Section One: Short answer **40% (64 Marks)**

This section has **17** questions. Answer **all** questions. Write your answers in the space provided.
Suggested working time for this section is 60 minutes.

Question 1

Write balanced nuclear equations for the following decays.

a. Potassium-42 by beta negative decay.

(2)

$^{42}_{19}K \rightarrow {}^{42}_{20}Ca + {}^{0}_{-1}\beta + \bar{\nu} + energy$ Balances top and bottom✓correct symbols✓

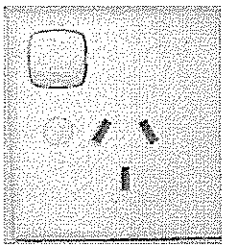
b. Polonium-210 by alpha decay.

(2)

$^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha + energy$ Balances top and bottom✓ correct symbols✓

Question 2

If a switch is placed on the neutral wire rather than the active wire in a household electrical circuit the switch is still able to turn devices on and off. However, a switch is placed on the neutral wire is potentially hazardous. Explain why.



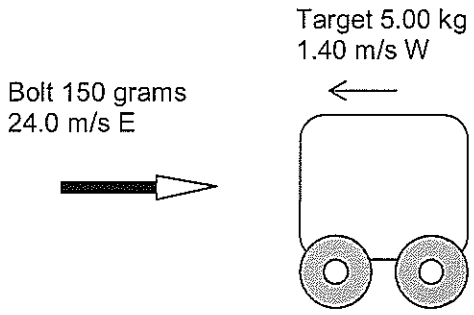
(3)

- Although current is cut when the switch is off, any components within the device will be at an absolute potential of +240 V since the active wire is not switched off✓.
- A person coming into contact with one of the components has an absolute potential of zero volts✓.
- A potential difference now exists and current is established along this path which could lead to electrocution ✓

Or 3 good points to that effect.

Question 3

A steel bolt of mass 150 g is fired from a crossbow at a rolling wooden target that is moving toward the crossbow. The crossbow bolt is moving at 24.0 m s^{-1} East. The rolling target has a mass of 5.00 kg and is moving at 1.40 m s^{-1} West. On impact the crossbow bolt becomes embedded into the target. Calculate the velocity of the target and embedded bolt after the collision.



(3)

Let East = +ve,

$m_1 = 0.150$ kg $u_1 = +24.0$ m/s $m_2 = 5.00$ kg $u_2 = -1.40$ m/s ✓

$\Sigma P_{before} = \Sigma P_{after}$

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$(0.150 \times +24.0) + (5.00 \times -1.40) = (5.15) \times v$ ✓

v = -0.660 m/s ✓ (negative = West)

Question 4

Explain the concept of electrical current and also explain how an electrical current is established.

(3)

- Current is a measurement of the flow charge per second past a point ✓
- When a potential difference is established between two locations an electric field is formed✓.
- Charge that is free to move is induced to flow through the electric field (across the potential difference) ✓

Or 3 good points to that effect.

Question 5

A rocket of mass 10 tonnes (including fuel) is in deep space where the effects of gravity from any other objects can be ignored. When it starts to burn fuel there is a constant thrust force from its engines. *Refer to Newton's laws of motion in your answers to this question.*

a) Explain how the burning of fuel to make exhaust gas exit from the back of the jet cones can accelerate the rocket forwards.

(2)

Gas particles are colliding with the jet cones exerting an action force on them. According to Newton's 3rd law the jet cones apply a reaction force to the gas particles✓ Gas particles are forced backwards and the rocket is forced forwards. ✓

b) Explain what happens to the magnitude of acceleration as the rocket is burning fuel.

(2)

According to Newton's 2nd Law the acceleration is directly proportional to the applied force but indirectly proportional to the mass✓, so as mass decreases then acceleration increases✓.

c) The rocket burns 2 tonnes of fuel to accelerate to 1500 m s^{-1} over a distance of 100 km. How much fuel would be needed to continue forwards at a constant velocity of 1500 m s^{-1} for a distance of 2,000 km? Explain briefly.(no calculation required)

(2)

According to Newton's 1st law a body will continue at a constant velocity unless acted on by an external force✓, so no fuel is required to maintain a constant velocity.✓

Question 6

Explain the process of heat transfer by convection with reference to kinetic molecular theory.

(3)

- Convection can occur in fluids (liquids or gases). When heat transfers into a pocket of fluid its internal energy increases✓.
- A rise in potential energy results in the thermal expansion of this pocket within the main body of fluid.✓
- This pocket now has lower density compared the surrounding body of fluid so will rise (or expresses concept of buoyancy/flotation). ✓
- Cooler, more dense particles will move into the spaces.
- Or 3 good points to that effect.

Question 7

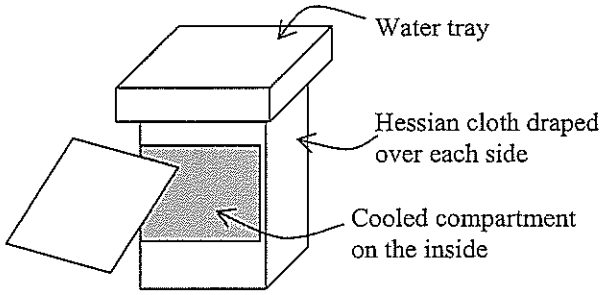
Polonium-210 is a radioactive isotope that decays by alpha emission. It is present in tobacco smoke. Explain why this presents risks to someone inhaling smoke from a cigarette and compare it with the risks to somebody handling packets of cigarettes in a supermarket.

(3)

Alpha particles have low penetration ability so are contained within a packet in the supermarket so present negligible risk in this context✓
When smoke is inhaled into the lungs then alpha particles can collide directly with sensitive tissues in the lung. Alpha particles have a high quality factor which indicates they are highly ionising and present a much greater risk in this context. ✓✓

Question 8

The Coolgardie Safe was a simple refrigerator used in Australia up until the 1950s. The Coolgardie Safe was made of wire mesh on a wooden frame with an iron tray on top filled with water. Hessian cloth was hung over every side with the top end of the cloth placed in the water tray. The Hessian cloth would soak up water and become wet all over. It was placed on a verandah so that the breeze would blow across the cloth and evaporate the water. This had the effect of cooling food stored inside the safe.



a) Briefly explain how the Coolgardie Safe can keep food cool?

(2)

Either - average KE of water reduced by high energy particles escaping from Hessian✓ in thermal contact with and air leads to heat transfer ✓. Or - Energy for latent heat of vaporisation ✓ is transferred from contents to Hessian to evaporating water. ✓.

b) Explain how the effectiveness of the Coolgardie Safe would change in humid conditions.

(1)

In high humidity the spaces in atmospheric air have been filled by water vapour molecules, which reduce opportunity for other water molecules to fill this space by evaporation. ✓

c) State one factor that could change to increase the rate of cooling in the safe.

(1)

Increase air flow, increase surface area of filters etc. ✓

Question 9

Four 1.50 V, AA batteries connected in series are used to power an mp3 player. The mp3 player has a resistance of 200 Ω. Calculate how much electrical potential energy is transformed whilst listening to a 3½ minute song on the mp3 player.

(3)

$V_{emf} = 4 \times 1.50 = 6.00$ V ✓ (= V_d in single element series circuit)
$R = 200\ \Omega$
$t = 3.5 \times 60 = 210$ seconds ✓

$E = (V_d^2 / R) \times t$

$E = (6^2 / 200) \times 210$ ✓ $= 37.8$ J ✓

Question 10

A 428 g block of stainless steel is heated in a flame and placed into 1.20 L of water at 18°C. The final temperature of the steel and water mixture was 37°C when they reached thermal equilibrium in a fully insulated container. (density of water = 1 g cm^{-3})

a. Calculate how much energy was transferred from the stainless steel block to the water.

(2)

$m = 1.20$ kg $\quad \Delta T = 37 - 18 = 19$ K $\quad c = 4180$ J kg^{-1} K^{-1} ✓

$Q = m.c.\Delta T = 1.20 \times 4180 \times 19 = 95{,}304$ J $\quad = \underline{+ 9.53 \times 10^4 \text{ J}}$ ✓

b. Calculate the initial temperature of the stainless steel block. The specific heat capacity of stainless steel is 4.45×10^2 J Kg^{-1} K^{-1}.

(2)

$Q = -95{,}304$ J $\quad m = 0.428$ kg $\quad c = 445$ J kg^{-1} K^{-1}

$\Delta T = Q / (m.c)$

$\Delta T = -95304 / (0.428 \times 445) = -500$ K ✓ $= T_{final} - T_{initial}$

$T_{initial} = T_{final} - (-500) = 37 + 500 = 537$ °C ✓

Question 11

Give an example of how a house in Western Australia can be insulated from heat transfer into the house by radiation. As part of your answer you must explain the physics principles involved.

(3)

Radiation is the transfer of heat energy via electromagnetic radiation such as visible light and infra red radiation from the sun ✓

The transfer can be reduced by blocking or reflecting these rays. ✓

The rays travel in straight lines through a given medium so by placing items such as trees/shade cloth/curtains/shutters etc. in the path then the transfer is reduced. ✓

Or 3 good points to that effect.

Question 12

Workers at the Fukushima Daiichi nuclear power plant have recovered a case of radioactive waste. They measured its activity from a set distance to be 242 Bq. The average half-life of the waste is 5.40×10^4 years. Calculate how much time it will take for the waste to have an activity of 8.00 Bq.

(4)

A = 8 Bq A_0 = 242 Bq $t_{\frac{1}{2}} = 5 \times 10^4$ years

$A = A_o(\frac{1}{2})^n$

$8 = 242(\frac{1}{2})^n$ ✓

$\frac{8}{242} = (\frac{1}{2})^n$

$\log(\frac{8}{242}) = \log(\frac{1}{2})^n$

$\log(0.28125) = n\log(\frac{1}{2})$

$\frac{\log(8/242)}{\log(\frac{1}{2})} = n$

n = 4.92 ✓

$t = n \times t_{\frac{1}{2}}$

$t = 4.92 \times 5 \times 10^4 = 2.46 \times 10^5$

time taken = 2.46×10^5 years ✓

Or guess check and improve method if used by your school

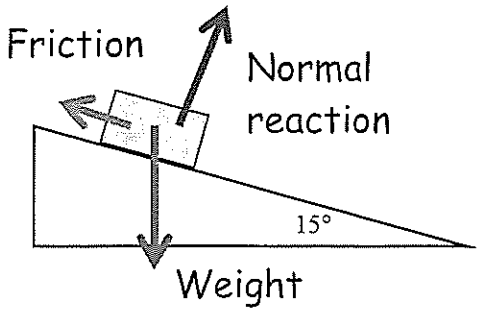
242 ➔121➔60.5➔ 30.25➔15.125➔7.5625= 5 half lives,

so a little less than 5 half lives = approx $5 \times 5 \times 10^4$ yrs

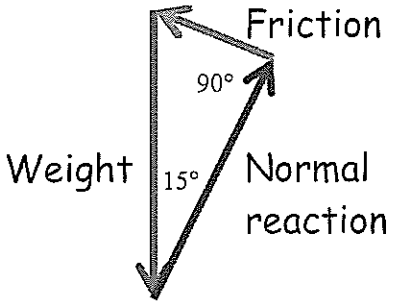
= approx 2.50×10^5 yrs

Question 13

A brick of mass 3 kg is at rest on an inclined plane which has a rough surface. The incline makes an angle of 15° with the horizontal.



Vector diagram:



a. Identify the 3 forces acting on the brick by placing arrows on the diagram and labelling them to make a free body diagram.

(1)

b. Transfer the forces to the space on the right to construct a vector diagram for this situation. You must show relevant angles and label your forces.

(1)

c. Calculate the force of friction acting to keep the brick in equilibrium on the plane.

(2)

$W = m.g$ Friction = F = ? $\theta = 15°$

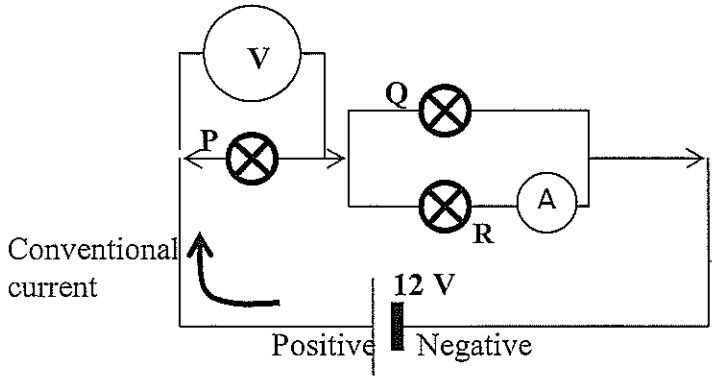
$F = m.g.\sin\theta°$

$F = 3 \times 9.8 \times \sin 15°$ ✓

F = 7.61 N along the slope

Question 14

The diagram shows 3 electric light globes P, Q and R connected in a circuit.



a. Show, by sketching on the diagram, where you would connect a voltmeter to measure the potential difference for globe P. as above ✓

(1)

b. Show, by sketching on the diagram, where you would connect an ammeter to measure the current in globe R. as above ✓

(1)

c. Indica te on the diagram which part of the dry cell is positive and which part is negative.

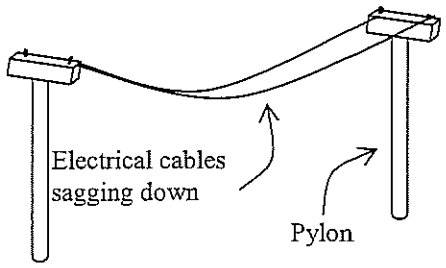
as above ✓ (1)

d. Indica te the direction of conventional current in this circuit with an arrow and label it 'conventional current'. as above ✓

(1)

Question 15

When electrical power lines are constructed, the metal cables between each pylon have sufficient length to allow the cables to sag down somewhat. Explain why the power lines are designed in this way.



(3)

- In colder weather there is a transfer of heat energy out of the cables. ✓
- The cables contract i.e. their length decreases (a decrease in potential energy)✓.
- The extra length of the cables at warmer temperatures means that they won't become too short, go into tension and possibly snap ✓

Or 3 good points to that effect.

Question 16

When a uranium-235 nucleus absorbs a thermal neutron it can undergo fission. One reaction results in the formation of Antimony-133 (Sb), Niobium-98 (Nb) and neutrons.

a) Write the equation for this reaction and clearly identify the number of neutrons produced.

(2)

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{133}_{51}Sb + ^{98}_{41}Nb + 5\,^{1}_{0}n + energy$$

b) The total number of protons and neutrons is balanced on either side of the equation. Explain then why there is a mass difference between each side.

(2)

The nucleons have variable mass depending on how they are arranged with each other in a nucleus. ✓
The average mass of the nucleons is lower on the right hand side of the equation compared to the left. ✓
Or words to that effect.

Question 17

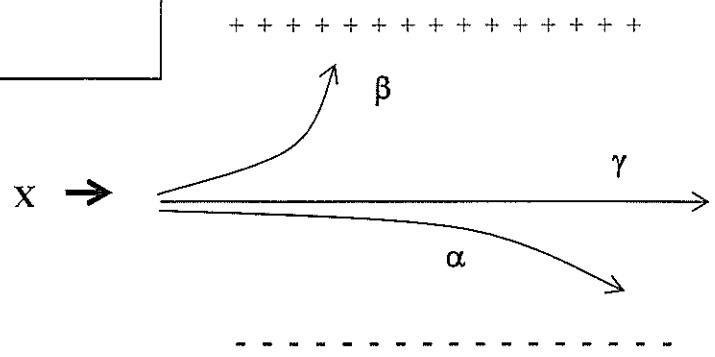
A uniform electric field exists between the two charged parallel plates shown below. Three particles (alpha, beta and gamma) are moving right through location X and then enter the uniform field.

a. Sketch the approximate paths of the α, β and γ particles as they enter the electric field showing the relative degree of curvature for each particle and clearly label each path.

(2)

Charge effects ✓
Momentum effects ✓

Particle	Relative Speed
α	0.1 c
β	0.9 c
γ	c



b. Explain the curvature of your paths relative to each other, with reference to the momentum and charge of each particle.

(3)

The positively charged α particle is attracted to the negative plate, the negatively charged β particle is attracted to the positive plate, γ has no charge so is not deviated ✓

The α particle has the greatest momentum so is harder to divert and has less curvature ✓

Momentum = mass x velocity, so although α only has 11.1% of speed compared to β, the α particle is approximately 7300 times more massive. Therefore momentum of α is the greatest. ✓

c. Circle the best response. The direction of the electric field between the two parallel plates is:

Up (Down) Left Right Into Page Out of Page

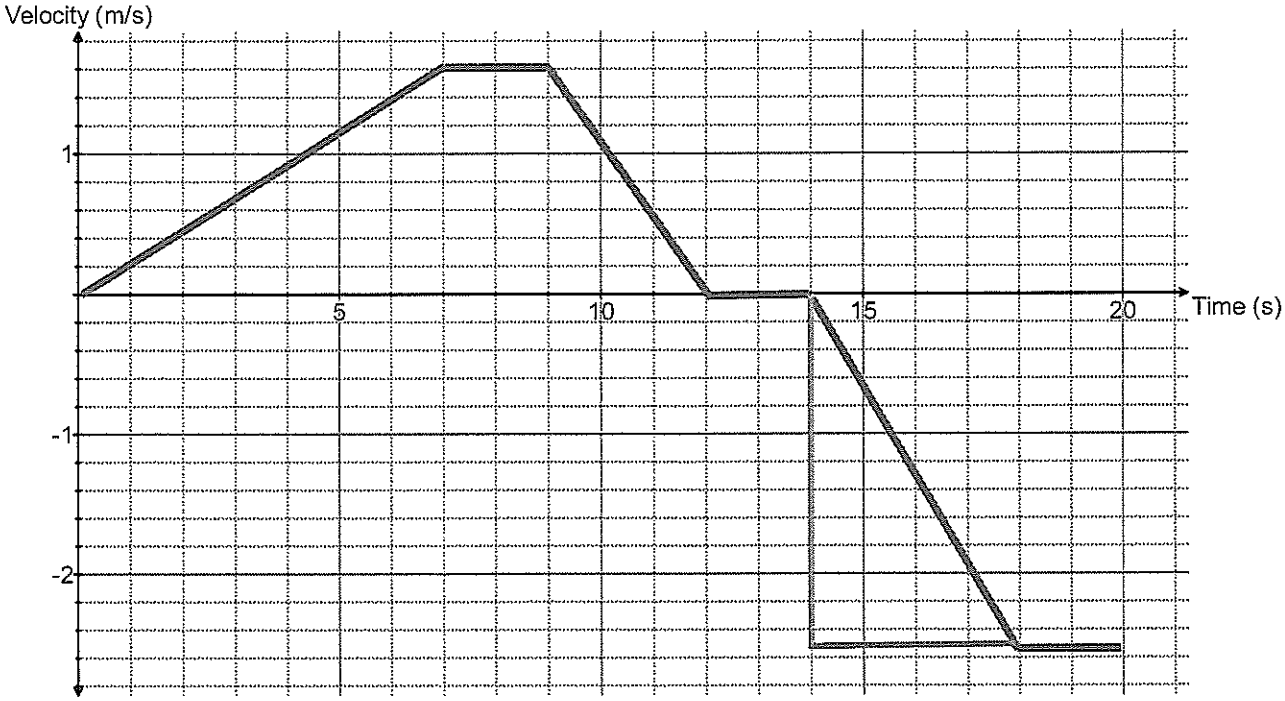
(1)

End of Section One

Section Two: Problem-solving 50% (80 Marks)

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the space provided. **Suggested working time for this section is 75 minutes.**

Question 18 [11 marks]



The graph shows the velocity of a toy car over a 20 second period. The car can only move back and forth along a straight line. East of the start point is considered positive.

a) From the graph, determine the velocity of the car after 3 seconds of travel.

(1)

From the graph = 0.700 m s^{-1} East ✓

b) For how many seconds was the car stationary?

(1)

From the graph = 2 seconds ✓

c) At a time of 10 seconds, explain whether the car was moving towards or away from the initial position.

(2)

Car is still moving East ✓ which is away from the start position ✓

d) Between which two times was the magnitude of acceleration the greatest?

(1)

Between 14 and 18 seconds, the magnitude of gradient is the steepest ✓

e) From your graph, determine the acceleration at 16 seconds.

(2)

From the graph rise = -2.5 m/s
Run = 4 seconds ✓

Gradient = -2.5 / 4 = -0.625 m s^{-2} (West)✓

Answer_____

f) Determine the displacement of the car after 20 seconds.

(4)

Displacement = Area bounded by the graph lines and the time axis
Some concept demonstrated. ✓

Positive displacement = $(\frac{1}{2} \times 7 \times 1.6) + (2 \times 1.6) + (\frac{1}{2} \times 3 \times 1.6)$
= +11.2 m ✓

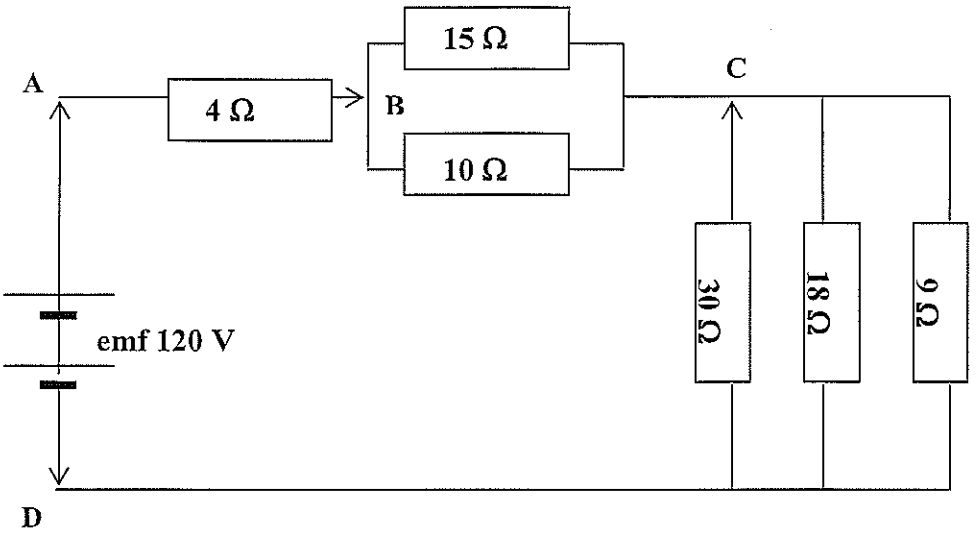
Negative displacement = $(\frac{1}{2} \times 4 \times -2.5) + (2 \times -2.5)$
= -10.0 m ✓

Total displacement = +11.2 - 10 = +1.20 m (East) ✓

Answer_____

Question 19 [12 marks]

A complex circuit diagram is shown below.



a) Calculate the effective resistance of the circuit between points A and D. (3)

$R_{BC} = (1/15 + 1/10)^{-1} = 6.00\ \Omega$ ✓

$R_{CD} = (1/10 + 1/18 + 1/9)^{-1} = 5.00\ \Omega$ ✓

$R_{total} = 4 + 6 + 5$ ✓ $= 15.0\ \Omega$ ✓

b) Calculate the current through the 4.00 Ω resistor. (2)

$V_{emf} = \Sigma V_d = 120$ V $\qquad R_{total} = 15\ \Omega$ ✓

$V_{emf} = I.\ R_{total}$

$120 = I\ .\ 15$ ✓

$I = 120 / 15 = 8.00$ A ✓

c) Calculate the potential difference across the 30.0 Ω resistor. (3)

Correct analysis of variables ✓
By proportion V_d (CD) = 5 /15 × 120 = 40.0 V

or

$V_d = I.R_{CD}$
$V_d = 8 \times 5$ ✓
$V_d = 40.0$ V ✓

d) Calculate the current flowing through the 18.0 Ω resistor. (2)

$V_d = 40$ V R = 18 Ω ✓

$I = V_d / R$

$I = 40 / 18 = 2.22$ A ✓

e) Calculate the power of the 9.00 Ω resistor. (2)

$P = V_d^2 / R$
$P = 40^2 / 9$ ✓

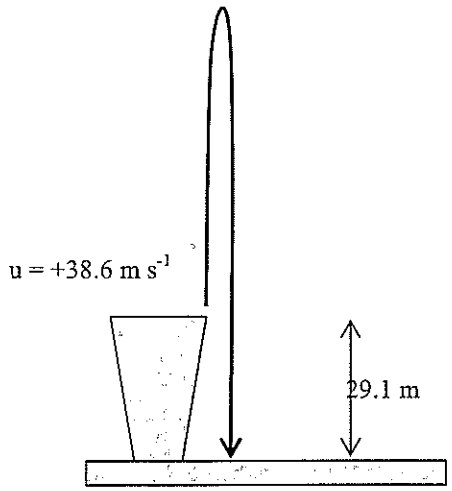
P = 178 W ✓ (3 sig. figs)

Alternative $I = V_d / R = 40 / 9 = 4.44$ A
$P = I.V_d = 4.44 \times 40 = 178$ W or $= I^2R = 4.44^2 \times 9 = 178$ W

Question 20 [12 marks]

A hunter leans over the edge of a cliff and fires a crossbow bolt vertically upwards with an initial velocity of 38.6 m s^{-1}.

The bottom of the cliff is 29.1 m below the point where the bolt left the crossbow.



a) Calculate the maximum height reached by the bolt above the launch height of the hunter. (3)

Let up + +ve

u = +38.6 m/s a = -9.8 m/s^2 v_{max} = 0 s = ?

$v^2 = u^2 + 2.a.s$
$0 = 38.6^2 + (2 \times -9.8 \times s)$ ✓
$s = -38.6^2 / -19.6$
s = +76.0 ✓

$s_{above\ launch}$ = +76.0 m ✓

b) Determine the acceleration of the bolt at its maximum height. (1)

Acceleration = 9.80 m s^{-2} down (or indicated by negative) ✓

c) Calculate the velocity of the bolt 5.00 seconds after leaving the crossbow.

(2)

Let up + +ve
$u = +38.6$ m/s $a = -9.8$ m/s^2 $t = 5.00$ s $v = ?$
$v = u + a.t$
$v = 38.6 + (-9.8 \times 5)$ ✓
$v = -10.4$ m/s (negative indicates down) ✓

d) Calculate the total time the bolt was in flight from leaving the crossbow to arriving at the bottom of the cliff.

(4)

Let up + +ve $u = +38.6$ m/s $a = -9.8$ m/s^2 $s = -29.1$ m

$v^2 = u^2 + 2.a.s$
$v^2 = 38.6^2 + (2 \times -9.8 \times -29.1)$ ✓
$v^2 = 2060.32$
$v = -45.391..$ ✓ (negative indicates going down)

$v = u + a.t$
$-45.391 = 38.6 + (-9.8 \times t)$ ✓
$-45.391 - 38.6 = -9.8 \times t$
$t = -83.991 / -9.8$ $t = 8.57$ seconds ✓

Alternatively general solution of a quadratic using $s = ut + \frac{1}{2} at^2$
$-29.1 = 38.6t - 4.9t^2$
$-4.9t^2 + 38.6t + 29.1 = 0$ ($a = -4.9$, $b = 38.6$, $c = 29.1$) to solution.

e) Calculate the average velocity of the bolt from leaving the crossbow to arriving at the bottom of the cliff.

(2)

$v_{av} = s / t = -29.1 / 8.57$ ✓ $= -3.40$ m s^{-1} (down) ✓

Or

$v_{av} = (v + u) / 2 = (-45.391 + 38.6) / 2 = -3.40$ m s^{-1} (down) ✓

Question 21 [10 marks]

The Carbon-Nitrogen-Oxygen cycle is a complex set of fusion reactions by which stars convert hydrogen to helium. One of these reactions is shown below

$$^{14}_{7}N + ^{1}_{1}p \rightarrow ^{15}_{8}O + \gamma$$

a. Use the data in the table below to calculate the energy (in MeV) released in this reaction

Particle	Nitrogen-14	Proton	Oxygen-15
Mass (u)	13.999234	1.00728	14.998677

(3)

Mass of reactants = 13.999234 + 1.00728 = 15.006514
Mass of daughter products = 14.998677 ✓

Δm = 15.006514 - 14.998677 = 0.007837 u ✓

E (MeV) = Δm (u) × 931
E = 0.007837 × 931 = 7.30

E = 7.30 MeV ✓

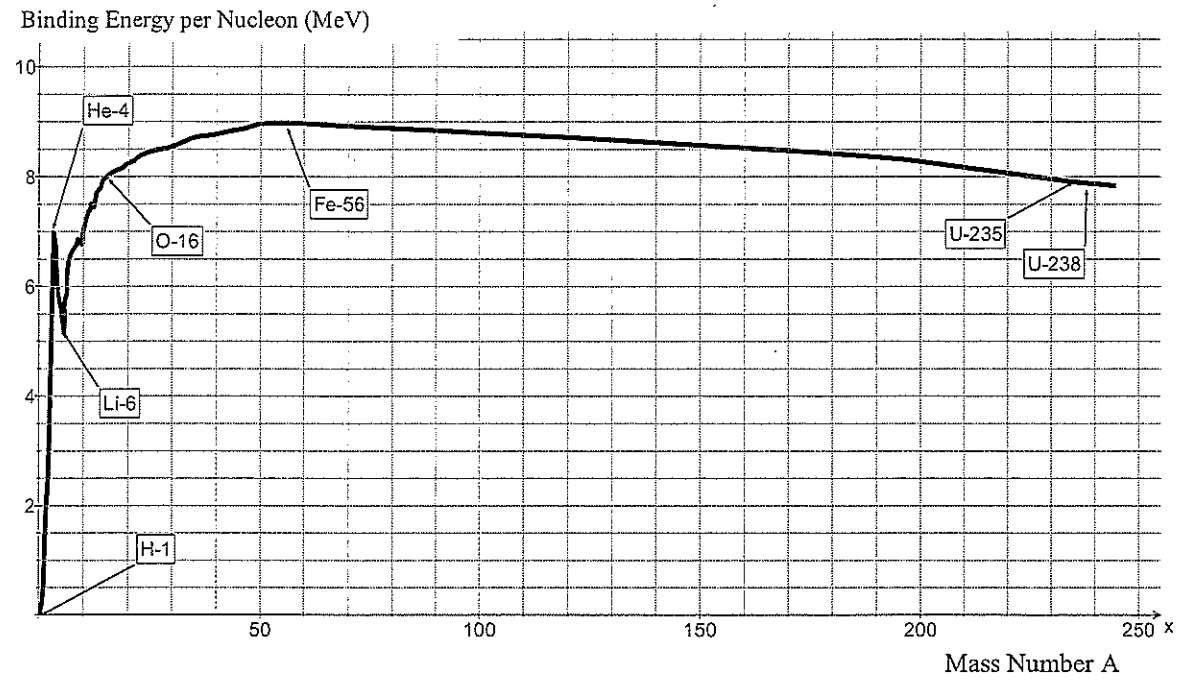
b. Mass is converted to energy in nuclear reactions. In what form could this energy be. Describe two examples.

(2)

- Kinetic energy of the daughter products
- Energy associated with the gamma radiation
- Increased particle vibration of the daughter products (heat energy)

Any 2 acceptable examples

The graph below shows the binding energy per nucleon versus mass number for the nuclei of some common isotopes.



c. What is binding energy essentially a measure of in the context of nuclear physics?

(2)

Binding energy is the (mechanical) energy required to disassemble a whole into separate parts. In this case the energy required to separate a nucleus into the individual nucleons that it comprises of.
Or,
The energy released to the surroundings when a nucleus is formed from individual nucleons.

d. The oxygen-16 nucleus has a mass of 15.990526 u, a proton has a mass of 1.00728 u and a neutron has a mass of 1.00867 u. Calculate the average binding energy per nucleon for the oxygen-16 nucleus in MeV. (The above graph allows you to verify your answer).

(3)

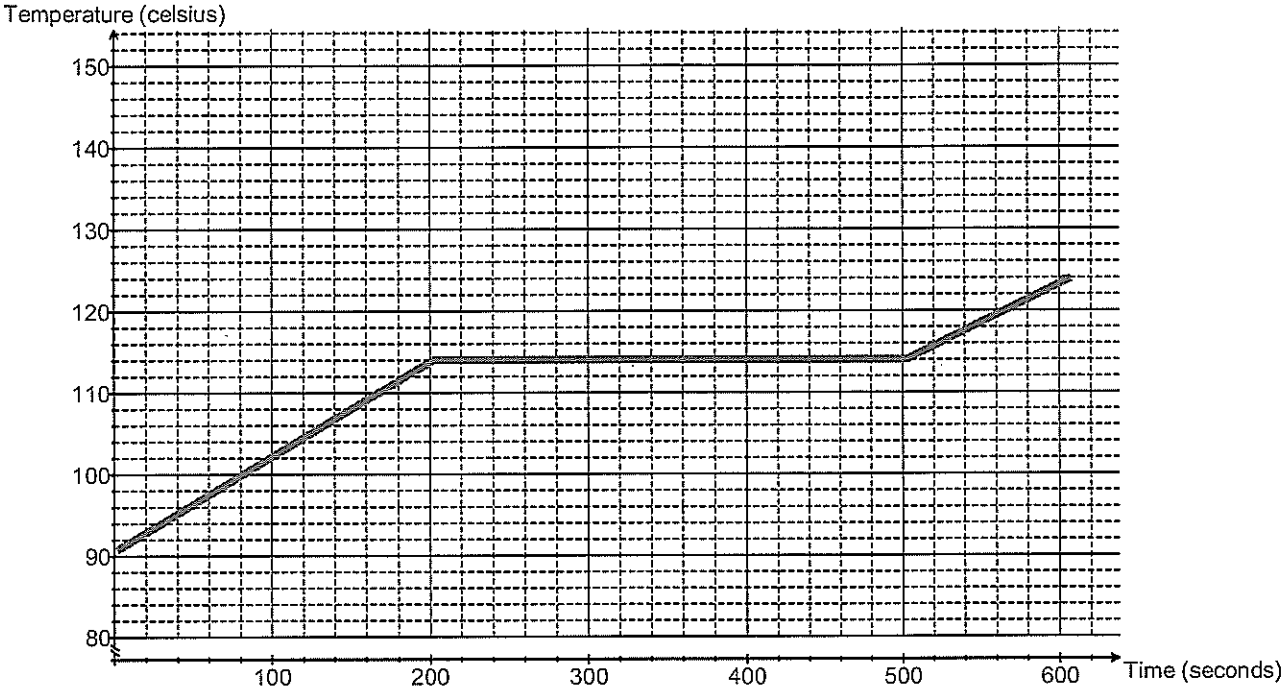
Mass of individual nucleons = (8 × 1.00728 + 8 × 1.00867) = 16.12760

Δm = 16.12760 - 15.990526 = 0.137074 u ✓

E (MeV) = Δm (u) × 931
E = 0.137074 × 931 = 127.615894 MeV ✓
BE per nucleon = 127.615894 / 16 E = 7.98 MeV per nucleon ✓

Question 22 [9 marks]

Some students are investigating the latent heat of fusion for sulphur. They place a 50.0 g sample of solid sulphur into a crucible in a fume cupboard and record the temperature of the sample for a period of 600 seconds whilst the energy input to the sulphur is fixed at 6.50 J per second. A graph of the results is shown below.



a. Referring to Kinetic Molecular Theory, explain why the temperature of the sulphur stayed constant in the middle section of the graph even though its internal energy was increasing.

(3)

At the melting point internal energy of the sulphur is increasing but only as an increase in potential energy. (Particle separation is increasing). ✓

The kinetic energy component of internal energy is unchanged. ✓

Temperature is a measure related to average kinetic energy of particles so this is constant.✓

This section of the graph indicates the solid sulphur is changing from solid to liquid.

Any 3 relevant points.

b. In terms of Kinetic Molecular Theory explain the difference between heat and temperature.

(2)

Temperature is a measure related to and directly proportional to the average kinetic energy of particles within a substance✓ (it is not the average kinetic energy itself)
Heat is the transfer of energy from a location of higher temperature to a location of lower temperature because of the difference in temperature. ✓
Or words to that effect.

c. Determine the melting point of sulphur from the graph.

(1)

Refers to graph = 114°C ✓

d. Determine the latent heat of fusion of sulphur.

(3)

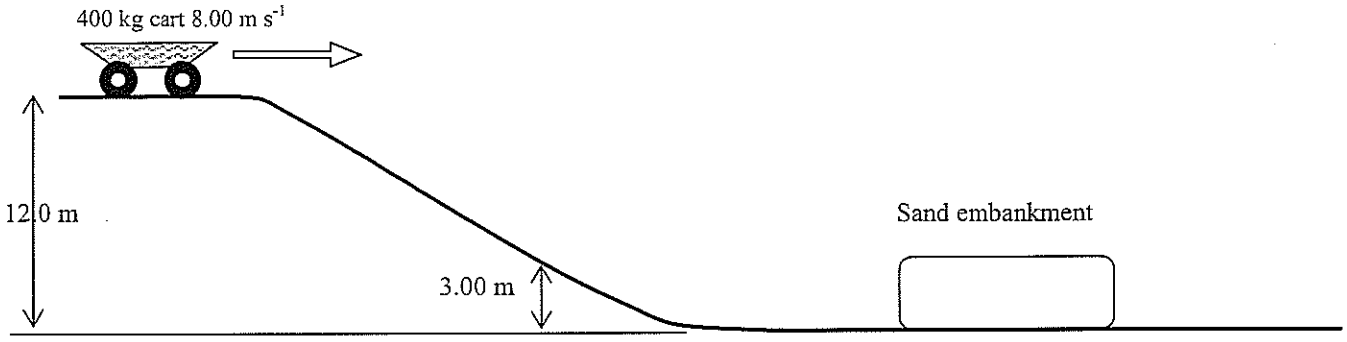
Refers to graph to get 300 seconds of time for phase change
$Q = 300 \times 6.50 = 1950$ J
$m = 50 \times 10^{-3}$ kg ✓

$Q = m \times L_f$
i.e. $L_f = Q / m = 1950 / (50 \times 10^{-3})$ ✓

$L_v = \underline{3.90 \times 10^4 \text{ J kg}^{-1}}$ ✓

Question 23 [11 marks]

A cart of mass 400 kg is travelling at 8.00 m s^{-1} at the top of an inclined plane 12.0 m above ground level. It rolls down the inclined plane and is stopped by colliding with a sand embankment.



a. With reference to the principal of conservation of mechanical energy, calculate the speed of the cart when it is at a height of 3.00 m above ground level on the inclined plane.

(3)

Total Mechanical Energy = KE + GPE = constant
u = 8.00 m/s h_i = +12.0 m h_{final} = +3.00 m m = 400 kg v = ?
g = field strength (taken as positive here so that increased height has greater magnitude of potential energy) = +9.8 N Kg^{-1} ✓

$\frac{1}{2}$ m u^2 + m.g.$h_{initial}$ = $\frac{1}{2}$ m v^2 + m.g.h_{final}
$\frac{1}{2}$ 400 × 8^2 + (400 × 9.8 × 12) = $\frac{1}{2}$ 400 × v^2 + (400 × 9.8 × 3) ✓

v = 15.5048.. v = 15.5 m s^{-1} ✓

b. When the cart arrives at the sand embankment it has a velocity of 17.3 m s^{-1} right. It collides with the sand embankment and is brought to rest by an average force of 27 680 N left. Calculate the time taken to bring the cart to rest.

(2)

u = 17.3 m/s v = 0 m = 400 kg F = -27680 N Δt = ?

$F.\Delta t = \Delta p = mv - mu$

$-27680 \times \Delta t = 400\ (0 - 17.3)$ ✓
$-27680 \times \Delta t = -6920$
$\Delta t = -6920 / -27680$
$\Delta t = 0.250$ s ✓

Alternatively, uses a = (v-u) / t and F = m.a

c. Determine the distance travelled by the cart during the collision with sand embankment.

(2)

u = 17.3 m/s v = 0 m = 400 kg F = -27680 N

$W = \Delta KE = F \times s$
$-(\frac{1}{2} m v^2) = F \times s$
$-(\frac{1}{2} \times 400 \times 17.3^2) = -27680 \times s$ ✓
$s = 2.1625$ m (left) s = 2.16 m ✓

d. If the cart was required to be stopped in a shorter distance explain any changes in the force acting on the cart.

(2)

According to the equation $\Delta KE = F \times s$ ✓
If s decreases then F must increase for a fixed value of ΔKE ✓

e. Explain any two possible energy transformations that occur during the collision.

(2)

Kinetic energy transforms to sound energy.
Kinetic energy transforms to heat energy.
Kinetic energy of cart transfers to kinetic energy of sand.
Any 2 correct responses. ✓ ✓

Question 24 [15 marks]

Determining the Specific Heat Capacity of Mercury.

A group of physics students are conducting an experiment to determine the **specific heat capacity** of the mercury (Hg).

- 275 g of mercury is placed in an insulated heating vessel at an initial temperature of 22.0 °C.
- Heat energy is delivered to the vessel by an electrical heating element in its base
- The students control the energy delivered to the vessel and record the temperature of the mercury as the energy input increases:

Energy (J)	200	400	600	800	1000	1200	1400	1600
Temperature (°C)	27	30	37	41	45	52	56	58
ΔT (°C)	+5	+8	+15	+19	+23	+30	+34	+36

Answer the following questions: ✓

a) Complete the table by filling in the row for ΔT. (The first value has been done for you).

(1)

b) From the starting point of an equation on your data sheet, show algebraic steps to derive the following expression which shows the relationship between the variables in a

y = m.x format where the gradient of the line of best fit is an average value of $\frac{1}{m.c}$

$$\Delta T = \frac{1}{m.c}.Q$$

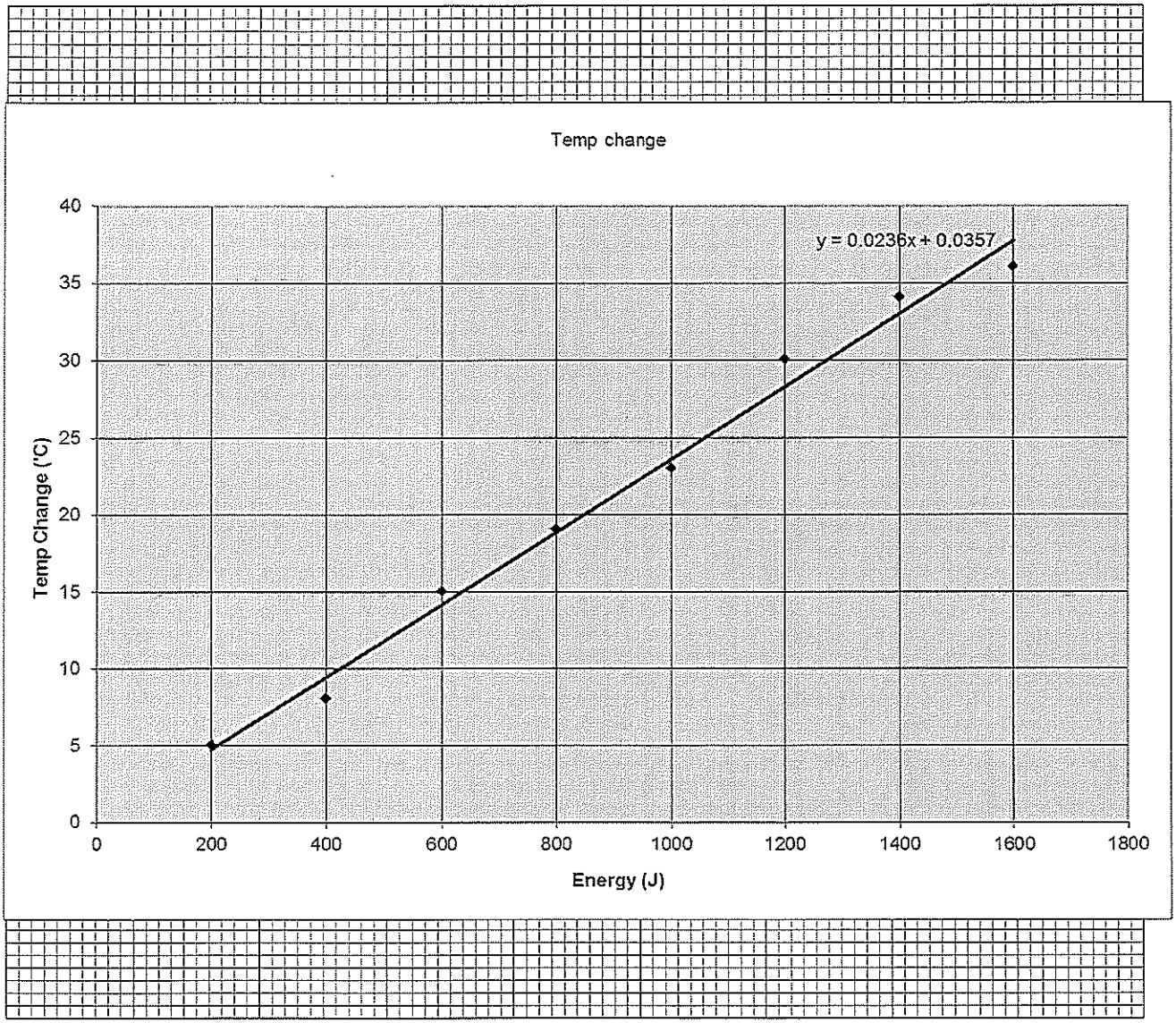
ΔT = change in temperature (K or °C)
m = mass of mercury (kg)
c = specific heat capacity of mercury
Q = energy (J)

(2)

$Q = m.c.\Delta T$ ✓

$\Delta T = \frac{Q}{m.c}$

$\Delta T = \frac{1}{m.c} \times Q$ ✓



c) Plot a graph of Change in Temperature (ΔT) on the y-axis versus Energy (J) on the x-axis on the graph paper above and put a line of best fit onto your graph. Ensure that the graph is correctly labelled.

(4)

Scaling + plotting ✓
axes labels ✓
axes units ✓
line of best fit ✓

d) Calculate the gradient of your line of best fit. Show your working clearly on the graph. (3)

gradient = rise / run = 32.6 / 1400 ✓ (taken from line of best fit NOT data points) ✓

gradient = 0.0233 kJ^{-1} (+/-) ✓

e) By using the value of the gradient you calculated from your graph and other data in the question, calculate the specific heat capacity (**c**) of the mercury. (3)

$m = 0.275\ kg$ ✓

$\frac{1}{m.c} = 0.0233$ ✓

$C = \frac{1}{m \cdot 0.0233}$ ✓

$C = \frac{1}{0.275 \times 0.0233} = 156\ J\,K^{-1}\,kg^{-1}$

f) Compare your calculated value with the accepted value of 140 J kg^{-1} K^{-1} and calculate the percentage error of your result. If you were unable to obtain an answer use an experimental result of 156 J kg^{-1} K^{-1}. (2)

value = 140 J kg^{-1} K^{-1} ✓

$\%\ error = \frac{experimental - accepted}{accepted}$ ✓

$\%\ error = \frac{156 - 140}{140} = 11.4\%$

End of section B

Section Three: Comprehension 10% (16 Marks)

This section contains **one (1)** question. You must answer this question. Write your answer in the space provided. Suggested working time for this section is 15 minutes.

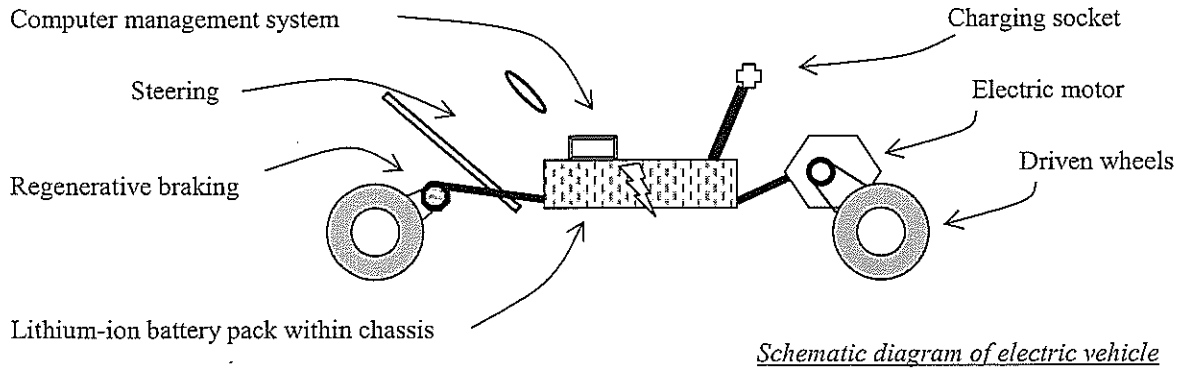
Question 25 Full Battery Electric Vehicles

Vehicles powered by the internal combustion engine (ICE) have been in use for over a century. The operating principles of the engine are practically unchanged and they are still very inefficient. Alternative forms of propulsion are now receiving serious consideration.

Earth's finite energy resources are being used unsustainably and urban transport plays a major role in energy wastage and pollution that contributes to climate change. The unremitting increase in oil costs and the dramatic improvement in the performance, price and lifecycle of batteries are making a compelling case for Electric Vehicles.

Hybrid vehicles recently entered the Australian market. They have both a fuel burning engine and an electric motor with a small battery that is recharged by the engine. A full battery Electric Vehicle (EV) has an electric drive system only and is powered by batteries.

The comparatively affordable technology required for Electric Vehicles is ready now. It is a solution that produces zero emissions, has the highest motor-to-wheel efficiency and requires minimal support infrastructure.



Schematic diagram of electric vehicle

The main components of an Electric Vehicle are as follows

Battery - lithium-ion technology as used in mobile telephones and laptop computers which can provide a typical range of up to 300 km.

Electric Motor – drives the wheels with high torque, giving sports car like performance, but with a very low noise level and smooth delivery.

Regenerative Braking System - energy recovered recharges the battery.

Computerised Management System - controls all electrical systems to ensure optimal performance and durability of the battery. Also allows charging to be synchronised with off-peak electricity.

Charging socket – can be connected to a normal 240 V AC household outlet to recharge the battery in typically six to eight hours. Many councils are considering providing charging stations within cities.

Until the production volume of EVs rises significantly they will be more expensive to manufacture compared to similar sized petrol cars. Electric vehicles allow savings of up to 90% on fuel expenses and 50% on maintenance costs which makes them viable when all costs are considered.

A perceived financial risk is the lifetime and expense of the battery so some manufacturers will opt for leasing of the vehicle rather than outright purchase or leasing of the battery pack alone.

The main drawback of an EV over conventional ICE vehicles is the limited range and the time taken to recharge the battery. However, studies have shown that 99% of urban users do less than 150 km per day.

So when used as an urban vehicle that can be charged overnight, drivers should be able to adapt quickly and enjoy the benefits of this mode of transport. The EV may be the car of the future for many Australian families.

Answer the following questions

a. State 4 advantages of an EV over an ICE vehicle. (2)

- Zero emissions (non-polluting)
- Efficient in terms of energy transformations from power source.
- Not using oil which is still a valuable resource elsewhere.
- Quiet operation
- Convenient to recharge at home (any 4 appropriate responses)

Subtract 1 mark for any missing or incorrect response (or award $\frac{1}{2}$ marks if this is your department's policy)

b. _____ Why is an EV more suited to urban driving rather than cross-country trips? (2)

Limited range (up to 300 km) and several hours to recharge make long distance driving slow and fragmented and drivers rely on being able to obtain access to an electrical power point.

Or words to that effect.

c. Explain why braking is more efficient on an EV compared to a conventional ICE car by describing the energy transformations in each case.

(3)

On a conventional ICE car the kinetic energy of motion is transformed to heat energy (via the force of friction on brake pads). ✓ This energy cannot be reused by the vehicle.

On an EV the kinetic energy of motion is transformed into chemical potential energy in the Lithium-ion battery. ✓
This energy can be re-used for propulsion. ✓

Or words to that effect.

d. A certain EV has an electric motor with a maximum electrical power rating of 40 kW. Over a 5 minute driving cycle at full power engineers measured 1.02×10^7 J of mechanical energy available at the driven wheels. Calculate the efficiency of the electric motor.

(3)

$P_{electrical}$ = 40 000 W t = 5 × 60 = 300 s ✓
Electrical energy offered by motor E = P × t
$E_{electrical}$ = 40 000 × 300 = 1.20×10^7 J ✓

Efficiency = energy taken / energy offered (%)
Efficiency = 1.02×10^7 / 1.20×10^7
Efficiency = 85.0 % ✓

e. The computer management system controls a component in the vehicle called an inverter. This enables household electricity to be used to charge the battery and is needed because of fundamental difference between the electricity from a household socket and the electricity in a battery. What is this fundamental difference?

(2)

The household circuit is alternating current (alternating voltage that fluctuates between positive and negative). ✓
The battery is direct current (the voltage is constant)✓

Or words to that effect.

f. A certain lithium-ion battery pack has an energy capacity of 56.1 kW hours. It takes 8 hours to recharge the battery from empty. Calculate the current in the charging socket from a 240 V household supply assuming 100% efficiency and a steady rate of charge.

(1 kW hour = 3.60 MJ)

(3)

$E_{electrical}$ = 56.1 kW hours time = 8 hours
$E = P \times t$
$P_{electrical} = E / t = 56.1 / 8$ ✓ = 7.01 kW ✓

$P_{electrical} = V \times I$
$I = P_{electrical} / V$
$I = 7010 / 240$ ✓
$I = 29.2$ A

Or students can convert
56.1 kW hrs = $56.1 \times 3.6 \times 10^6 = 2.02 \times 10^8$ J
8 hours = $8 \times 60 \times 60 = 2.88 \times 10^4$ s
$P = E / t = 2.02 \times 10^8 / 2.88 \times 10^4 = 7.01 \times 10^3$ W

g. The cost of electricity from Synergy is 20.8 cents per kilowatt hour. Calculate how much it will cost to recharge the battery with a capacity of 56.1 kW hours.

(1)

Cost ($) = price per kW hr × # of kW hrs
Cost = 0.208 × 56.1 = $11.67 ✓

End of questions