

Gravitational force, potential and satellite orbits

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

How strong is the Earth's gravitational field in your classroom? In this lab you film a ball falling from several heights, count frames to find the fall times and calculate g . You then use g and the Earth's radius to estimate the mass of the Earth.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB D.1

Aim

To measure the gravitational field strength g near the Earth's surface from the fall times of a ball, and to use your value to estimate the mass of the Earth.

Equipment

- Steel ball (about 20 g) or a marble
- Metre rule and masking tape for marks at every 0.40 m up a wall
- Phone that records slow motion at 240 frames per second
- Soft mat or folded towel on the floor
- Books to prop up the phone

Safety

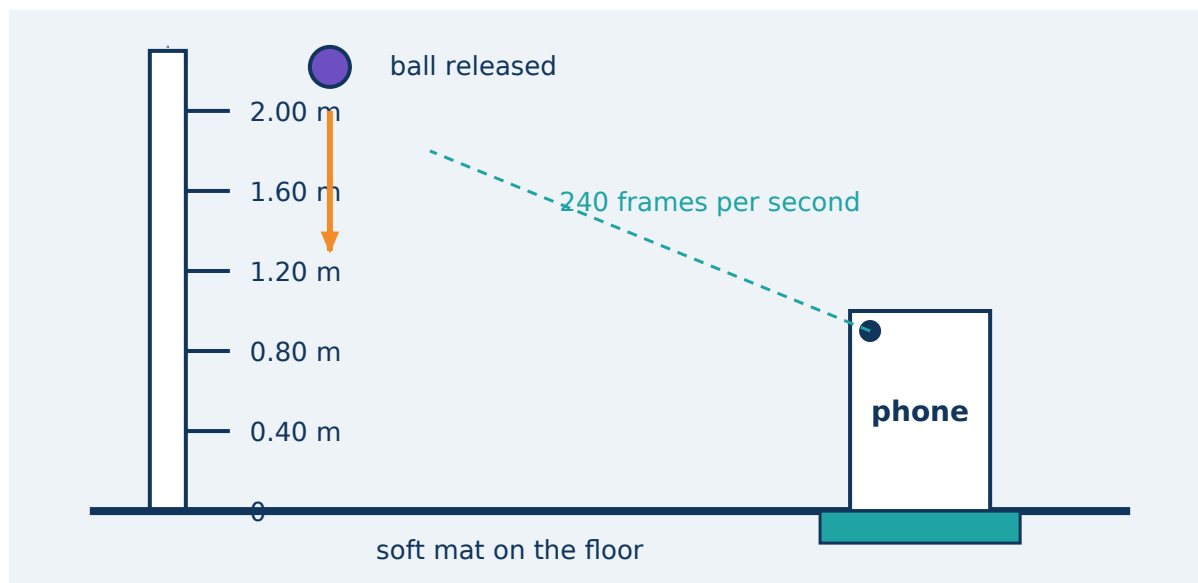
Safety

Stand on a stable step only if the height is below 1.0 m; otherwise ask a partner to release from a higher mark with a long-handled tool. Keep feet away from the landing zone and pick the ball up straight after each drop so nobody trips on it.

Method

1. Fix the tape marks on the wall from the floor up at 0.40, 0.80, 1.20, 1.60 and 2.00 m. Place the mat at the foot of the wall.
2. Put the phone on the books 2 m away, level with the middle mark, and start the slow-motion video.
3. Release the ball from the 0.40 m mark so that it drops straight down without being pushed.

4. Play the video frame by frame. Count the frames from the frame when the ball first moves to the frame when it first touches the mat.
5. Repeat from each height. Divide the number of frames by 240 to obtain the time.



The phone films the fall of the ball so that you can count frames from release to impact.

Results

Sample results from Emma's physics club in Leeds. The time is $t = \text{frames} \div 240$.

height h (m)	frames	time t (s)	t^2 (s^2)	$g = 2h \div t^2$ (m/s^2)
0.40	68	0.2833	0.0803	9.97
0.80	97	0.4042	0.1634	9.79
1.20	118	0.4917	0.2417	9.93
1.60	138	0.5750	0.3306	9.68
2.00	153	0.6375	0.4064	9.84

Analysis questions

Question 1 Time from frames

Calculate the time for the 1.20 m drop and explain why the ball can be treated as starting from rest.

Question 2 Value of g

Calculate g for the 0.40 m drop and check the entry in the table.

Question 3 Mean value

Calculate the mean of the five values of g and its percentage difference from the accepted 9.81 N/kg.

Question 4 Graph

Describe a graph of h against t^2 and say what its gradient gives.

Question 5 Field strength and the Earth

Use $g = 9.81 \text{ N/kg}$, $R = 6.37 \times 10^6 \text{ m}$ and $G = 6.67 \times 10^{-11}$ to estimate the mass of the Earth.

Question 6 Uncertainty in frames

The frame count is uncertain by ± 1 frame. Calculate the percentage uncertainty in g for the 0.40 m drop.

Question 7 Air resistance

Explain the effect of air resistance on the values of g and why it is small here.

Question 8 Improvements

Suggest two improvements that would make the result more accurate.