Projectile Lab – Angled Launch

Link for online lab:
https://phet.colorado.edu/en/simulation/projectile-motion

OBJECTIVES:

- Draw motion diagrams for a projectile launched at an angle
- Investigate how range, maximum height and flight time of a projectile changes with the launch angle
- Determine gravitational field strength at a location by using a projectile and performing curve fitting on linearized data

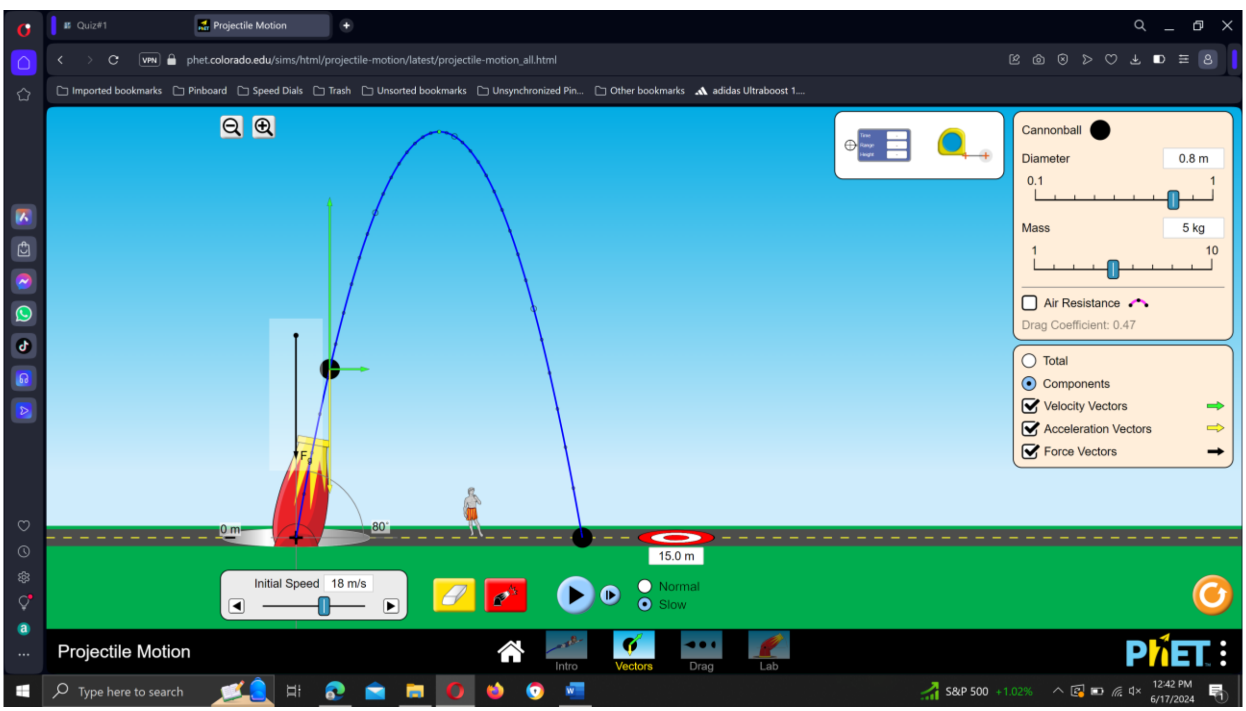
PROCEDURE:

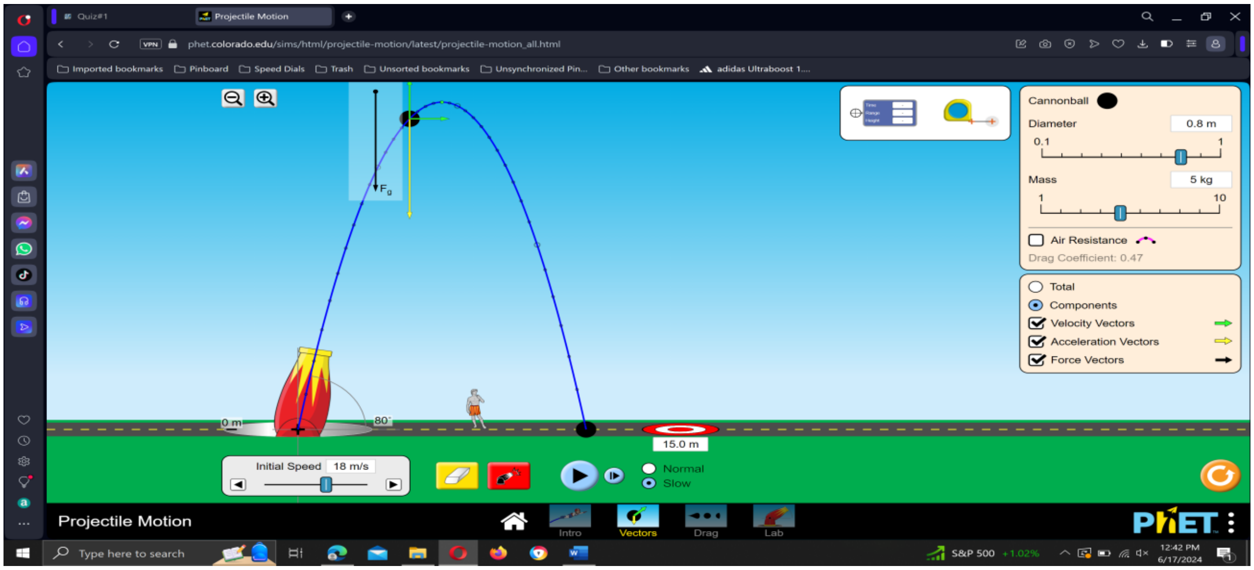
Click on the Vectors window. Deselect **Air Resistance**. Air resistance will remain zero for this experiment. Mass and diameter of the cannonball will also remain fixed at default values.

Part 1 – Motion Diagrams

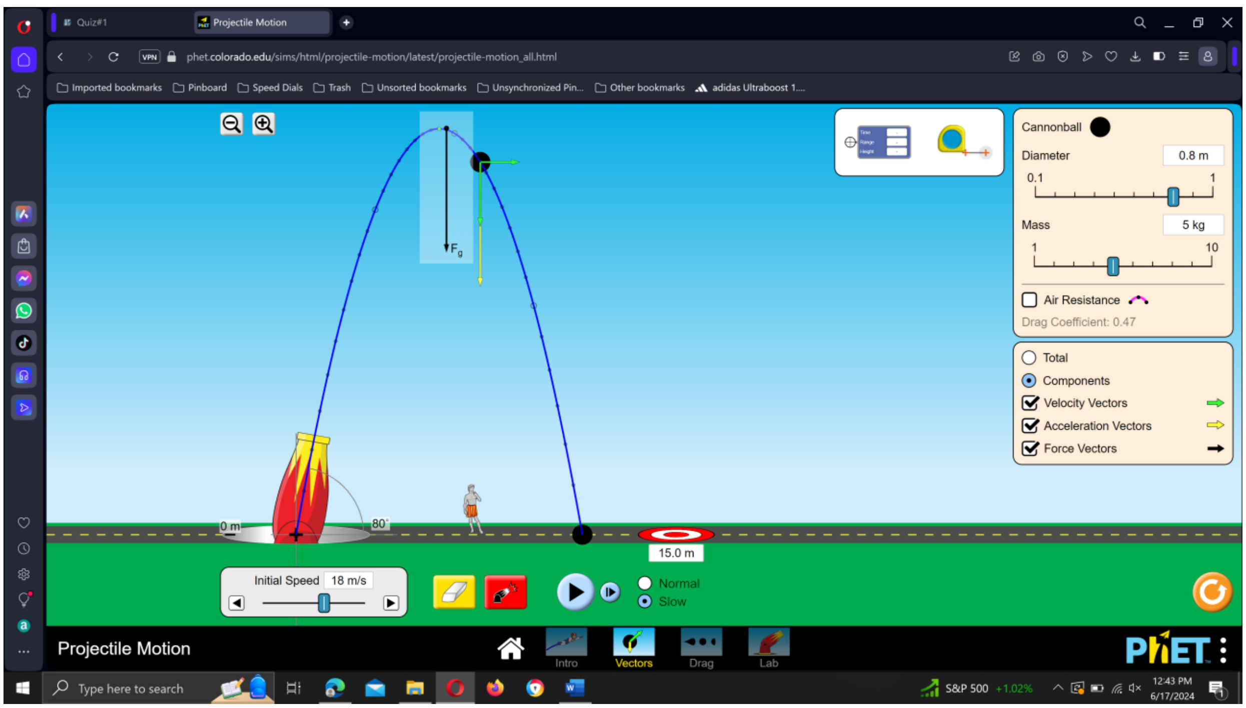
1. Select the **Velocity Vectors** in the vectors box and choose "Components" from the radio buttons. Keeping rest of the settings on default, fire the projectile and observe how the vectors change as the projectile falls to the ground.

   a) Draw a motion diagram showing velocity components at different locations.





Projectile Motion
phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_all.html
Cannonball
Diameter
0.8 m
Mass
5 kg
Air Resistance
Drag Coefficient: 0.47
Total
Components
Velocity Vectors
Acceleration Vectors
Force Vectors
15.0 m
80°
0 m
Initial Speed
18 m/s
Normal
Slow
Intro
Vectors
Drag
Lab
PhET



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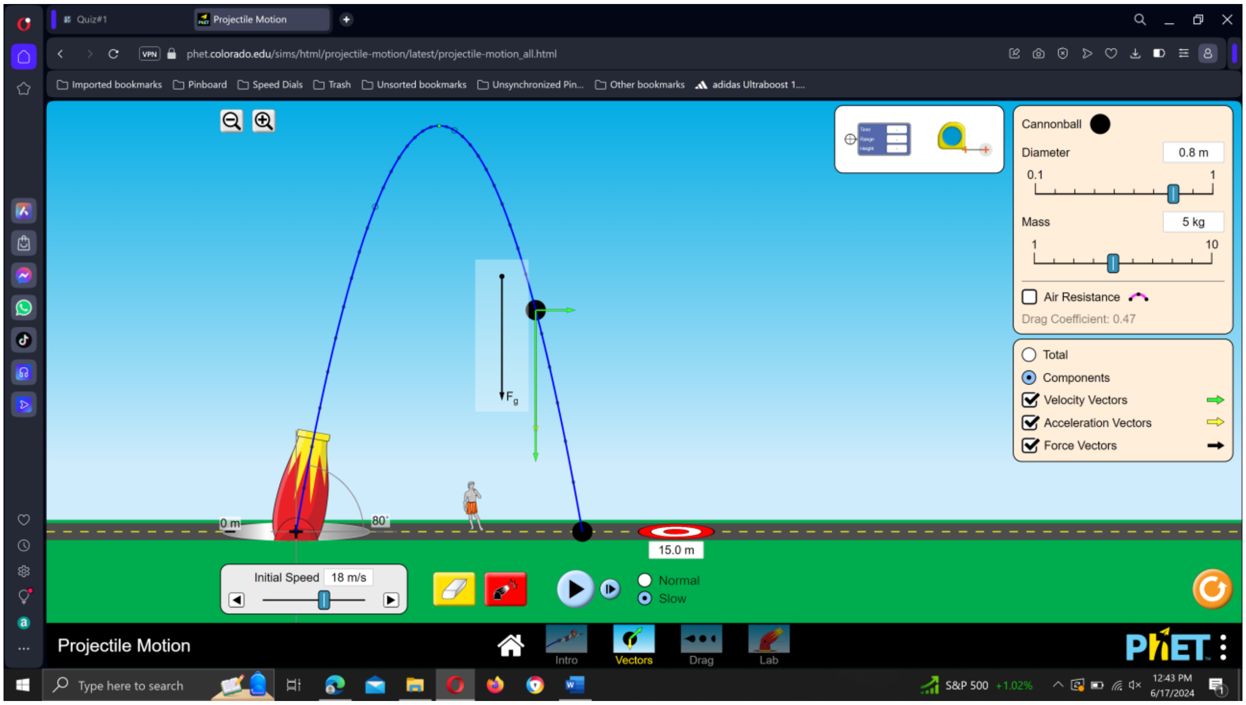
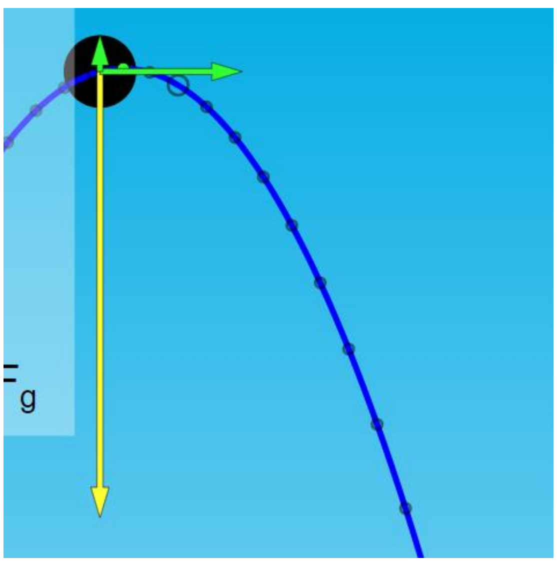


b) What happens to the velocity y-component at the peak of the projectile? Explain why?



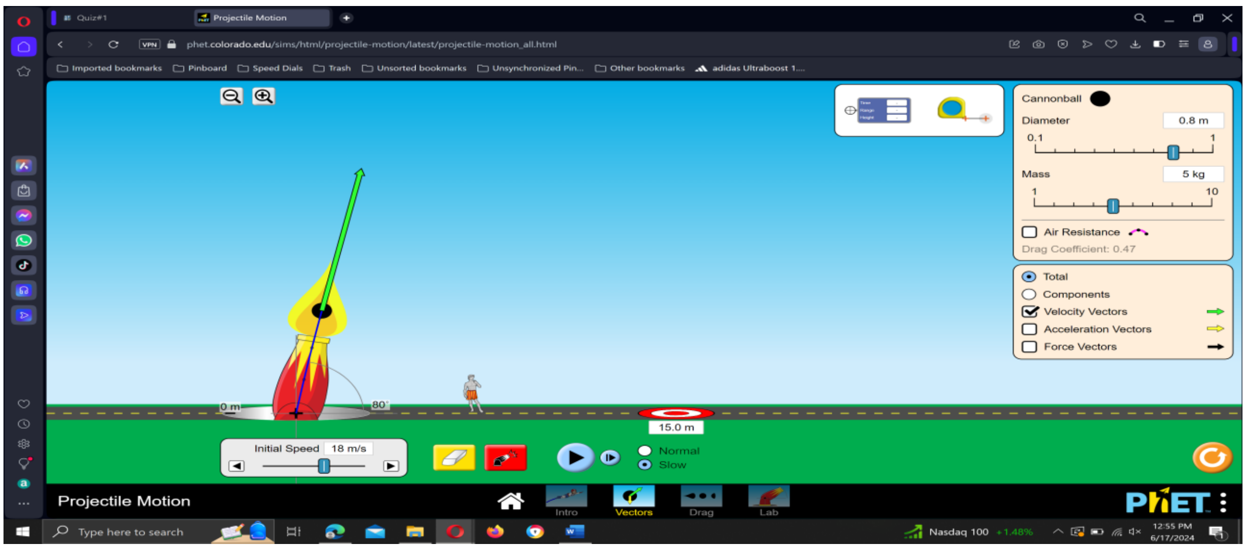
At the peak of this projectile's motion, the velocity y-component becomes zero. This happens because at the peak of the projectile's trajectory, the object momentarily stops moving upwards before it starts to fall back down due to gravity.

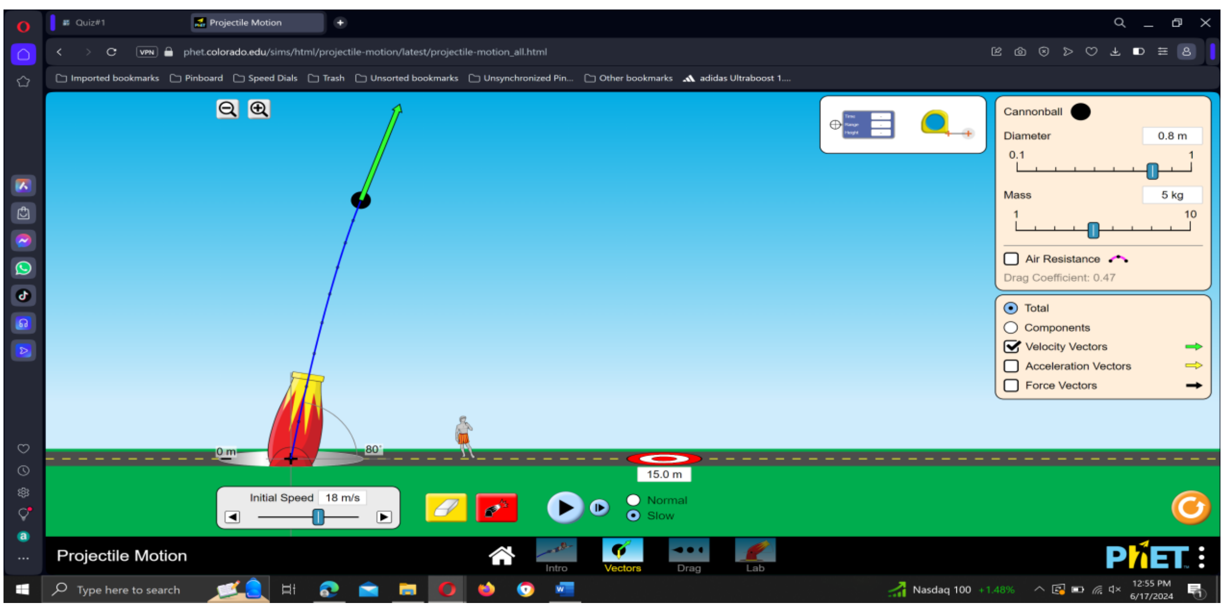
c) Compare initial velocity y-component (at the moment of launch from the cannon) to final velocity y-component (at the moment when the projectile hits the ground)? Discuss any similarity and/or difference.

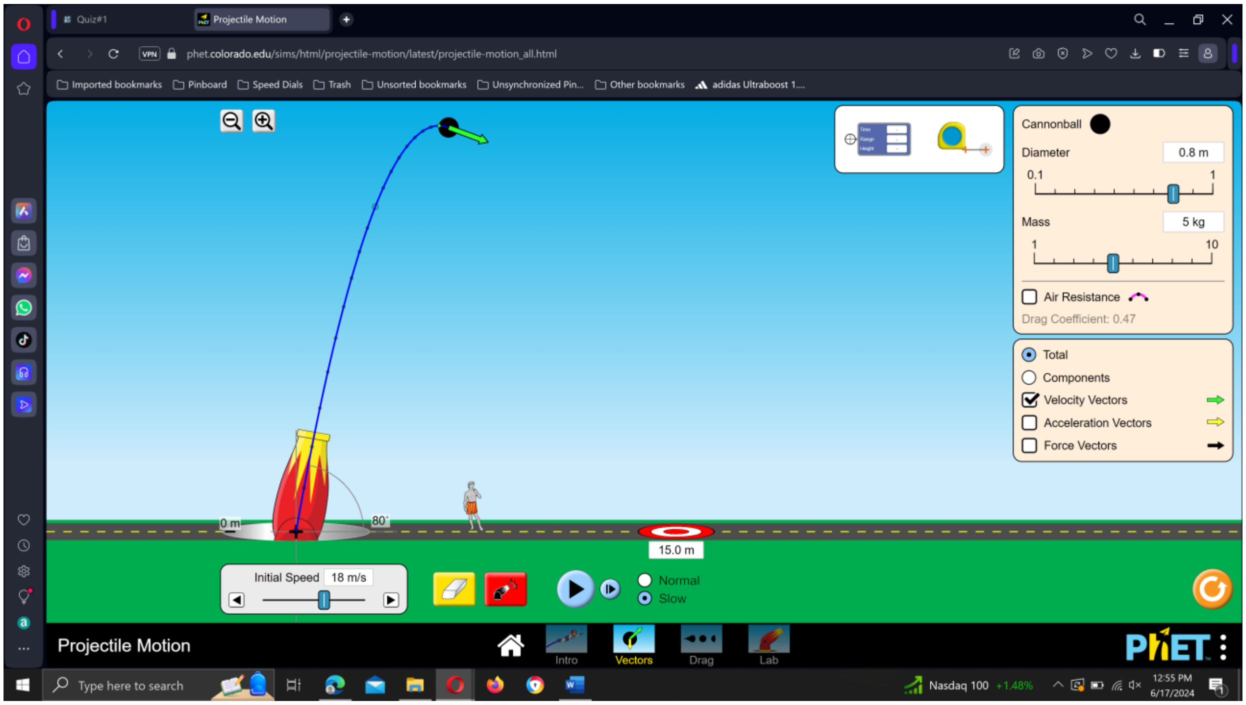
At the moment of launch from the cannon, the projectile's initial velocity y-component is positive, indicating us the upward motion. When the projectile hits the ground, the final velocity y-component, will be the negative of the initial velocity y-component due to gravity. Even though the change in direction, the magnitudes of the initial and final velocity y-components are equal in the absence of external forces like air resistance. This tells us about the conservation of energy and momentum in projectile motion, showing that the projectile's speed remains constant throughout its trajectory, only changing direction as it falls back to the ground.

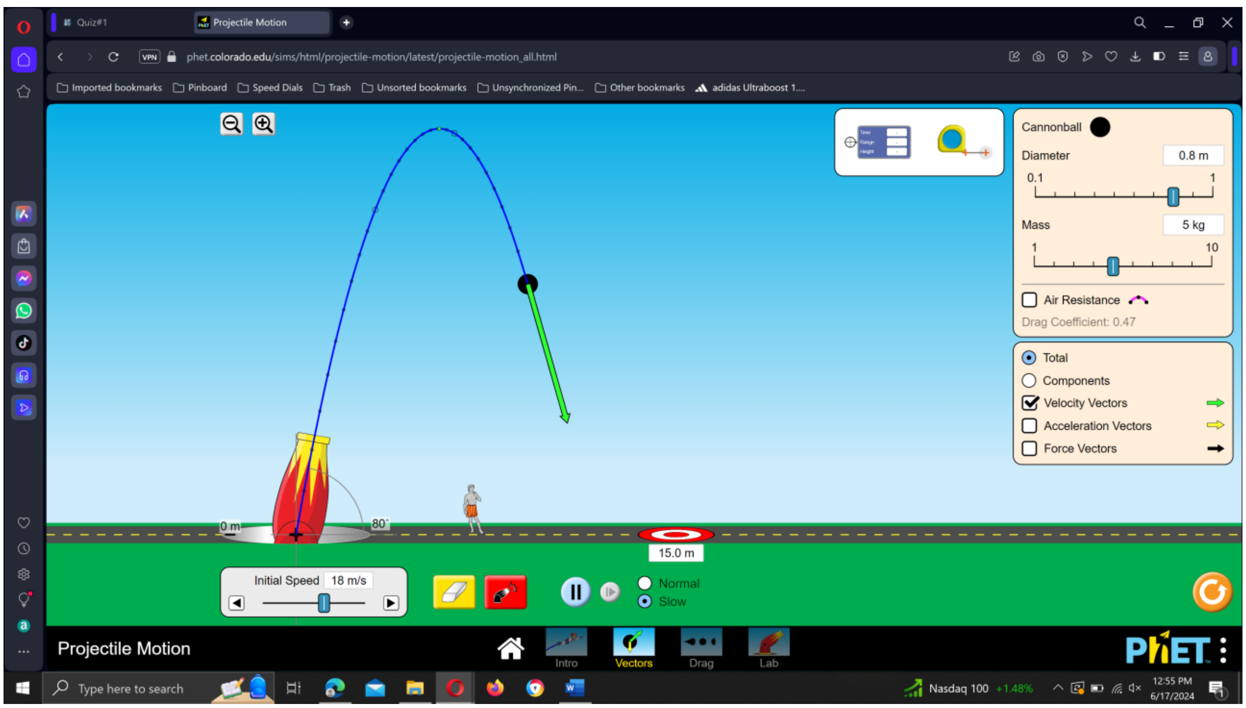
2. Now keeping the **Velocity Vectors** selected, choose “Total” from the radio buttons. Fire the projectile and observe how the velocity vector changes as the projectile falls to the ground.

   a) Draw a motion diagram showing the velocity vector at different locations.









b) How do the magnitude and direction of the velocity vector change as the projectile moves?

As the projectile moves, we can see its velocity vector decreases in magnitude during ascent, reaching zero at the peak, then increases in magnitude during descent. The direction changes from upward to downward at the peak and remains downward until impact. These changes reflect the influence of gravity on the projectile's motion, with the velocity vector adjusting continuously to the projectile's position and motion in the vertical direction.

c) What can you say about the velocity vector at the peak of the projectile?

At the peak of the projectile's motion, the velocity vector is entirely horizontal. This says that the velocity vector at the peak has no vertical component; it is purely horizontal. The magnitude of the velocity vector at the peak is also at its minimum value before the projectile starts descending.

d) How is the velocity vector related to the path of the projectile (i.e. how is this vector drawn in relation to the path)?

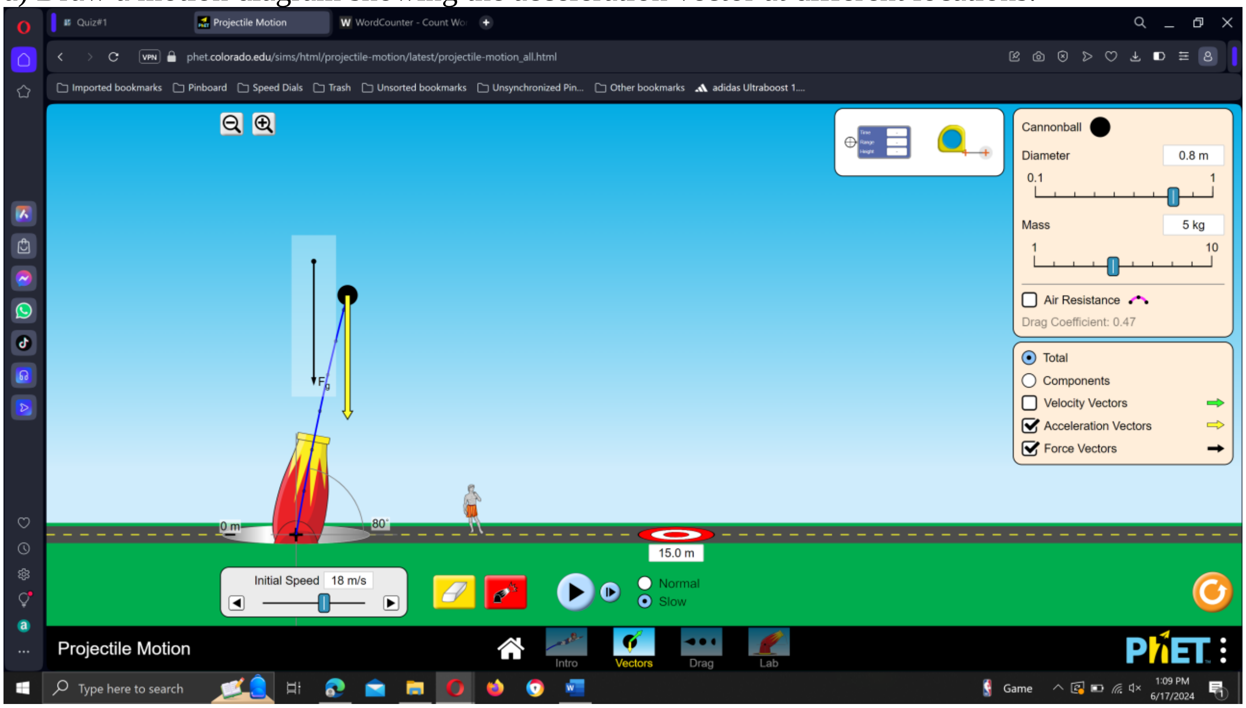
The velocity vector of the projectile is tangent to the path of the projectile at any given point. This means that at each point along the path, the velocity vector indicates the direction in which the projectile is moving at that instant. The angle between the velocity vector and the path of the projectile represents the direction and speed of the projectile's motion at that specific point in time

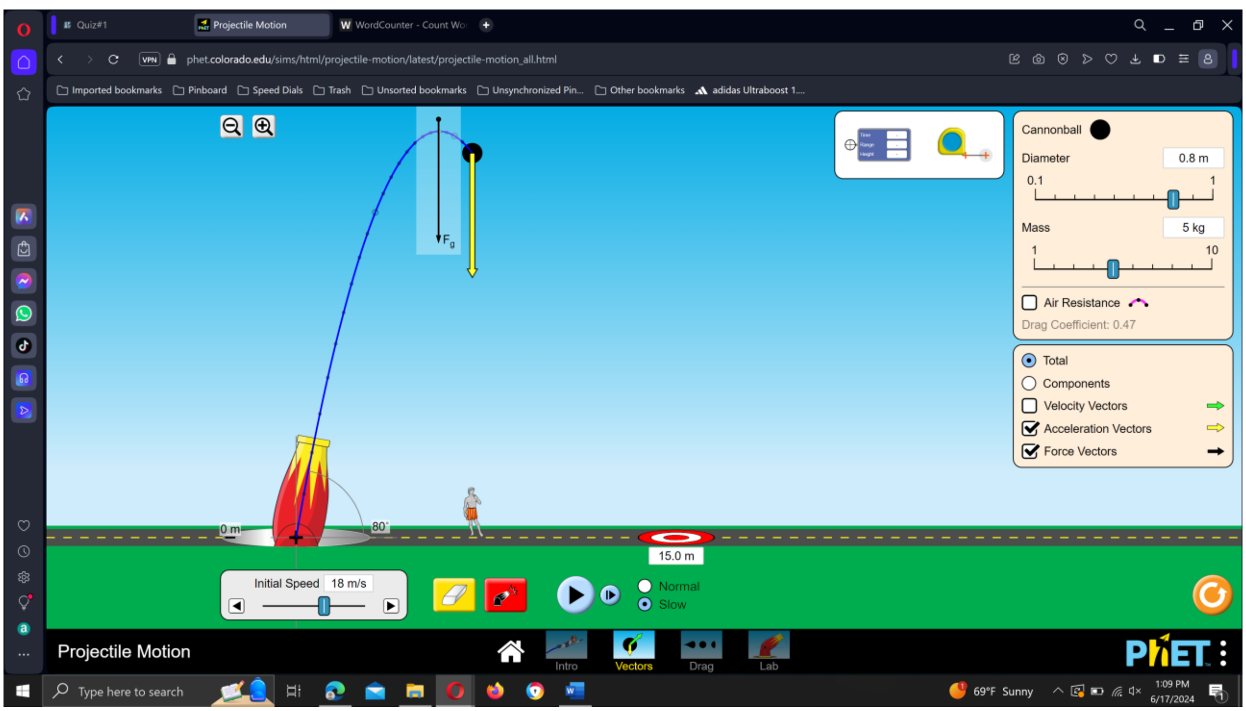
e) Compare initial velocity vector (at the moment of launch from the cannon) to final velocity vector (at the moment when the projectile hits the ground)? Discuss any similarity and/or difference.

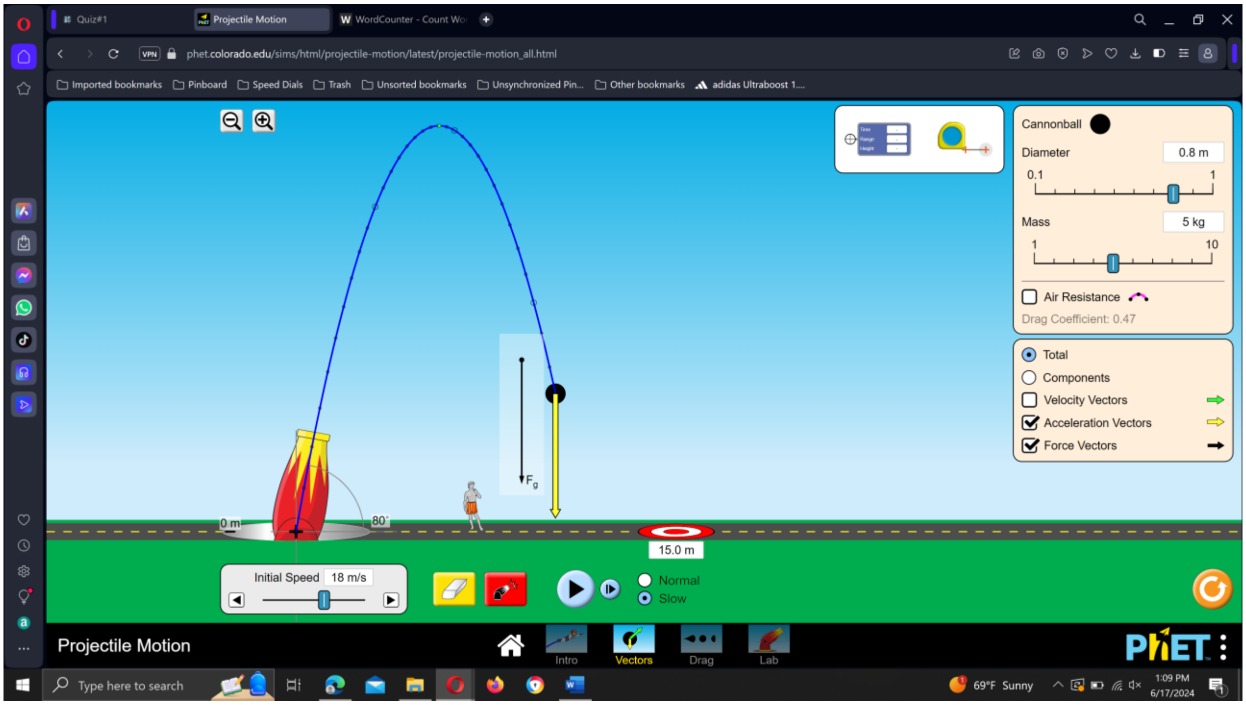
We can say that the initial velocity vector at launch is typically larger than the final velocity vector at impact. Both vectors have vertical and horizontal components determining the projectile's motion. Also, The initial vertical component points upward, while the final vertical component points downward. The horizontal components of both vectors remain constant unless external forces act. The final velocity vector has a lower speed due to factors like gravity and air resistance, leading to a decrease in magnitude as the projectile approaches the ground.

3. Now choose the **Acceleration Vectors** and **Force Vectors** in the vectors box and keep “Total” selected from the radio buttons. Fire the projectile and observe how the acceleration and force vectors change as the projectile falls to the ground.

   a) Draw a motion diagram showing the acceleration vector at different locations.







b) Are the acceleration and force vectors related? Does the simulation show this relation?

We can see in the picture and our observation that as the projectile falls to the ground, the acceleration vector remains constant in the vertical direction due to gravity acting downward. The force vector also remains constant and is equal to the force of gravity acting on the projectile. The acceleration and force vectors are related through Newton's second law, where force is directly proportional to acceleration ($F = ma$). The force vector causes the acceleration vector, leading to a constant downward acceleration of the projectile.

In this scenario, the acceleration and force vectors are directly related, with the force of gravity causing a constant acceleration downward until the projectile hits the ground.

Part 2 – Effects of launch angle on the motion of projectile

4. Reset the simulation and deselect **Air Resistance**. Air resistance will remain zero for this experiment. Set initial speed to 15 m/s. For constant values of initial speed (15 m/s), fire the projectile for 8 different angles (25, 35, 45, 55, 65, 75, 85, 90 degrees). Using the Time, Height and Range tool, collect data in the following data table. Time, Height and Range tool is accessible in the top right corner of the simulation and looks like this:

Measure the following quantities:

- **R** - Range (at the location where projectile hits the ground)
- **T_f** - Flight Time (at the location where projectile hits the ground)
- **H** - Maximum Height (at the peak of the projectile)
- **T_h** - Time at Max Height (at the peak of the projectile)

Launch Speed v_x (m/s)	Launch Angle θ (degrees)	Range R (m)	Flight Time T_f (s)	Max. Height H (m)	Time to Max. Height T_h (s)	sin θ	$\sin^2$ θ	sin 2θ
15	25	17.5	1.29	2.05	0.65	0.42	0.17	0.74
15	35	21.55	1.75	3.77	0.88	0.57	0.32	0.93
15	45	22.94	2.16	5.73	1.08	0.70	0.50	1
15	55	21.5	2.5	7.69	1.25	0.81	0.67	0.98
15	65	17.5	2.77	9.42	1.39	0.9	0.82	0.99
15	75	11.47	2.95	10.7	1.48	0.96	0.93	0.99
15	85	3.98	3.05	11.38	1.52	0.99	0.99	0.98
15	90	0	1.53	11.47	1.53	1	1	0

5. Using the data table, answer the following questions:

   a) For which angle is the maximum height **H** of the projectile greatest? Explain why?

   The maximum height H of the projectile is greatest for an angle of 90 degrees (vertical launch). This is because when the projectile is launched vertically upwards, all of the initial velocity contributes to the vertical component, resulting in the maximum height reached by the projectile.

b) For which angle is the flight time $\mathbf{T_f}$ of the projectile greatest? Explain why?

The flight time Tf of the projectile is greatest for an angle of 85 degrees. This is because at 85 degrees, the launch angle is very close to vertical, resulting in the projectile spending the most time in the air before hitting the ground.

c) For which angle is the range **R** of the projectile greatest? Explain why?

The range R of this projectile is greatest for an angle of 45 degrees. This is because at 45 degrees, the horizontal component of the initial velocity is at its maximum, leading to the furthest horizontal distance traveled by the projectile.

d) How is the flight time $\mathbf{T_f}$ of the projectile related to the time to maximum height $\mathbf{T_h}$? What does it tell us about the projectile motion?

The flight time Tf of the projectile is related to the time to maximum height Th in the following way:

Tf = 2 * Th

This relationship tells us that the time taken for the projectile to reach its maximum height is half the total time the projectile is in the air. This is because the projectile reaches its maximum height halfway through its flight path, spending equal time ascending and descending.

(**HINT** for parts a, b & c above: For constant value of magnitude of initial velocity i.e. 15 m/s, the components of initial velocity change with launch angle.)

6. Flight time a projectile launched at an angle is given by: $T_f = \frac{2v_i sin\theta}{g}$
   Explain how you can graphically obtain gravitational field strength g, by plotting T_f vs. sinθ.
   Use this graph to calculate g and compare it with known value of 9.81 m/s^2.
   (Paste the graph with linear fit here.)

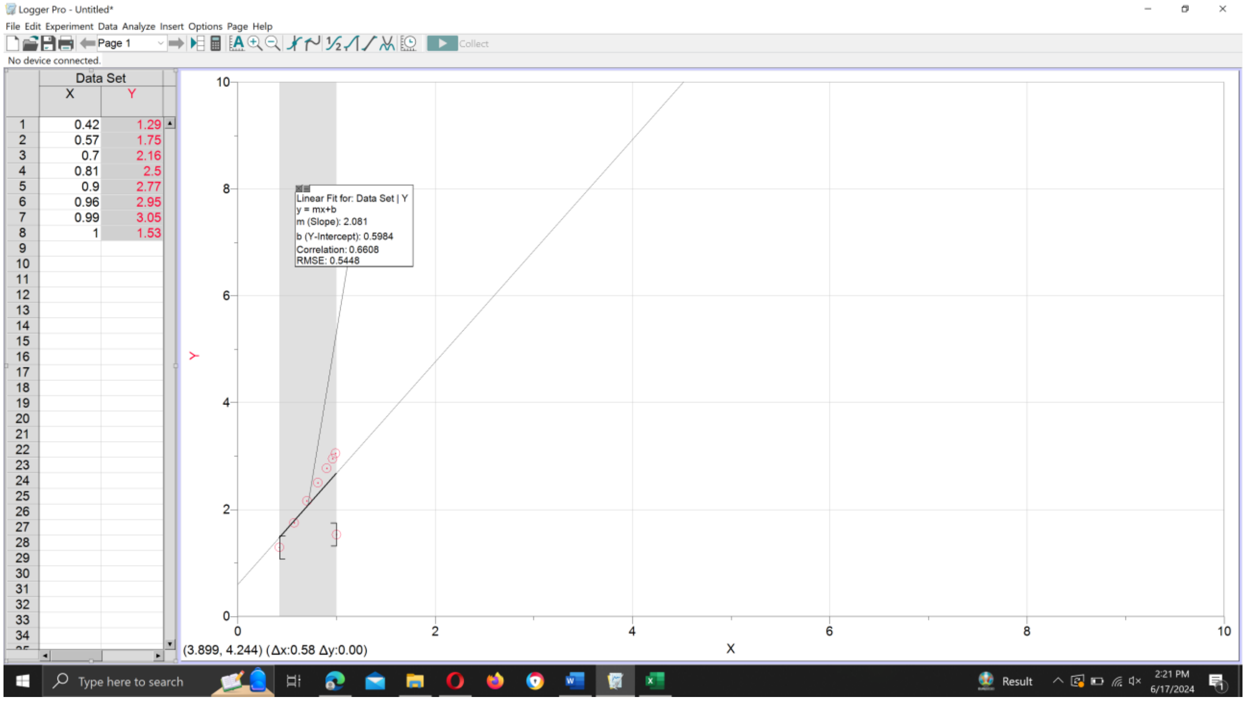
From the linear fit equation, y=2.08x + 0.59

= 2.08 Sin theta + 0.59

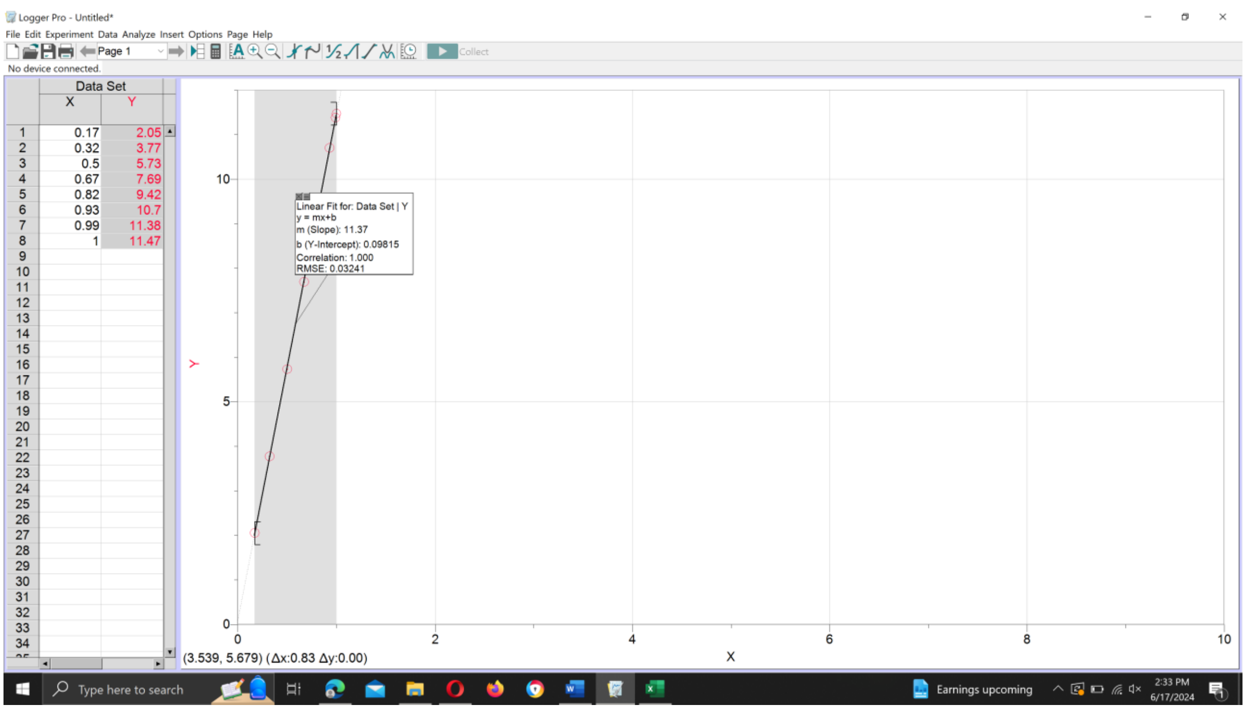
2.08 = 2vi/g

G= 30/2.08

= 14.42m/s^2 which is somehow little close to g=9.81



7. Maximum height of a projectile launched at an angle is given by: $H = \frac{{v_i}^2 sin^2\theta}{2g}$
Explain how you can graphically obtain gravitational field strength g, by plotting H vs. $\sin^2\theta$.
Use this graph to calculate g and compare it with known value of 9.81 m/s^2.
(Paste the graph with linear fit here.)



Our linear fit is :

Y= 11.37x + 0.09

H = 11.37 Sin^2 theta + 0.09

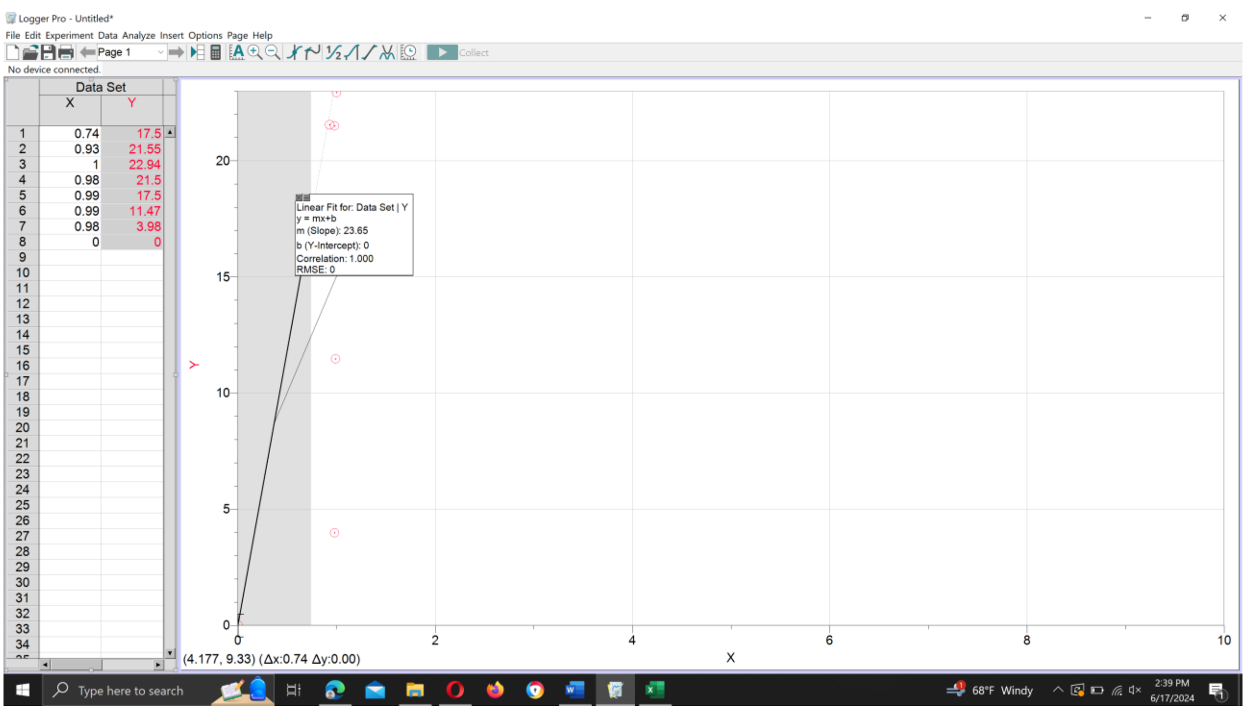
G= v^2_i/ 2m

= (15)^2 / 2 * 11.37

= 9.89m/s^2

Which is pretty close to 9.81m/s^2

8. Range of a projectile launched at an angle is given by: $R = \frac{v_i{}^2 sin2\theta}{g}$
   Explain how you can graphically obtain gravitational field strength g, by plotting R vs. sin 2θ.
   Use this graph to calculate g and compare it with known value of 9.81 m/s^2.
   (Paste the graph with linear fit here.)



Our linear fit is:

Y= 23.65x + 0

So,

R= 23.65 Sin2 theta

G= v^2_i/ m

= $(15)^2$ / 2 * 15

= 225/23.65

= 9.51m/s^2 which is also very close to 9.81m/s^2