

# Impulse, momentum and force-time graphs

AP Physics 1 (algebra-based) · Lab

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class: \_\_\_\_\_

Does a softer surface change the impulse on a bouncing ball, or only the force? In this lab you use a slow-motion phone video to measure the rebound height and the contact time on three surfaces, then calculate impulse and average force. Everything fits on a table or a kitchen floor.

**Level:** AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 4

## Aim

To find the impulse and the average force on a ball bouncing off three different surfaces by measuring its drop height, its rebound height and the time of contact.

## Equipment

- Tennis ball (mass about 57 g; weigh it on a kitchen scale)
- Metre rule fixed upright beside the drop point
- Phone with a slow-motion camera mode (240 frames per second)
- Three surfaces: a hard floor tile, a piece of carpet and a thick foam mat

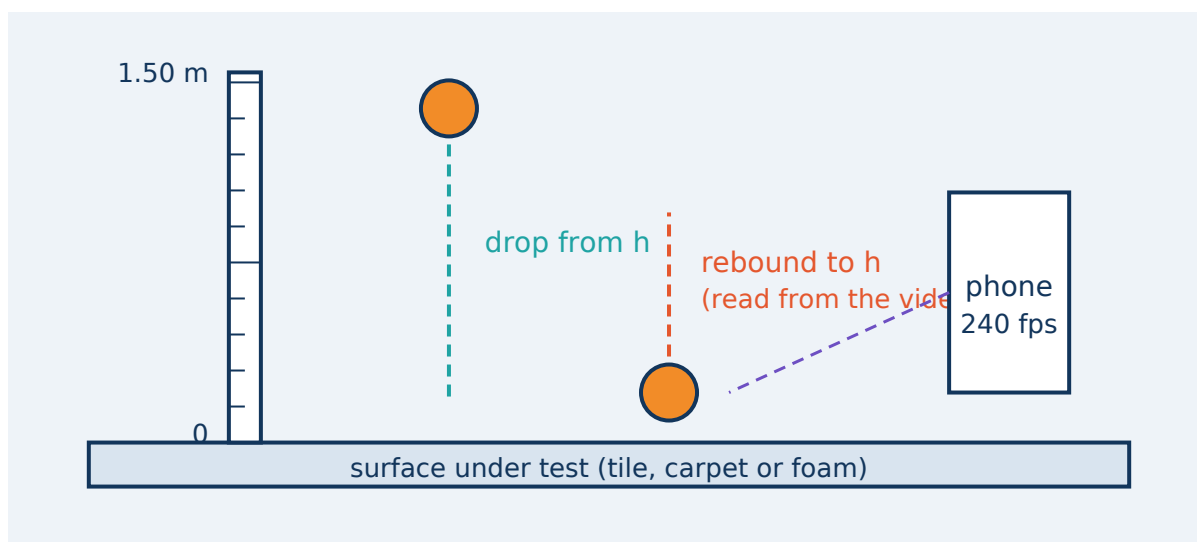
## Safety

### Safety

Keep the area clear of people and breakable items. Do not stand on chairs to drop the ball from high places. Pick up balls at once so nobody trips.

## Method

1. Find the mass of the ball and fix the metre rule vertically beside the first surface.
2. Place the phone on a stand at floor level, pointing at the ruler, and start the slow-motion recording.
3. Release the ball from rest with its lowest point at the 1.50 m mark.
4. Play the video back frame by frame. Read the highest point reached after the bounce ( $h_2$ ) from the rule.
5. Count the frames in which the ball touches the surface. At 240 frames per second, each frame lasts  $1/240 \text{ s} = 0.0042 \text{ s}$ .
6. Repeat for the carpet and the foam mat, always releasing from 1.50 m.



Set-up: the phone films in slow motion, level with the floor, while the ball is dropped beside the metre rule.

## Results

Sample data for a ball of mass 0.057 kg dropped from 1.50 m:

| Surface   | Rebound height $h_2$ (m) | Frames in contact |
|-----------|--------------------------|-------------------|
| Hard tile | 0.83                     | 3                 |
| Carpet    | 0.62                     | 4                 |
| Foam mat  | 0.35                     | 6                 |

## Analysis questions

### Question 1 Speed before impact

Calculate the speed of the ball just before it hits any surface, using energy conservation from the 1.50 m drop.

### Question 2 Speed after impact

Calculate the speed just after impact on each surface from its rebound height.

### Question 3 Impulse on the ball

Calculate the impulse on the ball on each surface. State the direction convention you use.

### Question 4 Contact times

Convert the frame counts into contact times in seconds.

**Question 5 Average force**

Calculate the average force from each surface on the ball, and state whether the weight of the ball matters.

**Question 6 Trend**

Describe how impulse, contact time and force change from tile to foam, and explain the trend in terms of energy.

**Question 7 Uncertainty in contact time**

The contact time is uncertain by about one frame. Calculate the percentage uncertainty in the tile result and say how it affects the force.

**Question 8 Improvements**

Suggest two improvements that would give more reliable values of the average force.