

Momentum conservation, impulse and collision types

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

The answers use the sample table, so your own readings will differ a little. Check the signs of the velocities, the units of time (milliseconds against seconds) and the uncertainty from counting frames.

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

Question 1 Speed before and after

Speed before = $\sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.50} = 3.13 \text{ m/s}$; speed after = $\sqrt{2 \times 9.81 \times 0.30} = 2.43 \text{ m/s}$. Kinetic energy is lost as thermal energy and sound in the bounce, so the ball rebounds more slowly.

3.13 m/s down, 2.43 m/s up.

Question 2 Change in momentum

$\Delta p = m(v + u) = 0.058 \times (3.43 + 4.43) = 0.456 \text{ kg m/s}$. The velocity reverses, so with up as positive the change is $+v - (-u) = v + u$.

$\Delta p = 0.456 \text{ kg m/s}$ upwards.

Question 3 Average force

$t = 6 \text{ frames} \div 960 = 6.25 \text{ ms}$. $F = \Delta p \div \Delta t = 0.556 \div 0.00625 = 89 \text{ N}$.

F average = 89 N.

Question 4 Graph of Δp

Δp is proportional to the speed before impact, which is $\sqrt{2gh}$, so Δp against $\sqrt{h}$ is a straight line through the origin. The gradient is $m\sqrt{2g}(1 + \sqrt{h_r \div h})$, which depends on the rebound fraction.

straight line through the origin.

Question 5 Force and weight

Weight = $0.058 \times 9.81 = 0.569 \text{ N}$. The average force is 103 N, about 181 times the weight, so during contact the floor force is far larger than the weight.

about 181 times the weight.

Question 6 Uncertainty in contact time

One frame is 1.04 ms and the contact is 5 frames, so the uncertainty is $1 \div 5 = 20 \%$. The force is inversely proportional to the time, so the average force has the same percentage uncertainty (about $\pm 20 \%$).

$\pm 20 \%$.

Question 7 Coefficient of restitution

$e = \sqrt{(h_r \div h)}$: 0.77, 0.77, 0.77, 0.77. The values lie between 0.75 and 0.78, so e is nearly constant and the bounce loses a similar fraction of speed at each height.

$e \approx 0.77$.

Question 8 Improvement

Film from a greater distance with zoom to reduce parallax in height readings, and measure the contact time with a force sensor or a microphone trace, which is more precise than counting frames. Repeat each drop three times and average the heights.

reduce parallax and use a force sensor.