Year 11 PHYSICS ATAR

Semester 1 Examination, 2017

Question/Answer Booklet

Student Number: In figures | | | | | | | | |

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	**150**	**100%**

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.

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.

Question 2 **(5 marks)**

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

a) Calculate the absorbed dose that the doctor receives.

(2 marks)

b) The annual recommend maximum dose equivalent for the doctor is 2000 µSv. Determine what percentage of this annual dose the doctor received.

(3 marks)

Question 3 **(4 marks)**

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

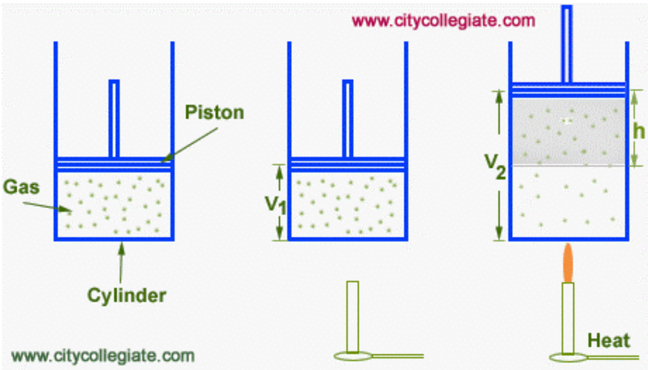
a) Which resistor draws the most current? (1 mark)

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

(3 marks)

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.

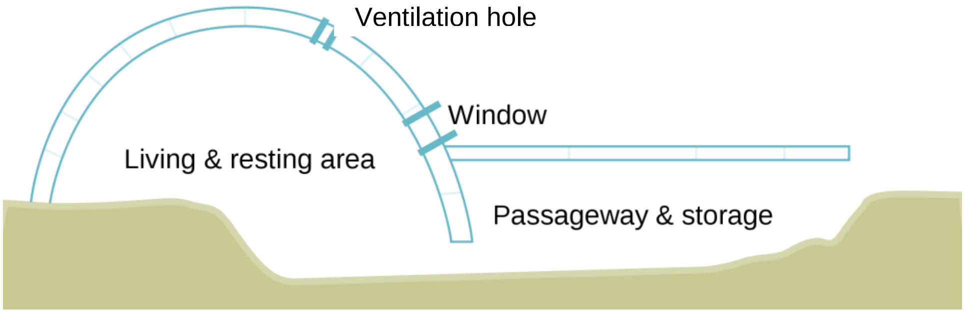
When this happens the overall energy of the system increases by 270 J and 77 J is lost to the surroundings. Calculate the mass of the iron block that is lifted.

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.

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 °C to 16 °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.

(3 marks)

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

Question 7 **(4 marks)**

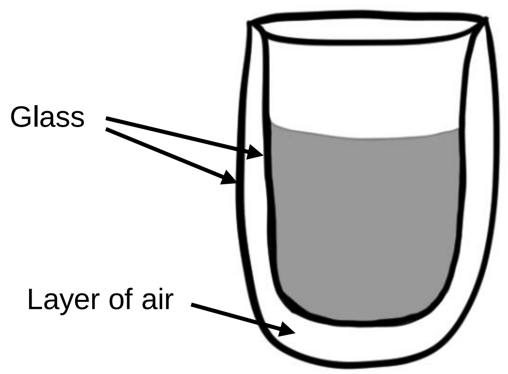
Complete the following nuclear decay equations:

a) Polonium-84 undergoes alpha decay. (2 marks)

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.

Question 9 **(3 marks)**

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

Question 10 **(4 marks)**

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

Critical Mass:

Chain Reaction:

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 $^{12}_{8}O$ isotope and determine if it is a stable isotope. (2 marks)

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

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.

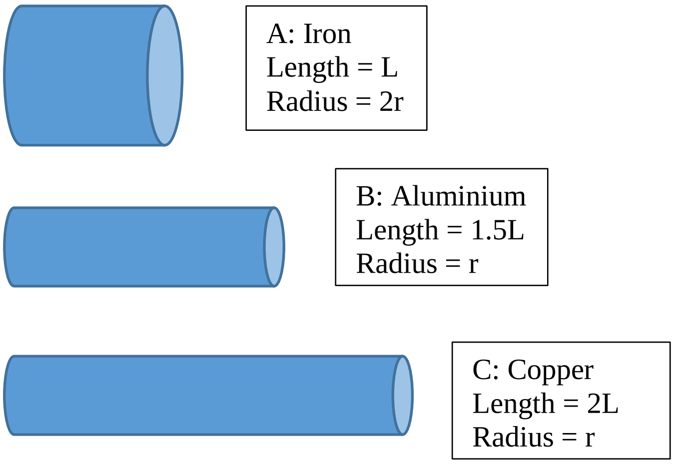
Question 13 **(3 marks)**

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.

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 (Ω m)
Copper	1.68×10^{-8}
Aluminium	2.65×10^{-8}
Iron	9.71×10^{-8}



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

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.

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.

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)**

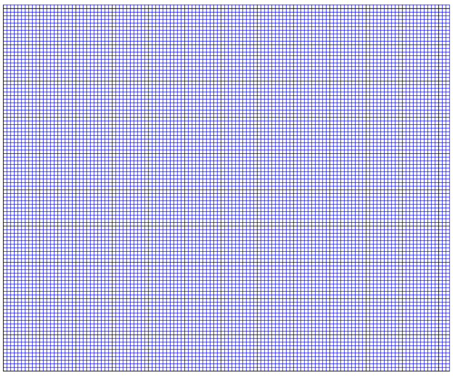
Two physics students conducted an experiment to examine the electrical properties of a semiconductor component used in complex circuits. The relationship between potential difference and current for the component is given by the equation:

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

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



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

(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.

(3 marks)

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 7.2×10^{-4}. Give your answer to 2 significant figures.

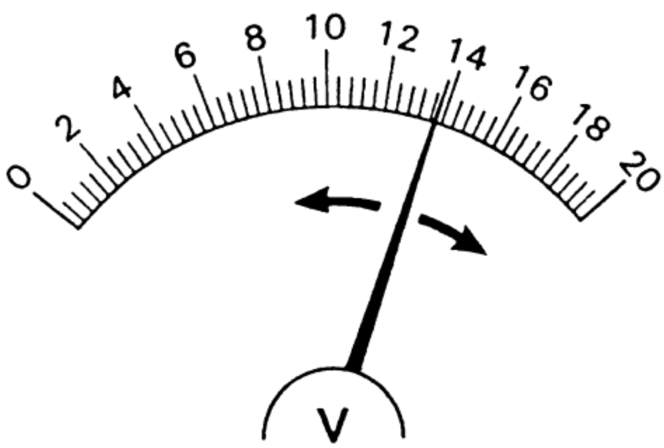
(3 marks)

d) The accepted value for Z is 1.9×10^4. Calculate the percentage difference between an experimental value of 1.7×10^4 and the accepted value.

(2 marks)

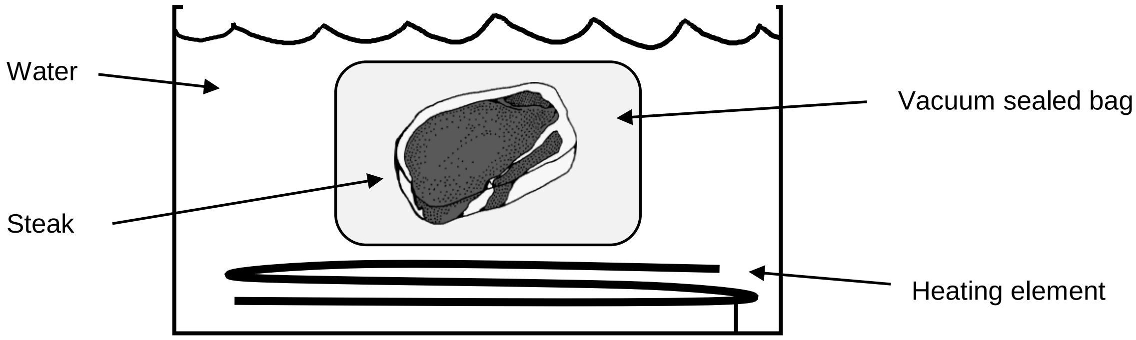
e) The diagram shows a voltmeter taking a reading. Determine the value of the voltage being measured with the appropriate relative (%) uncertainty of this measurement.

(3 marks)



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)

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)

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)

Food	**Specific Heat Capacity (J K^{-1} kg^{-1})**
Steak	2.76×10^3
Carrot	3.81×10^3

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.

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)

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)

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)

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.

(2 marks)

e) Explain what electrical power is a measurement of.

(1 mark)

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°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°C.

(2 marks)

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.

(3 marks)

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

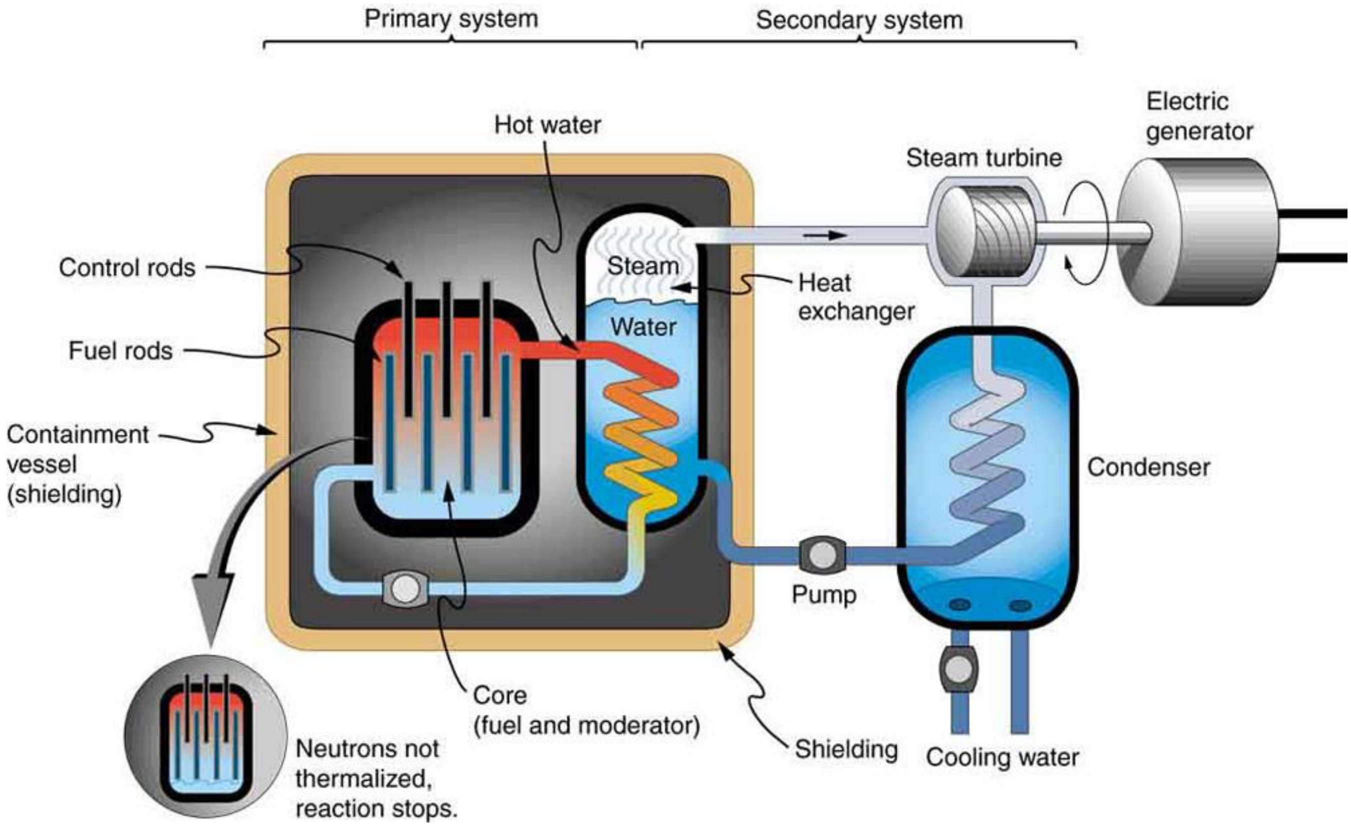
Explanation:

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

(2 marks)

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:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n$$

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

(2 marks)

b) Describe the function of the control rods.

(2 marks)

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)

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

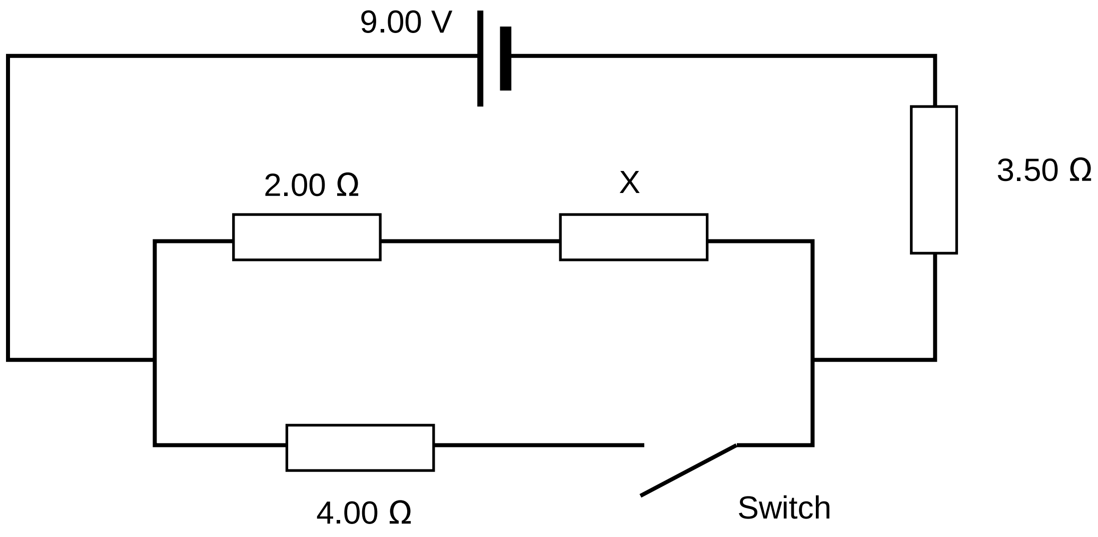
(2 marks)

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.

(5 marks)

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)

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

(2 marks)

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

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

(2 marks)

d) Calculate the potential difference across the 3.50 Ω resistor while the switch is closed (on).

(3 marks)

e) Calculate the current through the 4.00 Ω resistor while the switch is closed (on).

(3 marks)

f) Calculate the power of the 2.00 Ω resistor when the switch is closed (on).

(2 marks)

END OF SECTION TWO

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
Decays by:	100% Gamma	90% Beta, 10% Gamma
Half-life:	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.

(2 mark)

1.

2.

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

(2 marks)

1.

2.

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

(2 marks)

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

(3 marks)

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.

(2 marks)

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.

(4 marks)

END OF EXAMINATION