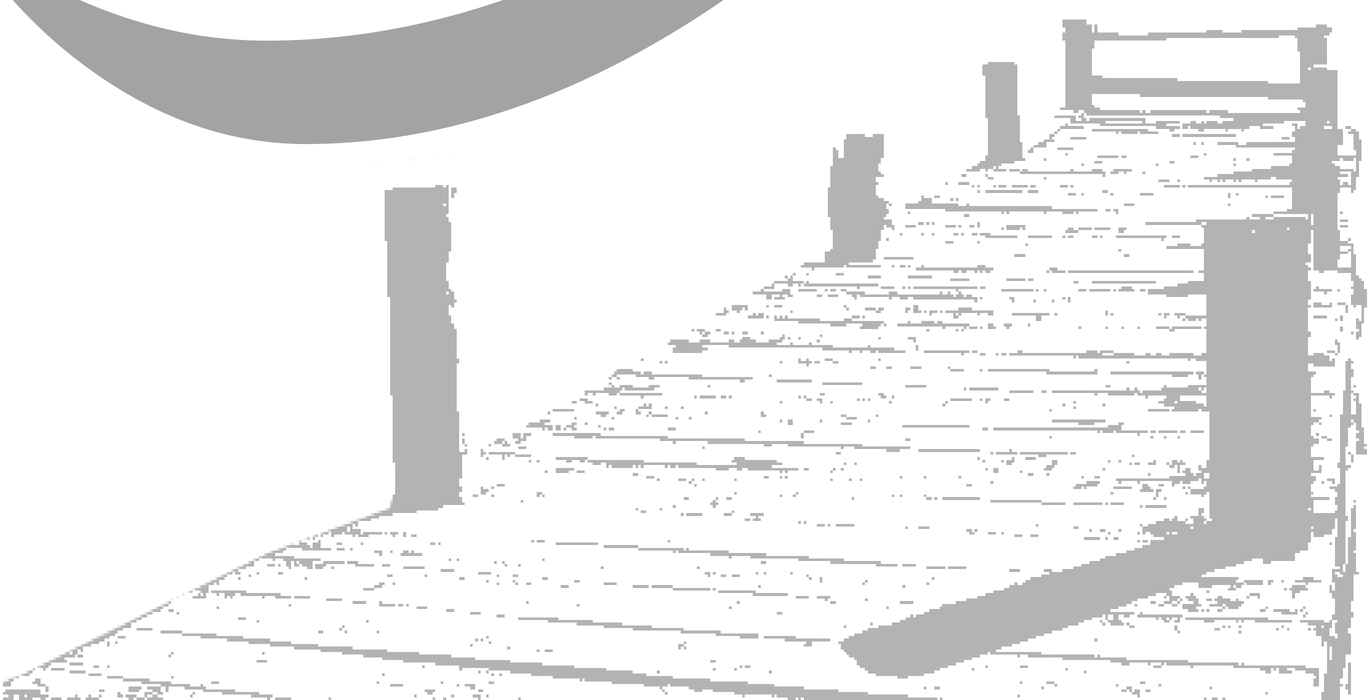
GCE
AS and A Level

Physics B: Physics In Context

AS exams 2009 onwards
A2 exams 2010 onwards

Unit 5: Approved specimen question paper

Version 1.1



Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
2010
Advanced Examination

version 1.1

PHYSICS IN CONTEXT PHYB5
Unit 5 Energy Under the Microscope:

Module 1 Matter Under the Microscope
Module 2 Breaking Matter Down
Module 3 Energy from the Nucleus

SPECIMEN PAPER

Time allowed: 1 ¼ hours

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- A *Formulae and Data Booklet* is attached as a loose insert.

Information

- The maximum mark for this paper is 100.
- The marks for the questions are shown in brackets.
- You are reminded of the need for good English and clear presentation in your answers. You will be assessed on your quality of written communication where indicated in the question.

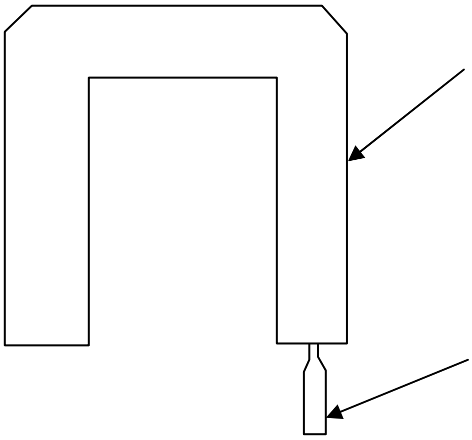
For Examiner's Use			
Number	Mark	Number	Mark
1		4	
2		5	
3		6	
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

LEAVE MARGIN BLANK

Answer **all** questions in the spaces provided.

1 A life jacket inflates using gas released from a small carbon dioxide cylinder. The arrangement is shown in **Figure 1**.

Figure 1



(a) The cylinder initially contains 1.7×10^{23} molecules of carbon dioxide at a temperature of 12^{o}C and occupying a volume of 3.0×10^{-5} m^3.

(i) Calculate the initial pressure, in Pa, in the carbon dioxide cylinder.

(ii) When the life jacket inflates, the pressure falls to 1.9×10^5 Pa and the final temperature is the same as the initial temperature. Calculate the new volume of the gas.

(iii) Calculate the mean molecular kinetic energy, in J, of the carbon dioxide in the cylinder.

(6 marks)

(b) (i) Explain, in terms of the kinetic theory model, why the pressure drops when the carbon dioxide is released into the life jacket.

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(ii) Explain why the kinetic theory model would apply more accurately to the gas in the inflated life jacket compared with the gas in the small cylinder.

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(6 marks)

(c) Explain, in terms of the first law of thermodynamics, how the temperature of the gas in the system can be the same at the beginning and the end of the process.

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(4 marks)

Total 16 marks

2 (a) $^{212}_{83}Bi$ can decay into $^{208}_{82}Pb$ by a β^- followed by an α decay, or by an α followed by a β^- decay. One or more of the following elements is involved in these decays:

$$_{80}Hg,\ _{81}Tl,\ _{84}Po,\ _{85}At.$$

Write out decay equations showing each stage in both of these decays.

First decay path	**Second decay path**

(6 marks)

(b) (i) Describe how you would perform an experiment that demonstrates that gamma radiation obeys an inverse square law.

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(ii) Explain why gamma radiation obeys an inverse square law but alpha and beta radiation do not.

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(9 marks)

Total 15 marks

3 (a) An example of a fission reaction is given in the equation below.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$$

Calculate the energy released in the fission process. Give your answer in J.

Mass of a neutron	=	1.0087 u
mass of $^{235}_{92}U$	=	235.0439 u
mass of $^{236}_{92}U$	=	236.0456 u
mass of $^{92}_{36}Kr$	=	91.9262 u
mass of $^{141}_{56}Ba$	=	140.9144 u

(5 marks)

(b) (i) State and explain the function of the moderator in a nuclear reactor.

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(ii) What material is used as a moderator in a pressurised water reactor?

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(iii) Give two properties of the material you have named in part (ii) that make it suitable for use as a moderator.

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(5 marks)

(c) (i) State how control is achieved in a pressurised water reactor.

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(ii) What material is used for control in a pressurised water reactor?

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(iii) Give a property of the material you have named in part (ii) that make it suitable for use as a control material.

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(4 marks)

(d) Some groups of people maintain that the use of fission power for electricity generation is ethically correct while others maintain the opposite. Examine the ethical arguments for and against the use fission power. Ignore cost considerations.

The quality of your written answer will be assessed in this question.

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(6 marks)

(e) The generation of electricity by nuclear fusion is considered to be potentially safer than fission power. State **two** reasons why this may be the case.

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(2 marks)

Total 22 marks

4 (a) (i) Define the capacitance of a capacitor.

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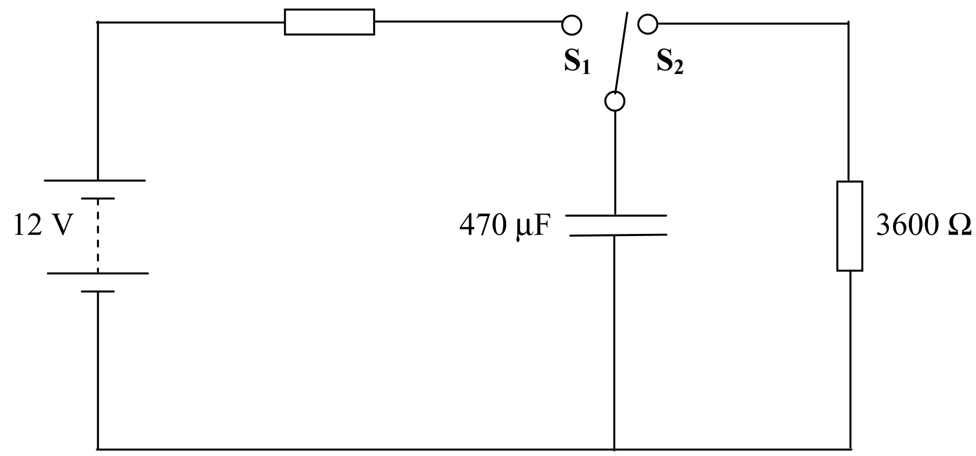
(ii) Calculate the charge, in C, stored on a 470 μF capacitor which has a potential difference of 2.3×10^2 V across it.

(2 marks)

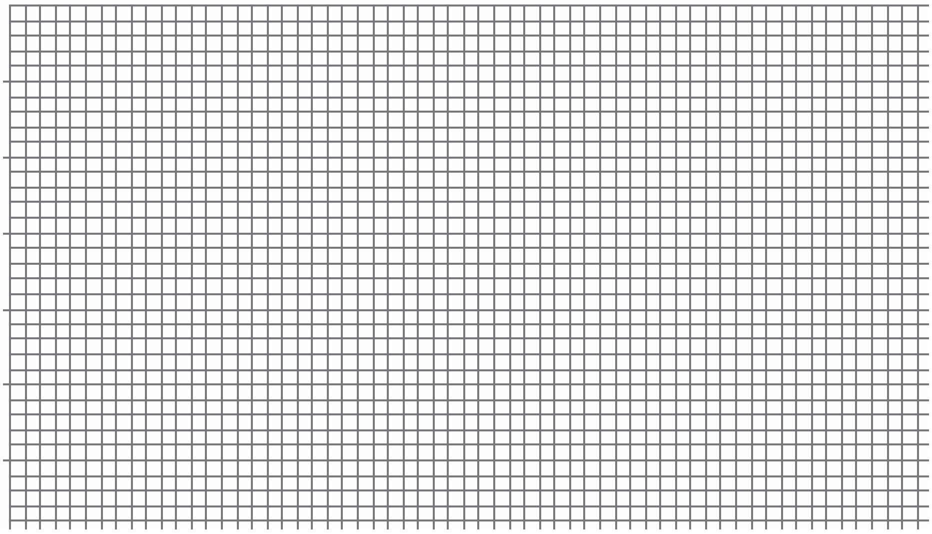
(b) A 470 μF capacitor is connected in a circuit which enables it to charged when the switch is in position $\mathbf{S_1}$ and discharged when the switch is in position $\mathbf{S_2}$. The arrangement is shown in **Figure 2**.

Figure 2



(i) Calculate the time constant of the discharge circuit when the switch is in position $\mathbf{S_2}$.
Give your answer in s.

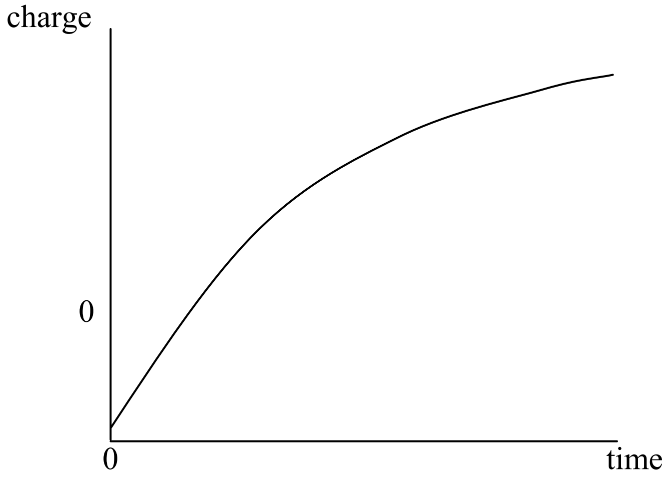
(ii) The capacitor is fully charged and then discharged. On the axes below, mark appropriate scales and draw a graph to show the variation of the potential difference across the capacitor with time for the discharge of the capacitor.



(4 marks)

(c) **Figure 3** shows the variation of charge with time for the charging of the capacitor.

Figure 3



Explain why the charge across the capacitor changes in the way shown by the graph.

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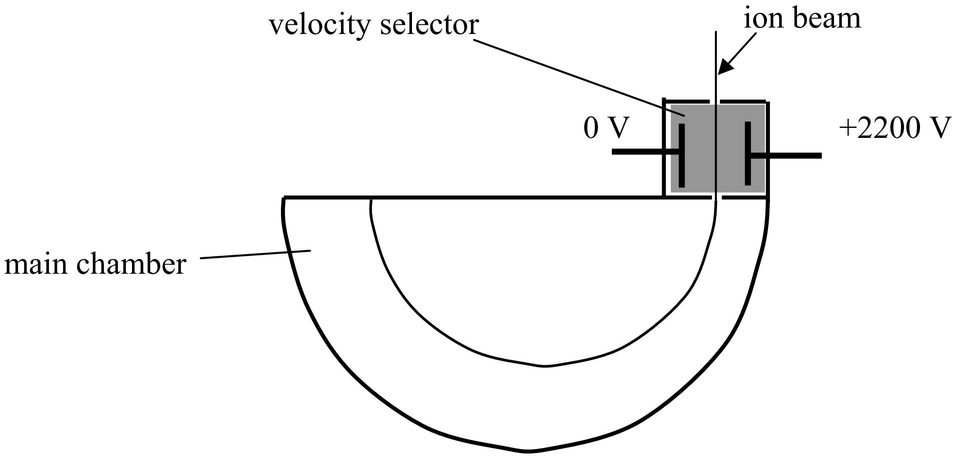
(3 marks)

Total 9 marks

5 (a) **Figure 4** shows parts of a mass spectrograph. The magnetic field in the velocity selector and in the main chamber are both of flux density 0.63 T. The electrostatic plates in the velocity selector are separated by a distance of 18 mm.

Figure 4



(i) Explain how the velocity selector works.

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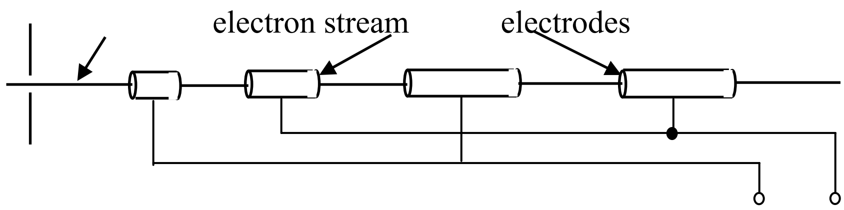
(ii) Show that the speed of ions in the ion beam shown in **Figure 4** is approximately 1.2×10^5 m s^{-1}.

(iii) The singly charged ions have a mass of 70 u. Calculate the diameter, in m, of their path.

(8 marks)

(b) **Figure 5** shows parts of a linear particle accelerator in which a stream of electrons of identical speed is passed through a series of hollow, cylindrical electrodes.

Figure 5



(i) Explain the operation of the accelerator, including why the electrodes vary in length.

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(ii) An electron is accelerated to 2.8×10^{8} m s^{-1}. Calculate the relativistic mass, in kg, of the electron.

(7 marks)

Total 15 marks

6 Question 6 relates to the following passage about artificial pacemakers and their power sources.

Artificial pacemakers can be used to stimulate the heart when the bodies own pacemaker is faulty. These artificial pacemakers need to contain an electrical power source and timing circuits to control the beat. Since these pacemakers need to be implanted within the patient's body, the batteries that power them must be both long-lasting and safe.

Atomic powered batteries contain a radioisotope and can provide appropriate power sources for these devices. The casing of the unit needs to prevent irradiation of the surrounding area. In one design a thermal converter uses the energy of radioactive decay to heat thermocouples which produce electricity.

The selection of a suitable radioisotope for the battery in a pacemaker is crucial. Critical issues are the avoidance of isotopes that include gamma emitters in their decay chains and the choice of an isotope with a long half-life. Beta emitters are used more often than alpha emitters because an alpha particle can sometimes lead to neutron production when it is absorbed. Low energy beta emissions are preferred because high energy particles can produce gamma radiation that would necessitate shielding. The table below gives data for some of the useable isotopes.

The early atomic batteries for pacemakers contained 0.16 grams of Plutonium-238. This battery produced an average electrical power 0.75 mW when new. Use of this type of battery was discontinued shortly afterwards, partly for security reasons.

Isotope	Mode of decay	Decay energy /keV	Half life Year	Activity of 1 g of isotope /10^{12} Bq
Nickel-63	β	70	100	2.1
Hydrogen-3	β	19	12	3600
Strontium-90	β	550	29	5.2
Polonium-210	α	5400	0.38	1700
Plutonium-238	α	5600	88	0.63
Curium-244	α	5900	18	3.0

(a) (i) Show that the decay constant of plutonium is approximately $2.5 \times 10^{-10}\ s^{-1}$.

(ii) Show that the initial number of atoms in the plutonium source mentioned in the passage is approximately 4×10^{20}.

(iii) Show that the initial activity of the source is approximately 1×10^{11} Bq.

(6 marks)

(b) (i) Calculate the energy released per second by the radioactive decay of the plutonium when the source is new. Give your answer in J.

(ii) Calculate the efficiency of the battery. Express your answer as a percentage.

(c) Calculate the maximum life, in s, of the battery if the power output should not be allowed to fall below 0.60W.

(4 marks)

(d) A thermal converter device delivers 0.58 mW of heating to a 6.7 g of a material which has a specific heat capacity of 410 J kg^{-1} K^{-1}. Calculate the temperature rise in the first 12 hours of operation assuming that there are no energy losses.

(3 marks)

(e) (i) Inspect the data in the table a select an alternative choice for an isotope for use in an atomic battery designed for pacemakers. Explain your choice.

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(ii) Suggest why it would be useful to investigate the decay chain from an isotope before making a selection.

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(4 marks)

(f) Like any surgical procedure, the insertion of a pacemaker carries some risk to the patient.
Describe the factors that might influence the decision about whether to proceed with the use of a pacemaker and what scientific processes might have been used in development work.

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(3 marks)

Total 23 Marks