Christ Church
Grammar School

Science Department
Year 11 Physics

Semester 1 Examination, 2019

Question/Answer booklet

PHYSICS UNIT 1

SECTION ONE

SHORT ANSWER

Fix student label here

SOLUTIONS

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: two hours

Materials required/recommended for this paper

To be provided by the supervisor

Three Question/Answer booklets
Formulae and Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction tape/fluid, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations

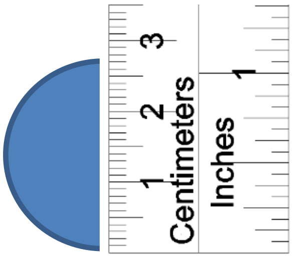
Important note to candidates

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.

See next page

Question 1 (3 marks)

Aiden is measuring the following shaded perfect circle and he places a ruler over the widest point of the circle, as shown on the right. Write the absolute and percentage uncertainties of the diameter of the circle below.



(a) Diameter with absolute uncertainty:

2.70 cm ± 0.05 cm (or ± 0.10 cm if student assumes two measurements)

(b) Diameter with percentage uncertainty:

$\frac{0.05}{2.70} \times 100 = 1.85\%$ (or 3.70% if student assumes two measurements)

2.70 cm ± 1.85%

Question 2 (3 marks)

The American Condor is a bird that often relies on “thermal updrafts”; a pocket of rising air that helps them generate lift and fly without using significant energy. Condors look for regions over large plain fields. As the field is heated by the sun, it is able to operate more efficiently. Explain the heating of the field enables the Condor to fly more efficiently.

- As field is heated by the sun, the air molecules near the surface gain kinetic energy and collide with their neighbours with more force.
- This causes the particles to occupy more volume and become less dense and rises.
- This causes a **convection current** of rising hot air that the bird can use to create lift.

Question 3 **(5 marks)**

Sodium-24 has a half-life of 15.0 hours and decays via beta decay into magnesium-24. It has applications in medicine and engineering.

(a) How much of a 34.0 g sample of Sodium-24 will remain undecayed after two days? Show clear working.

(3 marks)

$t = 2 \times 24 = 48 \text{ hours}$

$$N = N_o \left(\frac{1}{2}\right)^{\frac{t}{t_{\frac{1}{2}}}}$$

$$= 34 \times \left(\frac{1}{2}\right)^{\frac{48}{15}}$$

= 3.70 g

(b) Write a balanced nuclear equation of the decay of sodium-24

(2 marks)

$${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\upsilon}$$

(If student selects beta + decay, max 1 mark)

Question 4 **(7 marks)**

A food shop sells hot beef soup. A number of slices of beef are put into a bowl, followed by pouring in a hot liquid vegetable stock. The soup is then ready to serve to customers.

Use the following information to answer the questions:

- Mass of vegetable stock: 0.800 kg
- Initial temperature of the stock: 96.0 °C
- Specific heat capacity of the stock: 4.00×10^3 $Jkg^{-1}K^{-1}$
- Mass of each beef slice: 50.0 g
- Initial temperature of beef: 6.00 °C
- Specific heat capacity of beef: 3.00×10^3 $Jkg^{-1}K^{-1}$

(a) According to safety regulations, the serving temperature of the soup should be below 60.0 °C. Estimate the minimum number of beef slices required to add to the stock to achieve this.

(6 marks)

$Q_{gain} + Q_{lost} = 0$ (1/2)

$Q = mc(T_f - T_i)$ (1/2)

$\Delta T_S = -36$ (1)
$\Delta T_B = +54$
(working out for -36 and +54 must be present)

$x(0.05 \times 3000 \times 54) + (0.800 \times 4000 \times -36.0) = 0$ (1)

$8100x - 115200 = 0$ (1)

$X = 14.2$ (1)

= at least 15 slices. (1)

(if x = 14, maximum 5 marks)

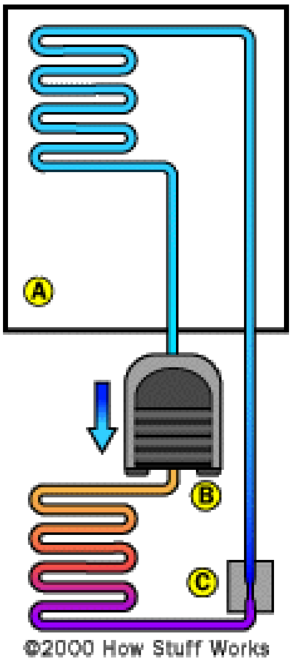
(b) State one assumption in the calculation in part (a).

(1 mark)

- Assuming no energy is lost to the environment.
- Bowl does not receive any heat from soup.
- Uniform consistency of beef.

Question 5 **(5 marks)**

The diagram below is a simple schematic diagram of a fridge. It consists of one long coil that goes through the inside compartment of the fridge and then flows outside. Fluid refrigerant is sealed inside this coil. The arrow, in the diagram below, shows the direction of the refrigerant. Part C is called an expansion valve.



(a) The pressure inside the pipe is reduced by the expansion valve, causing the refrigerant to evaporate. Explain how this helps to cool the fridge.

(3 marks)

- As the refrigerant evaporates, turning from liquid to gas, energy is required to increase the PE of the particles.
- It then absorbs energy from the surrounding to change the state of the refrigerant.
- This allows the heat to be removed from the air inside the fridge, so it becomes cooler.

When there is a power outage, a fridge can still keep the contents cold for as long as 2 hours.

(b) Describe the features of a fridge which help to keep the fridge cold.

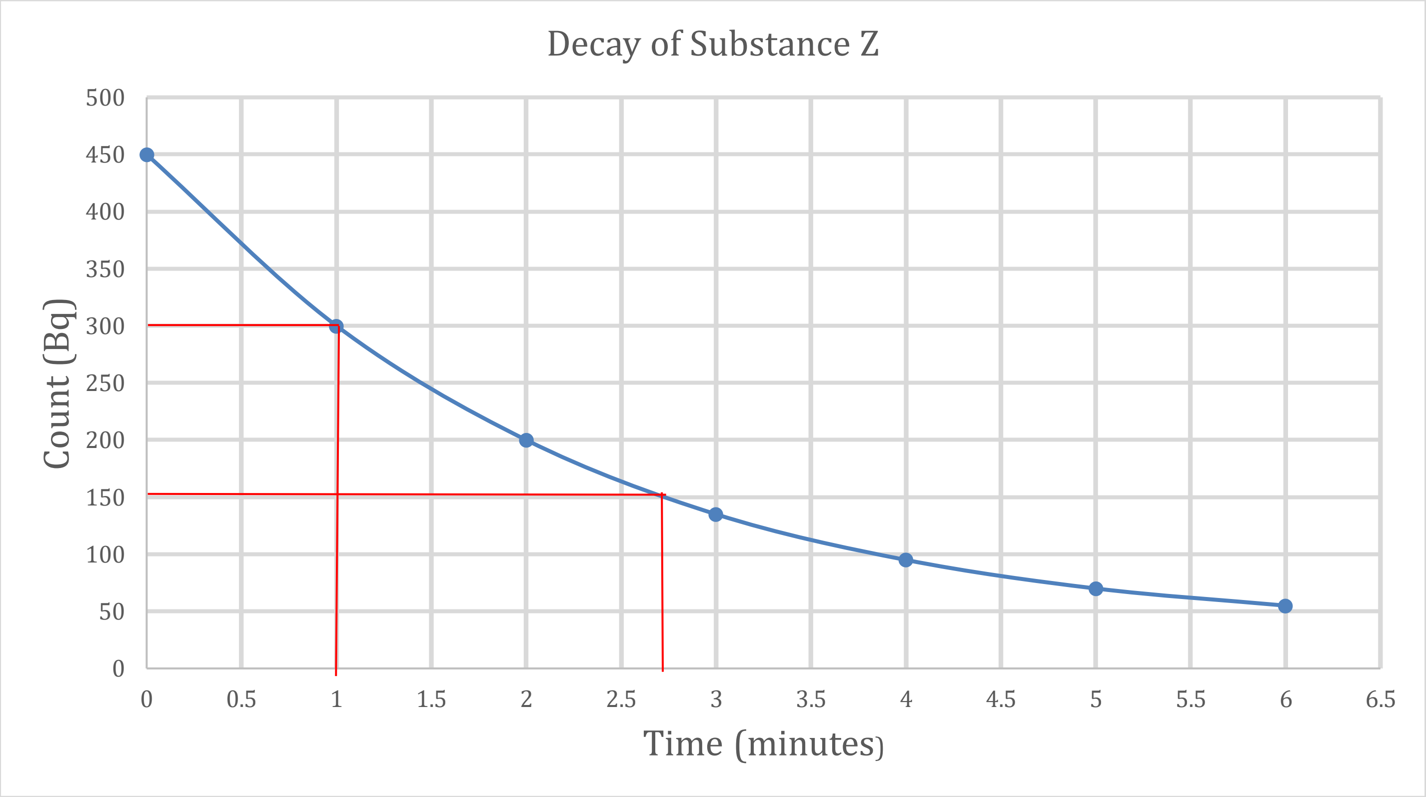
(2 marks)

- A fridge is made of insulators.
- Sealed shut to prevent heat coming from outside.
- Hollow doors to prevent conduction while silver to reflect
  OR radiation.

(any two features relate to conduction, convection and radiation)

Question 6 **(5 marks)**

The graph below shows the decay of radiative substance **Z**.



(a) Use the graph above to estimate the half-life of substance **Z**. Show your working on the graph above.

(2 marks)

$t_2 - t_1 = 2.75 – 1$ (1)

$= 1.75$ minutes (1)

(b) Hence, estimate how long it would take for substance **Z** to decrease to 28.125 Bq of activity.

(3 marks)

$A_0/A = (2)^n$ (1/2)

$450/28.125 = (2)^n$ (1/2)

$16 = 2^4$ (1)

$n = 4$ (1)

$t = n.t_{1/2}$

$= 4. 1.75$ (1/2)

$=7.00$ minutes. (1)

Question 7 **(5 marks)**

Find the binding energy, per nucleon in, MeV, for Uranium-236 atom.

Use the following data:

Mass of proton = 1.007276 u
Mass of neutron = 1.008665 u
Mass of electron = 0.000548 u
Mass of Hydrogen-1 = 1.007825 u
Mass of Uranium-236 = 236.045568 u

m.d. = 92 x m(^1_1H) + (236-62) x m(n) - m(Al-27)

= 92 x (1.007825) + 144 x (1.008665) – 236.045568 (1)

= 1.922221 u (6.d.p) (1)

BE = m.d. x 931 (1/2)

= 1.922221 x 931 (1/2)

= 1790 MeV (1)

BE/nuc = 1790 / 236

= 7.58. MeV/nucleon (1)

Question 8 **(16 marks)**

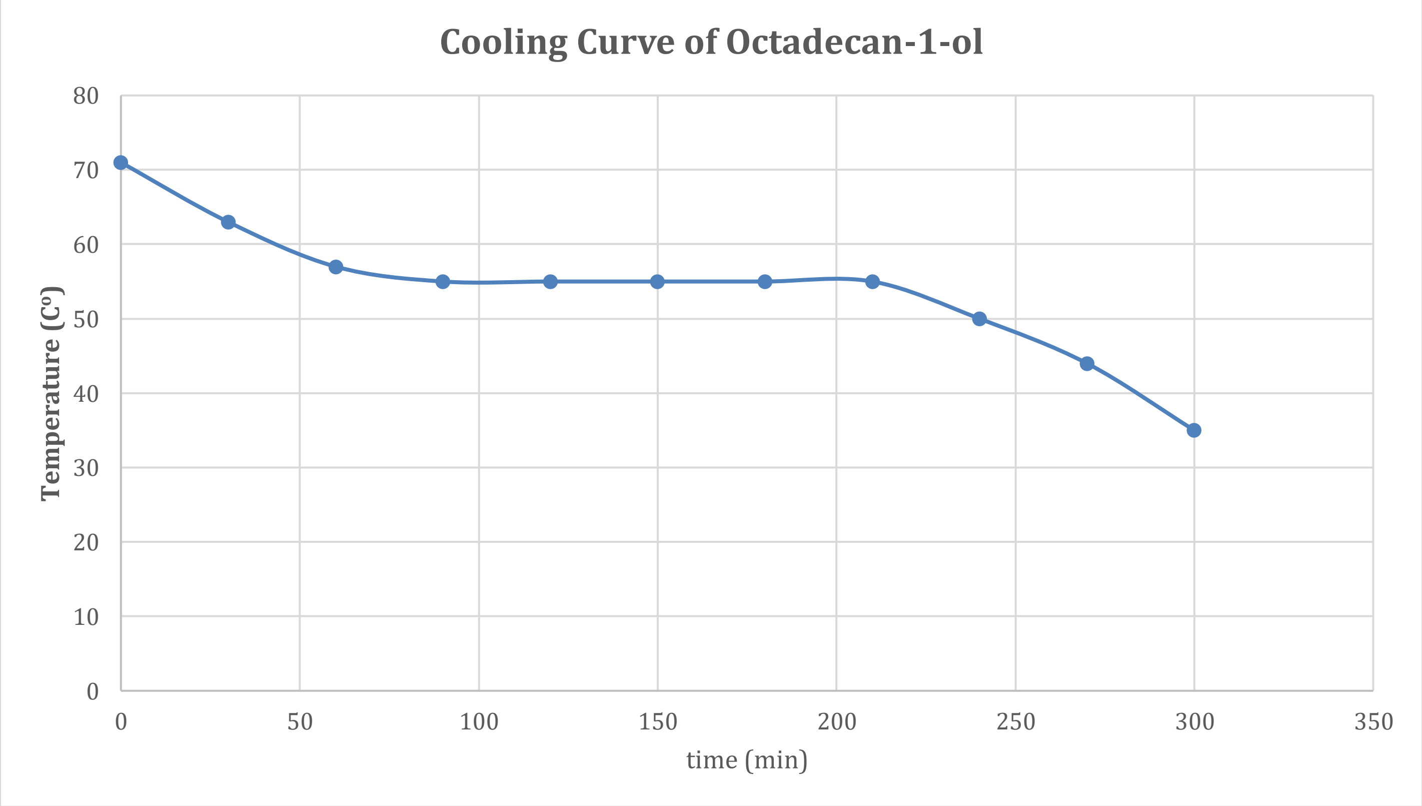
John carries out an experiment to investigate the cooling properties of Octadecan-1-ol. Octadecan-1-ol is one type of alcohol that can be used in anti-freeze products and lubricants. Its latent heat of fusion is 331 J kg^{-1}. John heats a glass test tube containing of 0.250 kg of liquid Octadecan-1-ol to 80.0 ºC. He then puts the test tube immediately into a beaker of iced water.

The temperature of the Octadecan-1-ol is then recorded over a time interval of 5.00 minutes. The results are shown below:

Time (s)	0	30	60	90	120	150	180	210	240	270	300
Temperature (ºC)	71.0	63.0	57.0	55.0	55.0	55.0	55.0	55.0	50.0	44.0	35.0

(a) Plot a cooling curve of Octadecan-1-ol in the graph below. A spare graph paper can be found on page 24.

(2 marks)



Accuracy of data
Axes with units

(b) Estimate the melting point of Octadecan-1-ol, in Kelvin.

(2 marks)

55 ºC + 273
= 328 K

(If not 0.d.p, maximum 1.5 marks)

(c) Using terms of heat and internal energy, explain the shape of the curve between 90 seconds and 210 seconds.

(3 marks)

- As the Octadecan-1-ol **heats** the iced water, it's internal energy decreases
- **Internal energy** is the sum of Ek and EP of all particles in the substance
- However, at 90-120 seconds, all energy provided by Ep of the bonds/molecules coming closer together, not Ek, hence no change in temperature.

Allow suitable explanation of increase of Ep going into forming bonds etc.

(d) Use the given information to calculate the rate of heat loss of the 0.250 kg of Octadencan-1-ol in between 90 seconds and 210 seconds.

(4 marks)

Time t = 210 – 90 = 120 s (1)

$Q = mL_F$ (1/2)

$= 331 \times 0.25$ (1/2)

$= 82.75 \text{ J}$ (1)

$P = \frac{82.75}{120}$ (1/2)

$= 0.69 \text{ W}$ (1/2) Sig figs not penalised as time is to nearest 10.

(e) Another student conducts the same experiment but with a thicker-walled glass test tube. State and explain whether your answer for part d) be higher or lower.

(3 marks)

- If the walls are thicker, then the rate of heat transfer out of the Octadecan-1-ol will reduce
- And take longer to transfer its latent heat (as $Q / t \propto 1 / L$)
- This will provide a lower rate of heat transfer as per $P = E/t$

(f) List one possible example of random error and one possible example of systematic error in this experiment.

(2 marks)

Random error:

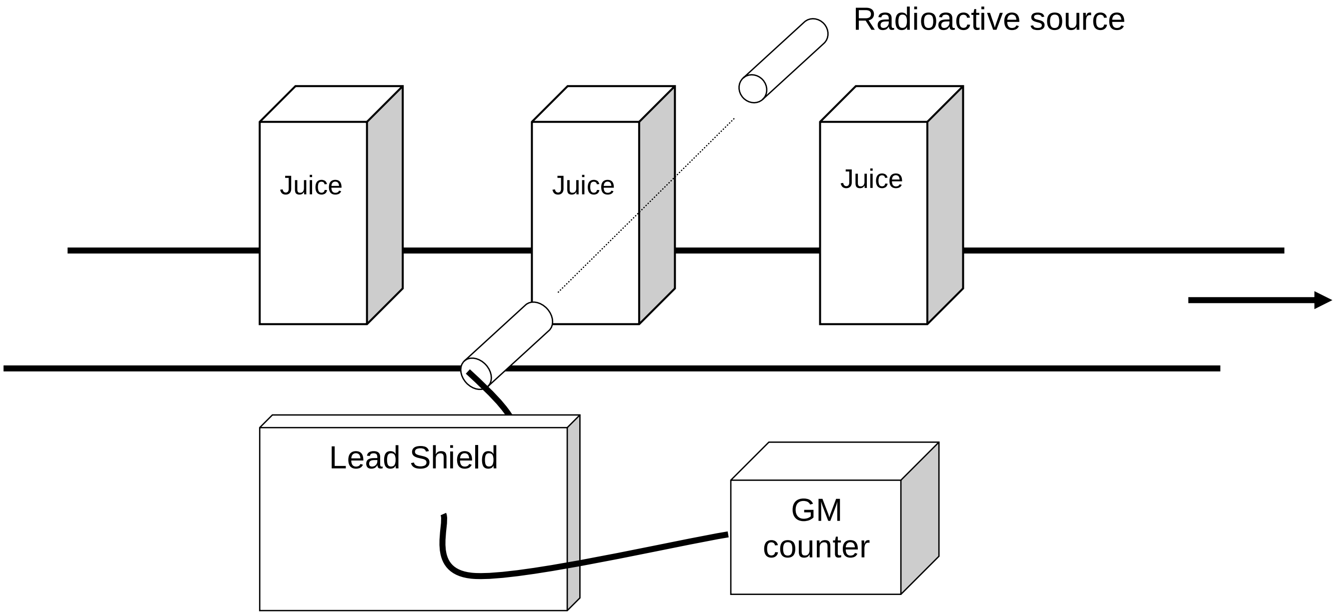
uncertain amount of heat lost to the environment

Systematic error:

thermometer reading / mass of substance may not be calibrated properly

Question 9 **(13 marks)**

In a juice factory, a radioactive source and a Geiger-Muller (GM) counter are used to ensure each box of juice is full before delivering to the shops. The radiation emitted by the source penetrate through the top section part of each box and are then detected by the GM counter as shown in the following diagram.



The following table shows a sample of results recorded by the GM counter:

Box Number	**1**	**2**	**3**	**4**	**5**
Measured count rate (Bq)	645	652	648	729	654

(a) State and explain what type of radiation (alpha, beta or gamma) should be used for the radioactive source.

(2 marks)

- Gamma radiation
- High penetration ability allows the particles to be stopped according to the amount of juice. (beta and alpha are not penetrating enough to pass through box + juice)

(b) Provide and explain a possible reason for why there was an increase in the measured count rate when the fourth box of juice passes through the detector.

(2 marks)

- The volume of the juice in the box must have been less than others.
- This provides less shielding and more particles reach the GM counter.

(c) It is claimed that as long as the radiation penetrates through the top part of the juice box and are detected by the GM counter, then the distance between the source and the detector is **NOT** critical. Comment on the accuracy of this statement.

(2 marks)

- Comment is accurate as long as the distance remains constant throughout testing.
- So an increase in detected activity is purely a result of low juice levels.

(d) The manager of the factory has a choice of radioactive source with their half-lives shown below.

(i) Circle the most suitable source.

(1 mark)

10 seconds **10 hours** [✓ **10 years**]

(ii) Briefly explain your answer of your above choice.

(1 mark)

This is because the radioactive source does not required replacement more often.

(e) Comment on the purpose of the lead shield.

(1 mark)

To protect the factory employees from harmful radiation.

All factory workers who work in this juice factory must wear radiation monitoring badges. These badges monitor the radiation exposure to a factor worker. A person whose mass is 75.0 kg receives an average of 3.00 J a day according to the badge.

(f) Estimate the dose equivalent this person receives every day. Use your answer in part (a) for the calculation.

(4 marks)

$AD = \frac{E}{m}$ (1/2)

$= \frac{3}{75}$ (1/2)

$= 0.040\ \mathrm{Gy}$ (1)

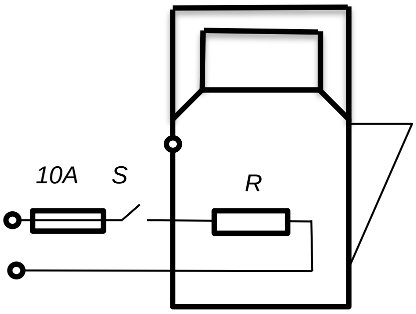
$DE = AD \times QF$ (1/2) (follow through from chosen particle in (a)

$= 0.04 \times 1$ (1/2)

$= 0.0400\ \mathrm{Sv}$ (1) 3 s.f. as Q.F is a discrete value.

Question 10 **(15 marks)**

The schematic diagram on the right shows how wires are connected to an electric kettle. The main source of resistance in the kettle is the heating element. The rating of this kettle is “240V, 2.00 kW”. Note: **S** is a switch and **R** is the resistance.



(a) Describe the main energy transformation taking place in the kettle. (1 mark)

Converting electrical energy into heat.

(b) Calculate the current that flows through the heating element when it is operating. (3 marks)

$$I = \frac{P}{V}$$ (1)

$$= \frac{2000}{240}$$ (1)

$= 8.33\text{A}$ (1) (Sig figs not penalised as voltage is to nearest 10)

(c) Calculate the resistance of the heating element given the rating values provided. (3 marks)

V = I R (1)

240 = 8.33 R (1)

R = 28.8 Ω (1) (Sig figs not penalised as voltage is to nearest 10)

(d) This kettle is now filled with 1.50 L of water. If the kettle has an efficiency of 40% and is turned on for 2.00 minutes, calculate the temperature rise of the water. Note: density of water is 1.00 kg L^{-1}.

(5 marks)

$Q = P \cdot t$ (1/2)

$= 2000 \times 2 \times 60$ (1/2)

$= 240000 \text{ J}$ (1)

Useful energy:

$Q = 240000 \times 0.4$

$= 96000 \text{ J}$ (1)

$\Delta Q = mc\Delta T$ (1/2)

$96000 = 1.5 \times 4180 \times \Delta T$ (1/2)

$\Delta T = 15.3\ ^{o}\text{C}$ (1)

(e) When boiling water, placing the lid on the top of the kettle allows it to bring water to the boil faster than without a lid on. Explain, using kinetic theory, why using the lid increases the effectiveness of the kettle.

(3 marks)

- It reduces heat loss due to convection and evaporation.
- Hotter particles (vapour) cannot leave water i.e. average kinetic energy of particles is not reduced.
- With the lid, the kinetic energy increases more rapidly. i.e. boiling point is reached more quickly.

Question 11 **(13 marks)**

On average, a person, through perspiration, loses up to 0.400 L of water every hour even sitting in a comfortable office. The latent heat of vaporisation of water at a comfortable temperature is 2.26×10^6 J kg^{-1}. Note: density of water is 1.00 kg L^{-1}

(a) Explain how water assists heat loss for human bodies to prevent hyperthermia, a scientific term to describe a body temperature above 40.0 °C.

(3 marks)

- When water is evaporated it requires energy to do so (via $Q = mL_V$).
- The energy can be drawn from the human body.
- Which results in a decrease in body temperature.

(b) Jane, whose mass is 55.0 kg, has been at work for 8.00 hours.

i) How much heat energy does Jane's body lose at work, through the evaporation of water? Assume the evaporating perspiration does not absorb heat from anywhere else.

(3 marks)

Mass of water over 8 hours:

$m = 0.4 \times 8$

$= 3.20 \text{ kg}$ (1)

$\Delta Q = mL_V$ (1/2)

$= 0.4 \times 2.26 \times 10^6$ (1/2)

$= 7{,}232{,}000 \text{ J}$

$= 7.23 \times 10^6$ J (1)

ii) Calculate the rise in Jane's body temperature if the same amount of water in part i) did not evaporate from her skin? Assume the specific heat capacity of a human body is 3500 J kg^{-1} K^{-1}.

(2 marks)

$\Delta Q = mc\Delta T$ (1/2)

$7{,}232{,}000 = 55 \times 3500 \times \Delta T$ (1/2)

$\Delta T = +37.6$ °C (2 sig fig allowed for interpretation of c = 3500 2.s.f)

(c) Jane finds that using a fan which blows air across her skin helps her feel more comfortable while working in a hot office. Explain why this is the case.

(3 marks)

- The fan removes the water vapour around the skin which reduces the saturation of the water vapour.
- As a result, it encourages more water on the skin to evaporate
- which in turn removes more heat from Jane's body.

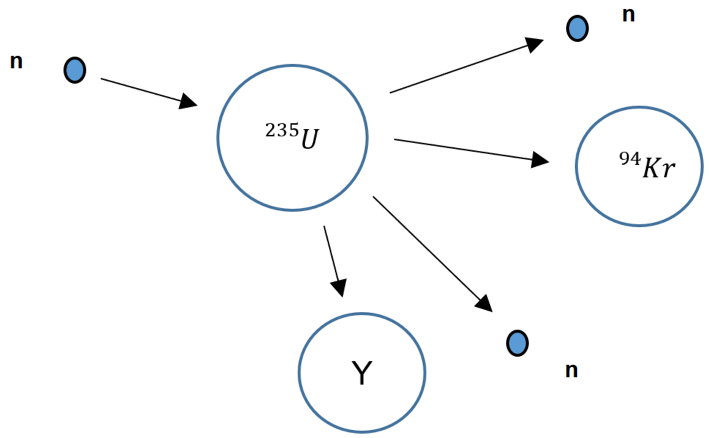
(d) After work, Jane goes to a swimming pool. Explain why she often feels colder when she gets out of the water, even if the temperature of the air and the water are the same.

(2 marks)

- in the pool, less molecules can evaporate compared to out of the pool,
- As a result, more heat is removed via evaporative cooling outside of the pool which will reduce the skin temperature.

Question 12 **(16 marks)**

Nuclear reactors rely on energy being released from the splitting of heavy nuclei and releasing energy to generate electricity. The diagram below shows one possible event that can occur in a reactor: a neutron, **n**, being absorbed by a Uranium-235 atom. The remaining neutrons then continue to react with other Uranium-235 atoms.



(a) Complete the following table by writing the correct physical terms. The first term has been done for you.

(3 marks)

Descriptions	**Physical Term**
A neutron collides with a Uranium nucleus and is absorbed.	Neutron capture
The atom splits into different two atoms and two neutrons.	Fission
The released neutrons continue to be absorbed by other Uranium-235 nuclei.	Chain reaction
The condition where one neutron is released for every one neutron being absorbed.	Critical / critical mass

(b) Predict what substance **Y** be. Write the symbol of the substance, its atomic number and mass number in a correct format.

(2 marks)

Mass number = 235 + 1 – (94 + 2) = 140

$^{140}_{56}\mathrm{Ba}$

(c) If the Krypton-94 continues to decay and release a beta negative particle. Write the full nuclear equation for this decay.

(2 marks)

$^{94}_{36}\mathrm{Kr} \rightarrow {}^{0}_{-1}\beta + {}^{94}_{37}\mathrm{Rb} + {}^{0}_{0}\bar{\nu}$ -1 mark for each error/omission

In the reactor, the neutrons need to be slowed down to increase the rate of energy being released.

(d) State the name of the part of the nuclear reactor that enables this to occur.

(1 mark)

Moderator

If too much energy is being released, there is a safety mechanism that can be inserted into the reactor to slow down the power being generated in the reactor.

(e) State the part of the nuclear reactor that enables this and explain how it functions.

(3 marks)

- Control rod
- Are able to absorb neutrons in the reactor
- And reduce the rate of neutron capture / criticality

(f) A typical event releases an average 215 MeV. If the reactor is producing a power of 1.50 MW, determine the average number of events per second that must be occurring in the reactor.

(5 marks)

$E = 215 \times 10^{6} \times 1.60 \times 10^{-19}$ (1)

$= 3.44 \times 10^{-11}$ J / event (1)

Number of event / s = Power / [Energy/event] (1)

$= \frac{1.50\times10^{6}}{3.44 \times10^{-11}}$ (1)

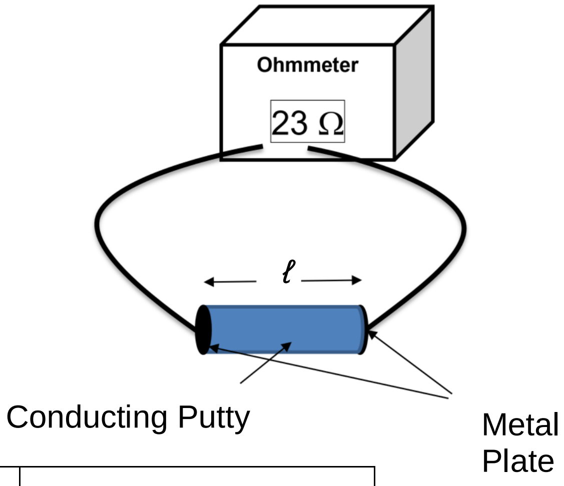
$= 4.36 \times 10^{16}$ events per second (1)

End of Section Two

Question 13 **(24 marks)**

An experiment is carried by Jamie to investigate how the resistance of a fixed volume of conducting putty varied with its length. This conducting putty is a soft material that be easily shaped into different lengths. The experiment apparatus is shown below.

Jamie conducts the experiment and records the result in the table below. Note that one column is deliberately left blank for further analysis.



$\boldsymbol{\ell}$ (cm)	$\boldsymbol{R}$ (Ω)	$\boldsymbol{\ell}^2$ (cm^2)
6.0	25	36 (2 sig fig)
11.0	60	121
13.5	110	182
17.0	180	289
22.5	280	506
25.0	370	625

All values in the column are correct
All values are corrected to number sf
Column heading and units correct

Jamie discovered that the suggested resistivity of the conducting putty, ρ (pronounced *rho*), is given by the formula:

$$\rho = \frac{(\boldsymbol{R} - R_o)V}{\boldsymbol{\ell}^2}$$

where $\boldsymbol{R_o}$ is the resistance of the connecting wires and ***V*** is the volume, in cm^3, of the conducting putty.

(a) For this experiment, state: (2 marks)

i) Dependent variable: Resistance (in Ω)

ii) One controlled variable: Same volume of putty (or similar)

The formula on the previous page can be rearranged as: $\boldsymbol{R} = \frac{\rho}{V}\boldsymbol{\ell}^2 + R_o$

(b) Show clear working to demonstrate how the formula can be established.

(3 marks)

$$\rho\ell^2 = RV - R_oV$$

$$\rho\ell^2 + R_oV = RV$$

$$\frac{\rho\ell^2}{V} + \frac{R_o\cancel{V}}{\cancel{V}} = \frac{R\cancel{V}}{\cancel{V}}$$

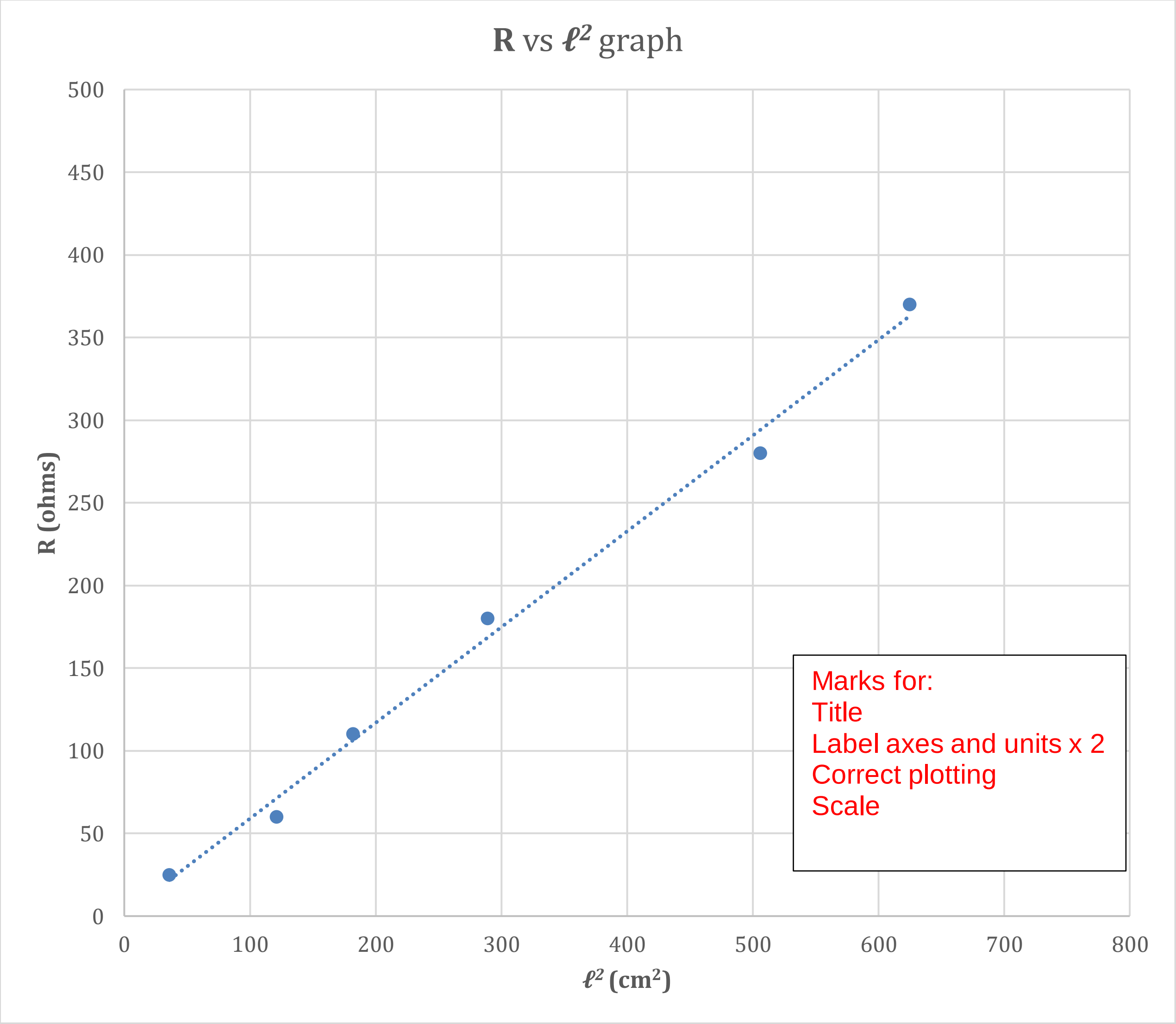
$$R = \frac{\rho}{V}\ell^2 + R_o$$

(c) Calculate and record values of $\boldsymbol{\ell}^2$ in the table on the previous page. State your answer to appropriate number of significant figures.

(3 marks)

(d) Plot a graph of ***R*** vs $\boldsymbol{\ell}^2$ below. If you make a mistake, spare graph paper is on page 29.

(5 marks)



Marks for:
Title
Label axes and units x 2
Correct plotting
Scale

(e) Use your data to obtain the line of best fit.

(1 mark)

(f) Hence, calculate the gradient of the line of best fit. Include the unit.

(4 marks)

Use two points from the line of best fit. - 1 mark
Showing rise over run.
Equation – 1 mark, work – 1 mark
Gradient = 0.58 (± 0.1) Ω cm^{-1} - 1 mark

(g) Assume the volume of the putty is 15.0 cm^3. Use your gradient in part (f) to calculate resistivity of the conducting putty, ρ. The unit of the conductivity is not required.

(3 marks)

$$R = \frac{\rho}{V}\ell^2 + R_o$$

$$\frac{\rho}{V} = 0.58$$

$$\rho = 0.58 \times 15$$

$$= 8.7$$

(h) Describe and explain one possible source of error for this experiment.

(2 marks)

- The putty may not exactly cylindrically shaped.
- This will cause uneven distribution of resistance.

OR

- Internal resistance of wire.
- The reading is combination of both wire and putty.