AP Physics 1
California Crosspoint High School
Mr. Darrell Yee
Projectile Motion Lab

During this lab you will be using an online Flash program to investigate projectile motion. Go to the following website to access the simulation:
https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html

Using this program, you can vary the initial height, angle and speed of the projectile, as well as several other factors. You will be investigating various aspects of projectile motion during this lab by changing the initial variables and measuring how far the projectile goes and how long it is in the air.

Projectile Shot Out Horizontally

Investigation 1.1: Horizontal Launch Speed vs Time

This first investigation involves a projectile which is launched horizontally at various speeds.

Once you have opened the Projectile Motion program, set the initial launch angle to 0^0 and the height of the platform to anything other than 0. Record your height in the space appropriate space below. Vary the launch speed between zero and 30 m/s, taking at least 5 data points. Include v = 0 m/s as one of your data points. Record the time of flight and the range (how far the projectile goes horizontally before landing).

Constant: Height of Cannon (non-zero)
Variable: Launch (Initial) Speed
Measuring: Time, Range

	Launch Speed (m/s)	Time of flight (s)	Horizontal Range (m)
Height of Cannon: 5 meters	5	1	5
	10	1	10
	15	1	15
	20	1	20
	25	1	25

- How does the horizontal velocity affect the time of flight?

  It does not affect time of flight at all. The time of flight will always remain the same.

- How does the horizontal velocity affect the range of the projectile? For example, if two balls are launched from the same height, one with twice the velocity of the other, how do their ranges compare?

  The horizontal velocity directly translates to the horizontal range. For the example provided, let's say Ball B was launched at twice the velocity as Ball A, that means that Ball B's final position (horizontal range) will be twice as big as Ball A's

Investigation 2 Height vs Time

Now set the launch angle to zero and the horizontal velocity to any fixed value. Vary the height of the canon with at least 5 different heights. Record time of flight and the range again.

Constant: Initial Launch Speed, Horizontal Launch Angle
Varying: Non-zero Height
Measuring: Time, Range

	Canon Height (m)	Time of flight (s)	Horizontal Range (m)
Initial Velocity: 15 m/s Launch Angle: 0	5	1.01	15.14
	8	1.28	19.16
	10	1.43	21.42
	13	1.63	24.42
	15	1.75	26.23

- How does the canon height affect the time of flight? What is the mathematical nature of this relationship? (Linear, quadratic, cubic?) What kinematic equation would best explain this relationship?

  As the canon height increases, the time of flight will also increase. The relationship is quadratic. The best kinematic equation that would describe this would be $x = x_0 + v_0 t + \frac{at^2}{2}$. Because this has t^2, then we know that the relationship is quadratic.

- How does the canon height affect the range of the projectile even though they all have the same initial velocity and launch angle? Explain.

  Canon height is the independent variable, time of flight is dependent on it. We also know that horizontal range is dependent on time of flight, the more time there is, the larger the horizontal range. Therefore, horizontal range will be dependent on canon height.

Projectiles Shot from Ground Level

Investigation 3: Angle vs Time

To start, set the initial height to 0. Vary the launch angle and launch speed and record the following data. Round all values to the nearest whole number.

Constant: Height
Varying: Launch Angle, Launch Speed
Measuring: Time, Max Height, Range

Initial height (m): 0	Case	Launch Angle (Degrees)	Launch Speed (m/s)	Horizontal Component of Velocity (m/s) *	Vertical Component of Velocity (m/s) *	Time of flight (s)	Peak Height (m)	Horizontal Range (m)
	1	30	30	26	10	3	11	80
	2	35	26	21	10	3	11	65
	3	70	16	5	10	3	12	17

* Use calculator to calculate.

- Hang Time
    - Rank the cases by hang time.
      They are all the same
    - Which component of velocity affects the hang time?
      The vertical component affects hang time.
    - Use the recorded data of that component of velocity to explain your hang time results.

      Using the recorded data, we know that vertical component affects hang time because the vertical component for all three cases are the same. Therefore, the hang time (time of flight) will also be the same.

- Peak

- Rank the cases by peak height.

  Case 3 has the largest peak height according to the recorded data, Case 1 and 2 have the same peak height.

- Which component of velocity affects peak height?

  The vertical component affects peak height.

- Use the recorded data of that component of velocity to explain your peak height results.

  All of the vertical components are the same, but the reason Case 3 has a higher peak by 1 is because of the rounding. If we were to calculate it without rounding, it would be around ~11.52, which is extremely close to Case 1's ~11.47.

- Range
  - Rank the cases by range.

    Case 1 > Case 2 > Case 3

  - Both components of velocity have an affect on range. Explain how each component affects the range.

    The horizontal component will never change, but it determines how far the projectile goes in a certain amount of time. The vertical component determines the air time, which determines the horizontal range. Therefore both components have an effect on horizontal range.

  - Use the recorded data of both components of velocity to explain your range results.

    Since the vertical components for all the cases about the same, the horizontal components will be affecting the horizontal range. Since Case 1 has the largest horizontal component, then the horizontal range will also be the largest. Case 2 has the second largest horizontal range because it's horizontal component is smaller than Case 1's but larger than Case 3's, and Case 3 has the smallest horizontal range because it has the smallest horizontal component.

Investigation 4: Mass

To start, set the launch speed and launch angle to be a constant value and the initial height to 0. Vary the mass and record the following data.

<table>
<tr><td rowspan="6">Initial Velocity: 15 m/s

Launch Angle: 45 Degrees</td><th>Mass (kg)</th><th>Time of flight (s)</th><th>Horizontal Range (m)</th></tr>
<tr><td>1</td><td>2.87</td><td>14.74</td></tr>
<tr><td>5</td><td>2.87</td><td>14.74</td></tr>
<tr><td>10</td><td>2.87</td><td>14.74</td></tr>
<tr><td>15</td><td>2.87</td><td>14.74</td></tr>
<tr><td>30</td><td>2.87</td><td>14.74</td></tr>
</table>

- How did the mass of the ball affect the time of flight? The horizontal range? Explain the physics behind why.

  Because there is no air resistance, there will not be a change in the vertical component. Because there is no change in the vertical component, initial velocity, and launch angle, then the horizontal component will also remain constant, causing the time of flight and horizontal range to also remain constant.

Projectiles Shot Out Vertically

Investigation 5: Hang Time

To start, set the launch angle to 90 and the initial height to 0. Vary the launch speeds and record the following data.

Launch Velocity (m/s)	Time of Peak (s)	Time of Flight (s)
5	0.51	1.02
10	1.02	2.04
15	1.53	3.06
20	2.04	4.08
25	2.55	5.1

- What is the relationship between the launch velocity and the time to reach the peak? How would one easily estimate the time to reach the peak from a given vertical launch velocity? For example, about how long would it take an object launched vertically with a speed of 128 m/s to reach the peak?

  As launch velocity increases, the time it takes to reach the peak also increases (in a quadratic manner). The time it takes to reach the peak is dependant on launch velocity. One can very easily estimate the time it takes to reach the peak by using this equation $t = \frac{v_0}{g}$. $t$is the time it takes to reach the peak, $v_0$being initial velocity, and g being gravity. By rounding $g \approx 10m/s^2$, we can determine the time it would take for a projectile launched at a speed of 128 m/s will take around 13 seconds. Just simply divide initial velocity by gravity and you'll have the time it takes to reach the peak.