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Chapter 1

1 **a)** 8 m/s

2 **a)** 10 500 m (10.5 km)

b) 105 000 m (105 km)

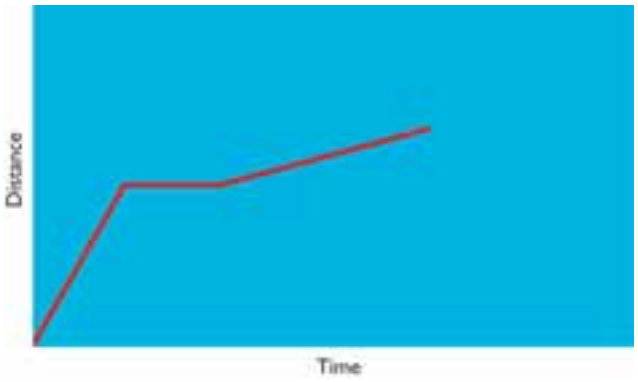
c) 630 000 m (630 km)

3 4000 s (Snails can actually move faster than this! At a more realistic 4 mm/s (0.004 m/s) it would only take the snail 400 s or 6 minutes 40 seconds.)

4 **a)** graph D **b)** graph C

c) graph A **d)** graph B

5



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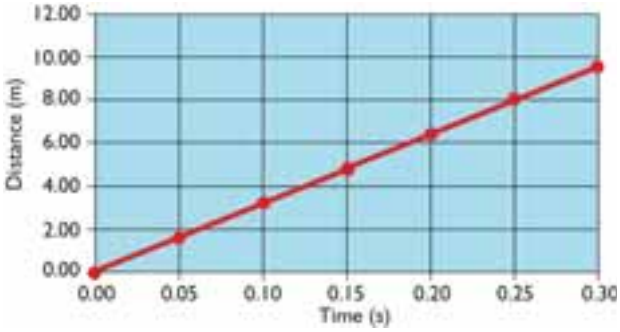
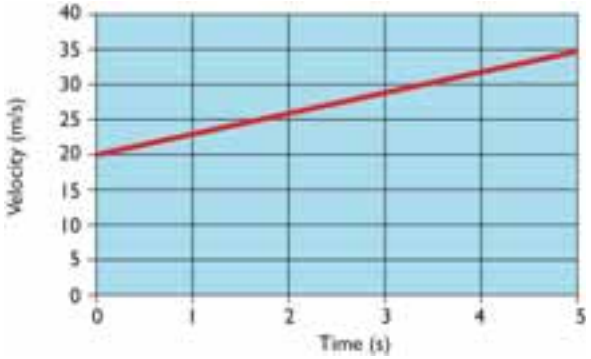


$$\text{gradient} = \frac{\text{distance}}{\text{time}} = \frac{8\,\text{m}}{0.25\,\text{s}} = 32\ \text{m/s}$$

7 **a)** The car is moving at constant velocity (speed).

b) Time interval between first and seventh drip is 15 s (6×2.5 s) so average speed is 135 m ÷ 15 s = 9 m/s.

8 **a)**



b) Distance travelled is given by the area under the graph

$= (5\ s \times 20\ m) + (0.5 \times 5\ s \times 15\ s)$

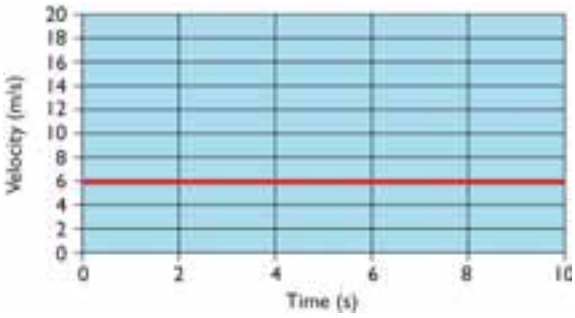
$= 137.5\ m$

9 **a)** Average speed is found by dividing the total distance a body has travelled by the time it has taken; the speed may vary from moment to moment during this time. The instantaneous speed is the speed at which the body is travelling at a moment in time.

b) Speed is a scalar quantity – it is distance travelled divided by time without regard to direction. Velocity is a vector quantity – it is speed in a specified direction.

10 $4\ m/s^2$

11 **a)**



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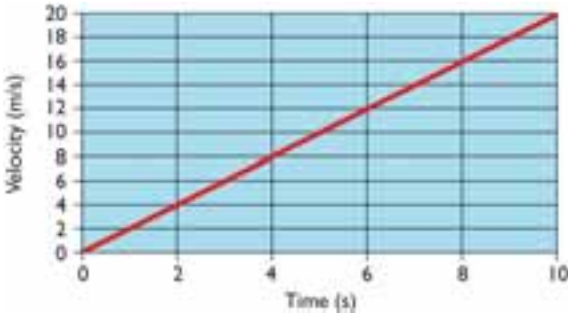

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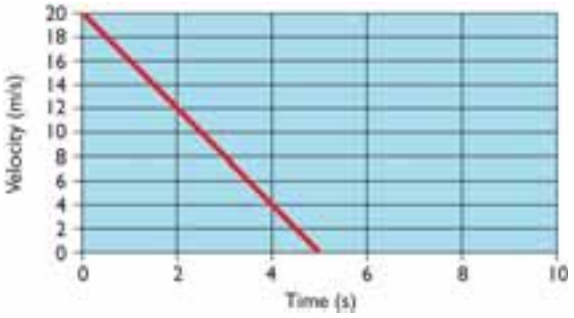


12 **a)** 3 m/s

b) 15 m/s

c) 75 m/s

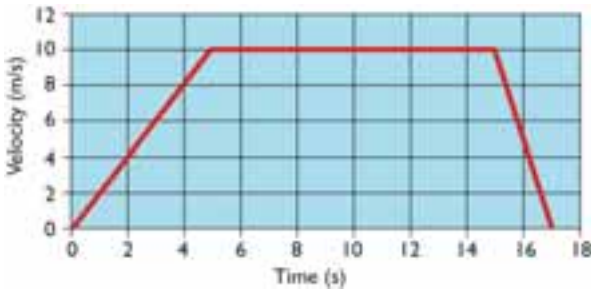
13 **a)** graph B

b) graph A

c) graph D

d) graph C

14



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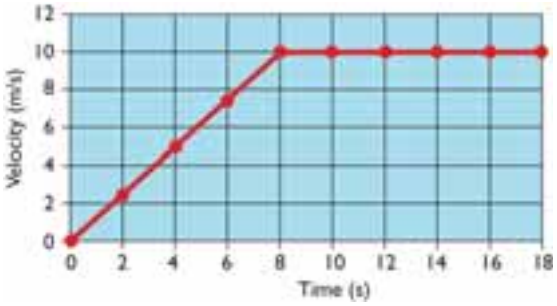


a) 2.5 m/s^2

b) i) 20 m

ii) 50 m

c) average speed = total distance travelled ÷ time taken.

= 70 m ÷ 9 s

= 7.78 m/s

16 The total distance travelled increases with the square of the time from the start, 0.5 m after 1 s, 2.0 m after 2 s, 4.5 m after 3 s, etc. Calculating the average velocity over each 1 s time interval (between the drips) and then plotting a graph of average velocity against time allows the acceleration to be calculated from the gradient of the graph. The acceleration is 1 m/s^2.

Chapter 2

1 **a)** gravity

b) friction

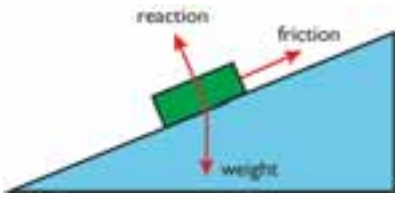
c) normal reaction or contact force

2 Friction and air resistance (or viscous drag)

3 **a)** 1200 N **b)** 1250 N

c) 50 N **d)** red

4



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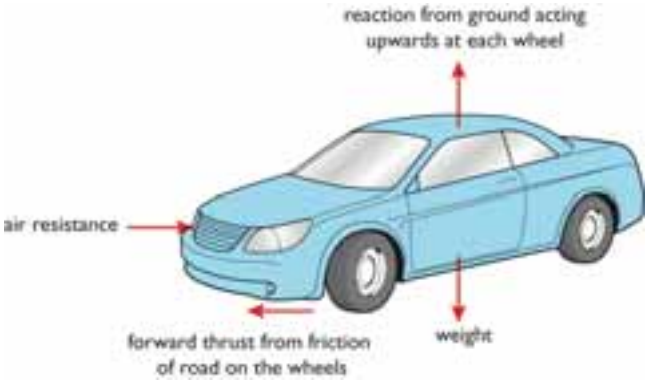
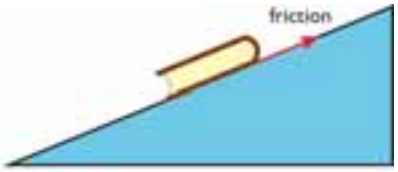


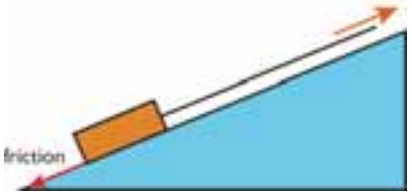
6 **a)** Without friction, objects would not be able to start moving from a stationary position, or stop moving when in motion. It would not be possible to build things because it would be difficult to pick up the building materials, and structures rely on friction to remain intact.

b) Any two sensible examples, such as: walking would be impossible without friction acting between your feet and the ground; climbing a rope would be impossible without friction acting between your hands and the rope.

7 **a)**



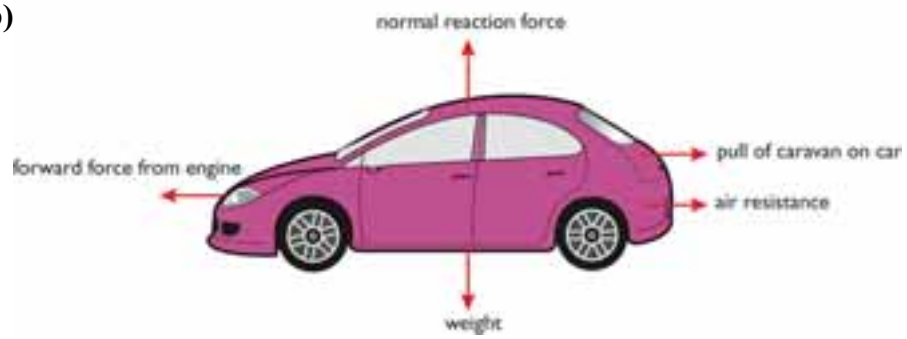
b)



8 **a)**



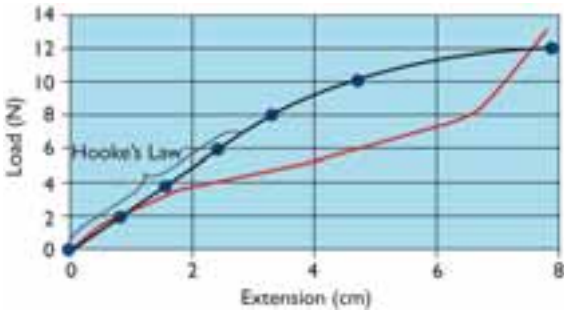
b)



9 a)

Load force on spring (newtons)	Length of spring (cm)	Extension of spring (cm)
0	5.0	0.0
2	5.8	0.8
4	6.5	1.5
6	7.4	2.4
8	8.3	3.3
10	9.7	4.7
12	12.9	7.9

b) c) (**d** – red line)



Chapter 3

1 A force that is not balanced by a force in the opposite direction. An accelerating car has an unbalanced force when the forwards force from the engine is bigger than the backwards force from air resistance.

2 From the equation *force* = *mass* × *acceleration* ($F = ma$) we can see that if F, the thrust force of the rocket engines, is constant and m, the mass of the rocket, decreases then the acceleration must increase.

3 a) $F = ma$, where mass = 0.5 kg and acceleration = 4 m/s^2

So F = 0.5 kg × 4 m/s^2 = 2 N

b) $m = F \div a$, where force = 200 N and acceleration = 0.8 m/s^2

So m = 200 N ÷ 0.8 m/s^2 = 250 kg

c) Use $a = F \div m$, where force = 250 N and mass = 25 kg

So a = 250 N ÷ 25 kg = 10 m/s^2

4 By bending their legs and rolling on landing, parachutists extend the time over which their velocity is reduced to zero. This reduces the deceleration they undergo, and hence the forces that act on the body. Reducing the forces that act reduces the chances of broken bones and other body damage.

5 **a)** Thinking distance is the distance a car travels after the driver has seen a hazard but *before* the driver applies the brakes; during this period the car is not decelerating.

b) The braking distance is the distance travelled by the car *after* the driver has started braking and the car is decelerating to rest.

c) The overall stopping distance is the sum of the thinking distance and the braking distance.

6 The braking distance of a car depends on the speed that the car is travelling and the braking force that can be applied without the car skidding (as skidding means the car is out of control). The maximum braking force will be limited by factors that affect the friction between the car tyres and the road surface: the condition of the tyres and the road surface – if the road surface is wet, icy or oily friction will be reduced. The braking distance is greater if either the speed of the car is higher or the maximum safe braking force is reduced.

7 **a)** 0.75 s (the period during which the velocity of the car is constant at 24 m/s)

b) 18 m (given by the area under the velocity–time graph during the first 0.75 s)

c) 2.5 s (the period during which the velocity of the car is decreasing to zero)

d) 48 m (the sum of the thinking distance and the braking distance – the total area under the graph)

8 **a)** Use *weight* = *mass* × *gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Earth is approximately 10 N/kg

weight of apple on the Earth = 0.1 kg × 10 N/kg = 1 N

b) Use *weight* = *mass* × *gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Moon is approximately 1.6 N/kg

weight of apple on the Moon = 0.1 kg × 1.6 N/kg = 0.16 N

9 The factors affecting the drag force on a high speed train are:

- the speed of the train
- the shape of the train
- the direction of any wind that may be blowing
- (harder) the viscosity of the air that it is travelling through; this will depend on temperature, humidity, etc.

10 See page 31 for description of a suitable experiment.

11 At **A**: velocity is zero at start, so air resistance is zero and the unbalanced force is **downwards** (and is due to gravity or the weight of the parachutist).

At **B**: as the velocity of the parachutist increases so does the size of the upward air resistance force – so the **unbalanced downwards force is smaller**.

At **C**: here the velocity of the parachutist has increased to the point where the upward air resistance force is exactly the same as the downward force of gravity on the parachutist – the **unbalanced force is zero** and the parachutist has reached terminal velocity.

At **D**: the parachutist has opened her parachute at this time. This greatly increases the upward air resistance force so the **unbalanced force** on the parachutist is now **upwards** – so the parachutist's velocity decreases.

At **F:** as the parachutist slows down, the upward air resistance force due to the parachute decreases. This means that the **unbalanced upward force is smaller.** (So the rate of deceleration of the parachutist decreases.)

At **G**: the parachutist has slowed to a velocity at which the upward acting air resistance is once again equal to the downward acting force of gravity. The **unbalanced force is again zero.** (But note that the effect of opening the parachute is to make the new terminal velocity lower.)

Chapter 4

1 All three examples use the formula *momentum* = *mass* × *velocity*.

a) 48 kg m/s

b) 150 000 kg m/s

c) 3 kg m/s (Remember to express the mass in kilograms and the velocity in m/s, thus: 0.06 kg × 50 m/s)

2 **a)** In an elastic collision, the total kinetic energy of the colliding bodies is conserved, i.e. unchanged by the collision. Partially elastic and inelastic collisions (in which the colliding bodies coalesce or stick together) involve the conversion of kinetic energy into other forms, like heat and sound.

b) i) An example of an almost completely elastic collision is the collision of snooker balls (though some kinetic energy is converted to sound and heat). Collisions between the molecules in a gas are considered to be perfectly elastic.

ii) Throwing a wet sponge at your teacher at a charity event is an example of an inelastic collision. A car driving into a wall and an egg hitting the ground are other examples.

3 momentum before the collision = momentum after the collision

momentum of pellet + momentum of truck at start = momentum of truck with pellet after

0.002 kg × v + 0 (truck is stationary) = 0.102 kg × 0.8 m/s

So the velocity, v, of the pellet is 40.8 m/s

4 impulse = increase in momentum where impulse = force × time

impulse = 10 000 N × 60 s

So the increase in momentum is 600 000 kg m/s

increase in momentum = mass × increase in velocity

So the increase in velocity = 600 000 kg m/s ÷ 1200 kg = 500 m/s

The new velocity is, therefore, 2500 m/s (initial velocity plus the increase in velocity).

5 When a mass, like a person in a crashing car, is brought rapidly to a halt, it is subject to a large deceleration. This large deceleration means that the mass must be subject to a huge force. Large forces result in damage. By building crumple zones into cars, the time that the car takes to come to a

halt is extended – this means that the deceleration, and therefore the forces that act during the deceleration, are reduced.

Chapter 5

1 B has the largest turning moment, having the biggest force applied at the greatest perpendicular distance from the pivot. D has a greater moment than C because the line of action of the 5 N force in C has a smaller perpendicular distance from the pivot. A shows the situation with the least turning moment because the 10 N force is applied at a perpendicular distance from the pivot that is clearly less than half the perpendicular distance of the line of action of the 5 N force in C.

So B, D, C, A is the correct order.

2 **a)** C is balanced as the clockwise moment is equal to the anticlockwise moment.

b) A tips down to the left, clockwise moment = 25 Nm, anticlockwise moment = 375 Nm

B tips down to the right, clockwise moment = 400 Nm, anticlockwise moment = 375 Nm

D tips down to the left, clockwise moment = 350 Nm, anticlockwise moment = 375 Nm

3 **a)**



b) 5 N on each support (this answer ignores the weight of the shelf itself).

c)



The book is $\frac{3}{4}$ of the way between P and Q. $\frac{1}{4}$ of its weight will be on P, and $\frac{3}{4}$ on Q, so P supports 2.5 N and Q supports 7.5 N.

d) The forces due to the new book are 2.5 N on each support, so the total force on P is 5 N and the total force on Q is 10 N.

e) The weight of the shelf is spread evenly along the shelf, so each support takes half the weight (5 N).

So with one 10 N book in the middle of the shelf, there is 10 N on each support. With the book 50 cm from Q, there is a force of 7.5 N on P and 12.5 N on Q.

Chapter 6

1 **a)** An asteroid is a rocky body, usually between several metres or several hundreds of kilometres across, which is orbiting the Sun.

b) A comet is a body composed of dust and ice, which orbits the Sun following a very elliptical path.

c) Most asteroids have an orbit which lies between the planets Mars and Jupiter. The orbits of comets at times take them very close to the Sun and at other times to the outer reaches of the Solar System. Asteroids are composed of rocks. Comets are composed of ice and dust.

d) Away from the Sun.

e) Comets move very quickly when they are close to the Sun, and much more slowly when they are a long way from the Sun.

2 The Milky Way is the name of our galaxy.

3 **a)** orbital speed $= \frac{2\pi r}{T}$, so $T = \frac{2\pi r}{\text{speed}} = 2 \times \pi \times \frac{(35786 + 6400)\text{km}}{3.07}$

$T = 86340$ s

b) This is 24 hours, so the satellite completes one orbit in the same time as the Earth spins once. If the satellite is over the equator, it is in a geostationary orbit.

4 orbital speed $= \frac{2\pi r}{T}$

If you use distances in km and times in hours, the speeds you work out will be in km/h.

a) radius of Earth's orbit = 150 million km

period of Earth's orbit = 1 year (which is 365.25×24 hours = 8766 hours)

$$\text{speed} = 2 \times \pi \times \frac{150000000\text{km}}{8766\text{h}}$$

$$= 107\,515 \text{ km/h}$$

b) radius of Jupiter's orbit = $5 \times$ radius of Earth's orbit = 750 million km

period of Jupiter's orbit = 12 Earth years = 105 192 hours

$$\text{speed} = 2 \times \pi \times \frac{750000000\text{km}}{105192\text{h}}$$

$$= 44\,798 \text{ km/h}$$

End of Section A questions

1 vector, shape, acceleration, mass, weight, terminal, balanced.

moments, perpendicular, pivot. (10)

2 **a)** Speed is found from slope of graph (1)

= 60 m ÷ 30 s (1)

= 2 m/s (1 for correct answer with unit)

b) Standing still (1)

c) Walking back to starting point quickly (1)

or walking at –4 m/s (1 mark for sign, 1 mark for correct value, 1 mark for correct unit)

d) Average velocity = 60 m ÷ 45 s (1)

= 1.3 m/s (1)

3 **a)** Acceleration = increase in velocity ÷ time taken (1)

= 150 m/s ÷ 5 s (1)

= 30 m/s^2 (1)

b) Area under graph = distance travelled (1)

Approximate to suitable shapes, e.g. triangle and trapezium (1)

Calculate appropriate areas (1)

Answer in range 6200 m to 6600 m (1)

c) Average velocity = total distance travelled ÷ time taken (1)

= value from above say 6400 m ÷ 30 s (1)

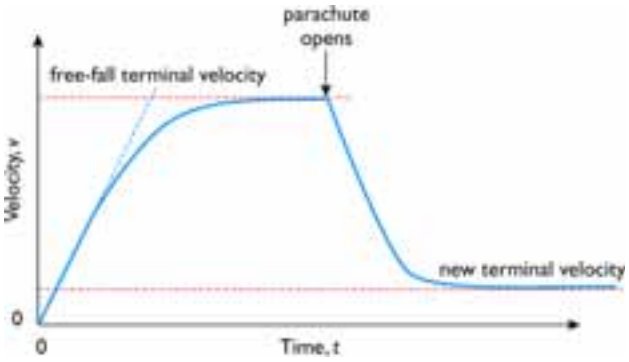
= 213 m/s (1)

4 a) Use $v = u + at$, where $u = 0$, $a = 9.8$ m/s^2 and $t = 30$ s

so speed, v, after 30 s = 9.8 m/s^2 × 30 s (1)

= 294 m/s (1)

b) Your graph should look similar to this: (2)



The acceleration gets less as she gets faster, as the air resistance increases. (1)

She slows down when the parachute opens because it increases her air resistance suddenly. (1)

5 a) Deceleration = reduction in velocity ÷ time taken (1)

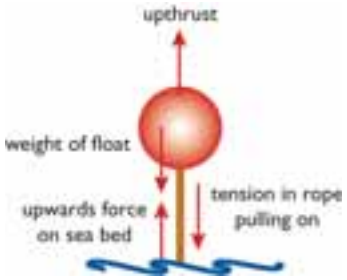
= (40 m/s – 0 m/s) ÷ 10 s (1)

= 4 m/s^2 (1)

b) Use $F = ma$, so braking force, F = 700 kg × 4 m/s^2 (1)

= 2800 N (1)

6 a) (1) for each correctly identified force in the correct direction.

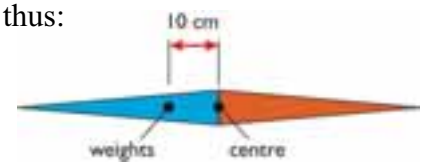


b) There is no unbalanced force on the float (1); the sum of the forces acting on the float is zero (1)

c) When the rope breaks there is a resultant upward force on the float (1) so it accelerates upwards (1).

7 **a)** The moment of a force about a point is the product of the force (1) and the perpendicular distance from the line of action of the force to the point. (1)

b) Position five 0.1 N weights (1) on the hand, to the left of the centre of the hand (1), at a distance of 0.1 m (10 cm) from the centre (1), thus:



(2 marks for clearly labelled diagram)

8 **a)** 150 N at A (1) and 150 N at B (1)

b) Total weight hanging on frame = 650 N (1)

They are $\frac{1}{3}$ of the way from A (1)

so $\frac{2}{3}$ of the weight will be supported by A (1)

so the force on A is 433 N (1)

c) At A (1)

9 **a)** Momentum = mass × velocity (2)

b) Use total momentum before explosion = total momentum after explosion. (1)

Cannon and ball are stationary initially, so momentum before is zero. (1)

Momentum of cannon ball = 10 kg × 60 m/s = 600 kg m/s (1)

so 200 kg × velocity of cannon after explosion = –600 kg m/s (1)

velocity of cannon after explosion = 3 m/s (1)

which means the cannon recoils, moving in the opposite direction from the cannon ball (1)

10 **a)** Mercury, Venus and Mars (1)

b) 30 years

c) 1425 million kilometres (2)

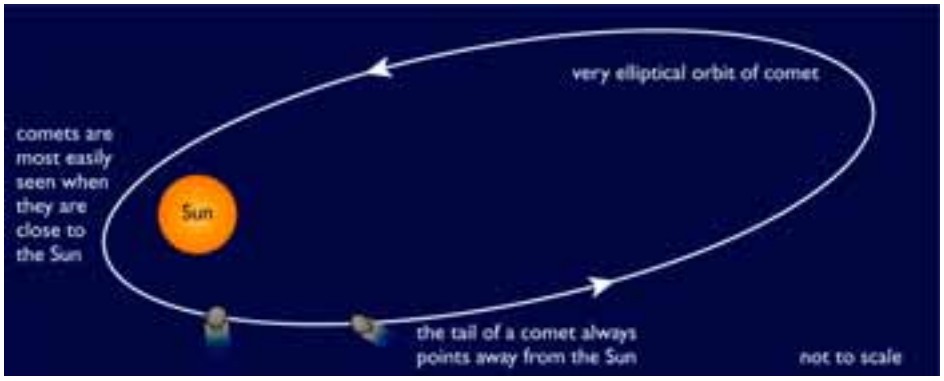
d) orbital speed = $\frac{2\pi r}{T}$

T in seconds = 30 × 365.25 × 24 × 60 × 60 = 946 728 000 s

speed = $2 \times \pi \times \frac{1425000000}{946728000}$

= 9.5 km/s

11 **a)** Your diagram should show an ellipse (1), with the Sun near one end of it (1):



b) As a comet gets closer to the Sun, the gravitational forces acting upon it increase (1) and it speeds up (1). As it travels away from the Sun, the Sun's gravity slows it down (1) so its speed is least when it is furthest from the Sun (1).

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Chapter 7

1 **a)** 3 W

b) 50 V

c) 0.26 A

d) 100 W × 18 000 s = 1 800 000 J (1800 kJ)

2 **a)** The kettle is designed for a voltage of 230 V. At this voltage, 1.5 kJ of electrical energy is transferred into heat energy each second.

b) $I = \frac{P}{V} = \frac{1500\,\text{W}}{230\,\text{V}} = 6.52$ A. The fuse should be rated at around 7 A or above. The next common rating above this is 13 A, so a 13 A fuse is needed.

c) Electrical energy is being transferred at the rate of 100 J/s in the 100 W bulb but only at 60 J/s for the 60 W bulb.

3 **a)** It can be reset. It does not need to be replaced.

b) So no electrical energy can enter the appliance. If the switch was in the neutral wire, electricity could enter the appliance and could possibly cause a shock if the appliance was faulty.

c) The outer casing is made from an insulator, e.g. plastic.

Chapter 8

1 **a)** i) +1

ii) –1

iii) no charge

b) Protons and neutrons are in the nucleus of an atom. Electrons orbit the nucleus of an atom.

c) The same number.

d) An ion.

e) Your diagrams should show that the rubbing transfers electrons from one object to the other. The object that gains electrons becomes negatively charged. The object that loses electrons becomes positively charged.

2 **a)** Static electricity, i.e. excess charge escaping from the shirt/blouse causes tiny sparks which make a noise.

b) Static electricity is escaping through you and the door handle to earth.

c) The comb has become charged with static electricity whilst being used. It induces charge on the paper, and the two attract.

d) Whilst turned on, the screens become charged. They induce charges on nearby small objects such as dust particles. The particles are then attracted to the screens.

3 **a)** The toner will stick only to those parts of the drum that are charged.

b) As they pass through the negatively charged mesh, the dust particles become negatively charged. Higher up the chimney, these charged particles induce the opposite charge on the earthed metal plates, and so are attracted to them.

4 **a)** i) Clouds possibly become charged as tiny ice particles are moved up and down within them. There are other possible explanations.

ii) The conductor is a metal strip, usually from a lightning rod on the roof, and running down the outside of the building. This provides a low-resistance path to earth, so current caused by the lightning flows down the conductor instead of through the building (which would damage the building).

b) i) Unsafe – any two from: near isolated trees/pylons, in swimming pools, on high ground, on top of buildings.

ii) Safe – inside a building or inside a car.

5 Workers connect themselves to the casing of the appliance on which they are working, using a wrist loop and wire. This allows any difference in charge between the worker and the computer to travel along the wire safely, rather than causing a sudden spark.

Chapter 9

1 **a)** Electrons

b) There is a large number of free charge carriers (free electrons) in metals, but very few in a plastic.

c) i) 3 C

ii) 1800 C

iii) 10 800 C

2 **a)** i) Charges can travel all the way around a complete circuit. An incomplete circuit has gaps, so charges cannot travel all the way around.

ii) In a series circuit there is only one path for the current to follow. In a parallel circuit there is more than one path for the current to follow.

b) S1 Bulbs A, B and C will go out.

S2 Bulbs A, B and C will go out.

S3 Bulbs D, E, F, G and H will go out.

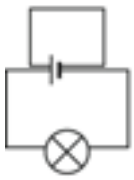
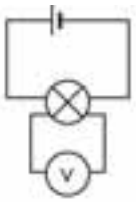
S4 Bulbs D and E will go out.

S5 Bulbs F, G and H will go out.

S6 Bulbs G and H will go out.

c) All the bulbs will glow with equal brightness.

d) It is a series circuit, therefore the current through all bulbs is the same.

3 **a)** i)  ii) 

b) As each coulomb of charge passes through the 1.5 V cell, it receives 1.5 J of electrical energy.

4 **a)** In the positions shown, the bulb will glow. If S1 is moved to B, the circuit is incomplete and the bulb will be turned off. If S2 is then moved to D, the circuit is again complete and the bulb will glow.

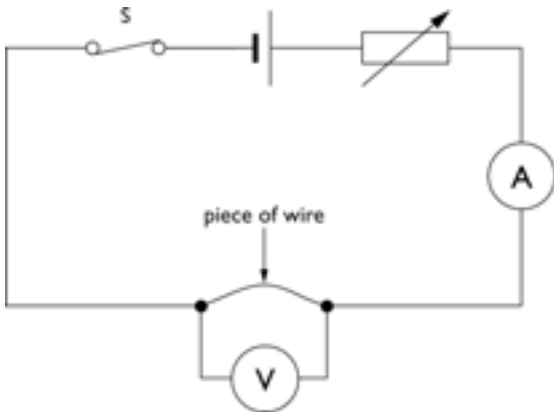
b) Turning lighting on and off from top and bottom of a staircase.

5 In parallel. If the lights are wired in series, the current through the string of lights will be too small to make them glow, and any faulty bulbs will result in all the bulbs going off.

Chapter 10

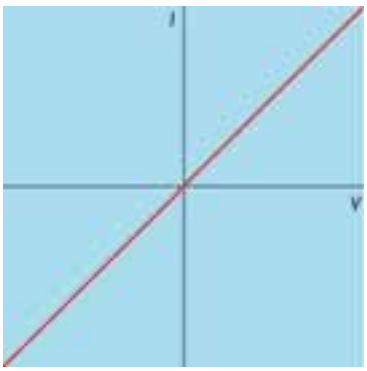
1 **a)** The current that flows through a conductor is directly proportional to the potential difference (or voltage) across its ends, provided its temperature remains constant.

b)

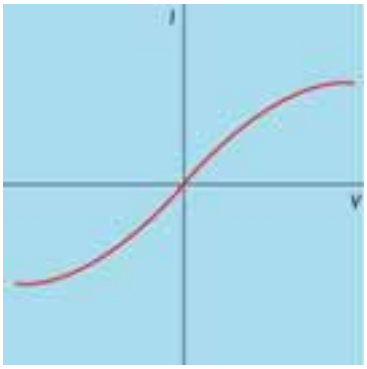


c) Close the switch and take readings on ammeter and voltmeter. Alter the variable resistor and take new readings. Repeat this at least six times. A graph of *I* against *V* will show a straight line passing through the origin, confirming Ohm's law.

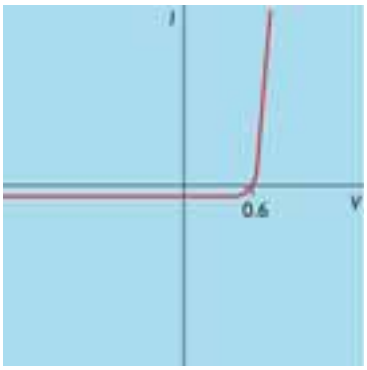
d) i) A straight line graph passing through the origin, indicating a constant resistance.



ii) As the current increases, the filament gets hotter and its resistance increases.



iii) The resistance in one direction is very high, i.e. the diode will not conduct. The resistance in the opposite direction is much smaller, i.e. the diode will conduct.



2 **a)** 4 Ω

b) 0.24 A

c) 30 V

3 **a)** i) Decrease its temperature.

ii) Decrease the intensity of the light.

b) Thermistors can be used in temperature circuits such as fire alarms and thermostats. LDRs can be used in light-sensitive circuits such as automatic lighting controls.

End of Section B questions

1 electrons, coulomb, energy

resistance, lower (5)

2 **a)** Y is an ammeter, (1)

Z is a voltmeter (1)

b) variable resistor (1)

c) It can be used to change the current. (1)

d) 2.5 A (1)

e) 4.0 V (1)

f) $R = 4.0\ \text{V}/2.0\ \text{A}$ (1)

$= 2.0\ \Omega$ (1)

g) It increases. (1)

3 **a)** $I = V/R$ (1)

$= 12\ \text{V}/10\ \Omega = 1.2\ \text{A}$ (1)

b) $Q = I \times t$ (1)

$= 1.2\ \text{A} \times 5\ \text{s} = 6\ \text{C}$ (1)

c) $\text{E} = \text{V} \times \text{I} \times \text{t}$ (1)

$= 12\ \text{V} \times 1.2\ \text{A} \times 60\ \text{s} = 864\ \text{J}$ (1)

4 **a)** $I = \frac{P}{V}$ (1)

$= \frac{2000\ \text{W}}{230\ \text{V}}$ (1)

$= 8.7\ \text{A}$ (1)

b) 13 A (1)

c) A double-insulated appliance has an outer casing made of plastic or other insulating material. (1)

So even if there is a fault inside, making a live wire touch the casing, the user will not get a shock. (1)

5 **a)** Two insulating materials are rubbed together (1), which transfers some electrons from one material to the other (1). The material that gains electrons has a negative charge (1) and the material losing electrons has a positive charge (1).

b) i) Any static charge that has built up on the aircraft in flight (1) can be discharged through the earthing wire (1) instead of causing a spark which could ignite fuel vapour (1).

ii) A wire is attached from the aircraft to a point on the tanker. (1)

c) Electrostatic painting attracts paint to the object being painted (1) so less paint is wasted (1) and therefore less paint can be used (1).

d) An inkjet printer uses the fact that opposite charges attract (1) and similar charges repel (1) to direct drops of ink to the correct places on the paper (1).

6 **a)** Any four uses, such as cooking, heating water for washing, heating the house, drying hair, etc.(1)

b) Any four rules ($\frac{1}{2}$ mark each), such as:

- do not poke objects into sockets, as you may get a shock
- make sure plugs are wired correctly, as an incorrectly wired plug may prevent the earth and fuse working properly
- use the correct size fuse, so that a fault cannot cause overheating and a fire
- never use broken plugs or frayed wires, as this may lead to bare wire being exposed which could cause a shock.

c) A fault in an appliance could lead to a live wire touching the casing ($\frac{1}{2}$), and the presence of an earth wire conducts the current to earth and blows the fuse ($\frac{1}{2}$). This prevents someone touching the casing getting a shock ($\frac{1}{2}$). A double-insulated hairdryer has an insulating case, so the person cannot get a shock even if the fuse has not blown ($\frac{1}{2}$).

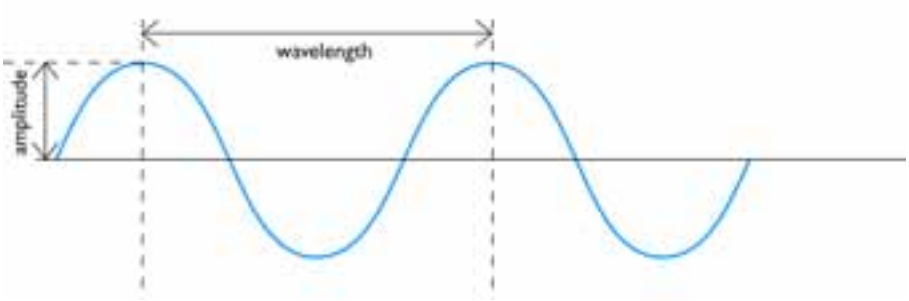
Chapter 11

1 **a)** The vibrations of a transverse wave are **across** the direction in which the wave is moving. The vibrations of a longitudinal wave are **along** the direction in which the wave is moving.

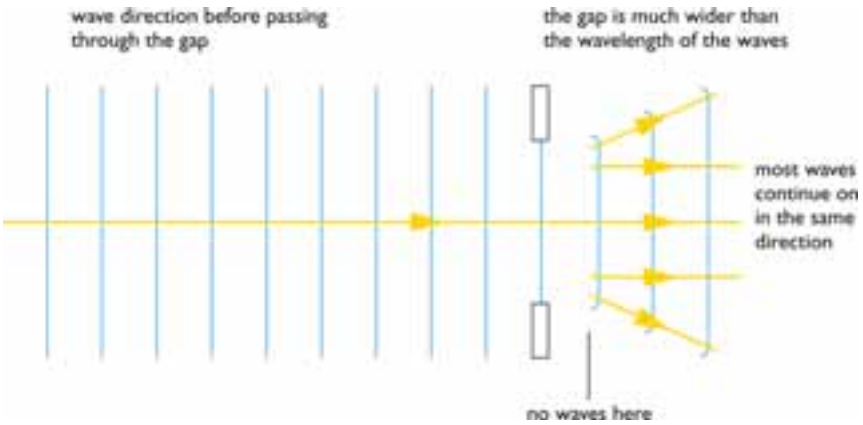
b) Transverse waves: light (or any other electromagnetic wave) or surface water waves.

Longitudinal waves: sound waves.

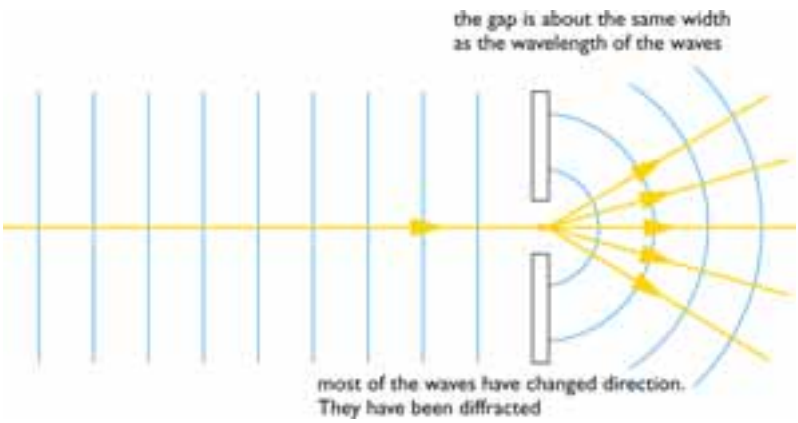
c)



2 **a)**



b)



c) It is not desirable to have the harbour entrance the same size as the wavelength of water waves during a storm. If this does happen, the waves will be greatly diffracted as they enter the harbour and there will be very few areas where the water is calm.

3 **a)** 0.4 s

b) 2.5 Hz

4 **a)** $f = \frac{v}{-} = \frac{1500\,\text{m/s}}{1.5\,\text{m}} = 1000\ \text{Hz}$

b) $T = \frac{1}{f} = 0.001\ \text{s}$

Chapter 12

1 **a)** They all transfer energy, are transverse waves, travel at the same speed through a vacuum, can be reflected, refracted and diffracted.

b) Light, microwaves and radio waves

c) Microwaves and infra-red waves

d) Gamma rays

e) Infra-red

f) Microwaves

2 **a)** Water molecules within the food absorb the microwaves and become hot, so the food cooks throughout, not just from the outside as in the case of a normal oven.

b) X-rays pass easily through soft body tissue but cannot travel through bones. Therefore bones leave 'shadows' on X-ray photographs, which show the shape of the bone and therefore can show if bones have been broken.

c) The Earth's ozone layer absorbs large quantities of the Sun's UV radiation. If this layer is damaged, more UV light will reach the surface of the Earth. UV light is harmful to human eyes and can cause skin cancer.

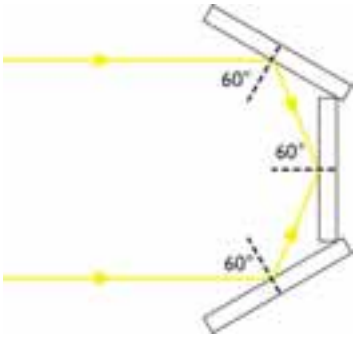
d) Exposure to gamma radiation kills the micro-organisms in food and so delays their decay.

3 **a)** A signal that is converted into electrical voltages or currents that vary continuously is called an analogue signal. A signal that is converted into a sequence of numbers is called a digital signal.

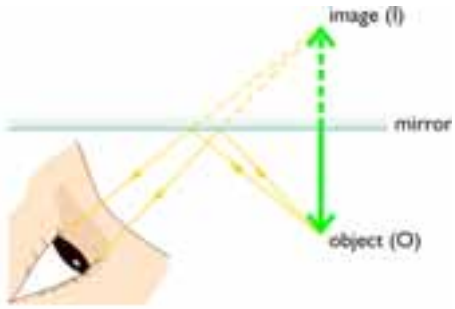
c) Regeneration of a digital signal produces a clean, accurate copy of the original. The data are often more easily processed.

Chapter 13

1 Your diagram could look something like this:



2 a)

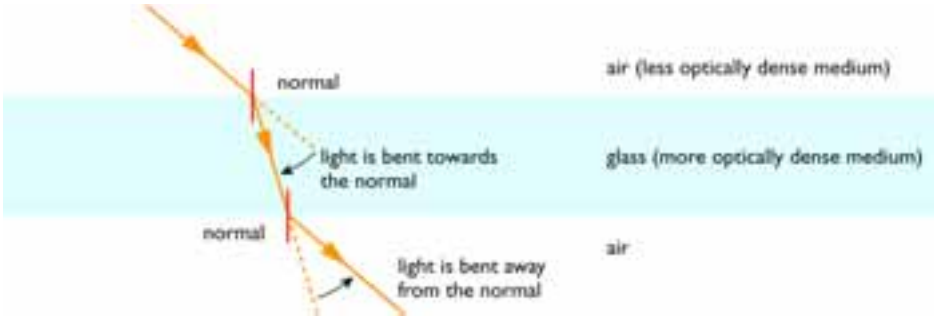


b) The image is as far behind the mirror as the object is in front. The image is the same size as the object. The image is virtual. The image is laterally inverted. The image is the same colour as the object.

c) 10 m

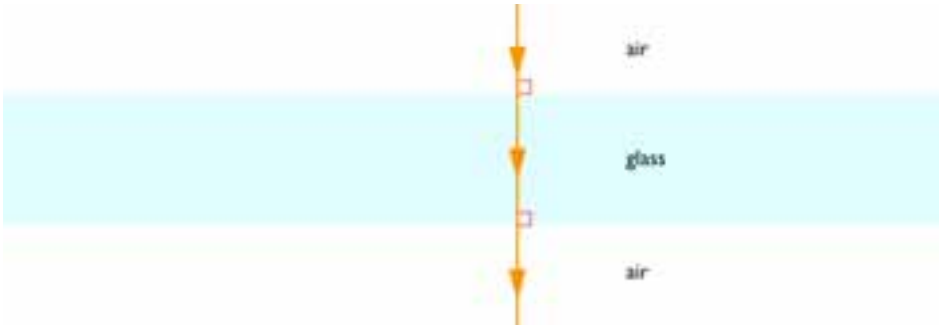
d) 2 m/s

3 a) and **b)**



c) As the ray of light enters the glass block, it slows down and is refracted towards the normal. As the ray leaves the glass block, its speed increases and it is refracted away from the normal.

d)



4 a) $n = \frac{\sin i}{\sin r} = \frac{\sin 55°}{\sin 31°} = 1.59$

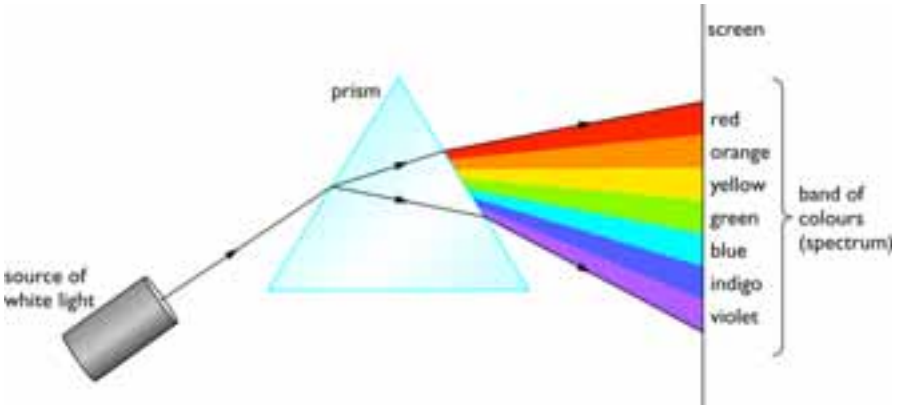
b) $\sin r = \frac{\sin i}{n} = \frac{\sin 45°}{1.59} = 0.445$

$r = 26.4°$

c) $\sin c = \frac{1}{n} = \frac{1}{1.59} = 0.629$

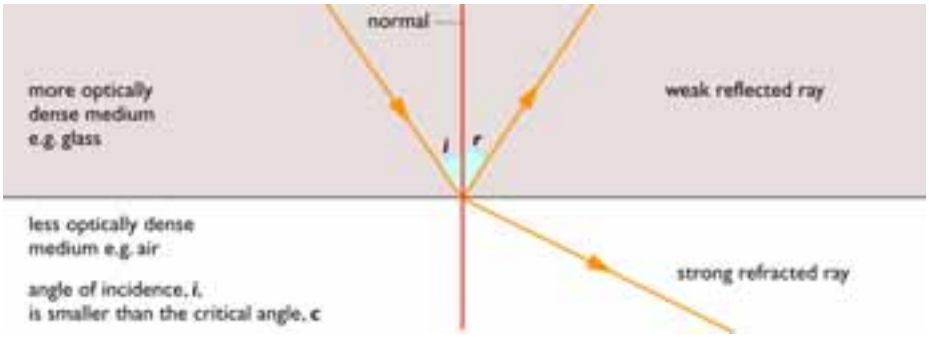
$c = 39°$

5 a)

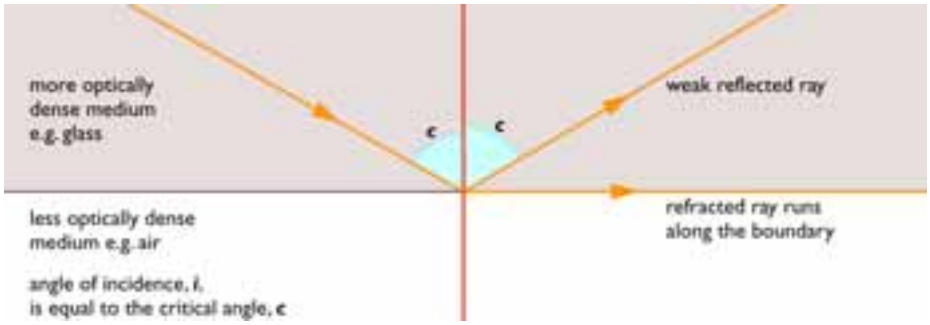


b) White light is composed of a mixture of colours. Because each colour travels at a different speed through the prism, they are refracted through different angles.

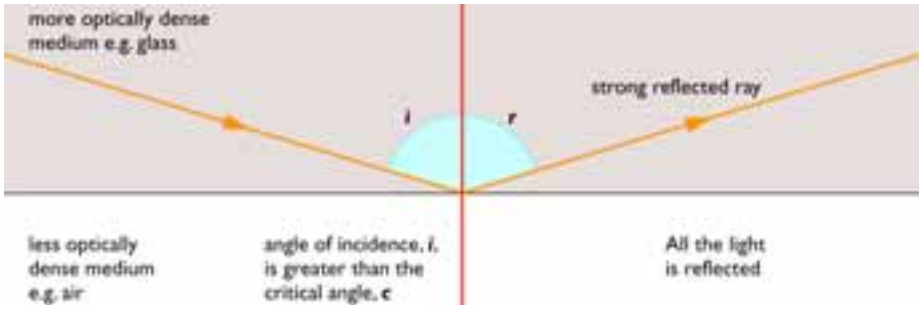
6 a)



b)

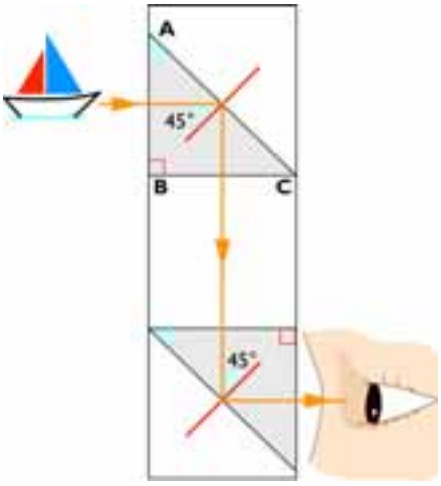


c)



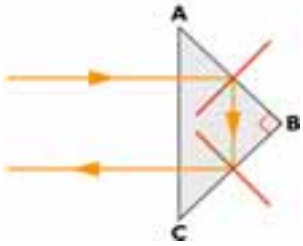
7 **a)** If a ray of light travelling from a more dense medium into a less dense medium strikes the boundary between the two at an angle greater than the critical angle, the ray is reflected by the boundary and is not refracted. This phenomenon is called total internal reflection.

b)



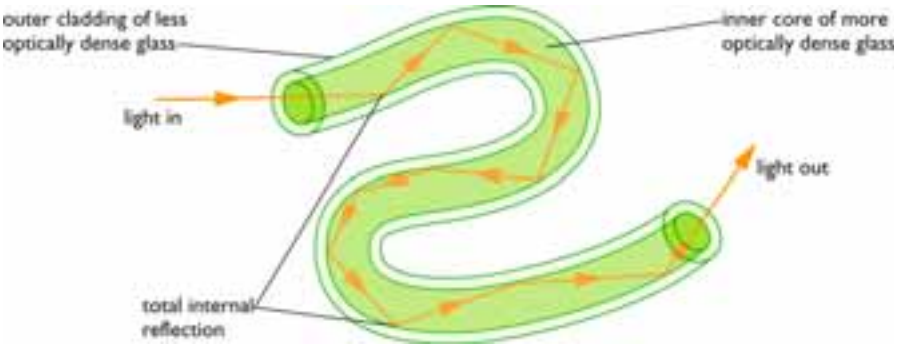
c) The final image created by a prismatic periscope is likely to be sharper and brighter than that produced by a periscope, which uses mirrors.

d)



Bicycle reflectors and binoculars use prisms to turn light through 180°.

8 **a)**



As the fibres are very narrow, light entering the inner core always strikes the boundary of the two glasses at an angle that is greater than the critical angle.

b) If the outer glass of an optical fibre had a higher refractive index, light within the fibre striking the boundary would be refracted and escape through the sides.

c) Optical fibres are used in the construction of endoscopes. Bundles of optical fibres carry light into and out of a patient's body. Images of the inside of the body can be created from the reflected light.

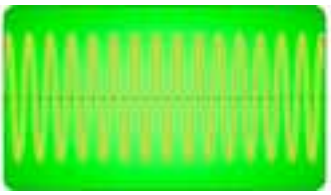
Chapter 14

1 **a)** Any suitable instrument, e.g. piccolo, flute, violin etc.

b) The air column is short/strings are short, and so vibrate quickly, i.e. at a high frequency.

c) Blow harder/bow the strings more vigorously so that the amplitude of vibration is larger.

d)



2 **a)** An echo is a reflected sound wave.

b) Sound waves are emitted from the ship and travel to the seabed. Equipment on the ship detects some of the sound waves reflected from the seabed. The depth of the sea can be calculated from the time between sending the sound wave and detecting the echo.

c) Distance travelled in 4 s = 1500 m/s × 4 s = 6000 m, so depth of water = 3000 m

3 **a)** This person cannot hear sounds with frequencies less than 20 Hz or greater than 20 000 Hz.

b) Sounds with frequencies greater than 20 kHz that cannot be heard by the human ear are called ultrasounds.

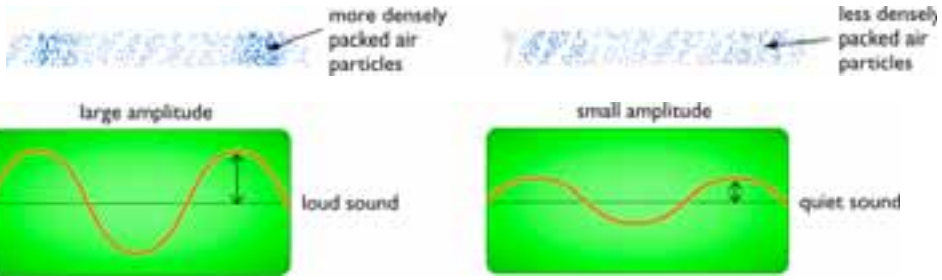
c) $\lambda = \frac{v}{f} = \frac{340\,\text{m/s}}{69\,000\,\text{Hz}} = 0.005\,\text{m}$

4 **a)** There is no atmosphere on the Moon, i.e. there are no particles to carry the sound energy.

b) When their helmets touch there is no longer a vacuum between them, the sound energy can travel through their helmets.

5 **a)** When the source is vibrating with a small amplitude, the disturbance of each air particle as the wave passes is fairly small and the sound is quiet. If the source is vibrating with a large amplitude, the particles are displaced further from their rest position as each wave passes, and we hear a louder sound.

b)

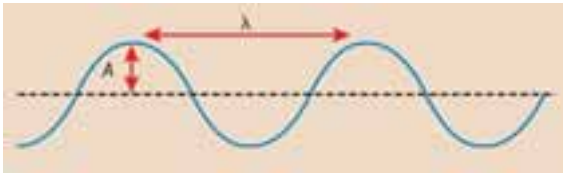


End of Section C questions

1 **a)** The waves spread out. (1)

b) Diffraction (1)

c) Make the gap in the harbour wall much larger. (1)

d) 

e) $f = v / \lambda$ (1)

$= \frac{20\,\text{m/s}}{2.5\,\text{s}}$ (1)

$= 8$ Hz (1)

2 **a)** A less dense glass, i.e. a glass with a lower refractive index. (1)

b) A more dense glass, i.e. a glass with a higher refractive index. (1)

c) The light is striking the boundary at an angle greater than the critical angle (1) so total internal reflection takes place. (1)

d) Optical fibres are used in endoscopes. These allow doctors/surgeons to see inside the body, and make keyhole surgery possible. (1)

3 **a)** i) The vibrations of a longitudinal wave are along the direction in which the wave is travelling (1). The vibrations of a transverse wave are across the direction in which the wave is travelling. (1)

ii) Sound waves are longitudinal waves. (1) Light waves and surface water waves are transverse waves. (1)

b) To improve the accuracy of the experiment. (1)

c)

Experiment	Time in seconds	Speed of sound in m/s
1	2.95	339
2	3.00	333
3	2.90	345
4	3.20	313
5	2.95	339

(1 mark for each row of table completed)

Average speed of sound from experiment = 334 m/s (1)

d) No. The effect of any wind is cancelled out as the sound travels in one direction as it approaches the building, and in the opposite direction as it returns.

4 **a)** Radio waves, microwaves, infra-red waves, visible spectrum, ultraviolet waves, X-rays, gamma rays. (2)

b) All these waves transfer energy (1), are transverse waves (1), travel at the speed of light in a vacuum (1), can be reflected, refracted and diffracted (1).

c) Radio waves – communication (1); microwaves – communication/cooking (1); infra-red waves – cooker/heater/remote control/night vision (1); visible light – seeing/communication (1); ultraviolet waves – fluorescent tubes/tanning lamps (1); X-rays – X-radiography (1); gamma rays – sterilising food or equipment/radiotherapy (1).

d) Gamma rays (1), X-rays (1) and ultraviolet waves (1).

e) Radio waves (1), microwaves (1) and visible light (1).

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Chapter 15

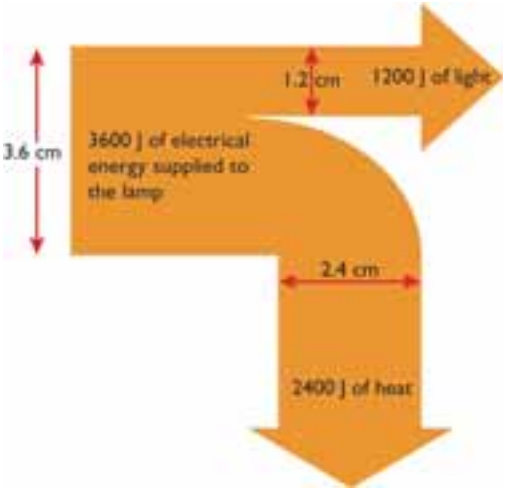
1 **a)** Stored chemical energy in the battery → electrical energy in the circuit → heat and light in the lamp filament.

b) Stored chemical energy in the paraffin wax → heat and light as the candle burns.

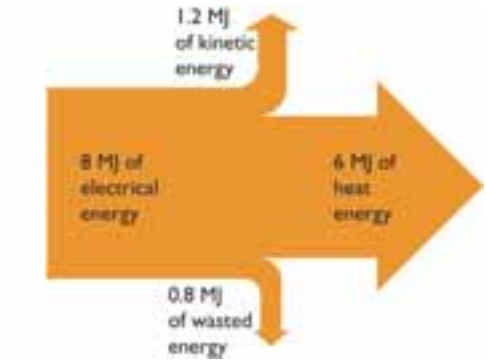
c) Kinetic energy of moving hands → heat energy.

d) Stored energy in the stretched elastic of the trampoline → kinetic energy of the trampolinist moving upwards → gravitational potential energy as the trampolinist slows to a halt at the top of the bounce.

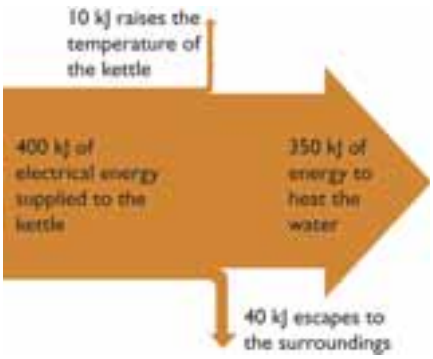
2 **a)**



b)



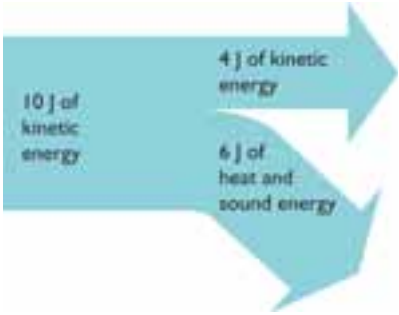
3 **a)**



b) Efficiency $= \frac{350}{400} = 0.875$

4 **a)** 6 J of energy is converted to heat in the ball and the ground and to sound.

b)



Chapter 16

1 **a)** Some of the heat energy in the tea is transferred to the spoon. Also, the metal spoon is a good conductor of heat, so it increases the area from which the heat of the tea can be lost.

b) The plastic lid traps a layer of air above the tea. Air is a poor conductor of heat. The trapped layer of air also greatly reduces heat loss from the surface of the hot tea by preventing convection currents in the air above the cup. It also reduces the amount of heat lost through evaporation.

2 **a)** Copper is a very good conductor of heat – this allows the water in the kettle to heat up quickly, as the energy from the stove is easily transferred through the copper to the water within the kettle. This might be considered to be a disadvantage also, as the heat transfer from the water inside the kettle to the outer surface of the kettle is also rapid.

b) A shiny surface reduces heat loss by thermal radiation. A kettle allowed to go black would radiate more heat from its surface than a shiny, clean one.

3 Although paper is a poor thermal conductor, it is thin, so heat can transfer through it quite rapidly. This heat energy is then rapidly conducted away from the paper by the brass section, because brass is a very good thermal conductor. Wood is a poor thermal conductor, so heat is transferred from the paper much more slowly, so the temperature of the paper rises enough for the paper covering it to start to scorch.

4 Both benches will be in thermal equilibrium with the surroundings, that is, they will both be at the same temperature as their surroundings and, therefore, each other. Thus the metal bench is not actually colder than the wooden one *to start with*. However, the metal bench conducts heat much more readily than the wooden bench. Heat from the body is quickly conducted away from the body by the metal bench, and the region beneath the person's body remains close to the air temperature. As heat travels much more slowly through the wood, the region under the person sitting on the wooden bench *does* warm up – as its temperature gets close to the person's body temperature, the rate at which heat is transferred from the body into the bench is reduced and the bench does not feel as cold.

5 **a)** Water is a relatively poor thermal conductor. As it is a fluid (capable of flowing or moving around), the main mechanism of heat transfer is convection. Convection means that heated water, which expands and becomes less dense, is displaced upward by colder and therefore denser water. If the heating element was positioned near the top of the water in the kettle, only the top layer of water would be heated, because the colder denser water would be *below* the element and would not be directly heated by contact with the heating element.

b) At the top. Air cooled by the element will become more dense and will sink down the freezer. If the cooling element was placed at the bottom, only the bottom layer of air would become cold.

6 The slots at the top allow air that has been heated by the computer circuitry and thus become less dense to be pushed upwards by colder, denser air drawn in through the slots in the base of the computer case. This convection current means that there is a steady stream of cooler air drawn across the electronic circuitry, helping to keep it cool. Convection does not take place so effectively if the ventilation slots are in the sides of the case at the same level, so fans are necessary to maintain a sufficient circulation of cool air across the circuitry.

7 The fire heats the air in the right-hand shaft in the diagram. This air expands and becomes less dense, and is therefore pushed upwards by colder, denser air drawn down the other shafts in the mine. This ensures there is a steady circulation of fresh (colder, denser) air drawn down the shaft on the left of the diagram.

Chapter 17

1 **a)** A wide range of answers possible, e.g. rubbing hands to warm them.

b) Heat water to produce steam, which is then used to rotate a turbine.

2 **a)** joule

b) The joule is the amount of work done when a force of 1 N is applied through a distance of 1 m in the direction of the force.

c) For each use, work done = force × distance

i) $W = 6 \times 1\ \text{N} \times 0.8\ \text{m} = 4.8\ \text{J}$

ii) $W = 100\,000\ \text{N} \times 200\ \text{m} = 20\ \text{MJ}$

iii) $W = (60\ \text{kg} \times 10\ \text{N/kg}) \times 2.8\ \text{m} = 1680\ \text{J}$

iv) $W = (350\ \text{kg} \times 10\ \text{N/kg}) \times 45\ \text{m} = 157.5\ \text{kJ}$

3 Use gravitational potential energy = mgh

GPE = 200 000 000 kg × 10 N/kg × 550 m = 1 100 000 MJ

4 **a)** Use the formula $\text{KE} = \frac{1}{2}\ mv^2$ where m is the mass of the moving object in kg and v is its velocity in m/s to give the KE in joules.

b) i) $\text{KE} = \frac{1}{2} \times 80\ \text{kg} \times (9\ \text{m/s})^2$ so KE = 3240 J

ii) $\text{KE} = \frac{1}{2} \times 0.0002\ \text{kg} \times (50\ \text{m/s})^2$ so KE = 0.25 J

iii) $\text{KE} = \frac{1}{2} \times 0.06\ \text{kg} \times (24\ \text{m/s})^2$ so KE = 17.28 J

5 At the top of the stone's flight, all of its initial KE is converted to GPE, so

48 J = mgh, where m = 0.04 kg and g = 10 N/kg, hence

h = 48 J ÷ (0.04 kg × 10 N/kg) = 120 m.

6 The initial GPE that the coin has is completely converted to KE when it reaches the ground, so $mgh = \frac{1}{2}mv^2$. As mass, m, is common to both sides of the equation, it cancels to give $gh = \frac{1}{2}v^2$. Rearranging, we can calculate the velocity $v = \sqrt{(2gh)}$, so $v = \sqrt{(2 \times 10\,\text{N/kg} \times 80\,\text{m})}$, so $v = 40$ m/s.

7 Power is the rate of doing work (or the rate of converting energy) and can be calculated using power = work done in J ÷ time taken in s. The unit of power is the watt.

8 **a)** Weight = mass × gravitational field strength, so the person weighs 400 N

b) Total height = height of one step × number of steps = 4 m

c) Work done = force × distance = 1600 J

d) Power = work done ÷ time taken, so the person's power output is 133 W

9 **a)** i) 144 km/h × 1000 m/km = 144 000 m/h

ii) 144 000 m/h ÷ 3600 s/h = 40 m/s

b) KE = $\frac{1}{2} \times 500\,\text{kg} \times (40\,\text{m/s})^2 = 400\,000$ J

c) Assuming no energy is converted to other forms than movement (impossible in reality), then the average power developed by the engine is 400 000 J ÷ 5 s = 80 000 W

Chapter 18

1 **a)** A non-renewable energy resource is not replaced at the same rate as it is used.

b) Coal, oil and gas are all examples of non-renewable energy sources, as they have all been produced by very slow processes in the Earth's crust. Nuclear fuels such as uranium are also non-renewable resources.

2 **a)** The greenhouse effect is the insulating effect that certain gases in the Earth's atmosphere cause. Carbon dioxide is a 'greenhouse' gas. Greenhouse gases allow the short wavelength infrared (thermal) radiation from the Sun to pass through to heat the Earth's surface. The heat that is re-radiated from the Earth is longer-wavelength infrared. The longer-wavelength thermal radiation is absorbed and re-radiated by gases such as carbon dioxide, so some of the heat is trapped in the atmosphere, causing it to heat up.

b) One of the main 'greenhouse' gases in the atmosphere is carbon dioxide. Carbon dioxide is produced when carbon-based fuels, like coal, oil, gas and wood are burnt. Much of the energy we use is obtained directly from burning these fuels, or from electricity that is produced by burning these fuels. If we reduce the amount of energy we use, and we reduce the amount of energy that we waste by having poor thermal insulation in our homes, then we can reduce the amount of carbon dioxide in the Earth's atmosphere.

3 **a)** Fossil fuels are fuels formed from long-dead organic materials (plants and animals) that have been converted into fuels such as coal, oil and gas.

b) All fossil fuels have carbon in them. When they are burnt, they produce waste products such as carbon dioxide. The waste products often have a damaging effect on the atmosphere and the environment.

4 **a)** There is enough nuclear fuel to meet our energy requirements for hundreds of years; with 'breeder' nuclear reactors that generate more nuclear fuel, we can meet the demand for energy indefinitely.

b) Nuclear power stations produce very dangerous radioactive waste products. These remain radioactive for tens of thousands of years. The processing and storage of the waste products is expensive, and no-one really knows whether they can be safely stored for all the time they remain dangerous. The radioactive materials could be used by terrorists to produce nuclear weapons. The cost of setting up and decommissioning (closing down) nuclear power stations is far greater than that for conventional power stations. Accidents involving leaks and explosions at nuclear power stations can have devastating effects over a large area, that last for very long periods.

5 **a)** Three examples from: wind energy, wave energy, tidal energy, solar energy, geothermal energy, hydroelectricity, biomass, etc.

	Advantages	Disadvantages
Wind energy	Relatively cheap to set up Clean – no waste products Relatively efficient at converting energy into electricity	Only produce energy when it is windy Can be used only in certain places Can be an eyesore Can produce noise pollution
Wave energy	Continuously available Clean – no waste products Moderately efficient	Expensive to set up Only suitable in certain locations
Tide energy	Continuously available Clean – no waste products Efficient	Damaging to environment Expensive to set up Only suitable in certain geographical locations
Solar energy	Clean – no waste products	Expensive in terms of amount of energy produced Not very efficient method of converting energy into electricity Energy supply not continuously available Best suited to climates with low amounts of cloud cover
Geothermal energy	Clean – no waste products Can provide direct heating as well as heat/steam to drive electricity generators Moderate start-up costs	Suited only to geographical locations with relatively thin 'crust' or high volcanic activity
Hydroelectricity	Clean – no waste products Continuously available (unless severe drought)	Needs large reservoirs, which may displace people and/or wildlife Can be built only in hilly areas with plenty of rainfall
Biomass	The carbon dioxide it releases when it burns has only recently been taken out of the atmosphere by crops	Growing biomass crops instead of food can cause higher food prices and/or food shortages

6 **a)** Predictable changes in demand for electricity occur at times like the start of the day when people get up and turn on lights, make breakfast, wash, etc., and when factories start and finish work. Unpredictable changes in demand for electricity occur when there is a sudden change in the weather – e.g. a sudden cold spell, or when there is an advertising break during the coverage of a big sporting event and people switch on electric kettles to make a hot drink.

b) Any three from:

gas-fired power stations	Can respond to changes in demand quite quickly
coal-fired power stations	Take longer to respond to demand changes as it takes longer to 'fire up' a coal power station
nuclear-fired power stations	Only suited to steady supply of electricity as the reactors cannot be quickly run up to operating temperature or closed down
hydroelectric power stations	Can start up very quickly

7 Tidal power is continuously available and is produced by the gravitational effects of the Sun and Moon, so in this respect the energy supply is free. Tidal power produces no waste products to damage and pollute the environment. However, the cost of building and maintaining tidal power stations is quite high, and this must be included when costing energy produced in this way – it is thus not really zero cost. Tidal power stations may affect the ecology of their location, causing changes in sea currents and sea temperatures, so they are not really without any polluting effects.

End of Section D questions

1 **a)** A renewable energy source is one that is continuously available (1) or quickly replaceable (1)

b) Solar panels can be used whenever there is daylight (windmills can be used only when the wind is blowing) (1)

Solar panels can be used in space (windmills cannot as they require air movement) (1)

c) Windmills may affect local birdlife, but the land under them can still be farmed (1). Tidal power involves the construction of huge barrages, which can affect shipping and also tidal habitats and river habitats in the river being used (1). Wind turbines therefore have the least impact.

d) Advantage: available at predictable times. (1)

Disadvantage: not continuously available. (1)

2 **a)** Gain in KE = loss in GPE = mgh

= 1 kg × 10 N/kg × 400 m (1 for method)

= 4000 J (1 for answer with correct unit)

b) Energy transferred per kg of water = 4000 J (1)

Power = energy transferred each second (1)

= 300 kg/s × 4000 J/kg = 1 200 000 W (1)

60% is converted into useful output power = 720 000 W (720 kW) (1)

c) The power station can start up to supply electricity very quickly. (1)

Surplus electricity can be used to pump water up to the top reservoir, so 'storing' the energy. (1)

3 **a)** Work = force × distance (1)

= 8000 N × 30 m (1)

= 240 000 J (1)

b) Power output = $\frac{\text{work done}}{\text{time}}$ (1)

= $\frac{240000\,\text{J}}{7.5\,\text{s}}$ (1)

= 32 000 W (or 32 kW) (1)

c) Energy is wasted as heating in the motor (1), as friction in the motor bearings and winding gear (1), noise (1) and as air resistance to the moving lift (1).

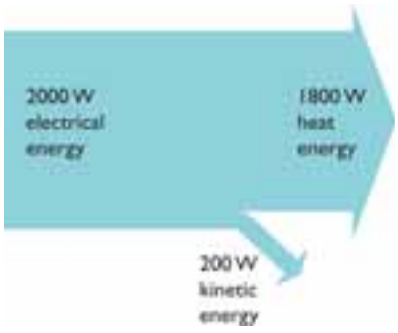
d) The counterweights should have approximately the same mass as the lift (1) with an average load (1).

e) When the motor is raising the lift, the counterbalance weights are falling (1) and as they do so they are transferring stored GPE (1), which helps to raise the lift, reducing the required energy output from the motor (1).

4 **a)** Double glazing traps a layer of air between the glass panes (1). As air is a poor conductor, this cuts down heat transfer by conduction (1). The width of the air gap is designed to restrict air circulation between the panes (1), thus cutting down heat transfer by convection (1). Glass allows short-wavelength IR waves from the Sun to enter the house (1), but traps longer-wavelength IR, stopping it being radiated back out of the window (1).

b) The gap (cavity) between the two layers of brick can be filled with an insulating material (1), which prevents convection currents transferring heat from the inside to the outside layer of bricks (1).

5 **a)** 1 mark for each part of the Sankey diagram drawn to the correct scale (3), plus 1 mark for correct labelling.



b) Efficiency = useful power output ÷ total power input (1)

= 1800 W ÷ 2000 W (1)

= 0.9 (or 90%) (1)

c) Air heated by the elements will become less dense (1) and will rise out of the heater (1). This will draw in colder air at the bottom of the heater (1) and a convection current will be set up around the room (1).

6 The bung is made of a poor thermal conductor (plastic or cork) (1). The vacuum between the two glass walls means that heat transfer through the flask walls *cannot* occur through either conduction or convection (1), as these both require a material to operate (1). The silvered surfaces reduce heat transfer by thermal radiation (1) because the silvered surface on the hotter side is a poor radiator of heat energy (1) and the second silvered surface is a very poor absorber of thermal radiation (1).

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Chapter 19

1 **a)** Submerged the crown in water and measured the volume of water displaced.

b) density = $\frac{\text{mass}}{\text{volume}}$, so mass = density × volume

mass of crown should be 19 000 kg/m^3 × 0.0001 m^3

= 1.9 kg

2 **a)** The person's weight will be spread out over the area of the ladder, so the pressure on the roof will be less.

b) Area of one foot = 0.021 m^2

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{850\,\text{N}}{0.021\,\text{m}^2} = 40\,476\ \text{N/m}^2$$

c) Force = 850 N + 70 N = 920 N

$$\text{Pressure} = \frac{920\,\text{N}}{0.3\,\text{m}^2} = 3067\ \text{N/m}^2$$

3 **a)** p = 0.1 m × 1000 kg/m^3 × 10 N/kg

= 1000 N/m^2

b) 1000 N/m^2

c) The gas pressure at B is supporting 10 cm of water, plus the pressure of the atmosphere on the surface of the liquid at A.

Chapter 20

1 **a)**

Property	Solids	Liquids	Gases
Spacing of particles	Very close	Very close	Far apart
Pattern	Regular pattern	Random	Random
Forces between particles	Very strong	Strong	Weak

b) The spacing between particles explains why solids and liquids are very difficult to compress, but gases can easily be compressed.

The forces between particles explain why solids have a fixed shape, but liquids and gases do not.

The very weak forces between particles in a gas explain why gases expand to fill their containers.

2 particles, motion, particles, faster, particles, colliding, increase, particles, faster

3 As a substance is cooled, the pressure it exerts gets smaller as the particles move more slowly. Absolute zero is the temperature at which the particles are not moving/the gas is exerting zero pressure.

4 **a)** i) 273 K

ii) 373 K

iii) 293 K

b) i) –23 °C

ii) –4 °C

iii) 32 °C

5 **a)** The piston moves out. The particles will move faster when they are heated, so there will be more, and harder, collisions with the walls of the container and the piston, increasing the pressure. The increased force on the piston will make it move.

b) As the beaker is pushed down, pressure from the water will tend to compress the air trapped in the beaker, so the particles in the air will be closer together.

c) As the container is heated the particles inside will move faster. The pressure will increase, and may increase enough to force the cork out of the opening.

6 **a)** $p_1V_1 = p_2V_2$

$$\text{so } V_2 = \frac{p_1V_1}{p_2} = \frac{100\,\text{kPa} \times 500\,\text{m}^3}{125\,\text{kPa}} = 400\,\text{m}^3$$

b) The temperature remains constant, as the equation used is only valid if there are no changes in temperature.

7 **a)** $\frac{p_1}{T_1} = \frac{p_2}{T_2}$, assume atmospheric pressure is 100 kPa

$$\text{so } p_2 = \frac{p_1 \times T_2}{T_1} = \frac{100\,\text{kPa} \times 268\,\text{K}}{293\,\text{K}} = 91.5\,\text{kPa}$$

b) The pressure inside the jar is now less than atmospheric pressure, so there will be a force holding the lid onto the jar.

End of Section E questions

1 increases, Absolute, cool, –273, Kelvin

pressure, increase, harder (8)

2 **a)** Mass of one bar = volume × density (1)

$= 0.0004\ \text{m}^3 \times 19\,000\ \text{kg/m}^3$ (1)

$= 7.6\ \text{kg}$ (1)

$$\text{So no. of bars} = \frac{70}{7.6} = 9.21$$ (1)

So 9 bars per crate, as we need an answer in whole numbers. (1)

b) volume of iron in crate $= \dfrac{\text{mass}}{\text{density}}$ (1)

$= \dfrac{64\,kg}{8000\,kg/m^3}$ (1)

$= 0.008\ m^3$ (1)

So there are $\dfrac{0.008}{0.0004} = 20$ bars (1)

3 **a)** Pressure $= \text{depth} \times \text{density} \times g$ (1)

$= 30\ m \times 1030\ kg/m^3 \times 10\ N/kg$ (1)

$= 309\,000\ Pa$

b) depth $= \dfrac{\text{pressure}}{(\text{density} \times g)}$ (1)

$= \dfrac{20000}{(1030 \times 10)}$ (1)

$= 1.94\ m$ (1)

c) density $= \dfrac{\text{pressure}}{(\text{depth} \times g)}$ (1)

$= \dfrac{197000}{(20 \times 10)}$ (1)

$= 985\ kg/m^3$ (1)

4 **a)** $30 \times 50\ cm^3$ (1)

$= 1500\ cm^3$ (1)

b) $p_1V_1 = p_2V_2$ (1)

so $p_2 = \dfrac{p_1V_1}{V_2}$ (1)

$= 100\ kPa \times 1500\ cm^3 / 1000\ cm^3$ (1)

$= 150\ kPa$ (1)

5 **a)** $\dfrac{p_1}{T_1} = \dfrac{p_2}{T_2}$ (1)

so $p_2 = p_1 \times \dfrac{T_2}{T_1}$ (1)

$= 100\ kPa \times \dfrac{333\,K}{293\,K}$ (1)

$= 113.7\ kPa$ (1)

b) Difference in pressure = 113.7 kPa – 100 kPa (1)

= 13.7 kPa (1)

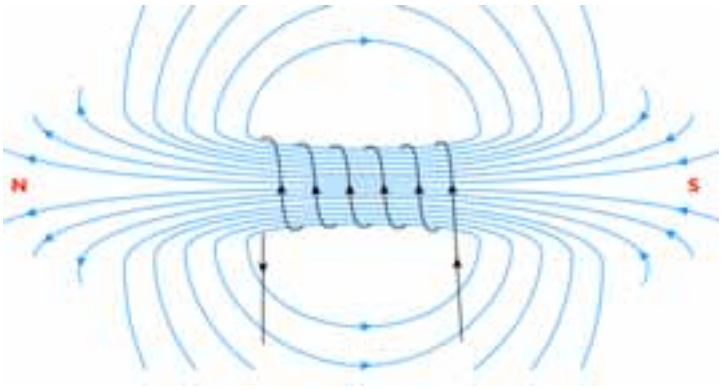
Force = pressure × area (1)

= 13 700 N/m^2 × 0.001 m^2 (1)

= 13.7 N (1)

Chapter 21

1 a)



b) The magnetic field is strongest where the field lines are closest together and weakest where they are furthest apart.

c) The directions of the magnetic field and its poles are also reversed.

2 a) A magnetic field was created around the wire when current passed through it.

b) From right to left. The magnetic field around the wire is circular, with the wire at its centre. It therefore is in opposite directions on opposite sides of the wire.

c) No. If the current flowing through the wire is reversed, the direction of the magnetic field around the wire is also reversed.

3 a) Iron loses its magnetism when the current through the coil is turned off, i.e. the electromagnet is turned off. This is not the case with steel. It retains its magnetism after the current/electromagnet has been turned off.

b) Increase the current flowing through the coils, increase the number of coils.

Chapter 22

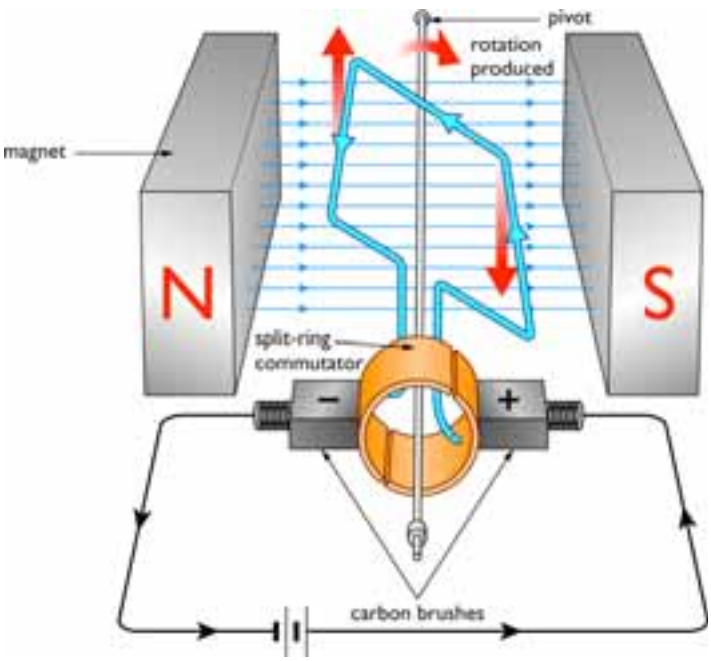
1 a) The wire is pushed upwards.

b) The wire is pushed downwards.

c) The wire is pushed upwards.

d) The wire is pushed with a large force.

2 a)



b) The split ring changes the direction of the current flowing through the coil after every half turn. The brushes provide connections between the power supply and the rotating coil.

c) Increase the current flowing through the coils, increase the number of coils and increase the strength of the magnetic field.

d) Permanent magnets are replaced by electromagnets, the single coil is replaced with several all wrapped on the same axis or the coils are wrapped on a laminated soft iron core.

3 **a)** Large deflection on meter.

b) No deflection on meter.

c) Smaller deflection on meter than **a)** and in opposite direction.

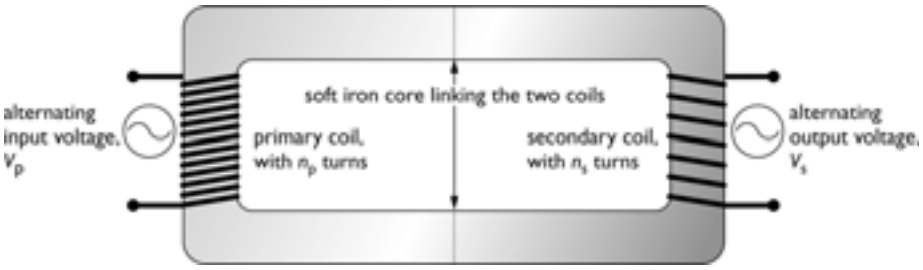
d) Meter deflects in same direction as **a)**.

4 **a)** A step-up transformer makes the output voltage higher than the input. A step-down transformer makes the output voltage smaller than the input.

b) Step-up transformers are used immediately before transmission through the National Grid. Step-down transformers are used when the supply approaches towns, villages or the place where the electrical energy is needed, e.g. a factory.

c) Reduces energy loss in the wires.

d)



e) The magnetic field created when dc current is passing through a coil is stationary, so no current is induced in the secondary coil.

f) 50 V

End of Section F questions

1 force, magnetic, loudspeakers, motors

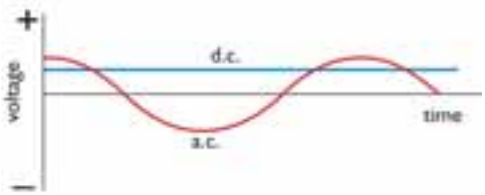
coil, induced, dynamos, generators (8)

2 **a)** As the cyclist pedals, a magnet rotates (1). Its magnetic field cuts through a coil (1), inducing current in it (1).

b) The magnet is stationary, there is no movement of the magnet and its magnetic field, so no current is produced. (1)

c) A generator which produces alternating current. (1)

d) Direct current (dc) flows in the same direction all the time. (1) Alternating current (ac) changes direction many times each second (1).



(1)

e) The alternating current (1) makes 50 complete cycles each second (1).

3 **a)** Less energy is wasted in the transmission wires. (1)

b) The high voltages would be dangerous. (1)

c) $\frac{V_p}{V_s} = \frac{n_p}{n_s}$, so $V_s = V_p \times \frac{n_s}{n_p}$ (1)

$V_s = \frac{12\,\text{V} \times 20000}{100}$ (1)

$= 2400\ \text{V}$ (1)

d) $V_p \times I_p = V_s \times I_s$ (1)

so $I_s = V_p \times \frac{I_p}{V_s}$ (1)

$= \frac{12 \times 10}{2400}$

$= 0.05\ \text{A}$ (1)

(You can also do this using ratios: The voltage is increased by a factor of 200 (1), so the current will be decreased by a factor of 200 (1), so the current is $\frac{10}{200} = 0.05$ A (1))

4 **a)** A magnetic field. (1)

b) It becomes magnetised. (1)

c) There is a gap in the high-voltage circuit at C (1) so current cannot flow until the gap is closed (1), which happens when the contacts of C touch (1).

d) If switch S is opened, the current stops flowing in the coil (1), the soft iron core loses its magnetism (1), and the contacts at C spring open again (1).

e) The steel would retain its magnetism even after the current in the low-voltage circuit stopped, so the high-voltage circuit could not be switched off again. (1)

5 **a)** $V_p \times I_p = V_s \times I_s$ (1)

so $I_p = V_s \times I_s / V_p$ (1)

$= \frac{230\,\text{V} \times 13\,\text{A}}{33000\,\text{V}}$ (1)

$= 0.091\ \text{A}$ (1)

b) $V_p \times I_p = V_s \times I_s$ (1)

so $I_p = V_s \times I_s / V_p$ (1)

$= \frac{230\,\text{V} \times 13\,\text{A}}{400000\,\text{V}}$ (1)

$= 0.0075\ \text{A}$

6 **a)** When current flows through the coil, the core becomes magnetised and tries to attract the catch (1). When the current is less than a certain value, the force is insufficient to move the catch so the contacts remain touching (1). If the current exceeds a certain value, the force becomes large enough to attract the catch and the contacts part, turning off the circuit (1).

b) When the fault in the circuit has been corrected, the circuit breaker can be reset by pressing the reset button, blown cartridge fuses would have to be replaced. (1)

7 **a)** The permanent magnet will attract the iron armature but then not release it (1), so the hammer will not vibrate up and down (1).

b) Iron is a magnetically soft material and therefore loses its magnetism when the current is turned off (1). Steel is a magnetically hard material and therefore retains its magnetism when the current is turned off (1). The hammer would therefore not vibrate up and down as the electromagnet is turned on and off (1).

Chapter 23

1

Atomic particle	Relative mass of particle	Relative charge of particle
electron	1	+1
proton	2000	–1
neutron	2000	0

2 **a)** neutron **b)** electron

c) proton **d)** proton

e) electron

3 **a)** The volume occupied by an atom is defined by the diameter of the outermost electron orbits. The space within this is empty of particles apart from the nucleus, which approximately $\frac{1}{10000}$ of the diameter of the atom as a whole.

b) The nucleus contains protons and neutrons, both of which particles have nearly 2000 times the mass of an electron – this means that only a tiny fraction of the total mass of the atom is outside the nucleus of an atom.

c) Atoms contain equal numbers of electrons and protons. Protons and electrons carry an equal quantity of electric charge, but with opposite sign, thus the overall charge of an atom is zero.

4 **a)** The atomic number of an atom is equal to the number of protons in the atomic nucleus. This defines the chemical element. Different chemical elements have different atomic numbers.

b) The mass number of an atom is equal to the total number of protons and neutrons in the nucleus.

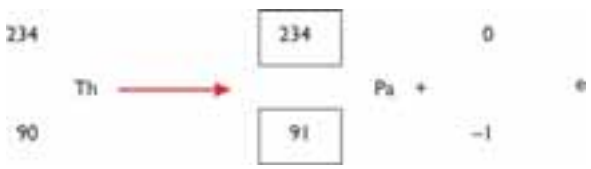
5

	$\binom{3}{2}$He	$\binom{13}{6}$C	$\binom{23}{11}$Na
protons	2	6	11
neutrons	1	7	12
electrons	2	6	11

6 **a)** nucleons, protons, neutrons, +2 **b)** electron, proton, neutron

c) gamma, short **d)** electromagnetic

7 **a)**



b) beta decay

c)



d) alpha decay

Chapter 24

1 **a)** Background radiation is radiation produced by radioactive material in the Earth and in the Earth's atmosphere. It should be measured and taken into account when measuring the activity of radiation from a particular source.

b) Natural background radiation is due to the decay of naturally occurring radioactive isotopes in the Earth that were formed when the Solar System was created. Natural radiation also results from high-energy particles that bombard the Earth. Artificial background radiation comes from man-made sources, rather than from the rocks that make up the Earth.

c) Uranium in rocks in the Earth's crust (natural). Radioactive materials that have escaped into the environment from nuclear power stations (artificial). Fallout from atmospheric nuclear weapon testing in the 1950s and 1960s (artificial).

2 **a)** Ionising radiation causes ionisation of a low-pressure gas inside the tube. The ionised gas allows a current to flow between two electrodes, and the current is detected by an electronic circuit.

b) A rate meter gives an indication of the number of decays occurring per second.

c) A bequerel is a rate of decay of one disintegration per second. 1 kBq is 1000 disintegrations per second.

3 Alpha particles do not penetrate card; as the count rate dropped when card was placed between the source and the counter, the source must be emitting alpha radiation. Aluminium will block all but the most energetic beta particles. As the count rate is unchanged by the aluminium, the source may not contain a beta emitter. Gamma radiation must be present because there is a further decrease in the count when lead is placed between the source and the detector.

4 **a)** The half-life of a radioactive sample is the average time taken for half the unstable atoms in the sample to undergo radioactive decay.

b) Random means that the decay of an individual atom is unpredictable; we cannot say when any particular atom will undergo decay.

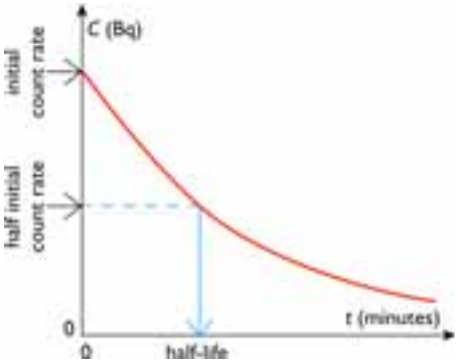
5 In 1.5 hours the sample has halved in activity three times (240 → 120 → 60 → 30) so three half-life periods have passed; the half-life is, therefore, 30 minutes.

6 **a)** 35 seconds is the time taken for half the water to drain away. If the arrangement is a good model, in a further 35 seconds the amount of water in the burette will have halved again and three-quarters of the water will have drained away, so the answer is 70 seconds (1 minute 10 seconds).

b) After 1¾ minutes, three 'half-lives', a further halving will have taken place, leaving the burette one-eighth full, i.e. containing 6.25 ml.

7 **a)** Students should measure the background radiation. They should then measure the radioactivity of the sample using a GM tube and rate meter at regular intervals of, say, 5 minutes for a period of 30–40 minutes.

b) The readings of the activity of the sample should be corrected by subtracting the average background radiation count. The corrected readings should then be plotted on a graph of count rate against time. The time taken for the initial activity to fall to half can then be measured from the graph.



Chapter 25

1 **a)** It has a short half-life, so its activity drops to a negligible level in a day or two. Beta particles and low energy gamma rays penetrate soft tissue easily, so the progress of the isotope through the body can be monitored easily. The emitted radiation is not strongly ionising, so the risk of tissue damage is acceptably small. (It is also relatively easy to produce.)

b) By using a detector such as a GM tube.

2 β decay. The process involves a change in element – molybdenum to technetium – but with negligible change in mass – the mass number remains the same, 99.

3 **a)** Iodine-131 is taken up by the thyroid gland in the same way as ordinary iodine. An overactive thyroid concentrates more iodine – if the concentration of I-131 is greater than normal, this can be detected by measuring the activity and comparing it with the expected take-up from a normal thyroid gland.

b) I-31 is a high-energy beta-emitter. The radiation is sufficiently ionising to destroy cells in the thyroid, reducing its activity.

4 Surgical instruments may be sealed into wrappers and then sterilised using radiation. The radiation passes through the wrapper, destroying any organisms on the instrument, which then remains sterile within its wrapper.

5 **a)** β radiation is used. It can pass through paper (unlike α particles) but the thicker the paper, the greater the amount of β radiation absorbed.

A β-emitting source is placed above the paper as it emerges from the rollers used to press it to the required thickness and a detector is placed beneath the paper in line with the source. The count rate will decrease as the thickness of the paper passing between the emitter and the detector increases.

To ensure accuracy, the background radiation count should be taken regularly so that the reading from the detector can be corrected. The half-life of the β-emitting source needs to be quite long (so that the count rate does not fall significantly over short intervals), but the apparatus will need to be recalibrated regularly using paper of known thickness.

Care should be taken to ensure workers cannot come within range of the radiation from the source. The source must be stored in a secure container that is lined with lead to ensure no ionising radiation can escape. The storage area and the part of the paper-making works in which the radiation source is being used should be clearly identified with standard signs. The source must be selected and screened to ensure that it emits only β radiation.

6 **a)** Cosmic radiation causes C-14 to form from nitrogen in the atmosphere.

$$^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{14}_{6}C + {}^{1}_{1}p$$

b) Carbon-14 has the same chemical behaviour as the abundant stable isotope C-12. Carbon reacts with oxygen to form carbon dioxide. Through photosynthesis, carbon-14 enters the food chain and therefore all living material.

c) Once an organism is dead, no new C-14 is taken in via photosynthesis (plants) or food (animals). The proportion of C-14 in organic material decreases as the C-14 decays.

d) The principal assumption is that the rate of production of C-14 through cosmic rays has remained constant over time. In practice this is not so, but it is possible to make adjustments for the variation in C-14 by taking samples from objects of known age.

e) The half-life of C-14 is roughly 5600 years. After 10 half-lives have elapsed, the activity remaining C-14 is too small for accurate measurement.

7 **a)** $4.5 \times 10^9 \div 1600 = 2\ 812\ 500$ half-lives

b) Student A is correct – radium formed when the Earth was formed would, by now, have decayed to an immeasurably small amount. Student B is incorrect, as the difference in the initial amount of radium would have to be immense. (As a model of this you can try folding a sheet of paper in half repeatedly – it becomes impossible after seven or eight folds, regardless of how large your starting sheet of paper is.) Student C is correct because radium is continuously being formed by the decay of isotopes of elements with very long half-lives.

c) Information about what other radioactive isotopes are present on the Earth, and whether any of them decay to form radium.

8 **a)** Alpha radiation has a very limited range. After alpha particles have travelled only a few centimetres in air, they have lost most of their kinetic energy and thus lose their ionising power. Alpha particles are stopped completely by quite thin layers of material that are not very dense. Thus alpha radiation is not particularly dangerous to living cells, as in the human body, unless the source is very close to living tissue. If a source is very close to the skin it may, if the exposure is prolonged, cause burns and other tissue damage. The greatest danger is when alpha-emitting material is absorbed into the body. Inside the body, cells do not even have the protection of a layer of skin and fat, so are readily affected by the highly ionising alpha particles. This will result in cell destruction or mutation.

b) Radon-220 is an alpha-emitter. It is a dense gas and therefore accumulates in the lower parts of buildings, etc. As it is a gas, it is readily inhaled and thus comes into close contact with internal cells. As described above, this is the most hazardous condition for alpha sources.

Chapter 26

1 In Thomson's model, the mass of the atom is uniformly distributed through the whole of the atom. The atom was thought to be a positively charged sphere with negative charges distributed evenly throughout the sphere. In Rutherford's model, nearly all the mass of the atom and all its positive charge is concentrated in the small central core or nucleus.

2 **a)** A: radioactive alpha emitter

B: thin gold foil

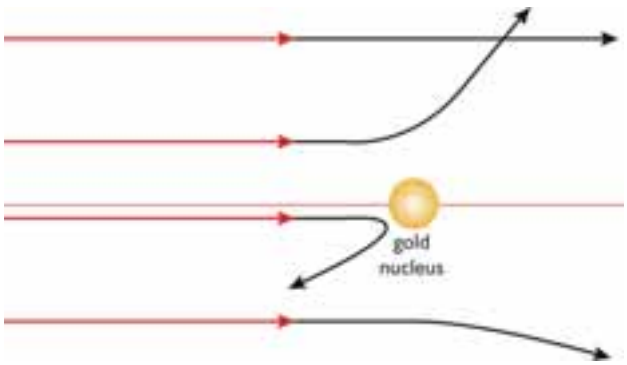
C: undeflected alpha particles

D: deflected particle

E: particle that has rebounded

b) That most of the volume of a gold atom is empty space, and most of the mass and positive charge is concentrated in a very small volume at the centre of the atom.

3 **a)**



b) i) the particles would have travelled closer to the nucleus before rebounding

ii) the particles would have travelled closer to the nucleus before suffering a rebound and be deflected through smaller angles at any specific distance from the nucleus than the more highly charged particles.

4 **a)** The nuclei of its atoms can be split apart by a nucleus.

b) i) A reaction that produces further reactions – in this case, neutrons produced when a uranium nucleus splits can cause further nuclei to split.

ii) If there is only a small amount, neutrons can escape the material without hitting any more nuclei.

5 Advantages: virtually inexhaustible supply of energy; does not produce 'greenhouse' gases.

Disadvantages: produces waste that remains extremely dangerous for thousands of years; very high set-up and decommissioning costs.

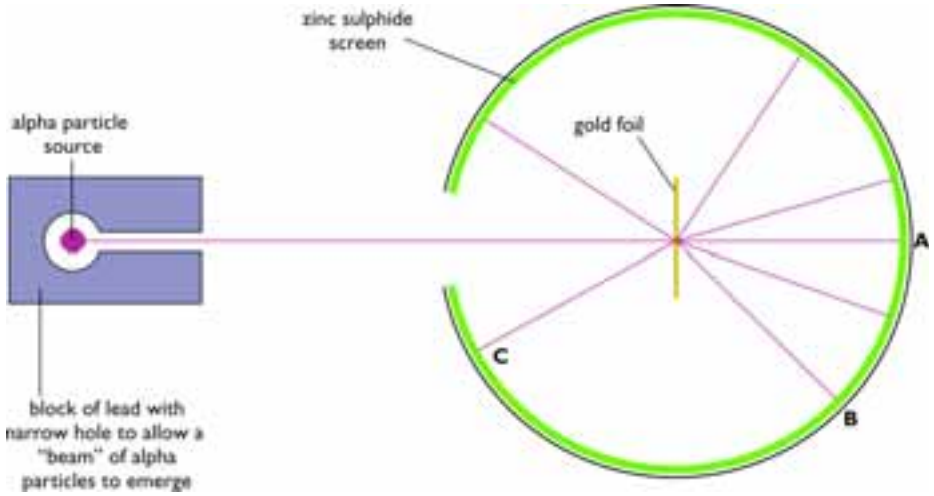
End of Section G questions

1 electrons, protons, neutrons, nucleus, nucleons

electrons, protons (7)

2 **a)** Alpha particles are helium nuclei (1) ejected at high speed from the decaying nucleus (1).

b) Your diagram should look something like this, with the following labels: alpha source (1) producing 'beam' from lead block (1), striking gold foil (1) and zinc sulphide screen (1)



c) Most alpha particles passed straight through, undeflected (1). Some were deflected (1) and a very small proportion actually rebounded (1). Rutherford deduced that the mass and charge of an atom was concentrated in a very small central core or nucleus (1).

d) In the plum pudding model, the mass is uniformly distributed throughout the volume of the atom (1). The atom was considered to be a positively charged sphere with electrons studded in it like plums in a pudding or raisins in a cake (1).

3 **a)** The 200-dice experiment is more likely to produce the best model (1). In radioactive decay, millions of atoms are involved. The larger the number of dice, the more statistically valid the experiment will be (1).

b) If the dice are 'fair', on average, one-sixth of the dice will be removed after each throw. (1)

c) By removing more dice on each throw (1) – for example, removing all the dice that land on 4 or above (1).

4 **a)** 12 is the (relative) atomic mass (1). It is the number of nucleons in the nucleus (1). 6 is the atomic number (1). It is the number of electrons orbiting the nucleus (and the number of protons in the nucleus) (1).

b) Isotopes of an element have the same atomic number (1) and the same chemical properties (1). Isotopes differ in their atomic mass (having different numbers of neutrons) (1) and have different physical properties (1).

c) Another example of an isotope of carbon is carbon-14 (1). It has two extra neutrons in its nucleus (1). It is unstable (1). It is written as below (1).

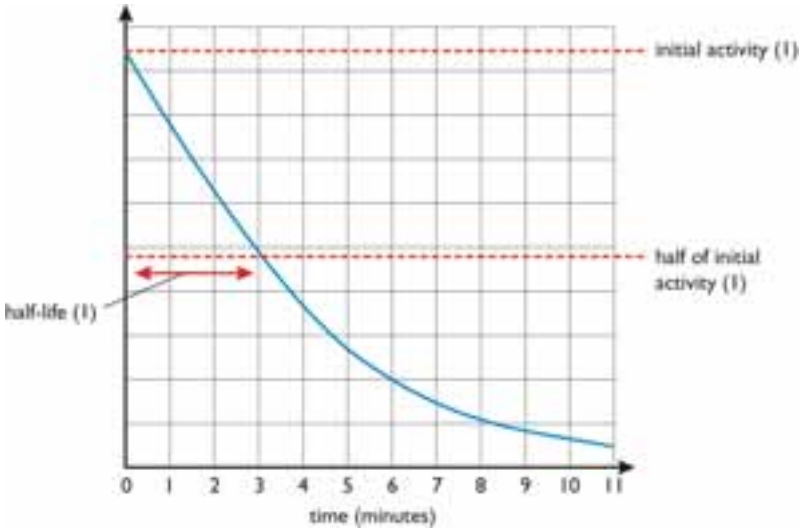
$$^{14}_{6}C$$

d) Living organisms take in carbon-14, and so have a relatively fixed proportion of carbon-14 to carbon-12 in their body (1). When they die, the carbon-14 decays and is not replenished (1) so the proportion of carbon-14 decreases (1). By measuring the relative amounts of the two isotopes of carbon, we can work out how long ago the organism died (1).

5 **a)** Using a GM tube and counter (1), measure the background radiation over a period of time to find the average count rate (1). Place the radioactive sample a fixed distance from the detector, taking care to handle the source with handling tongs at arm's length (1). Measure the activity of the sample at regular intervals (of a minute or two) (1). Plot a graph of activity against time (activity corrected for background count) (1). Measure how long it takes for the activity to halve from the graph (1).

b) i) Bequerel (1).

ii)



iii) 3 minutes

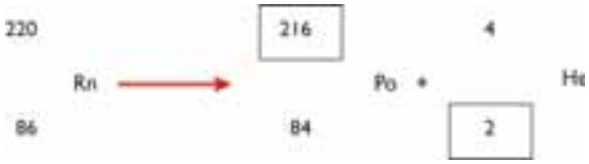
c) 30 minutes is three half-life periods (1). The amount will, therefore, have halved three times (1) to 25 μg (1).

6 a) An alpha-emitter (1) that can be attached to a material that is readily absorbed by the target tissue (1). Alpha radiation is heavily ionising (so short range) and will destroy the tissue in the immediate vicinity of the emitter (1).

b) A beta-emitter (1) with a relatively short half-life (1). The radiation can be detected outside the body (1) and will fall to a safe level of activity in a short period (1)

c) Iodine is taken up by the thyroid (1). An overactive thyroid concentrates more iodine than a healthy one (1). Using a radioisotope of iodine means that cancerous cells within the thyroid can be destroyed without damage to other surrounding tissue (1).

7 a)



(2)

b)



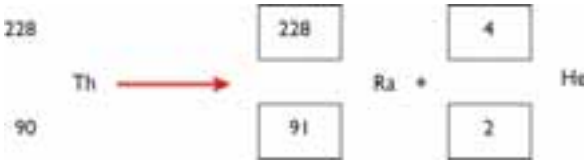
(2)

c)



(3)

d)



(3)