Page 183 Test yourself on prior knowledge

1 Velocity is a vector; it has direction as well as magnitude.

Momentum = mass × velocity, so momentum must therefore also be a vector.

2 Momentum = m × v

= 80 kg × 8 m s^{-1}

= 640 kg m s^{-1}

3 acc $= \frac{v-u}{t}$

$= \frac{14\ \text{m s}^{-1} - 6\ \text{m s}^{-1}}{4\ \text{s}}$

= 2 m s^{-2}

m $= \frac{F}{a}$

$= \frac{1\,470\ \text{N}}{2\ \text{m s}^{-2}}$

= 735 kg

4 The paired Newton's third law force is the gravitational pull of the book on the Earth. This is 2N.

5 a) KE $= \frac{1}{2}mv^2$

$= \frac{1}{2}$ × 1200 kg × (25 m $s^{-1})^2$

= 380 kJ (2 s.f.)

b) Most of the kinetic energy is transferred to thermal energy in the brake pads; some to thermal energy on the road if there is skidding; some sound energy.

Page 186 Test yourself

1 a, b and c) In each case use the equation F = $\frac{\Delta (m\,v)}{\Delta t}$ to explain that the action/protection leads to a longer time, Δt, before the moving body comes to rest and so causes a smaller force to act on the body for the same momentum change.

2 a) v^2 = 2gh

= 2 × 9.8 N kg^{-1} × 3 m

v = 7.7 m s^{-1}

mv = 45 kg × 7.7 m s^{-1}

= 350 kg m s^{-1} (2 s.f.)

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b) $F = \frac{\Delta(mv)}{\Delta t}$

$= \frac{350 \text{ kg m s}^{-1}}{0.2 \text{ s}}$

= 1 700 N

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3 a) The crumple zone increases the time of collision, thus the force slowing the car is less.

$$F = \frac{\Delta(mv)}{\Delta t}$$

The seat belt is vital to make sure the passengers use the whole time, Δt. If someone is not strapped in, they keep moving and end up stopping in a shorter time. Seat belts also stretch a little in a crash, so this makes the stopping time even longer. (Seat belts must be replaced after a crash – if the car survives – because their function will have been impaired by stretching.)

b) Helicopters have crumple zones under the passengers' seats, so that they slow down in a longer time. This is very important, as the body is more sensitive to upward or downward accelerations than it is to forward or backward accelerations.

4 a) i) F = ma; so if there is a large acceleration it has been caused by a large force.

ii) FΔt = Δ(mv); if F Δt is larger, the increase in momentum will be larger. If you apply this idea to a soft organ – an eye for example – then the organ is going to continue to move forwards or backwards even though it has come into contact with the rest of the body – the skull, in the case of the eye – and so crushing injuries are more likely to happen.

b) The maximum force acting on each passenger can be read from the graph:

A: a $= \frac{F}{m}$

$= \frac{79 \text{ kN}}{82 \text{ kg}}$

= 960 m s^{-2}

A is most unlikely to survive the crash.

B: a $= \frac{F}{m}$

$= \frac{31 \text{ kN}}{100 \text{ kg}}$

= 310 m s^{-1}

B is likely to receive quite serious injuries but should recover.

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c) $\Delta v = \frac{F\Delta t}{m}$

By counting squares the area under the graph is approximately 3 500 Ns (2 s.f.).

$\Delta v = \frac{3\,500 \text{ N s}}{100 \text{ kg}}$

$= 35 \text{ m s}^{-1}$

5 a) Impulse = change of momentum

$= 2.2 \text{ kg} \times 12 \text{ ms}^{-1} - 2.2 \text{ kg} \times (-4 \text{ ms}^{-1})$

$= 35 \text{ kg ms}^{-1}$

b) $F = \frac{\Delta(mv)}{\Delta t}$

$= \frac{35 \text{ kg ms}^{-1}}{0.064 \text{ s}}$

$= 550 \text{ N}$

c) 550 N (Newton's Third Law)

Pages 187–188 Activity

Investigating varying forces

1 a)

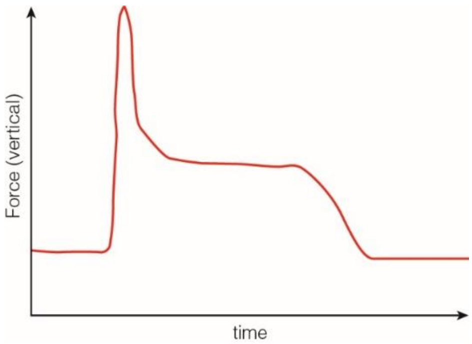
- AB – stepping on to the plate
- BC – A_1 is the impulse as he accelerates, when he begins to stand up. A_2 is the impulse as he slows down, having stood up.
- CD – standing still
- DE – stepping off the plate

b) $A_1 = +\Delta(mv)$

$A_2 = -\Delta(mv)$

Since he begins and ends at rest: $+\Delta(mv) = -\Delta(mv)$

c) There is a large impact force as the student lands.



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2 a) Area under the graph is about 250 N s, so that momentum change is 250 N s^{-1} or 250 kg m s^{-1}.

So $\Delta(mv)$ = 250 kg m s^{-1}

b) The downwards momentum before impact was + 125 kg m s^{-1}, and the upwards momentum after impact is – 125 kg m s^{-1}.

c) 125 kg m s^{-1} = 80 kg × v

v = 1.6 m s^{-1}

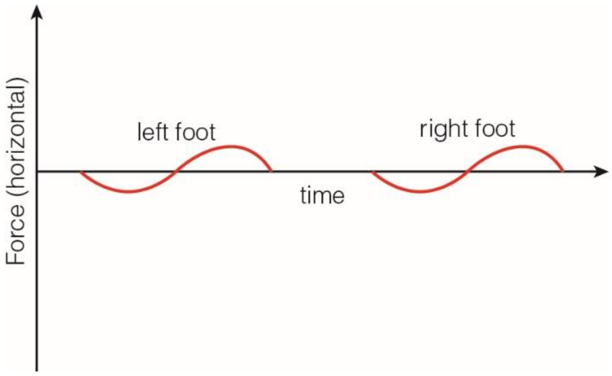
$v^2 = 2\,g\,h$

So $h = \frac{v^2}{2g}$

$= \frac{(1.6\text{ m s}^{-1})^2}{2 \times 9.8\text{ m s}^{-2}}$

= 0.124 m or 0.12 m (2 s.f.)

d) When moving at a constant speed the forwards impulse (here marked positive), must be the same size as the backwards impulse (here shown negative) which the foot experiences as it hits the ground.



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6 a) The momentums of the matchstick and foil are equal in size (but in opposite directions).

$m_1 v_1 = m_2 v_2$

$0.15 \times 7.1 = 0.06 \times v_2$

v_2 = 17.8 m s^{-1}

(NOTE: it is possible to work in g m s^{-1} here.)

b) i) $KE = \frac{1}{2}mv^2$

$= \frac{1}{2} \times 0.06 \times 10^{-3}\text{ kg} \times (17.8\text{ m s}^{-1})^2$

= 9.5×10^{-3} J (aluminium foil)

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ii) KE = $\frac{1}{2}mv^2$

$= \frac{1}{2} \times 0.15 \times 10^{-3}\ \text{kg} \times (7.1\ \text{m s}^{-1})^2$

= 3.8×10^{-3} J (matchstick)

6 c) 9.5 mJ + 3.8 mJ = 13.3 mJ

The match head will store more energy as energy is transferred to thermal energy and sound.

d) Although the initial speed of the foil is faster, it will experience more drag than the matchstick (which is streamlined by its shape) and this will result in a greater deceleration

7 The momentum before the collision = the momentum after the collision.

$m_Av_A + m_Bv_B = (m_A + m_B)v$

This equation is now applied to each example, taking right as positive.

a) 0.63 kg × 2.0 m s^{-1} + 0.42 kg × 1.0 m s^{-1} = 1.05 v

v = 1.6 m s^{-1} (to the right)

b) 0 – 0.42 kg x 2.0 m s^{-1} = 1.05 v

v = - 0.8 m s^{-1} (to the left)

c) 0.63 kg x 1.0 m s^{-1} – 0.42 kg x 1.5 m s^{-1} = 1.05 v

v = 0

8 Now the gliders move independently so the equation to calculate momentum becomes:

$m_Au_A + m_Bu_B = m_Av_A + m_Bv_B$

u_A and u_B are the velocities of A and B before the collisions and v_A and v_B the velocities of A and B after the collisions. Applying this, and again taking right as positive:

a) 0.63 kg × 2.0 m s^{-1} + 0.42 kg × 1.0 m s^{-1} = 0.63 kg × 1.2 m s^{-1} + 0.42 v_B

0.42 v_B = 0.92

v_B = 2.2 m s^{-1} (to the right)

b) 0 – 0.42 kg × 2.0 m s^{-1} = - 0.63 kg × 1.6 m s^{-1} + 0.42 kg × v_B

0.42 kg v_B = 0.17 kg m s^{-1}

v_B = 0.4 m s^{-1} (to the right)

So glider B rebounds, moving off in the opposite direction.

c) 0.63 kg × 1.0 m s^{-1} – 0.42 kg × 1.5 m s^{-1} = -0.63 kg × 1.0 m s^{-1} + 0.42 v_B

0.42 v_B = 0.63 kg m s^{-1}

v_B = 1.5 m s^{-1} (to the right)

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9 A volt is defined as a joule per coulomb.

$$V = \frac{\text{Energy (J)}}{\text{Charge (C)}}$$

10 a) Electrical potential energy, eV, is transferred to kinetic energy.

$$E_k = eV = \frac{1}{2}mv^2$$

$$v^2 = \frac{2eV}{m}$$

$$v = \left(\frac{2eV}{m}\right)^{\frac{1}{2}}$$

$$= \left(\frac{2 \times 1.6 \times 10^{-19}\ \text{C} \times 5\,000\ \text{V}}{9.1 \times 10^{-31}\ \text{kg}}\right)^{\frac{1}{2}}$$

$= 4.2 \times 10^{7}$ m s^{-1}

b) $E_k = \frac{p^2}{2m}$

$$p = (2\ m\ E_k)^{\frac{1}{2}}$$

Since the charge and accelerating voltage are the same for both particles, they have the same kinetic energy, so the proton, which has the larger mass, has the larger momentum.

$p_p = (2 \times 1.67 \times 10^{-27}\ \text{kg} \times 1.6 \times 10^{-19} \times 20 \times 10^{3}\ \text{V})^{\frac{1}{2}}$

$= 3.3 \times 10^{-21}$ kg m s^{-1}

$P_e = (2 \times 9.1 \times 10^{-31}\ \text{kg} \times 1.6 \times 10^{-19} \times 20 \times 10^{3}\ \text{V})^{\frac{1}{2}}$

$= 7.6 \times 10^{-23}$ kg m s^{-1}

Pages 192–193 Test yourself

11 a) Momentum before the collision $m_Av_A + m_Bv_B$

$= 200$ kg $\times$ 5 m s^{-1} + 160 kg $\times$ 3 m s^{-1} = 1480 kg m s^{-1}

Momentum after the collision = $m_Av_A + m_Bv_B$

$= 200$ kg $\times$ 3.4 m s^{-1} + 160 kg $\times$ v_B

$\Rightarrow$ 1480 kg m s^{-1} = 200 kg $\times$ 3.4 m s^{-1} +160 kg $\times$ v_B

$\Rightarrow$ 160 kg v_B = 1480 kg m s^{-1} – 680 kg m s^{-1}

= 800 kg m s^{-1}

v_B = 5 m s^{-1}

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b) Kinetic energy before the collision:

$E_k = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$

$= \frac{1}{2} \times 200 \text{ kg} \times (5 \text{ m s}^{-1})^2 + \frac{1}{2} \times 160 \text{ kg} \times (3 \text{ m s}^{-1})^2$

= 3220 J

Kinetic energy after the collision:

$E_k = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$

$= \frac{1}{2} \times 200 \text{ kg} \times (3.4 \text{ m s}^{-1})^2 + \frac{1}{2} \times 160 \text{ kg} \times (5 \text{ m s}^{-1})^2$

= 3156 J

The collision is inelastic, as kinetic energy has been transferred to other forms of energy.

12 a) The total momentum before the collision is zero:

$0 = +\,65 \text{ kg} \times 1 \text{ m s}^{-1} - 65 \text{ kg} \times 1 \text{ m s}^{-1}$

The total momentum after the collision is also zero:

$0 = +\,65 \text{ kg} \times 2 \text{ m s}^{-1} - 65 \text{ kg} \times 2 \text{ m s}^{-1}$

b) Gain in KE of one skater:

$\frac{1}{2} \times 65 \text{ kg } (2 \text{ m s}^{-1})^2 - \frac{1}{2} \times 65 \text{ kg } (1 \text{ m s}^{-1})^2$

= 98 J (2 sig figs)

c) Work has been done by the skaters’ arms by pushing each other to increase their kinetic energies.

13 In all cases, showing KE is conserved demonstrates the collision is elastic.

a) KE before the collision:

$\frac{1}{2} \times 0.63 \text{ kg} \times (2.0 \text{ m s}^{-1})^2 + \frac{1}{2} \times 0.42 \text{ kg} \times (1.0 \text{ m s}^{-1})^2 = 1.47 \text{ J}$

KE after the collision:

$\frac{1}{2} \times 0.63 \text{ kg} \times (1.2 \text{ m s}^{-1})^2 + \frac{1}{2} \times 0.42 \text{ kg} \times (2.2 \text{ m s}^{-1})^2 = 1.47 \text{ J}$

b) KE before the collision:

$0 + \frac{1}{2} \times 0.42 \times (2.0 \text{ m s}^{-1})^2 = 0.84 \text{ J}$

KE after the collision:

$\frac{1}{2} \times 0.63 \text{ kg} \times (1.6 \text{ m s}^{-1})^2 + \frac{1}{2} \times 0.42 \text{ kg} \times (0.4 \text{ m s}^{-1})^2 = 0.84 \text{ J}$

c) No calculation is required to show KE is conserved here: as each glider has the same speed (although opposite velocity) after the collision.

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14 a) $v^2 = 2\,g\,h$

$v^2 = 2 \times 10\ \text{m s}^{-2} \times 5\ \text{m}$

$= 100\ (\text{m s}^{-1})^2$

$v = 10\ \text{m s}^{-1}$ downwards

b) $v_r^2 = 2\,g\,h_r$

$= 2 \times 10\ \text{m s}^{-2} \times 3.2\ \text{m}$

$= 64\ (\text{m s}^{-1})^2$

$v_r = 8\ \text{m s}^{-1}$ upwards

c) Taking down as positive, the change of momentum of the ball:

$0.1\ \text{kg} \times 10\ \text{m s}^{-1} - 0.1\ \text{kg} \times (-8\ \text{m s}^{-1}) = 1.8\ \text{kg m s}^{-1}$

$F = \frac{\Delta(mv)}{\Delta t}$

$= \frac{1.8\ \text{kg m s}^{-1}}{0.004\ \text{s}}$

$= 450\ \text{N}$

d) The combined momentum of the ball and the Earth remains zero throughout this process. Just as the ball hits the Earth the ball's momentum is $1\ \text{kg m s}^{-1}$ downwards; at that moment the Earth has momentum of $1\ \text{kg m s}^{-1}$ upwards. After the ball has bounced, its momentum is $0.8\ \text{kg m s}^{-1}$ upwards and the Earth has the same momentum in the opposite direction. The Newton's third law paired force to the ball's weight is the ball's gravitational pull on the Earth.

Page 194 Test yourself

15 a) $\frac{p^2}{2\,m} = E_k$ and $E_k = eV$

$\Rightarrow p = (2\,m\,e\,V)^{\frac{1}{2}}$

$= (2 \times 4 \times 1.67 \times 10^{-27}\ \text{kg} \times 4.9 \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J})^{\frac{1}{2}}$

$= 1.02 \times 10^{-19}\ \text{kg m s}^{-1}$

b) $p = 1.02 \times 10^{-19}\ \text{kg m s}^{-1}$ (in the opposite direction to the alpha particle)

c) $E_k = \frac{p^2}{2\,m}$

$= \frac{(1.02 \times 10^{-19}\ \text{kg m s}^{-1})^2}{2 \times (234 \times 1.67 \times 10^{-27}\ \text{kg}}$

$= 1.3 \times 10^{-14}\ \text{J} = 0.17\ \text{MeV}$

d) Nuclear binding energy has been transferred to the kinetic energy of the two particles.

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16 a) F $= \frac{\Delta(mv)}{\Delta t}$

$= 1\,600 \text{ kg s}^{-1} \times 2\,600 \text{ m s}^{-1}$

$= 4.16 \times 10^6$ N

b) i) Resultant force on the rocket:

$4.16 \times 10^6 \text{ N} - m g$

$= 4.16 \times 10^6 \text{ N} - 400\,000 \text{ kg} \times 9.8 \text{ N kg}^{-1}$

= 240 kN

$a = \frac{F}{m}$

$= \frac{240 \text{ kN}}{4 \times 10^5 \text{ kg}}$

$= 0.6 \text{ m s}^{-2}$

ii) After 90 seconds the amount of fuel burnt is:

$1600 \text{ kg s}^{-1} \times 90 \text{ s} = 144\,000$ kg

So the mass of the rocket = 400 000 kg – 144 000 kg = 256 000 kg

$a = \frac{F}{m}$

$= \frac{4.16 \times 10^6 \text{ N} - 256\,000 \text{ kg} \times 9.8 \text{ N kg}^{-1}}{256\,000 \text{ kg}}$

$= 6.5 \text{ m s}^{-2}$

(The acceleration might be even more than this, as g will get less as the rocket rises.)

Pages 195–198 Practice questions

1 A

2 C

3 B

4 D

5 C

6 D

7 D

8 C

9 B

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10 D

11 a) The change of momentum is the area under the graph: [1]

Area $= 2 \times \frac{1}{2} \times 260$ kN × 0.1 s [1]

= 26 000 N s (or 26 000 kg m s^{-1}) [1]

b) Change of momentum = mv

26 000 N s = 1300 kg × v [1]

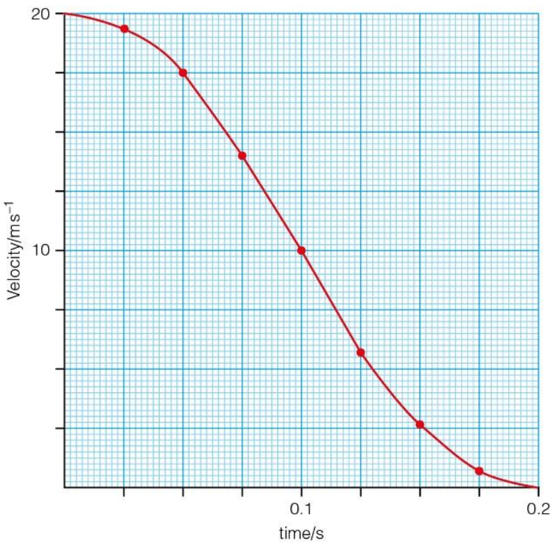
v = 20 m s^{-1} [1]

c) The passenger with the seat belt travels at the same speed as the car. He/she stops in 0.2 s. The unstrapped passenger does not use all that time; She/he keeps moving until she/he hits the car and then stops in a shorter time. [1]

$F = \frac{\Delta(mv)}{\Delta t}$ [1]

So the average force acting on the passenger without a seatbelt is greater. [1]

d) [One mark for correct axes; 2 marks for S shaped curve (passing through 10 m s^{-1}, 0.1 s) **OR** one mark for straight line from 20 m s^{-1} to 0.]



12 a) $m_1v_1 = m_2v_2$ [1]

6.8×10^{-27} kg × 1.5×10^{7} m s^{-1} = 4.0×10^{-25} kg × v [1]

v = 2.6×10^{5} m s^{-1} [1]

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b) KE (alpha) $= \frac{1}{2} \times 6.8 \times 10^{-27}$ kg $\times (1.5 \times 10^{7}$ m s$^{-1})^2$ [1]

$= 7.65 \times 10^{-13}$ J [1]

= 4.78 MeV [1]

KE (nucleus) $= \frac{1}{2} \times 4.0 \times 10^{-25}$ kg $\times (2.6 \times 10^{5}$ m s$^{-1})^2$

$= 1.35 \times 10^{-14}$ J

= 0.08 MeV [1]

Total energy = 4.86 MeV [1]

c) The initial momentum of the two particles was zero as the nucleus was at rest; it is still zero after the alpha emission as the daughter nucleus and alpha particle have equal and opposite momentums. [1]

The kinetic energy of the two particles has come from the nuclear binding energy, which is reduced by the emission of the alpha particle. [1]

13 a) In this example, the momentum of the vehicle as it hits the water

will be the same as the momentum of the vehicle and the water after the splash. [2]

b) Momentum change of vehicle = 240 kg (14 – 5) m s^{-1} = 2160 kg m s^{-1} [1]

So 2160 kg m s^{-1} = m × 18 m s^{-1} [1]

m = 120 kg [1]

c) Vehicle: Δ(KE) $= \frac{1}{2} \times 240$ kg $(14$ m s$^{-1})^2 - \frac{1}{2} \times 240$ kg $(5$ m s$^{-1})^2$

= 20.5 kJ [2]

Water: Δ(KE) $= \frac{1}{2} \times 120$ kg $(18$ m s$^{-1})^2$

= 19.4 kJ [2]

d) The calculation shows that 20.5 kJ – 19.4 kJ = 1.1 kJ of energy has yet to be accounted for. There may be some water moving sideways which also has kinetic energy. (This will be symmetric so that there is no resultant momentum sideways.)
Some energy has been transferred to thermal energy – eventually all the kinetic energy in the water will be transferred to thermal energy. [2]

e) a $= \frac{\Delta v}{\Delta t}$

$= \frac{14\ m\ s^{-1} - 5\ m\ s^{-1}}{0.6\ s}$ [1]

= 15 m s^{-2} [1]

14 a) 0.1 s [1]

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b) $\Delta(mv)$ = 0.08 kg × 8 m s^{-1} – 0.08 kg × (-5 m s^{-1}) [1]

= 0.08 kg × 13 m s^{-1} [1]

= 1.0 kg m s^{-1} (2 sig figs) [1]

c) F $= \frac{\Delta(mv)}{\Delta t}$ [1]

$= \frac{1.0 \text{ kg m s}^{-1}}{0.1 \text{ s}}$

= 10 N [1]

d) The force on the ground is 10 N. (Newton's Third Law) [1]

e) Any two from the points below – in each case one mark for change, the other for explanation:

- Because the ball will not deform on hitting the ground the time of contact will be shorter (B will move closer to the *y*-axis) [2]
- Because the ball is not deformed, less energy will be transferred to elastic potential energy, so the return speed will be greater (B will be further from the *x*-axis). [2]
- Since $F = \frac{\Delta(mv)}{\Delta t}$ both a larger Δv and a smaller Δt increase the force acting on the ball and hence its acceleration (line AB is steeper) [2]
- After the bounce, the ball is once again only affected by gravity (and drag) so it will take a longer time before the velocity again returns to zero/the ball reaches the top of the bounce (the segment of the line after B will have the same gradient as that before A and so will meet the *x*-axis further from O). [2]

15 a) $m = \frac{4}{3}\pi \rho r^3$

$= \frac{4}{3}\pi \times 9000 \text{ kg m}^{-3} \times (0.05 \text{ m})^3$ [1]

= 4.71 kg [1]

b) v^2 = 2 g h

= 2 × 9.8 N kg^{-1} × 2.0 m [1]

= 39.2 (m s^{-1})^2

v = 6.3 m s^{-1} [1]

c) Momentum before the collision = momentum after the collision

4.7 kg × 6.3 m s^{-1} = (4.7 kg + 2.6 kg) v [1]

v = 4.1 m s^{-1} [1]

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d) Initial KE of ball = $\frac{1}{2}\ m_b v_b^2$

$= \frac{1}{2} \times 4.7\ \text{kg} \times (6.3\ \text{m s}^{-1})^2$

= 93 J [1]

KE of ball and spike $= \frac{1}{2}\ (m_b + m_s)\ v^2$ [1]

$= \frac{1}{2} \times 7.3\ \text{kg} \times (4.1\ \text{m s}^{-1})^2$

= 61 J [1]

KE is transferred to other forms of energy, so it is inelastic. [1]

e) $F \times s = \Delta\ (\frac{1}{2} m\ v^2)$ [1]

$F = \frac{61\ \text{J}}{0.035\ \text{cm}}$ [1]

= 1 800 N (2 s.f.) [1]

16 a) Momentum of neutron before = momentum of neutron and nucleus after the collision [1]

$1 \times 1.2 \times 10^7 = 239 \times v$ [1]

$v = 5.0 \times 10^4\ \text{ms}^{-1}$ [1]

b) Momentum of alpha particle is equal and opposite to that of nucleus [1]

$4 \times 1.5 \times 10^7 = 204 \times v$ [1]

$v = 2.9 \times 10^5\ \text{m s}^{-1}$ [1]

Page 194 Stretch and challenge

17 a) mass of air displaced per second = density of air × Area swept out by rotor × speed of air

$F = \frac{\Delta(mv)}{\Delta t} = \rho\ A\ v^2$

$= 1.2\ \text{kg m}^{-3} \times \pi \times (9\ \text{m})^2 \times (5.0\ \text{m s}^{-1})^2$

= 7.63 kN (3 s.f.)

b) The force produced by the displaced air must equal the weight of the helicopter (Newton's First Law).

$m = \frac{w}{g}$

$= \frac{7.63\ \text{kN}}{9.8\ \text{N kg}^{-1}}$

= 778 kg

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c) i) $\rho \, A \, v^2 \cos 14^o = 7.63 \text{ kN}$

$\Longrightarrow v^2 = \frac{7630 \text{ N}}{1.2 \text{ kg m}^{-3} \times \pi \times (9 \text{ m})^2 \times \cos 14^o}$

$v^2 = 25.8 \text{ (m s}^{-1})^2$

$v = 5.1 \text{ m s}^{-1}$

ii) In this situation, the weight of the helicopter must be balanced by the vertical component of the force created by the rotors

So $F = \frac{7.63 \text{ kN}}{\cos 14} = 7860 \text{ N}$

So resultant forwards force = 7860 × sin 14 = 1 900 N

$a = \frac{F}{m}$

$= \frac{1\,900 \text{ N}}{778 \text{ kg}}$

$= 2.4 \text{ m s}^{-1}$

18 Momentum is conserved, so all the fragments have the same speed as they are distributed spherically. Each fragment therefore has (0.8 × 2 kJ) ÷ 100 = 16 J.

$16 = \frac{1}{2} mv^2$

$v^2 = \frac{2 \times 16}{0.02}$

$v = 40 \text{ m s}^{-1}$

19 a) The field direction is out of the paper. Use Fleming's left hand rule; remember that the conventional current is in the opposite direction to the electron movement.

b) The track thickness depends on the amount of ionisation per metre produced by the particle. The ionisation is greater when the particle has more charge, q, and it is greater when the particle has low speed, v. The energy transfer per metre is proportional to $\frac{q^2}{v^2}$.

The ß-particle travels close to the speed of light, so is weakly ionising and has a much longer range than a lithium ion.

The Lithium nucleus has 3 charges and travels relatively slowly, so is strongly ionising over a short distance, over which it transfers its kinetic energy.

c) For momentum to be conserved, there must be another particle which has momentum equal to the vector sum of $-p_1 + -p_2$.

d) $p = \{(p_1)^2 + (p_2)^2\}^{1/2}$ at an angle Ø to p_1, where tan Ø = p_2/p_1.