

Impulse, momentum and force-time graphs

AP Physics 1 (algebra-based) · Lab answers

The model answers use the sample data above, with the up direction as positive. Your numbers will differ with your ball and surfaces, but the ranking of forces and the discussion of frame-count uncertainty should be similar.

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

Question 1 Speed before impact

$v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.50} = \sqrt{29.43} = \mathbf{5.42 \text{ m/s}}$ downward.

Question 2 Speed after impact

$v = \sqrt{2gh_2}$. Tile: $\sqrt{2 \times 9.81 \times 0.83} = \mathbf{4.04 \text{ m/s}}$. Carpet: $\sqrt{2 \times 9.81 \times 0.62} = \mathbf{3.49 \text{ m/s}}$. Foam: $\sqrt{2 \times 9.81 \times 0.35} = \mathbf{2.62 \text{ m/s}}$, all upward.

Question 3 Impulse on the ball

Take up as positive, so $v_i = -5.42 \text{ m/s}$. $J = m(v_f - v_i)$. Tile: $0.057 \times (4.04 + 5.42) = \mathbf{0.539 \text{ N s}}$. Carpet: $0.057 \times (3.49 + 5.42) = \mathbf{0.508 \text{ N s}}$. Foam: $0.057 \times (2.62 + 5.42) = \mathbf{0.459 \text{ N s}}$, all upward.

Question 4 Contact times

Each frame is $1/240 \text{ s} = 0.00417 \text{ s}$. Tile: 3 frames = $\mathbf{0.0125 \text{ s}}$. Carpet: 4 frames = $\mathbf{0.0167 \text{ s}}$. Foam: 6 frames = $\mathbf{0.0250 \text{ s}}$.

Question 5 Average force

$F = J/\Delta t$. Tile: $0.539 \div 0.0125 = \mathbf{43.1 \text{ N}}$. Carpet: $0.508 \div 0.0167 = \mathbf{30.5 \text{ N}}$. Foam: $0.459 \div 0.0250 = \mathbf{18.3 \text{ N}}$. The weight is $mg = 0.56 \text{ N}$, only 1 to 3 % of these values, so it is negligible.

Question 6 Trend

From tile to foam the impulse decreases a little (0.539 to 0.459 N s), contact time doubles and the force falls to less than half. The softer surfaces absorb more of the ball's energy as thermal energy, so the ball rebounds more slowly. A longer contact time at a similar impulse gives a **lower average force on softer surfaces**.

Question 7 Uncertainty in contact time

± 1 frame on 3 frames is $1 \div 3 = 33\%$. The force is inversely proportional to the time, so the force has about the same percentage uncertainty: $43.1 \text{ N} \pm 14 \text{ N}$. The foam result (± 1 on 6 frames, 17%) is more reliable.

Question 8 Improvements

Use a higher frame rate or a high-speed camera, so that the contact time is counted over more frames. Repeat each drop several times and average the heights and frame counts.

Both reduce the uncertainty in the average force.