

Solutions

2.1 $p = mv = 60 \times 8.0 = \mathbf{480}$ kg m/s (C1, A1).

2.2 In a closed system the total momentum before an event equals the total momentum after it.

2.3 The helmet's foam deforms, increasing the time over which the head's momentum changes; in $F = m\Delta v/\Delta t$ the same $m\Delta v$ over a longer Δt gives a smaller force on the head.

3.1 (a) $p = 2.0 \times 3.0 + 1.0 \times 0 = \mathbf{6.0}$ kg m/s (right) (C1, A1). (b) $3.0v = 6.0$ so $v = \mathbf{2.0}$ m/s right (C1, A1). (c) Closed system – no external horizontal forces (or friction negligible).

3.2 (a) Change $= m(v_{after} - v_{before}) = 0.16 \times (-8.0 - 12) = 0.16 \times (-20) = \mathbf{-3.2}$ kg m/s (sign convention C1, substitution C1, answer A1). (b) $F = \Delta p/\Delta t = -3.2/0.020 = \mathbf{-160}$ N – 160 N on the ball, to the left (C1, A1). (c) By the third law the wall feels an **equal and opposite** force: 160 N to the right.

3.3 (a) $\Delta p = m\Delta v = 1200 \times 15 = \mathbf{18\,000}$ kg m/s (C1, A1). (b) Without: $F = 18\,000/0.12 = \mathbf{150\,000}$ N (C1); with: $F = 18\,000/0.30 = \mathbf{60\,000}$ N. (c) The same momentum change spread over more than double the time cuts the force by 60 % (C1 for the comparison), far below the injury threshold of body structures; the kinetic store of the car empties into the **thermal** store of the deforming metal (and some sound).