UNIT 1 ANSWERS

CHAPTER 1

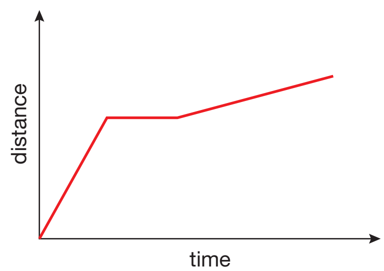
1 ▶ 8 m/s

2 ▶ a 10 500 m (10.5 km)
b 105 000 m (105 km)
c 630 000 m (630 km)

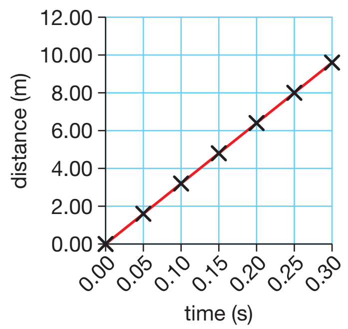
3 ▶ 4000 s (Snails can actually move faster than this! At a more realistic 4 mm/s (0.004 m/s) it would only take the snail 400 s or 6 minutes 40 seconds.)

4 ▶ a graph D **b** graph C **c** graph A **d** graph B

5 ▶



6 ▶



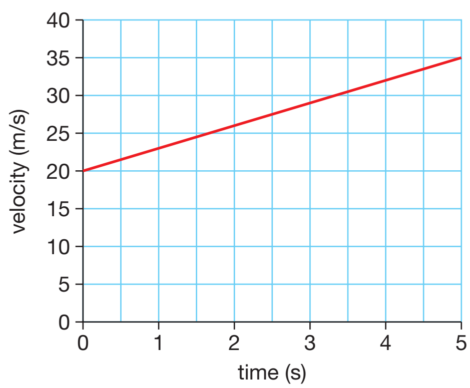
$$\text{gradient} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{8\text{ m}}{0.25\text{ s}}$$

$$= 32\text{ m/s}$$

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

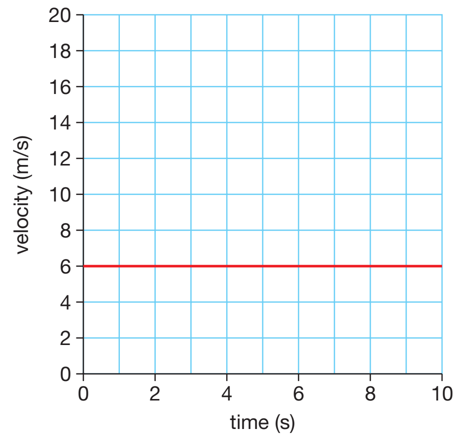


b Distance travelled is given by the area under the graph. (Divide area into a rectangle and a triangle.)
= (5 s × 20 m) + (0.5 × 5 s × 15 s) = 137.5 m

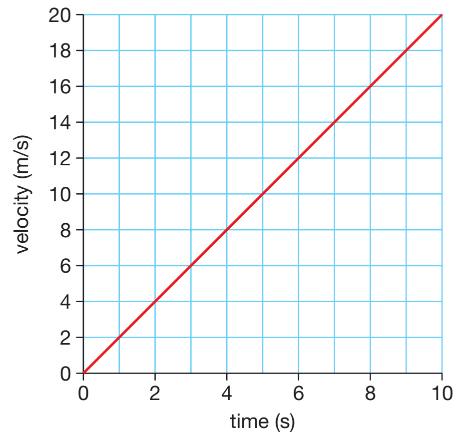
9 ▶ a Average speed is found by dividing the total distance a body has travelled by the time it has taken; the speed may vary from moment to moment during this time. The instantaneous speed is the speed at which the body is travelling at a moment in time.
b Speed is a scalar quantity – it is distance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

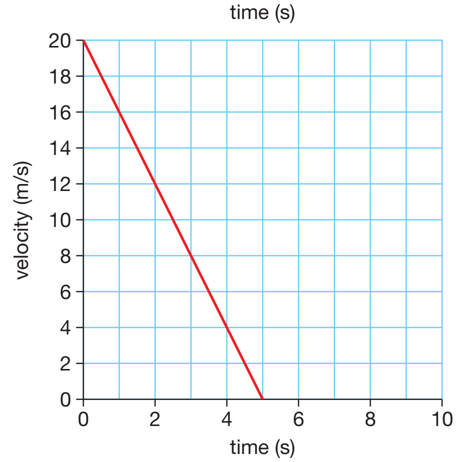
11 ▶ a



b



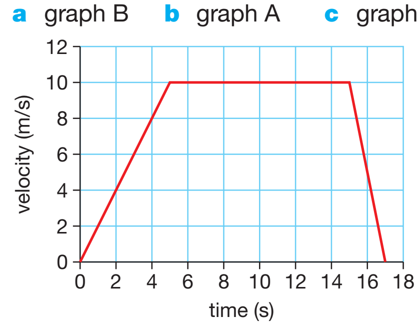
c



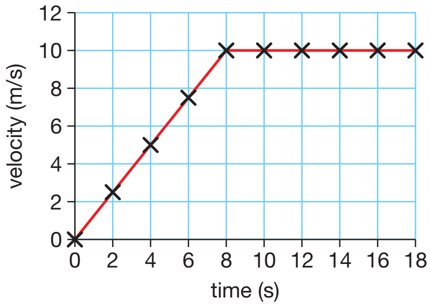
12 ▶ a 3 m/s **b** 15 m/s **c** 75 m/s

13 ▶ a graph B **b** graph A **c** graph D **d** graph C

14 ▶



15 ▶ a



b 2.5 m/s^2

c i 20 m **ii** 50 m

d 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.

17 ▶ a Student answer will vary

b 32 m

CHAPTER 2

1 ▶ a gravity

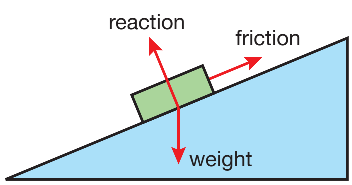
b friction

c normal reaction or contact force

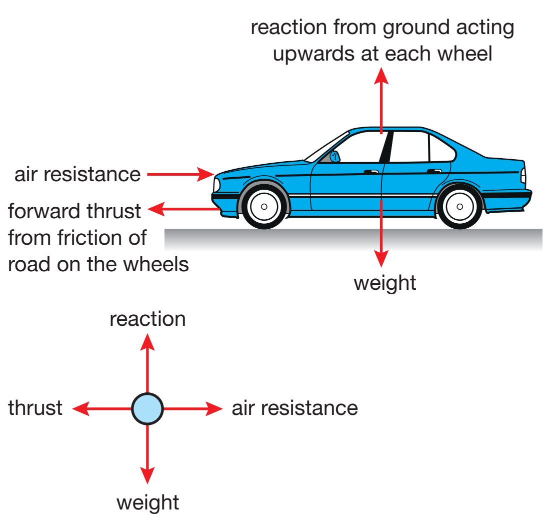
2 ▶ Friction and air resistance (or viscous drag)

3 ▶ a 1200 N **b** 1250 N **c** 50 N **d** red

4 ▶



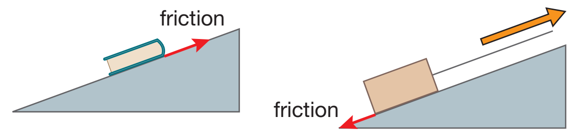
5 ▶



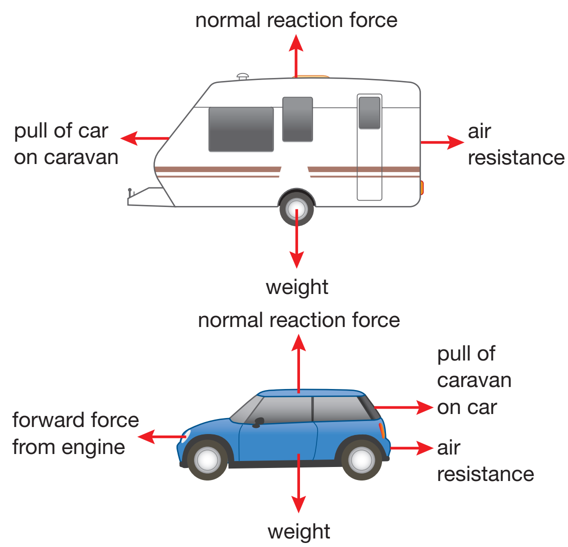
6 ▶ a Without friction, objects would not be able to start moving from a stationary position, or stop moving when in motion. It would not be possible to build things because it would be difficult to pick up the building materials, and structures rely on friction to remain intact.

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 ▶



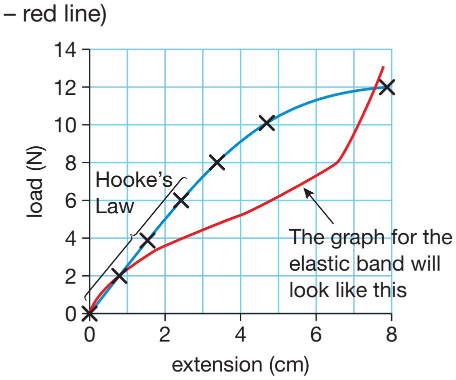
8 ▶



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 ▶ **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.

5 ▶ 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.

6 ▶ **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)

7 ▶ **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

8 ▶ 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.

9 ▶ See page 36 for description of a suitable experiment.

10 ▶ 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** momentum of truck with pellet after the collision = 0.102 kg × 0.8 m/s → 0.0816 kg m/s

b momentum of pellet before the collision = 0.002 kg × v (where v is the velocity we are trying to find.)

c Since the momentum of truck before the collision is zero because the truck is stationary and the momentum before and after the collision is the same 0.002v = 0.0816 kg m/s the velocity, v, of the pellet is 40.8 m/s

d This assumes that no other forces (like friction) act in the line of travel of the pellet and the truck.

3 ▶ **a** increase in momentum (impulse) = $F \times t$
= 10 000 N × 60 s
so the increase in momentum is 600 000 kg m/s

b 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).

4 ▶ a No, the air bag slowly deflates as the driver collides with it.

b 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. The air bag deflates slowly so the time for the driver to come to a halt is extended – this means that the deceleration, and therefore the forces acting on the driver during the deceleration, are reduced.

CHAPTER 5

1 ▶ a B has the largest turning moment, having the biggest force applied at the greatest perpendicular distance from the pivot.

b 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 lines of action of the 5 N force in C and D.

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

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

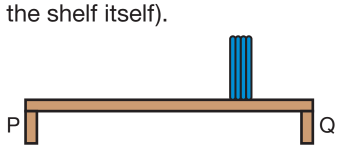
c D tips down to the left, clockwise moment = 350 Nm, anticlockwise moment = 375 Nm

d A tips down to the left, clockwise moment = 250Nm, 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 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.

END OF UNIT 1 QUESTIONS

1 ▶ a B **b** D **c** A **d** C (4)

2 ▶ a B (1)

b i Displacement is distance travelled in a specified direction. Distance is how far you have travelled not taking changes in your direction of travel into account. (2)

ii 1 m vertically above the ground (1)

c i The ball falls with an acceleration downwards, $a = 10\,m/s^2$ (1)

The downward displacement of the ball on reaching the ground s = 3 m (1)

The ball had an initial velocity, u = 0 m/s (1)

So $v^2 = u^2 + 2as$ gives $v^2 = 0^2 + 2 \times 10\,m/s^2 \times 3m$ (1)

$v = \sqrt{60}\,m^2/s^2 = 7.75\,m/s$ (1)

You need to find the answer to **iii** first!

iii Time for the tennis ball to reach the ground, t = (v – u)/a (1)

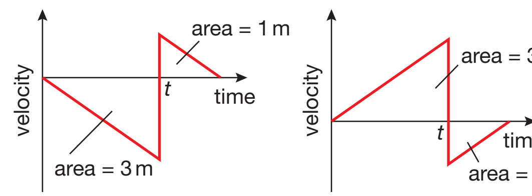
$t = 7.75\,m/s \div 10\,m/s^2 = 0.775\,s$ (1)

ii Average speed = distance travelled ÷ time taken (1)

Average speed = 3 m ÷ 0.775 s = 3.87 m/s (1)

d From the area beneath the graph line (1)

e



gradient of both line segments = $10\,m/s^2$

2 marks for shape showing acceleration and abrupt change in direction, 1 mark for value of t as calculated in **c iii**, 1 mark for labelling area of larger triangle 3 m, 1 mark for labelling area of smaller triangle 1 m, and 1 mark for stating that the gradient of both line segments is the acceleration due to gravity taken as $10\,m/s^2$.

The left-hand sketch graph assumes that up is positive for velocity; the right-hand sketch graph assumes that down is positive for velocity.

3 ▶ a i The load force on the wire (from the number of weights). (1)

ii The extension in length. (1)

iii Temperature (or type of wire, or diameter of wire, or initial length of wire under test). (1)

b Using F = mg (1)

c *(1) mark for each point in italics and (1) mark for any other from this list (max 5 marks):*

Note type of wire

Monitor temperature during experiment

Measure diameter of wire under test with micrometer

Measure the extension produced by a range of increasing load forces

Measure the extension produced by the same load forces as the wire is unloaded

Plot a graph of extension against load force

Draw the best fit line through the plotted points

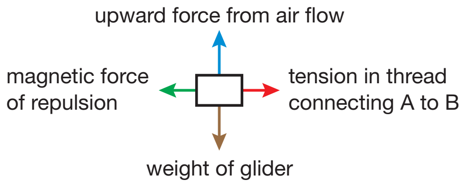
If best fit line is a straight line through the origin of the axes then wire obeys Hooke's law

d The student also wants to know if the sample behaves elastically. Explain how the student can improve the investigation and discover whether or not the wire behaves elastically

4 ▶ a The momentum of an object is the product of the mass of the object and its velocity. Velocity is speed in a particular direction and is, therefore, a vector quantity. This means that momentum also has both size and a specific direction and is therefore also a vector quantity. (3)

b Both gliders are at rest so the initial momentum is zero. (1)

c i (4)



ii Newton's third law states that for every action there is an equal and opposite reaction. This means that glider A experiences an unbalanced magnetic force to the left from B and glider B experiences an unbalanced magnetic force to the right from A and that each of these forces is the same size. (3)

iii Each glider experiences an unbalanced force which causes them to accelerate away from each other. (1)

d i speed = distance travelled ÷ time taken, speed = 5cm ÷ 1.25s

therefore speed is 4cm/s (2)

ii The momentum of A *to the left* = 500 g × 4 m/s

This is equal to the momentum of glider B *to the right* since the total momentum of the gliders remains zero

The momentum of B to the right = 800 g × v m/s so

800 g × v m/s = 500 g × 4 m/s

Therefore v = 2.5 cm/s (5)

e If the magnets are closer together, the repelling force between them will be greater so the acceleration of each glider after the thread is cut will be greater causing the gliders to move apart more quickly. However, glider A, with a smaller mass than B, will move faster as shown in the above calculation. (3)

UNIT 2 ANSWERS

CHAPTER 6

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 $I = \frac{P}{V} = \frac{1500\,\text{W}}{230\,\text{V}} = 6.52\,\text{A}$. 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.

4 ▶ The power ratings of most appliances are shown on the appliance itself.

CHAPTER 7

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.

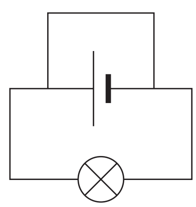
S5 Bulbs F, G and H will go out.

S6 Bulbs G and H will go out.

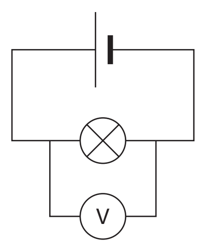
c All the bulbs will glow with equal brightness.

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.

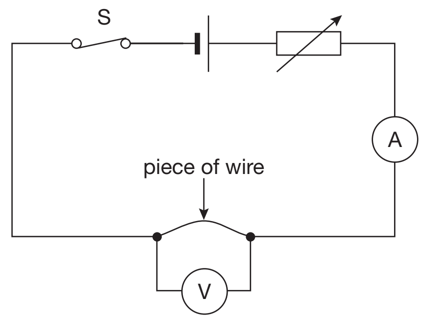
5 ▶ In parallel. If the lights are wired in series, the current through the string of lights will be too small to make them glow, and any faulty bulbs will result in all the bulbs going off.

6 ▶ If connected in series, turning one part of the cooker on would turn on all the other parts as well.

CHAPTER 8

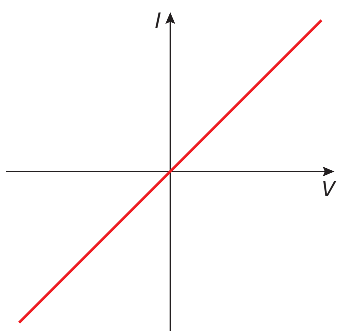
1 ▶ a The current that flows through a conductor is directly proportional to the potential difference (or voltage) across its ends, provided its temperature remains constant.

b

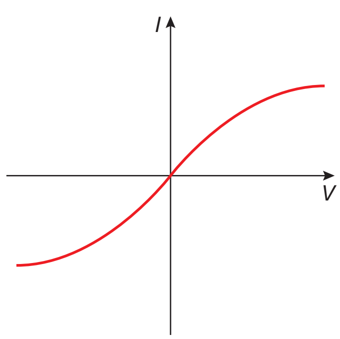


c Close the switch and take readings on ammeter and voltmeter. Alter the variable resistor and take new readings. Repeat this at least six times. A graph of *I* against *V* will show a straight line passing through the origin, confirming Ohm's law.

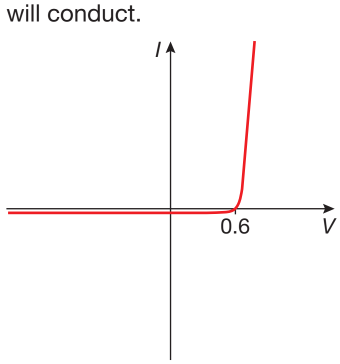
d i A straight line graph passing through the origin, indicating a constant resistance.



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.

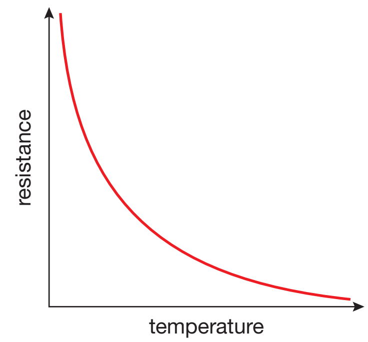


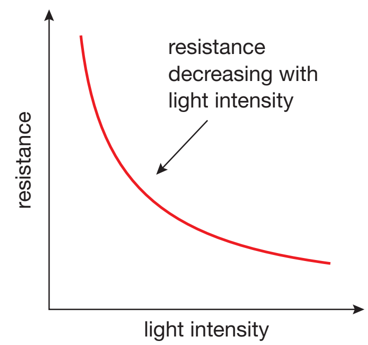
2 ▶ a 4 Ω **b** 0.24 A **c** 30 V

3 ▶ a i Decrease, with increase of temperature.

ii Decrease, with an increase in the intensity of light.

iii





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.

CHAPTER 9

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.

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.

END OF UNIT 2 QUESTIONS

1 ▶ a B **b** D **c** A **d** B (4)

2 ▶ electrons, coulomb,
energy resistance, lower (5)

3 ▶ 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 $R = 4.0\,V/2.0\,A$ (1)
$= 2.0\,\Omega$ (1)

g It increases. (1)

4 ▶ a $I = V/R$ (1)
$= 12\,V/10\,\Omega = 1.2\,A$ (1)

b $Q = I \times t$ (1)
$= 1.2\,A \times 5\,s = 6\,C$ (1)

c $E = V \times I \times t$ (1)
$= 12\,V \times 1.2\,A \times 60\,s = 864\,J$ (1)

5 ▶ a $I = \frac{P}{V}$ (1)
$= \frac{2300\,W}{230\,V}$ (1)
$= 8.7\,A$ (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)

d $R = V/I = 230V / 8.7A = 26.4\Omega$ (1)

6 ▶ 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).

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

b 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 ($\frac{1}{2}$).

8 ▶ a 10V (2) **b** 2V (2) **c** 12V (1)

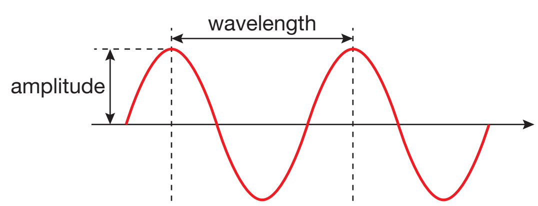
UNIT 3 ANSWERS

CHAPTER 10

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 0.4 s **b** 2.5 Hz

3 ▶ a $f = \frac{v}{\lambda} = \frac{1500\,m/s}{1.5\,m} = 1000\,Hz$

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

4 ▶ a The wavefronts are squashed closer together as the car approaches.

b It would be higher.

c It would be lower than when the car is stationary.

5 ▶ Rays of light from the fish have been refracted at the surface of the water so the hunter does not see the correct position of the fish.

CHAPTER 11

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 i Wear lead lined clothes, stand behind lead screen

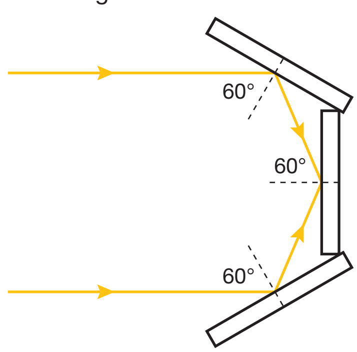
ii Wear clothing, use sunblock.

4 ▶

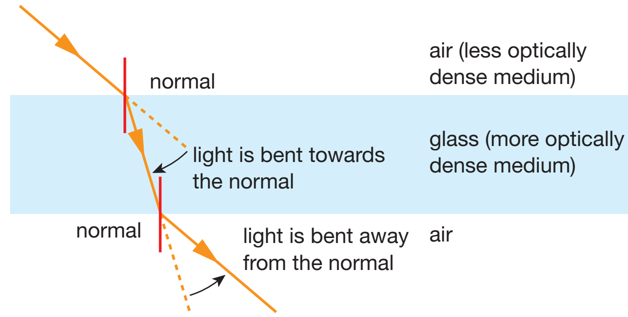
Type of radiation	Possible harm	Precautions
x-ray	cancer	lead screening
microwaves	cancer	metal screening
infra-red	skin burns	avoid over-exposure
ultraviolet	cancer/skin damage	glasses, sunblock

CHAPTER 12

1 ▶ Your diagram could look something like this:

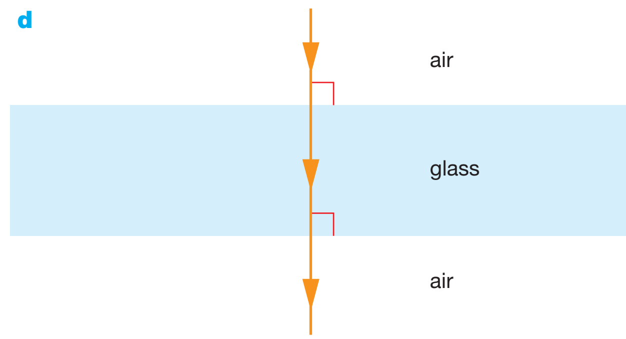


2 ▶ a and **b**



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



3 ▶ a $n = \frac{\sin i}{\sin r} = \frac{\sin 55°}{\sin 31°} = 1.59$

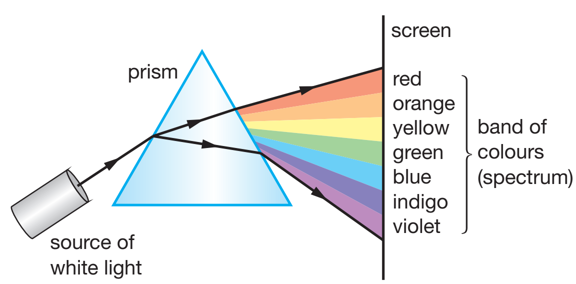
b $\sin r = \frac{\sin i}{n} = \frac{\sin 45°}{1.59} = 0.445$

$r = 26.4°$

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

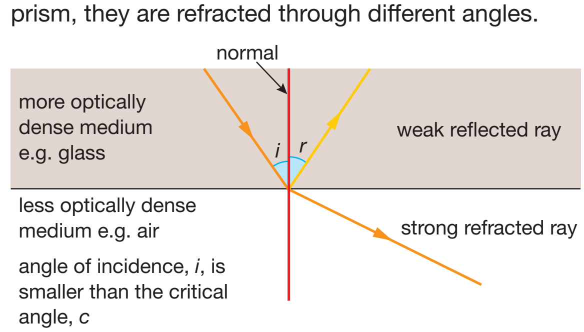
$c = 39°$

4 ▶ a

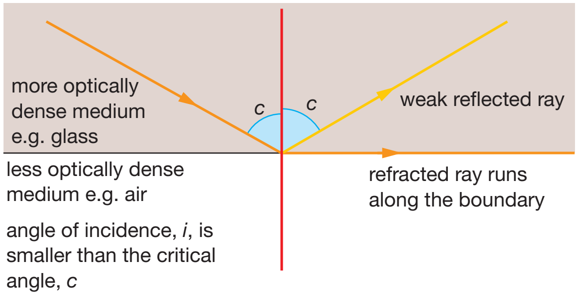


b White light is composed of a mixture of colours. Because each colour travels at a different speed through the prism, they are refracted through different angles.

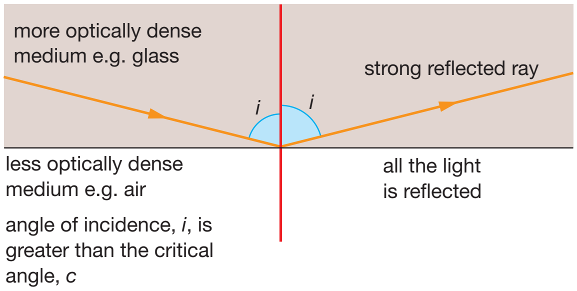
5 ▶ a



b

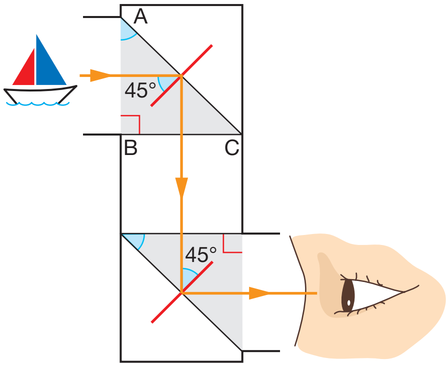


c



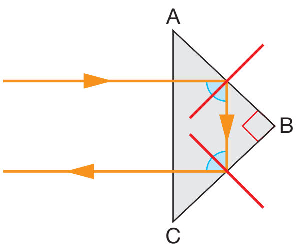
6 ▶ a If a ray of light travelling from glass or water to air strikes the boundary between the two at an angle greater than the critical angle, the ray is reflected by the boundary and is not refracted. This phenomenon is called total internal reflection.

b



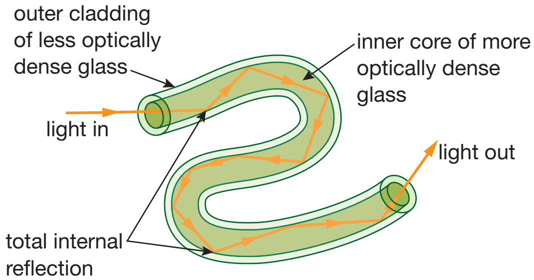
c The final image created by a prismatic periscope is likely to be sharper and brighter than that produced by a periscope, which uses mirrors.

d



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

7 ▶ 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 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.

c Telecommunications

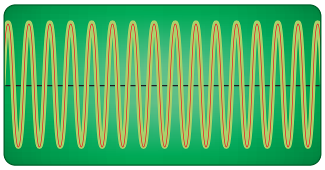
CHAPTER 13

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

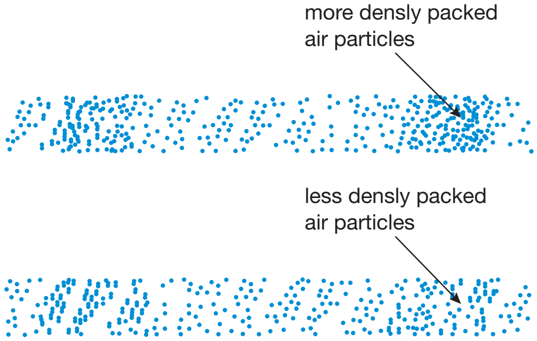
3 ▶ a This person cannot hear sounds with frequencies less than 20 Hz or greater than 20 000 Hz.

b The strings of a violin are shorter and vibrate more quickly.

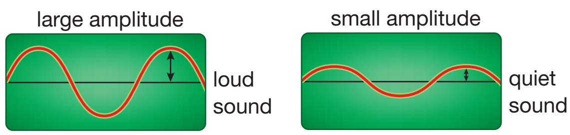
c $\lambda = \frac{v}{f} = \frac{340\,\text{m/s}}{69\,000\,\text{Hz}} = 0.005\,\text{m}$

4 ▶ a f = 100Hz **b** λ = 3.4m

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.



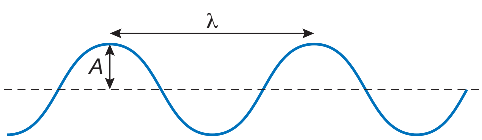
b



END OF UNIT 3 QUESTIONS

1 ▶ a B **b** D **c** A (3)

2 ▶ a



b i $f = v / \lambda$ (1)

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

$= 8\,\text{Hz}$ (1)

ii T = 1/f

= 1/8Hz

= 0.125s (1)

3 ▶ 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)

4 ▶ 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.

5 ▶ 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).

6 ▶ a i $n = \frac{\sin i}{\sin r} = \frac{\sin 38}{\sin 24} = 1.51$

ii $n = \frac{1}{\sin c}$, $c = 41.3$

b $n = \frac{1}{\sin c}$ $n = \frac{1}{\sin 42} = 1.49$

UNIT 4 ANSWERS

CHAPTER 14

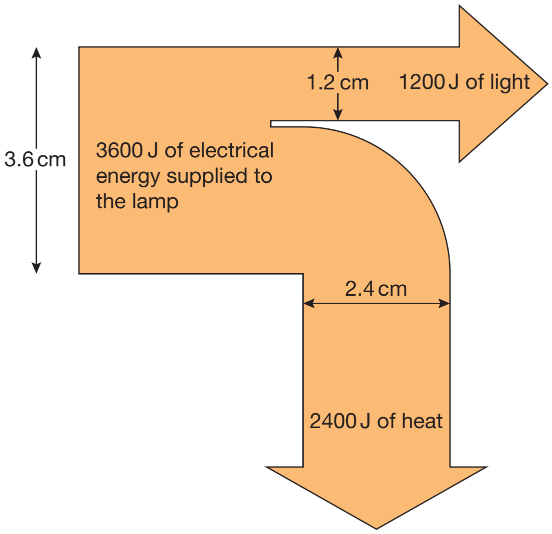
1 ▶ a Stored chemical energy in the battery → electrical energy in the circuit → heat and light in the lamp filament.

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

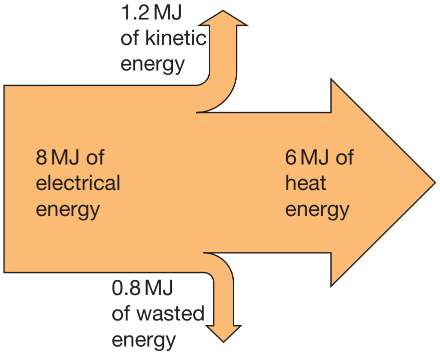
c Kinetic energy of moving hands → heat energy.

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.

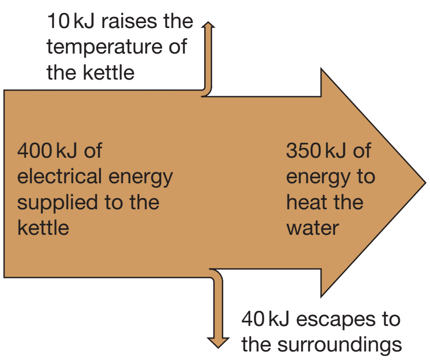
2 ▶ a



b



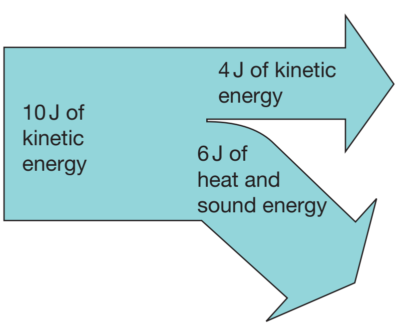
3 ▶ a



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 15

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.

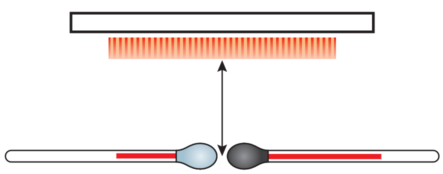
5 ▶ a Water is a relatively poor thermal conductor. As it is a fluid (capable of flowing or moving around), the main mechanism of heat transfer is convection. Convection means that heated water, which expands and becomes less dense, is displaced upward by colder and therefore denser water. If the heating 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.

8 ▶ a



The apparatus shown above will show if heat is absorbed more readily by thermometer B with a black bulb than A with a shiny bulb.

b Measure the initial temperatures on each thermometer and then at 30 s intervals.

c The thermometers should be identical apart from the bulbs and should be placed at the same distance from the heater. The apparatus should be screened from draughts and from other sources of heat. The experiment should be repeated.

d Placing the thermometers below the heat source means that heat cannot be transferred from the source to the thermometers by convection. Air is a very poor thermal conductor so little heat will be transferred by conduction. If the temperature shown on thermometer B rises more quickly than the temperature shown on thermometer A we may therefore conclude that the blackened bulb of thermometer B is a better absorber of thermal radiation than the shiny bulb of thermometer A.

CHAPTER 16

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. The turbine can then raise a weight.

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 × 800 m = 160 000 MJ

4 ▶ a Use the formula 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 KE = $\frac{1}{2} \times 80\,\text{kg} \times (9\,\text{m/s})^2$ so KE = 3240 J

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

iii 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.

Assumption: air resistance has little effect.

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 17

1 ▶ a A, C, F and G

b B and E

c A and F (Geothermal energy is not renewable but will last for a very long time)

d D

2 ▶ Wind farms can only be used in windy places.

Hydroelectric power stations must be situated in mountainous regions with plenty of rain.

Tidal power stations can only be used in coastal regions with a large difference between low and high tide levels.

3 ▶ 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.

4 ▶ 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.

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

END OF UNIT 4 QUESTIONS

1 ▶ a D (1) **b** C (1) **c** B (1) **d** A (1) **e** D (1)

2 ▶ a Work done = force × distance (1)

= 800 N × 30 m (1)

= 24000 J (1)

b Power = energy transferred ÷ time taken

= 24000 J ÷ 16 s (1)

= 1500 W (1)

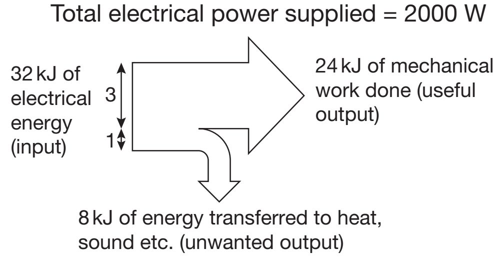
c i This means that only 75% of the electrical power supplied to the motor is transferred usefully in raising the load. (2)

ii Efficiency = Useful power transferred ÷ Total electrical power supplied. (1)

Total electrical power supplied = Useful power transferred ÷ 75/100 (1)

Total electrical power supplied = 2000 W (1)

d



(3)

3 ▶ a B (1)

b Once the rocket has left the launcher it loses speed as KE is transferred to GPE (1)

At the top of the flight the rocket comes to a stop: KE = zero, GPE is maximum (1)

It then falls and gains speed as GPE is transferred to KE (1)

It hits the ground with max KE which is then transferred to heat, sound etc. as it hits the ground (1)

4 ▶ a Any 3 from the following (1 mark each, maximum 3 marks)

Make the mass of ice in each experiment the same (1)

Ensure the initial temperature of the ice is the same in each experiment (1)

Ensure the initial temperature of the water in each tube is the same (1)

Make sure that the source of heat is the same in each experiment (1)

Make sure that room temperature is the same during each experiment (1)

b **i** A C B (1) because heating directly beneath the ice, in B, will mean that more energy is transferred to the ice directly (1) but in C the water in the tube will also need to heat up (1) and in A the water must be heated up and heat transfer down through the water will take longer than in C (1)

ii In B the ice melts quickly because it is almost in direct contact with the heat source (conduction takes place through the glass wall and a thin layer of water).

In cases A and C heat must be transferred through roughly the same length of water, but convection currents will transfer heat from the bottom of the tube as the directly heated water becomes less dense and is pushed to the top of the tube by colder denser water.

This causes heat to be transferred to the top of the tube quite quickly. (1)

Convection will not transfer heat from the top of the tube to the bottom so conduction is the principal way in which heat can be transferred between the heated water at the top and the ice at the bottom. (1)

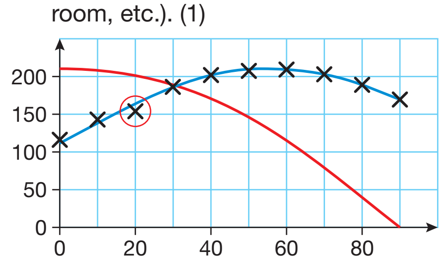
The water at the top can be boiling without the ice at the bottom melting quickly, so we can assume that water is a poor conductor of heat. (1)

5 ▶ a i the current through the load (1)

ii the angle between the plane of the pv cell and the horizontal (1)

iii the distance between the lamp and the pv cell (or the brightness of the lamp, other lighting in the room, etc.). (1)

b



Plotting points (2)
Sensible scales (1)
Scales labelled (1)
Best fit smooth line (1)

c i anomalous result ringed in red (1)

ii peak between 50° and 60° (1)

d i By raising the lamp keeping the stand position where it is (and the lamp reangled to keep the pv cell in the beam (1)

ii See red graph line:

Peak at 0° (any magnitude, likely to be greater than for original graph) (1)

Curves downwards (1)

To a very low level at 90° (1)

UNIT 5 ANSWERS

CHAPTER 18

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 $19\,000\,\text{kg/m}^3 \times 0.0001\,\text{m}^3$

$= 1.9\,\text{kg}$

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 = $0.021\,\text{m}^2$

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

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

3 ▶ a $p = 0.1\,\text{m} \times 1000\,\text{kg/m}^3 \times 10\,\text{N/kg} = 1000\,\text{N/m}^2$

b 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.

c Atmospheric pressure restored in right-hand tube, water levels in both sides of monometer will be equalised.

CHAPTER 19

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 $p_1V_1 = p_2V_2$

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

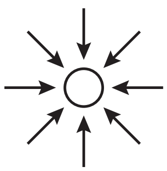
so $p_2 = \frac{p_1 \times T_2}{T_1} = \frac{100\,\text{kPa} \times 268\,\text{K}}{293\,\text{K}} = 91.5\,\text{kPa}$

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 UNIT 5 QUESTIONS

1 ▶ a B **b** C **c** C **d** C **e** D

2 ▶ a



b The pressure on the bubble decreases as it rises towards the surface of the cola (1)

so the bubble gets bigger (1)

because pressure × volume is constant (for a fixed mass of gas at constant temperature) (1)

3 ▶ a i The volume of the stone (1)

ii A measuring cylinder (1)

iii Possible answers: make sure the stone does not splash water out of the big beaker; (1) make sure the measuring cylinder is level; measure to the bottom of the liquid meniscus; look at the scale straight on (avoid parallax error) (1)

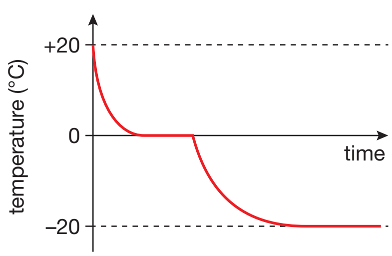
b i Density = mass ÷ volume (1)

ii The mass must be measure on a digital balance (1)

4 ▶ h = 76 cm convert to m = 0.76 m (1)

pressure = h × ρ × g → pressure
= 0.76 m × 13 600 kg/m³ × 10 N/kg (1)
= 103 360 Pa (1)

5 ▶



a Temperature shown falling from 20° to 0° (1)

Correct curve (1)

Levels out at 0 °C (1)

Temperature falling from 0° to -20°C (1)

Levels out at -20 °C (1)

b The temperature falls (1) rapidly at first then more and more slowly as the temperature difference between the water and its surroundings falls. (1)

The temperature stops falling as the water undergoes a change of state from liquid to solid. (1)

The temperature starts to fall again when all the water has solidified. (1)

The temperature stops falling when the ice temperature is the same as the interior temperature of the freezer. (1)

6 ▶ a Heat needed to raise temperature of kettle

= $m_k \times c_k \times \triangle\theta$

= 0.5 kg × 500 J/kg °C × (100 - 20)°C

= 20 000 J (2)

Heat needed to raise temperature of water

= $m_w \times c_w \times \triangle\theta$

= 1.5 kg × 4200 J/kg °C × (100 - 20)°C

= 504 000 J (2)

Therefore total amount of heat energy needed = 524 000 J (1)

b Power of kettle heating element is 2 500 W

Power = energy transferred / time taken (1)

Therefore time taken = Energy transferred / power (1)

= 524 000 J ÷ 2500 W (1)

= 209.6 s (~3.5 minutes) (1)

c The kettle does not heat the water uniformly, so some water will not heat or boil as quickly as the rest. (1)

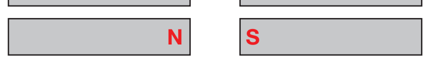
UNIT 6 ANSWERS

CHAPTER 20

1 ▶ c, e, g

2 ▶ a

b

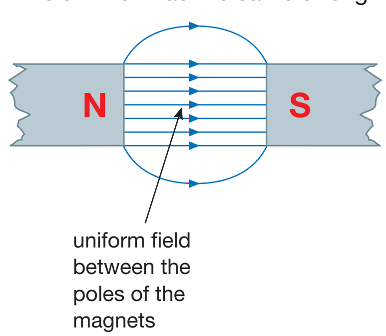


Similar poles repeal and opposite poles attract.

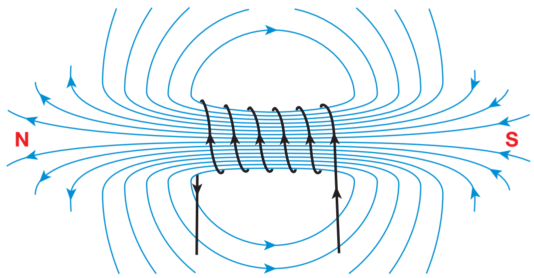
3 ▶ a Shape, strength and direction.

b A field which has the same strength everywhere.

c



4 ▶ 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.

5 ▶ 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.

6 ▶ 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 21

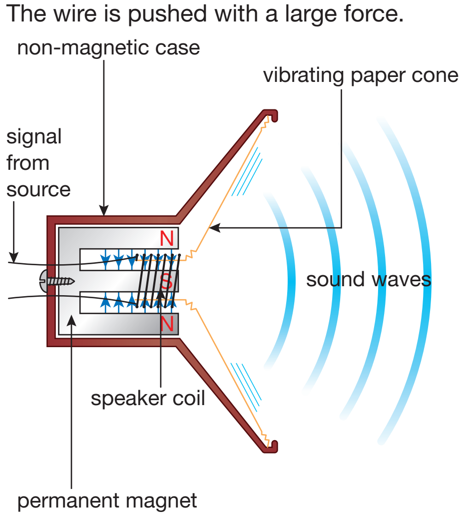
1 ▶ a The wire is pushed upwards.

b The wire is pushed downwards.

c The wire is pushed upwards.

d The wire is pushed with a large force.

2 ▶ a



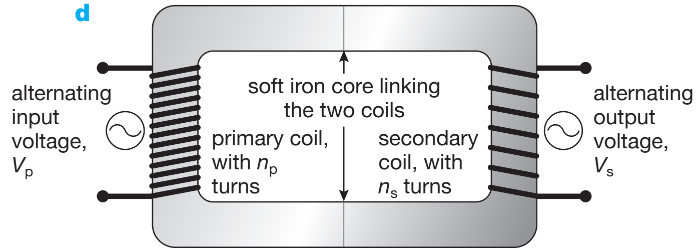
b Varying electric currents from the source create magnetic fields (around the speaker coil) whose strength and direction keeps changing. These changes make the speaker vibrate creating the sound waves we hear.

3 ▶ 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

4 ▶ 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**.

END OF UNIT 6 QUESTIONS

1 ▶ a C **b** D **c** B (3)

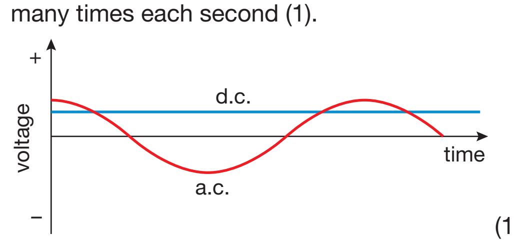
2 ▶ force, magnetic, loudspeakers, motors
coil, induced, dynamos, generators (8)

3 ▶ 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)

4 ▶ 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)

$V_s = \frac{12\,V \times 20\,000}{100}$ (1)

= 2400 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)

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

$= 0.05\,A$ (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))

5 ▶ Increase the number of turns on the coil. (1) Use a stronger magnet. (1) He could pedal faster. (1)

6 ▶ 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).

7 ▶ a A step-up transformer has more turns on its secondary coil than on its primary coil. It is used to increase voltages. A step-down transformer has fewer turns on its secondary coil than on its primary coil. It is used to decrease voltages. (4)

b $V_s = (N_s / N_p) \times V_p = (6000 / 2000) \times 12 = 36V$ (4)

UNIT 7 ANSWERS

CHAPTER 22

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 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.

4 ▶

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

5 ▶ a nucleons, protons, neutrons, +2

b electron, proton, neutron

c gamma, short

d electromagnetic

6 ▶ a i C **ii** B

b ${}^{1}_{1}p \rightarrow {}^{1}_{0}\boxed{p} + {}^{\boxed{0}}_{\boxed{1}}e$

7 ▶ Alpha radiation is stopped by card; since there is a drop in the detected radiation when the card is placed between the source and the detector the source must be emitting alpha particles.

Beta radiation is stopped by a thin sheet of aluminium; since there is no change when the aluminium sheet is used the source *cannot* be emitting beta particles.

Gamma radiation is stopped by a thick block of lead; since there is a drop in the detected radiation when the lead block is placed between the source and the detector the source must be emitting gamma radiation.

8 ▶ a ${}^{\boxed{234}}_{\boxed{90}}Th \rightarrow {}^{\boxed{234}}_{\boxed{91}}Pa + {}^{0}_{-1}e$

b beta decay

c ${}^{216}_{\boxed{84}}Po \rightarrow {}^{\boxed{212}}_{82}Pb + {}^{4}_{2}\boxed{He}$

d alpha decay

CHAPTER 23

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 weapons 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 ▶ 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.

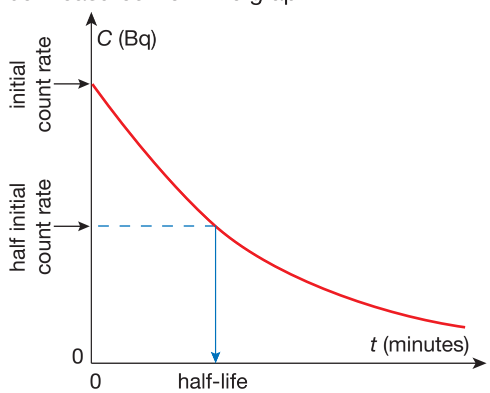
4 ▶ In 1.5 hours the sample has halved in activity three times (240 → 120 → 60 → 30) so three half-life periods have passed; the half-life is, therefore, 30 minutes.

5 ▶ 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 $1\frac{1}{2}$ minutes, three 'half-lives', a further halving will have taken place, leaving the burette one-eighth full, i.e. containing 6.25 ml.

6 ▶ 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 24

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 ▶ a Radioactive contamination is the accidental transfer of radioactive material onto or into an object or living organism. If safety procedures are ignored, people working with radioactive materials could be contaminated by radioactive materials.

Irradiation is the deliberate exposure to ionizing radiation, like gamma rays or X-rays. The irradiation lasts for a controlled period of time and then is turned off.

b Irradiation is used to sterilize surgical instruments. The instruments are sealed into wrappers and then sterilised by irradiating them with ionizing radiation. The radiation passes through the wrapper, destroying any organisms on the instrument, which then remains sterile within its wrapper. The process does not contaminate the instruments with radioactive material.

5 ▶ 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 α 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 in 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.

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 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 25

1 ▶ 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.

2 ▶ 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.

3 ▶ a Graphite acts as a moderator. It slows down the neutrons produced by the random decay of U-235 and this increases their ability to cause fission when they encounter other atoms of U-235.

b The control rods absorb neutrons. When they are raised out of the reactor more neutrons are available to cause fission, so more fissions occur and more energy is transferred from nuclear mass into heat.

c The reactor is encased in several metres of concrete and this prevents nearly all radiation from escaping from the reactor vessel. Workers are also required to wear badges and to carry electronic devices to monitor the total amount of exposure to radiation they have received over a period of time; these are checked regularly to ensure that workers do not exceed the recommended maximum safe exposure.

4 ▶ Nuclear fission is the splitting of large unstable atoms of isotopes of elements, like uranium, into smaller atoms and other particles producing large amounts of energy.

Nuclear fusion occurs when atoms of light elements, like hydrogen, are brought together with enough energy to make them combine to form heavier atoms like helium.

5 ▶ Fission is a process that occurs naturally in isotopes of some elements. Controlling the fission process in a nuclear reactor means that the fission process can be shut down when energy is not required. The conditions for nuclear fusion to take place are much more difficult to create. Nuclei of the fusion elements, isotopes of hydrogen, need to be brought together in conditions of high density (lots of nuclei per cubic metre) and extremely high temperatures. These conditions occur in the hearts of stars but creating the conditions for a controlled fusion reaction on Earth present a huge challenge to scientists and engineers.

END OF UNIT 7 QUESTIONS

1 ▶ a D **b** A **c** B **d** B **e** C (5)

2 ▶ a $^{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{\boxed{2}}_{1}\text{H} + {}^{0}\text{e}$ (2) **b** ${}^{2}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{\boxed{3}}_{\boxed{2}}\text{He}$ (2)

c ${}^{\boxed{3}}_{2}\text{He} + {}^{\boxed{3}}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{\boxed{0}}\boxed{\text{n}} + {}^{1}_{\boxed{0}}\boxed{\text{n}}$ (3)

3 ▶ a E **b** D **c** A **d** C **e** B (5)

4 ▶ a i Nuclear fission is the splitting of large unstable atoms of isotopes of elements, like uranium, into smaller atoms and other particles producing large amounts of energy. (4)

ii Nuclear fusion occurs when atoms of light elements, like hydrogen, are brought together with enough energy to make them combine to form heavier atoms like helium. (4)

b i A chain reaction occurs when neutrons emitted from a nucleus of a fissile material like U-235 collide with further unstable nuclei causing them to decay in turn emitting further neutrons. If each decay trigger more than one further decay then the reaction accelerates causing a huge release of energy in a nuclear explosion. (4)

ii To control the chain reaction and slow down the rate at which decays occur and energy is released it is necessary to reduce the number of emitted neutrons that go on to trigger further nuclei to decay. This is done by lowering control rods into the reactor core to absorb neutrons before they can collide with nuclei in the fissile fuel rods. When the control rods are fully lowered into the reactor core the reaction is shut down and the rate of energy release is very small. (4)

5 ▶ a Nuclear fusion requires plasma made up of deuterium nuclei under high pressure raised to an extremely high temperature. Under these conditions the nuclei can overcome the electrostatic repulsion between the proton in the nuclei, are forced into close contact and combine to form heavier nuclei of helium. (3)

b The nuclear fuel, an isotope of hydrogen, is in abundant supply in water unlike uranium which has a limited supply and is dangerous to mine and transport because of its radioactivity. Fusion reactors produce no long-lived nuclear waste. (2)

6 ▶ a A is the atomic mass of the element equal to the number of the nucleons (protons and neutrons) in the nucleus. Z is the atomic number equal to the number of protons in the nucleus. (2)

b i D ii B iii A iv C (4)

UNIT 8 ANSWERS

CHAPTER 26

1 ▶ a gravitational forces

b the mass and diameter of the planet

c the orbit of Mercury is much more curved than the orbit of Neptune because the gravitational forces between the Sun and Mercury are much stronger than those between Neptune and the Sun.

d the closer a comet is to the Sun the faster it travels.

2 ▶ Moons orbit planets. Planets and comets orbit the Sun. The orbits of moons are circular. The orbits of planets are a little elongated (squashed circles or ellipses). The orbits of most comets are very elongated.

3 ▶ a orbital speed $= \frac{2\pi r}{T}$ so $T = \frac{2\pi r}{\text{speed}}$

$$= 2 \times \pi \times \frac{(35786 + 6400)\,\text{km}}{3.07}$$

$T = 86340\,\text{s}$

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 ▶ a 29.9 km/s (29 886 m/s) b 12.4 km/s (12 452 m/s)

CHAPTER 27

1 ▶ a galaxies

b attractive gravitational forces pull them together

c the Milky Way

d billions.

2 ▶ a B class stars have a surface temperature of 33 000 – 10 000 K and a lot of the light they emit is in the blue part of the visible spectrum. K class stars have a surface temperature of 5200 – 3700 K emit a lot of light in the orange / yellow part of the visible spectrum.

b M class

c F or G class

d 5200 – 7500 K

3 ▶ The apparent brightness of a star is a measure of how bright the star appears when seen from the Earth. The absolute brightness of a star is a measure of how bright a star would appear if it was placed 10 parsecs (32.6 light years) away from the Earth.

4 ▶ Clouds of particle are pulled together so strongly by gravity that nuclear reactions begin, (the star is born) Forces of expansion due to the nuclear reactions and forces of contraction due to gravitational forces become balanced. The star is in its stable period. As the nuclear reactions between Hydrogen nuclei become rarer there is no longer a balance of forces. The star collapses, becomes very hot, new nuclear reactions begin and the star expands greatly until a new balance of forces is established. For stars much more massive than our Sun the new star is called a red supergiant. At the end of this period the balance between forces again disappears and the star collapses. The collapse is so violent the star becomes unstable and explodes. This is a supernova.

5 ▶ a A supernova is an exploding star.

b A supernova occurs when a very massive star e.g. a red supergiant reaches the end of this period. It collapses, becomes very unstable and explodes.

6 ▶ a Canopus is a supergiant and Sirius B is a white dwarf

b Nuclear reactions between Helium nuclei are taking place.

c Sirius B is a white dwarf and will gradually cool and become a black dwarf.

CHAPTER 28

1 ▶ a The sound heard by the observer will have a higher frequency than that heard from the car when stationary.

b The sound heard by the observer will have a lower frequency than that heard from the car when stationary

2 ▶ Red-shift.

3 ▶ The spectrum from the more distant galaxy will show greater red-shift than that from the closer galaxy. This indicates the further galaxy is moving away from the Earth at a greater rate.

4 ▶ The existence of cosmic microwave background radiation. Increased red-shift with more distant galaxies.

5 ▶ speed of galaxy $= \frac{\triangle\lambda}{\lambda} \times c = \frac{600 - 300}{600} \times 3 \times 10^8$

$= 1.5 \times 10^8\,\text{ms}$

END OF UNIT 8 QUESTIONS

1 ▶ a B b B c D d B (4)

2 ▶ comets, orbit, closest, Mercury, Venus, strongest, curved, furthest, Uranus, Neptune, weakest, curved, circular, elliptical, satellites, moons. (16)

3 ▶ a W = 80 × 9 = 720N (3)

b W = 80 × 4 = 320N (3)

c W = 80 × 11 = 880N (3)

4 ▶ $V = \frac{2\pi r}{T} = 2 \times \pi \times (250 + 6400) \times 10^3/2 \times 60 \times 60$
$= 5.8\,\text{km/s}$ (5)

5 ▶ **a** Mercury, Venus and Mars (1)

b 30 years (1)

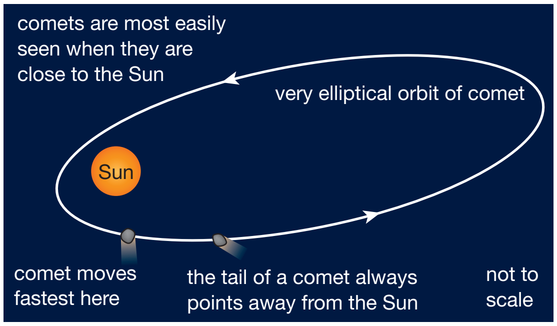
c 1425 million kilometres (2)

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

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

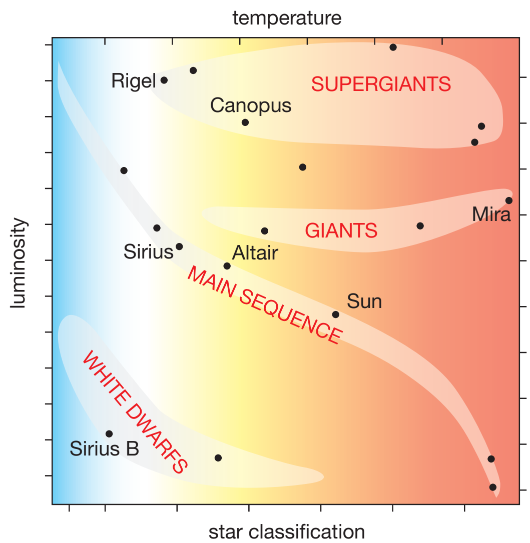
speed $= 2 \times \pi \times \frac{1\,425\,000\,000}{946\,728\,000} = 9.5$ km/s (3)

6 ▶ **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).

7 ▶ (6)



The Hertzsprung-Russell diagram is important because it can be used to describe the life story of a star and predict the future stages of its life. (6)

8 ▶ During the Big Bang lots of energy was released in the form of waves. As the universe expanded these waves became longer and are now in the microwave part of of the electromagnetic spectrum. We call these waves "cosmic microwave background radiation" (3)

9 ▶ VA = $(200 \times 10^{-9} / 500 \times 10^{-9}) \times 3 \times 10^8 = 1.2 \times 10^8$ m/s
VB = $(450 \times 10^{-9} / 500 \times 10^{-9}) \times 3 \times 10^8 = 2.7 \times 10^8$ m/s (10)