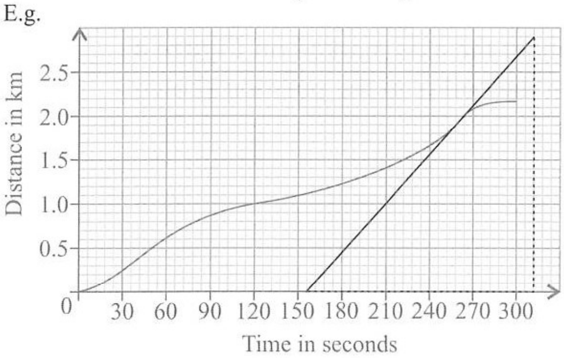
Answers

Section 1 — Motion, Forces and Conservation of Energy

Pages 1-3: Motion

1 a) Total distance travelled = 740 + 1400 + 360 = 2500 m
Average speed = 27.2 m/s
total distance travelled = average speed × total time taken
so, total time taken = total distance travelled ÷ average speed
= 2500 ÷ 27.2
= 91.9117... s
Time taken for last 360 m = 91.9117... – 27 – 50
= 14.9117... s
= 14.9 s (to 3 s.f.)
[4 marks for correct answer, otherwise 1 mark for correct rearrangement of speed equation, 1 mark for correct substitution to find total time taken and 1 mark for correct unrounded answer]

b) Speed is the gradient of a distance/time graph. Maximum speed occurs at point when gradient is greatest, between around 252-264 s. Draw a tangent at this point.
E.g.



Find the gradient of the tangent:
change in y = 2.9 – 0 = 2.9 km
change in x = 312 – 156 = 156 s
speed = gradient = $\frac{\text{change in } y}{\text{change in } x} = \frac{2.9}{156}$ = 0.01858... km/s
To convert to km/h, multiply km/s by 60 × 60 = 3600
speed = 0.01858... × 3600 = 66.923... = **67 km/h (to 2 s.f.)**
(Accept between 62 km/h and 72 km/h)
[5 marks for correct answer, otherwise 1 mark for suitable tangent drawn, 1 mark for attempt to calculate gradient, 1 mark for correct calculation of speed in km/s or m/s and 1 mark for correct unrounded answer]

2 a) 18.0 knots ***[1 mark]***
The maximum speed is 9 m/s.
So the speed in knots is 9 ÷ 0.5 = 18.0 knots.

b) average speed = total distance travelled ÷ total time
Distance travelled is given by area under graph.
Each square = 2 × (5 × 60) = 600 m
Number of squares under graph = 31.5
So, area under graph = 31.5 × 600 = 18 900 m
(Accept between 18 600 m and 19 200 m)
time = 50 minutes = 50 × 60 = 3000 s
So, average speed = 18 900 ÷ 3000 = **6.3 m/s**
(Accept between 6.2 m/s and 6.4 m/s)
[4 marks for correct answer, otherwise 1 mark for correct calculation of area of each square, 1 mark for multiplying area of one square by total number of squares and 1 mark for correct substitution into equation for speed]

3 a) First find the final speed using the equation $v^2 - u^2 = 2ax$
$v = \sqrt{u^2 + 2ax} = \sqrt{1^2 + (2 \times 10 \times 0.75)} = 4$ m/s
$a = \frac{(v - u)}{t}$
so $t = \frac{(v - u)}{a} = \frac{4 - 1}{10} = \mathbf{0.3\ s}$
[5 marks for correct answer, otherwise 1 mark for correct rearrangement of equation for final speed, 1 mark for correct substitution to find the final speed, 1 mark for correct calculation of final speed, and 1 mark for correct substitution into equation to find time]

b) C ***[1 mark]***
Since the stone is moving in a horizontal circle, the resultant force must be a centripetal force.

c) 25 cm = 0.25 m
75 g = 0.075 kg
Substitute into the equation for v^2:
$v^2 = \frac{r^2 T}{ml}$
$= \frac{0.25^2 \times 0.80}{0.075 \times 0.30}$
= 2.22... m/s
Square root to find v:
$v = \sqrt{2.22...}$
= 1.49... m/s = **1.5 m/s (to 2 s.f.)**
[5 marks for correct answer, otherwise 1 mark for correctly converting all units, 1 mark for correctly substituting into the given equation, 1 mark for square-rooting to find v and 1 mark for correct unrounded answer]

Pages 4-5: More on Motion

1 a) Inertial mass is the ratio of force ÷ acceleration.
The gradient of the graph is acceleration ÷ force.
Therefore, inertial mass = 1 ÷ gradient.
gradient = $\frac{4.0 - 0}{2.0 - 0} = 2$
inertial mass = 1 ÷ 2 = **0.5 kg**
[3 marks for correct answer, otherwise 1 mark for calculation of gradient and 1 mark for attempting to find the inverse of the gradient]

b) Read correct acceleration from the line of best fit in Figure 2.
At 1.3 N, a = 2.6 m/s^2
$v^2 - u^2 = 2ax$, so:
$u = \sqrt{v^2 - 2ax} = \sqrt{2.53^2 - (2 \times 2.6 \times 1)}$
= 1.09585... = **1.1 m/s (to 2 s.f.)**
[5 marks for correct answer, otherwise 1 mark for correct value of acceleration from the line of best fit, 1 mark for correct rearrangement, 1 mark for correct substitution and 1 mark for correct unrounded answer]

c) For the car to travel at a constant speed, the braking force must equal the force causing it to accelerate down the hill.
$F = ma$
Typical mass of a car ≈ 1000 kg
So, braking force = 1000 × 1.8 = **1800 N**
[3 marks for correct answer, otherwise 1 mark for suitable typical mass of a car and 1 mark for correct substitution]
You'd get full marks here for correct calculations using any suitable value for the mass of a car.

2 The Earth exerts an attractive force on a person equal to their weight *[1 mark]*. Due to Newton's third law, the person must exert an equal and opposite force on the Earth *[1 mark]*. The Earth does not noticeably move towards the person because the Earth has a much higher mass than a person *[1 mark]* and since acceleration is inversely proportional to mass (Newton's second law) the Earth's acceleration towards the person is very small/negligible *[1 mark]*.

Pages 6-9: Stopping Distances and Momentum

1 a) How to grade your answer:

Level 0: There is no relevant information. *[No marks]*

Level 1: There is a brief explanation of the general trends of the graphs, but the points made are vague and not well connected. An equation of motion or energy transfer is mentioned, but its link to the graphs is not clear. *[1 to 2 marks]*

Level 2: There is some explanation of the shapes of the two graphs, with reference to equations of motion and energy changes. Some relevant equations of motion or energy transfers are missing. *[3 to 4 marks]*

Level 3: There is a clear and detailed explanation of the shapes of the graphs, with reference to equations of motion and energy changes. Points made are clearly linked and all relevant equations of motion and energy transfers are included. *[5 to 6 marks]*

Here are some points your answer may include:
Thinking distance is the distance travelled during the driver's reaction time.
Reaction time does not depend on speed.
So, since distance travelled = speed × time, and time is constant, thinking distance increases linearly with speed.
So the graph of thinking distance is a straight line.
Braking distance is the distance travelled between applying the brakes and coming to a stop.
When a vehicle brakes, the brakes do work to transfer energy away from the kinetic energy store of the vehicle.
Work done = force × distance, and the braking force is assumed to be constant at the maximum force the brakes can apply.
So the braking distance is proportional to the work done by the brakes.
To stop the vehicle, the brakes must do work equal to the energy in the kinetic energy store of the vehicle.
The energy in the vehicle's kinetic energy store = ½ × mass × $(\text{speed})^2$.
So braking distance is proportional to the speed of the vehicle squared.
This produces the curved graph of braking distance against speed.

b) Convert 33 m/s to mph:
Speed in mph = 33 ÷ 0.447 = 73.8... mph ≈ 74 mph
Evaluate both graphs at 74 mph:
Thinking distance = 22 m
Braking distance = 84 m
Stopping distance = 22 + 84 = **106 m**
[3 marks for correct answer, otherwise 1 mark for correctly converting the speed to mph and 1 mark for correctly reading distance from one of the graphs]

c) Thinking distance/reaction time is not affected by road conditions and so the thinking distance graph will remain the same *[1 mark]*. A slippery road means there will be less friction between the tyres and the road once the brakes have been applied *[1 mark]*. This will result in the car travelling further for the same speed *[1 mark]*, so the gradient of the braking distance graph will be greater at all speeds *[1 mark]*.

2 a) First, calculate the final velocity of the ruler when it is caught.

$$a = \frac{(v - u)}{t} \text{ so}$$

$(v - u) = at = 10 \times 0.20 = 2.0$ m/s
As initial velocity = 0 m/s, the final velocity = 2.0 m/s.
Rearrange $v^2 - u^2 = 2ax$, for distance travelled:

$$x = \frac{v^2 - u^2}{2a} = \frac{2.0^2 - 0^2}{2 \times 10} = 0.20 \text{ m}$$

$$= \mathbf{20\ cm}$$

[5 marks for correct answer, otherwise 1 mark for correct calculation of the final velocity, 1 mark for correct rearrangement for distance travelled, 1 mark for correct substitution to find distance travelled and 1 mark for correct answer in m]

b) Any two from: e.g. The ruler could be weighted at the bottom (e.g. with modelling clay) *[1 mark]*. This would ensure that the ruler falls vertically downwards, so distance measured is more accurate *[1 mark]*. / Another person should be present to make sure the ruler is aligned correctly with the thumb before being dropped *[1 mark]*. This will help prevent parallax errors in measuring the starting position of the ruler *[1 mark]*. / Several repeat measurements should be taken and the average reaction time calculated *[1 mark]*. This will help reduce the effect of any random errors on the final result *[1 mark]*.

3 a) 25 cm = 0.25 m
For marble B:
kinetic energy immediately after the collision = gravitational potential energy at the top of the ramp

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

$v = \sqrt{2gh}$

$= \sqrt{2 \times 10 \times 0.25}$

$= 2.236...$ m/s

= 2.2 m/s (to 2 s.f.)

[4 marks for the correct answer, otherwise 1 mark for equating gravitational potential and kinetic energies, 1 mark for correctly rearranging for Marble B's speed immediately after collision and 1 mark for correct substitution]

b) Momentum before the collision = momentum after

$(m_A \times 2.9) + (m_B \times 0) = 0.7\,m_A + (2.236... \times m_B)$

$2.9\,m_A = 0.7\,m_A + (2.236... \times m_B)$

$2.2\,m_A = 2.236... \times m_B$

$m_A = 1.016... \times m_B$

$\frac{m_A}{m_B}$ **= 1 (to 1 s.f.)**

[4 marks for correct answer, otherwise 1 mark for showing the conservation of momentum, 1 mark for a correct expression of the momentum before the collision, 1 mark for a correct expression of the momentum after the collision]

c) The marble is dropped from the same height each time, which means its change in momentum will be the same ***[1 mark]***. However, the carpet is less able to deform than the sponge, so the marble's impact time will be shorter. This means the average force exerted during impact with the carpet will be greater (as the average force experienced by the marble is given by Newton's second law $F = \frac{(mv - mu)}{t}$) ***[1 mark]***.

4 a) Calculate the driver's thinking distance:
Thinking distance = reaction time × speed
= 1.50 × 27.0 = 40.5 m
Calculate the car's braking distance:
stopping distance = thinking distance + braking distance
braking distance = stopping distance – thinking distance
= 113 – 40.5 = 72.5 m
Calculate the resultant force acting on the car whilst braking:
work done by the brakes = energy in the car's k.e. store

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

$F = \frac{mv^2}{2d} = \frac{1500 \times 27^2}{2 \times 72.5} = 7541.3...$ N = **7540 N (to 3 s.f.)**

[6 marks for correct answer, otherwise 1 mark for correctly substituting into thinking distance equation, 1 mark for correctly calculating thinking distance, 1 mark for correctly calculating braking distance, 1 mark for equating initial kinetic energy with work done and 1 mark for correctly rearranging this equation for force]

b) B ***[1 mark]***

The amount of work required to bring the car to a stop is equal to the amount of energy in the car's kinetic energy store, $\frac{1}{2}mv^2$, so it will depend on the car's mass and speed.

c) Energy is transferred from the kinetic energy store of the car to the chemical energy store of the car's battery ***[1 mark]***. Also, energy is transferred from the kinetic energy store of the car to the thermal energy stores of the brakes (and the surroundings) ***[1 mark]***.

Pages 10-12: Energy Transfers and Energy Resources

1 a) mass of stone, m_s = 20 g = 20 ÷ 1000 = 0.02 kg
mass of box = 100 g = 100 ÷ 1000 = 0.1 kg
total mass of box and stone, m_T = 0.1 + 0.02 = 0.12 kg
height of swing = 20 cm = 20 ÷ 100 = 0.2 m
$\Delta GPE = m_T g \Delta h = 0.12 \times 10 \times 0.2 = 0.24$ J
energy transferred to GPE stores of box and stone = energy transferred from kinetic energy store of the stone.
$\Delta GPE = KE = \frac{1}{2}m_s v^2$

$v = \sqrt{\frac{2\,KE}{m_s}} = \sqrt{\frac{2 \times 0.24}{0.02}}$

$= 4.8989...$ m/s

= 4.9 m/s (to 2 s.f.)

[6 marks for correct answer, otherwise 1 mark for correct substitution into equation for gravitational potential energy, 1 mark for correct calculation of energy in gravitational potential energy store, 1 mark for correct rearrangement of the kinetic energy equation, 1 mark for correct substitution into the kinetic energy equation and 1 mark for correct unrounded answer]

b) E.g. as the box swings energy is dissipated to the thermal stores of the surroundings, reducing the energy in the gravitational potential energy store each time the swing peaks ***[1 mark]***.

2 a) Calculate the energy supplied to the heater:

efficiency = $\frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$

total energy supplied to the device

$= \frac{\text{useful energy transferred by the device}}{\text{efficiency}}$

$= \frac{0.68}{0.98} = 0.693...$ MJ

Calculate the energy supplied to the turbine by the wind:
total energy supplied to the device

$= \frac{\text{useful energy transferred by the device}}{\text{efficiency}}$

$= \frac{0.693...}{0.37} = 1.87...$ MJ = **1.9 MJ (to 2 s.f.)**

[4 marks for correct answer, otherwise 1 mark for correctly rearranging the efficiency equation, 1 mark for correctly calculating the energy supplied to the heater and 1 mark for correct unrounded answer]

b) Typically, most energy is dissipated to the thermal energy stores of the surroundings ***[1 mark]***. In a heater, energy transferred to the thermal energy stores of the surroundings is considered useful, meaning there is little waste and efficiency is high ***[1 mark]***.

c) E.g. the new insulation has a lower thermal conductivity than the old insulation ***[1 mark]***.

3 a) How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: There are some relevant points but they are basic or unclear. Mentions a benefit and a drawback for using more wind power, or makes a comparison of wind and coal in at least one area. ***[1 to 2 marks]***
Level 2: There is a description referring to at least one benefit and one drawback of using more wind power and how this compares to using coal. The points made have some detail, but may not be linked. ***[3 to 4 marks]***
Level 3: There is a clear and detailed description referring to both benefits and drawbacks of using more wind power and how they compare to using coal. The answer refers to reliability and environmental factors. ***[5 to 6 marks]***

Here are some points your answer may include:

Benefits:
Using more wind power will be more sustainable for the future, as wind is renewable and can be replenished/will not run out, but coal is non-renewable and can't be replenished/ will run out.
Using more wind and less coal to generate electricity will reduce the harm done to the environment, such as the amount of pollutants released into the atmosphere.
Using wind to generate electricity does not produce carbon dioxide but burning coal does.
Carbon dioxide contributes to the greenhouse effect/climate change/global warming.
Using wind to generate electricity does not release sulfur dioxide but burning coal does.
Sulfur dioxide contributes to acid rain, which can be harmful to trees and soils and can have far-reaching effects in ecosystems.
Wind does not need to be mined, but coal does, which can destroy habitats and changes the landscape.

Drawbacks:
Using more wind than coal to generate electricity may cause electricity supply issues.
Wind is less reliable than coal as power cannot be generated when it isn't windy / it is too windy, whereas coal is currently always in stock, and can be burnt at any time to produce energy.
Wind power cannot be increased to meet demand, whereas a coal-fuelled power station can be made to increase its power by burning coal at a greater rate.
Using more wind than coal to generate electricity may also raise economic and social issues.
It costs money to build new wind turbines and connect them to the national grid, but it does not cost any extra to continue using existing coal plants.
Wind turbines may be noisy, which can disrupt local residents and wildlife.
Wind turbines are considered by some people to be an eyesore.

b) To find the total percentage greater than 10 m/s, multiply the height of each bar to the right of 10 m/s by its width, then add them all together:
Percentage time $= (7 \times 2) + (5 \times 4) + (2 \times 4) + (1 \times 4)$
$= \mathbf{46\%}$
[2 marks for correct answer, otherwise 1 mark for correctly reading widths and heights of the correct bars from the graph]

Section 2 — Waves and the Electromagnetic Spectrum

Page 13: Measuring Waves

1 a) The distance between ten shadow lines is equal to nine wavelengths, so one wavelength is equal to
$27 \div 9 = 3 \text{ cm} = 0.03 \text{ m}$
$v = f \times \lambda = 4.0 \times 0.03 = 0.12 \text{ m/s}$
$v = \frac{x}{t}$
$x = 18 \text{ cm} = 0.18 \text{ m}$
Rearrange for t:
$t = \frac{x}{v}$
$= \frac{0.18}{0.12} = \mathbf{1.5 \text{ s}}$
[5 marks for the correct answer, otherwise 1 mark for calculating the correct wavelength, 1 mark for correct substitution into $v = f \times \lambda$, 1 mark for calculating the correct wave speed and 1 mark for correct rearrangement and substitution into $t = x \div v$]

b) If the ripple tank was illuminated at an angle, the shadows produced would be distorted/uneven, so it would be difficult to measure the wavelength accurately ***[1 mark]***.

c) The time interval is 0.25 s ***[1 mark]***. The time taken for a wave to travel exactly one wavelength ahead and take the place of the previous wave (and so appear to have not moved) is equal to the period of the wave ***[1 mark]***.

Pages 14-15: Exploring Structures Using Waves

1 Ultrasound is partially reflected when it crosses the boundary between two different materials ***[1 mark]***. In a solid gold bar, the first reflection would occur when ultrasound enters the bar., then there would be a second reflection when the ultrasound hits/reaches the other side of the bar ***[1 mark]***. If the bar has a tungsten core, there would be a third reflection when the ultrasound enters the tungsten, and a fourth reflection when the ultrasound leaves the tungsten ***[1 mark]***. So if the bar was solid gold there would be two reflections in total, but if the bar had a tungsten core then there would be four reflections in total ***[1 mark]***.
OR
The speed of a sound wave will be different in gold than it is in tungsten ***[1 mark]***. Measure the width of the bar and the time it takes for an ultrasound signal to travel through the bar ***[1 mark]***. From this the speed of the ultrasound wave can be calculated ***[1 mark]***. Compare the speed measured to the speed of ultrasound in gold — if it is different, the bar is fake ***[1 mark]***.

2 The distance the ultrasound travels at the deepest point is twice the depth, because it travels from the ship to the sea floor, and from the sea floor back up to the ship:
$175 \times 2 = 350$ m
The speed of the ultrasound wave:
$x = v \times t$ so $v = x \div t$
$= 350 \div 0.23 = 1521.7...$ m/s
The distance the ultrasound travels at the second point is twice the depth like before:
$63 \times 2 = 126$ m
The time taken for the wave to travel to the sea floor and back at the second point:
$x = v \times t$ so $t = x \div v$
$= 126 \div 1521.7...$
$= 0.0828 =$ **0.83 s (to 2 s.f.)**
[5 marks for the correct answer, otherwise 1 mark for correct substitution into v = x ÷ t, 1 mark for correctly calculating the speed of ultrasound in sea water, 1 mark for correct substitution into t = x ÷ v and 1 mark for the correct unrounded answer]

3 a) How to grade your answer:
Level 0: There is no relevant information. ***[No marks]***
Level 1: A brief explanation of the properties of S-waves and P-waves is given, but no clear link is made with the shaded regions in Figure 1 or to what information these provide about the Earth's interior structure. ***[1 to 2 marks]***
Level 2: A clear explanation is given, although it may be lacking in detail. The relevant properties of both kinds of seismic wave are stated. These properties are linked to an explanation of how the patterns of detected waves are produced by the Earth's interior, with reference to the shaded regions in Figure 1. ***[3 to 4 marks]***
Level 3: A well-written, detailed and coherent explanation is given. The relevant properties of both kinds of seismic wave are stated. These properties are clearly linked to a full and detailed explanation of how the patterns of detected waves are produced by the Earth's interior with reference to the shaded regions in Figure 1. ***[5 to 6 marks]***
Here are some points your answer may include:
P-waves can travel through liquids and solids.
S-waves can travel through solids, but not liquids.
S-waves are detected near to point X, so they are able to travel through the outer layer of the Earth.
This means that the outer layer of the Earth must be solid.
There is a shaded region on the opposite side of the Earth where P-waves are detected but S-waves are not.
Since P-waves are able to pass through the centre of the Earth but S-waves are not, there must be liquid present.
There are also zones where no P-waves are detected. This is because the P-waves are refracted when crossing the boundaries from solid to liquid and back to solid again.
So the interior structure of the Earth must consist of a liquid layer surrounded by a solid outer layer.

b) The wave slows down as it passes from the mantle to the outer core, so it refracts and bends towards the normal to the boundary ***[1 mark]***. The wave speeds up as it passes back from the outer core to the mantle, so it refracts and bends away from the normal to the boundary ***[1 mark]***.

Pages 16-19: Electromagnetic Waves

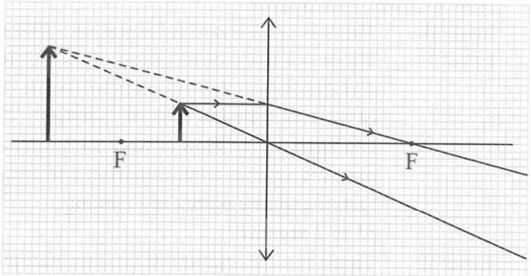
1 a) 20% of the energy is absorbed by the atmosphere and 10% of the energy is reflected by the atmosphere, so
$100 - 20 - 10 = 70\%$ (or 0.7) is transmitted through.
Energy of radiation that is transmitted through the atmosphere $= 0.7 \times 400 = 280$ J
The ratio of energy absorbed by the planet's surface to the energy reflected by the planet's surface is 5:2.
So the radiation that passes through the atmosphere transfers $\frac{5}{7}$ of its energy to the surface.
Energy absorbed by the surface $= \frac{5}{7} \times 280 =$ **200 J**
[2 marks for the correct answer, otherwise 1 mark for correctly calculating the energy of the radiation that is transmitted through the atmosphere]

b) The temperature of the surface of the planet will decrease ***[1 mark]*** because the moon will block radiation from the star from reaching the planet and transferring energy to the surface ***[1 mark]***.

2 a) 100% of the light with a wavelength of 600 nm is reflected. This wavelength corresponds to the colour of the paint.
$v = f \times \lambda$
Rearrange for f:
$f = v \div \lambda$
$= (3.0 \times 10^8) \div (600 \times 10^{-9})$
$= 5 \times 10^{14}$ Hz (or 500 THz)
From the table, this frequency corresponds to **orange**.
[4 marks for the correct answer with supporting calculation, otherwise 1 mark for rearranging the equation, 1 mark for correct substitution, 1 mark for correctly calculating the frequency of the reflected light]

b) The pigment has a rough surface, so the higher the ratio of binder to pigment, the smoother the surface ***[1 mark]***. Light undergoes specular reflection from smooth surfaces, and diffuse reflection from rough surfaces ***[1 mark]***. Light undergoes more specular reflection from glossy surfaces than matte surfaces, so there must be a higher ratio of binder to pigment in glossy paints than in matte paints ***[1 mark]***.

3 a) i)



[1 mark for virtual rays drawn correctly, 1 mark for ray drawn through the principal focus then parallel to the axis, 1 mark for ray drawn diagonally through the axis and the lens, 1 mark for object drawn with correct position and size]

ii) B ***[1 mark]***

iii) The image produced by the concave lens will also be the right way up/to the left of the lens ***[1 mark]***, but will be smaller than the object rather than larger ***[1 mark]***.

b) 640 nm = 640×10^{-9} m

Find the frequency of the red light in air:

$v = f \times \lambda$ so $f = v \div \lambda$

$= (3.0 \times 10^8) \div (640 \times 10^{-9})$

$= 4.6875 \times 10^{14}$ Hz

The frequency of a wave does not change when it enters a new medium, so this is also the frequency in the lens.

So wavelength of the red light in the lens:

$v = f \times \lambda$ so $\lambda = v \div f$

$= (2.0 \times 10^8) \div (4.6875 \times 10^{14})$

$= 4.266... \times 10^{-7}$

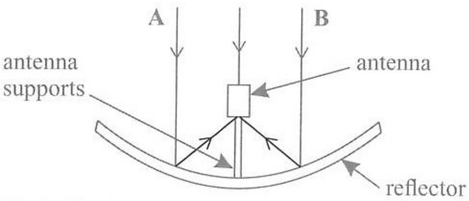
= 430 nm (to 2 s.f.)

[5 marks for correct answer, otherwise 1 mark for rearrangement of $v = f \times \lambda$ to $f = v \div \lambda$, 1 mark for correct substitution into $f = v \div \lambda$, 1 mark for correctly calculating frequency, 1 mark for correct substitution into $\lambda = v \div f$]

c) White light is a mixture of different colours of visible light, which all have different wavelengths ***[1 mark]***. The amount light is refracted by the lens varies depending on the wavelength of the light ***[1 mark]***. So the rays of different coloured light converge at slightly different points to form the image, leading to the violet fringes around the edge ***[1 mark]***.

4 a) E.g. Gamma radiation has hazardous effects on the human body, so using it in communications would be dangerous ***[1 mark]***.

b) i)



[1 mark]

ii) The radio waves represented by both rays are travelling at the same speed ***[1 mark]***, but those in ray A have to travel further than those in ray B, so they take longer to reach the antenna (as $v = x \div t$) ***[1 mark]***.

Section 3 — Radioactivity and Astronomy

Pages 20-22: The Atomic Model and Nuclear Radiation

1 a) Beta decay ***[1 mark]***.

b) ${}^{93}_{39}\text{Y} \rightarrow {}^{93}_{40}\text{Zr} + {}^{0}_{-1}\text{e}$

[2 marks for the correct answer, otherwise 1 mark for correct symbol for a beta particle or 1 mark for all the atomic and mass numbers correct]

c) E.g. The mass number has decreased by 4, so the nucleus has lost 4 nucleons. This means the particle emitted was an alpha particle ***[1 mark]***. The nucleus has lost 2 protons and 2 neutrons ***[1 mark]***.

d) 55 – 2 = 53 ***[1 mark]***

When a caesium nucleus emits an alpha particle to become iodine, it loses two protons, so its atomic number decreases by 2.

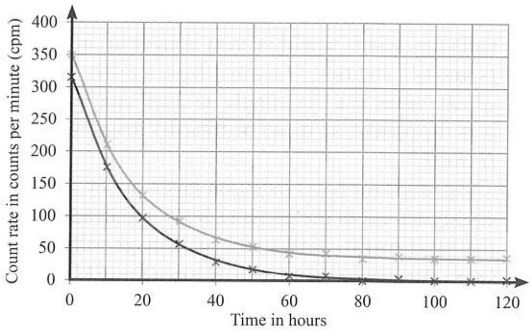
e) A ***[1 mark]***

In fusion, lighter elements fuse together to form heavier elements. Calcium is the only element with a lower atomic number than titanium in the list, so it's the only lighter element than titanium.

f) There are different isotopes of some elements. Isotopes have the same atomic number but different mass numbers so an element doesn't have one fixed mass number. ***[1 mark]***

2 a) 35 counts per minute ***[1 mark, accept any answer between 32 cpm and 37 cpm]***

b)



[2 marks for all points and line correctly plotted, otherwise 1 mark for all points being 35 cpm below the original curve]

Even if you got the answer to 2.1 wrong, you get full marks for 2.2 if you drew the correct curve using your answer for 2.1.

c) 12 hours

Use the curve you drew in 2.2 and work out the time taken for the count rate to halve, e.g. from 315 cpm to 157.5 cpm.

[2 marks for correct answer found from the graph with background radiation removed, otherwise 1 mark for calculating an incorrect value for half-life using the correct method but the original uncorrected graph]

d) Since the measurements are accurate to ± 5 cpm, the count rate will definitely be below 25 if the corrected count rate is below 20 cpm ***[1 mark]***.

The water is safe to drink after 49 hours ***[1 mark — accept any value between 48 and 50]***.

e) E.g. radioactivity is a random process. A single reading below 25 cpm does not necessarily indicate that the count rate will stay below 25 cpm ***[1 mark]***.

3 a) D *[1 mark]*.

b) The initial decay of polonium-218 to lead-214 emits α radiation, but no β^- radiation. So the count rate of β^- emission is initially zero *[1 mark]*. The subsequent decay of lead-214 to bismuth-214 does emit β^- radiation *[1 mark]*. So, as the amount of lead-214 present increases, so will the count rate of β^- emission *[1 mark]*. After some time the rate at which lead-214 decays will exceed the rate at which it is created, reducing the amount present in the sample. In turn the count rate of β^- emission will also decrease *[1 mark]*.

Pages 23-25: Uses and Dangers of Nuclear Radiation

1 a) $^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$

[2 marks for the correct answer, otherwise 1 mark for correct symbol for a beta particle or 1 mark for all the atomic and mass numbers correct]

$^{131}_{54}Xe \rightarrow {}^{131}_{54}Xe + \gamma$

[2 marks for the correct answer, otherwise 1 mark for correct symbol for gamma radiation or 1 mark for all the atomic and mass numbers correct]

b) When gamma radiation is emitted, the nucleus loses energy *[1 mark]* and the nucleons are rearranged *[1 mark]*.

c) Any two from: e.g. Iodine-131 decays to release gamma radiation which is penetrative enough to be detected outside of the body *[1 mark]*. / Iodine-131 doesn't give out alpha radiation, which would be very dangerous inside the body *[1 mark]*. / Iodine-131 doesn't have a really short half-life, which means that the sample will still emit radiation once it is in the patient, so it can be traced/a diagnosis can be made *[1 mark]*.

d) The gamma (or beta) radiation given out by the iodine-131 could pass out of the patient's body and irradiate others nearby *[1 mark]*. Radiation can damage cells and so could cause damage to the people nearby *[1 mark]*.

e) E.g. Each tellurium nucleus occupies a very small fraction of the atom's volume, which is mostly empty space. Neutrons may pass through this empty space without interacting with the nucleus *[1 mark]*. Neutrons have no electric charge and so they won't be attracted to (or repelled by) the positively charged nuclei *[1 mark]*.

2 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There is a basic description of contamination and irradiation, but no comparison or discussion of the risk for each type of radiation. Or there is a basic suggestion of how the protective suit protects against contamination and irradiation. Detail and key points are lacking. ***[1 to 2 marks]***

Level 2: There is a description of contamination and irradiation and an attempt to compare the risk for each type of radiation. There is a basic suggestion of how the protective suit protects against contamination and irradiation. Key points are mentioned but detail may be lacking. ***[3 to 4 marks]***

Level 3: A detailed description and explanation is provided. The answer contains examples of how the risk of contamination and irradiation differs for each type of radiation, and a full explanation of how the protective suit protects against contamination and irradiation. ***[5 to 6 marks]***

Here are some points your answer may include:

The workers are at risk of contamination if the uranium-235 gets onto their skin or if they breathe it in.

They are also at risk of irradiation if they are exposed to radiation.

The risk posed by contamination is high as uranium-235 emits alpha particles which do a lot of damage inside the body.

Gamma radiation isn't as dangerous inside the body as alpha radiation.

The risk posed by irradiation is also high because uranium-235 emits gamma radiation which can easily penetrate deep into the body from outside and damage organs / tissues.

Alpha particles cannot penetrate the body so gamma radiation is more dangerous outside of the body.

The radiation shielding material helps to protect against irradiation as some radiation will be blocked/absorbed before it reaches the body.

The breathing mask protects against contamination as it stops the worker breathing in any radioactive particles in the air.

The protective gloves protect against contamination as they stop radioactive particles getting on the worker's hands.

The sealed zips protect against contamination as they stop any radioactive particles getting into the protective suit.

The sealed zips ensure that there are no gaps in the radiation shielding suit, so they protect against irradiation.

b) C *[1 mark]*

The first option cannot be correct as fission is a chain reaction, so more neutrons need to be released along with the products. The second option cannot be correct as the nucleus has to absorb a neutron to undergo fission. The fourth option cannot be correct as the equation is unbalanced — the mass numbers are not equal on both sides of the arrow.

3 a) C *[1 mark]*

Energy is released when an atom undergoes fission, so increasing the number of fissions increases the energy released.

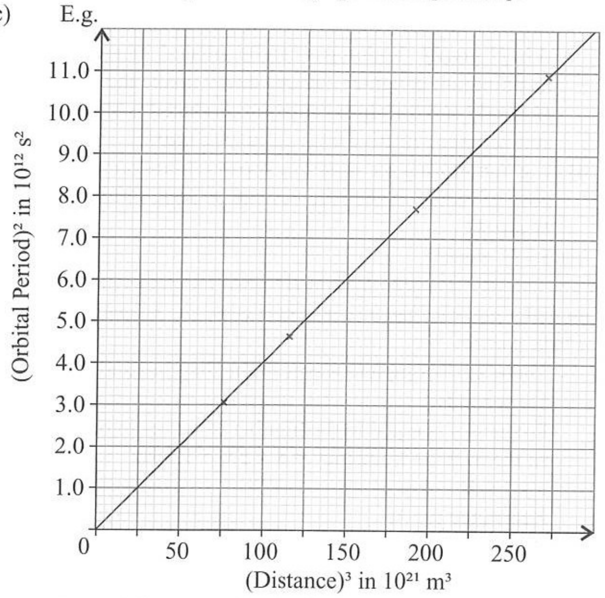
b) Iodine-131 is dangerous when inhaled or ingested as beta radiation is ionising and can cause damage to the body internally *[1 mark]*. If this iodine were absorbed by the thyroid, it would remain in the body for a long time / travel around the body in molecules made by the thyroid *[1 mark]*. Ingesting a potassium iodide tablet with a stable iodine isotope allows the thyroid to absorb enough iodine in the form of a stable isotope, preventing the radioactive iodine-131 from being absorbed by the thyroid *[1 mark]*. The stable iodine does no harm and the iodine-131 is then removed from the body, which minimises the time that the ionising radiation spends in the body and so minimises damage through irradiation *[1 mark]*.

Pages 26-28: Astronomy

1 a) The planet's speed is constant, but its direction is constantly changing, so its velocity is changing *[1 mark]*. Since acceleration is the change in velocity over time, the planet is constantly accelerating *[1 mark]*.

b) E.g. Some light is absorbed by the atmosphere when light passes through it to get to ground-based telescopes. More light can reach space-based telescopes (and allow them to create clearer images) because light doesn't have to pass through the atmosphere to reach them *[1 mark]*. Ground-based telescopes also produce less clear images than space-based telescopes due to light pollution *[1 mark]*.

c) E.g.



[1 mark for correctly plotting the point, 1 mark for suitable straight line of best fit]

d) Compare Kepler's third law, $T^2 = kr^3$, to the equation of a straight line, $y = mx + c$.

$y = T^2$, $m = k$, $x = r^3$ and $c = 0$

So Kepler's constant, k = gradient of the graph, m

E.g. $k = \frac{\text{change in } y}{\text{change in } x} = \frac{10.1 \times 10^{12} - 0}{250 \times 10^{21} - 0} = \mathbf{4.04 \times 10^{-11}\ s^2/m^3}$

(Accept between 4.00×10^{-11} s²/m³ and 4.08×10^{-11} s²/m³)

[2 marks for correct answer, otherwise 1 mark for attempt to calculate gradient]

e) Charon's orbital speed will have decreased when it moved to its current orbit from its old orbit *[1 mark]*, because, as the moon is further from Pluto, it experiences a weaker gravitational force towards Pluto, and so it must travel slower in order to remain in a stable orbit *[1 mark]*.

2 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There is a basic description of the Big Bang and Steady State theories, but no evidence given in support of either. The Big Bang theory is named as the accepted theory but no justification is given. ***[1 to 2 marks]***

Level 2: There is a description of the Big Bang and Steady State theories and an attempt to provide evidence in support of each. The Big Bang theory is named as the accepted theory and some justification is given. ***[3 to 4 marks]***

Level 3: A detailed description and explanation is provided for each theory. The answer contains a full explanation and comparison of the evidence that supports each theory. The Big Bang theory is named as the accepted theory and accurate justification is given. ***[5 to 6 marks]***

Here are some points your answer may include:

The Steady State theory proposes that the Universe has always been and always will be in the same state as it is now.

In the Steady State theory the Universe is expanding as a result of the steady creation of new matter.

The Universe has no defined beginning or end in the Steady State theory.

The Big Bang theory proposes that the Universe had a definite beginning. At this beginning, the Universe rapidly expanded from a very small point.

In the Big Bang theory, this initial expansion continues into the present day.

Both theories are supported by the red-shift of light from distant galaxies (since this indicates the Universe is expanding, a feature of both theories).

The Cosmic Microwave Background radiation (CMB) provides strong evidence in support of the Big Bang theory (the radiation is the 'aftermath' of the Big Bang).

The Steady State theory does not explain the presence of the Cosmic Microwave Background.

The Big Bang theory is the accepted theory for the evolution of the Universe.

The Big Bang theory is accepted since it provides an explanation for the Cosmic Microwave Background, whereas the Steady State theory cannot.

b) Whilst still a nebula, the dominant force acting is gravity, pulling matter tightly together *[1 mark]*. During the star's main phase, gravity and pressure due to thermal expansion are balanced and the star is stable *[1 mark]*. At the point when a main sequence star becomes a red giant, gravity in the core exceeds pressure due to thermal expansion. The core contracts and the energy released causes outer layers to expand *[1 mark]*.

c) The black hole will have less mass than the red supergiant *[1 mark]*, since the star loses mass when it goes supernova *[1 mark]*. The black hole will be more dense than the red supergiant *[1 mark]* because, to become a black hole, the red supergiant's core has collapsed and become much smaller *[1 mark]*.

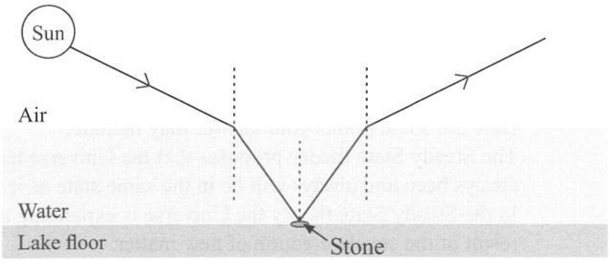
Mixed Questions for Paper 1

Pages 29-33: Mixed Questions for Paper 1

1 a) i) The stone is travelling downwards ***[1 mark]*** with a constant acceleration ***[1 mark]***.

ii) The maximum height is reached when the stone's velocity reaches 0 m/s for the first time, which is 0.11 s after it hits the water. The distance travelled during this time is equal to the area under the graph up to this time.
Area of a triangle is 0.5 × base × height
So maximum height of the stone = 0.5 × 0.11 × 1.0
= **0.055 m**
[2 marks for the correct answer, otherwise 1 mark for reading the correct values from the graph]

b)



[1 mark for drawing light rays so that the angle of incidence on the stone is equal to the angle of reflection and 1 mark for drawing the light refracting away from the normal as it leaves the water]

2 a) The universe is expanding, and so galaxy X is moving away from the Earth ***[1 mark]***. Red-shift occurs when an object that is emitting light is moving away from the observer, and so the wavelengths of the light from galaxy X are stretched out and the light is red-shifted ***[1 mark]***.

b) Read wavelengths of equivalent dark lines from the spectra and find difference between them:
E.g. reading fourth dark line:
Wavelength in spectrum B, λ = 656 nm
Wavelength in spectrum A = 670 nm
So, $\Delta\lambda$ = 670 – 656 = 14 nm
$z = \frac{\Delta\lambda}{\lambda} = \frac{14}{656} = 0.021341...$ = **0.021 (to 2 s.f.)**
(Accept between 0.019 and 0.023)
[4 marks for correct answer, otherwise 1 mark for reading correct pair of values from the spectra, 1 mark for correct substitution and 1 mark for correct unrounded answer]

c) Galaxy Y is further from Earth, and so the light emitted from it will undergo a larger red-shift ***[1 mark]***. The range of wavelengths in which the absorption lines sit has been shifted so much that these lines are no longer in the visible spectrum ***[1 mark]***. The astronomer could observe the infrared radiation reaching Earth from galaxy Y (as the absorption lines will have been shifted into the infrared part of the electromagnetic spectrum) ***[1 mark]***.

3 a) The curve for a cooler star would be at a lower intensity for all wavelengths ***[1 mark]***, and would have a longer peak wavelength ***[1 mark]***.

b) i) Find the gravitational field strength of star X's gravitational field at planet Y:

$$g = \frac{GM_X}{r^2} = \frac{(6.67\times10^{-11})\times(2.78\times10^{30})}{(3.29\times10^{11})^2} = 0.00171...\text{ N/kg}$$

$W = m \times g$
so $m = W \div g$
$m = 1.24 \times 10^{21} \div 0.00171...$
$= 7.2384... \times 10^{23}$
= **7.24 × 10²³ kg (to 3 s.f.)**
[6 marks for correct answer, otherwise 1 mark for correct substitution into gravitational field strength equation, 1 mark for correct calculation of gravitational field strength, 1 mark for correct rearrangement of weight equation, 1 mark for correct substitution into weight equation and 1 mark for correct unrounded answer]

ii) Planet Z has the higher orbital speed, as it has the smaller orbital radius ***[1 mark]***. The shorter the distance from star X, the stronger the gravitational force on the planet ***[1 mark]***. Planet Z is nearer star X, so it must travel at a higher speed to balance this stronger force and remain in a stable orbit ***[1 mark]***.

4 a) White light contains all colours, but the red filter only allows red light to pass through, so it appears red ***[1 mark]***. The helmet absorbs red light/all colours apart from blue, so it does not reflect any red light and so appears black ***[1 mark]***.

b) i) E.g. alpha radiation from a solid source cannot usually enter the body, because alpha radiation is only weakly penetrating and can only travel a few centimetres in air/is stopped by the skin ***[1 mark]***. Radon gas can be inhaled, meaning that it and its polonium daughter nucleus decay inside the body/lungs ***[1 mark]*** and the alpha radiation produced is able to reach and damage sensitive body tissues ***[1 mark]***.

ii) E.g. monitoring the miner's exposure to radon means the dose of radiation she receives can be kept within safe limits ***[1 mark]***.

iii) 85 ***[1 mark]***

The atomic number decreases by 2 to 84 when the radon-222 nucleus emits an alpha particle, then increases by 1 when the polonium-218 nucleus emits a beta particle.

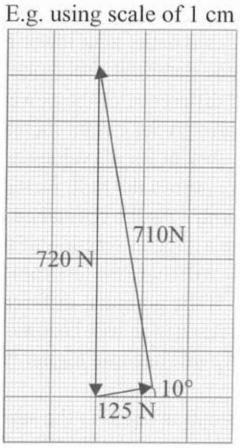
c) There are 8 complete waves in the diagram and it spans 5.0 seconds.
Frequency is equal to the number of waves in one second, so the average frequency = 8 ÷ 5.0 = 1.6 Hz
$v = f \times \lambda$
Rearrange for λ:
$\lambda = v \div f$
= 6400 ÷ 1.6
= **4000 m**
[4 marks for the correct answer, otherwise 1 mark for correctly calculating the frequency, 1 mark for correctly rearranging wave speed equation and 1 mark for correct substitution into the wave speed equation]

Section 4 — Forces and Energy

Pages 34-36: Forces and Work Done

1 a) Total energy transferred by adult = total work done by adult
Energy transferred to gravitational potential energy stores
= 5.44 kJ = 5.44 × 1000 = 5440 J
So, total work done by adult = 5440 + 2270 = 7710 J
$E = F \times d$, rearrange for F:
$F = E \div d$
= 7710 ÷ 105
= 73.4 N (to 3 s.f.)
[4 marks for correct answer, otherwise 1 mark for correct calculation of total work done by adult, 1 mark for correct rearrangement of work done equation, 1 mark for correct substitution into work done equation]

b) E.g. using scale of 1 cm = 100 N



Construct a closed triangle, and measure the length of the weight vector. Convert the length to force using the scale.
Weight = 7.2 cm = 7.2 × 100 = **720 N**
(Accept between 715 N and 725 N)
[3 marks for correct answer with suitable scale diagram, otherwise 1 mark for arrows drawn with a suitable scale and 1 mark for 3 arrows drawn with correct lengths in a closed triangle]

2 a) Since the girder is uniform, the weight of the girder acts at the centre, 6 m from support A.
The distance from support A to support C is twice the distance from C to D, so:
Distance AC = 8.0 m, Distance CD = 4.0 m,
Distance AB = Distance BC = 4.0 m
The weight of the girder acts at 2.0 m from point C.
Let the force applied by support A = F_A
Taking moments about point C, given that the girder is balanced:
clockwise moments = anticlockwise moments
$F_A \times 8.0 = (6.0 \times 10^3 \times 4.0) + (3.4 \times 10^4 \times 2.0)$
$$F_A = \frac{(6.0 \times 10^3 \times 4.0) + (3.4 \times 10^4 \times 2.0)}{8.0}$$
= 11 500 N or 12 000 N (to 2 s.f.)
[4 marks for correct answer, otherwise 1 mark for equating the clockwise and anticlockwise moments about point C, 1 mark for correct substitution into this equation and 1 mark for correct rearrangement to find the force at point A]

b) A ***[1 mark]***
The block is the same distance from both pivots, but the distance from point D to point C is shorter than that from point D to point A, and that from point A to point C. So the most force will be required to lift the block by pressing down at point D and pivoting about point C.

3 a) i) Since no unwanted energy transfers take place, all the energy must be transferred to the gravitational potential energy store of the rocket.
2.0 km = 2000 m
$\Delta GPE = m \times g \times \Delta h$
$= 7.6 \times 10^5 \times 10 \times 2000$
$= 1.52 \times 10^{10}$ J
$P = E \div t$, rearrange for t:
$t = E \div P$
$= 1.52 \times 10^{10} \div 5.0 \times 10^8$
= 30 s (to 2 s.f.)
[5 marks for correct answer, otherwise 1 mark for correct substitution into GPE equation, 1 mark for correct calculation of change in GPE, 1 mark for correct rearrangement of power equation, 1 mark for correct substitution into power equation]

ii) The time taken for Rocket B to travel 2.0 km will be half that taken by Rocket A to travel 2.0 km ***[1 mark]***. Power is the rate of energy transfer, so doubling the power means the energy is transferred in half the time ***[1 mark]***.
The amount of energy that must be transferred is the same for both rockets as their mass is the same.

b) Rocket B's engine is twice as powerful as Rocket A's, so
$P = (5.0 \times 10^8) \times 2 = 1.0 \times 10^9$
$P = E \div t$, so $E = P \times t = (1.0 \times 10^9) \times 60 = 6.0 \times 10^{10}$ J
efficiency = 69% = 0.69
$$\text{efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}\text{, so}$$
useful energy transferred = efficiency × total energy supplied
$= 0.69 \times (6.0 \times 10^{10})$
$= 4.14 \times 10^{10}$
$= 4.1 \times 10^{10}$ J (to 2 s.f.)
[5 marks for correct answer, otherwise 1 mark for correct substitution into power equation, 1 mark for correct calculation of total energy transferred, 1 mark for correct rearrangement of efficiency equation, 1 mark for correct substitution into efficiency equation]

Section 5 — Electricity and Circuits

Pages 37-39: Circuits

1 a) $Q = I \times t$

$t = 2.0$ hours $= 2.0 \times 60 \times 60 = 7200$ s

$Q = 0.50 \times 7200 = 3600$ C

Divide the total charge that passes through the thermistor by the charge on one electron to find the number of electrons:

Number of electrons $= \frac{3600}{1.6 \times 10^{-19}}$

$= 2.25 \times 10^{22} =$ **2.3×10^{22} (to 2 s.f.)**

[3 marks for correct answer, otherwise 1 mark for correct substitution into Q = It and 1 mark for dividing the total charge by the charge on an electron]

b) Find the potential difference across the resistor, V_2, and use this to find the current in the circuit:

$V_2 = V_{total} - V_1 = 6 - 0.25 = 5.75$ V

$V = I \times R$, so:

$I = \frac{V_2}{R_2} = \frac{5.75}{1.0} = 5.75$ A

Use the current in the circuit and V_1 to find the resistance of the thermistor:

$R_1 = \frac{V_1}{I} = \frac{0.25}{5.75}$

$= 0.043478...\ \Omega =$ **$0.043\ \Omega$ (to 2 s.f.)**

[5 marks for correct answer, otherwise 1 mark for correct calculation of V_2, 1 mark for correct substitution to find current through circuit, 1 mark for correct calculation of current and 1 mark for correct substitution to find R_1]

c) The heater should be connected across the thermistor, as when the external temperature decreases, the thermistor's resistance increases ***[1 mark]*** and so the potential difference across the thermistor increases ***[1 mark]***. As they would be connected in parallel, the potential difference across the heater would be equal to the potential difference across the thermistor, so the heater would get hotter as the temperature decreased ***[1 mark]***.

2 a) i) Line of best fit is a straight line, so it has an equation of the form $y = mx + c$,

where $y = R$, $m =$ gradient, $x = L$, and $c = y$-intercept.

Line goes through origin, so $c = 0$.

$m = \text{gradient} = \frac{\text{change in } y}{\text{change in } x}$

E.g. $m = \frac{54 - 0}{5.4 - 0} = 10$

So, equation of line is $\mathbf{R = 10\,L}$

[2 marks for correct answer, otherwise 1 mark for correct calculation of the gradient]

Make sure you calculate the gradient from changes in y and x that cover at least half of the line of best fit.

ii) Calculate resistance of length of wire:

$R = 10L$,

so $R = 10 \times 0.375$

$= 3.75\ \Omega$

Calculate current through wire:

$V = I \times R$ so $I = V \div R$

$V = 0.5$ kV $= 0.5 \times 1000 = 500$ V

$I = 500 \div 3.75$

$= 133.333...$ A

= 133 A (to 3 s.f.)

[5 marks for correct answer, otherwise 1 mark for correct calculation of resistance of wire, 1 mark for correct rearrangement of V = I × R, 1 mark for correct substitution to find current and 1 mark for correct unrounded answer]

Even if you got the answer to 2 a) i) wrong, you get full marks for 2 a) ii) if you did the calculations correctly using your answer for 2 a) i).

b) From the graph: A 1.2 m length of the first wire, has a resistance of 12 Ω.

$R = \frac{k}{A}$

So $k = R \times A = 12 \times 0.11 = 1.32$

For the second wire:

$R = \frac{1.32}{0.44} =$ **$3.0\ \Omega$**

[5 marks for correct answer, otherwise 1 mark for reading correct resistance value from graph, 1 mark for correct substitution into k = R × A, 1 mark for correctly calculating k, 1 mark for correct substitution into $R = \frac{k}{A}$]

You don't need to convert the areas to m^2 in this calculation. The equation shows that $R \propto 1/A$, i.e. R and A are inversely proportional. So if A is multiplied by 4, R is divided by 4.

3 a) The reading on A_1 is initially lower than the reading on A_2, because the bulb has a lower resistance, and in parallel circuits more current flows down paths with lower resistance, since each branch has the same potential difference across it ***[1 mark]***. As the potential difference of the power supply increases, the total current through the circuit increases. The resistance of the resistor is constant for all values of current, but as the potential difference across the bulb increases, its resistance increases ***[1 mark]***. As the resistance of the bulb increases, it will receive a smaller fraction of the total current, so the reading on A_2 will increase less rapidly than the reading on A_1 ***[1 mark]***. If the potential difference increases enough, the bulb's resistance will become higher than that of the resistor, so A_1 will become higher than A_2 ***[1 mark]***.

b) The total resistance of the circuit is equal to the sum of the resistances of the resistor and component X ***[1 mark]***. As potential difference increases, the value of $\frac{V}{I}$ decreases (as shown by measuring V and I at points along the trendline and dividing the values), so the resistance of component X decreases ***[1 mark]***. The resistance of the resistor is constant, so as the potential difference of the power supply increases, the total resistance of the circuit must decrease ***[1 mark]***.

Pages 40-42: Electrical Appliances

1 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There is a description of what the graph shows and some attempt at an explanation in terms of the factors affecting power, but a full explanation of how the heating effect is produced is not given. ***[1 to 2 marks]***

Level 2: There is a description of what the graph shows and an explanation in terms of the factors affecting power. The answer includes some explanation of how the heating effect is produced, but is lacking in detail. ***[3 to 4 marks]***

Level 3: There is a full description of what the graph shows. A clear and detailed explanation is given of how the heating effect is produced, and of how this effect leads to the change in output power. ***[5 to 6 marks]***

Here are some points your answer may include:
The power output of the heating element decreased over the period of time it was switched on.
The power output initially decreases quite rapidly but the rate of decrease gradually slows down until the power is almost constant.
The heating element produces heat when the electrical current flowing through it does work against resistance.
The heating element is made up of a lattice of ions.
The electrons collide with the ions in the lattice.
The collisions give the ions energy, causing them to vibrate more and heat up.
The vibrations transfer energy to the thermal energy stores of the surroundings.
As the heating element heats up and the ions vibrate more, more collisions occur between the ions and the electrons.
So it becomes more difficult for the current to flow through the heating element.
The resistance of the heating element has increased.
$P = I \times V$, where I is the current through the element and V is the potential difference across it.
As the temperature of the heating element increases, its resistance increases and the current flowing through it decreases, so its power output must also decrease.
Fewer electrons travel through the heating element per second, so there are fewer collisions with the lattice ions per second.
Therefore the amount of energy transferred to the thermal stores of the surroundings per second decreases.
When it is first switched on, the temperature of the heating element increases rapidly to its intended operating temperature.
So the resistance of the heating element also increases rapidly, and its power output decreases rapidly.
As it reaches its operating temperature the temperature and so resistance changes more slowly, and so the power output does too.

b) i) $V = I \times R$

$I = V \div R = 9.0 \div 1.7 = 5.294...$ A

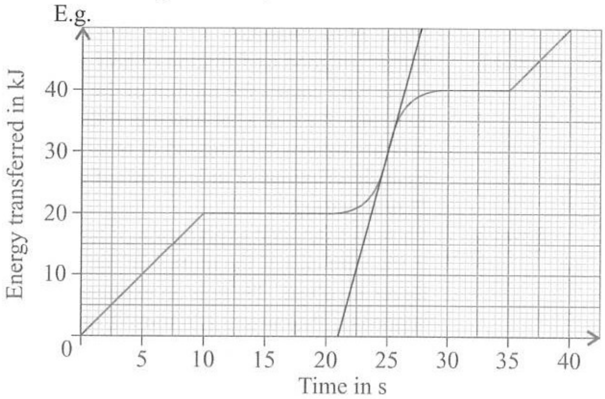
$E = I \times V \times t$

$t = \frac{E}{I \times V} = \frac{8400}{5.294... \times 9.0} = 176.296... =$ **180 s (to 2 s.f.)**

[5 marks for correct answer, otherwise 1 mark for correct substitution of $I = V \div R$, 1 mark for correctly calculating current, 1 mark for correct rearrangement of $E = I \times V \times t$, 1 mark for correct substitution of $t = \frac{E}{I \times V}$]

ii) The time taken will halve/decrease ***[1 mark]***. Each branch of the circuit receives the full supply potential difference, and so the current through each of the two heating elements in parallel will be the same as the current through one heating element in series ***[1 mark]***. $P = I \times V$, and so the output power of each heating element in parallel will be the same as that of one heating element in series, meaning the total output power for the parallel circuit will be doubled ***[1 mark]***.

2 a) Power is equal to the gradient of the graph, so instantaneous power is greatest when gradient of graph is steepest.
So time of greatest power = 25 s
Draw a tangent at 25 s,
E.g.



power = gradient of tangent $= \frac{48\,000 - 0}{27.5 - 21} = 7384.615...$

$=$ **7400 W (to 2 s.f.)**

(Accept between 6400 W and 8400 W)

[3 marks for correct answer, otherwise 1 mark for correctly drawn tangent at 25 s, 1 mark for attempt to calculate the gradient of the tangent]

b) $E = Q \times V$

Energy transferred between 20 s and 30 s = 40 kJ – 20 kJ
= 20 kJ
= 20 × 1000
= 20 000 J

$V = E \div Q$
$= 20\,000 \div 12$
$= 1666.66...$ V
= **1700 V (to 2 s.f.)**

[5 marks for correct answer, otherwise 1 mark for correct energy values read from the graph, 1 mark for correct rearrangement, 1 mark for correct substitution and 1 mark for correct unrounded answer]

c) i) $P = I^2 \times R$

Resistance = 250 mΩ = 250 ÷ 1000 = 0.25 Ω

$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{36}{0.25}} =$ **12 A**

[3 marks for correct answer, otherwise 1 mark for correct rearrangement and 1 mark for correct substitution]

ii) 7.56 units worth of energy $= 7.56 \times 3.6 \times 10^6$
$= 2.7216 \times 10^7$ J

$E = P \times t$ so $t = E \div P$

$t = (2.7216 \times 10^7) \div 36 = 7.56 \times 10^5$ s

Number of hours $= 7.56 \times 10^5 \div (60 \times 60)$
= **210 hours**

[5 marks for correct answer, otherwise 1 mark for correct calculation of total energy wasted, 1 mark for correct rearrangement of power equation, 1 mark for correct substitution into power equation and 1 mark for correct time in seconds]

Section 6 — Electric and Magnetic Fields

Page 43: Static Electricity and Electric Fields

1 a) The particles have a positive charge, so they will be attracted towards the negative plate (and repelled by the positive plate). They will collide with the negative plate and stick to it. ***[1 mark]***.

b) As an ash particle passes near a charged plate, the electrons on the surface of the particle will be either attracted to or repelled by the plate ***[1 mark]***, causing a charge to be induced on the ash particle ***[1 mark]***. The particle will then be attracted to the plate, causing it to move towards the plate ***[1 mark]***. This will happen to particles passing near both plates, so ash will be attracted and collect on both plates ***[1 mark]***.

Pages 44-45: Magnetism and Transformers

1 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There is a basic explanation of how a current in the wire causes the motion of the coil in the field. ***[1 to 2 marks]***

Level 2: There is a good explanation of how a current in the wire causes the motion of the coil and an explanation of what happens if the current is either removed, increased or reversed (or basic descriptions of at least two of the three). ***[3 to 4 marks]***

Level 3: There is a detailed explanation of how a current in the wire causes the motion of the coil and the forces involved. There is an explanation of what happens if the current is removed, increased and reversed. ***[5 to 6 marks]***

Here are some points your answer may include:
Current from the circuit flows round the coil.
This produces a magnetic field around the coil.
This magnetic field interacts with the magnetic field of the magnets.
The parts of the coil perpendicular to the field, i.e. the sides of the coil, feel a force due to the motor effect.
The forces on the two sides act in opposite directions, which causes rotation.
The coil (and so the pointer) rotates and the spring stretches (or compresses).
As the spring stretches (or compresses) it applies a force to the coil in the opposite direction to the force from the motor effect.
The force applied by the spring increases as the coil rotates more.
The forces will eventually balance and the pointer will come to a rest.
The larger the current through the coil, the larger the force due to the motor effect, and the more the pointer will turn before the forces balance.
When the current stops flowing, the force disappears and the spring returns the pointer back to its original position.
If the current is reversed then the pointer moves in the opposite direction because the force on each side of the coil is reversed (Fleming's left-hand rule).

b) $F = 10\text{ mN} = 10 \div 1000 = 0.01\text{ N}$
$l = 25\text{ mm} = 25 \div 1000 = 0.025\text{ m}$
$F = B \times I \times l$ so $B = F \div (I \times l)$

$$= \frac{0.01}{2 \times 0.025} = \mathbf{0.2\ T}$$

[4 marks for correct answer with units, otherwise 1 mark for correct rearrangement, 1 mark for correct substitution and 1 mark for correct unit or correct value]

c) Any two from: e.g. decrease the strength of the magnets/ magnetic field ***[1 mark]***. / Decrease the length of the iron core/side of coil perpendicular to the field ***[1 mark]***. / Decrease the number of turns on the coil ***[1 mark]***. / Use a stiffer spring ***[1 mark]***.

The overall force needs to be smaller or the spring stiffer so that the pointer doesn't move as far for the same current. F = BIl for each wire in the side of the coil, so to decrease the force, the strength of the magnetic field, the length or the number of wires need to be decreased.

2 a) D ***[1 mark]***
To be effective, the national grid needs to transmit a large amount of power ***[1 mark]***.
$P = I \times V$ so I or V needs to be high ***[1 mark]***.
To be efficient, the national grid needs to minimise energy losses. A high current leads to energy losses as the wires heat up and transfer energy to the thermal energy store of the surroundings, so the electricity needs to be transmitted at a low current ***[1 mark]***.

b) $1.2\text{ kA} = 1.2 \times 1000 = 1200\text{ A}$
Using $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ and $V_p \times I_p = V_s \times I_s$

$$I_s = \frac{V_p \times I_p}{V_s} = I_p \times \frac{N_p}{N_s}$$

$$= 1200 \times \frac{60\,000}{45\,000} = \mathbf{1600\ A\ (= 1.6 \times 10^3\ A)}$$

[3 marks for correct answer, otherwise 1 mark for getting an expression involving current and number of turns and 1 mark for correct substitution]

Pages 46-47: Electromagnetic Induction

1 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There is a brief explanation of how a generator works. ***[1 to 2 marks]***

Level 2: There is a good explanation of how a generator works and which type of current each generator produces has been identified (ac or dc). ***[3 to 4 marks]***

Level 3: There is a detailed explanation of how a generator works and an explanation of how the different generators produce ac and dc. ***[5 to 6 marks]***

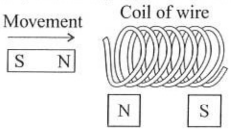
Here are some points your answer may include:
As the coil turns, the magnetic field through it changes.
This causes a potential difference to be induced across the ends of the coil.
If the wire is part of a complete circuit, current flows through the coil.
An alternator has slip rings which allow the ends of the rotating coil to stay connected to the same ends of the circuit at all times.
As the coil turns, the direction of the current induced changes direction as the direction of motion on each arm reverses every half turn.
The current produced is alternating (ac).
The dynamo has a split ring which swaps the connection between the rotating coil and the rest of the circuit every half turn, keeping the current flowing in one direction.
The current produced is direct (dc).

b) A is the alternator output current because the current changes direction every half turn ***[1 mark]***.

c) E.g. it has a stronger magnetic field / more turns in the coil ***[1 mark]***.

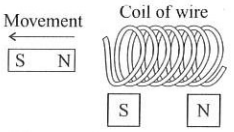
Do not accept 'it spins faster'. This would also increase the frequency but you can see from the graph that the frequencies match.

2 a)



[1 mark]

The coil opposes the movement of the magnet. If you push the N pole into the coil then the coil tries to do the opposite by pushing the N pole back out.



[1 mark]

The coil opposes the movement of the magnet. If you pull the N pole away from the coil then the coil tries to do the opposite by pulling the N pole back in.

b) The coil of wire should be put into a magnetic field that is perpendicular to the wire at all times/a radial magnetic field/a magnetic field caused by one pole inside the coil and one pole around it ***[1 mark]***. Sound waves hitting the cone cause it to vibrate ***[1 mark]***. This causes the coil of wire to vibrate back and forth inside the magnetic field of the permanent magnet ***[1 mark]***, which induces a current in the coil of wire due to the generator effect ***[1 mark]***.

Section 7 — Matter

Page 48: Density

1 a) Rearrange $\rho = m \div V$ for V:
$V = m \div \rho$
Calculate the total volume of the block of aerogel:
$V = 0.50 \div 1.50 = 0.333...\ \text{m}^3$
Divide the volume below the waterline by the total volume and multiply by 100 to get the percentage of the volume beneath the waterline:

percentage of volume $= \dfrac{5 \times 10^{-4}}{0.333...} \times 100 =$ **0.15%**

[4 marks for correct answer, otherwise 1 mark for correctly rearranging $\rho = m \div V$ for V, 1 mark for correct substitution into $V = m \div \rho$ and 1 mark for correctly calculating the total volume of the aerogel]

b) $\rho = m \div V$
Rearranging for m gives:
$m = \rho \times V$
mass produced in 24 hours $= \rho \times V$
$= 1.50 \times 0.360$
$= 0.54$ kg
minutes in one day $= 24 \times 60 = 1440$ minutes
rate of production = mass ÷ time
$= 0.54 \div 1440$
$= 0.000375$ kg/min
Convert kg/min to g/min:
$0.000375 \times 1000 =$ **0.375 g/min**

[5 marks for the correct answer, otherwise 1 mark for correctly rearranging $\rho = m \div V$ for m, 1 mark for correct substitution into $m = \rho \times V$, 1 mark for correctly calculating the mass of aerogel produced in 24 hours and 1 mark for dividing this mass by the number of minutes in a day]

Pages 55-56: Forces and Distortion of Objects

1 a) How to grade your answer:

Level 0: There is no relevant information. ***[No marks]***

Level 1: There are some relevant points, but the answer is unclear and may contain inaccuracies. Some comment is made on why one of the ropes is more suited, with reference to the spring constant or the elastic limit. ***[1 to 2 marks]***

Level 2: Rope B is correctly identified as being better suited, with some explanation in terms of the spring constants and/or the elastic limits of both ropes. The answer is clear and factually correct but may be lacking in detail. ***[3 to 4 marks]***

Level 3: There is a clear and detailed explanation of why rope B is better suited, which includes a comparison of the materials' spring constants and elastic limits. ***[5 to 6 marks]***

Here are some points your answer may include:
The engineer should make the rope swing from rope B.
Under the average weight of a person, rope A extends by around 0.06 m, while rope B only extends by around 0.025 m.
This means that rope A may extend past the maximum allowed extension of 7 cm (0.07 m) when used by a person of above average weight, while rope B will not.
The gradient of the linear part of a force-extension graph is equal to the spring constant, since the linear part of the graph is defined by $F = k \times x$.
The gradient of the linear part of rope B's graph is greater than that of rope A, so it has a greater spring constant.
This means rope B will extend less under a given force, and extend less for the same increase in force.
So rope B's extension will be more consistent over a range of weights.
Rope A reaches its elastic limit at 800 N.
This is close to the average weight of a person, so the rope could deform permanently when a person's weight is applied.
This means the rope swing would have to be replaced (as it has permanently changed shape).
Rope B does not reach its elastic limit until around 1400 N, so it can safely support a wide range of human weights.

b) First find the spring constant of rope B.
The gradient of the straight line part of the force-extension graph is equal to the spring constant, k.

E.g. so $k = \frac{\text{change in } y}{\text{change in } x} = \frac{1120 - 0}{0.040 - 0} = 28\,000$ N/m

work done to stretch spring = energy transferred to elastic potential energy store

$E = \frac{1}{2} \times k \times x^2$

Rearrange for extension:

$$x = \sqrt{\frac{2E}{k}}$$

$$= \sqrt{\frac{2 \times 21.0}{28\,000}}$$

= 0.038729...

= **0.0387 m (to 3 s.f.)**

[5 marks for correct answer, otherwise 1 mark for correct calculation of spring constant by use of the gradient, 1 mark for correct rearrangement of elastic potential energy equation for extension, 1 mark for correct substitution into the equation to find extension and 1 mark for correct unrounded answer]

c) i) The small mass is added to straighten out the fibre so that the length can be measured accurately ***[1 mark]***.

ii) B ***[1 mark]***

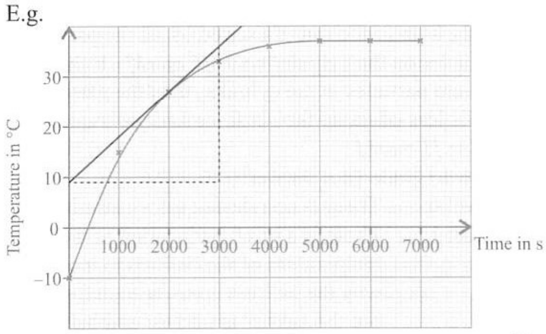
F = k × x, so if the force applied is the same but the spring constant is 10 times larger, the extension must be 10 times smaller.

Mixed Questions for Paper 2

Pages 57-61: Mixed Questions for Paper 2

1 a) i) Draw a tangent at (2000, 27)

E.g.



rate of temperature change = gradient of tangent = $\frac{36 - 9}{3000 - 0}$

= **0.009 °C/s**

(Accept any answer between 0.0085 °C/s and 0.0095 °C/s)

[3 marks for correct answer, otherwise 1 mark for correctly drawn tangent and 1 mark for attempt to calculate gradient]

ii) $\Delta Q = m \times c \times \Delta\theta$

Replace change in temperature with rate of temperature change to find rate of energy transfer.

So, rate of energy transfer = mass × specific heat capacity × rate of temperature change

= 2.0 × 1800 × 0.009

= **32.4 J/s**

[2 marks for correct answer, otherwise 1 mark for correct substitution]

Even if you got the answer to 1 a) i) wrong, you get full marks for 1 a) ii) if you did the calculations correctly using your answer for 1 a) i).

b) Find the total input energy transferred to the freezer:
power = energy transferred ÷ time, so:
energy transferred = power × time
20.0 minutes = 20.0 × 60 = 1200 s
so total input energy transfer = 250 × 1200 = 300 000 J

efficiency = $\frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$

efficiency = 95% = 0.95

useful energy transferred by the device
= efficiency × total energy supplied to the device
= 0.95 × 300 000
= **285 000 J**

[5 marks for correct answer, otherwise 1 mark for correct substitution into energy transferred equation, 1 mark for correct calculation of total input energy transferred, 1 mark for correct rearrangement of efficiency equation and 1 mark for correct substitution into efficiency equation]

2 a) Use $\rho = m \div V$ to calculate the density of a neutron star:
$\rho = (2.1 \times 10^{30}) \div (1.4 \times 10^{13})$
$= 1.5 \times 10^{17}$ kg/m^3
Rearrange $\rho = m \div V$ for m:
$m = \rho \times V$
$= 1.5 \times 10^{17} \times 1.0 \times 10^{-6}$
$= \mathbf{1.5 \times 10^{11}}$ **kg**
[5 marks for the correct answer, otherwise 1 mark for correct substitution into $\rho = m \div V$, 1 mark for the correct value of ρ for a neutron star, 1 mark for rearranging the equation for m and 1 mark for correct substitution into $m = \rho \times V$]

b) The number of seconds in one year is:
$60 \times 60 \times 24 \times 365 = 3.1536 \times 10^7$ s
Calculate the energy released by the Sun in one year:
$(4 \times 10^{26}) \times 3.1536 \times 10^7 = 1.26144 \times 10^{34}$ J
So the number of years it would take the Sun to release 1×10^{44} J is:
$(1 \times 10^{44}) \div (1.26144 \times 10^{34}) = 7.92... \times 10^9$
$= \mathbf{8 \times 10^9}$ **years (to 1 s.f.)**
[3 marks for the correct answer, otherwise 1 mark for dividing 1×10^{44} by the amount of energy released by the Sun in either a year or a second and 1 mark for correctly converting to years from seconds at some point in the calculation]

c) Energy from the nearby star is transferred to the kinetic energy stores of the particles of the gas cloud ***[1 mark]***, which causes the particles to move faster and so to collide more often / to collide with more force ***[1 mark]***. This results in an increase in pressure in the gas cloud ***[1 mark]***.

3 a) $V_P \times I_P = V_S \times I_S$
So $V_S = \frac{V_P \times I_P}{I_S} =$
40 mA = 0.04 A   1840 mA = 1.84 A
$V_S = \frac{230 \times 0.04}{1.84} = 5$ V
$\frac{V_P}{V_S} = \frac{N_P}{N_S}$
So $N_S = N_P \times \frac{V_S}{V_P} = 920 \times \frac{5}{230} = \mathbf{20}$ **turns**
[5 marks for correct answer, otherwise 1 mark for correctly rearranging $V_P \times I_P = V_S \times I_S$, 1 mark for correct substitution, 1 mark for correctly calculating V_S, 1 mark for correct substitution into $\frac{V_P}{V_S} = \frac{N_P}{N_S}$]

As you're dealing with the ratio of the currents here, it actually only matters that both currents are given in the same unit — so you don't need to convert from mA to A to get the right answer.

b) C ***[1 mark]***

A diode allows current to flow in one direction only.

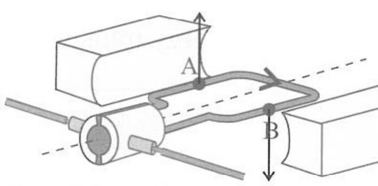
c) The maximum current expected in the circuit is 1840 mA (or 1.84 A) ***[1 mark]***. If a fault developed the current could reach several times this before a 5 A fuse melted and broke the circuit ***[1 mark]***, causing damage to components/a fire risk ***[1 mark]***.

4 a) The level of the mercury in the barometer is lower at the top of the skyscraper than at the bottom because atmospheric pressure decreases with altitude (height above earth) ***[1 mark]***, and so the force pushing it up the tube is less at the top of the skyscraper ***[1 mark]***. Atmospheric pressure is created on the exposed surface of the mercury by air molecules colliding with the surface ***[1 mark]***. As altitude increases the atmosphere becomes less dense, so there are fewer air molecules able to collide with the surface. / As altitude increases there are fewer air molecules above the surface, and so the weight of the air above it pushing down is lower ***[1 mark]***.

b) Using $P = I \times V$:
$I = \frac{P}{V} = \frac{75}{120} = 0.625$ A
$P = I^2 \times R$ so $R = \frac{P}{I^2} = \frac{75}{(0.625)^2} = \mathbf{192\ \Omega}$
[5 marks for the correct answer, otherwise 1 mark for substituting into $P = I \times V$, 1 mark for correct value of I, 1 mark for rearranging $P = I^2 \times R$ or $V = I \times R$ and 1 mark for substituting into rearranged equation]

You could also use $V = I \times R$ to calculate the resistance once you have used $P = I \times V$ to calculate the current.

5 a) i)



[1 mark for each correctly drawn arrow]

ii) $F = B \times I \times l$
24 mm = 0.024 m
So the force on each part of the coil that is perpendicular to the magnetic field is:
$F = 0.45 \times 3.7 \times 0.024 = 0.03996$ N
Moment of a force = force × distance normal to the direction of the force
The distance from the axis to each part of the coil perpendicular to the magnetic field is:
$16 \div 2 = 8.0$ mm $= 0.0080$ m
So the moment of each force on the coil is:
moment $= 0.03996 \times 0.008 = 3.1968 \times 10^{-4}$ Nm
Both moments are in the clockwise direction about the axis, so the net moment $= (3.1968 \times 10^{-4}) \times 2$
$= 6.3936 \times 10^{-4}$
$= \mathbf{6.4 \times 10^{-4}}$ **Nm (to 2 s.f.)**
Direction = clockwise
[5 marks for correct answer including direction, otherwise 1 mark for correct substitution into $F = B \times I \times l$, 1 mark for correctly calculating the force on each part of the coil perpendicular to the magnetic field, 1 mark for correct substitution into moment equation, 1 mark for correctly calculating the moment of each force]

iii) E.g. by increasing the current through the coil/the number of turns on the coil/the magnetic flux density/the width of the coil ***[1 mark]***.

b) Switching the direction of the current every half turn means the forces on the arms of the coil change direction, so that they always act in the correct direction to keep the coil turning ***[1 mark]***.

Equations List

Here are some equations you might find useful when you're working through the book — you'll be given these equations in the exams.

Section 1 — Motion, Forces and Conservation of Energy

$v^2 - u^2 = 2 \times a \times x$	(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance
$F = \frac{(mv - mu)}{t}$	force = change in momentum ÷ time

Make sure you understand all the equations on this page, and you're happy using and rearranging them.

Section 5 — Electricity and Circuits

$E = I \times V \times t$	energy transferred = current × potential difference × time

Section 6 — Electric and Magnetic Fields

$F = B \times I \times l$	force on a conductor at right angles to a magnetic field carrying a current = magnetic flux density × current × length
$\frac{V_p}{V_s} = \frac{N_p}{N_s}$	$\frac{\text{potential difference across primary coil}}{\text{potential difference across secondary coil}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$
$V_p \times I_p = V_s \times I_s$	potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil (for transformers with 100% efficiency)

Section 7 — Matter

$\Delta Q = m \times c \times \Delta\theta$	change in thermal energy = mass × specific heat capacity × change in temperature
$Q = m \times L$	thermal energy for a change of state = mass × specific latent heat
$P_1 \times V_1 = P_2 \times V_2$	pressure at volume 1 × volume 1 = pressure at volume 2 × volume 2 (for a fixed mass of gas at a constant temperature)
$E = \frac{1}{2} \times k \times x^2$	energy transferred in stretching = 0.5 × spring constant × (extension)^2
$P = h \times \rho \times g$	pressure due to a column of liquid = height of column × density of liquid × gravitational field strength

PE9Q41