Kinematics in Two Dimensions

Vocabulary

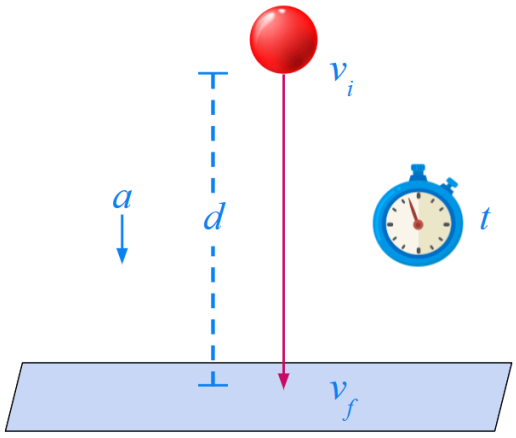
Velocity - The speed of an object in a specific direction.
Acceleration - The rate at which an object's speed changes (speeds up or slows down).
Gravity - A force that pulls objects towards the center of a mass.

Direct Instruction

Introduction

1. Hold up a small ball and ask students to describe what will happen to the ball once you let go of it. If students need a bit of extra guidance, pose the following questions:

    - What is the velocity of the ball when it is released?
    - Does the ball's velocity stay the same or does it accelerate?
    - What is causing the ball to accelerate?
    - How can we find the total distance that the ball fell?
    - How can we find the time it takes the ball to fall?



2. There are a few important points to bring up during the discussion, namely:

    - There is an initial velocity (v_i) and a final velocity (v_f)
    - When the ball is released, $v_i = 0$
    - Velocity can change over time. This change is called **acceleration**, and it can be positive or negative
    - The acceleration in this demonstration is caused by gravity

3. Displacement, the distance an object travels, can often be measured using a tool like Ari, but it can also be calculated using the following formula:

$$d = \frac{v_i + v_f}{2} \times t$$

$d = displacement$ $\quad v_i = initial\ velocity$

$t = time$ $\quad v_f = final\ velocity$

4. If we know the initial velocity, final velocity, and displacement, we can also calculate the acceleration of the object.

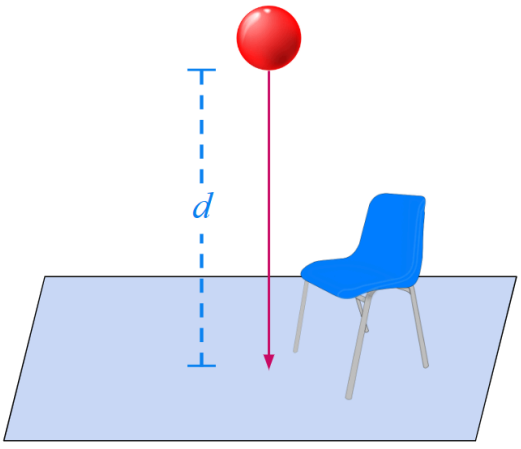
$$a = \frac{v_f - v_i}{t}$$

Activity 1 - Calculating Final Velocity

1. For this activity, students will use Ari to measure the displacement of a ball and then time how long it takes for the ball to hit the floor. From that, they will calculate the final velocity upon impact with the floor.

2. Place students in groups. Each group should have its own Ari, a stopwatch, and a ball.

3. For the experiment, students will need to drop the ball. Higher displacements will give a more accurate calculation but make sure that students are following proper safety protocols regardless of how you choose to run the experiment.



4. Before dropping the ball, students will need to use Ari to measure the displacement. They should record this value in their Student Activity Sheet, in meters.
5. Once displacement is measured, it's time for the experiment. One student will need to let go of the ball. Another student will need to

start the stopwatch once the ball is released and stop it as soon as it hits the ground.

6. Students should repeat the drop two more times and take the average of all three trials.

7. Students should now have all they need to calculate the final velocity. The displacement equation can be rearranged to solve for v_f, like so:

$$d = \frac{v_i + v_f}{2} \times t$$

$$v_f = \frac{2d}{t} - v_i$$

Note: Initial velocity, v_i, is 0 m/s.

Activity 2 - Calculating Acceleration due to Gravity

1. Students should now have values for time, initial velocity, and final velocity. With these values, they can now calculate the acceleration.

2. Using the formula for acceleration, have students calculate acceleration due to gravity.

$$a = \frac{v_f - v_i}{t}$$

3. The value students observed should be close to the gravitational constant. The gravitational constant is

$$g = 9.81\ m/s^2$$

4. Students should compare their experimental value to the gravitational constant and calculate the percent error.

Percentage Error

$$\left|\frac{\text{Measured} - \text{True}}{\text{True}}\right| \times 100$$

Evaluate: Exit Ticket

Students will fill out and submit their Exit Tickets (The last page of the Student Activity Sheet).