

## Year 11 PHYSICS ATAR

Semester 1 Examination, 2017

Question/Answer Booklet

Student Number: In figures

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In words

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### Time allowed for this paper

Reading time before commencing work: ten minutes

Working time for paper: two and a half hours

### Materials required/recommended for this paper

#### To be provided by the supervisor

This Question/Answer Booklet  
Formulae and Constants Sheet

#### To be provided by the candidate

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course

### Important note to candidates

No other items may be taken into the examination room. It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**STRUCTURE OF THIS PAPER**

Section	No. of Questions	No. of questions to be attempted	Suggested working time (minutes)	Marks available	Percentage of exam
1: Short Response	16	ALL	60	60	40%
2: Problem Solving	6	ALL	75	75	50%
3: Comprehension	1	ALL	15	15	10%
Total				<b>150</b>	<b>100%</b>

**INSTRUCTIONS TO CANDIDATES**

Write your answers in the spaces provided beneath each question. The value of each question (out of 150) is shown following each question.

The enclosed Physics: Formulae and Constants Sheet may be removed from the booklet and used as required.

Calculators satisfying conditions set by the School Curriculum and Standards Authority may be used to evaluate numerical answers. The calculator **cannot** be a "**graphics**" calculator.

Answers to questions involving calculations should be evaluated and given in decimal form. Final answers should be given up to three significant figures and include appropriate units where appropriate. Despite an incorrect final result, credit may be obtained for method and working providing these are clearly and legibly set out.

Questions containing specific instructions to **show working** should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; correct answers which do not show working will not be awarded full marks.

Questions containing the instruction "**ESTIMATE**" may give insufficient numerical data for their solution. Show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

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**Section One: Short Response****40% (60 marks)**

This section has 16 questions. Answer **all** questions. Answer the questions in the spaces provided.  
Suggested working time: 50 minutes.

**Question 1****(3 marks)**

In the nucleus of an atom many positively charged protons are packed closely together. Explain why the protons in the nucleus don't fly apart due to electrostatic repulsion.

Strong nuclear force acts between nucleons (protons, neutrons) only at close range i.e. when packed together within nucleus.  
SNF attraction > electrostatic repulsion  
3 valid separate points.

**Question 2****(5 marks)**

A doctor of mass 75.0 kg receives  $8.10 \times 10^{-2}$  J of energy from a radioisotope that emits slow neutrons.

- a) Calculate the absorbed dose that the doctor receives.

$$AD = \frac{\text{energy}}{\text{mass}} = \frac{8.10 \times 10^{-2}}{75} = 1.08 \times 10^{-3} \text{ Gy}$$

**(2 marks)**

- b) The annual recommend maximum dose equivalent for the doctor is 2000  $\mu\text{Sv}$ . Determine what percentage of this annual dose the doctor received.

$$DE = AD \times QF = 1.08 \times 10^{-3} \times 3$$

$$DE = 3.24 \times 10^{-3} \text{ Sv}$$

**(3 marks)**

$$\% \text{ of annual} = \frac{DE}{\text{annual dose}} = \frac{3.24 \times 10^{-3}}{2000 \times 10^{-6}}$$

$$\% \text{ of annual} = 162\%$$

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**Question 3****(4 marks)**

Two resistors are connected in parallel to a 24.0 V DC battery. Resistor A is rated as 6.00  $\Omega$  and Resistor B is rated as 8.00  $\Omega$

a) Which resistor draws the most current?

**(1 mark)**

$$A - 6.00 \Omega$$

b) The resistors are then placed in series. Calculate the current through resistor A

**(3 marks)**

$$R_T = R_1 + R_2 = 6 + 8 = 14.0 \Omega$$

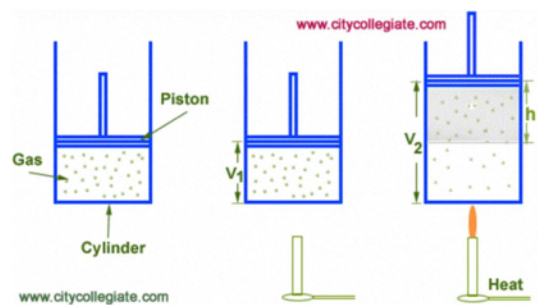
$$I_T = \frac{V_A}{R_T} = \frac{24}{14} = 1.71 A$$

**Question 4****(4 marks)**

A simple thermo-mechanical system consists of a piston free to move in a cylinder containing a gas. When heat is transferred into the gas it will expand and push the piston up.

This is shown in the diagram.

An iron block is placed on top of the piston and a burner transfers 890 J of heat into the system. This causes the iron block to be lifted by a height of 37.0 cm.



When this happens the overall energy of the system increases by 270 J and 77 J is lost to the surroundings. Calculate the mass of the iron block that is lifted.

$$\begin{aligned} \Delta E &= Q_{in} - Q_{out} - W_a \\ +270 &= 890 - 77 - W_a \\ W_a &= 890 - 77 - 270 = +543 \text{ J} \\ W_a &= m \cdot g \cdot \Delta h \\ 543 &= m \times 9.8 \times 0.37 \\ m &= 150 \text{ kg} \end{aligned}$$

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**Question 5****(3 marks)**

A 3.85 V battery is used to power a smart phone. The smart phone draws a current of 21.1 mA when watching videos. Calculate how much electrical potential energy is transformed while watching a 5.00 minute video clip.

$$t = 5 \times 60 = 300 \text{ s}$$

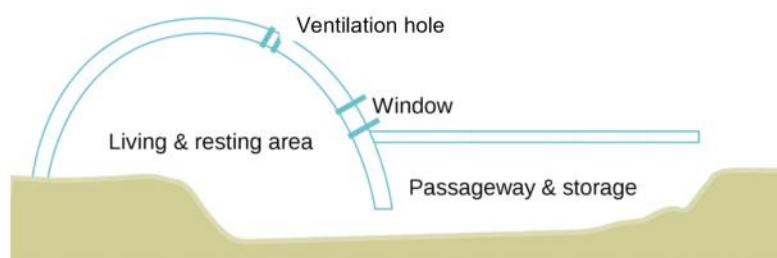
$$E = V I t = 3.85 \times 0.0211 \times 300$$

$$E = 24.4 \text{ J}$$

$$\left( P = \frac{\Delta E}{t} = V I \right)$$

**Question 6****(5 marks)**

Igloos are made from compressed snow which is chopped into large blocks and stacked in a dome shape. Compressed snow has much less density compared to solid ice blocks. Inside the igloo the floor is uneven with a raised section for sleeping. The entrance area acts as a 'cold trap' whereas the sleeping area holds any heat generated by stoves, lamps or body heat. Inside the igloo, temperatures can range from  $-7^\circ\text{C}$  to  $16^\circ\text{C}$  when warmed by body heat alone.



- a) Explain why the raised sleeping area would be warmer than the lower level. You must refer to kinetic molecular theory in your response.

Hot air rises due to convection ✓ (3 marks)  
 When heat transfers to particles in a fluid KE and collisions between particles increase. This leads to increased particle separation, lower density, buoyancy. (or similar) ✓

- b) Explain why compressed snow is a better insulator than a solid ice block. (2 marks)

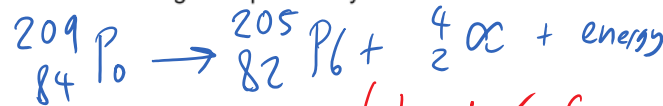
lower density snow c.f. ice blocks means snow contains air pockets ✓ Air is a poor conductor therefore a better insulator. ✓

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**Question 7****(4 marks)**

Complete the following nuclear decay equations:

- a) Polonium-~~84~~<sup>209</sup> undergoes alpha decay. (2 marks)

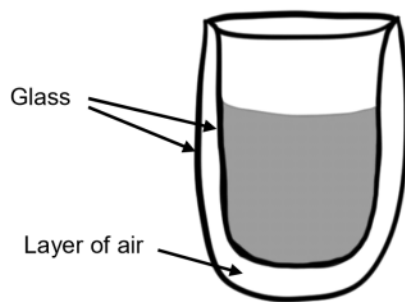


balanced ✓ Components ✓

- b) Francium-223 undergoes beta-negative decay. (2 marks)

**Question 8****(4 marks)**

The cups shown below are used to hold hot drinks, such as tea or coffee.



Glass double-wall cup with internal reflective coating



Aluminium cup

Explain why the glass cup is better at preventing your hand from getting burnt. Refer to modes of heat transfer in your response and how the transfers occur according to Kinetic Molecular Theory.

Internal reflective surface means that transfer by IR radiation is minimised as electromagnetic radiation is reflected back into the liquid.

Glass is a poor conductor compared to aluminium. So heat transfer due to collisions between neighbouring particles is reduced.

**Question 9****(3 marks)**

In the science fiction movie 'Pitch Black' an ice planet is described as having a temperature of  $-5000^{\circ}\text{C}$ . Comment on whether this is possible or not with reference to physics principles.

Not possible.  
Minimum temperature is absolute zero  
zero kelvin =  $-273^{\circ}\text{C}$   
Occurs when particle vibration stops  
So temperature related to KE average  
Cannot be less than this.

**Question 10****(4 marks)**

Explain the concepts of "critical mass" and "chain reaction" in the context of nuclear technology.

Critical Mass:

The minimum mass of fissile material of a given shape that can undergo self-sustaining fission. Sufficient mass and energy is provided from the critical mass.

Chain Reaction:

A sequence of fission reactions that increase exponentially. Initiated by neutron capture where more neutrons are released from each reaction to increase number of reactions in each step of the sequence.

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**Question 11****(3 marks)**

The ratio of neutrons (N) to protons (Z) can be used to determine the stability of a nucleus. For light elements with an atomic number less than 20, stable isotopes should have a N:Z ratio of 1:1.

- a) Find the N:Z ratio for the  $^{12}_8\text{O}$  isotope and determine if it is a stable isotope. (2 marks)

$$N = 12 - 8 = 4 \quad Z = 8$$

$$N:Z = 4:8$$

$$4:8 < 1:1 \quad \therefore \text{unstable}$$

- b) Describe what happens to an isotope if it is unstable. (1 mark)

It undergoes spontaneous radioactive decay.

**Question 12****(3 marks)**

A residual current device (RCD) also known as a residual current circuit breaker (RCCB) is a device that improves electrical safety in a house. Describe how the device works and prevents a person from receiving an electric shock.

Detects and compares current in active and neutral wires. ✓  
 An imbalance can occur if a person is drawing current from circuit when receiving electrical shock. ✓  
 RCD shuts off current in a time that is short enough to prevent serious injury. ✓





**Question 13**

**(3 marks)**

A sample of a radioactive element has a mass of 45.0 g. If the element has a half-life of 12.5 minutes, calculate the mass of this element remaining after 1.00 hour. State your answer in grams.

$$N_0 = 45\text{g} \quad n = \frac{t}{t_{1/2}} = \frac{60}{12.5} = 4.80$$

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$$N = 45 \left(\frac{1}{2}\right)^{4.8} = 1.62\text{g}$$

**Question 14**

**(4 marks)**

The resistivity of 3 metals is shown in the table. The diagram shows the relative length, radius and material of 3 cylindrical conductors.

Metal	Resistivity ( $\Omega\text{ m}$ )
Copper	$1.68 \times 10^{-8}$
Aluminium	$2.65 \times 10^{-8}$
Iron	$9.71 \times 10^{-8}$



A: Iron  
Length = L  
Radius = 2r



B: Aluminium  
Length = 1.5L  
Radius = r



C: Copper  
Length = 2L  
Radius = r

Determine which conductor has the highest resistance. You must show your working.

$$R = \frac{\rho L}{A}$$

$$R_A = \frac{9.71 \times 10^{-8} L}{\pi (2r)^2} = 2.43 \times 10^{-8} \times \frac{L}{\pi r^2}$$

$$R_B = \frac{2.65 \times 10^{-8} \times 1.5 L}{\pi r^2} = 3.98 \times 10^{-8} \frac{L}{\pi r^2}$$

$$R_C = \frac{1.68 \times 10^{-8} \times 2 L}{\pi r^2} = 3.36 \times 10^{-8} \frac{L}{\pi r^2}$$

$\therefore$  Conductor B (aluminium)

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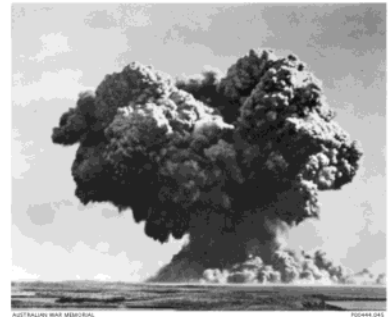
**Question 15****(4 marks)**

Operation Hurricane was the test of the first UK atomic device, on 3 October 1952. A plutonium implosion device was detonated in the lagoon in the Monte Bello Islands in Western Australia. With the success of Operation Hurricane, Britain became the third nuclear power after the United States and the Soviet Union.

The weapon released energy equivalent to 25,000 tonnes of TNT.

One kilotonne of TNT is equal to 4 TJ in SI units.

Calculate the mass that converted to energy in this explosion.



$$E = 25 \times 4 = 100 \times 10^{12} \text{ J} \quad \checkmark$$

$$E = mc^2$$

$$100 \times 10^{12} = m \times (3 \times 10^8)^2 \quad \checkmark$$

$$m = \frac{100 \times 10^{12}}{(3 \times 10^8)^2} = 1.11 \times 10^{-3} \text{ kg} \quad \checkmark$$

**Question 16****(4 marks)**

The activity of a radioactive sample is measured with a Geiger counter as 16.4 kBq. After 300 minutes the activity has reduced to 878 Bq. Calculate the half-life of this sample.

$$A_0 = 16,400 \text{ Bq} \quad A = 878 \text{ Bq}$$

$$A = A_0 \left(\frac{1}{2}\right)^n =$$

$$878 = 16,400 \times \left(\frac{1}{2}\right)^n \quad \checkmark$$

$$\log\left(\frac{878}{16400}\right) = n \log\left(\frac{1}{2}\right) \quad n = 4.22 \quad \checkmark$$

$$n = \frac{t}{t_{1/2}} \quad \therefore \quad t_{1/2} = \frac{t}{n} = \frac{300}{4.22} = 71.0 \text{ mins} \quad \checkmark$$

**END OF SECTION ONE**

**Section Two: Problem-solving**

**50% (75 marks)**

This section contains 6 questions. Answer **all** questions. Suggested working time 90 minutes.

**Question 17**

**(15 marks)**

Two physics students conducted an experiment to examine the electrical properties of a semiconductor component used in complex circuits. The relationship between potential difference and current for the component is given by the equation:

$$I = \frac{4\pi}{Z} \cdot V$$

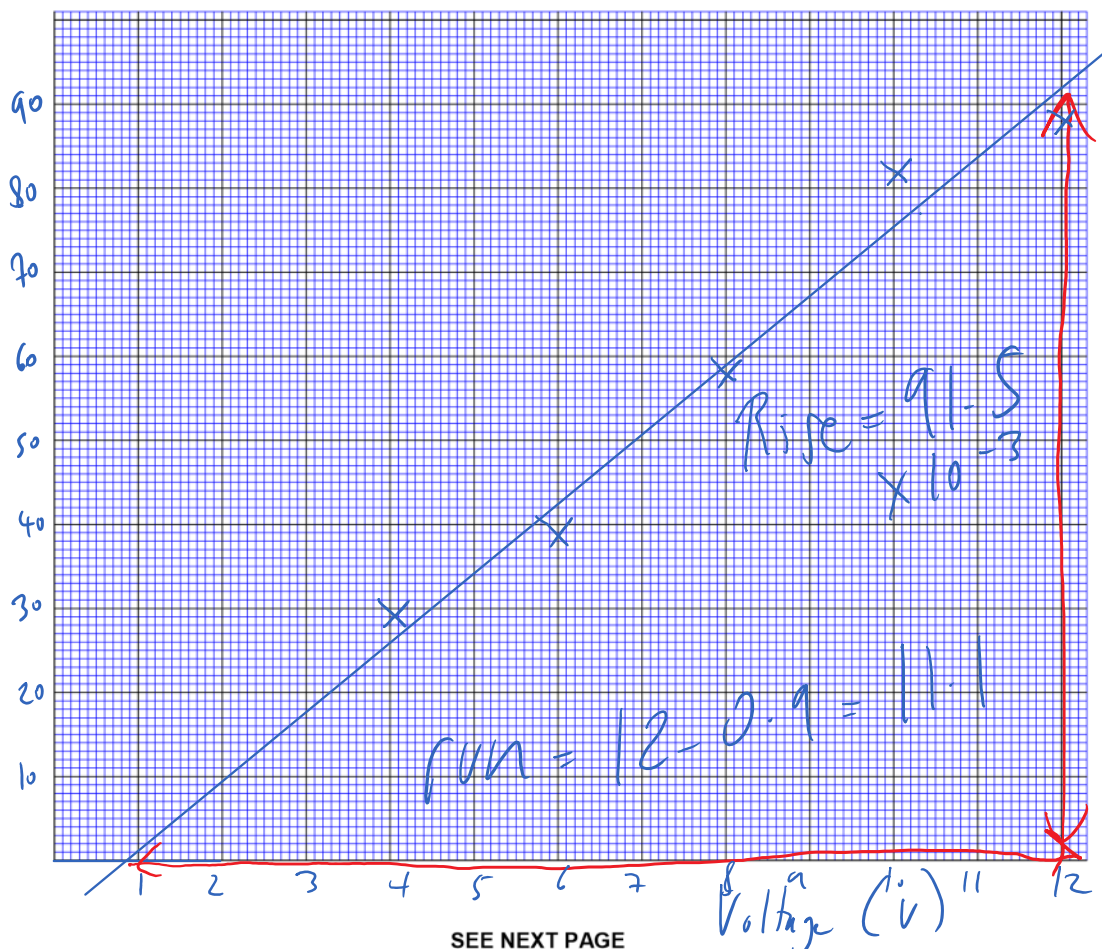
*y = mx*  
gradient

Where I is current, V is potential difference and Z is an impedance value for the component.

The students wanted to determine an experimental value for Z. They increased the potential difference across the component and measured the current. Their results are shown in the table below.

Voltage (V)	Current (mA)
4	29
6	39
8	58
10	82
12	88

*Current  
( $\times 10^{-3}$  A)*



- a) Construct a fully labelled graph of the results and include a line of best fit.

plots, axes scale, labels, l.o.f.

(4 marks)

- b) Determine the gradient of the line of best fit. You must show clearly on your graph how you obtained values for the rise and run. Give your gradient to 2 significant figures.

$$\text{gradient} = \frac{\text{rise}}{\text{run}} \quad (\text{clearly from graph}) \quad (3 \text{ marks})$$

$$= \frac{91.5 \times 10^{-3}}{11.1}$$

$$\text{range} = (7.5 - 8.5) \times 10^{-3}$$

- c) Use the gradient you obtained to determine an experimental value for  $Z$ . If you could not determine a gradient or you are unsure of your answer then use a value of  $7.2 \times 10^{-4}$ . Give your answer to 2 significant figures.

$$\text{gradient} = \frac{4\pi}{Z} \quad (3 \text{ marks})$$

$$7.20 \times 10^{-4} = \frac{4\pi}{Z}$$

$$Z = \frac{4\pi}{7.20 \times 10^{-4}} = 1.7 \times 10^4$$

value above

$$Z = \frac{4\pi}{8.24 \times 10^{-3}} = 1524 = 1.5 \times 10^3$$

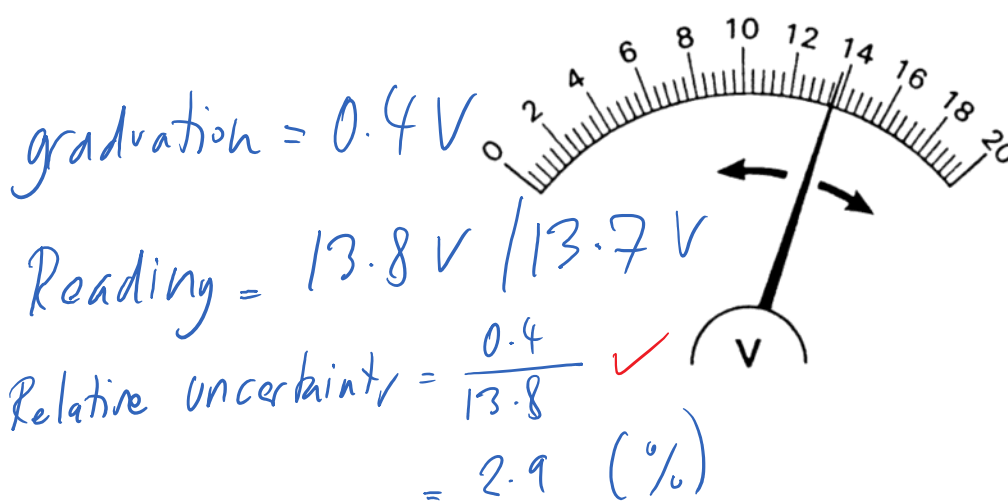
- d) The accepted value for  $Z$  is  $1.9 \times 10^4$ . Calculate the percentage difference between an experimental value of  $1.7 \times 10^4$  and the accepted value. (2 marks)

$$\% \text{ difference} = \frac{\text{experimental} - \text{accepted}}{\text{accepted}} \quad (2 \text{ marks})$$

$$= \frac{1.7 \times 10^4 - 1.9 \times 10^4}{1.9 \times 10^4} \quad \checkmark$$

$$\% \text{ difference} = -10.5\% \quad \checkmark$$

- e) The diagram shows a voltmeter taking a reading. Determine the value of the voltage being measured with the appropriate relative (%) uncertainty of this measurement. (3 marks)

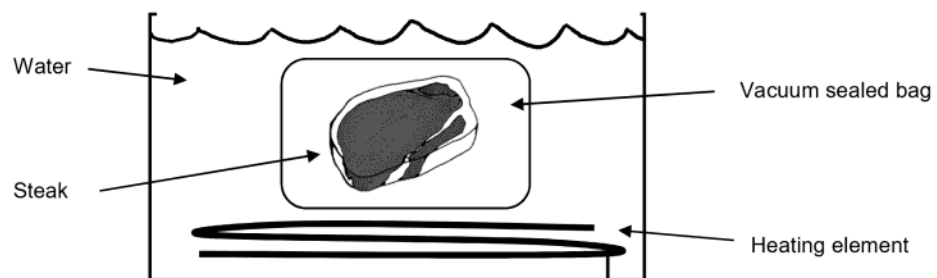


$$\text{Value} = 13.8 \text{ V} \pm 2.9\% \quad \checkmark$$

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**Question 18****(10 marks)**

Sous vide is a way of cooking food at a low temperature over a long period of time. A sous vide machine is made of a container of water with a submerged heating element (see diagram below). An electrical current passes through the heating element, warming it up which then warms the water to a constant temperature. Food (e.g. steak) is placed in sealed bags and cooks in the warm water.



- a) A chef places 6.20 L of 28.0 °C water into a sous vide machine. Calculate how much energy is required to heat the water up to 56.5 °C. (3 marks)

$$Q = m \cdot c \cdot \Delta T$$

$$Q = 6.20 \times 4180 \times (56.5 - 28.0)$$

$$Q = 738,606 = 7.39 \times 10^5 \text{ J}$$

- b) The machine has an electrical power rating of 2.10 kW. It took the sous vide machine 8 minutes 18 seconds to heat up the water from 28.0 °C to 56.5 °C. Calculate the efficiency of the sous vide machine. (If you could not calculate for part a) use a value of 740 kJ) (3 marks)

$$t = 8'18'' = 498 \text{ s}$$

$$\text{Energy offered} = \text{power} \times \text{time}$$

$$= 2100 \times 498 = 1,045,800 \text{ J}$$

$$\text{Efficiency} = \frac{\text{energy taken}}{\text{energy offered}} = \frac{740,000}{1,045,800} = 70.8 \%$$

- c) A 300 g steak and 250 g of carrots were taken out of the fridge at 5.00 °C. The food was added to the sous vide machine when the water was 56.5 °C, however, the sous vide machine was accidentally turned off as soon as the food was added (so no extra heat was added to the water). Calculate the final temperature of the steak and carrots.

Assume no energy is lost to the environment and ignore any effects due to the bag material.

(4 marks)

*mixtures*

Food	Specific Heat Capacity (J K <sup>-1</sup> kg <sup>-1</sup> )
Steak	$2.76 \times 10^3$
Carrot	$3.81 \times 10^3$

$$Q = m_1 c_1 \Delta T + m_2 c_2 \Delta T + m_3 c_3 \Delta T$$

$$0 = 0.3 \times 2760 \times (T_f - 5) + 0.25 \times 3810 \times (T_f - 5) + 6.2 \times 4180 \times (T_f - 56.5)$$

$$0 = 828 T_f - 4140 + 952.5 T_f - 4762.5 + 25916 T_f - 1464254$$

$$27696.5 T_f = 1473156.5$$

$$T_f = 53.2 \text{ } ^\circ\text{C}$$

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**Question 19****(10 marks)**

A power bank is a portable charge storage device used to recharge phones and power other devices when mains electricity is not available.

The power bank in the photograph can deliver a current of up to 2.20 A for an hour at a supply voltage of 5.00 V.

$$I = 2.20 \text{ A}$$

$$V = 5.00 \text{ V}$$

$$t = 60 \times 60 = 3600 \text{ s}$$



- a) Explain in general terms how an 'electrical potential difference' is established. You must use the terms 'charge' and 'electrical potential energy' in your response.

**(2 marks)**

Electrical potential energy is given to charge when like charges are grouped together. (charges want to repel) ✓  
 potential difference is a measure of the difference of energy per unit charge when comparing 2 locations. ✓

- b) Calculate the number of electrons leaving a power bank when a current of 2.20 A flows for a time of 2.00 minutes.

**(3 marks)**

$$I = \frac{Q}{t}$$

$$Q = I \times t = 2.20 \times 120$$

$$Q = 264 \text{ C} \quad \checkmark$$

$$\# \text{ electrons} = \frac{Q}{q_e} = \frac{264}{1.60 \times 10^{-19}} \quad \checkmark$$

$$\# \text{ electrons} = 1.65 \times 10^{21} \text{ electrons} \quad \checkmark$$



- c) When the power bank is used to power a portable speaker a current of only 1.32 A is drawn. Determine how long the speaker can be powered until the available charge from the power bank is depleted.

(2 marks)

$$I_1 \times t_1 = I_2 \times t_2$$

$$2.20 \times 3600 = 1.32 \times t_2 \quad \checkmark$$

$$t_2 = \frac{2.20 \times 3600}{1.32} \quad \checkmark$$

$$t_2 = 6000 \text{ s (100 mins / 1 hr 40')} \quad \checkmark$$

- d) After a certain time the power bank stops working. Explain how you can account for the electrical potential energy that was present in the power bank when it started to power the portable speaker.

It has been transformed to other forms such as sound and heat. (2 marks)

- e) Explain what electrical power is a measurement of.

The rate of transformation of energy. (1 mark)

The energy (J) transformed per second

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**Question 20****(10 marks)**

A student conducts an experiment using an electric heater with a power rating of 3.00 kW to heat 25 g of ice, initially at  $-10^{\circ}\text{C}$ . The ice melts and after a while the resulting water increases in temperature. Assume the heater transfers heat to the ice/water with 100% efficiency at a constant rate.

- a) Calculate how much energy is required to completely melt the ice once it has reached  $0^{\circ}\text{C}$ .

(2 marks)

$$Q = m \cdot L_f$$

$$Q = 0.025 \times 3.34 \times 10^5$$

$$Q = 8350 \text{ J}$$

- b) Explain why the temperature is constant during the phase change even though energy is being added to the ice/water by the electric heater. You must refer to kinetic molecular theory in your response.

Temperature proportional to KE (average) (3 marks)  
 At phase change KE (average) is constant.  
 Energy transfer is used to increase particle separation which is stored as Potential Energy in substance.

- c) Compare the time taken to raise the temperature of the ice by 10 K with the time taken to raise the temperature of the water by 10 K. Which will take a longer amount of time. Circle a response and explain your reasoning.

(3 marks)

Ice takes longer      Same time for both      Water takes longer      Insufficient data to respond

Explanation:

Specific heat capacity for water is higher than ice.  
 $\therefore$  more energy required to raise temperature of water.  
 As energy transferred at a constant rate more time is required.

- d) Explain how a substance has "internal energy". Your response must refer to the physical properties of particles in the substance.

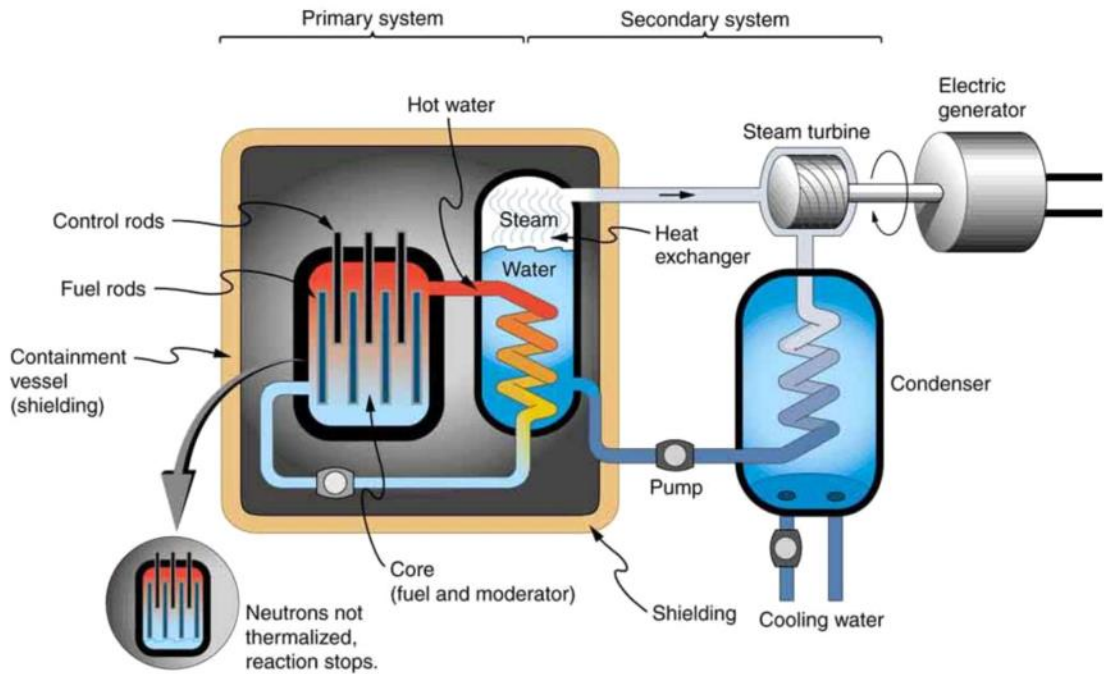
(2 marks)

Internal Energy is the sum of all kinetic energy and all potential energies of all particles within a substance.  
 $KE \propto$  motion / vibration of particles  
 $PE \propto$  separation of particles.  
 (Work must be done to separate particles)

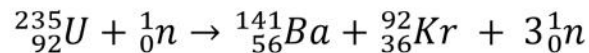
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**Question 21****(15 marks)**

Nuclear reactors use fission reactions to generate electricity. In the nuclear reactor shown below the energy generated by fission heats up the water, the water boils creating steam which turns a turbine creating electricity. This is a pressurised water nuclear reactor.



The nuclear reactor shown above uses Uranium-235 as a fuel source. The Uranium undergoes fission according to the following equation:



- a) Explain why it is easier for a neutron to enter the nucleus compared to an alpha particle or a proton.

Neutron has zero charge so not repelled by Coulomb force from protons in nucleus. (2 marks) ✓  
 Protons and Alpha particle both positively charged so are repelled from entering positive nucleus. ✓

- b) Describe the function of the control rods.

Capture neutrons liberated from fission reactions (2 marks) ✓  
 Rate of capture controls rate of fission reactions permitted. ✓  
 Control power output of reactor. ✓

- c) Calculate the energy (MeV) released by the fission reaction. Work only in atomic mass units and electron volts and give your answer to 6 decimal places.

(4 marks)

$$\begin{aligned} \text{Mass of products} &= 234.993454 + 1.008670 \\ &= 236.002124 \text{ u} \end{aligned}$$

$$\begin{aligned} \text{Mass of reactants} &= 91.906404 + 140.883686 + (3 \times 1.008670) \\ &= 235.816100 \text{ u} \end{aligned}$$

$$\Delta m = m_p - m_r = 236.002124 - 235.816100 = 0.186024$$

$$\begin{aligned} E (\text{MeV}) &= \Delta m \times 931 = 0.186024 \times 931 \\ E (\text{MeV}) &= 173.188344 \text{ MeV} \end{aligned}$$

- d) Describe the function of a safety feature that is shown on the diagram.

(2 marks)

Containment vessel (Shielding) block transfer of radioactive to the environment outside reactor  
 OR Heat exchanger - allows heat transfer & separate water circuit so radioactive water can be contained within reactor vessel.

- e) The electrical power output of the nuclear reactor facility is 901 MW. Calculate the mass (kg) of Uranium-235 nuclei that underwent fission in one year of operation. If you could not solve for part c) or you are unsure about your answer then use a value of 173 MeV. Assume that there are 365 days in one year.

energy per reaction

(5 marks)

$$173 \text{ MeV} = 173 \times 1.60 \times 10^{-13} = 2.77 \times 10^{-11} \text{ J}$$

Energy in one year

$$\begin{aligned} E &= P \times t = 901 \times 10^6 \times 365 \times 24 \times 60 \times 60 \\ E &= 2.8413936 \times 10^{16} \text{ J} \end{aligned}$$

$$\# \text{ reactions} = \frac{E(\text{Total})}{E(\text{reaction})} = \frac{2.8413936 \times 10^{16}}{2.77 \times 10^{-11}}$$

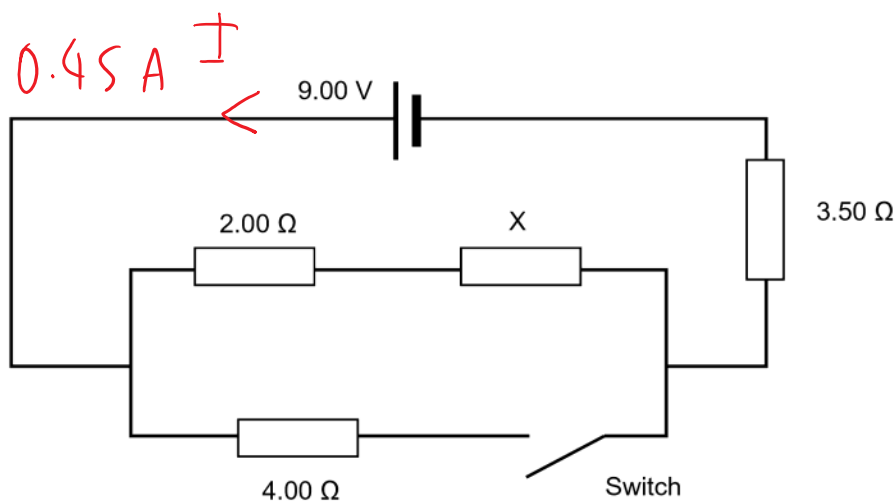
$$\# \text{ reactions} = 1.03 \times 10^{27}$$

$$\begin{aligned} \text{Total mass} &= \# \text{ reactions} \times \text{mass U-235} = 1.03 \times 10^{27} \times 3.90216 \times 10^{-25} \\ \text{Total mass} &= 400 \text{ kg} \end{aligned}$$

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**Question 22****(15 marks)**

A circuit consisting of a 9.00 V battery and four resistors is shown below. When the switch is open (off) the total current in the circuit is 450 mA.



- a) Calculate the resistance value of the resistor labelled X.

**(3 marks)**

$$V_T = I_T \times R_T$$

$$9.00 = 0.45 \times R_T \quad R_T = \frac{9.00}{0.45} = 20.0 \Omega$$

$$R_X = R_T - (R_2 + R_{3.5})$$

$$R_X = 20 - (2 + 3.5) = 14.5 \Omega$$

- b) Calculate the potential difference across the 3.50 Ω resistor while the switch is open (off).

**(2 marks)**

$$V = IR = 0.45 \times 3.50$$

$$V = 1.575 = 1.58 \text{ V}$$

For the following questions let the value of resistor X = 14.5  $\Omega$  and assume that the switch is closed (on)

- c) Calculate the total resistance of the circuit when the switch is closed.

$$R_{\text{parallel}} = \left( \frac{1}{14.5+2} + \frac{1}{4} \right)^{-1} = 3.22 \Omega \quad (2 \text{ marks})$$

$$R_{\text{TOTAL}} = R_{\text{parallel}} + R_{3.50} = 3.22 + 3.50$$

$$R_{\text{TOTAL}} = 6.72 \Omega$$

- d) Calculate the potential difference across the 3.50  $\Omega$  resistor while the switch is closed (on).

$$I_T = \frac{V_T}{R_T} = \frac{9.00}{6.72} = 1.33938 \text{ A} \quad (3 \text{ marks})$$

$$V_{3.5} = I \cdot R = 1.33938 \times 3.50 =$$

$$V_{3.5} = 4.68784 = 4.69 \text{ V}$$

- e) Calculate the current through the 4.00  $\Omega$  resistor while the switch is closed (on).

$$V_{\text{parallel}} = V_T - V_{3.5} = 9.00 - 4.69 \quad (3 \text{ marks})$$

$$V_{||} = 4.31215$$

$$I = \frac{V_{||}}{R} = \frac{4.31215}{4} = 1.078$$

$$= 1.08 \text{ A}$$

- f) Calculate the power of the 2.00  $\Omega$  resistor when the switch is closed (on).

$$I = \frac{V_{\text{parallel}}}{R_{2+X}} = \frac{4.31215}{16.5} = 0.261 \text{ A} \quad (2 \text{ marks})$$

$$P = I^2 R_2 = 0.261^2 \times 2 = 0.137 \text{ W}$$

END OF SECTION TWO

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**Section Three: Comprehension****15% (15 marks)**

Suggested working time: 15 minutes.

**Question 23****(15 marks)****Nuclear Imaging with Radioisotopes****Nuclear Imaging**

Nuclear imaging is a technique that uses radioisotopes to emit radiation from within a patient's body. A radioisotope is given to a patient either orally, by injection or it can be inhaled. Nuclear imaging can provide doctors with information that other techniques cannot. For example, X-rays can only image bone but nuclear imaging can take pictures of both bone and soft tissue. With nuclear imaging doctors can detect a secondary cancer up to two years before it can be seen in a standard X-ray.

The radioisotopes used in nuclear imaging are usually gamma emitters. Doctors use a special gamma camera to detect the gamma radiation and create an image to help diagnose diseases such as cancer. Different elements are used including isotopes of technetium, gallium, iodine, xenon and thallium. The type of radioisotope used depends on which part of the body is being investigated. For example, iodine-131 is used to take images of the thyroid.

Nuclear imaging can show the position and concentration of the radioisotope in the patient's body. A 'hot spot', an area where the radioisotope has been absorbed into the tissue or organ, may be due to a diseased state, such as infection or cancer.

Once identified treatment can begin by using techniques such as radiotherapy.

**Iodine Radioisotopes**

Iodine radioisotopes are often used to take images of the thyroid, a gland in your neck. Iodine-131 is not used often due to the danger it can pose to the patients' health. Other less-damaging radioisotopes such as Iodine-123 are preferred in most situations.

Iodine-131 contributed to the health problems experienced after the Chernobyl nuclear power plant meltdown. It was also spread through the air after the Fukushima nuclear crisis.

	Iodine-123	Iodine-131
<b>Decays by:</b>	100% Gamma	90% Beta, 10% Gamma
<b>Half-life:</b>	13.22 hours	8.02 days



**Figure 3:** Nuclear images of a patient's head and chest. The thyroid (circled in the third image) appears as a 'hot spot'.



a) Describe two key differences between nuclear imaging and radiotherapy.

1. Emission of radiation through body to detect condition. (2 marks) ✓
2. Emission of radiation within body to treat a condition. ✓

b) State two advantages that nuclear imaging has compared to X-ray.

1. Can also image soft tissue ✓ (2 marks)
2. Can detect secondary cancer 2 years before X-ray. ✓

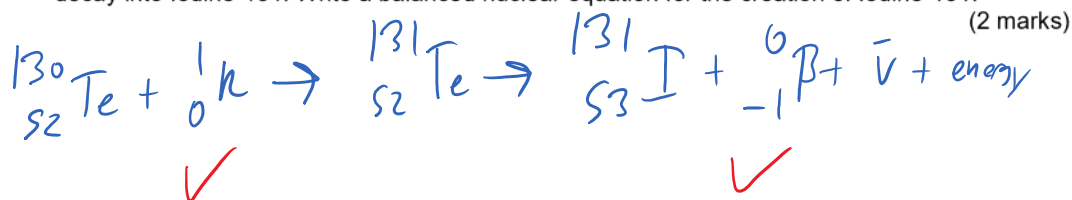
c) Explain why radioisotopes that emit alpha particles will not provide images to the detectors used in nuclear imaging.

- Required to penetrate body to reach detector. ✓ (2 marks)  
Alpha poor penetration ability, will not reach detector. ✓

d) Explain why Iodine-123 is used more often in nuclear imaging than Iodine-131.

- Iodine 131 is hazardous to human health ✓ (3 marks)  
Only gamma emitted (no beta) ✓  
Better half-life / activity ratio. ✓

e) Iodine-131 is created by Tellurium-130 absorbing a neutron. The Tellurium then undergoes beta-decay into Iodine-131. Write a balanced nuclear equation for the creation of Iodine-131.

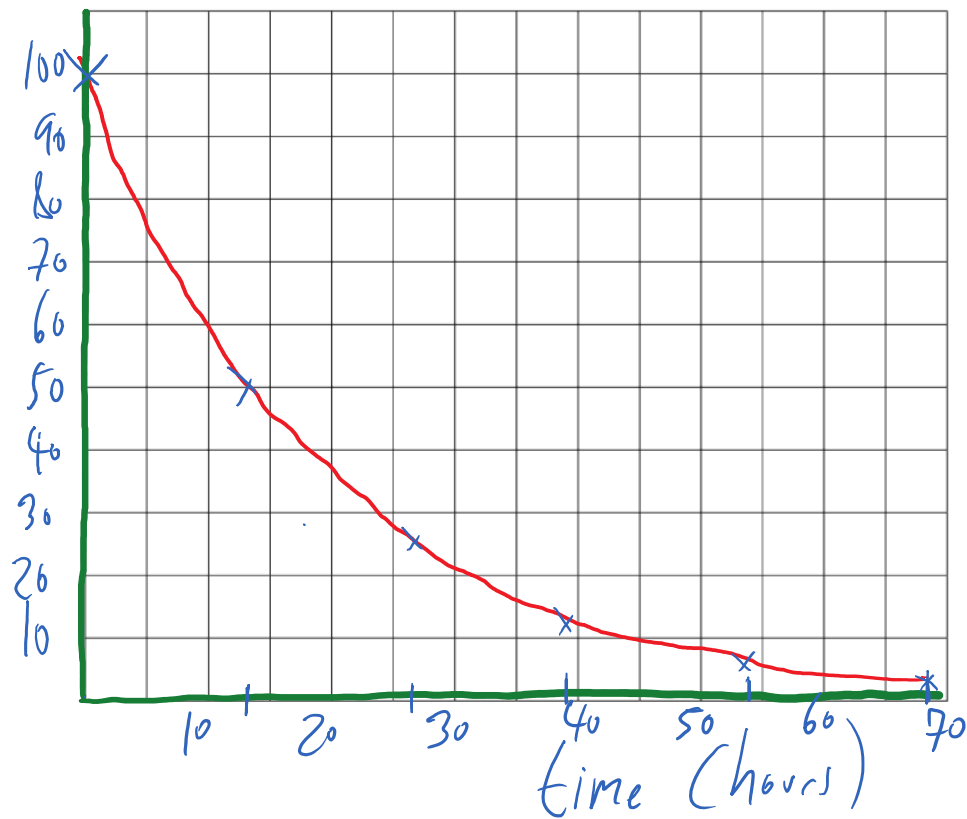


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- f) Draw a fully labelled graph to show the radioactive decay of Iodine-123. The y-axis should show the percentage of Iodine-123 remaining and be scaled from 0 to 100%. The x-axis should show time and be scaled from 0 to 70 hours. It is recommended to plot 6 points to allow you to sketch a curve/line.

Iodine-123 (%)

(4 marks)



labels, units, plots, curve

✓ ✓ ✓ ✓

END OF EXAMINATION