SI Physics - Full Discipline Demo

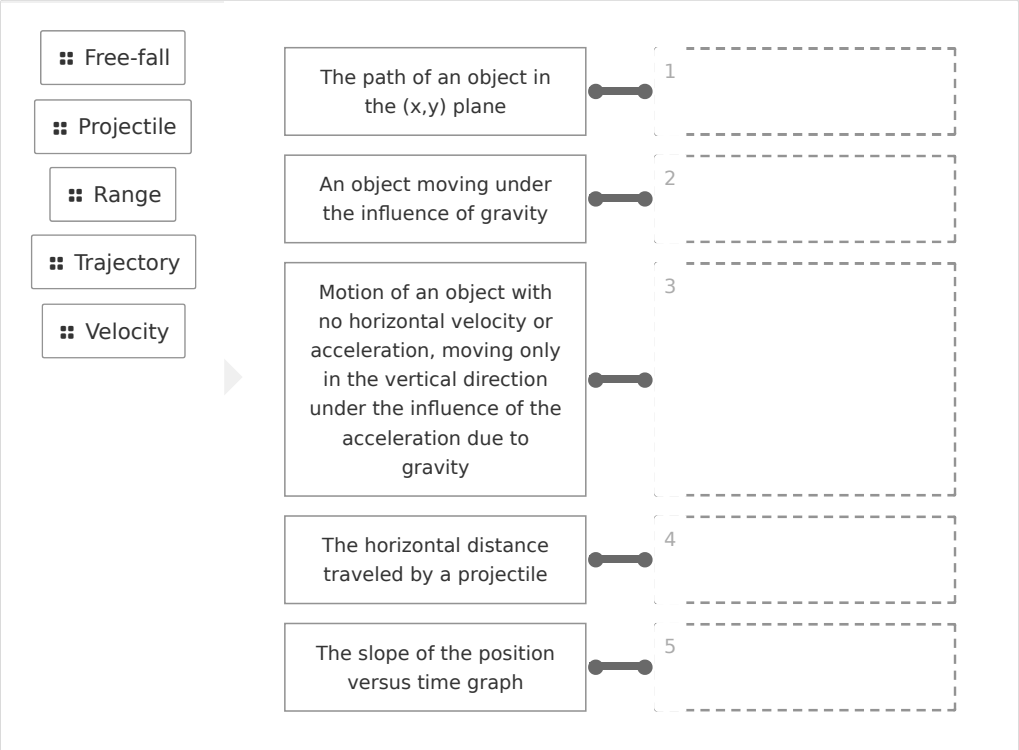
Projectile Motion

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.



Correct answers:

1 Trajectory 2 Projectile 3 Free-fall 4 Range 5 Velocity

Categorize each statement as True or False.

A change in the initial angle or the initial velocity of a projectile changes the range and maximum height of the projectile.

A larger acceleration would increase the range and maximum height of a projectile.

The acceleration in the horizontal direction is always zero for projectile motion.

The acceleration in the vertical direction is always the acceleration due to gravity for projectile motion.

The kinematic equations for vertical motion have only one possible solution for time of flight based on velocity.

True	False
1	2

Correct answers:

1

A change in the initial angle or the initial velocity of a projectile changes the range and maximum height of the projectile.

The acceleration in the horizontal direction is always zero for projectile motion.

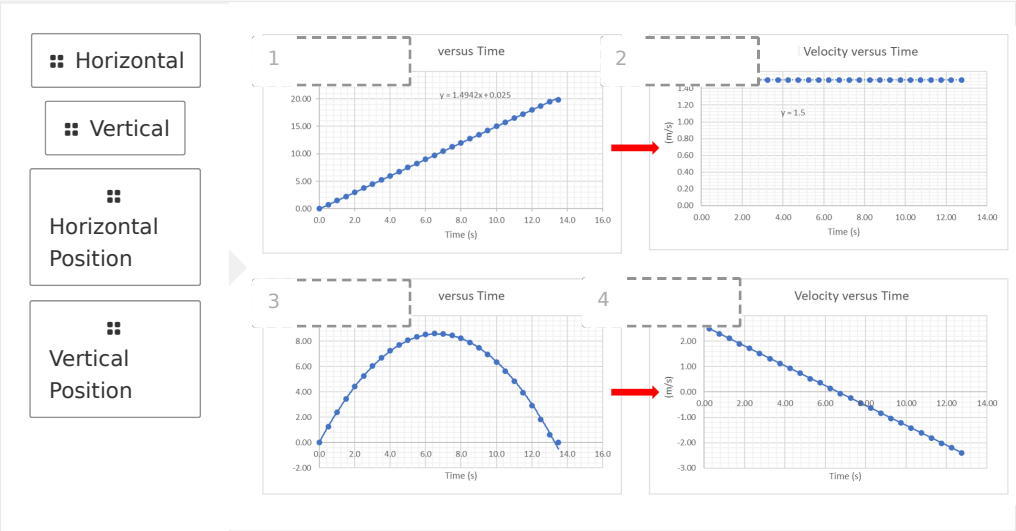
The acceleration in the vertical direction is always the acceleration due to gravity for projectile motion.

2

A larger acceleration would increase the range and maximum height of a projectile.

The kinematic equations for vertical motion have only one possible solution for time of flight based on velocity.

Label the graphs with the correct titles for projectile motion.



Correct answers:

1 Horizontal Position 2 Horizontal 3 Vertical Position 4 Vertical

Exploration

Free-fall motion is a type of projectile motion.

- [x] True
- [ ] False

The only factor connecting horizontal and vertical components of projectile motion is _____.

- [ ] velocity
- [x] time
- [ ] acceleration
- [ ] None of the above

The _____ initial velocity of a projectile can be used in the kinematic equations for horizontal motion.

- total
- vertical
- horizontal ✔
- None of the above

The acceleration in the horizontal direction is always _____ for projectile motion.

- the acceleration due to gravity
- positive
- zero ✔
- None of the above

The range equation can be used to find the horizontal distance a projectile travels only when the initial and final heights are different.

- True
- False ✔

When air resistance is ignored, _____ of the projectile affect(s) the range and maximum height of the projectile.

- the mass
- the shape
- both the mass and shape
- None of the above ✔

The slope of the _____ versus time graph at each point in time is the _____ at that time.

- [x] position; velocity
- [ ] velocity; position
- [ ] acceleration; position
- [ ] None of the above

During projectile motion, the horizontal acceleration is zero throughout the motion, so the horizontal velocity _____.

- [ ] decreases at a constant rate
- [x] is constant
- [ ] increases linearly
- [ ] None of the above

Exercise 1

How are free-fall and parabolic motion similar? How are they different?

The motion in the vertical direction is the same for free-fall and parabolic motion, meaning the vertical velocity at each time is governed by the acceleration due to gravity. The horizontal motion in both cases is constant, but in free-fall it is zero, while in parabolic motion, it has a positive magnitude.

In what circumstances is it appropriate to use the range equation?

It is appropriate to use the range equation when the starting and ending heights of the flight are equal.

How did the horizontal velocity vector component change during the flight of the cannonball in the simulation? How did the vertical velocity vector component change? What are the causes of these changes? Refer to Photo 1 and Data Table 1 to support your answer.

The horizontal velocity vector component stayed exactly the same throughout the flight. The vertical velocity vector started out positive, decreased to zero, and became negative, eventually reaching the same value it started with at the same height as the initial height. The horizontal motion has no acceleration, so the velocity is constant. The vertical motion is accelerated throughout the motion by the acceleration due to gravity, so the vertical velocity is increasingly negative throughout the flight.

How long was the free-falling cannonball in flight? How long was the horizontally-launched projectile in flight? How did the initial and final velocities of these two flights compare? Refer to Data Table 2 to explain what these times and velocities suggest about how the horizontal and vertical motions of a projectile are related.

The free-falling and horizontally-launched projectile were both in flight for 1.43 seconds. The final vertical velocities of both flights were the same, but the horizontally-launched projectile had a greater total final velocity because it had a horizontal component. These results suggest that the horizontal and vertical motion of a projectile are completely independent from one another.

Photo 1: Velocity Vectors and Components - Initial Conditions
(SAMPLE ANSWER BELOW)

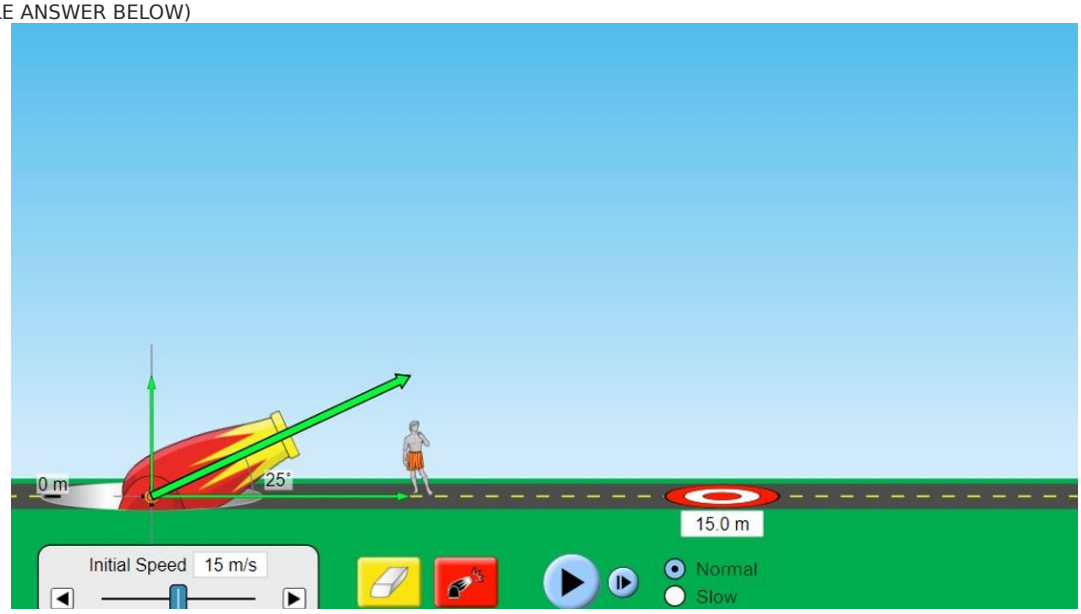


Photo 2: Velocity Vectors and Components - Maximum Height

(SAMPLE ANSWER BELOW)

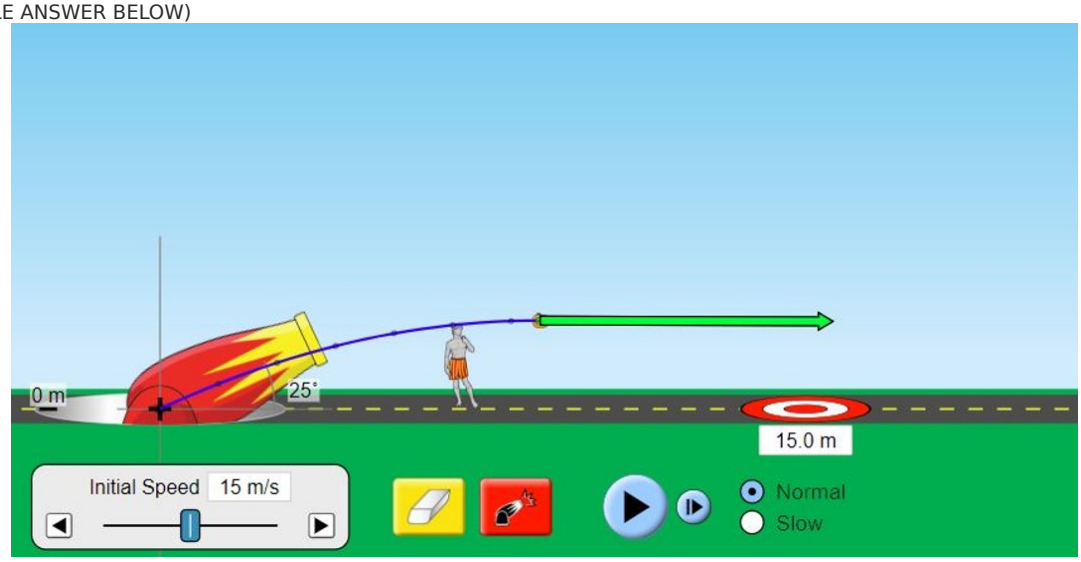
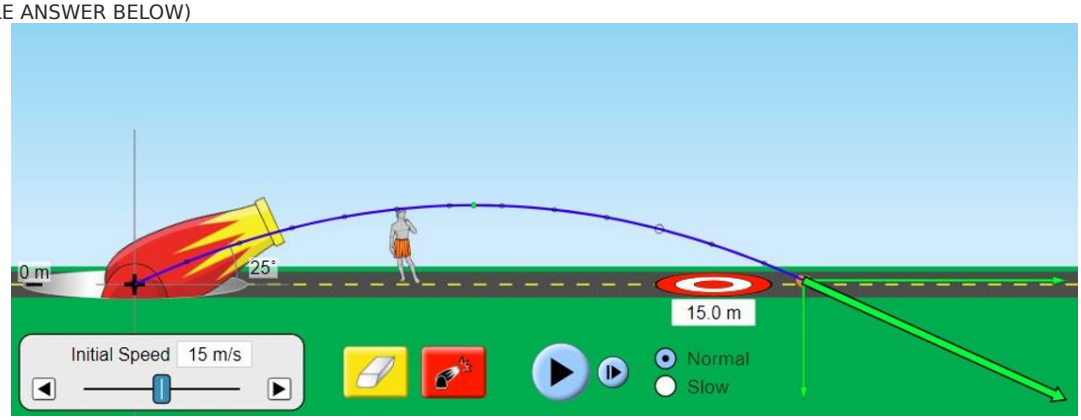


Photo 3: Velocity Vectors and Components - Landing

(SAMPLE ANSWER BELOW)



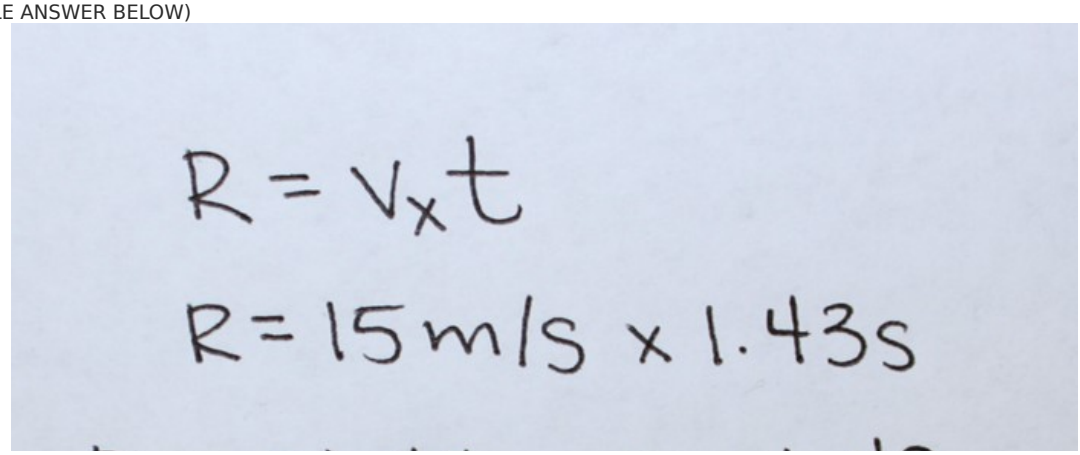
Data Table 1: Vector Components of Velocity
(SAMPLE ANSWER BELOW)

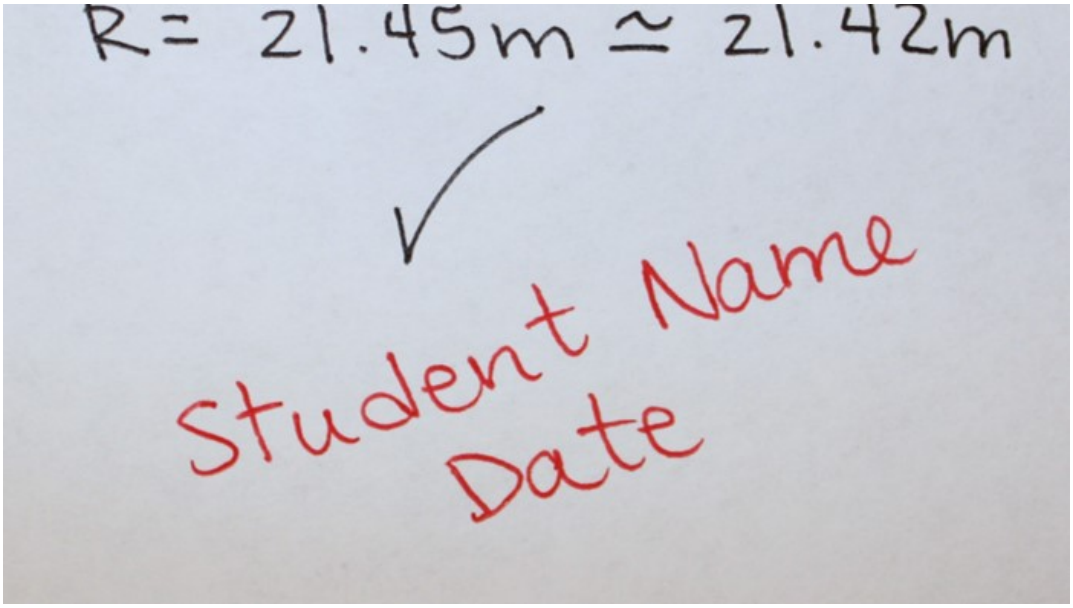
Cannon Height (m)	Angle (°)	Initial Speed (m/s)	$v_{x,i}$ (m/s)	$v_{y,i}$ (m/s)	$v_{x,f}$ (m/s)	$v_{y,f}$ (m/s)
0	25	15	13.59	6.34	13.59	-6.34

Data Table 2: Free Fall and Projectile Motion
(SAMPLE ANSWER BELOW)

Trial	Description	Angle (°)	Launch Height y (m)	Initial Speed (m/s)	Time (s)	Range x (m)	$v_{f,x}$ (m/s)	$v_{f,y}$ (m/s)	v_f (m/s)
1	Projectile	0	10	15	1.43	21.42	15	-14.03	20.54
2	Free Fall	-90	10	0	1.43	0	0	-14.03	14.03

Photo 4: Calculated Range
(SAMPLE ANSWER BELOW)





Exercise 2

What is the effect on range and maximum height of a projectile as the launch height, launch speed, and launch angle are increased? Refer to your data in Data Tables 3-5 to support your answer.

The range and maximum height increased as the launch height and launch speed increased. The range decreased as the launch angle increased, but the maximum height increased as the launch angle increased.

How does the shape of the trajectory of a projectile change as the launch angle is changed? Refer to Photo 2 to support your answer.

The trajectory becomes more pointed, less stretched out as the launch angle is increased. The projectile travels a shorter horizontal distance, but a larger vertical distance.

What additional (if any) force(s)/variable(s) should be accounted for when applying the calculations used in the simulation to the real world? Explain your answer.

Air resistance needs to be taken into account when applying the calculations to the real world. The force due to air resistance affects the acceleration of an object in the horizontal and vertical directions, impacting the trajectory of the projectile, including range and maximum height achieved.

Data Table 3: Varying Launch Height
(SAMPLE ANSWER BELOW)

Launch Height (m)	Time (s)	Range (m)
10	1.43	21.42
8	1.28	19.16
6	1.11	16.59
4	0.9	13.55
2	0.64	9.58

Data Table 4: Varying Launch Speed
(SAMPLE ANSWER BELOW)

Launch Speed (m/s)	Time (s)	Range (m)	Maximum Height (m)
5	0.43	1.95	0.23
10	0.86	7.81	0.91
15	1.29	17.57	2.05
20	1.72	31.24	3.64
25	2.15	48.81	5.69

Data Table 5: Varying Firing Angle
(SAMPLE ANSWER BELOW)

Angle (°)	Flight Time (s)	Flight Range (m)	Maximum Height (m)	$v_{x,i}$ (m/s)	$v_{y,i}$ (m/s)	Calculated Final Speed v_f (m/s)
0	0.64	9.58	2.00	15.00	0.00	16.23
15	1.15	16.62	2.77	14.49	3.88	16.24
30	1.76	22.87	4.87	12.99	7.50	16.25
45	2.34	24.79	7.73	10.61	10.61	16.27
60	2.79	20.96	10.60	7.50	12.99	16.22
75	3.09	11.98	12.70	3.88	14.49	16.29
90	3.19	0.00	13.47	0.00	15.00	16.29

Photo 5: Varying Launch Angles
(SAMPLE ANSWER BELOW)

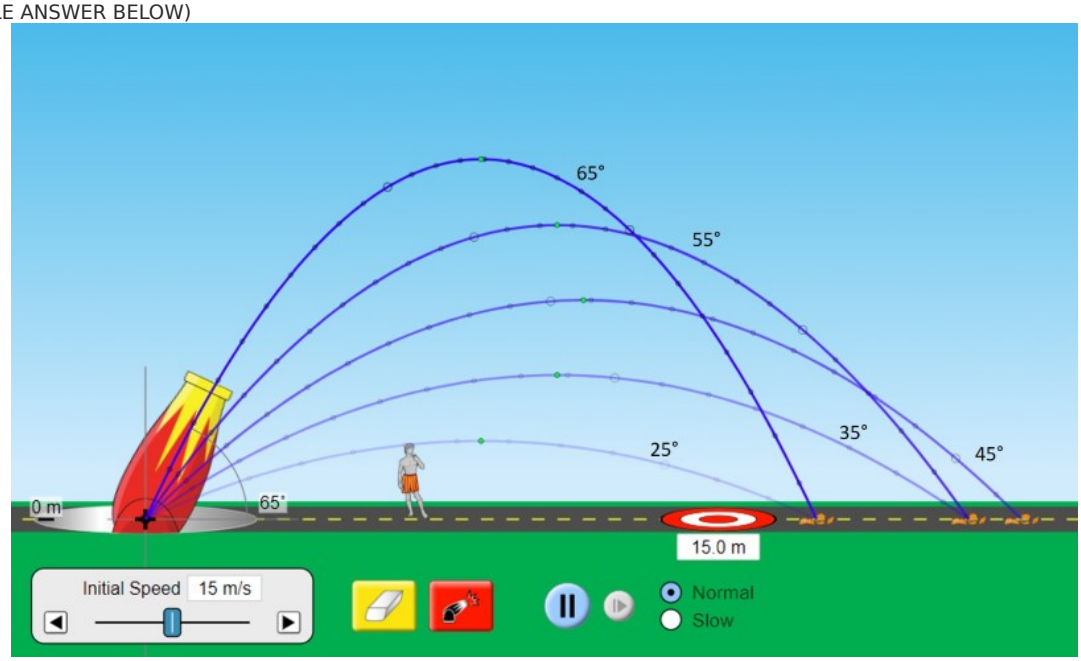
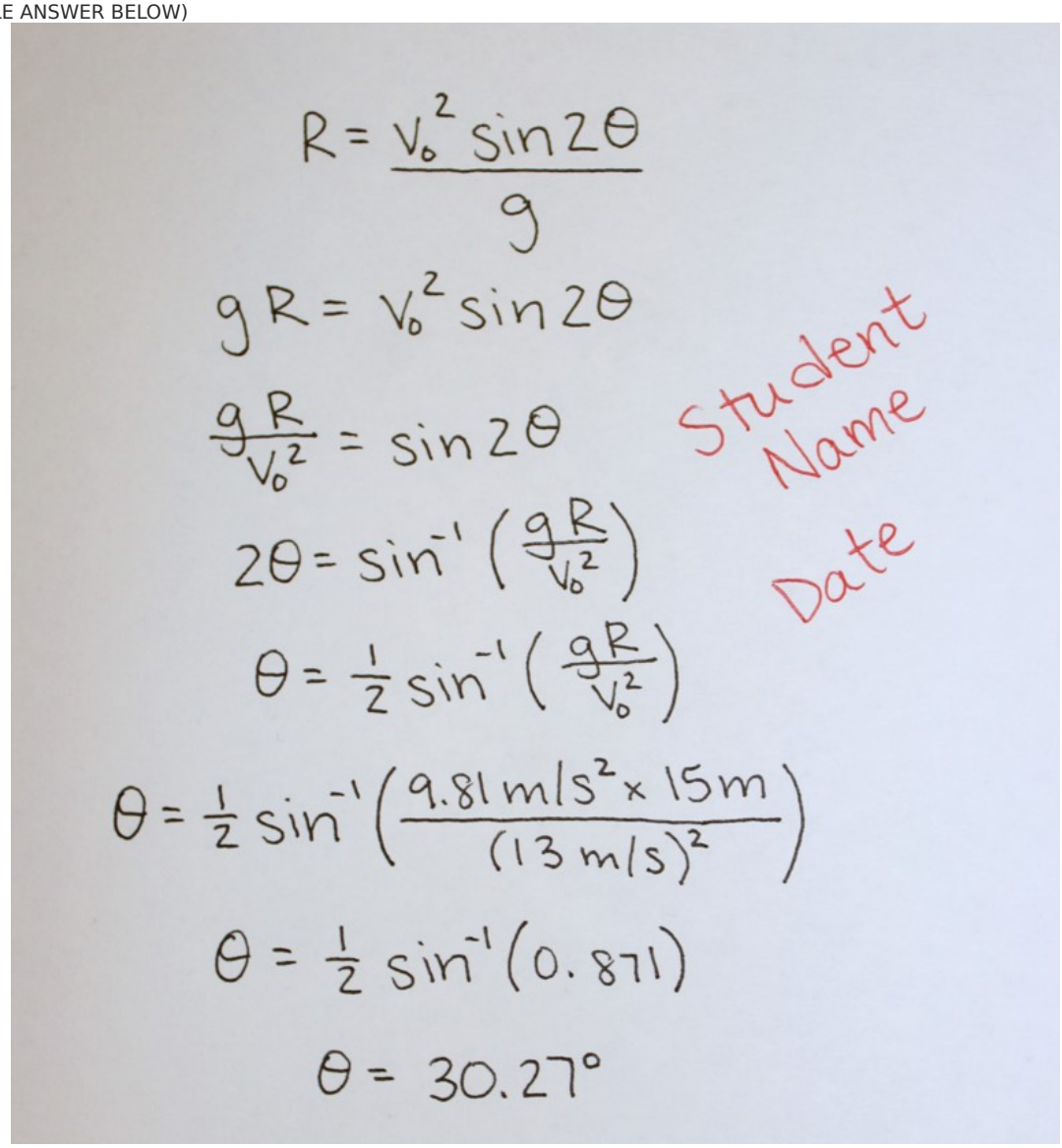


Photo 6: Calculation of Launch Angle
(SAMPLE ANSWER BELOW)



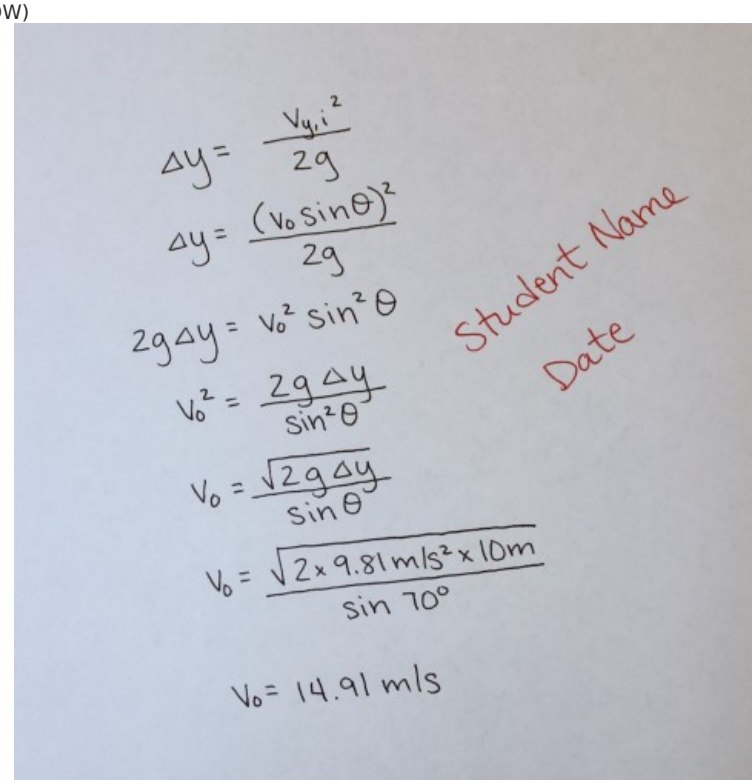
Data Table 6: Predictions

(SAMPLE ANSWER BELOW)

Predicted Angle (°)	Prediction Correct?	Predicted Speed (m/s)	Prediction Correct?
30	Yes	15	Yes

Photo 7: Calculation of Initial Speed

(SAMPLE ANSWER BELOW)



Exercise 3

Compare the slope of the x-t graph in Graph 1 to the velocity v_x found in the v_x-t graph in Graph 3. Compare the slope of the v_y-t graph in Graph 4 to the acceleration due to gravity. Compare the shape of the y-t graph in Graph 2 to the trajectory of the cannonball in the simulation. Do these results meet your expectations? Why or why not?

The slope of the x-position graph is equal to the constant velocity in the horizontal direction. The slope of the vertical velocity-time graph is equal to 9.8 m/s^2, which is the acceleration due to gravity. The shape of the y-position graph is the same as the shape of the trajectory of the cannonball. These results match my expectations because they are graphical representations of the kinematic equations for projectile motion.

At what time does the v_y-t graph in Graph 4 cross the horizontal axis? What is the y-position at this time, as indicated in Graph 2? Explain your results.

The vertical velocity – time graph crosses the horizontal axis at t = 1.3 seconds, which is the same time that the y-t graph peaks at the maximum vertical position. The maximum vertical position (the maximum height) is the turning point of the projectile, when the vertical velocity is momentarily zero.

Data Table 7: Position at Different Timepoints

(SAMPLE ANSWER BELOW)

Time (s)	x (m)	y (m)
0.0	0.00	0.00
0.1	0.75	1.25
0.2	1.50	2.40
0.3	2.25	3.46

0.4	3.00	4.41
0.5	3.75	5.27
0.6	4.50	6.03
0.7	5.25	6.69
0.8	6.00	7.25
0.9	6.75	7.72
1.0	7.50	8.09
1.1	8.25	8.35
1.2	9.00	8.53
1.3	9.75	8.60
1.4	10.50	8.57
1.5	11.25	8.45
1.6	12.00	8.23
1.7	12.75	7.91
1.8	13.50	7.49
1.9	14.25	6.97
2.0	15.00	6.36
2.1	15.75	5.65
2.2	16.50	4.84
2.3	17.25	3.93
2.4	18.00	2.92
2.5	18.75	1.82
2.6	19.50	0.62
2.7	19.86	0.00

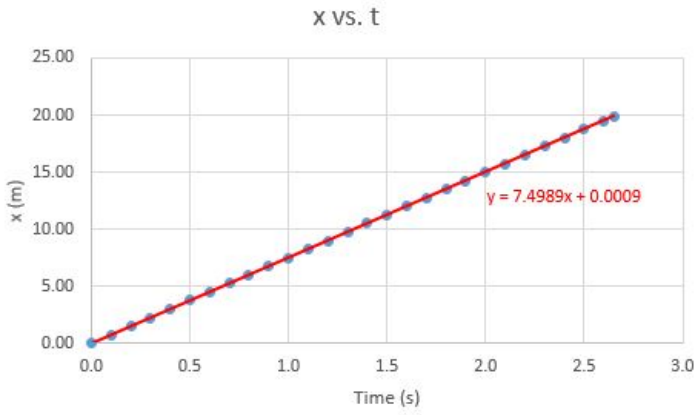
Data Table 8: Slope of Position at Different Timepoints

(SAMPLE ANSWER BELOW)

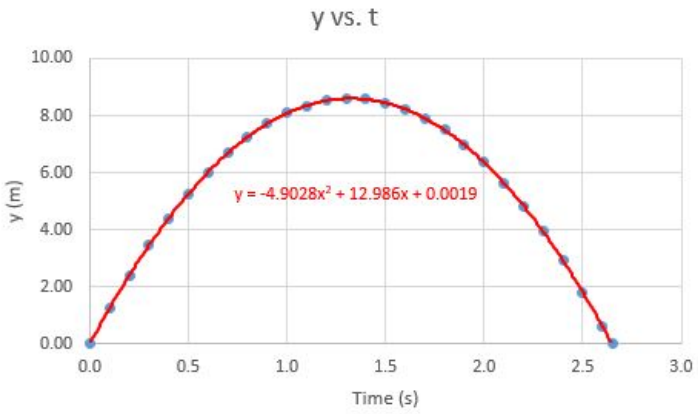
Time (s)	Δx (m)	Δy (m)	v_x (m/s)	v_y (m/s)
0.05	0.75	1.25	7.50	12.50
0.15	0.75	1.15	7.50	11.50
0.25	0.75	1.06	7.50	10.60
0.35	0.75	0.95	7.50	9.50
0.45	0.75	0.86	7.50	8.60
0.55	0.75	0.76	7.50	7.60
0.65	0.75	0.66	7.50	6.60
0.75	0.75	0.56	7.50	5.60
0.85	0.75	0.47	7.50	4.70
0.95	0.75	0.37	7.50	3.70

1.05	0.75	0.26	7.50	2.60
1.15	0.75	0.18	7.50	1.80
1.25	0.75	0.07	7.50	0.70
1.35	0.75	-0.03	7.50	-0.30
1.45	0.75	-0.12	7.50	-1.20
1.55	0.75	-0.22	7.50	-2.20
1.65	0.75	-0.32	7.50	-3.20
1.75	0.75	-0.42	7.50	-4.20
1.85	0.75	-0.52	7.50	-5.20
1.95	0.75	-0.61	7.50	-6.10
2.05	0.75	-0.71	7.50	-7.10
2.15	0.75	-0.81	7.50	-8.10
2.25	0.75	-0.91	7.50	-9.10
2.35	0.75	-1.01	7.50	-10.10
2.45	0.75	-1.10	7.50	-11.00
2.55	0.75	-1.20	7.50	-12.00

Graph 1: x-Position versus Time
(SAMPLE ANSWER BELOW)

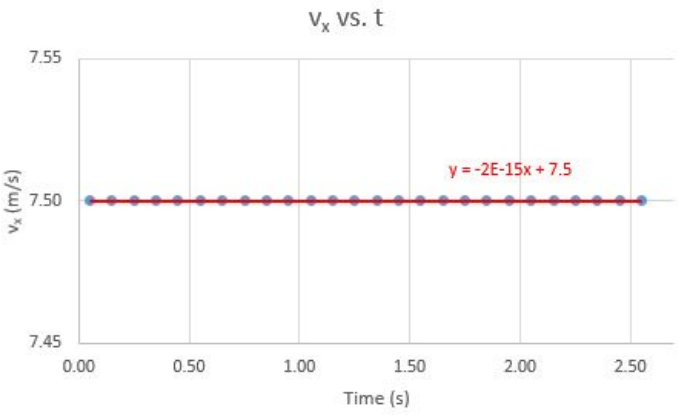


Graph 2: y-Position versus Time
(SAMPLE ANSWER BELOW)



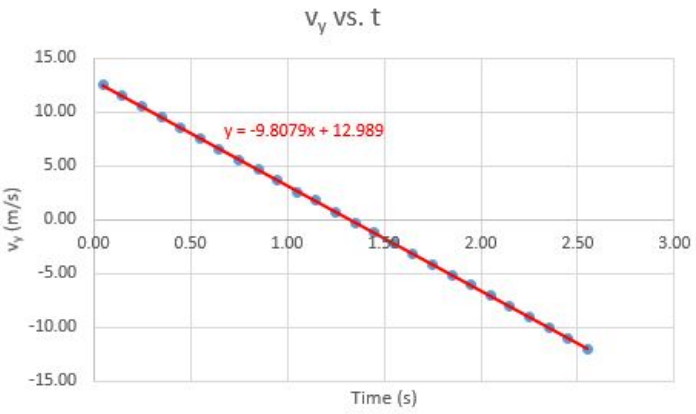
Graph 3: x-Velocity versus Time

(SAMPLE ANSWER BELOW)



Graph 4: y-Velocity versus Time

(SAMPLE ANSWER BELOW)



Competency Review

The _____ is the path of an object in the (x, y) plane.

- range
- trajectory ✔
- projectile
- All of the above

_____ is an example of projectile motion.

- Free-fall
- Parabolic motion
- An object tossed straight up into the air
- All of the above ✔

In the equation $y = y_0 + v_{y,0} - \frac{1}{2}gt^2,\ v_{y,0}$ stands for the _____ velocity.

- total initial
- initial horizontal
- initial vertical ✔
- None of the above

The vertical motion of a projectile is dependent on its horizontal motion.

- True
- False ✔

A change in the initial _____ of a projectile changes the range and maximum height of the projectile.

- angle
- velocity
- height
- All of the above ✔

If the acceleration due to gravity was larger, a projectile's range and maximum height for a particular set of initial conditions would be _____ than if the acceleration due to gravity was unchanged.

- larger
- smaller ✔
- unchanged
- None of the above

During projectile motion, the horizontal velocity is zero at the highest point of flight.

- True
- False ✔

A projectile launched horizontally will travel for the same amount of time as a projectile dropped vertically from the same height.

- True ✔
- False

When air resistance is ignored, the maximum range of a projectile is achieved for a launch angle of _____ degrees.

- 30
- 45 ✔
- 50
- None of the above

Increasing the initial launch speed of a projectile launched at a constant angle increases the _____.

- time of flight
- maximum height
- range
- All of the above ✔

The slope of a vertical velocity versus time graph is the _____.

- acceleration due to gravity ✔
- horizontal velocity
- vertical position
- None of the above

The horizontal acceleration of a projectile is _____.

- the acceleration due to gravity
- zero ✔
- dependent on the initial horizontal velocity
- None of the above

The vertical velocity versus time graph crosses the horizontal axis at the time when the vertical position graph _____.

- crosses the horizontal axis
- reaches its minimum value
- reaches its maximum value ✔
- None of the above

Extension Questions

A launched rocket is not initially considered a projectile. Explain why not and describe the point at which a rocket becomes a projectile during its flight. (SAMPLE ANSWER BELOW)

A rocket is not a projectile because it is not moving only under the influence of gravity. It is powered by the rocket fuel and thus accelerates at a different rate, potentially at a different angle than 90 degrees. A rocket becomes a projectile when its fuel runs out and its starts to move only under the influence of gravity.

Describe three everyday examples of objects that behave like projectiles. (SAMPLE ANSWER BELOW)

Answers will vary. Some possibilities are: a thrown or kicked football, a thrown or hit baseball, a coin dropped, a hit volleyball or tennis ball, a fruit or nut falling from a tree, a coin toss, etc.