Please write clearly in block capitals.

Centre number: 4 9 6 6 9

Candidate number: 6 7 6 2

Surname: Matheson

Forename(s): Lewis

Candidate signature:

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Turning points in physics

ALevelPhysicsOnline.com

Thursday 15 June 2023 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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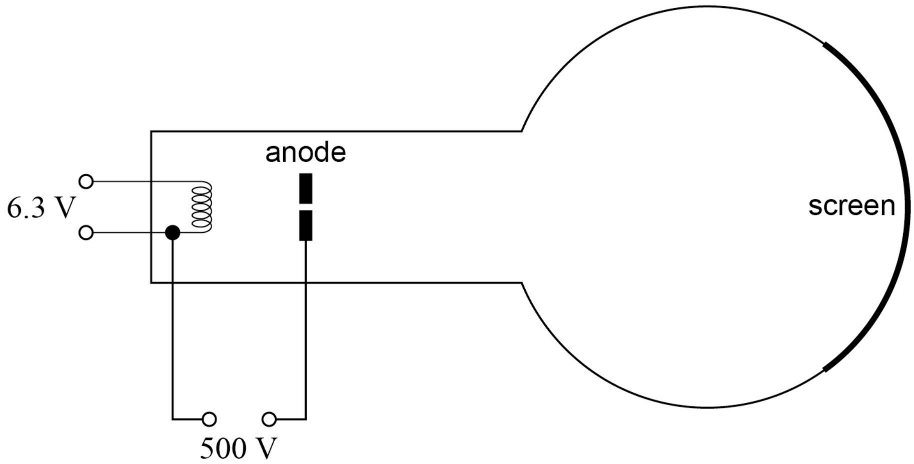
Section B

Answer **all** questions in this section.

0 1 In **Figure 1**, a beam of electrons travels through the aperture in the anode and hits the screen.

Figure 1



0 1 . 1 Explain how the electrons that form the beam are emitted.

[1 mark]

The filament is heated, providing enough energy to the electrons in the metal to leave the surface. ✓

0 1 . 2 Show that the maximum speed of the electrons in the beam is about 1.3×10^{7} m s^{-1}.

[1 mark]

$$eV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.60 \times 10^{-19} \times 500}{9.11 \times 10^{-31}}}$$

$$= 1.325 \times 10^{7}\ \text{ms}^{-1} ✓ \approx 1.3 \times 10^{7}$$

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0 1 . 3 A student suggests that the apparatus can be used to demonstrate the wave properties of electrons in the beam, provided that the aperture in the anode has a suitable diameter.

Discuss whether the student is correct.
Support your answer with a calculation.

[3 marks]

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times1.325\times10^{7}} = 5.49\times10^{-11}\,m$$ ✓

Diffraction occurs when the diameter of the aperture $\approx \lambda$ of the electrons. ✓

But in this case $\lambda_e <$ size of an atom
∴ aperture cannot be small enough
∴ the student is not correct. ✓

Question 1 continues on the next page

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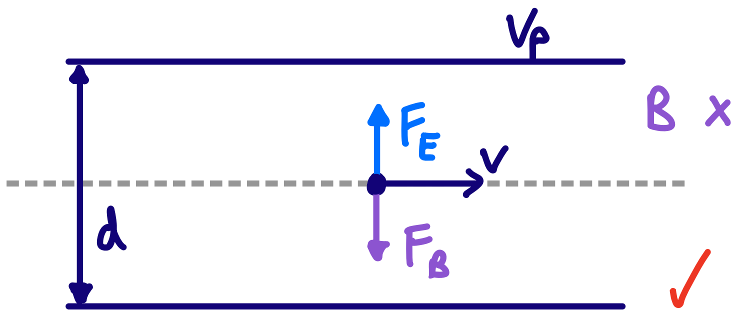
0 1 . 4 In 1897, J J Thomson determined a value for the specific charge of an unknown particle.
The unknown particle is now known to be the electron.

Describe **one** method to determine the specific charge of the electron.

Your answer should include:

- a description of the apparatus used and the measurements made
- a description of how the specific charge can be determined using these measurements
- an explanation of the conclusion made by Thomson from the value that he determined.

[6 marks]



Apply a potential difference, V_p, across parallel plates, in the region of a magnetic field, B, at right angles to this.

Electrons are accelerated by V_A and travel between the parallel plates in a horizontal path.

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Other measurements needed include: plate separation, d, and magnetic flux density, B.

specific charge $= \frac{Q}{m} = \frac{e}{m}$

$F_E = \frac{eV_P}{d}$ $F_B = Bev$ $\frac{eV_P}{d} = Bev$ $v = \frac{V_P}{dB}$

$E_K = \frac{1}{2}mv^2 = eV_A$ $\frac{e}{m} = \frac{v^2}{2V_A} = \frac{V_P^2}{2V_A d^2 B^2}$ ✓

Calculated value of e/m is very large, ✓ much larger than hydrogen ion

∴ particle has a very small mass. ✓

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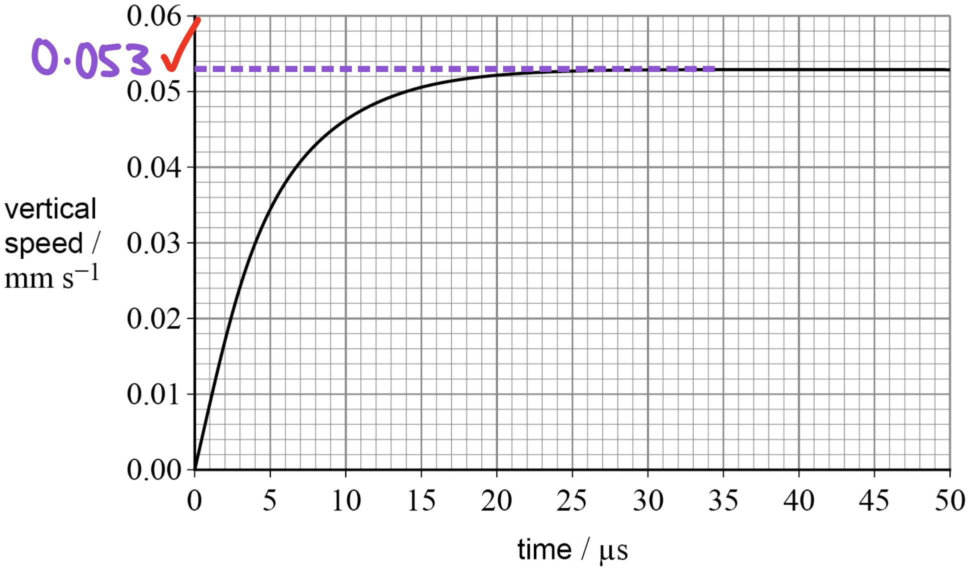
0 2 In an experiment to determine the electronic charge, a charged oil drop falls from rest between two uncharged plates.

The oil drop has a weight of 1.2×10^{-14} N and a radius of 6.8×10^{-7} m.
Ignore the buoyancy force of the air on the oil drop.

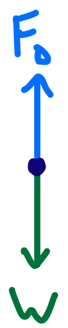
Figure 2 shows the variation of the vertical speed of the oil drop with time.

Figure 2



0 2 . 1 Calculate the viscosity of the air between the plates.

[3 marks]



$W = F_D$ $\quad W = 6\pi\eta r v$ ✓

$$\eta = \frac{W}{6\pi r v} = \frac{1.2\times10^{-14}}{6\pi \times 6.8\times10^{-7} \times 0.053\times10^{-3}}$$

$$\eta = 1.766\times10^{-5}$$

viscosity = 1.8×10^{-5} ✓ N s m^{-2}

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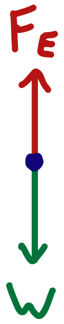
0 2 . 2 During the experiment, an electric field is produced between the plates and is adjusted until the oil drop is stationary.
The electric field strength is $18.8\ \text{kV m}^{-1}$.

Discuss whether the outcome of the experiment is consistent with the accepted value for electronic charge.

[3 marks]



$F_E = W \qquad qE = W$ ✓

$$q = \frac{W}{E} = \frac{1.2\times10^{-10}}{18.8\times10^{3}} = 6.38\times10^{-19}\ \text{C}$$ ✓

$$\frac{q}{e} = \frac{6.38\times10^{-19}}{1.60\times10^{-19}} = 3.99 \approx 4 \text{ electrons}$$

↑ whole number

∴ consistent with accepted value of e. ✓

Turn over for the next question

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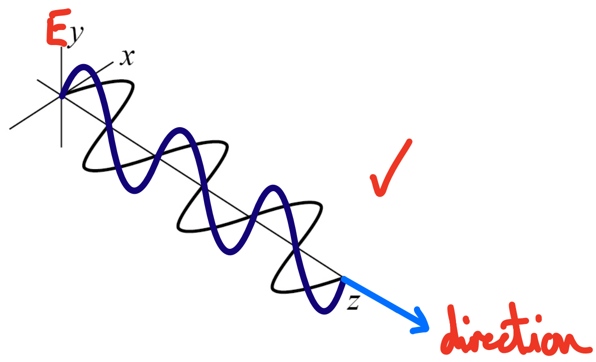
0 3 An electromagnetic wave is propagating through space.

Figure 3 shows the variation of the magnetic flux density of the wave with distance.
The magnetic field is in the xz plane.
The y-axis is at right-angles to the xz plane.

Figure 3



0 3 . 1 Draw and label on **Figure 3**:

- the corresponding electric field
- the direction of propagation of the wave.

[1 mark]

0 3 . 2 Which scientist proposed the electromagnetic wave model of light?

Tick (✓) **one** box.

[1 mark]

Hertz	☐
Huygens	☐
Maxwell	☑
Young	☐

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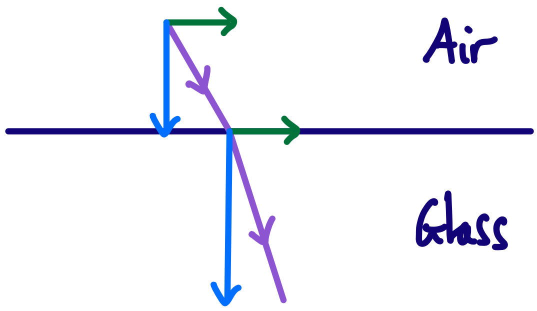
0 3 . 3 Another theory of the nature of light was proposed by Isaac Newton.

Describe how Newton's theory was used to explain the refraction of light as it moves from air into glass.

[3 marks]



Light is made of corpuscles ✓. At a boundary, component of velocity parallel to surface is unchanged but the component perpendicular to surface increases. ✓

Must be a short range attractive force that accelerates corpuscles towards glass ∴ light bends towards the normal. ✓

Question 3 continues on the next page

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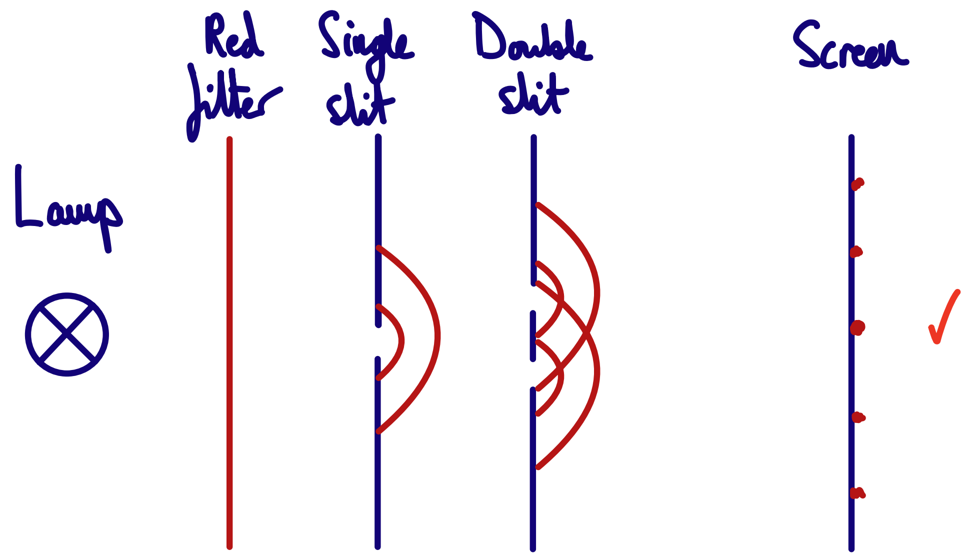
0 3 . 4 Describe a demonstration using visible light that can be performed in a school laboratory to show that Newton's theory is not correct.

[3 marks]



Use Young's double slits experiment, this shows a series of maxima and minima caused by interference of the diffracted light and it undergoes super-position which is a wavelike behaviour. ✓

If light consisted of corpuscles, you would only see two bright spots. ✓

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0 4 Einstein developed his theory of special relativity from two postulates. One postulate states that physical laws have the same form in all inertial frames.

0 4 . 1 State the other postulate and explain how it is consistent with the equation:

$$c = \sqrt{\frac{1}{\mu_0 \varepsilon_0}}$$

[2 marks]

Speed of light is invariant ✓, as the constants (μ_0, ε_0) don't depend on the reference frame. ✓

A proton leaves a particle accelerator at point **X** and moves at a constant speed towards a target at point **Y**.
The speed of the proton is 2.5×10^8 m s^{-1} in the frame of reference of the target.

The distance **XY** in the frame of reference of the proton is 38 m.

0 4 . 2 Calculate the distance **XY** in the frame of reference of the target.

[2 marks]

$$l = \frac{l_0}{\gamma} = 38$$

$$l_0 = l\gamma = 38 \times \frac{1}{\sqrt{1 - \left(\frac{2.5}{3.0}\right)^2}} = 68.7$$ ✓

distance **XY** in the frame of reference of the target = 69 ✓ m

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0 4 . 3 Show that the kinetic energy E_k of the proton is about 1.2×10^{-10} J.

[3 marks]

$E_T = E_K + E_0 \qquad E_K = E_T - E_0$

$E_K = \gamma m_0 c^2 - m_0 c^2$ ✓

$= m_0 c^2 (\gamma - 1)$

$= 9.11 \times 10^{-31} \times 9.00 \times 10^{16} \times \left(\frac{1}{\sqrt{1 - \left(\frac{2.5}{3.0}\right)^2}} - 1 \right)$ ✓

$= 1.216 \times 10^{-10}$ J ✓ $\approx 1.2 \times 10^{-10}$

0 4 . 4 Sketch on **Figure 4** the variation of E_k with speed v for a proton.

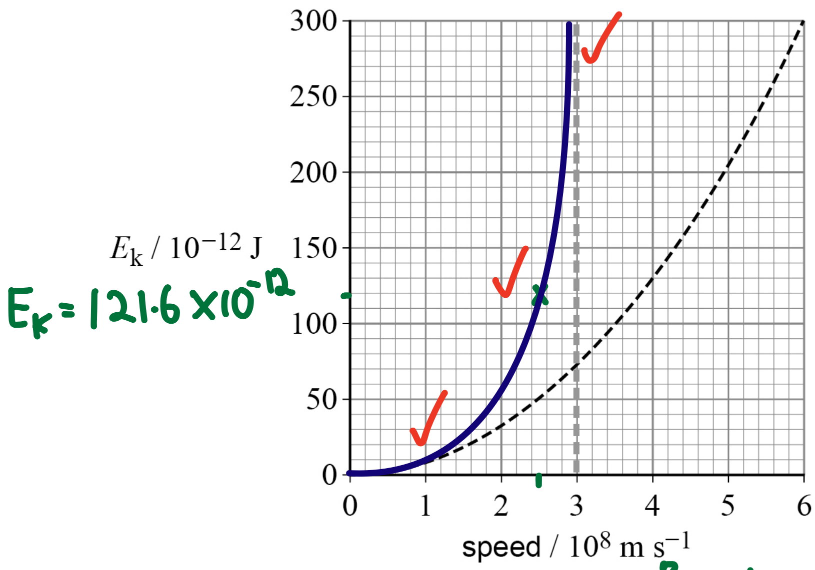
To help you, the dashed line represents

$$E_k = \frac{1}{2} m_0 v^2$$

where m_0 is equal to the mass of a proton at rest.

[3 marks]

Figure 4



$v = 2.5 \times 10^8$ m s^{-1}

END OF QUESTIONS

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