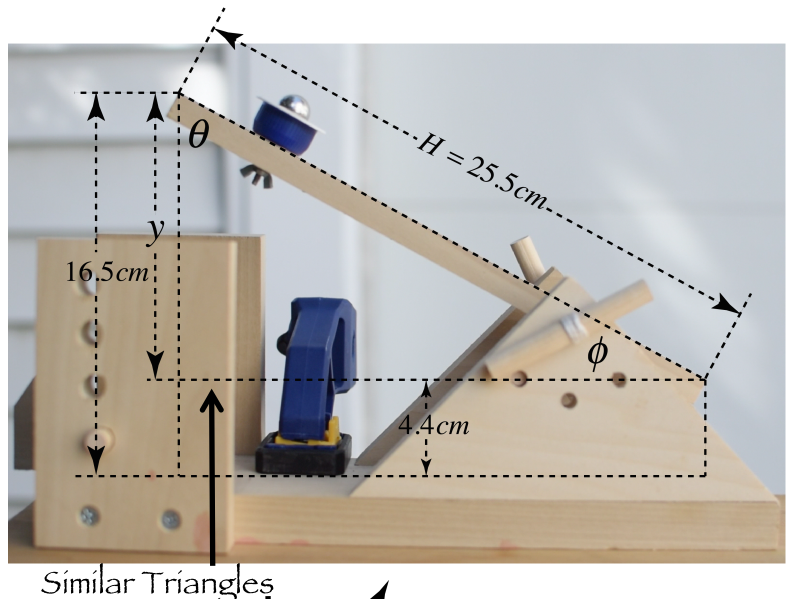
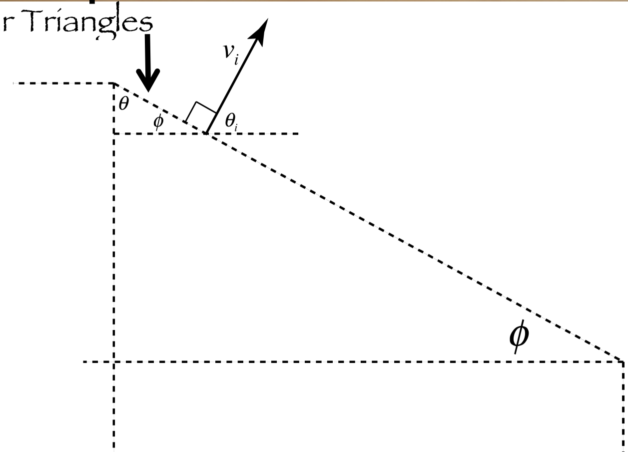
Flipping Physics Lecture Notes:
Nerd-A-Pult – Measuring the Initial Velocity

There are two things to measure, the initial speed and the initial angle. Let's start with the initial angle. I measured the hypotenuse of the triangle as 25.5 cm and took two measurement do determine the y side of the triangle: $y = 16.5 - 4.4 = 12.1cm$. Now we can find theta: $\sin\phi = \frac{O}{H} = \frac{y}{H}$

$$\Rightarrow \phi = \sin^{-1}\left(\frac{y}{H}\right) = \sin^{-1}\left(\frac{12.1}{25.5}\right) = 28.327°$$



Now we need to look at the initial velocity angle with the horizontal. Notice that the horizontal line for the initial velocity creates a smaller similar triangle with the original larger triangle.



This shows that, because the interior angles of a triangle add up to 180°, the initial launch angle with the horizontal is θ. And we can determine that angle:

$$180° = 90° + \phi + \theta \Rightarrow \theta = 180° - 90° - \phi = 90° - \phi$$
$$180° = 90° + \phi + \theta_i \Rightarrow \theta_i = 180° - 90° - \phi = 90° - \phi$$
$$\Rightarrow \theta_i = \theta = 90° - \phi = 90° - 28.327° = 61.673° \approx 61.7°$$

Now we need to determine the initial speed. For this I filmed several launches at 240 frames per second and measured the distance traveled by the ball in one frame. There were 5 that traveled 1.4 cm and 4 that traveled 1.3 cm for an average of: $distance_{avg} = \frac{(1.4 \times 5) + (1.3 \times 4)}{9} = 1.3\overline{5}cm$

Because there were 240 frames per second, that means that each frame lasts for 1/240th of a second.

$\left(240\frac{frames}{second}\right)^{-1} = \frac{1}{240}\frac{seconds}{frame}$ & then using the equation for average speed I determined the average initial speed:

$$speed_{avg} = \frac{distance_{avg}}{time_{avg}} = \frac{1.3\overline{5}cm}{\frac{1}{240}sec} = 325.\overline{3}\frac{cm}{s} \times \frac{1m}{100cm} = 3.25\overline{3}\frac{m}{s} \approx 3.25\frac{m}{s}$$

Therefore, with 3 significant figures: $\boxed{v_i = 3.25\frac{m}{s} @ 61.7° \text{ above the horizontal.}}$

It didn't occur to me until after I made the first video that I really only should have had 2 significant digits on the initial speed measurements because the original distance measurements only had 2 sig figs, oops.

Also, the change in time in the "air" in the Nerd-A-Pult video is about 1-2 frames shorter than it should be, I think there may be some error in the measurement of the initial launch angle because the wooden beam holding ball bent slightly on contact, which is something I was unable to measure.