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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*

## 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.

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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
<b>TOTAL</b>	



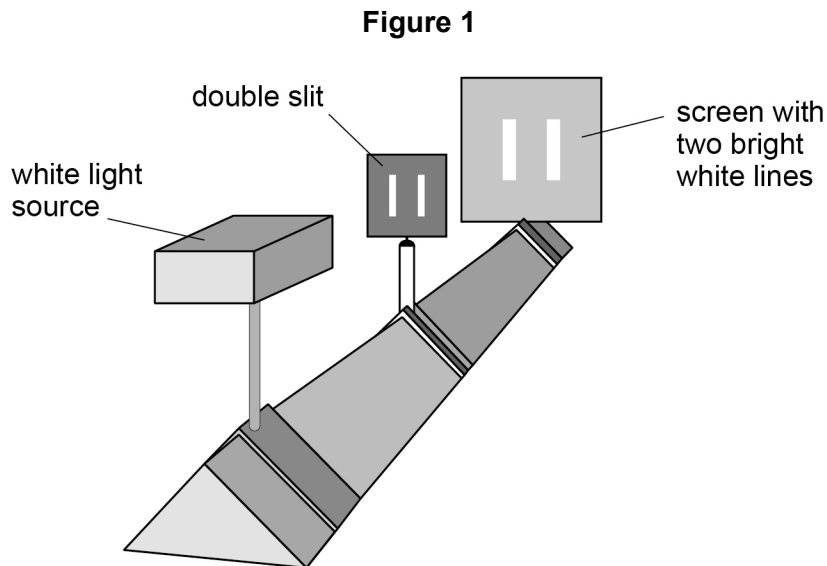
## Section B

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.



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]

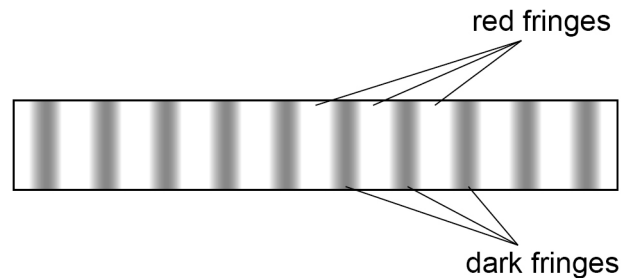
Newton's theory stated that light consisted of corpuscles that travelled in straight lines  $\checkmark$   $\therefore$  producing shadows with sharp edges.  $\checkmark$



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  $\approx$  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  $\therefore$  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.

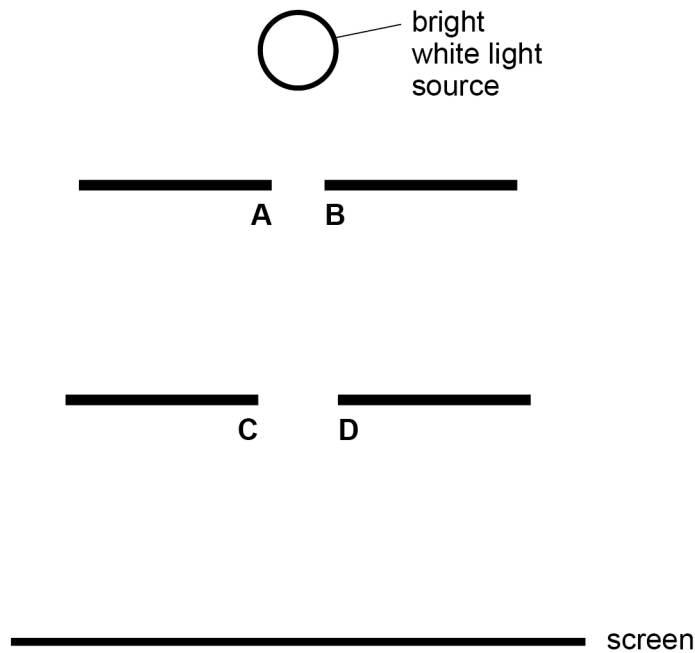
Dark fringes occur when waves are in antiphase and the path difference =  $(n + \frac{1}{2})\lambda$  causing destructive interference. ✓✓✓



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  $\therefore$  most of the screen is dark. ✓

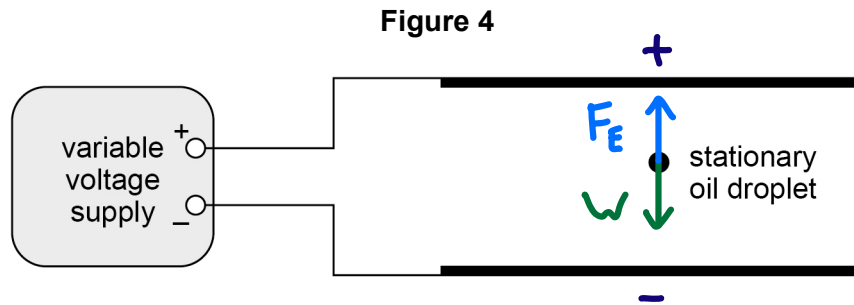
Huygens' theory of waves predicts a bright central region with fringes around the edge. ✓  
The edge of the fringes would be colored due to different wavelengths being diffracted by a different amount. ✓



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  $Q$ .



0 2 . 1

State and explain the sign of the charge on the oil droplet.

[1 mark]

Drop is negatively charged. It is stationary  
 $\therefore$  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  $3.8 \times 10^{-5} \text{ m s}^{-1}$  and the following measurements are recorded:

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

0 2 . 2

Show that the mass  $m$  of the oil droplet is about  $8 \times 10^{-16} \text{ kg}$ .

[3 marks]

$$F = 6\pi\eta rv = mg \quad \rho = \frac{m}{V} = \frac{m}{\frac{4}{3}\pi r^3}$$

$$6^3 \pi^3 \eta^3 \left(\frac{3m}{4\pi\rho}\right)^3 v^3 = m^3 g^3 \quad r^3 = \frac{3m}{4\pi\rho}$$

$$m = \sqrt{\frac{162\pi^2\eta^3 v^3}{\rho g^3}} = \underline{7.72 \times 10^{-16}} \approx 8 \times 10^{-16} \text{ kg}$$



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]

$$6\pi\eta r v_1 = mg$$

$$6\pi\eta r = \frac{mg}{v_1}$$

$$6\pi\eta r v_2 = F_E - mg$$

$$\frac{mg}{v_1} v_2 = F_E - mg$$

$$F_E = \frac{VQ}{d}$$

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

0 2 . 4

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

$$V = 715 \text{ V}$$

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

The separation of the plates  $d = 11.6 \text{ mm}$ .

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]

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

$$Q = \left( \frac{v_2}{v_1} + 1 \right) \frac{dmg}{V}$$

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

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

$\therefore$  Yes, droplet has a charge of  $-3e$

Question 2 continues on the next page

Turn over ►



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  $\therefore e$  smaller.

$$\eta \propto F \propto m \propto Q \propto e \quad \checkmark$$





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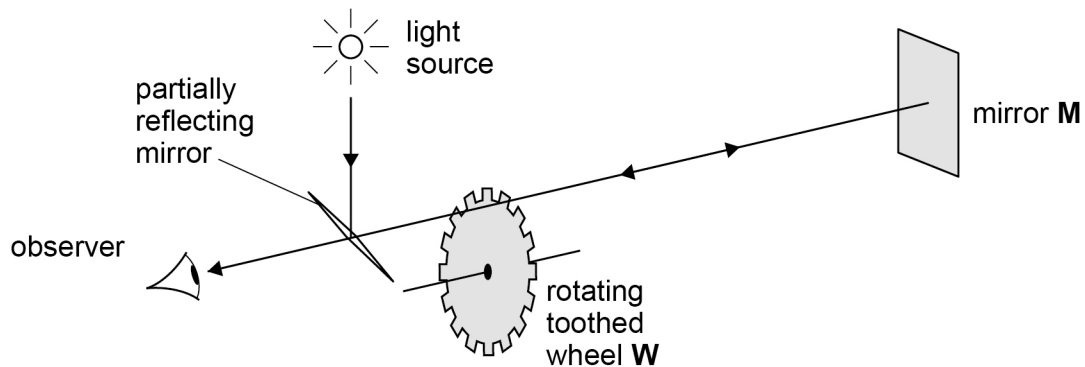
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0 3

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.



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]

$$\begin{aligned}
 c_{\max} &= 4dnf_0 \\
 &= 4 \times 8.5 \times 10^3 \times 720 \times (620/60) \\
 &= 2.53 \times 10^8 \text{ m s}^{-1} \checkmark \text{ (max measurable speed)} \\
 \therefore &< 3.00 \times 10^8 \text{ m s}^{-1} \\
 \therefore &\text{no, cannot measure } c \checkmark
 \end{aligned}$$

0 3 . 3

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

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

State how  $\epsilon_0$  and  $\mu_0$  are related to the types of field in the wave.

[2 marks]

$\epsilon_0$  Related to electric field strength in free space.  $\checkmark$

$\mu_0$  Related to magnetic field strength in free space.  $\checkmark$

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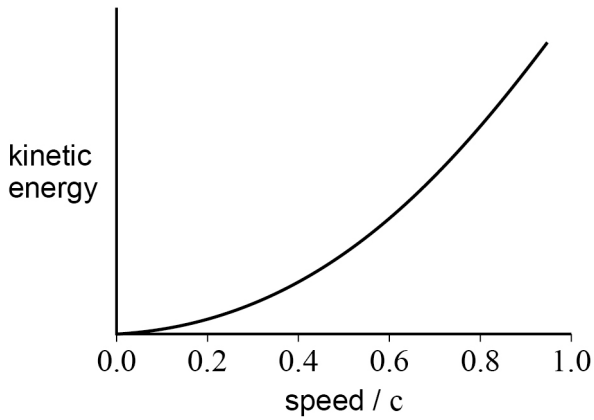


**0 4 . 1** Bertozzi investigated how the kinetic energy of electrons varies with speed.

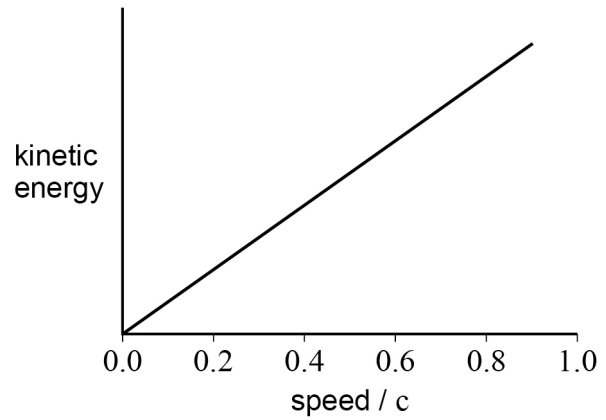
Which graph shows the variation of kinetic energy with speed?  
Tick (✓) **one** box.

[1 mark]

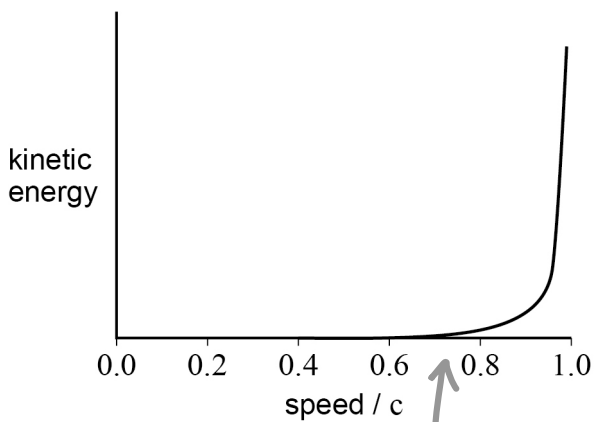
**A**



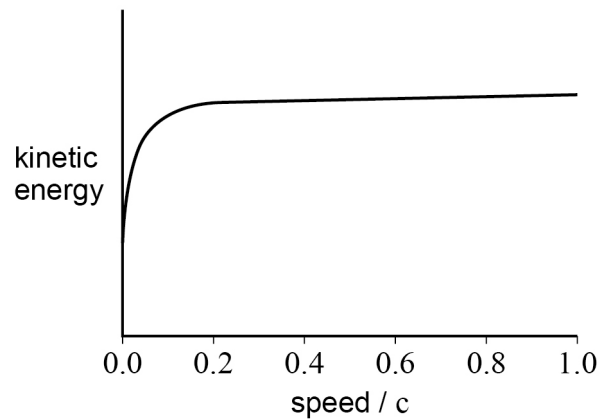
**B**



**C**



**D**



**A**

**B**

**C**



**D**

*No relativistic effects  
until  $v$  approaches  $c$*



0 4 . 2

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

[3 marks]

$$E_T = E_K + E_0 \quad \checkmark \quad E_K = E_0$$

$$E_T = 2E_0$$

$$\frac{\cancel{m_0}c^2}{\sqrt{1 - \frac{v^2}{c^2}}} = 2\cancel{m_0}c^2 \quad \checkmark$$

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

$$\text{speed} = \underline{2.60 \times 10^8} \quad \checkmark \quad \text{m s}^{-1}$$

0 4 . 3

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

[2 marks]

Mass - energy equivalence :  $E = mc^2$   $\checkmark$

When stretched the spring stores elastic potential energy  $\therefore$  observed mass increases.  $\checkmark$

6

END OF QUESTIONS



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