Chapter 3: Leaning Tower of Pisa Experiment

Student Worksheet

Objective: Investigate Galileo's experiments with gravity, determine the role of acceleration due to gravity on falling objects, and discover the influence of air resistance on falling bodies.

Engage: Imagine you are atop the Leaning Tower of Pisa. You hold in your hands a bowling ball, and a foam ball of the same size. You drop them. Do they hit the ground at the same time? Does one make it to the ground first? Explain your idea.

Introduction: In this activity you will drop various objects from a specific height to determine the acceleration of each.

Your Task: Come to an accurate conclusion on the role of gravity on falling objects.

Procedure:

Part 1:

1. Choose three objects of different masses and similar sizes.

2. Hypothesize the time it will take them to fall from the height where you will run the experiment. Will they fall at the same speed? Will they land at the same times? Record your hypothesis below.
   Hypothesis:

3. Measure the height of the dropping point in meters.
   Height:____________

4. Drop each object from rest and measure the time in seconds it took for the object to fall from the height you measured in step 3.

   Time for objects to fall:

   Object 1 ________ Object 2________ Object 3________

Part 2:

5. Calculate the average velocity each object had during its fall. Velocity = distance traveled/ time taken. Record your answers below.

   Average velocity:

   Object 1 ________ Object 2________ Object 3________

6. Calculate the speed each object had just before landing, otherwise known as the final velocity. The velocity you used in number 5 is the average velocity. The average velocity equals the initial velocity plus the final velocity multiplied by two--or $v_{av} = (v_i+v_f)/2$. Rearrange this formula to solve for V_f.

   Actual final velocity:

   Object 1 ________ Object 2________ Object 3________

7. Now calculate the speed at which the object should have hit the ground if it were accelerating at a rate of 9.8 m/s^2, or g, the acceleration due to gravity on Earth, using v=gt.

   Presumed final velocity:

   Object 1 ________ Object 2________ Object 3________

8. Are your answers to 6 and 7 equal? If not, propose a reason for the discrepancy.

9. Calculate the acceleration for each object using the formula a = Δv/t. Use the velocity calculated in step 6.

   Object 1 ________ Object 2________ Object 3________

   The acceleration of gravity is supposed to be a constant 9.8 m/s^2, but your answers probably don't equal 9.8 m/s^2. Using Newton's Second Law of Motion, $a = F/m$, you should be able to sort out the impact air resistance is having on your freefall.

10. Use a scale to measure the mass of each object. Provide your answers in kg.

    Object 1________ Object 2________ Object 3________

11. Calculate the weight, in Newtons (N), of each object. Recall that 1 kg weighs 9.8 N.

    Object 1________ Object 2________ Object 3________

12. The *F* in Newton's Second Law is net force. Gravity is one of the forces acting on each object and air resistance is another. The *F* we should be using, then, is each object's weight minus the air resistance. That is:

$$a = \frac{F}{m} = \frac{weight - resistance}{m}$$

Using the formula above, calculate the resistance on each object. Recall that you have already solved for or measured acceleration, weight, and mass in the previous steps.

Air resistance:

Object 1________ Object 2________ Object 3________

Conclusion:

1. What can you conclude about the acceleration of falling objects? Is the difference in falling speed due to air resistance, or to a difference in gravity?
2. In the absence of air, how would your results have changed?
3. In retrospect, what would you have changed about your objects or location?
4. What could you do to lessen error in this lab?

Extend:

- Research the story of Galileo's experiment. What was he trying to prove? Did he succeed? Why or why not?

- Research the term, terminal velocity. What does it have to do with falling objects? How would you design an experiment to find the terminal velocity of various objects? What is the terminal velocity of a human?

- Joe Kittenger in 1960 and Felix Baumgartner in 2012 jumped from the top of the atmosphere to Earth. Research their jumps using video footage. Why were they able to reach such fast terminal velocities? What was their initial acceleration?