Introduction to Free Falling Objects

Exploration

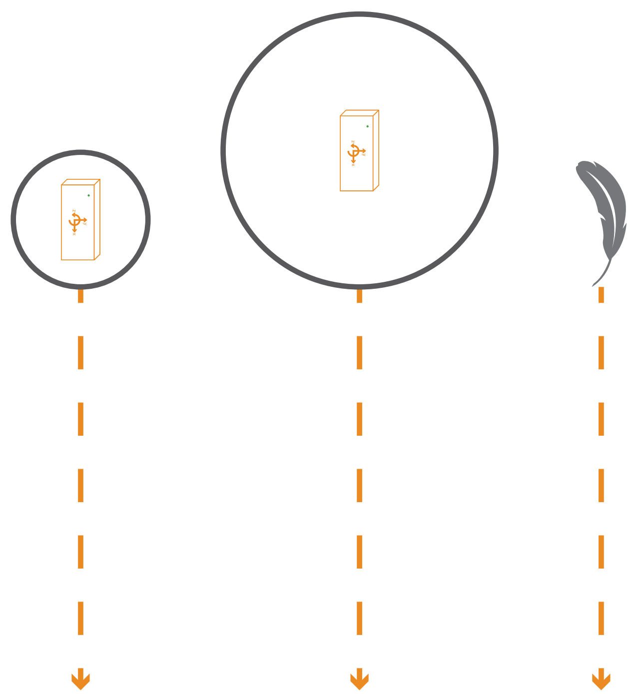
Galileo Galilei is often considered one of the founders of modern science. This is because he investigated questions through experimentation and observations. One of his most famous experiments involved dropping cannonballs of different mass to determine whether they would accelerate to the ground at different rates. Many at the time thought the mass of an object determined an object's acceleration in free fall. After all, doesn't a cannonball, which is heavy, fall faster than a feather, which is light? Galileo wanted to test this assumption using the scientific method.

Materials

- PocketLab
- Ball with larger mass
- Ball with smaller mass

(Note: If you have a foam or nerf-style ball, you can out a slot for the PocketLab. Place the PocketLab as close to the center of gravity as possible. If you don't have something like this available, you can also use two books. Both books should be hardcover and fairly large to get accurate results. One should still be obviously more massive than the other)

- Feather or piece of paper
- Measuring tape/meter stick/ruler



Objective

In this experiment, students will:

1. Use the accelerometer to determine whether objects in free fall accelerate to the ground at different rates.
2. Explain the collected data and observations using an understanding of Net Force.

Procedure

1. Answer Prediction Questions 1 and 2.
2. Place the PocketLab inside the large ball
3. Go to the highest point available to you for exploration and measure the height from which you will drop the ball.
4. Drop the large ball, and watch the data as it falls.
5. Record the acceleration of the large ball.
6. Repeat steps 3 and 4 to conduct at least 3 trials. Calculate the average acceleration for the large ball over the trials.
7. Place the PocketLab inside the small ball.
8. Return to the exact height where the large ball was dropped.
9. Drop the smaller ball, and watch the data as it falls.
10. Record the acceleration of the smaller ball.
11. Repeat steps 8 and 9 to conduct at least 3 trials. Calculate the average acceleration for the smaller ball over the trials.
12. Answer Observation Question 1 and Prediction Question 3.
13. Hold the feather or piece of paper parallel to the ground from the exact same height that the balls were dropped.
14. Drop the feather or piece of paper and record any observations that you make (Note: you will not be able to attach the PocketLab to the feather or piece of paper, so your observations will be strictly qualitative).

Predictions

1. Which ball do you think will have greater acceleration? How much faster will it fall? Why?
2. What forces will act on the balls in free fall (only include significant forces)?
3. (Answer this question after collecting data on the balls) What do you predict will be different about the way the feather or piece of paper will fall? What forces will act on the feather or piece of paper while falling?

Data Analysis and Observations

1. What do you notice about the acceleration of the two balls? Do they have different rates of acceleration? Explain your answer using the data you collected. Draw a free-body diagram showing the forces acting on the two balls in free fall.
2. What did you notice about the feather or piece of paper as it fell? Explain your answer using the qualitative observations you made while the feather or piece of paper fell. Draw a free-body diagram showing the forces acting on the feather or piece of paper.

Conclusions

1. Did your intuition about which ball would fall faster match the data you collected? Explain why or why not.
2. Compare the free-body diagrams of the balls and the feather or piece of paper. What is similar about them and what is different? Why?
3. Three objects, all with different masses were dropped. Two of the objects were the same shape, one was different. Did the mass or the shape have more of an affect on the rate of acceleration? Why?
4. If all three objects were dropped on the moon, where there is gravity but no air, which object would have the greatest acceleration, or would they all accelerate at the same rate? Why?
5. On Earth, objects under the influence of gravity accelerate at approximately 9.81 m/s^2. This can be derived from Newton's Law of Universal Gravitation and his Second Law of Motion. When referring to this value we use the variable 'g', 1g = 9.81 m/s^2
6. If all objects on Earth experience the same acceleration due to Earth's gravity, should objects always fall at the exact same rate of acceleration? What causes objects to fall at different rates of acceleration?

WATCH THE VIDEO

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TEACHER GUIDE

A nerf-type ball with some type of stuffing works best. Cut a slot in the ball that is roughly the same size as the PocketLab. Have the slot allow the PocketLab to fit in as close to the center of gravity of the ball as possible.

After examining the data, students should notice that the acceleration for both balls is the same. This is most likely different from what their intuition would tell them. It is therefore important for students to predict how they think the acceleration will be affected by the mass of the balls before they are dropped. Most will say the ball with the larger mass will “drop faster” or have greater acceleration.

Once they have observed the acceleration to be roughly the same, have students think about whether this is true for all objects. Have them think about a piece of paper or a feather. Make sure they predict whether the feather or piece of paper will drop at the same rate of acceleration as the other two balls after they have observed the two balls dropping at the same rate. Make sure they don’t try to attach the PocketLab to the piece of paper or feather. That would change the mass relative to shape of the paper or feather and may make the air resistance negligible.

The students should observe the paper or feather falling at a much slower rate than the two balls. Push them to the conclusion (free body diagrams will help) that when objects in free fall are only under the influence of gravity, they always accelerate toward Earth’s surface at approximately the same rate, 9.81 m/s^2. Differences in the acceleration of objects as they fall is a result of other forces, not gravity. This is observed with air resistance/friction in the case of the piece of paper or feather. For the two balls, the air resistance is essentially negligible at the height from which they are being dropped. For the piece of paper or feather however, the air resistance is not negligible, causing the net force and therefore the acceleration to change.
It will be extremely important for students to conduct multiple trials. We recommend five at the minimum.