Department of Biological, Chemical, and Physical Science
Illinois Institute of Technology
General Physics I: Mechanics (PHYS 123-02)

Projectile Motion

Lab 2

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Lab section L04
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UNPROCESSED DATA

Angle	0	15	45
Distance (m)	1.455	1.664	1.593
	1.442	1.679	1.596
	1.460	1.682	1.617
Avg Distance (m)	1.452	1.675	1.602
Time (s)	2.426	2.126	3.876
	1.602	2.463	3.449
	2.131	2.286	3.706
Avg Time(s)	2.053	2.292	3.677

Table 1: Low power firing

Angle	0	15	45
Distance (m)	1.907	2.297	1.392
	1.911	2.316	1.402
	1.918	2.321	1.402
Avg Distance (cm)	1.912	2.311	1.399
Time (s)	2.673	3.057	3.705
	2.218	3.559	2.311
	1.584	2.706	1.543
Avg Time (s)	2.158	3.107	2.520

Table 2: High power firing

Question 1

PART A

The two initial velocities can be found by taking one of the kinematic equations

$$\Delta x = v_0 t + \frac{1}{2} a t^2 \tag{1}$$

The acceleration in the x-direction is zero, so this is the resulting equation

$$v_0 = \frac{\Delta x}{t} \tag{2}$$

to find the resulting x-component of the initial velocity. In order to find initial velocity in the y component, we know this fact:

$$\begin{aligned} \tan(\theta) &= \frac{v_y}{v_x} \\ v_x \tan(\theta) &= v_y \\ v_y &= v_x \tan(\theta) \end{aligned} \tag{3}$$

Table 3 shows the resulting average initial velocities for Part A of Question 1.

Angle	0	15	45
Avg Initial Velocity ($\frac{\text{m}}{\text{s}}$)	0.7283	0.7593	0.6176
Avg x velocity ($\frac{\text{m}}{\text{s}}$)	0.7283	0.7334	0.4367
Avg y velocity ($\frac{\text{m}}{\text{s}}$)	0	0.1965	0.4367
Time (s)	2.053	2.292	3.677
Horizontal Distance (m)	1.452	1.675	1.602

Table 3: Initial velocities for the low power firing

Angle	0	15	45
Avg Initial Velocity ($\frac{\text{m}}{\text{s}}$)	0.9286	0.7799	0.8914
Avg x velocity ($\frac{\text{m}}{\text{s}}$)	0.9286	0.7533	0.6303
Avg y velocity ($\frac{\text{m}}{\text{s}}$)	0	0.2018	0.6303
Time (s)	2.158	3.107	2.520
Horizontal Distance (m)	1.912	2.311	1.399

Table 4: Initial velocities for the high power firing

PART B

The angle that gave us the longest range was 15°. To find y_{max}, we use the following kinematic equation:

$$\begin{aligned} v_f^2 &= v_0^2 + 2a\Delta y \\ \Delta y &= -\frac{v_0^2}{2a} \end{aligned} \tag{4}$$

Since the final velocity in the y direction is zero, we can cancel it out. Thus, the y_{max} for the low power firing is

$$\begin{aligned} \Delta y &= \frac{(0.1965\frac{\text{m}}{\text{s}})^2}{2(9.8\frac{\text{m}}{\text{s}^2})} \\ \Delta y &= 0.0020 \text{ m} \end{aligned} \tag{5}$$

and we do the same for the high power firing here.

$$\begin{aligned} \Delta y &= \frac{(0.2018\frac{\text{m}}{\text{s}})^2}{2(9.8\frac{\text{m}}{\text{s}^2})} \\ \Delta y &= 0.0021 \text{ m} \end{aligned} \tag{6}$$

The final y_{max} is then 0.0021 plus the initial height, 1.1 m. We also know that to find the angle with the highest y_{max}, we have to find out what y_{max} is with θ equaling 45°. We first find out what y_{max} is for the lower power firing, which ends up as

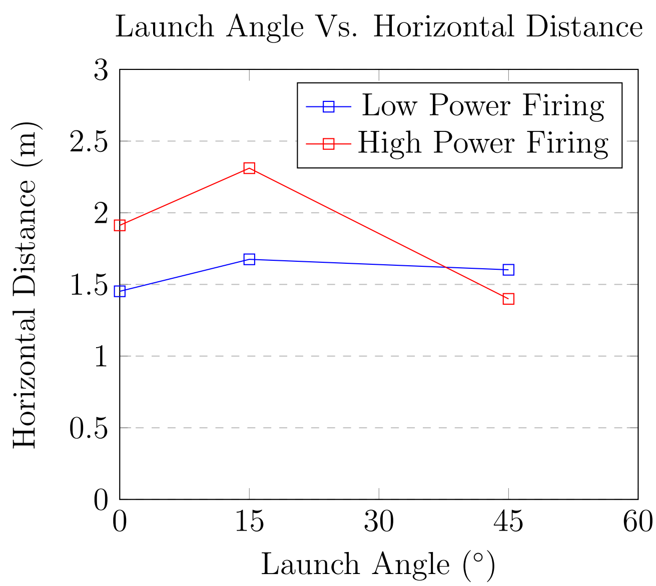
$$\begin{aligned} \Delta y &= \frac{(0.4367\frac{\text{m}}{\text{s}})^2}{2(9.8\frac{\text{m}}{\text{s}^2})} \\ \Delta y &= 0.009730 \text{ m} \end{aligned} \tag{7}$$

And for the high power firing:

$$\begin{aligned} \Delta y &= \frac{(0.6303\frac{\text{m}}{\text{s}})^2}{2(9.8\frac{\text{m}}{\text{s}^2})} \\ \Delta y &= 0.02027 \text{ m} \end{aligned} \tag{8}$$

As evidenced by the results for the two calculations, y_{max} is the highest when $\theta = 45°$.

PART C



PART D

To calculate the acceleration due to gravity, we can use the experiments where the angle θ was equal to 0°. For this, we can use the following kinematic equation:

$$\begin{aligned} \Delta y &= v_0 t - \frac{1}{2}at^2 \\ a &= \frac{-2\Delta y}{t^2} \end{aligned} \tag{9}$$

With this equation, we get -1.043 $\frac{\text{m}}{\text{s}^2}$ and -0.4724 $\frac{\text{m}}{\text{s}^2}$. No, this is not at all close to the accepted value of 9.8 $\frac{\text{m}}{\text{s}^2}$. Possible errors include the fact that we had to measure the height of the ball launcher after the fact and the timer didn't seem to work for the entirety of our experiments. In fact, these are definite errors.

PART E

To find the time it would take for the ball to reach the ground, we first have to find the y_{max} and calculate the times separately. The first kinematic equation involved is this one, where the final velocity is zero:

$$\begin{aligned} v_f &= v_0 + at \\ t &= \frac{-v_0}{a} \end{aligned} \tag{10}$$

The average initial velocity for the low power firing is about 0.7017 $\frac{\mathrm{m}}{\mathrm{s}^2}$ and 0.8665 $\frac{\mathrm{m}}{\mathrm{s}^2}$ for the initial high power firing velocity. So the times going up would be 0.07160 and 0.08842 seconds respectively. For the times going downwards, we first have the find the change in y distance. We then combine the equations to make it easier than solving one after the other.

$$\begin{aligned} v_f^2 &= v_0^2 + 2a\Delta y \\ \Delta y &= \frac{-v_0^2}{2a} \end{aligned} \tag{11}$$

The equation for the time going down:

$$\begin{aligned} \Delta x &= v_0 t + \frac{1}{2}at^2 \\ \frac{-v_0^2}{2a} + 1.1\mathrm{m} &= \frac{1}{2}at^2 \\ t &= \sqrt{\frac{2(\frac{v_0^2}{2a} + 1.1\mathrm{m})}{a}} \\ t &= \sqrt{\frac{\frac{v_0^2}{a} + 2.2\mathrm{m}}{a}} \end{aligned} \tag{12}$$

For the times going downwards, we calculate 0.4792 seconds and 0.4820 for the two firing speeds respectively. Together, the time it takes for the low power firing is 0.5508 and 0.5704 seconds for the high power firing.

Question 2

Ideally, the mathematical curve of the projectile motion trajectory is parabolic. For instance, two examples of this parabolic shape that I have seen are when I play badminton and I am serving the shuttlecock. Although the shuttlecock is aerodynamically different than a ball, it doesn't quite have a parabolic path.
Another example is when I see someone accidentally hit their phone while on a bridge, giving it an initial velocity. The phone's fall is similar to a parabolic line, falling to its death

when it reaches the ground. However, for both of these and especially for the badminton example, the objects are affected by air resistance, and the line of their motion will likely not be perfectly parabolic.

Question 3

Yes, there are two different angles that would give the same range. These are complimentary angles, or angles that add up to $90°$. This makes sense, because the x and y components of velocity are the same when θ is $45°$, and so must meet each other along all other angles. However, there are no two angles that give the same height, because as θ increases, so does the height.

Question 4

If the ball were launched horizontally from the launcher, it's time would be equal to taking the entire initial velocity and using kinematics equations. We actually did this in our experiment, and it took 2.053 seconds on average for the low power and 2.158 seconds on the high power. However, if we simply dropped the ball from the height of the launcher, we would get the same times due to the fact that the starting heights are the same, the accelerations are the same, and the x direction does not affect the y direction.