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| A blue and white logo  Description automatically generated with low confidence | **Harrisdale Senior High School****Science Department** |

**ATAR Physics Units 1 and 2**

**Task 7: Semester 1 Examination 2022**

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**Time allowed for this paper**

|  |  |
| --- | --- |
| Reading time before commencing work:Working time: | ten minutesone hundred and fifty minutes |

**Materials required/recommended for this paper
*To be provided by the supervisor***
This Question/Answer booklet
Formulae and Data booklet

***To be provided by the student***

|  |  |
| --- | --- |
| Standard items: | pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters |
| Special items: | calculators which do not have the capacity to create or store programmes or text and are permitted in ATAR course examinations, drawing templates, drawing compass and a protractor |

**Important note to students**No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time(minutes) | Marks available | Percentage of exam |
| Section One:Short answer | 9 | 9 | 45 | 44 | 29 |
| Section Two:Extended answer | 6 | 6 | 90 | 90 | 60 |
| Section Three:Comprehension and data analysis | 1 | 1 | 15 | 16 | 11 |
|  |  |  | **Total** | 150 | 100 |

**Instructions to candidates**

1. The rules for the conduct of examinations are detailed in the *Year 11 Information Handbook 2022: Part II Examinations.* Sitting this examination implies that you agree to abide by these rules.
2. Write your answers in this Question/Answer booklet, preferably using a black/blue pen. Do not use erasable or gel pens.
3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.
4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

In calculations, give final answers to three significant figures and include appropriate units where applicable.

 In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

1. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate in the original answer where the answer is continued, i.e., give the page number.
2. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

**Section One: Short response 29% (44 Marks)**

This section has **nine (9)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working and reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working and reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e., give the page number.

Suggested working time: 45 minutes.

**Question 1 (6 marks)**

A balloon contains helium gas and nitrogen gas. The gases are at a common temperature of 25 °C.

1. Describe the relative speeds of the gas particles. Explain your answer.

(3 marks)

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1. The gases are heated to 50 °C. Describe any change you would expect to notice in the balloon. Explain your answer using the kinetic theory of gases.

(3 marks)

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**Question 2 (6 marks)**

A worker in a uranium mine is exposed to three different types of radiation: alpha, beta and gamma. The worker has a mass of 95.5 kg and absorbs 10.7 J of ionising radiation. The worker estimates that 25.0% of this is due to alpha radiation; 30.0% due to beta radiation; and 45.0% due to gamma radiation. It is assumed that this is a full-body exposure.

1. Calculate the dose equivalent the worker received.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ Sv

1. Workers in uranium mines have dust landing on their clothing from minerals that emit all three types of radiation: alpha, beta and gamma. Which of these emissions do they most need protection from? Explain.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 3 (4 marks)**

A flashlight operates with a 3.00 V DC battery and draws a current of 0.500 A while it is operating.

1. Calculate the maximum amount of energy in Joules (J) supplied to each electron in the filament’s circuit.

(2 marks)

\_\_\_\_\_\_\_\_\_\_ J

1. Calculate the number of electrons that pass through the flashlight’s filament during a 10.0 second operation.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_ electrons

**Question 4 (6 marks)**

An aluminium kettle of mass 1.05 kg contains a quantity of water at a room temperature of 23.0 °C. The kettle has a power rating of 1.80 × 103 W and it takes 2.00 minutes to raise the temperature of the water to 75.0 °C. Assuming no heat is lost to the surroundings, calculate the mass of the water in the kettle.

[Specific heat capacity of aluminium = 904 J kg-1 °C-1]

\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

**Question 5 (4 marks)**

Cosmic radiation consists of high-speed protons (50%) and alpha particles (50%). Both of these ionising radiation sources are extremely dangerous to humans, so astronauts must be protected from them. Their quality factors are shown below:

|  |  |
| --- | --- |
| TYPES OF COSMIC RADIATION | QUALITY FACTORS |
| High-speed protons | 10 |
| Alpha particles | 20 |

During a typical 8-day Space Shuttle mission, a 78.5 kg astronaut can expect the following dose equivalents (in mSv) for their cosmic ray exposure:

|  |  |
| --- | --- |
| TYPES OF COSMIC RADIATION | DOSE EQUIVALENT (mSv) |
| High-speed protons | 3.60 |
| Alpha particles | 2.00 |

In the space below, calculate the total quantity of ionising radiation (in Joules, J) absorbed by the astronaut during this mission.

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_ Joules

**Question 6 (4 marks)**

A Physics student is examining the safety features associated with a toaster. They are able to identify the following protections:

RESIDUAL CURRENT DEVICE (RCD); CIRCUIT BREAKERS; EARTH WIRE

The student considers the following scenario:

The toaster malfunctions and does not eject the bread. The user decides to get the toast out with a metal knife.

1. Describe why this action is potentially dangerous.

(2 marks)

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. Explain how one of the safety features on the list above will protect the user in this situation.

(2 marks)

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**Question 7 (5 marks)**

Polonium-218 is an alpha emitter. During this transmutation, it produces the isotope lead-214.

The atomic masses of the particles involved in this decay are:

Po-218: 218.008966 u

Pb-214: 213.999805 u

He-4: 4.002603 u

1. Write a balanced nuclear equation for this alpha decay.

(2 marks)

1. Calculate the energy released (in MeV) during this decay.

(3 marks)

\_\_\_\_\_\_\_\_\_\_ MeV

**Question 8 (4 marks)**

An incandescent light globe is a good example of a non-ohmic resistor. Its resistance is low for low potential differences. The resistance rises as the potential difference increases and the temperature of the filament rises.

1. Using the information provided, sketch a ‘Current (I)’ vs ‘Voltage (V)’ graph for a filament in an incandescent light globe on the axes below. No values are required.

(2 marks)

CURRENT

VOLTAGE

1. Explain why the temperature of the filament of an incandescent light globe increases over time once current begins to flow through it. In your answer, consider the collisions that electrons undergo as they flow through the filament.

(2 marks)

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**Question 9 (6 marks)**

Water is being heated in a metal pan on an electric heating element as shown below. The handle for the pan is covered in hard plastic.

Water

Metal pan

Handle

Electric heating element

1. In terms of heat transfer, explain why the handle of the pan is made of plastic.

(2 marks)

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. It is found that placing a lid over the pan allows the temperature of the water to rise more quickly. In terms of heat transfer, explain why this is the case.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**End of Section One**

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**Section Two: Problem-solving 60% (90 Marks)**

This section has **six (6)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working and reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working and reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e., give the page number.

Suggested working time: 90 minutes.

**Question 10 (16 marks)**

A group of students conduct an investigation to identify a metal by determining its unique resistivity. The resistivity of a material is a measure of the opposition to flow of electric charge through that material. It is unique to each material and, like resistance, is also dependent on temperature – especially in materials that are non-ohmic conductors.

Resistivity values for some materials are shown below. The students know that their unknown material is on this list.

|  |  |
| --- | --- |
| MATERIAL | RESISTIVITY (×10-8 Ωm) |
| copper | 1.59 |
| aluminium | 2.65 |
| tungsten | 5.60 |
| iron | 9.71 |

The students know that the overall resistance of a conductor (measured in Ohms, Ω) can be calculated using the following formula:

$$R=ρ\frac{L}{A}$$

**Where:**

**R = resistance of conductor (Ω)**

**ρ = resistivity of conductor (Ω m)**

**L = length of conductor (m)**

**A = cross-sectional area (m2)**

**L = length**

**A = area**

The students decide to build a circuit that allows them to measure the potential difference across and current flowing through a wire made of the unknown material. The circuit will be built in such a way that it allows the length of the wire in the circuit to be varied. The students have the following pieces of equipment at their disposal:

One (1) metre of the wire made of the unknown material; 1 × voltmeter; 1 × ammeter; 1 × battery; 1 × switch; 1 × rheostat; 1 × one metre ruler; as many wires and alligator clips as required.

1. In the space below, the wire is shown. Complete a circuit diagram using the relevant symbols to illustrate the circuit that the students should build in their experiment.

(3 marks)

The students conduct their experiment and gather the data shown below:

**Cross-sectional area ‘A’ = 2.00 × 10-7 m2**

|  |  |  |  |
| --- | --- | --- | --- |
| **L (m)** | **V (V)** | **I (A)** | **R (Ω)** |
| **0.200** | **0.10** | **3.70** | **0.0270** |
| **0.400** | **0.21** | **3.79** | **0.0554** |
| **0.600** | **0.37** | **4.41** |  |
| **0.800** | **0.51** | **4.60** | **0.111** |
| **1.00** | **0.72** | **5.25** | **0.137** |

1. There is one value missing in the ‘R’ column in the table. Calculate this value and place it in the table. Shown clearly how you did this calculation in the space below.

(2 marks)

1. On the grid provided on the next page, draw a graph of ‘Length’ versus ‘Resistance’. Plot ‘Length’ on the horizontal axis. Draw a line of best fit for the data.

(4 marks)



1. Calculate the gradient of the line of best fit you have drawn. Show clearly how you did this. Include units in your answer.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_

Units: \_\_\_\_\_\_\_\_\_\_\_\_

1. Use the gradient in part d) to calculate the resistivity (ρ) of the unknown material.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ Ω m

1. Hence, identify the unknown material.

(1 mark)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 11 (14 marks)**

Whilst making a cup of coffee, 355 mL of hot water is added to a 320.0 g ceramic coffee mug. Both reach a common temperature of 90.0 °C.

It is known that water at this temperature can cause third degree burns, so a decision is made to cool it down to 55.0 °C. This is achieved by adding ice at -8.50 °C until this final cooler temperature is achieved.

Assume no heat is transferred to the surroundings.

1. Show that the heat energy lost by the water and the ceramic mug as their temperature drops to 55.0 °C is approximately 7.00 × 104 J.

The specific heat capacity of ceramic is 1.49 × 103 J kg-1 °C-1.

(3 marks)

\_\_\_\_\_\_\_\_\_\_ J

1. The mass of the ice added (*m*) is unknown. In terms of *m*, calculate the thermal energy gained by the ice as it is heated to 55.0 °C.

(5 marks)

1. Hence, use the answers from parts a) and b) to calculate *m*.

 [Note: if you were unable to calculate an answer for part a), use 7.00 × 104 J. If you were unable to get an answer for part b), use m × 6.00 × 105 J]

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_ kg

1. Instead of a ceramic mug, a Styrofoam cup (which is an effective thermal insulator) is used. State and explain the effect this would have on the amount of ice required to cool the coffee to 55.0 °C when compared to using a ceramic cup. Assume no heat is lost to the surroundings.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 12 (14 marks)**

One possible nuclear fission reaction is shown below:

$$\begin{matrix}235\\92\end{matrix}U+\begin{matrix}1\\0\end{matrix}n\rightarrow \begin{matrix}94\\40\end{matrix}Zr+\begin{matrix}139\\52\end{matrix}Te+3 \begin{matrix}1\\0\end{matrix}n$$

The atomic masses of the isotopes and neutrons that take part in this fission reaction are listed below:

|  |  |
| --- | --- |
| m(U-235) | 235.043928 u |
| m(neutron) | 1.00867 u |
| m(Zr-94) | 93.906313 u |
| m(Te-139) | 138.93473 u |

* 1. (i) Calculate the mass defect for the fission reaction.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ u

(ii) Hence, calculate the energy released by one fission reaction (in MeV).

[If you were unable to calculate a value for part (i), use 0.20000 u]

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_ MeV

Nuclear reactors typically use ‘low-enriched uranium’ as the fuel for power generation. This fuel consists mostly of two isotopes of uranium – uranium-235 (which is fissile) and uranium-238 (which is not fissile).

The concentration of U-235 in low-enriched uranium by mass is 5.00%; the concentration of U-238 is 95.0%.

* 1. Calculate the maximum total energy that could be released by this 10.0 kg sample of low-enriched uranium (in Joules). Assume that the energy is released exclusively by the nuclear fission reaction above.

(5 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ J

Whilst nuclear fission reactors generate a sizable proportion of the world’s electricity, it is hoped that nuclear fusion will replace these reactors in the future.

* 1. In the table below, state four (4) differences between nuclear fission and nuclear fusion.

(4 marks)

|  |  |  |
| --- | --- | --- |
|  | **NUCLEAR FISSION** | **NUCLEAR FUSION** |
| **Difference 1** |  |  |
| **Difference 2** |  |  |
| **Difference 3** |  |  |
| **Difference 4** |  |  |

**Question 13 (15 marks)**

A student constructs the circuit below to investigate current, voltage, and electric power. Note the positions of the ammeter and voltmeter. In the questions that follow, the resistances of the connecting wires and the power source are equal to zero.

**R4 = 5.00 Ω**

**R3 = 5.00 Ω**

**R2 = 5.00 Ω**

**R1 = 10.0 Ω**

**24.0 V**

**J**

**H**

**G**

**F**

**E**

**D**

**C**

**B**

**A**

**A**

**V**

1. Show with a calculation that the combined resistance between ‘C’ and ‘J’ is about 3 Ω.

(3 marks)

1. Hence, show with a calculation that reading on the ammeter is 1.80 A.

(2 marks)

1. Hence, calculate the reading on the voltmeter.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ V

1. Calculate the power generated in R4.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ W

1. During the experiment, a break in the circuit occurs between ‘C’ and ‘D’. Without performing any calculations, explain how the readings on the ammeter and voltmeter will be different compared to before the break occurred.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 14 (17 marks)**

Radiocarbon dating is a process that is used to determine the age of fossilised bones. All living cells contain the element carbon, the vast majority of which is the stable isotope carbon-12. However, a small amount is the radioisotope carbon-14, which is a beta emitter (β-) and has a half-life of 5730 years.

In a living organism, the ratio of carbon-14 : carbon-12 nuclei remains constant at approximately 1:100 000. When an organism dies, this ratio begins to decrease.

1. Write a nuclear equation for the beta decay (β-) of carbon-14.

(3 marks)

1. Explain why the carbon-14 : carbon-12 ratio decreases after an organism dies.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. A carbon-14 nucleus has a mass of 14.00324 u. A proton has a mass of 1.00727 u; a neutron has a mass of 1.00867 u. Use this data to calculate the binding energy per nucleon of carbon-14.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ MeV

1. Compare and explain the difference in the binding energy per nucleon between a carbon-12 and a carbon-14 nucleus.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. A fossilised bone is analysed and it is found that the carbon-14 : carbon-12 ratio has decreased to 15.0% of its value for a living organism. Using the half-life of carbon-14, estimate a value for the age of the fossilised bone.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ years

**Question 15 (14 marks)**

The diagram below shows the structure of an old-fashioned incandescent light globe mounted on a wall. The light operates for 4.50 hours every day.

The structure of the globe is as follows:

* Glass bulb enclosing a vacuum.
* Metal filament located inside the glass bulb; connected to the 240 V mains supply - this produces the light and excess heat.

filament

vacuum

glass bulb

The light globe has a power rating of 60.0 W.

1. Calculate the resistance of the light globe’s filament.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_ Ω

1. If electrical energy costs 28.5 cents per kilowatt hour, calculate the cost of operating this light globe for 4.50 hours.

(3 marks)

\_\_\_\_\_\_\_\_\_\_ cents

Incandescent light globes are only 10.0% efficient. The wasted energy is given off as heat.

1. Calculate the quantity of heat energy generated by the light globe in 4.50 hours.

(3 marks)

\_\_\_\_\_\_\_\_\_\_ J

1. The light globe is switched on and, after one minute, an observer notices that if they touch the glass bulb – or even hold their hand next to the globe – their hand feels hot.

Explain how the glass bulb gets so hot, even though the bulb contains a vacuum.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. The observer notices that if they hold their hand above the light globe it feels hotter than if they hold it underneath. Explain.

(2 marks)

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**End of Section Two**

**Section Three: Comprehension 11% (16 Marks)**

This section has **one (1)** question. Write your answers in the spaces provided.

When calculating numerical answers, show your working and reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working and reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e., give the page number.

Suggested working time: 15 minutes.

**Question 16 (16 marks)**

**Racing toward Absolute Zero**

The coldest theoretical temperature allowed by thermodynamics is called ‘absolute zero’ – a temperature that is colder than outer space. This temperature is assigned a value of zero degrees kelvin and is equal to −273.15 degrees Celsius or -459.67 degrees Fahrenheit. This is technically the temperature when a ‘system’ (such as a thermometer) reaches its lowest possible energy.

Humans have an intuitive understanding of temperature due to their experience with the sensations of feeling ‘hot’ and ‘cold’. However, what humans are really experiencing in situations where they are distinguishing between hot and cold objects is the amount of internal energy that these objects contain. Internal energy is partly defined by the amount of movement the particles in an object have (i.e., their ‘thermal motion’). An ice cube, for example, contains less internal energy than a cup of hot water because its particles are not moving as much as in the water. At absolute zero, the thermal motion of the particles would be at their minimum.

The concept of ‘absolute zero’ first emerged in the early 1700s when a French physicist and inventor called Guillaume Amontons related temperature to the amount of heat in a system. Amontons hypothesised that there would be a minimum amount of heat a system could possess and that this would correspond to a minimum temperature.

In the early 1900s, the Dutch physicist, Heike Onnes, used several precooling stages and a process called the Hampson-Linde Cycle to liquefy helium gas for the first time. In this experiment, he lowered the helium gas to a temperature just below its boiling point: -269 °C.

Onnes’ high-powered cooling system has been adopted by refrigeration systems used in physics laboratories around the world. The cooling process is like that which occurs when you blow on a hot beverage.

The latest step in the quest to achieving absolute zero is being pursued by the Quantum Matter Team at the University of Cambridge’s Cavendish Laboratory. As they lower the temperature of materials to super-cold levels, they are discovering exotic quantum properties that only emerge at these temperatures – some of which are extremely useful. Advances in technology enable this team to measure and observe energies at ever more extreme scales and at lower temperatures that are getting closer and closer to zero kelvin.

The Quantum Matter Team know, however, that achieving absolute zero is theoretically impossible. The refrigeration systems needed to achieve this consume energy as they operate. The work done by these systems increases exponentially as the temperature gets closer and closer to absolute zero. In theory, to achieve this temperature an *infinite* amount of work needs to be done. In addition, quantum mechanics dictates that even at absolute zero the particles’ thermal motion would not be at a minimum: they would still have some form of *irreducible* motion.

Nonetheless, the best refrigeration systems – based on Onnes’ original designs – are getting closer to this lowest temperature and are now able to reach a few millikelvins.

1. Define ‘heat energy’. As part of your answer, define ‘internal energy’ and describe the energy possessed by particles in a substance.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Explain three (3) reasons why a small block of ice has less internal energy than a large cup of hot water.

(5 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. The Celsius and the Kelvin scales are both the same – they just have different origins. Complete the table below converting the temperatures shown between degrees Celsius and kelvin. Round your answers to the nearest 0.01 of a degree.

(2 marks)

|  |  |
| --- | --- |
| Temperature (°C) | Temperature (K) |
| -273.15 | 0 |
|  | 100 |
| -269 |  |

1. The article states that a temperature of ‘absolute zero’ would be impossible to reach experimentally.

(i) Explain what should theoretically happen to an object’s particles at a temperature of zero Kelvin.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii) Hence, explain why scientists believe that is impossible to reach absolute zero.

(2 marks)

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e) Explain how blowing on a cup of coffee can cause it to cool down.

(3 marks)

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**End of Questions**

Supplementary page

Question number: \_\_\_\_\_\_\_\_\_\_\_\_

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**Spare grid for graph**

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