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: \( y = 16.5 - 4.4 = 12.1 \text{cm} \). Now we can find theta: 

\[
\sin \phi = \frac{O}{H} = \frac{y}{H}
\]

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

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 \( \theta \). And we can determine that angle:

\[
180^\circ = 90^\circ + \phi + \theta \Rightarrow \theta = 180^\circ - 90^\circ - \phi = 90^\circ - \phi
\]

\[
180^\circ = 90^\circ + \phi + \theta \Rightarrow \theta = 180^\circ - 90^\circ - \phi = 90^\circ - \phi
\]

\[
\Rightarrow \theta = \theta = 90^\circ - \phi = 90^\circ - 28.327^\circ = 61.673^\circ \approx 61.7^\circ
\]

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: 

\[
\text{distance}_{\text{avg}} = \frac{(1.4 \times 5) + (1.3 \times 4)}{9} = 1.35 \text{cm}
\]

Because there were 240 frames per second, that means that each frame lasts for \( \frac{1}{240} \text{th} \) of a second.

\[
\left( \frac{240 \text{ frames}}{\text{second}} \right)^t = \frac{1}{240} \text{ seconds per frame}
\]

& then using the equation for average speed I determined the average initial speed:

\[
\text{speed}_{\text{avg}} = \frac{\text{distance}_{\text{avg}}}{\text{time}_{\text{avg}}} = \frac{1.35 \text{cm}}{\frac{1}{240} \text{sec}} = 325.3 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 3.253 \text{ m/s} \approx 3.25 \text{ m/s}
\]

Therefore, with 3 significant figures: \( v_i = 3.25 \text{ m/s} \) at 61.7° 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.

\[\text{Flipping Physics Lecture Notes: Nerd-A-Pult – Measuring the Initial Velocity}\]