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

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	

J U N 2 1 7 4 0 8 3 B D 0 1

IB/M/Jun21/E6

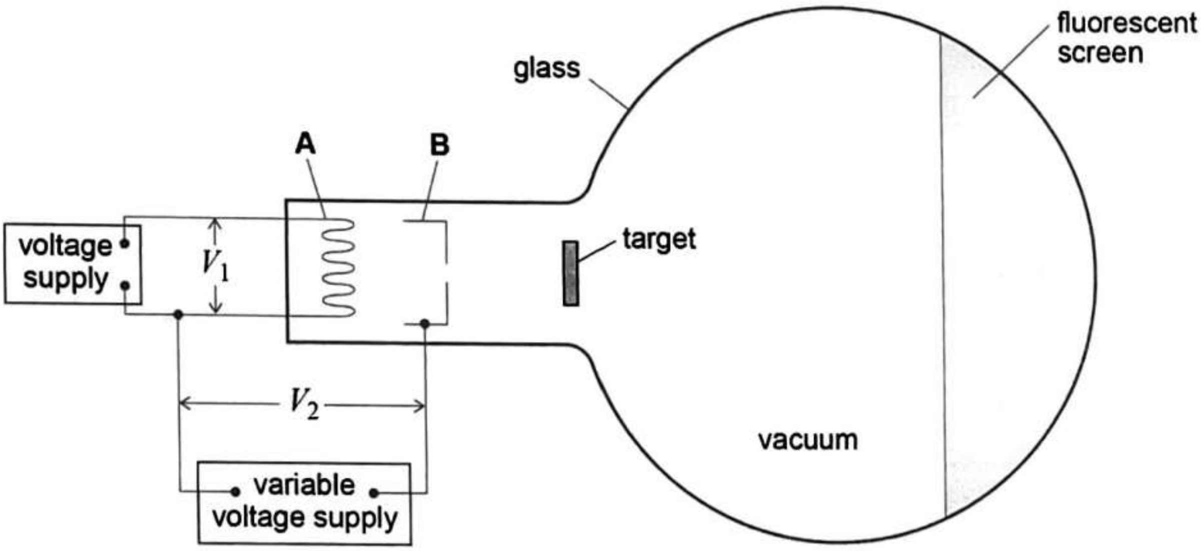
7408/3BD

Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows the apparatus used in an experiment to investigate electron diffraction and the de Broglie hypothesis.

Figure 1



0 1 . 1 Explain how high-speed electrons are produced in the apparatus in **Figure 1**.

In your answer you should:

- name parts **A** and **B**
- discuss the purposes of potential differences V_1 and V_2.

[4 marks]

A is the filament. B is the anode.
V_1 is the p.d. to supply drive current to heat the filament. V_2 is the p.d. that produces an electric field to accelerate electrons.

0 1 . 2 In the experiment, electrons are incident on a target made of a crystalline material. The electron wavelengths need to be about 50% the size of an atom to produce a diffraction pattern on the screen.

Suggest a suitable value for V_2.
Support your answer with a calculation.

[4 marks]

diameter of atom ≃ 0.1nm
⇒ λ should be ≃ 0.05nm.

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$V = \frac{h^2}{2me\lambda^2} = \frac{(6.63\times10^{-34})^2}{2\times9.11\times10^{-31}\times(0.05\times10^{-9})^2\times1.6\times10^{-19}}$$

= 600V.

V_2 = 600 V

Question 1 continues on the next page

Turn over ▶

0 1 . 3 **Figure 2** shows a typical diffraction pattern produced on the screen by the electrons.

Figure 2

Explain how measurements made with the apparatus in **Figure 1** can be used to support the de Broglie hypothesis.

[4 marks]

The de Broglie hypothesis states there is an inverse relationship between wavelength and momentum. Measure V_2 to determine the momentum of electrons and measure the diameter of the rings to determine wavelength (increased diameter indicates an increase in wavelength. The de Broglie hypothesis is supported if increasing V_2 increases the diameter of the rings.

0 1 . 4 STM and TEM are abbreviations for two types of electron microscope.

Which row links the type of microscope to a relevant property of moving electrons?
Tick (✓) **one** box.

[1 mark]

STM	**TEM**	
Moving electrons can cross a potential barrier.	Moving electrons can be deflected by a magnetic field.	✓
Moving electrons can be deflected by a magnetic field.	Moving electrons can be deflected by a magnetic field.	
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Moving electrons can cross a potential barrier.	Moving electrons can cross a potential barrier.	

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Turn over for the next question

Do not write outside the box

0 2 In 1864, James Clerk Maxwell published a theory that included an equation for the speed of electromagnetic waves in a vacuum.

0 2 . 1 Show that Maxwell's theory agrees with the accepted value for the speed of light in a vacuum.
Use information from the Data and Formulae Booklet in your answer.

[2 marks]

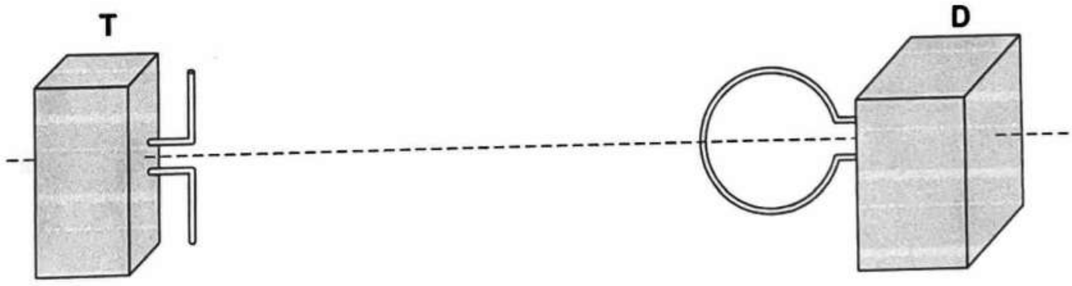
$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$= \frac{1}{\sqrt{4\pi \times 10^{-7} \times 8.85 \times 10^{-12}}} = 3.0 \times 10^{8} \text{ ms}^{-1}$$

c in booklet is 3.00×10^8 and so agrees with maxwell's theory.

Between 1886 and 1889, Heinrich Hertz completed a series of experiments in an attempt to verify Maxwell's theory. **Figure 3** shows a simplified arrangement similar to the one used by Hertz in one of his experiments.

Figure 3



T is a radio wave transmitter with an aerial consisting of two vertical metal rods.
D is a detector that uses a conducting loop aerial.

0 2 . 2 T is switched on so that an oscillating current is produced in the metal rods.
An emf is detected in the conducting loop aerial.

Explain this experiment with reference to Maxwell's model of electromagnetic waves.

[4 marks]

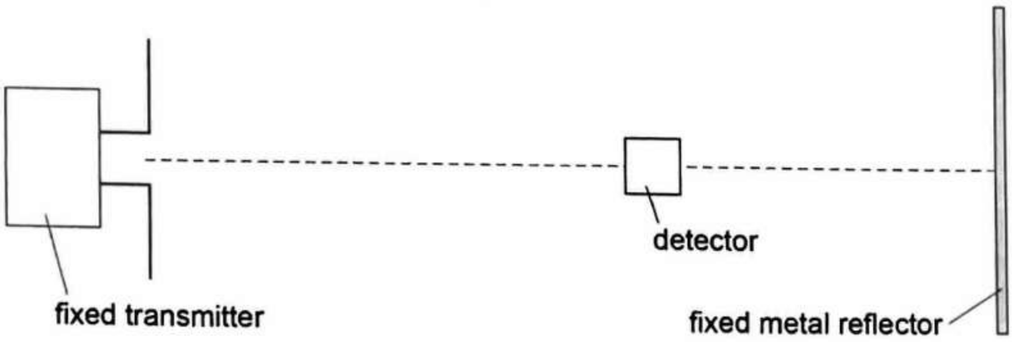
maxwell' model says electromagnetic waves are varying perpendicular E and B fields. The oscillating current in T indicates the presence of an oscillating E field. The oscillating current in T produces a horizontal B field. The varying horizontal B field induces a varying emf in the loop.

Question 2 continues on the next page

0 2 . 3 In a different experiment Hertz used stationary waves to determine the speed of radio waves.

Figure 4 shows an experimental arrangement similar to the arrangement Hertz used.

Figure 4



Stationary waves are produced between the fixed transmitter and the fixed metal reflector.

In one experiment the distance between the transmitter and reflector is about 12 m and the transmitter frequency is 75 MHz.

Deduce whether this arrangement can be used to measure the speed of electromagnetic waves suggested by Maxwell's equation.

[4 marks]

To determine the speed, you need to measure the distance between adjacent nodes or antinodes.

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{75\times10^6} = 4\text{m.}$$

This is less than the distance between the transmitter and reflector so

Yes - this arrangement can be used.

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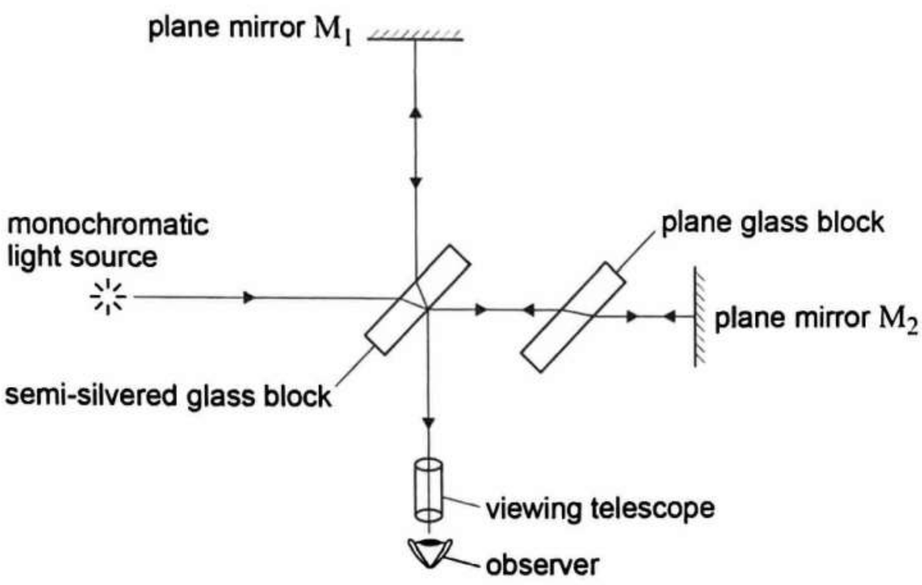
0 3 **Figure 5** shows the features of a Michelson-Morley interferometer.

Figure 5



Explain how, using this arrangement, Michelson and Morley attempted to detect the absolute motion of the Earth.

In your answer you should:

- outline the experimental procedure
- explain the expected result of the experiment
- describe the actual result and explain the significance of this result.

[6 marks]

The semi-silvered glass block splits the beam of monochromatic light into two beams. The plane block ensures that both beams pass through the same thickness of glass and air. The two beams combine at the telescope and produce an interference pattern due to the path difference of the beams arriving at the telescope. The apparatus is rotated 90° and the pattern observed again.

Do not write outside the box

it was expected that the pattern would shift because the path length would be different for the direction of travel of the apparatus, due to the rotation of the Earth. This would show that the ether exists.

The actual result shown no shift in pattern and hence there is no evidence for the ether. Also shows that the speed of light is invariant.

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Turn over for the next question

Do not write outside the box

0 4 . 1 State what is meant by an inertial frame of reference.

[1 mark]

One that moves at constant velocity.

0 4 . 2 A pair of detectors is set up to measure the intensity of a parallel beam of unstable particles.
In the reference frame of the laboratory, the detectors are separated by a distance of 45 m. The speed of the particles in the beam is $0.97c$.

The intensity of the beam at the second detector is 12.5% of the intensity at the first detector.

Calculate the half-life of the particles in the reference frame in which they are at rest.

[4 marks]

in frame of beam $\text{distance} = 45\sqrt{1 - \frac{(0.97)^2}{c^2}} = 10.9\text{m}.$

$\text{time} = \frac{10.9}{0.97c} = 3.8\times10^{-8}\text{s}.$

$\text{half life} \simeq \frac{\text{time}}{3} = 1.3\times10^{-8}\text{s}$

half-life = 1.3×10^{-8} s

0 4 . 3 In calculations involving time dilation, it is important to identify proper time.

Identify the proper time in the calculation in Question **04.2**.

[1 mark]

The time taken for a particle beam to travel between detectors measured in the frame of reference of the particle beam.

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END OF QUESTIONS