Christ Church Grammar School

Science Department
Year 11 Physics

Semester 1 Examination, 2021

Question/Answer booklet

PHYSICS UNIT 1

SECTION ONE

SHORT ANSWER

Fix student label here

Student Name: ___________________________________

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 fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination, drawing templates, drawing compass and a protractor.

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	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available		Percentage of exam	Percentage achieved
Section One: Short Answer	9	9	50		56	30	
Section Two: Problem Solving	6	6	80		78	50	
Section Three: Comprehension	1	1	20		17	20	
						100	

Instructions to candidates

1. The rules of conduct of Christ Church Grammar School assessments are detailed in the Reporting and Assessment Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. 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.

5. Information for questions has been repeated on the removable Information Booklet which has been inserted inside the front cover of this booklet so that you can refer more easily to it while answering the questions. Do not write your answers in the Information Booklet.

6. Provide all answers to three significant figures unless otherwise instructed.

Section One: Short Response **30% (56 marks)**

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

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

When estimating numerical answers, show your working or reasoning clearly. Give final answers to 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.

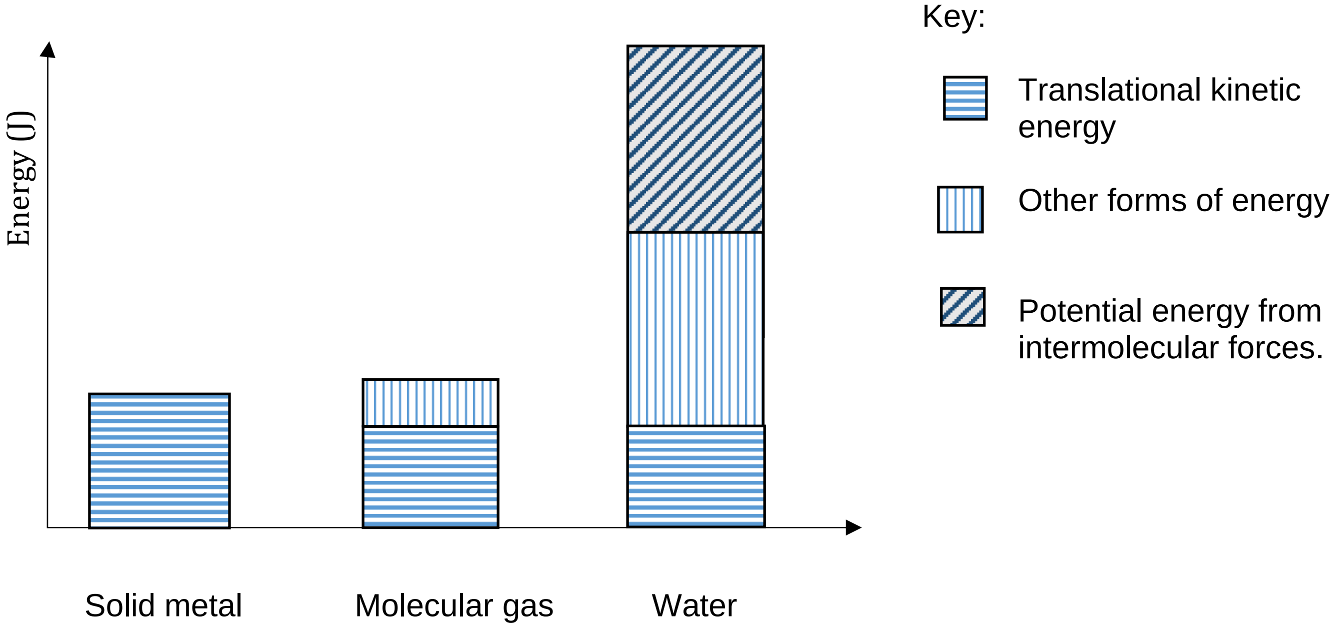
Suggested working time: 50 minutes.

Question 1 **(5 marks)**

A hockey player attains a high metabolic rate during a game and much of the excess heat generated must be lost by sweating. During such a game, he develops excess heat at the rate of 568 joules per second. If 90.0 % of this heat must be lost by sweating, calculate the mass of sweat produced in a 25.0 minute session. Assume all of the sweat evaporates and the latent heat of vaporisation of sweat is 2.26×10^6 J kg^{-1}.

Question 2 **(5 marks)**

Consider 3 systems below containing the same mass but different substances as listed on the chart below.



(a) Complete the table below by comparing the different features of each system shown above. Use the words "equal, higher, lower or medium" in the spaces below.

(2 marks)

Feature	Solid metal	Molecular gas	Water
Temperature of system			
Internal energy			

(b) Explain why the temperature of the water system differs to that of the solid metal system, even though it contains more energy.

(3 marks)

Question 3 **(7 marks)**

During an alpha decay of americium-241 mass is converted to energy which is shared as kinetic energy amongst the daughter particle and the alpha particle.

(a) Write an equation for this reaction.

(1 mark)

(b) Calculate the mass defect of the event in kilograms. Hint; you will not require all of the masses in the table below.

(4 marks)

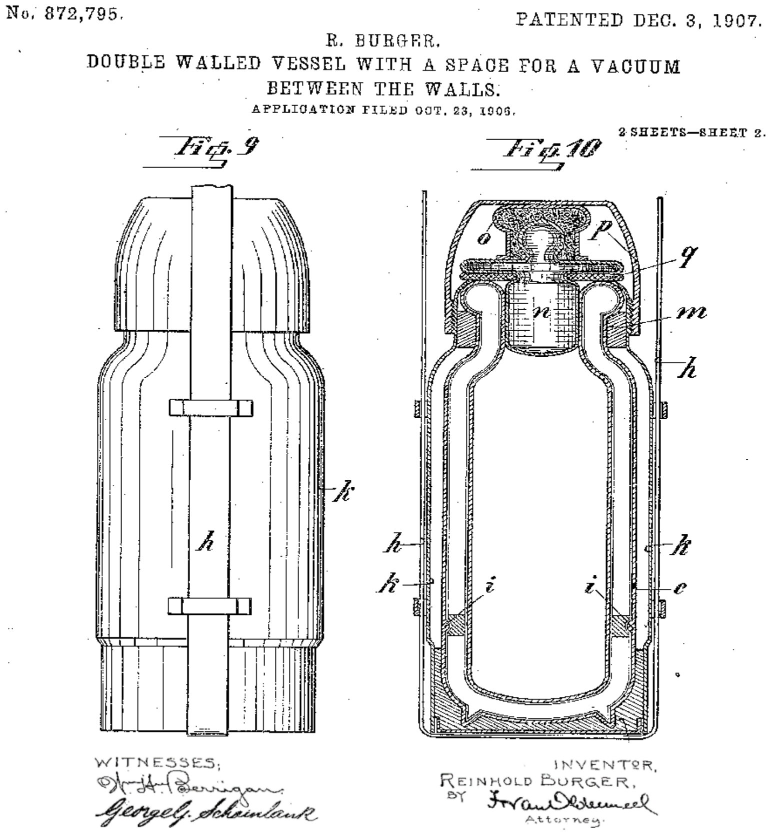
Particle	**Atomic mass (u)**
Americium-241	241.05683
Americium-237	237.05000
Neptunium-237	237.04817
Neptunium-241	241.05825
Alpha	4.00150
Electron	0.00054857
Helium	4.002602

(c) State and explain which of the isotopes, parent or daughter, is likely to have the highest binding energy per nucleon. You do not require a calculation.

(2 marks)

Question 4 **(6 marks)**

The following diagram shows the original patent for a vacuum thermos flask.

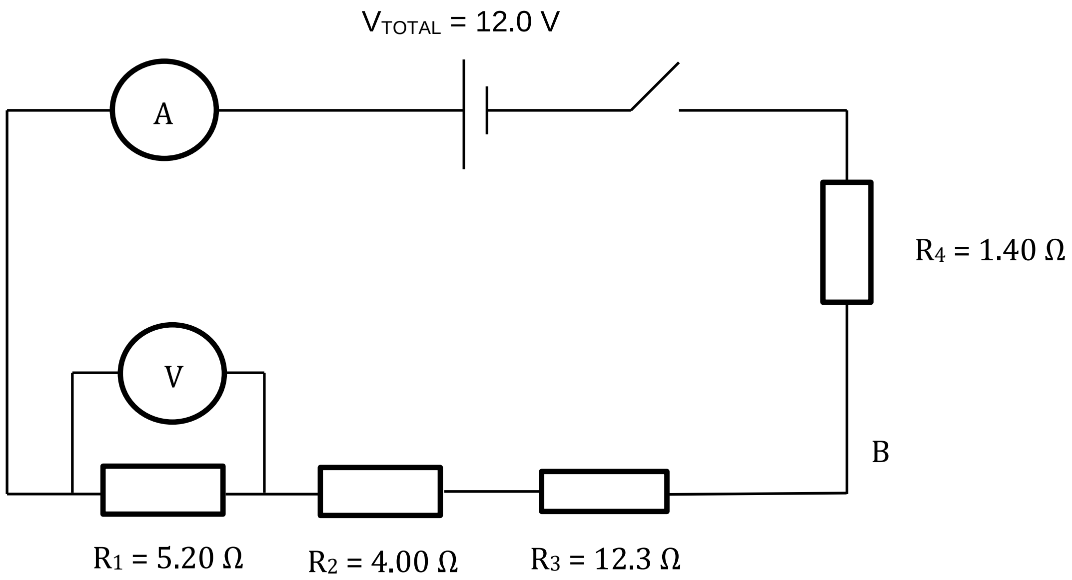


n :plastic stopper
i :foam sponges
p : plastic cup
q : rubber seal
k : evacuated space
h : white walled plastic
c : silvered inner liner

State and explain three design features that reduce heat loss. Your response must include all three heat transfer processes.

Question 5 **(8 marks)**

Consider the series circuit below:



(a) Determine the reading on the ammeter.

(4 marks)

(b) Determine the reading on the voltmeter.

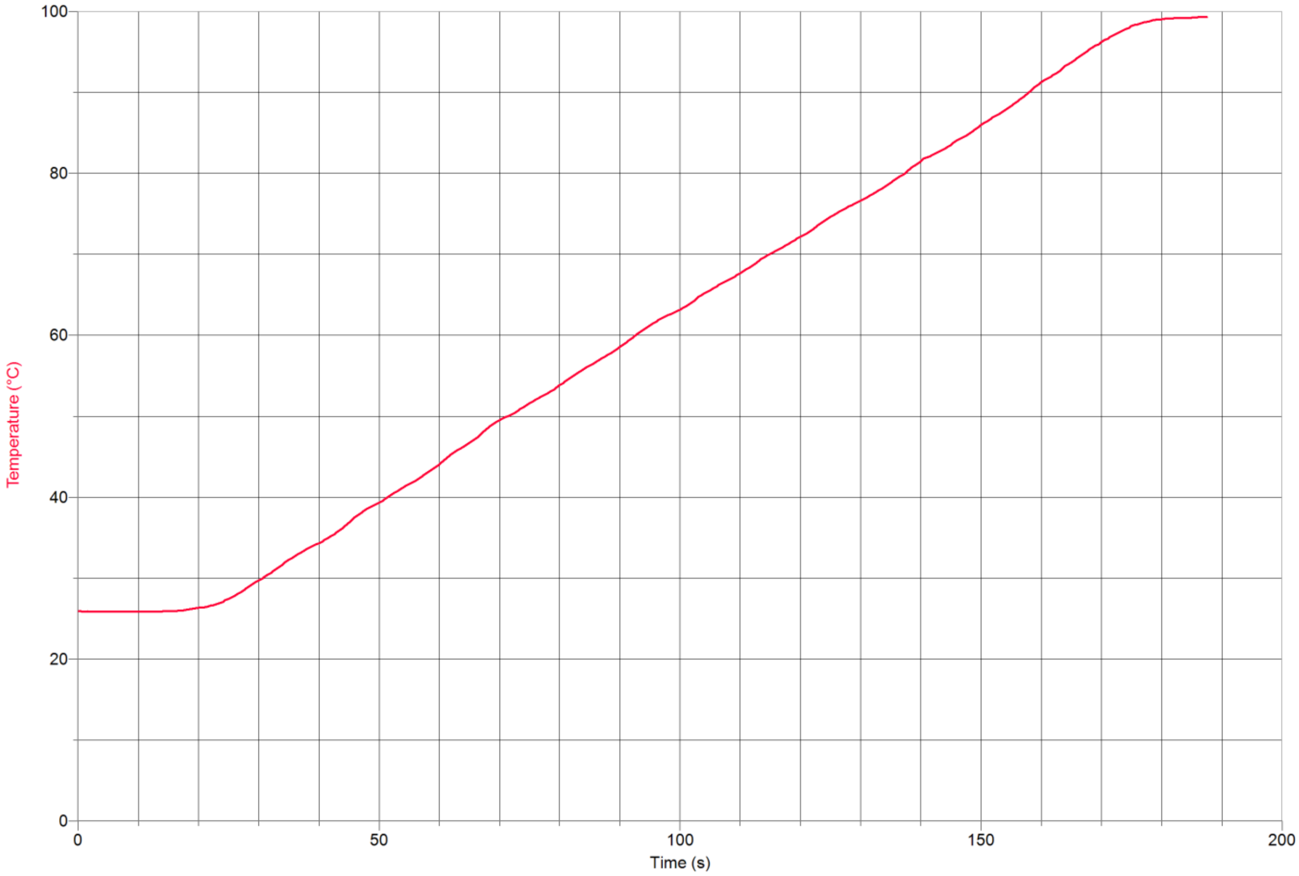
(2 marks)

(c) State and explain what the ammeter would read if it were placed at point B.

(2 marks)

Question 6 **(6 marks)**

The following graph shows how the temperature of 500 grams of water varies with time as it is heated with an electrical heating element.



(a) Calculate the gradient of the graph for the period of time where the temperature is changing.

(3 marks)

(b) Use the gradient to calculate the effective power of the heating element.

(3 marks)

Question 7 **(4 marks)**

A 0.900 kg aluminium tray is removed from a hot industrial furnace and 245 grams of water at 21.0 °C is immediately placed on it. It was discovered after reaching thermal equilibrium of 36.5 °C that 25 grams of water had vaporised and turned to steam at 100 °C, thus leaving the system and that the remaining 220 grams reached the equilibrium temperature. Assuming no other heat losses from the system, calculate the initial temperature of the aluminium tray.

c_{Al} = 900 J kg^{-1} K^{-1}
c_{water} = 4180 J kg^{-1} K^{-1}

Question 8 **(8 marks)**

There are similarities and differences in the nature and properties of alpha beta and gamma radiation.

(a) Describe what is occurring in the nucleus when a radionuclide undergoes beta + decay.
(2 marks)

After an alpha or a beta emission, the atom of the new isotope is often left in a *metastable* state.

(b) Explain what is meant by metastable and state what the new isotope must eventually do.
(2 marks)

(c) Compare the properties of alpha, beta and gamma radiation by completing the table below.
(4 marks)

	Emission speeds (Low medium high)	**Penetrating ability** (Low medium high)	**Charge**	**Mass (kg)**
Alpha				
Beta				
Gamma				

Question 9 **(7 marks)**

Determine each of the unknown particles in the nuclear equations below. If the particle is an isotope, provide its full name.

(4 marks)

(a) $^{45}_{20}Ca \rightarrow {}^{45}_{21}Sc$ + ______ + $^{0}_{0}\bar{\upsilon}$ particle: ______________________

(b) $^{11}_{5}B + {}^{4}_{2}\alpha \rightarrow {}^{14}_{7}N$ + ______ particle: ______________________

(c) $^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{140}_{38}Sr$ + ______ + $2{}^{1}_{0}n$

particle: ______________________

(d) $^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{1}_{0}n$ + ______ particle: ______________________

There are physical limitations that prevent the particle interaction in (d) from occurring.

(e) Describe why the limitations occur and how they are overcome in practical applications of the particle interaction.

(3 marks)

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End of Section One

Supplementary page

Question number: ____________________

Christ Church Grammar School

Science Department
Year 11 Physics

PHYSICS UNIT 1

SECTION TWO

PROBLEM SOLVING

Semester 1 Examination, 2021

Question/Answer booklet

Section Two: Problem Solving **50% (78 marks)**

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

Suggested working time for this section is **80 minutes**.

NAME:____

TEACHER: CJO JRM PCW
(please circle)

Question 10 **(15 marks)**

The gas hot water system breaks in a person's home and they wish to pour a hot bath. They fill a bathtub with 125 kg of water at 24.0 °C. They decide to use an electric kettle that can boil 2.00 kg of 24.0 °C water at a time and pour this boiling water into the bathtub to raise its temperature. The kettle is rated at 2400 W and is supplied by 240 V AC power.

(a) Calculate the electrical resistance of the kettle when it is operating.
(3 marks)

(b) Calculate the charge that flows through the kettle element in a time of 45.0 seconds.
(4 marks)

(c) Calculate the time taken for the kettle to bring the water to its boiling point.

(3 marks)

The person decides that they only have the patience to boil 5 kettles of water before they have had enough and want to have their bath.

(d) Calculate the final temperature of the bathtub.

(4 marks)

(e) State one valid assumption about any of the calculations you have made in this question.

(1 mark)

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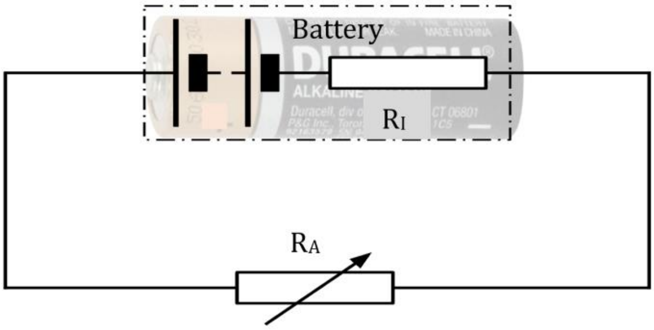
Question 11 **(14 marks)**

A cell in a circuit supplies electrical energy to other components of the circuit. If the cell has internal resistance, some of the electrical energy produced is wasted due to heating inside the cell. The internal resistance in the cell can be treated as a resistor that is in series with rest of the circuit. As the battery's internal resistance increases, it has said to have gone "flat", as it can no longer provide a suitable EMF (total voltage provided) to the circuit.



An interesting observation is that as the current through the circuit increases, the EMF provided by the battery decreases. Consider a cell connected to a resistance R_A. The cell's EMF is E and its internal resistance is R_I. Given Ohm's Law, current can be expressed as:

$E = IR_A + IR_I$ So: $IR_A = -IR_I + E.$

Or: $V = -R_I.I + E.$

Students conduct an experiment to test the internal resistance of two 1.5 Volt batteries to determine if they are flat or not. They use a variable resistor to vary the total resistance of the circuit and obtain the following voltages (V) across the resistor as provided in the table.

	Voltage (V)	
Current (A)	Battery 1	Battery 2
0.00	1.50	1.50
0.20	1.32	1.45
0.40	1.12	1.40
0.60	0.93	1.36
0.80	0.73	1.32
1.00	0.55	1.25

(a) On the graph on the following page, plot a graph of Voltage vs Current for both batteries on the same set of axes. A spare grid is provided on the end of this Question/Answer booklet. If you need to use it, cross out this attempt and clearly indicate that you have redrawn it on the spare page.

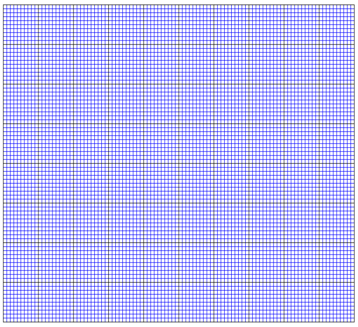
(5 marks)

(b) Calculate the gradient of both graphs.

(4 marks)

(c) Hence, determine the internal resistance of both batteries and state which battery is 'flatter'.

(2 marks)



(d) Explain why testing the voltage across a flat 1.50 V battery with a voltmeter might display a voltage of 1.50 V even though it is flat.

(3 marks)

Question 12 **(13 marks)**

Radon-222 (half-life = 3.83 days) is a naturally occurring inert gaseous isotope of radon that forms from the alpha decay of radium-226 (half-life 1.6 x10^3 years). Radium-226 is found in many rocks and building materials. Because radon-222 is a gas and its decay releases tissue-damaging radiation, it can cause lung cancer when inhaled into the lungs over a prolonged period

(a) Write the equation for the alpha decay of radium-226 to radon-222.

(2 marks)

(b) Radon-222 also undergoes alpha decay. Explain why these alpha particles are so much more dangerous to humans than those released by the parent radium.

(3 marks)

A sample of radon-222 was measured to have an initial activity of 1.40 kBq.

(c) Calculate the activity of the sample 2.00 weeks later.

(3 marks)

Consider a sample of radon that was trapped in a closed room. A 78.0 kg person stayed in the room for eight hours. In that time their lungs, of mass 2.40 kg absorbed energy released by alpha particles equal to 0.160 J.

(c) Determine the localised absorbed dose this person could receive.

(2 marks)

(d) Determine the maximum localised dose equivalent of this radiation.

(2 marks)

The table below describes the approximate physiological effects of different types of dose equivalents

Whole Body Dose (mSv)	**Effect**
0 – 100	No observable effect
100 – 1000	Slight to moderate decrease in white blood cell counts
350 - 500	Temporary Sterility women; men
1000- 2000	Significant reduction in blood cell counts, brief nausea and vomiting. Rarely fatal.
2000 – 5000	Radiation sickness - Nausea, vomiting, diarrhoea, hair loss, skin rashes, severe blood damage, bone marrow damaged, hemorrhage, fatalities.
Localised Dose	**Effect**
0 – 100	No observable effect
100 – 300	Decrease in red blood cell count. Inflammation of tissue
300 - 800	Damage to capillaries and smaller blood vessels.
1000- 2000	Significant hemorrhaging of large blood vessels. Significant tissue atrophy
2000 – 5000	Severe damage to tissues, major hemorrhaging, organ and tissue failure.

Table 1: Physiological Effects of Radiation on an Adult Human

(e) State the physiological effects that the person might receive after being in this room for 8 hours.

(1 marks)

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Question 13 **(11 marks)**

A group of year 11 physics students are reminiscing about their Venture trip. On this trip they rugged up warmly wearing woolen jumpers and thermal underwear and used a *trangia* (methylated spirit camp stove) to cook their pasta dinner. For the particular camp stove used, only 35.0% of the energy released in burning the fuel actually went in to heating the water in the pot on the stove.

(a) Calculate how much heat was required to raise the temperature of 0.750 kg of water from 15.0 °C to 100.0 °C.

(2 marks)

0.250 kg of the water boiled away while the pasta was cooking, requiring a further 1,688 kJ of energy from the trangia.

(b) If 1.00 g of methylated spirit releases 46.0 kJ, calculate the mass of methylated spirit used in the cooking of dinner.

(3 marks)

(c) Explain how woolen clothing and thermal underwear helped keep the students warm. (3 marks)

The students observe that in the morning after a cold night, a lot of dew (water) was present on the surfaces of their *hootchies* (tent).

(d) Explain the physical processes of how the water appeared on the surfaces of the hootchies. (3 marks)

Question 14 **(12 marks)**

The data sheet for the radioisotope lead-210 is shown below:

RADIONUCLIDE SAFETY DATA SHEET
NUCLIDE: Pb-210/Bi-210/Po210 FORMS: SOLUBLE

PHYSICAL CHARACTERISTICS:
HALF-LIFE: 20.4 years TYPE DECAY: beta -, beta -, alpha (Pb, Bi and Po, respectively.)

Energies: beta - (Pb) 0.061 MeV, beta - (Bi) 1.16 MeV, alpha (Po) 5.35 MeV

Hazard category: C - level (low hazard): .0001mCi to 0.1 mCi
B - level (Moderate hazard): > 0.01 mCi to 1.0 mCi
A - level (High hazard): greater than 1.0 mCi

EXTERNAL RADIATION HAZARDS AND SHIELDING:
The external exposure hazard is from the Bi-210 beta particle (99%) with maximum energy of 1.16 MeV. The maximum range of these betas in various materials is as follows: Air ~100 inches, Water ~0.17 inches, Glass ~0.07 inches. The beta dose rate at 1 cm from 1 mCi (from the Bi-210 in equilibrium) is approximately 310,000 mrad/hr.

HAZARDS IF INTERNALLY DEPOSITED:
This is a highly radiotoxic material. The principal hazard from Pb-210 occurs if the material is allowed into one's body. The Campus Annual Limit of Intake (oral), based upon 10% of the dose limit to bone surfaces, is 0.054 uCi. The effective half-life in the body is 1200 days. The campus ALI for inhalation is 0.0025 microcuries also based upon dose to bone surfaces.

(a) Write the 3 separate nuclear equations for the decays of lead-210, bismuth-210 and polonium-210.

(3 marks)

A curie (Ci) is another unit of radioactivity. Originally it was defined as the activity of 1 gram of radium-226. 1 Ci = 3.70×10^{10} Bq = 37.0 GBq.

(b) Calculate the activity range, in Bq, of hazard category C (low hazard)

(3 marks)

(c) Explain why the external exposure hazard is from bismuth-210 and not the other two radioisotopes.

(2 marks)

The millirad (mrad) is a unit of absorbed radiation dose, defined as 1 milirad = 1.00×10^{-5} Gy.

(d) Calculate the dose equivalent if a scientist stood 1.00 cm from 1.00 mCi of Bi-210 for a time of 0.200 hours.

(4 marks)

Question 15 **(13 marks)**

Nuclear power reactors and nuclear weapons both involve the release of nuclear energy by inducing fission. Neutron capture in a nuclear reactor or weapon primarily occurs with slow-moving neutrons. The chain reaction that occurs in the nuclear reactor is a 'controlled' chain reaction. This contrasts with the 'uncontrolled' chain reaction which occurs when a nuclear weapon is detonated.

(a) Name the structure in the nuclear fission reactor that is responsible for 'controlling' the chain reaction. Explain how this structure achieves this.

(3 marks)

In a 'gun-type' nuclear bomb, prior to detonation, two sub-critical samples of the fissile material are separated at either end of a long tube inside the bomb (see below). The bomb is carried on a long-range missile and is detonated at a determined altitude above the target. Upon detonation, conventional explosives force the two sub-critical samples together and a massive explosion results.

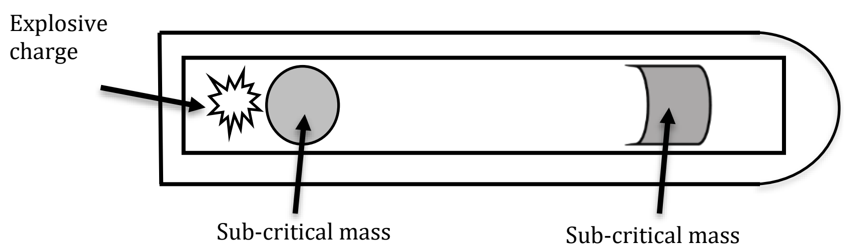


Figure 1: A basic diagram of a 'gun-type' nuclear bomb

(b) Define the terms 'critical mass' and 'sub-critical mass' and use them to explain the operation of the nuclear bomb described above.

(4 marks)

(c) State and explain one similarity and one difference (not mentioned in the first paragraph) of the processes occurring in a nuclear bomb and a nuclear power plant.

(4 marks)

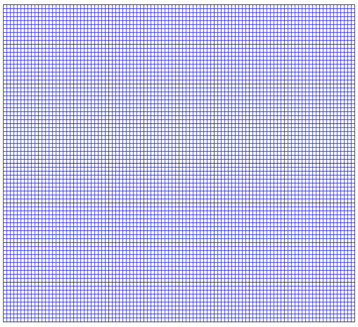
Aside from the initial immense pressure wave, one of the greater impacts of the bomb is the 'nuclear fallout'; fission fragment particulates that fall back down to the surface of the Earth. These fission fragments can remain highly radioactive for many decades after the blast and have ongoing adverse effects to organisms that inhabit that area.

(d) Explain why the fission fragments are radioactive and why they might remain active for many decades after the blast.

(3 marks)

End of Section Two

Spare grid



Supplementary page

Question number: ___________________

Christ Church Grammar School

Science Department
Year 11 Physics

PHYSICS UNIT 1

SECTION THREE

COMPREHENSION

Semester 1 Examination, 2021

Question/Answer booklet

Section Three: Comprehension **20% (17 marks)**

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

Suggested working time for this section is **20 minutes**.

NAME:____

TEACHER: CJO JRM PCW
(please circle)

Question 16 **(17 marks)**

Clocks in rocks
(Adapted from Lead-Lead Dating – Wikipedia)

Planet Earth doesn't have a birth certificate to record its formation, which means scientists spent hundreds of years struggling to determine the age of the planet. So, just how old is Earth?

Earth is currently estimated to be 4.50 billion years old, plus or minus about 50 million years. Scientists have scoured the Earth searching for the oldest rocks to radiometrically date; using the relative amounts of known radioisotopes found in rocks. In northwestern Canada, they discovered rocks about 4.03 billion years old. Then, in Australia, they discovered minerals about 4.30 billion years old. Researchers know that rocks are continuously recycling, due to the rock cycle, so they continued to search for data elsewhere. Since it is thought the bodies in the solar system may have formed at similar times (in regions known as planetesimals), scientists analysed moon rocks collected during the moon landing and even meteorites that have crash-landed on Earth. Both of these materials dated to between 4.40 and 4.50 billion years (4.40 – 4.50 Gyr).

Radiometric dating is a technique which is used to date materials such as rocks, in which small traces of radioisotopes were introduced into the rock sample when they were formed. The method compares the abundance of a naturally occurring radioisotope or "parent isotope" within the material to the abundance of its decay products or "daughter isotope", which form at a known constant rate of decay. Many rocks contain various isotopes of uranium which can decay via different decay series to stable isotopes of lead.

There are two stable daughter isotopes of lead that result from the radioactive decay of uranium in nature; they are Pb-206 and Pb-207. These daughter isotopes are the final decay products of uranium radioactive decay series beginning from U-238 and U-235 respectively. Pb-204 is the only *non-radiogenic* lead isotope: a stable isotope with no parent material forming it, and it doesn't decay to be the parent of another material.

With the progress of time, the final decay product accumulates as the parent isotope decays at a constant rate. This shifts the ratio of radiogenic Pb versus non-radiogenic Pb-204 ($^{207}Pb/^{204}Pb$ or $^{206}Pb/^{204}Pb$) in favor of radiogenic Pb-206.

The following values for the isotopes are given below:

$^{238}U \rightarrow {}^{206}Pb$ $t_{1/2} = 4.47 \times 10^9$ years (4.47 Gyr)

$^{235}U \rightarrow {}^{207}Pb$ $t_{1/2} = 0.70 \times 10^9$ years (0.70 Gyr)

^{204}Pb $t_{1/2} = 0.00$ years (stable)

Providing the sample contains enough traces of all 3 isotopes of lead, this "Pb-Pb" dating method can be simplified to an equation that can be used to determine the time since the sample was formed.

See next page

(a) Calculate the percentage uncertainty of the age of the Earth.

(2 marks)

The equations used in radiometric dating are formed from 4 main assumptions:

1. ***The sample is "closed".***

With respect to parent and daughter, if any parent isotope leaks in or if any daughter isotope leaks out of the sample then the ratio will not reflect the age of the sample. This can be difficult in certain rock types: Uranium atoms are water soluble and can easily *leak out* of a crystal lattice if there is sufficient water present. Whereas its daughter isotope; Thorium is the opposite, not wanting to be in solution and preferring to remain in a crystal lattice, resisting quite strongly. Metamorphic rocks which are made under immense heat and pressure can affect the amount of parent and daughter isotopes present in the sample throughout the eons of time.

2. ***The half-life of the parent-daughter pairs are constant.***

This is well established across the scientific community. And most radio-isotopes half-lives are now known to a high degree of precision.

3. ***The age of the rock is old enough such that there are enough daughter isotopes to be detected within acceptable error.***

Some igneous rocks have been formed from volcanic and tectonic activity too recently and cannot be used. As well, Sedimentary rocks contain too many varieties of rock types and crystals and are generally not suitable.

4. ***The relative amount of parent-daughter ratio in the crystal is known at its formation.***

The ratio of daughter isotope to the non-radiogenic isotope is a constant in its chemical mixture to begin with. Comparing the two ratios of radioisotopes to Pb-204 will enable us to create a graph known as an *Pb-Pb isochron* graph. From this graph, the gradient can reveal the time that the sample was formed.

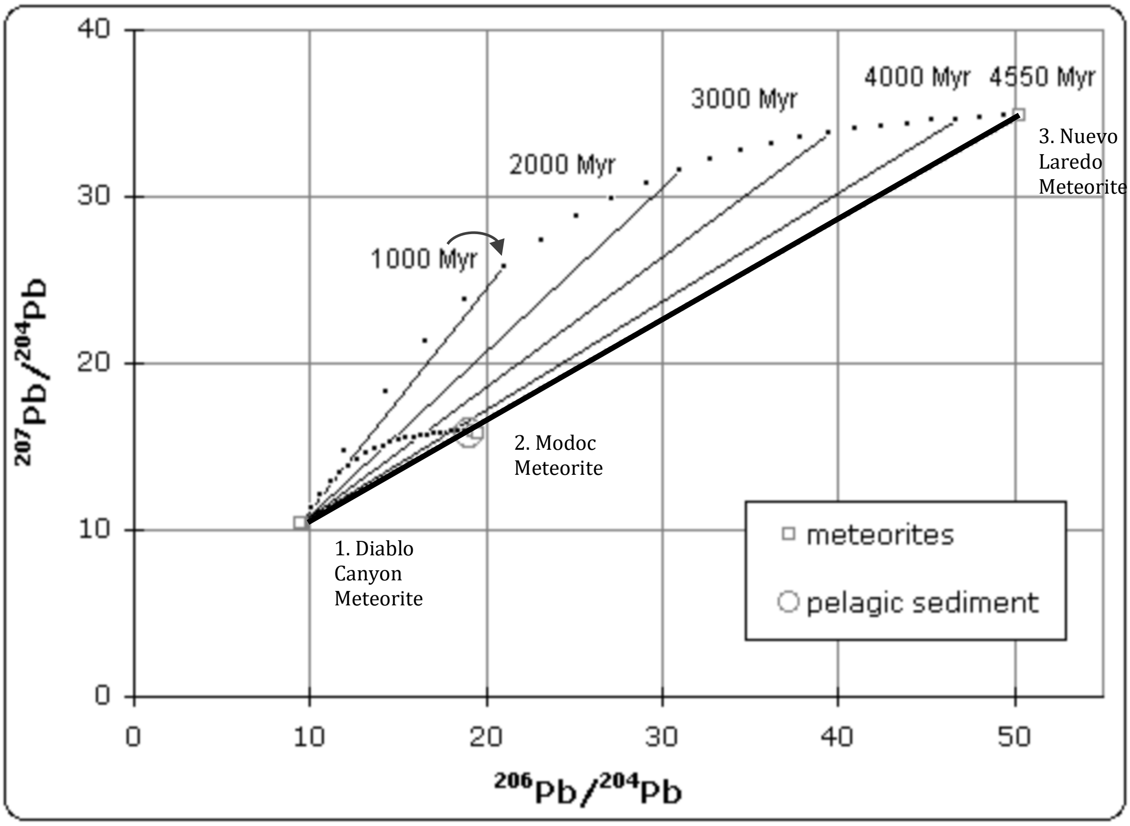


Figure 1: Original Isochron graph of Pb-Pb for collected meteorites and ocean floor sediment.

The Pb-Pb Isochron in Figure 1 represented a major breakthrough in the use of lead isochrons when it was published in 1956. It presented the analysis of three stony meteorites and showed that they fell on the same isochron. In addition, it showed that a sample of modern ocean (pelagic) sediment fell on the same isochron. Besides offering confirmation of the meteorite age that had been approached in many studies, it offered evidence that meteorites and the Earth are closely related and of the same age. It used a lead rich mineral from the Canyon Diablo meteorite as the standard. The isochron age was initially reported as 4.55 Gyr in 1956, but that became 4.50 Gyr with the application of the revised half-lives for the lead isotopes involved.

For questions (b), (c) and (d), make explicit reference to the relevant assumptions (provided on the previous page) used in radiometric dating to answer the questions below.

(b) State and explain which two rock types cannot be used and the most ideal rock type that can be used for isochron dating.

(3 marks)

(c) Explain why meteorites that fall to Earth can also be used to estimate the age of the Earth. (2 marks)

(d) Explain why the estimate of the age of the Earth was revised from 4.55 Gyr to 4.50 Gyr. (2 marks)

The bold line on the Isochron in figure 1 shows that the 3 stony meteorites and pelagic sediment all fall on a line which provides the currently accepted age of 4.50 Gy. The curved black dots show how the ratios of $^{207}Pb/^{204}Pb$ to $^{206}Pb/^{204}Pb$ change over time. Each black dot is a time interval of 200 million years (200 Myr).

Consider a sample of a stony meteorite that contained an initial measured ratio of $^{207}Pb/^{204}Pb$ to $^{206}Pb/^{204}Pb$ to be 10:10 (the start of the Pb-Pb isochron.)

(e) Use the isochron to estimate the $^{207}Pb/^{204}Pb$ to $^{206}Pb/^{204}Pb$ ratio after 1.4 Gyr. (2 marks)

A sample of U-235 was measured to have an activity of 1.45 mBq.

(f) Given the half of U-235 is 0.70×10^9 years, calculate its activity 4.50 Gyr ago.

(3 marks)

(g) Explain why the black dots curve away towards the horizontal axis.

(3 marks)

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End of Section Three

Supplementary page

Question number: ___________________

Supplementary page

Question number: ____________________