AQA

Please write clearly in block capitals.

Centre number 0 9 7 4 9 Candidate number 4 4 5 9

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

A Level Physics Online . com

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	
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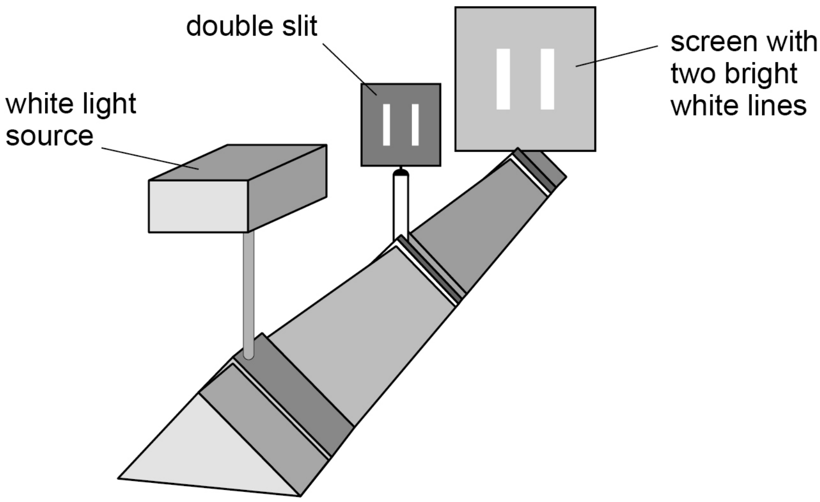
Section B

Answer **all** questions in this section.

0 1 In the 17th century, Isaac Newton proposed a theory to explain some of the properties of light. An alternative theory of light was proposed by Christiaan Huygens at about the same time.

A student uses the arrangement in **Figure 1** to investigate the two theories.

Figure 1



0 1 . 1 The student observes two bright white lines on the screen.

Explain how this observation supports Newton's theory of light.

[2 marks]

Newton's theory stated that light consisted of corpuscles that travelled in straight lines ✓ ∴ producing shadows with sharp edges. ✓

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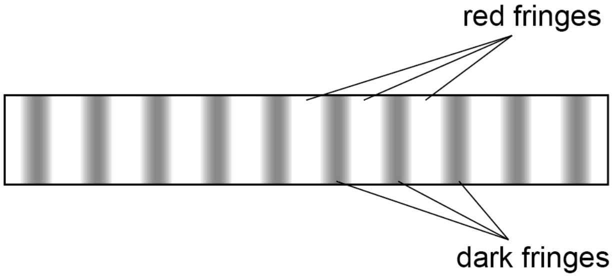
0 1 . 2 The student makes alterations to the apparatus in **Figure 1**.
Figure 2 shows the red and dark fringes that the student now observes on the screen.

Figure 2



Identify the alterations made by the student and explain how the observations in **Figure 2** support Huygens' theory of light.

In your answer you should:

- identify alterations made to the apparatus in **Figure 1**
- outline the key features of Huygens' theory
- explain how the result of this experiment supports Huygens' theory.

[6 marks]

Alterations : Light needs to be coherent and monochromatic so a laser should be used. Make slits narrower and closer together so separation ≈ wavelength. ✓✓

Huygen's theory: Light is a wave. Every point on a wavefront acts as a secondary source of spherical wavelets. ✓

Result: At slit, each point on wave produces secondary wavelets which overlap on the screen. Waves from each slit travel a different distance to the screen ∴ a path difference which produces a

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phase difference. Bright fringes occur when waves are in phase with a path difference of $n\lambda$ $\therefore$ constructive interference.
Dark fringes occur when waves are in antiphase and the path difference $= (n+\frac{1}{2})\lambda$ causing destructive interference. ✓✓✓

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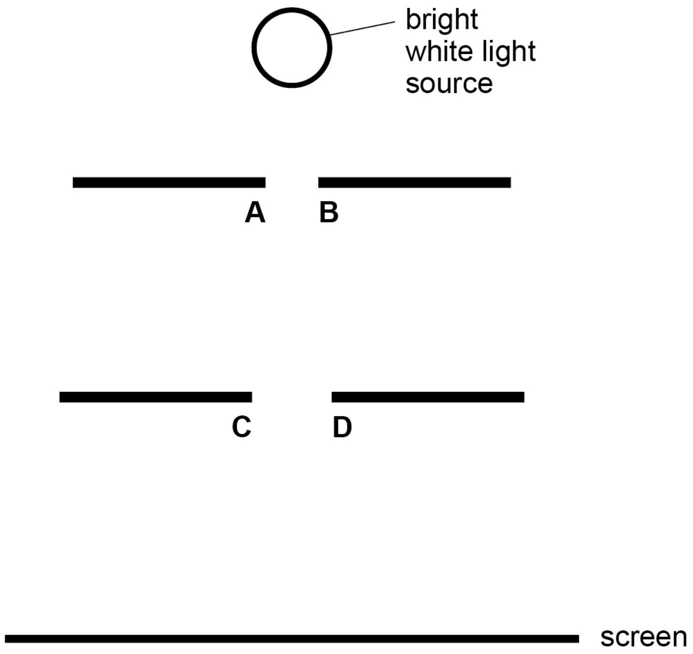
0 1 . 3 Shortly before the work of Newton and Huygens, Francesco Grimaldi carried out an experiment into the behaviour of light. **Figure 3** shows Grimaldi's arrangement.

Figure 3



A bright white light source is used to illuminate a small circular aperture, **AB**.
The light from this aperture illuminates a second, slightly larger circular aperture, **CD**.

The light passing through both apertures arrives at a screen.

Newton's theory and Huygens' theory make different predictions about the appearance of the light on the screen.

Discuss these differences in appearance.

[3 marks]

Newton's theory of corpuscles predicts a bright central spot surrounded by partial shadows ∴ most of the screen is dark. ✓
Huygens's theory of waves predicts a bright central region with fringes around the edge. ✓
The edge of the fringes would be coloured due to different wavelengths being diffracted by a different amount. ✓

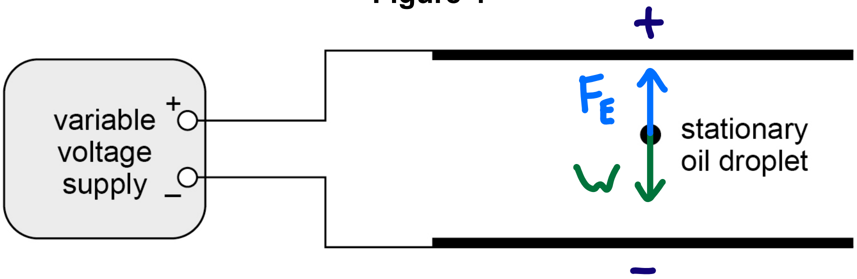
11

Turn over ▶

0 2 Robert Millikan experimented with oil drops to determine a value for the electronic charge.

Figure 4 shows a stationary oil droplet between two horizontal metal plates. The plates are connected to a variable voltage supply so that the upper plate is positive. The oil droplet has mass m and charge Q.

Figure 4



0 2 . 1 State and explain the sign of the charge on the oil droplet.

[1 mark]

Drop is negatively charged. It is stationary ∴ weight (down) balanced by electric force (up). It is −ve as it is attracted to the +ve plate. ✓

The variable voltage supply is set to zero volts. The oil drop falls. The constant speed v_1 of the falling oil droplet is found to be 3.8×10^{-5} m s^{-1} and the following measurements are recorded:

density of oil = 910 kg m^{-3}
viscosity of air = 1.8×10^{-5} N s m^{-2}

0 2 . 2 Show that the mass m of the oil droplet is about 8×10^{-16} kg.

[3 marks]

$F = 6\pi\eta r v = mg$ ✓

$\rho = \frac{m}{V} = \frac{m}{\frac{4}{3}\pi r^3}$

$r = \sqrt[3]{\frac{3m}{4\pi\rho}}$ ✓

$m = \frac{6\pi\eta v}{g} \cdot \sqrt[3]{\frac{3m}{4\pi\rho}}$

$m = 7.72 \times 10^{-16}$ ✓ $\approx 8 \times 10^{-16}$ kg

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0 2 . 3 The variable voltage supply is adjusted so that the oil droplet rises at a constant speed v_2. The potential difference (pd) across the plates is V and the distance between the plates is d.

In his experiment, Millikan measured the constant speed v_1 of a falling droplet when the pd was zero. He compared this with the speed v_2 of the same droplet when the droplet was made to rise.

Show that $$\frac{v_2}{v_1} = \frac{VQ}{dmg} - 1$$

[2 marks]

$6\pi\eta r v_1 = mg$ $\quad$ $6\pi\eta r v_2 = F_E - mg$ ✓

$6\pi\eta r = \frac{mg}{v_1}$ $\quad$ $\frac{mg}{v_1} v_2 = F_E - mg$ $\quad$ $F_E = \frac{VQ}{d}$

$\frac{V_2}{V_1} = \frac{VQ}{d\,mg} - 1$ ✓

0 2 . 4 The following measurements are made for the droplet in Question **02.2** when it is rising at constant speed.

$V = 715$ V

$v_2 = 1.1 \times 10^{-4}$ m s^{-1}

The separation of the plates $d = 11.6$ mm.

Deduce, using the equation in Question **02.3**, whether the value of the charge for this droplet is consistent with the currently accepted value of the electronic charge.

[3 marks]

$\frac{V_2}{V_1} = \frac{VQ}{d\,mg} - 1$ $\quad$ $Q = \left(\frac{V_2}{V_1} + 1\right)\frac{d\,mg}{V}$ ✓

$Q = \left(\frac{1.1 \times 10^{-4}}{3.8 \times 10^{-5}} + 1\right) \times \frac{11.6\times10^{-3} \times 7.72\times10^{-16} \times 9.81}{715}$

$Q = 4.78 \times 10^{-19}$ ✓ $\quad$ $Q \div 1.6\times10^{-19} = 2.99 \approx 3$

∴ Yes, droplet has a charge of -3e ✓

Question 2 continues on the next page

Turn over ►

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0 2 . 5 After Millikan published his results, it was found that he had used a value for the viscosity of air that was smaller than the actual value.

Discuss the effect this error had on Millikan's value of the electronic charge.

[3 marks]

A smaller viscosity leads to a smaller calculation of the force ✓ on the droplet and therefore a smaller calculated mass. ✓
If m is smaller, Q calculated smaller and ∴ e smaller.

$\eta \propto F \propto m \propto Q \propto e$ ✓

12

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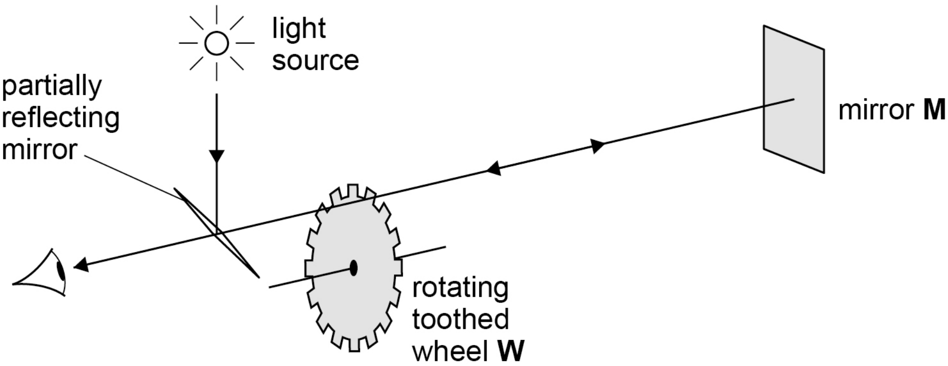
0 3 **Figure 5** shows the arrangement used by Fizeau to determine the speed of light.

Figure 5



The toothed wheel **W** is rotated and the reflected light from a distant mirror **M** is observed.

The speed of light is calculated from the equation

$$c = 4dnf_0$$

where d is the distance from **W** to **M** and
n is the number of teeth on the rotating wheel **W**.

0 3 . 1 State what f_0 represents in the equation.

[2 marks]

Frequency of rotation of W when no reflected light ✓ is first seen i.e the lowest frequency. ✓

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0 3 . 2 The experiment is attempted using a rotating wheel with 720 teeth that can be rotated at up to 620 revolutions per minute.
The distance between **W** and **M** is 8.5 km.

Deduce whether the speed of light can be determined with this particular arrangement.

[2 marks]

$c_{max} = 4 d n f_0$

$= 4 \times 8.5 \times 10^3 \times 720 \times (620/60)$

$= 2.53 \times 10^8 \text{ m s}^{-1}$ ✓ (max measurable speed)

$\therefore < 3.00 \times 10^8 \text{ m s}^{-1}$

∴ no, cannot measure c ✓

0 3 . 3 The determination of the speed of light took on extra significance when Maxwell derived the wave-speed equation

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

State how ε_0 and μ_0 are related to the types of field in the wave.

[2 marks]

ε_0 Related to electric field strength in free space. ✓

μ_0 Related to magnetic field strength in free space. ✓

6

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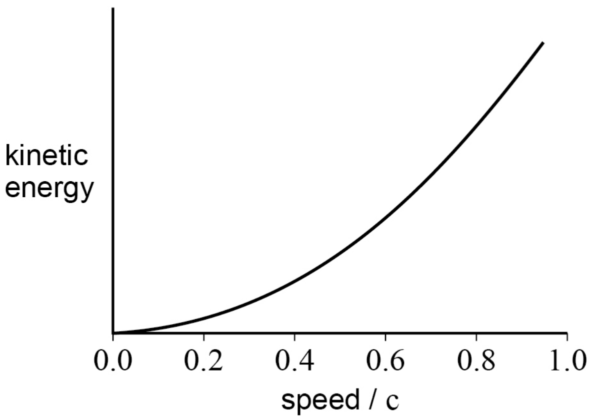
0 4 . 1 Bertozzi investigated how the kinetic energy of electrons varies with speed.

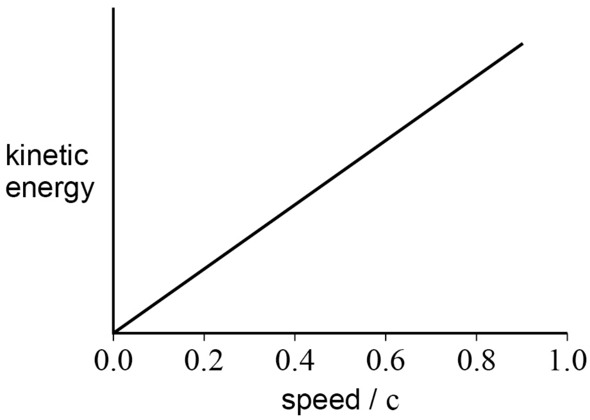
Which graph shows the variation of kinetic energy with speed?
Tick (✓) **one** box.

[1 mark]

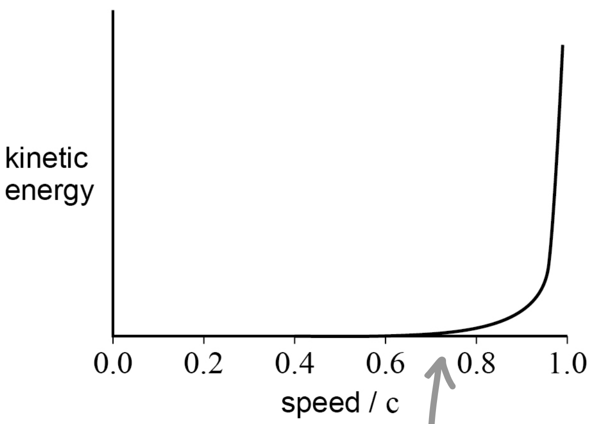
A



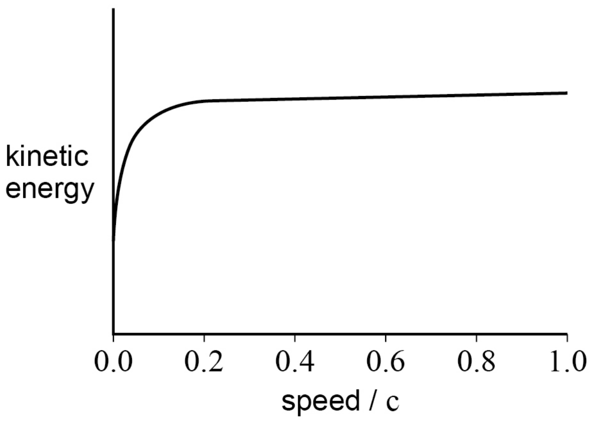
B



C



D



No relativistic effects until v approaches c

A ☐

B ☐

C ☑ ✓

D ☐

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0 4 . 2 Calculate the speed of a particle when its kinetic energy is equal to its rest energy.

[3 marks]

$E_T = E_k + E_0$ ✓ $E_k = E_0$

$E_T = 2E_0$

$\frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = 2 m_0 c^2$ ✓

$4\left(1 - \frac{v^2}{c^2}\right) = 1$ $1 - \frac{v^2}{c^2} = \frac{1}{4}$ $\frac{v}{c} = \sqrt{\frac{3}{4}}$

speed = 2.60×10^8 ✓ m s^{-1}

0 4 . 3 Discuss the change in the observed mass of a spring when it is stretched.

[2 marks]

Mass-energy equivalence : $E = mc^2$ ✓

When stretched the spring stores elastic potential energy ∴ observed mass increases. ✓

6

END OF QUESTIONS

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