InkPhysics

ANSWER BOOK

# Momentum and impulse

Mechanics · Year 12

AQA 3.4.1.6 · CIE 3.1.3, 3.1.4, 3.3.1, 3.3.2, 3.3.3, 3.3.4
OCR A 3.5.1(b), 3.5.1(c), 3.5.1(d), 3.5.1(e), 3.5.2(a), 3.5.2(b), 3.5.2(c)

19 questions · 58 marks

NAVY EDITION


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## SECTION A · Warm-up

**A1** $p = mv = 2.0 \times 8.0$ (1) [2]
$p = 16$ kg m s$^{-1}$ (or N s) (1)

**A2** In a collision or explosion, the total momentum before equals the total momentum after (1), provided no external resultant force acts on the system (1). [2]

**A3** Impulse = force × time for which it acts, $F\Delta t$ (1). It equals the change in momentum of the object, $\Delta(mv)$ (1). [2]

**A4** Momentum is a vector, directed along the velocity (1). On the bend the direction of the velocity changes, so the momentum changes even though its magnitude is constant. (1) [2]

**A5** The impulse of the force, equal to the change in momentum it produces. (1) [1]

**A6** In an elastic collision kinetic energy is conserved; in an inelastic collision some kinetic energy is transferred to other forms (1). Momentum is conserved in both. (1) [2]

## SECTION B · Standard

**B1** (a) Impulse = $F\Delta t = 20 \times 3.0$ (1) [4]
Impulse = 60 N s (1)
(b) Impulse = $\Delta(mv) = mv$, so $v = 60/4.0$ (1)
$v = 15$ m s$^{-1}$ (1)

**B2** Momentum is conserved: $2.0 \times 3.0 = (2.0 + 1.0)v$ (1) [3]
$v = 6.0/3.0$ (1)
$v = 2.0$ m s$^{-1}$ (1)

**B3** Before: $\frac{1}{2} \times 2.0 \times 3.0^2 = 9$ J (1) [4]
After: $\frac{1}{2} \times 3.0 \times 2.0^2 = 6$ J (1)
Kinetic energy falls by 3 J (1)
The collision is inelastic (1)

**B4** Total momentum starts at zero: $0 = m_{gun}v_{gun} + m_{bullet}v_{bullet}$ (1) [3]
$v_{gun} = -(0.040 \times 200)/4.0$ (1)
$v_{gun} = -2.0$ m s$^{-1}$, i.e. 2.0 m s$^{-1}$ backwards (1)

**B5** (a) Taking the rebound direction as positive, the velocity changes from -15 to +9.0 m $s^{-1}$, a change of 24 m $s^{-1}$ (1). $\Delta p = 0.060 \times 24 = 1.44$ kg m $s^{-1}$ (1). (b) $F = \Delta p/\Delta t = 1.44/0.0075$ (1) = 192 N, directed away from the wall. (1) [4]

**B6** Impulse = area under the force-time graph (1) = ½ × 0.040 × 3000 (1) = 60 N s. (1) [3]

**B7** Momentum of the water arriving each second = 4.2 × 15 = 63 kg m $s^{-1}$, all of it removed by the wall (1). The wall therefore exerts a force equal to this rate of change of momentum (1), and by Newton's third law the water exerts an equal force of 63 N on the wall. (1) [3]

## SECTION C · Stretch

**C1** Taking right as positive (1) [4]
(3.0 × 4.0) + (1.0 × -2.0) = (3.0 + 1.0)v (1)
v = 10/4.0 (1)
v = 2.5 m $s^{-1}$ to the right (1)

**C2** $F = \Delta(mv)/\Delta t$ (1) [4]
(a) F = (1000 × 20)/0.10 = 2.0 × $10^5$ N (1)
(b) F = (1000 × 20)/0.50 = 4.0 × $10^4$ N (1)
A crumple zone lengthens the stopping time, reducing the force for the same change in momentum (1)

**C3** The change in momentum of the occupant is fixed (1). Seatbelts and airbags increase the time over which they are brought to rest (1), and since force = change in momentum / time, a longer time means a smaller average force on the body (1). [3]

**C4** Momentum is conserved: 1400u = (1400 + 2100) × 8.0 (1). u = 3500 × 8.0/1400 (1) = 20 m $s^{-1}$ (1). This is well above 13.5 m $s^{-1}$, so the car was exceeding the limit. (1) [4]

**C5** (a) The total momentum stays zero: 1.2v = 0.80 × 0.90, so v = 0.60 m $s^{-1}$ in the opposite direction (1). (b) KE = ½ × 0.80 × $0.90^2$ + ½ × 1.2 × $0.60^2$ (1) = 0.32 + 0.22 = 0.54 J (1). It was transferred from the elastic potential energy stored in the compressed spring. (1) [4]

**C6** The engine pushes the exhaust gas backwards, giving it momentum backwards (1). No external force acts on the system of rocket and exhaust, so total momentum is conserved (1). The rocket therefore gains an equal amount of momentum forwards (1). Equivalently, by Newton's third law the expelled gas pushes forwards on the rocket: nothing needs to push on the surrounding air. (1) [4]