AQA

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.

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

**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.

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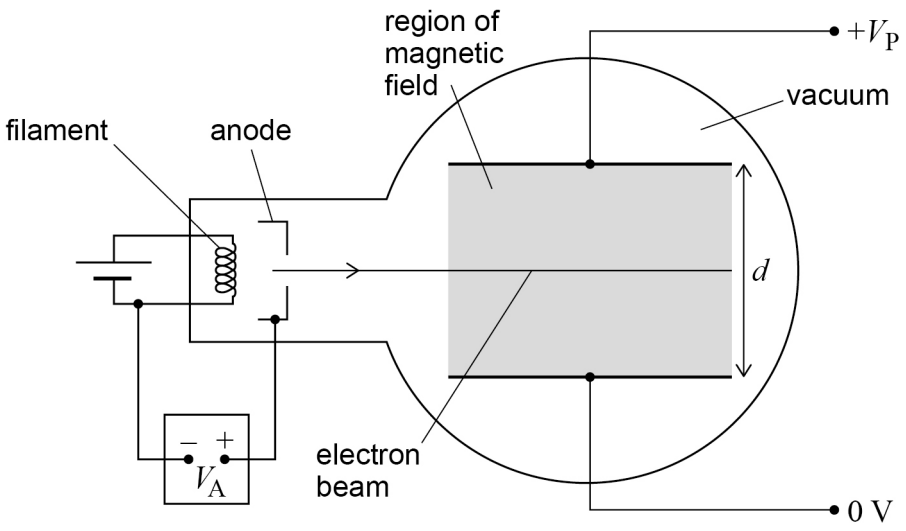
## Section B

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.

$B = 1.59$ mT
$V_P = 1.51$ kV
$d = 5.0$ cm
$V_A = 1.00$ kV

**[4 marks]**

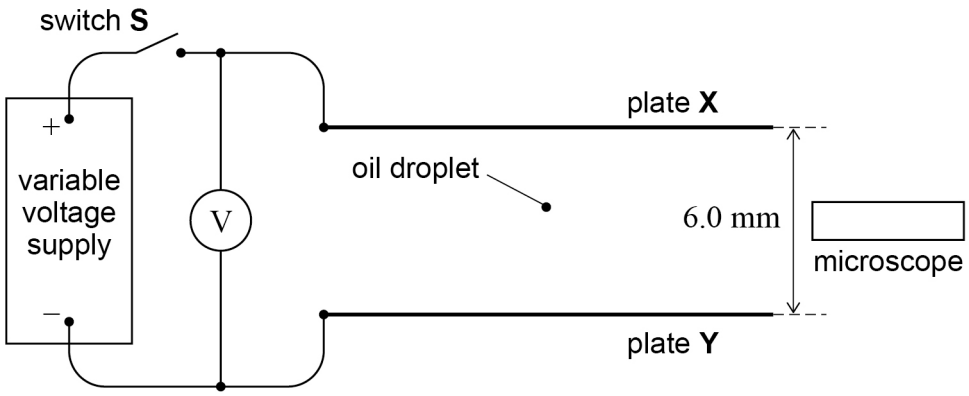
specific charge = _____ C kg$^{-1}$

6

**Turn over for the next question**

**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**

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

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

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

**[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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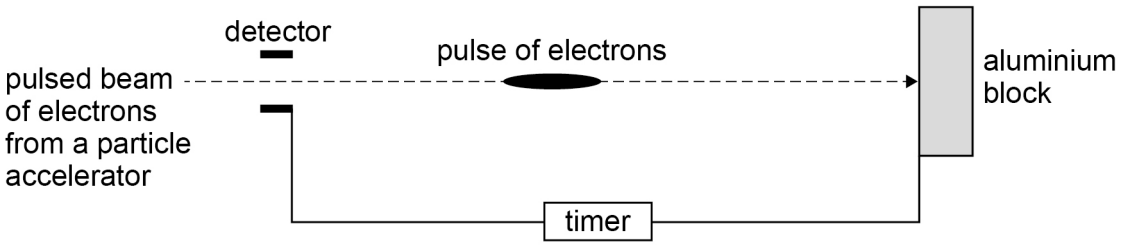
5

**Turn over for the next question**

*Do not write outside the box*

**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 $4.50 \times 10^{17}$

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 $2.88 \times 10^8$ 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 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 ns ☐

29.8 ns ☐

> 29.8 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 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]**

**12**

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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| Question number | **Additional page, if required.**<br>**Write the question numbers in the left-hand margin.** |
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