

Momentum conservation, impulse and collision types

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

Name: _____ Date: _____ Class: _____

How large is the impulse when a tennis ball bounces, and how big is the average force? In this lab you film a ball bouncing from several heights, find its speeds before and after, and use the contact time to estimate the force.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB A.2

Aim

To measure the change in momentum of a tennis ball bouncing from a hard floor and to estimate the average contact force and impulse for different drop heights.

Equipment

- Tennis ball (mass 0.058 kg) and a balance
- Metre rule fixed vertically against a wall
- Phone that records slow-motion video at 960 frames per second
- Hard floor or tile, and a few books to prop up the phone

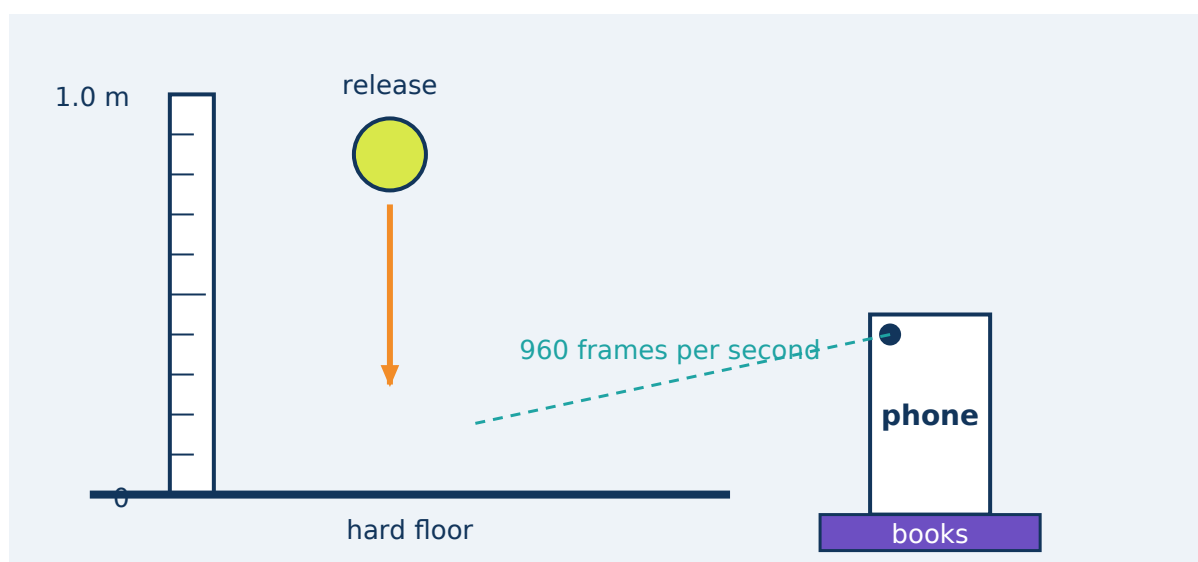
Safety

Safety

Clear the floor of obstacles and keep your head away from the path of the ball. Do not stand on a chair to release the ball from above 1.5 m; hold the ball at arm height next to the rule instead.

Method

1. Measure the mass of the ball. Prop the phone on the books so its lens is level with the floor, about 1 m from the rule.
2. Hold the ball so that its bottom edge is at 0.50 m on the rule and start the video.
3. Release the ball without pushing it. Play the video frame by frame to read the highest rebound height and to count the frames from first touching the floor to leaving it.
4. Repeat from 1.00 m, 1.50 m and 2.00 m.
5. Calculate the speed just before and after the bounce from $\sqrt{2gh}$.



The phone films the bounce side-on so you can read the rebound height and count the frames in contact.

Results

Sample results recorded by Mei and Aarav ($m = 0.058$ kg, 960 frames per second, $g = 9.81$ N/kg). Take upward as positive when you work out Δp .

drop height (m)	rebound height (m)	frames in contact	contact time (ms)	speed before (m/s)	speed after (m/s)	Δp (kg m/s)	average F (N)
0.50	0.30	5	5.21	3.13	2.43	0.322	62
1.00	0.60	5	5.21	4.43	3.43	0.456	88
1.50	0.88	6	6.25	5.42	4.16	0.556	89
2.00	1.18	6	6.25	6.26	4.81	0.642	103

Analysis questions

Question 1 Speed before and after

Show how the speeds in the first row were obtained, and state why the ball's speed after the bounce is smaller.

Question 2 Change in momentum

Calculate Δp for the 1.00 m drop. Explain why the speeds are added.

Question 3 Average force

Calculate the contact time and the average force for the 1.50 m drop.

Question 4 Graph of Δp

Describe a graph of Δp against $\sqrt{h}$ (drop height) and explain the shape.

Question 5 Force and weight

Compare the average force for the 2.00 m drop with the weight of the ball.

Question 6 Uncertainty in contact time

The contact time is read to ± 1 frame. Calculate the percentage uncertainty for the 0.50 m drop and its effect on the force.

Question 7 Coefficient of restitution

Calculate $e = \text{speed after} \div \text{speed before}$ for each drop and comment on the trend.

Question 8 Improvement

Suggest two improvements to the method.