inkMaths

ANSWER BOOK

Momentum and impulse

Further Mechanics 1 · Year FM

6 questions · 25 marks

NAVY EDITION

SECTION A · Warm-up

A1 Impulse is force times the time it acts, measured in newton seconds, and equals the change in momentum. Stopping a body removes its momentum; reversing it removes that momentum and supplies the same again the other way, so the change is the sum of the two speeds rather than just the first. B1 for the definition, B1 for newton seconds, B1 for the rebound explanation. [3]

A2 Taking the outgoing direction as positive, $u = -12$ and $v = 18$. Impulse = $0.2(18) - 0.2(-12) = 3.6 + 2.4 =$ **6** N s. Average force = $6/0.03 =$ **200** N. M1 for the change in momentum with signs, A1 for the impulse, A1 for the average force. [3]

SECTION B · Standard

B1 Take the original direction of motion as positive and draw a before and after diagram. Momentum before = $5(3) + 4(1) =$ **19** N s. After the collision $5(1.8) + 4v = 19$, so $4v = 19 - 9 = 10$ and $v =$ **2.5** m/s in the same direction. [4]
M1 for conservation of momentum, A1 for 19 N s before, M1 for the equation after the collision, A1 for 2.5 m/s.
The struck sphere has sped up and the striking one has slowed, and $2.5 > 1.8$ means the spheres have separated. Check that, since an answer with the rear sphere still faster than the front one is impossible.

B2 Total momentum before is zero, since nothing is moving. After: $3(6) + 5v = 0$, so $5v = -18$ and $v =$ **−3.6** m/s: the 5 kg piece moves at 3.6 m/s in the opposite direction. B1 for zero momentum before, M1 for the momentum equation after, A1 for the magnitude, A1 for the direction. An explosion is conservation of momentum with the masses grouped the other way round. [4]

B3 The change in momentum is fixed by the speeds before and after, so the impulse is fixed. Since impulse is force times time, spreading the same impulse over a longer contact reduces the average force in proportion. B1 for the impulse being fixed, B1 for the inverse relation between force and time, B1 for an example. Crumple zones, airbags, thick landing mats and bending the knees on landing all work this way. [3]

SECTION C · Stretch

C1 Speed on landing = $\sqrt{(2 \times 9.8 \times 5)}$ = **9.90** m/s downwards. Rebound speed = $\sqrt{(2 \times 9.8 \times 1.8)}$ = **5.94** m/s upwards. [8]

Taking upwards as positive, the change in momentum is 2(5.94) - 2(−9.90) = 11.88 + 19.80 = **31.7** N s upwards.

Ignoring the weight, the average force is 31.68/0.05 = **634** N.

Allowing for it, the weight acts downwards throughout the contact and contributes an impulse of 2(9.8)(0.05) = 0.98 N s downwards. The ground must supply 31.68 + 0.98 = 32.66 N s, an average force of 32.66/0.05 = **653** N.

M1 for a landing speed from the drop, A1 for 9.90 m/s, A1 for 5.94 m/s, M1 for the change in momentum with signs, A1 for 31.7 N s, A1 for 634 N, M1 for including the impulse of the weight, A1 for 653 N.

The two answers differ by about 3%. Over so short a contact the weight is normally neglected, and either answer stands provided the assumption is stated. Momentum is not conserved for the ball alone here, because the ground is an external body.