|  |  |
| --- | --- |
|  |  **HARRISDALE SENIOR HIGH SCHOOL** **Year 11 Semester 1 2022** |

PHYSICS

**SOLUTIONS**

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

**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)

|  |  |
| --- | --- |
| The particles in each gas will possess the same average kinetic energy (same temperature).  | 1 mark |
| Mass of nitrogen particles > mass of helium particles.  | 1 mark |
| Hence, average speed of nitrogen particles < average speed of helium particles.  | 1 mark |

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.

(3 marks)

|  |  |
| --- | --- |
| The balloon will expand.  | 1 mark |
| Increase in temperature of gases mean particles will travel faster / further. | 1 mark |
| Particles collide more frequently and with more force with the walls of the balloon.  | 1 mark |

**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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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

(2 marks)

|  |  |
| --- | --- |
| Gamma radiation. | 1 mark |
| This type of radiation is able to penetrate through the workers’ clothing and skin to the interior of their body. | 1 mark |

*or* gamma and beta (no marks for beta only)

**Question 3 (4 marks)**

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

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

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |

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

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |

 *Follow through as appropriate if first step incorrect*

**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 x 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]

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

*Max 3 marks if aluminium not included*

**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 and 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 Space Shuttle mission.

|  |  |
| --- | --- |
|  |  |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

 *-1 only for Sv instead of mSv*

**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)

|  |  |
| --- | --- |
| The metal knife is a conductor and could cause a live connection with the heating element. | 1 mark |
| This could cause an electric current to flow through the user to the earth. | 1 mark |

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

(2 marks)

|  |  |
| --- | --- |
| The current flowing through the user will mean that the current in the active wire will often be different to the current in the neutral wire. | 1 mark |
| This will cause the RCD / circuit breaker to open and cut off current flow to the toaster and the user.  | 1 mark |

**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)

|  |  |
| --- | --- |
|  |  |
| Correct species | 1 mark |
| Atomic numbers and mass numbers balanced | 1 mark |

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

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

**Question 8 (4 marks)**

A filament lamp or 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)

VOLTAGE

CURRENT

|  |  |
| --- | --- |
| Curved graph (not linear).  | 1 mark |
| Correct shape (see above).  | 1 mark |

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)

|  |  |
| --- | --- |
| The electrons collide with atoms in the filament.  | 1 mark |
| Each collision cause energy loss from the electrons in the form of heat.  | 1 mark |

**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)

|  |  |
| --- | --- |
| Plastic is a poor conductor. | 1 mark |
| This prevents / slows conduction of heat from the pan to the hand of a user, this preventing burns. | 1 mark |

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)

|  |  |
| --- | --- |
| Heat is transferred to the air above the water via conduction.  | 1 mark |
| The hotter air just above the water rises and transfers heat away from the water via convection. | 1 mark |
| The lid prevents this air from rising and halts the convection of heat from the pan.  | 1 mark |

**End of Section One**

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

**Question 10 (16 marks)**

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

(3 marks)

V

Alternate rheostat symbols:

A



|  |  |
| --- | --- |
| See circuit diagram above. |  |
| Ammeter in series with wire; voltmeter in parallel with wire. | 1 mark |
| All other components (rheostat, switch, power supply) in series with the wire.  | 1 mark |
| All circuit symbols correct. | 1 mark |

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

**Cross-sectional area ‘A’ = 2.00 x 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** | **0.0839** |
| **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 mark |
|  | 1 mark |

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 if best fit for the data.

(4 marks)

L (m)

R (Ω)

|  |  |
| --- | --- |
| Axes labelled correctly (‘L’ on horizontal axis).  | 1 mark |
| Correct units supplied on both axes. | 1 mark |
| Points plotted correctly. | 1 mark |
| Line of best fit plotted correctly.  | 1 mark |

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)

|  |  |
| --- | --- |
| Uses point from the line of best fit: (1.00, 0.14) and (0.150, 0.020) | 1 mark |
|  | 1 mark |
| Units: Ω m-1 (ohms per metre) | 1 mark |

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

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

1. Hence, identify the unknown material.

(1 mark)

|  |  |
| --- | --- |
| Aluminium | 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 x 104 J. The specific heat capacity of ceramic is 1.49 x 103 J kg-1 °C-1.

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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

(5 marks)

|  |  |
| --- | --- |
|  | 2 marks |
|  | 2 marks |
|  | 1 mark |

1. Hence, use the answers form parts a) and b) to calculate ‘m’ - the unknown mass of ice added.

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

(3 marks)

|  |  |
| --- | --- |
|  |  |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

1. Instead of a ceramic mug, a Styrofoam cup (which is an effective thermal insulator) is used. State and explain the effect on the amount of ice that would have to be used 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)

|  |  |
| --- | --- |
| The Styrofoam cup will not absorb or release any thermal energy. | 1 mark |
| Hence, the only substance that needs to be cooled to 55.0 °C is the hot water.  | 1 mark |
| Hence, less ice is required.  | 1 mark |

**Question 12 (14 marks)**

One possible nuclear fission reaction is shown below:

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)

|  |  |
| --- | --- |
| Mass of reactants = 235.043928 + 1.00867 = 236.052598 u | 1 mark |
| Mass of products = 93.906313 + 138.93473 + 3 x 1.00867 = 235.867053 u | 1 mark |
| Mass defect = 236.052598 - 235.867053 = 0.186 u | 1 mark |

(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)

|  |  |
| --- | --- |
| Energy released = 0.185545 x 931 | 1 mark |
| = 173 MeV (186 MeV) | 1 mark |

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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

Whilst nuclear fission reactors generate a sizable proportion of the world’s electricity, it 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)

|  |  |
| --- | --- |
| Any four (4) of the following – one (1) mark each to a maximum total of four (4) marks: |  |
| Fuel for fusion is hydrogen; fuel for fission is uranium. | 1 mark |
| Fuel for fusion is light nuclei; fuel for fission is heavy nuclei. | 1 mark |
| Fuel for fusion is a very common element; fuel for fission is a very rare isotope.  | 1 mark |
| Fusion – joining of two nuclei; fission – splitting of one nuclei.  | 1 mark |
| Fusion power has a higher energy yield than fission power. | 1 mark |
| Fusion power not yet commercially viable; fission power is commercially viable. | 1 mark |
| Fusion power does not produce long-term radioactive waste; fission power produces long-term radioactive waste.  | 1 mark |
| Any other reasonable responses.  | 1 mark |

**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 resistance 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 mark |
|  | 1 mark |
|  | 1 mark |

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

(2 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

1. Hence, calculate the reading on the voltmeter.

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

1. Calculate the power generated in R4.

(3 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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

(4 marks)

|  |  |
| --- | --- |
| The break between ‘C’ and ‘D’ removes R3 and R4 from the circuit.  | 1 mark |
| This creates an increase in the overall resistance of the circuit.  | 1 mark |
| Overall circuit voltage remains constant; hence, the overall current through both R1 and R2 and the ammeter decreases. | 1 mark |
| Voltmeter reading increases since resistance of that part of the network increases relative to R1.  | 1 mark |

**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 and 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 is a constant value of about 1:100 000. After an organism dies, this ratio decreases.

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

(3 marks)

|  |  |
| --- | --- |
|  |  |
| Correct symbols used | 1 mark |
| Atomic numbers balanced. | 1 mark |
| Mass numbers balanced. | 1 mark |

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

(3 marks)

|  |  |
| --- | --- |
| When an organism dies, it stops ingesting carbon/maintaining its carbon levels via eating, etc. | 1 mark |
| The carbon-12 level remains stable – its quantity does not change after the organism dies.  | 1 mark |
| Carbon-14 is an unstable radioisotope – it decays and its quantity, therefore, reduces after the organism dies. | 1 mark |

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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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

(3 marks)

|  |  |
| --- | --- |
| BE/nucleon (C-12) > BE/nucleon (C-14) | 1 mark |
| C-12 atoms are stable; C-14 atoms are unstable.  | 1 mark |
| C-14 atoms have inadequate BE/nucleon to hold the nucleons together in a stable formation. | 1 mark |

e) 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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
| 1 or 2 significant figures | 1 mark |

*or*

|  |  |
| --- | --- |
| Table or similar working to manually determine n | 1 mark |
|  | 1 mark |
|  | 1 mark |
| 1 or 2 significant figures | 1 mark |

**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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

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)

|  |  |
| --- | --- |
| Thermal energy is being transferred to the glass bulb via absorption of thermal radiation. | 1 mark |
| Radiation is a method of heat transfer that requires no medium for its transfer. | 1 mark |
| The glass bulb then conducts heat to the cooler fingers of the observer and the air surrounding it.  | 1 mark |

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)

|  |  |
| --- | --- |
| The hot air above the globe will rise to the person’s hand due to convection. | 1 mark |
| The hot air below the globe will rise away from the person’s hand. | 1 mark |

**End of Section Two**

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

**Question 16 (16 marks)**

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

(4)

|  |  |
| --- | --- |
| Internal energy is equal to the sum of the kinetic and potential energies of the particles in a substance.  | 1 mark |
| Heat energy is the flow of internal energy from a higher temperature object to a lower temperature object.  | 1 mark |

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

(5)

|  |  |
| --- | --- |
| A bowl of soup consists of more particles than ice cream in a cone. | 1 mark |
| The strength of attraction between the particles in a liquid are generally less than that in a solid.  | 1 mark |
| Therefore, a liquid’s particles generally have a higher potential energy than a solid.  | 1 mark |
| The ice cream’s temperature is lower than that of the bowl of soup. | 1 mark |
| Therefore, the average kinetic energy of the particles in the ice cream is less than that in a bowl of soup.  | 1 mark |

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 for ‘Temperature (°C)’ to the nearest 0.01 of a degree.

(2)

|  |  |
| --- | --- |
| Temperature (°C) | Temperature (K) |
| -273.15 | 0 |
| -173.15 | 100 |
| -269 | 4.15 |

|  |  |
| --- | --- |
| T = -173.15 = 100 K | 1 mark |
| T = -269 = 4.15 K | 1 mark |

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)

|  |  |
| --- | --- |
| A temperature of absolute zero should mean an average kinetic energy of the particles equal to zero.  | 1 mark |
| Hence, the particles should stop moving completely (ie – become stationary).  | 1 mark |

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

(2)

|  |  |
| --- | --- |
| Quantum physics implies that particles would always have some irreducible motion.  | 1 mark |
| Hence, the particles will always have some kinetic energy (ie - the kinetic energy of the particles can never be zero).  | 1 mark |

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

(3)

|  |  |
| --- | --- |
| The blowing causes high energy water particles to evaporate at a faster rate. | 1 mark |
| Hence, the lower energy particles remain in the coffee which reduces the overall average kinetic energy of the particles.  | 1 mark |
| Hence, the temperature of the coffee will reduce. | 1 mark |

*or*

|  |  |
| --- | --- |
| The blowing replaces warm air above the cup of coffee with cold air. | 1 mark |
| This increases the rate of conduction between the coffee and the air. | 1 mark |
| Hence, the temperature of the coffee will reduce faster. | 1 mark |