Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________
I declare this is my own work.

A-level
PHYSICS

Paper 3
Section B Turning points in physics

Monday 17 June 2024 Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
TOTAL	

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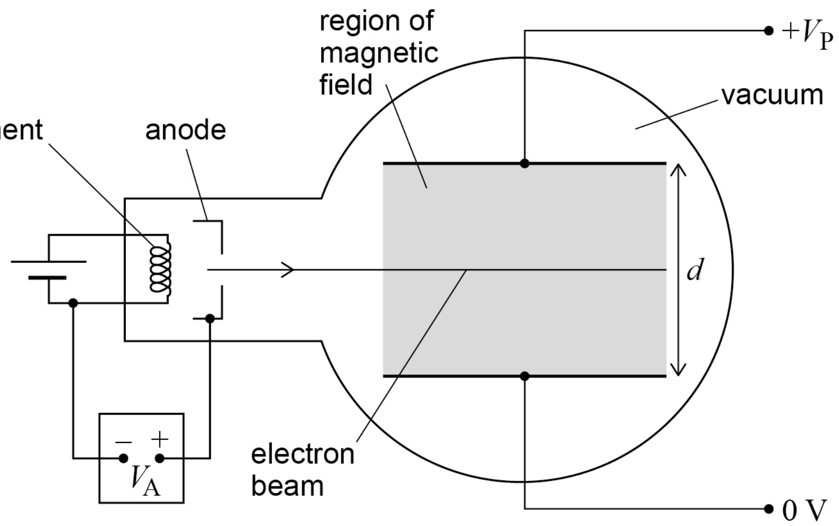
Section B

Answer **all** questions in this section.

0 1 . 1 **Figure 1** shows apparatus used in an experiment to measure the specific charge of the electron.

Figure 1



Electrons are accelerated by the potential difference V_A.

The electrons then enter the region between two parallel metal plates, shown shaded in **Figure 1**. The parallel metal plates are separated by a distance d with a potential difference V_P across them. In the same region there is a uniform magnetic field of flux density B into the plane of the diagram.

Explain why the electron beam is undeflected in the shaded region shown in **Figure 1**.
[2 marks]

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0 1 . 2 Determine, using the following data, a value for the specific charge of the electron.

$B = 1.59\ \mathrm{mT}$
$V_P = 1.51\ \mathrm{kV}$
$d = 5.0\ \mathrm{cm}$
$V_A = 1.00\ \mathrm{kV}$

[4 marks]

specific charge = ____________________ $\mathrm{C\ kg^{-1}}$

6

Turn over for the next question

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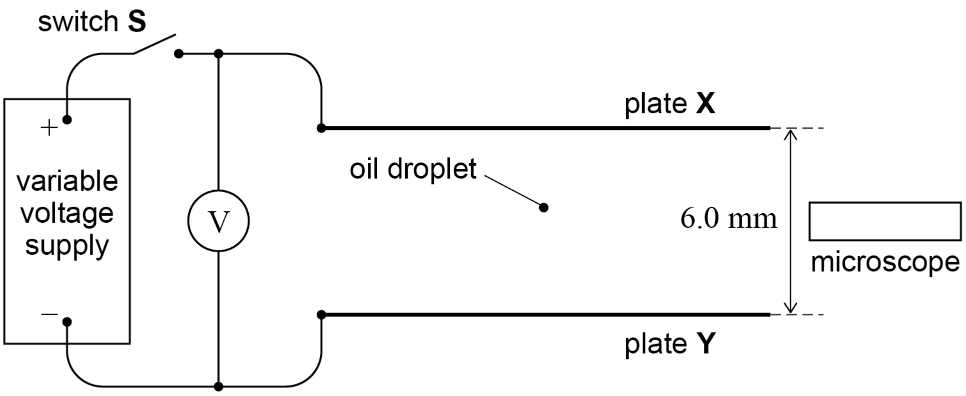
0 2 . 1 **Figure 2** shows a cross-sectional view of the arrangement that Millikan used to determine the charge on the electron.

Figure 2



Millikan's initial step was to determine the radius of the oil droplet.

Explain how Millikan used this apparatus to determine the radius of the oil droplet.

In your answer you should:
- describe the procedure used, the measurements taken and any additional data required
- describe how the radius was determined from the measurements
- state the physical principles and assumptions involved in the determination of the radius.

[6 marks]

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Question 2 continues on the next page

Turn over ►

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0 2 . 2 On one occasion, the radius of a droplet was determined to be 1.20×10^{-6} m. When the droplet was stationary, the voltmeter reading was 467 V.

Show that the charge on the droplet was approximately 8×10^{-19} C.

density of oil = 880 kg m^{-3}

[3 marks]

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0 2 . 3 **Table 1** shows the percentage uncertainty in each quantity.

Table 1

Quantity	**Percentage uncertainty**
radius of oil droplet	4%
density of oil	1%
gravitational field strength	0.1%
potential difference	0.2%
distance between the plates	2%

Show that the absolute uncertainty in your answer to Question **02.2** is approximately $\pm 1 \times 10^{-19}$ C.
Go on to discuss whether this uncertainty allows your answer to Question **02.2** to be used to support the quantisation of electric charge.

[3 marks]

12

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0 3 Hertz did an experiment to determine the speed of radio waves.

Describe this experiment.

In your answer you should:
- include a labelled diagram
- state the measurements that were taken
- describe how the data were used to determine the speed of radio waves.

[5 marks]

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5

Turn over for the next question

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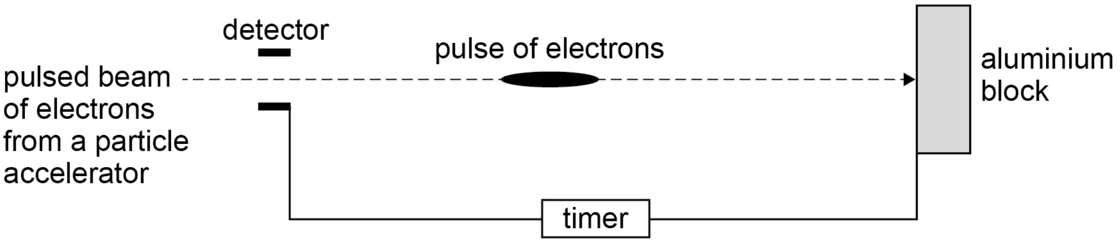
0 4 **Figure 3** shows a modern version of Bertozzi's experiment to measure the kinetic energy of high-speed electrons. A timer is used to measure the time taken for a pulse of electrons to travel from the detector to the aluminium block.

Figure 3



0 4 . 1 A potential difference (pd) of $1.30\ \text{MV}$ is used to accelerate the electrons.

Show that each electron gains approximately $2 \times 10^{-13}\ \text{J}$ of kinetic energy.

[1 mark]

0 4 . 2 These electrons cause the temperature of the aluminium block to increase by $68.0\ \text{K}$. The number of electrons that cause this increase in temperature is 4.50×10^{17}

Deduce whether this increase in temperature is consistent with an accelerating pd of $1.30\ \text{MV}$.

specific heat capacity of aluminium = $903\ \text{J kg}^{-1}\ \text{K}^{-1}$
mass of aluminium block = $1.50\ \text{kg}$

[2 marks]

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0 4 . 3 The speed of the electrons between the detector and the block is $2.88 \times 10^{8}\ \mathrm{m\ s^{-1}}$.

Student **A** suggests that the non-relativistic equation for kinetic energy could be used.
Student **B** suggests that the relativistic equation for kinetic energy is required in this situation.

Evaluate the suggestions of student **A** and student **B**.
Support your answer with calculations.

[4 marks]

Question 4 continues on the next page

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0 4 . 4 The timer in **Figure 3** records a time of $29.8\ \text{ns}$.

What is the proper time interval for an electron travelling from the detector to the aluminium block?

Tick (✓) **one** box.

[1 mark]

$< 29.8\ \text{ns}$ ☐

$29.8\ \text{ns}$ ☐

$> 29.8\ \text{ns}$ ☐

0 4 . 5 The electrons in **Figure 3** were accelerated from rest in 13 stages.

In each stage the electrons were accelerated by a pd of $100\ \text{kV}$.

As a result, an electron increases its speed and kinetic energy during each stage.

Compare, for an electron,
- its increase in speed for the first stage with that for the last stage
- its increase in kinetic energy for the first stage with that for the last stage.

Justify your answer.

No further calculations are required.

[4 marks]

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12

END OF QUESTIONS

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