Free fall: measuring g

FizziQ activity · High school · 25 min

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Reproducing Galileo's experiment, students drop a cushioned smartphone, time the free fall on the FizziQ accelerometer graph and calculate g from the drop height.

Learning objectives

- Measure the acceleration of gravity by analyzing the free fall of a smartphone
- Identify the different phases of motion (rest, free fall, impact) on the accelerometer graph
- Apply the kinematic equation $h = \frac{1}{2}gt^2$ to calculate g from the measured fall time and known height
- Compare the experimental value with the accepted value and evaluate sources of error
- Reproduce Galileo's historical discovery using modern digital tools

Instruments and sensors

Absolute acceleration · Accelerometer

Materials

- Smartphone with the FizziQ application
- A soft pillow to hold the smartphone
- Tape measure to measure the height of fall
- FizziQ experiment notebook
- Note: the protocol remains adaptable to any comparable acceleration measurement tool.

Protocol

1. Prepare a thick pillow or cushion on the floor to safely catch the smartphone.
2. Measure the drop height from the bottom of the smartphone (when held) to the top of the cushion. Use a tape measure and record the value in meters.
3. Open FizziQ and select the Accelerometer sensor. Choose absolute acceleration and set the sampling rate to maximum.
4. Place the smartphone in a protective padded sleeve or box (a sock stuffed with soft material works well).
5. Hold the protected smartphone at the measured height. Ensure the cushion is directly below.
6. Start recording in FizziQ. Wait 2-3 seconds (to record the initial resting phase), then release the phone cleanly without pushing or spinning it.
7. After the phone lands on the cushion, wait 2-3 seconds, then stop recording.
8. Examine the acceleration graph. You should see three distinct phases: a flat region near 9.81 m/s^2 (rest), a sudden drop to near 0 m/s^2 (free fall), and a sharp spike (impact).
9. Identify the start and end of the free-fall phase precisely. The start is where the acceleration drops below 1 m/s^2, and the end is where the impact spike begins.
10. Measure the duration of free fall (Δt) from the graph.
11. Calculate g using the equation: $g = 2h / (\Delta t)^2$, where h is the drop height.
12. Repeat the measurement 5 times from the same height and calculate the average and standard deviation of your g values.
13. Try a different drop height and verify that the same value of g is obtained.

Expected results

For a drop height of 1.0 meter, the free-fall duration should be approximately 0.45 seconds, yielding $g \approx 9.9$ m/s². Typical experimental values range from 8.5 to 11 m/s², with the main sources of error being the precise identification of the start and end of the free-fall phase (timing uncertainty of ±0.01-0.02 seconds has a large effect because the fall is so brief) and the measurement of the drop height (±2 cm). Air resistance is negligible for a smartphone-sized object over a 1-meter fall. The impact spike can reach 20-100 m/s² depending on the cushioning. Students should observe that the accelerometer reads near zero during free fall, not 9.81 m/s², which is a direct manifestation of Einstein's equivalence principle.

Questions

- Why does the accelerometer read approximately zero during free fall instead of 9.81 m/s²?
- How does this observation relate to Einstein's equivalence principle?
- What was Galileo's original experiment, and why did he use inclined planes instead of direct free fall?
- How does the precision of your measurement compare to Galileo's? What modern advantages do you have?
- If you dropped two phones of different masses simultaneously, would they hit the cushion at the same time?
- What is the terminal velocity of a smartphone, and at what drop height would air resistance become significant?

Going further

- Drop the phone from multiple heights (0.5 m, 1.0 m, 1.5 m) and plot h versus t^2 to extract g from the slope
- Compare the free-fall acceleration measured indoors with a measurement taken outdoors to check for environmental influences
- Drop the phone inside an elevator that is accelerating upward or downward and observe how the apparent g changes
- Use the accelerometer to measure the deceleration during the impact with the cushion and estimate the peak force
- Time the fall independently with a stopwatch and compare the manually measured time with the accelerometer-derived value