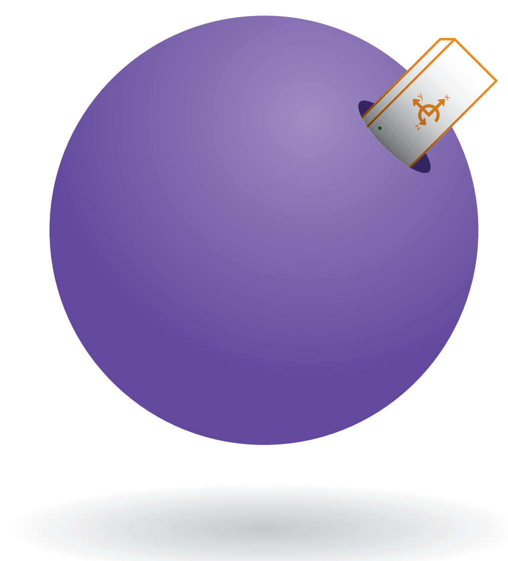
Projectile Motion of an Object

Exploration

When an object is in free fall, the only force acting on the object is gravity. In general terms, an object moving upward is not considered “falling,” however, if gravity is the only force acting on the object (air resistance being negligible) then the object is in fact in a state of free fall. The projectile motion of an object is the trajectory of an object in free fall near Earth’s surface after being thrown or launched in the air. The curved path of the projectile is under the effect of gravity only after being launched.

Materials

- Ball/sphere that can fit a PocketLab inside
- PocketLab



Objective

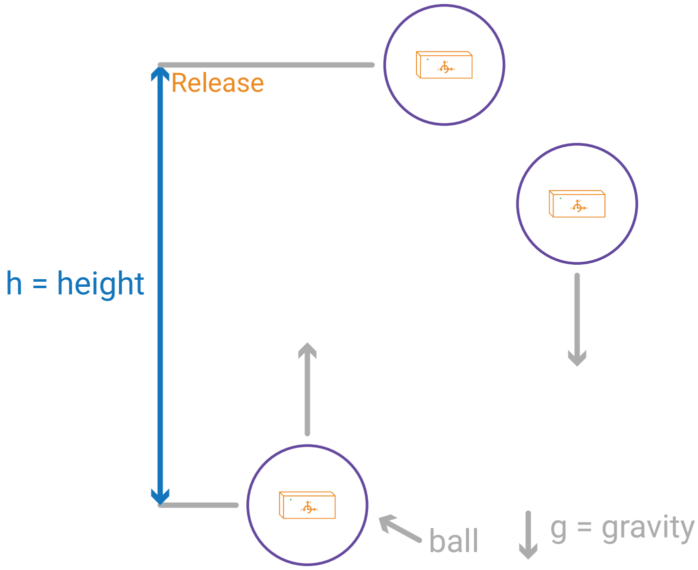
In this experiment, students will:

1. Explore the relationship between acceleration, altitude, and speed of a projectile object as it is thrown upward into the air.
2. Explore concepts of free fall and how the net force of gravity affects the object as it travels both up and down.
3. Use three graphs to illustrate the derivative and integral relationships of position, speed, and acceleration.

Method

1. Place the PocketLab inside the sphere so it is as close to center of gravity as possible.
2. Turn on the two-graph mode. Display both Altitude and Speed (Note: this will activate both the accelerometer and the altimeter, so you will be able to read the Acceleration Scalar graph later. However, if you display Speed and Acceleration Scalar you will only activate the accelerometer and the PocketLab would not collect any data with the altimeter. Therefore make sure you are displaying Altitude and Speed).
3. Hold the sphere at about waist level and "Zero" the speed.
4. Throw the sphere a couple of meters into the air and try to catch it from the same height you threw it.
5. Record/export the data for Altitude, Speed, and Acceleration Scalar.
6. Try throwing the sphere at increasing heights and repeat step 5 for each height to which the sphere was thrown.

Predictions



- When the sphere is on its way up, predict where the speed will be the greatest. Will the acceleration change? Will the acceleration be positive or negative on its way up?
- When the sphere reaches its apex, what will its speed be? Why? How will you see that on the graph?
- Predict the sphere's acceleration on its way down, in free fall? Will the acceleration change as the sphere continues to fall? How will the speed change as the sphere continues to fall?
- As the ball is thrown higher and higher, how will the speed of the ball change on its way up? Will the acceleration change? On its way down, will the acceleration change? How will the speed change? Explain your predictions.

Data Analysis and Observations/Conclusions

- Draw free body diagrams illustrating all the forces acting on the sphere at different points in its journey. Draw one when the sphere is in your hand, being thrown upward. Draw one when the sphere is traveling upward through the air. Draw one when the sphere is traveling back down. Draw one when the sphere is caught.
- Analyze all three graphs together. Pick out where the sphere was being thrown, where it was ascending, where it reached its apex, where it was descending and where it was caught in all three graphs. Label those moments on the graphs.

- Looking at the first throw, where is the speed the greatest on its way up? What is happening to the sphere's acceleration on its way up? Is it positive or negative? Explain the relationship between the sphere's speed and acceleration on its way up. In your explanation, think about the free-body diagrams from the previous question and Newton's First Law of Motion.
- Find the sphere's speed at its apex. Did it match your prediction? Explain the sphere's speed at this point. Do you think it seems odd? Why? Do you think the data is accurate, even if it seems different from what you may have observed with your eyes? Explain your answer.
- What was the sphere's acceleration on its way down? Did it change as it descended? How did the speed of the sphere change as it descended? Explain the relationship between the sphere's speed and acceleration on its way down. In your explanation, think about the free-body diagrams and Newton's First Law of Motion.
- Analyze the acceleration graph. Explain the acceleration reading (make sure to think about direction) while the ball is being thrown upward. Examine the acceleration of the ball on its way up and its way down. Does the acceleration change between its way up and its way down? Why or why not? Using Newton's First Law, relate the free body diagrams for the sphere on its way up and down to the acceleration data collected. Do the same analysis for when the sphere is caught.
- How does throwing the sphere to increasing heights affect the spheres acceleration on its way up and on its way down? Explain. How does it affect the acceleration when the sphere is thrown and when it is caught? Explain.
- How does throwing the sphere to increasing heights affect the spheres speed on its way up and on its way down? Explain.

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VIDEO

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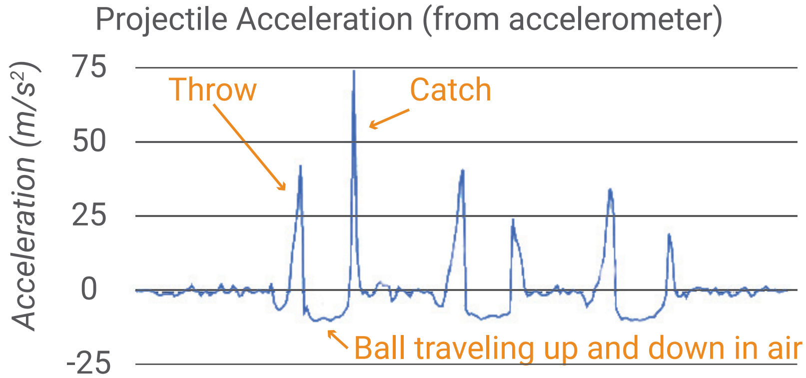
TEACHER GUIDE

Make sure the PocketLab can fit into the ball as close to the center of gravity as possible. The speed graph will need to be zeroed, so make sure the speed graph is one of the displayed graphs in the “two-graph” mode. Because the speed graph uses the accelerometer, by activating the speed graph, data from the acceleration scalar graph will also record. Make sure the other graph displayed is the altitude pressure graph, not acceleration scalar. This will ensure both the accelerometer and the barometer are activated. Once data are recorded, all three graphs can be viewed.

When looking at the acceleration scalar graph, have students identify where the ball was thrown and how the acceleration changes once the ball is released. Students should see a positive acceleration upward when the ball is being thrown, but a negative acceleration due to gravity as soon as the ball is released. Point to how the ball immediately begins slowing down on its way up because the net force of gravity pulling down is acting against the direction of motion causing negative acceleration at approximately -1g or -9.8 m/s^2. As the ball turns and heads back down, students should observe the acceleration remaining the same. This is because the net force acting on the ball never changes. The net force, as drawn in their free-body diagrams, is always F_{grav} while the ball is traveling in the air. The acceleration during the entire duration of free fall should therefore be the same at approximately -1g or -9.8 m/s^2. Note: Point out that the air resistance is still negligible for the distance the ball is traveling. To understand the acceleration it is very important students draw free-body diagrams and understand that a net force causes acceleration (Newton’s First Law).

Note the acceleration graph below:



The speed graph uses the accelerometer, so make sure it is zeroed when the ball is at the height from which it will be thrown. Make sure students relate the speed graph to the acceleration scalar graph. Have them identify where the ball is thrown, where it is traveling up, where it reaches the apex, where it is traveling down, and where it is caught. Students should note the velocity is 0 m/s at the apex. Point out that it is difficult to visually observe the ball at 0 m/s because it happens so fast, but it must happen in order for the ball to change directions. The graph shows the ball at 0 m/s briefly when the speed changes from positive to negative (direction moving up to direction moving down).