

Section One: Short answers

(54 Marks)

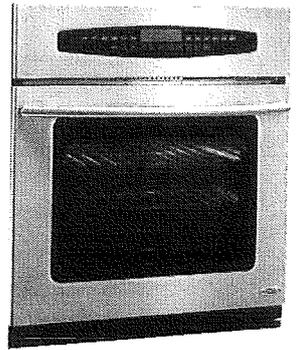
This section has thirteen (13) questions. Answer all questions. Write your answers in the spaces provided.

Suggested working time: 54 minutes.

Question 1

(5 marks)

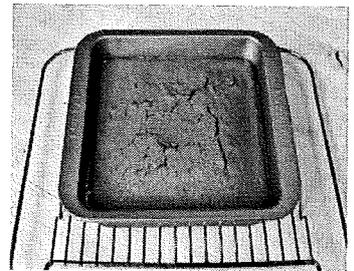
Suppose you have just finished baking a cake and you open the oven door to remove the cake. You can put your hand safely in the oven for a few seconds but you would be badly burnt if you held the cake tin for this same amount of time.



- (a) Explain why this would happen, even though the air inside the oven and the cake tin are at the same temperature. (2 marks)

Air is a poor conductor, so very little heat transfers to your hand from the hot air. The metal cake tin is a good conductor, so a lot of heat transfers quickly from it into your hand.

- (b) The cake you have finished baking is removed from the oven and placed on a nearby benchtop to cool down before icing. With reference to the three methods of heat transfer, briefly describe how the cake loses heat energy during this cooling process. (3 marks)

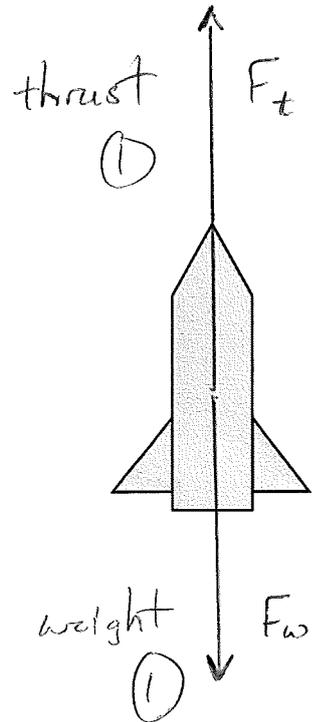


- heat conducts away through the metal cake tin and stand
- heat is removed by convection currents as warm air above the cake rises away
- heat is lost as invisible infrared radiation from the cake

Question 2**(5 marks)**

A model rocket has a mass at launch of 1.5 kg (of which 60% is fuel).

- (a) On the diagram at right, sketch and label the two forces acting on the rocket as it lifts off at launch. (1 mark)
- (b) If the initial acceleration of the rocket is 15 m/s^2 , calculate the thrust force of its engine at launch. (2 marks)



$$F_{\text{net}} = ma$$

$$F_t - mg = ma \quad \textcircled{1}$$

$$F_t = mg + ma = (1.5)(9.8) + (1.5)(15) \\ = \underline{37 \text{ N}} \quad \textcircled{1}$$

- (c) The acceleration of the rocket increases as it flies higher and higher. Suggest why this would happen. (2 marks)

As the rocket uses up its fuel it becomes lighter in mass $\textcircled{1}$. Hence its acceleration $a = \frac{F_{\text{net}}}{m}$ will increase (inverse proportion) $\textcircled{1}$

Question 3**(4 marks)**

A sound technician stands 15.0 m from a loudspeaker and measures the intensity of the sound to be $5.6 \times 10^{-3} \text{ W/m}^2$. Assume the sound waves spread out in a spherical pattern from the loudspeaker.

- (a) What is the intensity of the sound at a distance of 60.0 m? $\textcircled{1}$ (2 marks)

$$60 \text{ m} / 15 \text{ m} = 4 \Rightarrow 4^2 = 16 \times \text{lower in intensity}$$

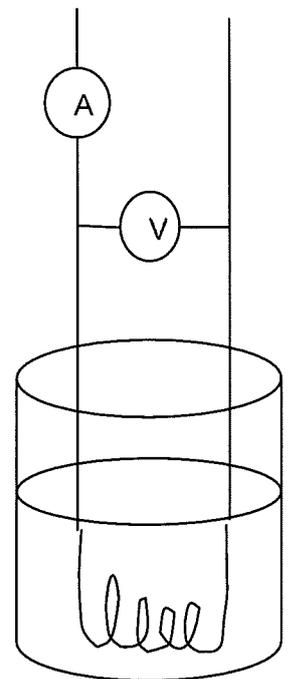
$$\therefore I = \frac{5.6 \times 10^{-3} \text{ W/m}^2}{4^2} = \underline{3.5 \times 10^{-4} \text{ W/m}^2} \quad \textcircled{1}$$

- (b) Calculate the power of the loudspeaker. (2 marks)

$$I = \frac{P}{4\pi r^2} \rightarrow P = I \times 4\pi r^2 \quad \textcircled{1} \\ = (3.5 \times 10^{-4} \text{ W/m}^2) \times 4\pi (60 \text{ m})^2 \\ = \underline{15.8 \text{ W}} \quad \textcircled{1}$$

Question 4**(3 marks)**

The apparatus shown at right is used to investigate the specific heat capacity of canola oil. The beaker contains 275 grams of canola oil and an electric current is passed through the heating element in the beaker for a period of 10.0 minutes. During this time the voltmeter shows a steady reading of 6.25 V and the ammeter of 2.20 A. A thermometer placed in the beaker shows that the temperature of the oil increases from 19.0°C to 32.5°C during this time. Find the specific heat capacity of the canola oil, assuming no heat losses to the surroundings.



$$\begin{aligned}
 Q_{\text{absorbed}} &= \text{electrical energy} \\
 &= VI t = (6.25 \text{ V})(2.20 \text{ A})(600 \text{ s}) \\
 &= 8250 \text{ J} \quad (1)
 \end{aligned}$$

$$Q = mc \Delta T$$

$$8250 \text{ J} = (0.275 \text{ kg}) c (13.5 \text{ K}) \quad (1)$$

$$\therefore c = \underline{2220 \text{ J kg}^{-1} \text{ K}^{-1}} \quad (1)$$

Question 5**(4 marks)**

A Transperth train leaves Mandurah train station and accelerates steadily up to its cruising speed of 120 km/hr within a distance of 750 m from the station platform. Calculate

- (a) the acceleration of the train.

$$u = 0, v = \frac{120}{3.6} = 33.3 \text{ m/s} \quad (2 \text{ marks})$$

$$v^2 = u^2 + 2as \quad (1) \quad (33.3)^2 = 0 + 2a(750)$$

$$\therefore a = \frac{33.3^2}{2(750)} = \underline{0.74 \text{ m/s}^2} \quad (1)$$

- (b) the time it takes to accelerate up to its cruising speed.

(2 marks)

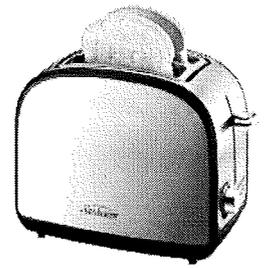
$$v = u + at \quad (1) \quad 33.3 = 0 + (0.74)t$$

$$\therefore t = \frac{33.3}{0.74} = \underline{45 \text{ s}} \quad (1)$$

Question 6

(4 marks)

The heating elements in a toaster are designed to get red hot in order to toast bread placed in the toaster. A typical toaster draws a current of 7.5 A when operating on household voltage (240 V).



- (a) Calculate the resistance of the heating elements and the power produced by the toaster when in normal operation. (2 marks)

$$R = \frac{V}{I} = \frac{240V}{7.5A} = \underline{32 \Omega} \text{ (1)}$$

$$P = VI = 240V \times 7.5A = \underline{1800 W} \text{ (1)}$$

- (b) Describe how and explain why the current through the heating element changes from when the toaster is first switched on until it reaches normal operating conditions. (2 marks)

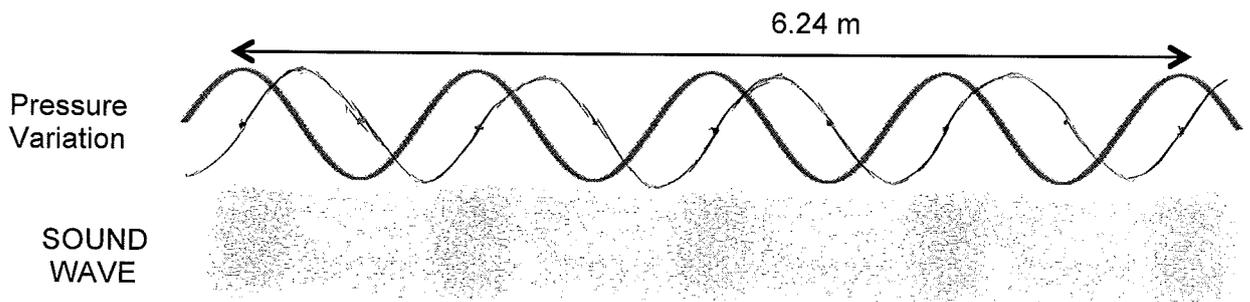
The current is initially high then decreases to a steady level (1)

The resistance is initially low, then increases as the element heats up, so current drops (1)

Question 7

(4 marks)

The diagram below shows a sound wave moving through air at 25°C. The sinusoidal graph above the sound wave indicates the variation in air pressure as the wave travels.



- (a) Calculate the value of each of the following quantities for this sound wave.

Wavelength: $\frac{6.24m}{4} = \underline{1.56 m} \text{ (1)}$ (1 mark)

Frequency: $\frac{346m/s}{1.56m} = \underline{222 Hz} \text{ (1)}$ (1 mark)

Period: $\frac{1}{222 Hz} = \underline{4.51 \times 10^{-3} s} \text{ (1)}$ (1 mark)

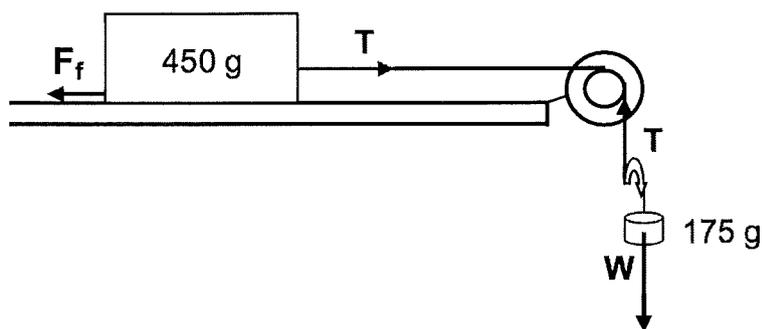
- (b) On the pressure variation graph above, superimpose a sinusoidal graph to show the variation in particle displacement as the wave travels through the air. (1 mark)

(out of phase by $\frac{1}{4}$ cycle)

Question 8

(5 marks)

A hanging mass of 175 g is connected to a 450 g block sitting on a table via a string and pulley as shown in the diagram at right. The two masses accelerate under the influence of gravity. The force of friction, F_f , acting on the block is 0.85 N.



- (a) Calculate the acceleration of the 450 g block. (3 marks)

$$a = \frac{F_{net}}{m} = \frac{W - F_f}{M + m} = \frac{(0.175)(9.8) - 0.85}{(0.450 + 0.175)} = \frac{0.865 \text{ N}}{0.625 \text{ kg}} = 1.38 \text{ m/s}^2$$

- (b) Calculate the tension T in the string. (2 marks)

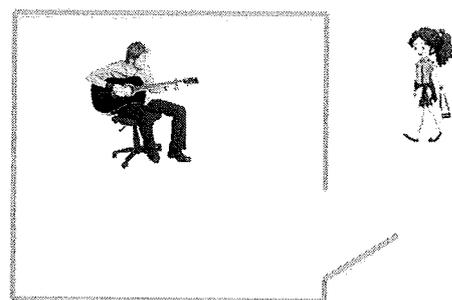
$$F_{net} = ma \rightarrow T - F_f = Ma \rightarrow T - 0.85 = (0.45)(1.38) \therefore T = 1.47 \text{ N}$$

[OR $W - T = ma \rightarrow 1.715 - T = (0.175)(1.38) \rightarrow T = 1.47 \text{ N}$]

Question 9

(4 marks)

Jimi is practicing guitar in his room with the door open, as shown in the diagram at right. With reference to relevant physics principles, explain why Joni, in the hallway outside his room, can hear the sound of the guitar but not see Jimi.

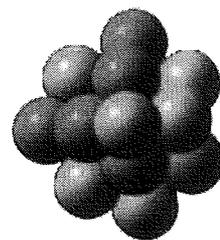


The sound waves from the guitar have a wavelength similar to the width of the doorway, so are able to diffract into the hallway and be heard by Joni. The light reflecting off Jimi has a very small wavelength and does not diffract significantly through the doorway, so Joni cannot see Jimi.

Question 10**(4 marks)**

- (a) Small nuclei, such as the carbon-12 nucleus, are quite stable despite the fact that the six protons in the nucleus repel each other strongly. Why is this? (2 marks)

The strong nuclear force ^① acts between all nucleons and is much stronger than the electrostatic repulsion between the protons ^①



- (b) Why are large nuclei, such as those of radium or plutonium, less stable and therefore prone to radioactive decay? (2 marks)

Large nuclei have many protons, so the electrostatic repulsion forces are much larger, ^① whereas the SNF, acting between neighbouring nucleons, remains similar in strength ^①

Question 11**(4 marks)**

A hair dryer is plugged into a domestic power point. Explain each of the following features.

- (a) The switch on the power point is located on the active wire. (2 marks)

When switched off, the appliance will be disconnected from the power supply ^①, and hence its wiring cannot remain live ^①

- (b) The hairdryer does not need an earth wire. (2 marks)

The outer casing of the hairdryer is made of plastic ^①, an insulator, so cannot become ^① live in case of a fault within the appliance (double insulated)

Question 12

(4 marks)

State which of the three types of nuclear radiation (α , β , γ), that results from natural radioactive decay, best matches each of the following properties.

the radiation that is most ionising α

the radiation consisting of **particles** of least mass β

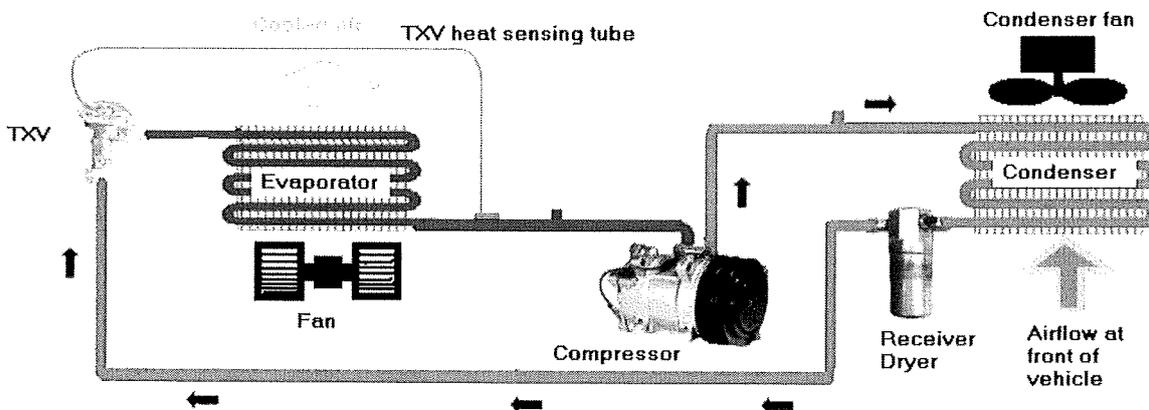
the radiation that is emitted at the lowest speed α

the radiation that is not deflected by an electric field γ

Question 13

(4 marks)

The diagram below shows how refrigerant fluid is cycled around a typical car air-conditioning system.



- (a) State the changes in phase and temperature of the refrigerant fluid after passing through
 (i) the compressor (1 mark)

the fluid becomes a hot liquid

- (ii) the TXV (expansion valve) (1 mark)

the fluid becomes a cold gas

- (b) Explain the following features of the evaporator and condenser coils, as shown above

- (i) each coil is contained within a metal grid (1 mark)

to increase conduction of heat to/from the coils by increasing surface area

- (ii) each coil has a fan helping move air over the coil (1 mark)

to increase heat transfer by convection

END OF SECTION ONE

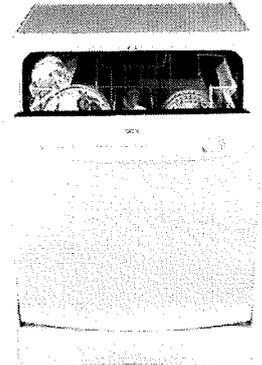
Section Two: Problem Solving**(90 Marks)**

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 90 minutes.

Question 14**(13 marks)**

Consider the dishwasher shown at right. Dishwashers work by heating a mixture of water and detergent, and spraying it against the dishes. The dishes are then rinsed with clean hot water and the hot dishes left to air dry. This particular model of dishwasher draws a current of 6.2 A from the normal household power supply and takes one hour to complete a wash.



- (a) For the initial wash 5.3 litres of water at a temperature of 18.0°C is drawn into the machine. How much heat energy is needed to heat this water to the washing temperature of 70.0°C? (2 marks)

$$\begin{aligned}
 Q &= mc \Delta T && \textcircled{1} \\
 &= (5.3 \text{ kg}) (4180 \text{ J kg}^{-1} \text{ K}^{-1}) (70 - 18) \text{ K} \\
 &= \underline{1.15 \times 10^6 \text{ J}} && \textcircled{1}
 \end{aligned}$$

- (b) Find the power of the water heater given it draws a current of 3.6 A. (2 marks)

$$\begin{aligned}
 P &= VI = \textcircled{1} 240 \text{ V} \times 3.6 \text{ A} \\
 &= \underline{864 \text{ W}} && \textcircled{1}
 \end{aligned}$$

- (c) Determine the time taken for the water heater to heat up the water from 18.0°C to the washing temperature of 70.0°C. Give your answer to the nearest minute. (2 marks)

$$\begin{aligned}
 P &= \frac{E}{t} \rightarrow t = \frac{E}{P} = \textcircled{1} \frac{1.15 \times 10^6 \text{ J}}{864 \text{ W}} \\
 &= 1333 \text{ s} = \underline{22 \text{ min}} && \textcircled{1}
 \end{aligned}$$

- (d) Do you think that the actual time taken is more or less than the time you calculated above in part (c)? Briefly justify your answer. (2 marks)

More^① - not all of the heat from the water heater passes into the water, some is lost into the surroundings^①

- (e) Why do you think that dishwashers have a large quantity of fiberglass foam between the case and the inside?^① (2 marks)

The fiberglass foam acts as an insulating layer^①, preventing heat loss^① and making the dishwasher more efficient^①

- (f) Could the energy efficiency label shown at right have come from this dishwasher? Explain your answer, using the energy consumption figure shown. (3 marks)

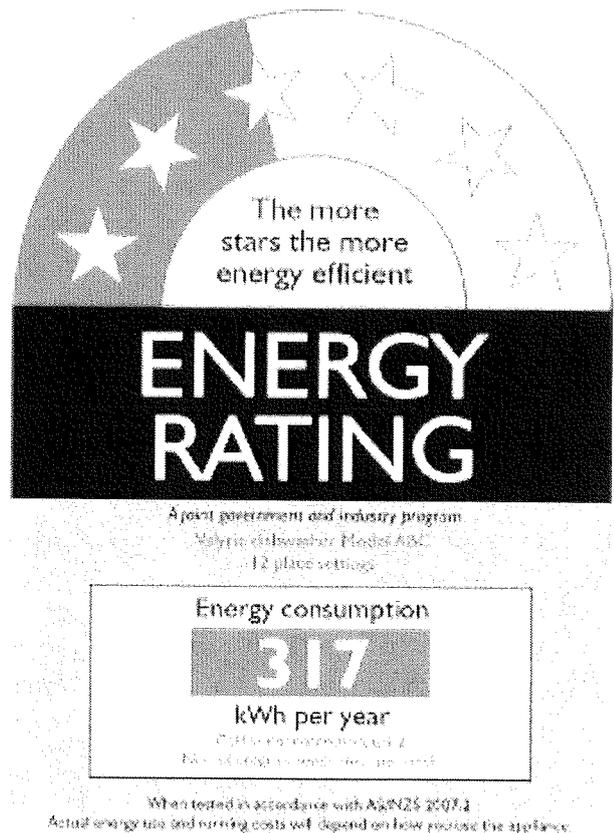
This dishwasher draws 6.2 A and takes one hour to complete a wash →

$$E = \left(\frac{240 \text{ V} \times 6.2 \text{ A}}{1000} \right) \times 1 \text{ hr} \quad \textcircled{1}$$

$$= 1.5 \text{ kW} \times 1 \text{ h} = 1.5 \text{ kWh}$$

Consumption over a year is
 $1.5 \text{ kWh} \times 365 = 540 \text{ kWh}$ ^①

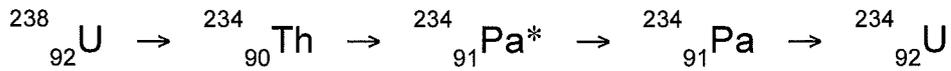
∴ Label is NOT from this dishwasher ^①



Question 15

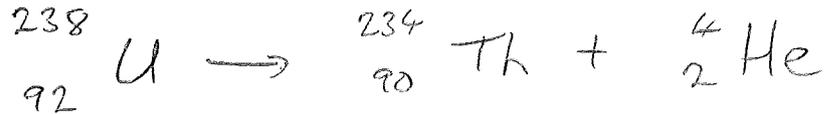
(12 marks)

The first few steps of the natural decay series of the nuclide uranium-238, via the radioactive elements thorium-234 and protactinium-234m ($^{234}_{91}\text{Pa}^*$), are shown below.

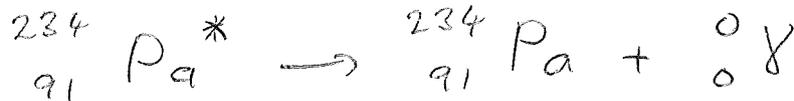


(a) Write balanced nuclear equations for

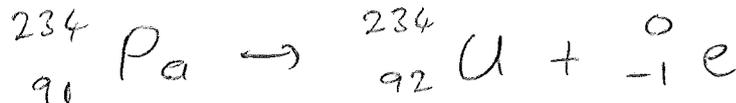
(i) the first decay in the series, uranium-238 into thorium-234 (1 mark)



(ii) the third decay in the series, protactinium-234m into protactinium-234 (1 mark)



(iii) the fourth decay in the series, protactinium-234 into uranium-234 (1 mark)



A radiation detector is used to measure the level of radioactivity near a sample of protactinium-234m over a period of several minutes. The results obtained are shown in the following table:

Activity A (Bq)	360	302	256	216	184	158	138	121	106	84	56	46	42
Time t (s)	0	20	40	60	80	100	120	140	160	200	300	400	500

(b) Use these results to plot a graph of activity against time on the graph paper supplied on the next page. (4 marks)

(c) From this graph:

(i) estimate the level of background radiation. (1 mark)

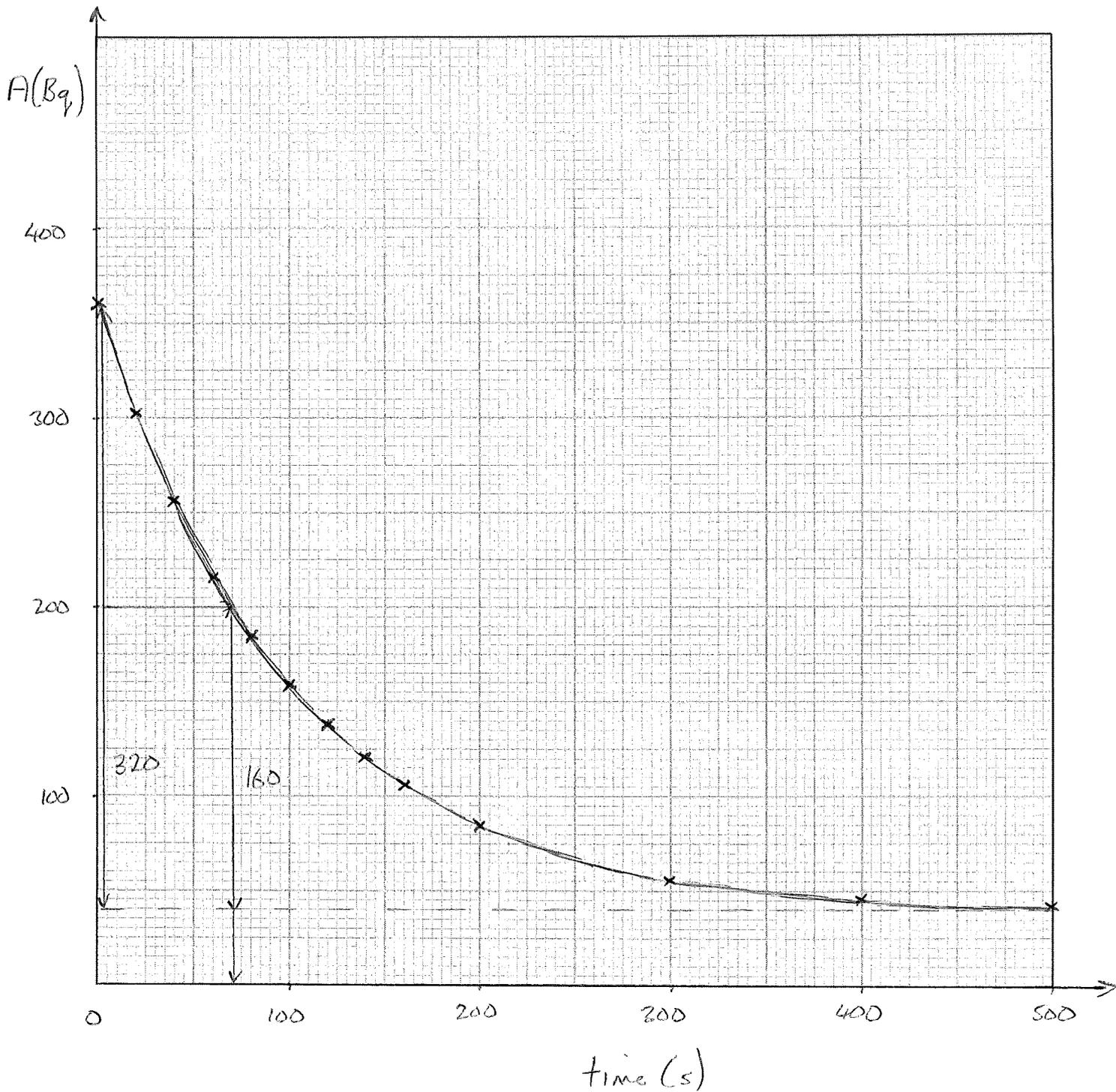
$$40 \text{ Bq}$$

(ii) calculate the half-life of Pa-234m. (2 marks)

$$360 - 40 = 320 \rightarrow \frac{1}{2}(320) = 160 \quad \textcircled{1}$$

$$\therefore 360 \rightarrow 200 \text{ takes 1 half-life} = \underline{70 \text{ s}} \quad \textcircled{1}$$

$$\left(\text{if use } \frac{1}{2}(360) = 180 \rightarrow 82 \text{ s} \quad \textcircled{1} \right)$$



(d) Using your value of half-life from above, calculate the expected level of activity after 580 seconds. (3 marks)

$$n = \frac{580 \text{ s}}{70 \text{ s}} = 8.29 \left(\frac{1}{2}\right), \quad A_0 = 360 - 40 = 320 \left(\frac{1}{2}\right)$$

$$A = A_0 \left(\frac{1}{2}\right)^n = 320 \left(\frac{1}{2}\right)^{8.29} = 1.03 \text{ Bq} \quad (1)$$

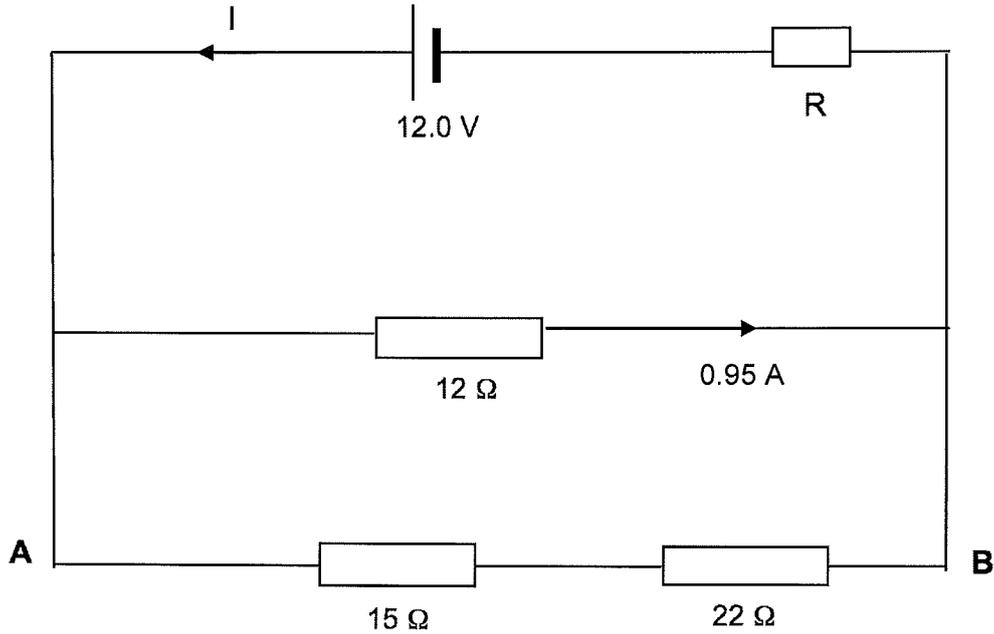
$$\therefore \text{total } A = \underline{41 \text{ Bq}} \quad (1)$$

[If use $T_{1/2} = 82 \text{ s}$, $A_0 = 360 \rightarrow A = 2.67 \text{ Bq} \quad (2)$]

Question 16

9
(10 marks)

A 12.0 V battery is connected to a circuit with four resistors as shown in the diagram below. A current of 0.95 A flows through the 12 Ω resistor.



- (a) Calculate the potential difference (voltage) between points A and B. (2 marks)

$$\begin{aligned} V_{AB} &= IR \quad (\text{upper branch}) \quad \textcircled{1} \\ &= (0.95 \text{ A})(12 \Omega) = \underline{11.4 \text{ V}} \quad \textcircled{1} \end{aligned}$$

- (b) Find the current flowing through the 15 Ω resistor. (2 marks)

$$\begin{aligned} I &= \frac{V}{R} \quad (\text{lower branch}) \\ &= \frac{11.4 \text{ V}}{(15 \Omega + 22 \Omega)} = \underline{0.31 \text{ A}} \quad \textcircled{1} \end{aligned}$$

- (c) Determine the rate at which heat is being produced in the 22Ω resistor. (2 marks)

$$\begin{aligned} P &= I^2 R \quad (1) \\ &= (0.31 \text{ A})^2 (22 \Omega) \\ &= \underline{2.1 \text{ W}} \quad (1) \end{aligned}$$

- (d) What is the current I from the battery? (2 marks)

$$\begin{aligned} I &= 0.95 \text{ A} + 0.31 \text{ A} \\ &= \underline{1.26 \text{ A}} \quad (1) \end{aligned}$$

- (e) Find the value of the resistance R in series with the battery. (2 marks)

$$\begin{aligned} V_{\text{drop}}(R) &= 12.0 - 11.4 = 0.6 \text{ V} \quad (1) \\ \therefore R &= \frac{V_{\text{drop}}}{I} = \frac{0.6 \text{ V}}{1.26 \text{ A}} = \underline{0.48 \Omega} \quad (1) \end{aligned}$$

Question 17**(15 Marks)**

The clarinet, pictured at right, is a wind instrument that behaves like a closed pipe with a fundamental frequency of 130 Hz in air at a room temperature of 25°C.



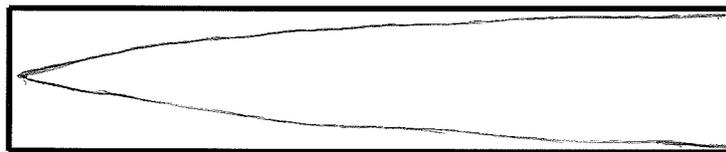
- (a) What are the frequencies of the next two higher harmonics? (2 marks)

$$f_3 = 3 \times 130 = \underline{390 \text{ Hz}} \text{ (1)}$$

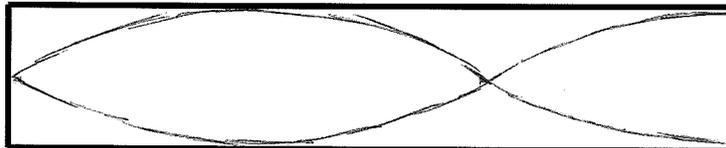
$$f_5 = 5 \times 130 = \underline{650 \text{ Hz}} \text{ (1)}$$

- (b) Sketch the particle displacement vs distance envelopes for the fundamental frequency and for the next harmonic frequency above the fundamental for this instrument. (2 marks)

fundamental frequency



next harmonic frequency



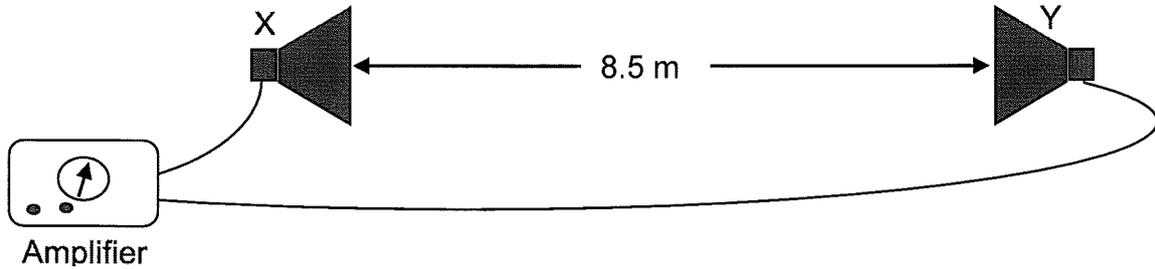
- (c) Calculate the length of the clarinet. (3 marks)

$$v = \lambda_1 f_1 \rightarrow \lambda_1 = \frac{346 \text{ m/s}}{130 \text{ Hz}} = 2.66 \text{ m}$$

For the 1st harmonic $\lambda_1 = 4L$

$$\therefore L = \frac{\lambda_1}{4} = \frac{2.66 \text{ m}}{4} = \underline{0.665 \text{ m}}$$

The clarinet is played so as to produce its fundamental frequency, and the sound is captured by a microphone and feed into an amplifier. Two loudspeakers X and Y are connected in phase to the amplifier and set up facing each other a distance of 8.5 m apart. A person walking from one of the loudspeakers towards the other hears points where the sound is extremely soft, alternating with points where it is loud.



- (d) Why will the person hear a series of soft and loud points as they walk from one loudspeaker towards the other? (2 marks)

The sound waves from the two speakers interfere to produce a standing wave between the speakers, with points of constructive (antinodes) and destructive (nodes) interference.

- (e) Calculate whether the sound is loud or soft when the person walking between the loudspeakers is 2.92 m from speaker X. (3 marks)

$$\text{distance from speaker Y} = 8.5 - 2.92 = 5.58 \text{ m}$$

$$\therefore \text{path diff} = 5.58 \text{ m} - 2.92 \text{ m} = 2.66 \text{ m} = 1\lambda$$

\therefore constructive interference so sound is loud.

- (e) What is the distance between a soft and a loud point? (1 mark)

$$d = \frac{1}{4} \lambda = 0.665 \text{ m}$$

- (f) Determine the number of soft points between the loudspeakers. (2 marks)

$$X \left(\begin{array}{cccccccc} A & A & A & A & A & A & A \end{array} \right) Y$$

$$0 \quad 0.25 \quad 1.6 \quad 2.9 \quad 4.25 \quad 5.6 \quad 6.9 \quad 8.25$$

Antinodes are $\frac{1}{2} \lambda = 1.33 \text{ m}$ apart (as shown), with nodes in between \rightarrow 6 soft points.

Question 18**(15 marks)**

A car of mass 1200 kg is being driven along a busy road at a steady speed when the driver, distracted by answering their phone, fails to notice that the lights ahead are red and runs into the back of a stationary 3.5 tonne van waiting at the lights. The car and van lock together after collision and slide to a halt in the middle of the intersection, leaving skid marks measured by the police to be 3.2 m long. The police also estimate that the frictional force acting on the tyres of the skidding vehicles was approximately 60% of their combined weight.



- (a) Give a value for the frictional force acting on the tyres of the skidding vehicles, and hence calculate the work done by friction in bringing the vehicles to a halt. (3 marks)

$$F_f = 60\% \times (1200 \text{ kg} + 3500 \text{ kg}) (9.8 \text{ m/s}^2) = 27600 \text{ N} \quad \textcircled{1}$$

$$\therefore W(\text{done by friction}) = F_f \times s \quad \textcircled{1}$$

$$= 27600 \text{ N} \times 3.2 \text{ m} = \underline{88400 \text{ J}} \quad \textcircled{1}$$

- (b) State the energy transformation that occurs as the two vehicles skid to a halt. (1 mark)

$$KE \rightarrow \text{heat}$$

- (c) Hence find the speed of the two vehicles immediately after the car runs into the van (at the beginning of their skid). (3 marks)

$$\text{At beginning of skid, } KE = 88400 \text{ J} \quad \textcircled{1}$$

$$\therefore KE = \frac{1}{2} m v^2 \rightarrow 88400 = \frac{1}{2} (4700) v^2 \quad \textcircled{1}$$

$$\therefore v^2 = 37.6 \rightarrow v = \underline{6.13 \text{ m/s}} \quad \textcircled{1}$$

- (d) Given that momentum is conserved during the collision of the car with the van, determine the speed of the car before hitting the van. (2 marks)

$$\Sigma p(\text{before}) = \Sigma p(\text{after})$$
$$(1200 \text{ kg})(u) + (3500 \text{ kg})(0) = (4700 \text{ kg})(6.13 \text{ m/s}) \quad (1)$$
$$\therefore u = \frac{28800 \text{ kg m/s}}{1200 \text{ kg}} = \underline{24.0 \text{ m/s}} \quad (1)$$

- (e) Compare the kinetic energy of the car before collision with the kinetic energy of the car plus van after collision. Account for any difference between the two values. (3 marks)

$$KE(\text{before}) = \frac{1}{2}(1200)(24.0)^2 = 346 \text{ kJ} \quad (1)$$
$$KE(\text{after}) = \frac{1}{2}(4700)(6.13)^2 = 88 \text{ kJ} \quad (1)$$

→ only 25.5% of original KE remains
The difference in energy represents KE of the car that was transformed into heat during the collision. (1)

- (f) Compare the force experienced by each vehicle during the collision. Explain why the car driver is more likely to suffer injuries as a result of the collision than the van driver. (3 marks)

Both vehicles experience the same size force during the collision, but in opposite directions (Newton's 3rd Law). However since the car has a smaller mass, this force will cause a larger acceleration to be experienced by it and its driver. Hence the car driver is more likely to suffer injuries in the crash. (1)

Question 19

(13 marks)

A water-cooled nuclear reactor is shown in the sketch at right. The fuel rods in the nuclear reactor contain the fissile isotope uranium-235, which releases large amounts of energy when it undergoes fission.

The heat produced by the reactor core is removed by the coolant flowing through it, in this case pressurised liquid water, which remains in the liquid state despite **increasing in temperature by 160 K** after passing through the reactor core.

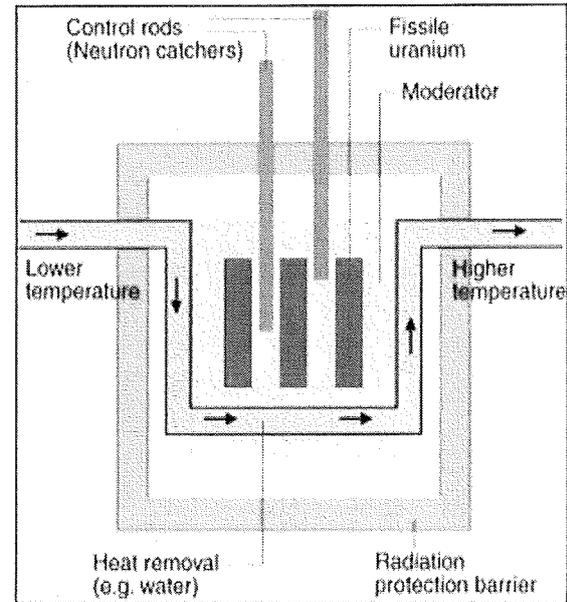
The masses of various particles involved in a typical fission reaction are given below

$$\text{mass (uranium-235)} = 3.90314 \times 10^{-25} \text{ kg}$$

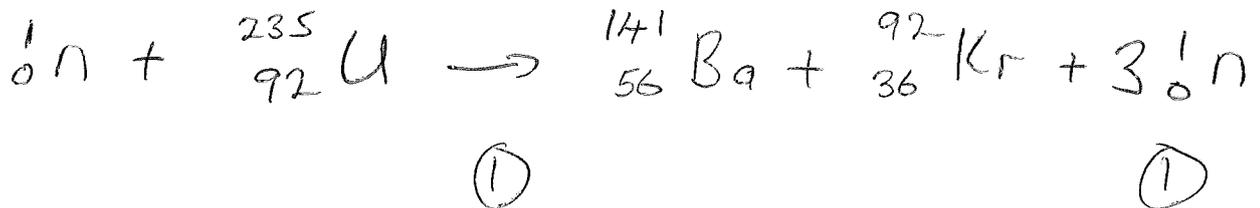
$$\text{mass (barium-141)} = 2.34002 \times 10^{-25} \text{ kg}$$

$$\text{mass (krypton-92)} = 1.52653 \times 10^{-25} \text{ kg}$$

$$\text{mass (neutron)} = 1.6750 \times 10^{-27} \text{ kg}$$



- (a) Write a balanced nuclear equation for the fission of a uranium-235 nucleus, after the absorption of a neutron, into barium-141 and krypton-92 nuclei along with the release of more neutrons. (2 marks)



- (b) Given the masses listed above, calculate the energy released per fission of a uranium-235 nucleus. (3 marks)

$$\begin{aligned} \Delta m &= m(\text{n}) + m(\text{U-235}) - m(\text{Ba-141}) - m(\text{Kr-92}) - 3m(\text{n}) \\ &= 3.90314 \times 10^{-25} \text{ kg} - 2.34002 \times 10^{-25} \text{ kg} \\ &\quad - 1.52653 \times 10^{-25} \text{ kg} - 2(1.6750 \times 10^{-27} \text{ kg}) \\ &= 3.09 \times 10^{-28} \text{ kg} \end{aligned}$$

①

$$\therefore E = mc^2 = (3.09 \times 10^{-28}) (3 \times 10^8)^2 = \underline{2.78 \times 10^{-11} \text{ J}}$$

①

- (c) The power output of the nuclear reactor is 250 MW. Calculate the rate at which the fuel rods lose mass in order to provide this amount of power. (2 marks)

Each second the reactor produces 250 MJ

$$\therefore E = mc^2 \rightarrow \textcircled{1} 250 \times 10^6 \text{ J} = m (3 \times 10^8 \text{ m/s})^2$$

$$\therefore m = \frac{2.78 \times 10^{-9} \text{ kg}}{\textcircled{1}} \text{ lost per second}$$

- (d) Calculate the mass of coolant that must pass through the reactor core every second to maintain it at a stable temperature when it has a power output of 250 MW. (2 marks)

$$\Delta T = 160 \text{ K}, Q = 250 \text{ MJ}$$

$$Q = mc \Delta T \rightarrow m = \frac{Q}{c \Delta T} \textcircled{1}$$

$$\therefore m = \frac{250 \times 10^6 \text{ J}}{(4180 \text{ J kg}^{-1} \text{K}^{-1})(160 \text{ K})} = \underline{374 \text{ kg/sec}} \textcircled{1}$$

- (e) Explain the function of the following components of the nuclear reactor.

- (i) the control rods (2 marks)

to absorb neutrons $\textcircled{1}$, and therefore control the rate of the reaction by $\textcircled{1}$ being raised/lowered into the reactor core

- (ii) the moderator (2 marks)

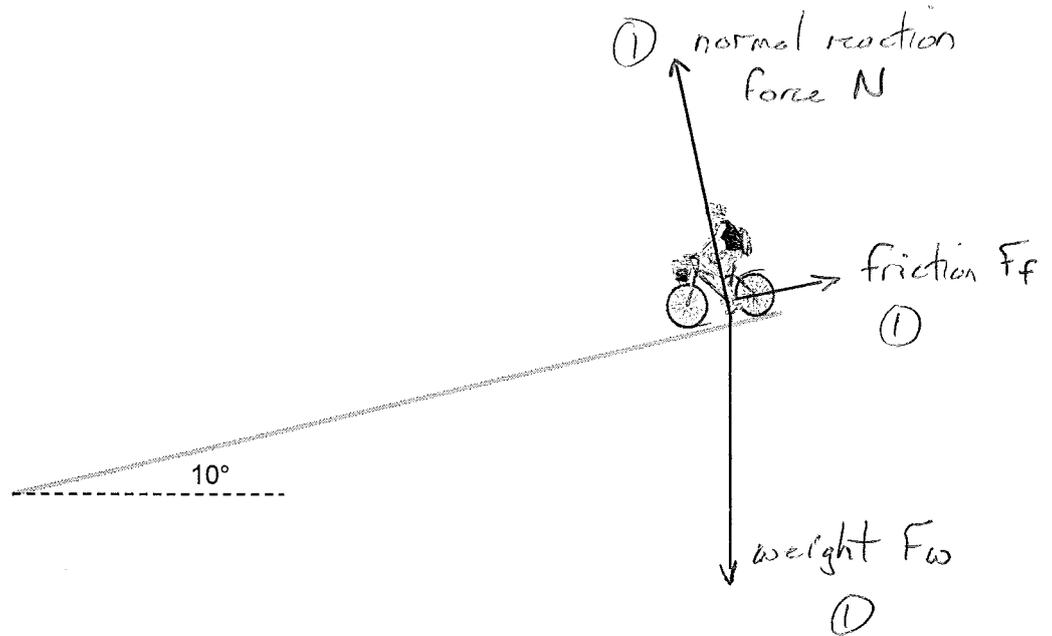
to slow down neutrons $\textcircled{1}$, so that they have greater probability of causing further fissions $\textcircled{1}$

Question 20

(12 marks)

A girl riding on her bike starts rolling from rest at the top of a steep 10° slope, as shown in the diagram below. The girl and her bike have a combined mass of 65 kg, and the friction force of the road against her tyres as she rolls down the slope is a constant 15 N.

- (a) On the diagram, draw in and label the three forces acting on the girl (and her bike) as she starts rolling down the slope. (3 marks)



- (b) How large is the normal reaction force of the road pushing on the tyres? (2 marks)

$$N = F_w \cos 10^\circ = mg \cos 10^\circ \quad (1)$$

$$= (65 \text{ kg})(9.8 \text{ m/s}^2) \cos 10^\circ = \underline{627 \text{ N}} \quad (1)$$

- (c) Calculate the size of the net force on the girl as she starts rolling down the slope, and her initial acceleration. (4 marks)

$$F_{\text{net}} = F_w \sin 10^\circ - F_f \quad (1)$$

$$= (65 \text{ kg})(9.8 \text{ m/s}^2) \sin 10^\circ - 15 \text{ N} \quad (1)$$

$$= \underline{96 \text{ N}} \quad (1)$$

$$a = \frac{F_{\text{net}}}{m} = \frac{96 \text{ N}}{65 \text{ kg}} = \underline{1.5 \text{ m/s}^2} \quad (1.47 \text{ m/s}^2)$$

In addition to the 15 N friction force, there is an air resistance force opposing her motion down the slope, which increases quadratically with speed according to the formula

$$F = 1.2 v^2, \text{ where } F = \text{air resistance force (in N)} \text{ and } v = \text{her speed (in m/s).}$$

- (d) Calculate the maximum speed she will reach rolling down the slope on her bike. (3 marks)

When she reaches maximum speed, the air resistance force F must balance the net force calculated above

$$\text{i.e. } F = 96 \text{ N} \quad \textcircled{1}$$

$$\therefore F = 1.2 v^2 = 96 \quad \textcircled{1}$$

$$\therefore v^2 = 80 \rightarrow v = \underline{8.9 \text{ m/s}} \quad \textcircled{1}$$

END OF SECTION TWO

Section Three: Comprehension**(36 Marks)**

This section has **two (2)** questions. Write your answers in the spaces provided.

Suggested working time: 36 minutes.

Question 21**ELECTRICITY IN THE CAR****(20 marks)***(Paragraph 1)*

Modern cars use electricity for a variety of tasks, including initiating the burning of fuel (in a petrol engine). The amount of electricity used to generate sparks in the spark plugs is quite low, so the power to propel the car clearly comes, not from the electricity, but from the fuel itself. It is possible, however, to use electricity to provide all the necessary power, using rechargeable batteries, or using energy directly from the sun via solar cells.

(Paragraph 2)

The idea of using electricity to power a car directly is not new. More than a hundred years ago, electric cars such as the Victoria electric carriage were built. This had a top speed of 18 km/hr and could carry four passengers a distance of 30 miles (approximately 48 km). The motor drew an average current of 26 amperes on a hard, flat road. As the internal combustion engine became more efficient, the electric car fell out of favour and has only recently again captured the public's attention, as concern over the effects of fossil fuels on the environment has grown.

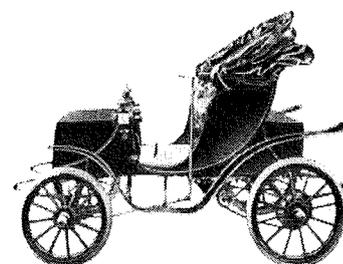
*(Paragraph 3)*

Table 1 below shows how the frictional force on a typical modern car varies with its speed. The power (in watts) needed by the car, at a particular speed, can be calculated by multiplying the frictional force on the car at that speed by the value of the speed.

Table 1

Frictional force F (N)	Speed v (m/s)
0	0
19	5
74	10
167	15
296	20
463	25
666	30
907	35
1184	40

(Paragraph 4)

A major problem with the direct use of electricity to drive a car is the limited energy-storage capacity of the batteries. Petrol, diesel and LPG are very energy efficient as they store a large amount of energy in a relatively small volume. There is enough energy stored in petrol, for example, to carry the initial weight of fuel more than 1500 kilometres. A lead-acid battery, in contrast, only stores enough energy to carry its own weight 15 kilometres, one-hundredth this distance. New battery designs have improved on this figure but, so far only by a factor of 5 or 6.

(Paragraph 5)

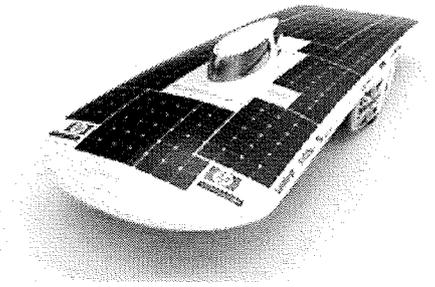
An alternative to batteries to power an electric vehicle is to make use of the sun's energy directly using solar cells. When light falls on a solar cell, it generates an EMF at the terminals of the solar cell, which can be used to produce a current in a circuit. Sunlight is converted directly to electrical energy by a solar cell.

(Paragraph 6)

Each square metre of a surface exposed to sunlight has about 1000 watts of energy per second falling on it, under the best conditions. Even if all of this energy arriving per second could be converted to useful electricity, it would be of limited value in driving an electric vehicle directly. One kilowatt of electrical power is a fraction of that produced by a modern petrol engine. In practice, the amount of energy available may be as low as 10% of this value on a very overcast day - typically rising only as high as 85% on a clear day.

(Paragraph 7)

Even then, not all the energy is usable. Theoretically, a solar cell can only reach an efficiency of 28%; that is, it can convert only 28% of the sunlight falling on it into electricity. Standard mass-produced solar cells are only 14% efficient, but specialised high-efficiency types have achieved efficiency as high as 26%. The energy available is also reduced because the solar cells will not always be oriented to receive the maximum amount of solar energy, as the vehicle turns or moves into a shady area, or when the sun is low in the sky. And, of course, no solar energy is available at night.



(a) In paragraph one it says, "The amount of electricity used to generate sparks in spark plugs is quite low..."

(i) What is meant by the phrase "the amount of electricity"? (1 mark)

• the amount of charge

• the amount of electrical energy

either

(ii) Why is the amount of electricity in a spark quite low given that a voltage of several thousand volts is used to produce sparks? (2 marks)

The spark only lasts for a tiny fraction of a second, so despite the high voltage the total energy in a spark is low due to the very small time ($E = V I t$)

(b) In paragraph two, information is given regarding one of the early electric cars. Use this information, along with the assumption that the voltage used in those cars was 12 V, to carry out the following calculations:

(i) Calculate the power of the vehicle. (2 marks)

$$P = VI = 12V \times 26A$$

$$= \underline{312W}$$

(ii) Calculate the energy stored in its batteries. (hint: the electric car had a range of about 48 km at its maximum speed of 18 km/hr) (3 marks)

$$\text{time} = \frac{48 \text{ km}}{18 \text{ km/hr}} = 2.67 \text{ hr}$$

$$\therefore E = P \times t = 312W \times (2.67 \times 60 \times 60 \text{ s})$$

$$= \underline{3.0 \times 10^6 \text{ J}}$$

(iii) Compare the power of the early electric car to the power of a modern vehicle moving at a speed of 40 m/s (use Table 1). (3 marks)

A modern vehicle moving at 40 m/s experiences a frictional force of 1184 N

$$\therefore P = F \times v = 1184N \times 40 \text{ m/s} = \underline{47400W}$$

$$\text{The modern car is } \frac{47400W}{312W} = \underline{152 \text{ times}}$$

as powerful as the early electric car

(c) State the main reason why electric vehicles are not in common use today. (2 marks)

the limited energy storage capacity of the batteries

(d) A solar car is fitted with standard mass-produced solar cells, which cover a total surface area of 6.20 m^2 .

(i) How much power is available to this solar car on a clear day? (hint: state the values from the article that you need to use for this calculation) (3 marks)

$1000 \text{ W per square metre}$, 85% available on clear day

standard mass-produced solar cells = 14% efficient

Power available on clear day is

$$\begin{aligned} & \overset{1/2}{1000 \text{ W/m}^2} \times \overset{1/2}{6.20 \text{ m}^2} \times \overset{1/2}{85\%} \times \overset{1/2}{14\%} \\ & = \underline{740 \text{ W}} \quad \textcircled{1} \end{aligned}$$

(ii) Assuming that Table 1 applies to this solar car, estimate the maximum speed of the solar car on a clear day. (2 marks)

$$P = F \times v \Rightarrow 740 \text{ W} = 74 \text{ N} \times 10 \text{ m/s} \quad \textcircled{1}$$

$$\therefore \text{max speed} = \underline{10 \text{ m/s}} \quad \textcircled{1}$$

(e) State two major problems with solar vehicles that have prevented their commercial use.

(2 marks)

• low power of sunlight per m^2 ($\leq 1000 \text{ W/m}^2$)

• low efficiency of solar cells ($\leq 28\%$)

• orientation relative to the Sun

• no sunlight at night

any 2

Question 22

OMHIC/NONOHMIC CIRCUIT COMPONENTS

(16 marks)

A Year 11 student carried out an experiment that measured the current through a particular circuit component, identified only as component A, as the voltage across it was successively increased. She then repeated the experiment for a second circuit component, identified only as component B. The tables below show the data collected in the experiment by the student.

Component A

current (Amps)	voltage (Volts)
0.00	0.00
0.93	0.99
1.23	2.00
1.49	2.93
1.68	3.76
1.99	5.20
2.12	5.82
2.24	6.41
2.32	6.94

Component B

current (Amps)	voltage (Volts)
0.00	0.00
0.13	1.37
0.26	2.66
0.40	3.94
0.51	5.05
0.63	6.23
0.73	7.19
0.84	8.26
0.95	9.25

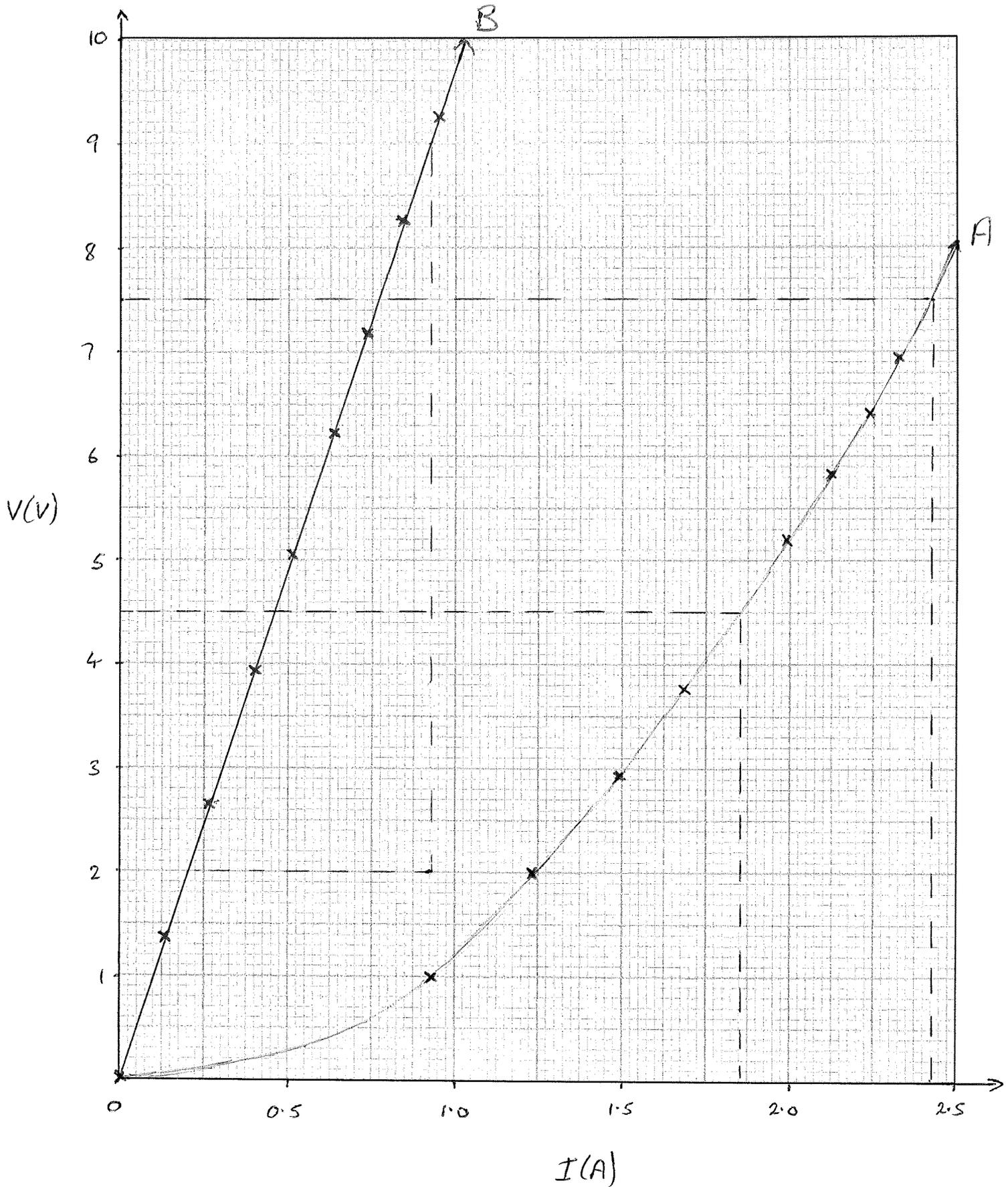
- (a) On the graph paper supplied on the next page, draw a graph of voltage versus current for each component, using the same set of axes. (5 marks)

- (b) Which of the two components is an ohmic conductor? Calculate its resistance from your graph. (3 marks)

B is ohmic as it has a linear graph (1)
 resistance $R = \text{gradient} = \frac{9V - 2V}{(0.925A - 0.2A)}$ (1)
 $= 9.7 \Omega$ (1)

- (c) What is the appropriate number of significant figures for your calculated value of resistance for the ohmic conductor? Briefly state why this is the appropriate number of significant figures. (2 marks)

R should be given with 2 sig figs (1)
 The values of current used to plot the points only have 2 sig figs each (1)



labelled axes, good scales ①

graph for A : points ①, curve ①

graph for B : points ①, line ①

- (d) Could you use your calculated value of resistance to predict the current through the **ohmic** conductor if a voltage of 25.00 V was applied across it? Briefly explain. (2 marks)

No ^① - 25V is outside the range of voltages used to calculate the resistance value ^①
(25V is so large that the ohmic conductor may begin to behave in a nonohmic manner)

- (e) From the graph, find the resistance of the **nonohmic** conductor when the voltage across it is

(i) 4.5 V \rightarrow 1.85 A (1 mark)

$$\therefore R = \frac{4.5 \text{ V}}{1.85 \text{ A}} = \underline{2.43 \Omega} \quad \text{①}$$

(ii) 7.5 V \rightarrow 2.425 A (1 mark)

$$R = \frac{7.5 \text{ V}}{2.425 \text{ A}} = \underline{3.09 \Omega} \quad \text{①}$$

- (f) Which of these estimated values of the resistance of the **nonohmic** conductor do you think is more reliable? Briefly explain your reasoning. (2 marks)

The value of 2.43Ω ^① (at 4.5V) is more reliable - it has been estimated from inside the range of voltage and current values given (interpolated), whereas the value of 3.09Ω has been extrapolated from the curve ^①

END OF PAPER