AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level PHYSICS

Paper 3
Section B Turning points in physics

Thursday 29 June 2017 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.

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.
- 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	
5	
TOTAL	

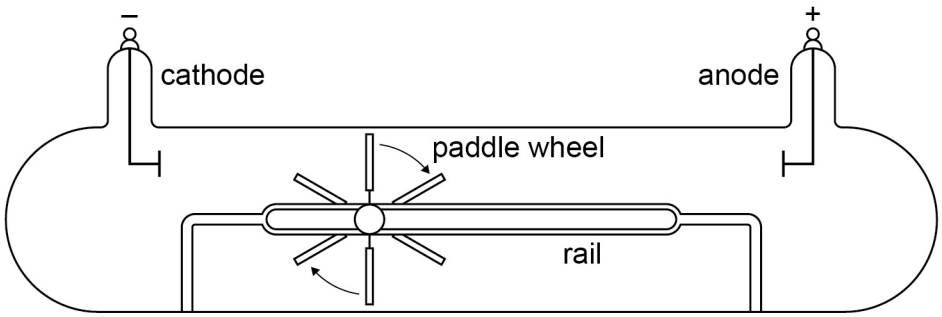
Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows a gas discharge tube devised by William Crookes in one of his investigations.

When a large potential difference is applied between the cathode and anode the paddle wheel is seen to rotate and travel along the rail towards the anode.

Figure 1



0 1 . 1 Explain how this experiment led Crookes to conclude that cathode rays are particles and that these particles caused the movement of the paddle.

[2 marks]

0 1 . 2 Later experiments showed that cathode rays are electrons in motion.

Explain how cathode rays are produced in a gas discharge tube.

[3 marks]

0 1 . 3 In a particular gas discharge tube, air molecules inside the tube are absorbed by the walls of the tube.

Suggest the effect that this absorption may have on the motion of the paddle wheel.

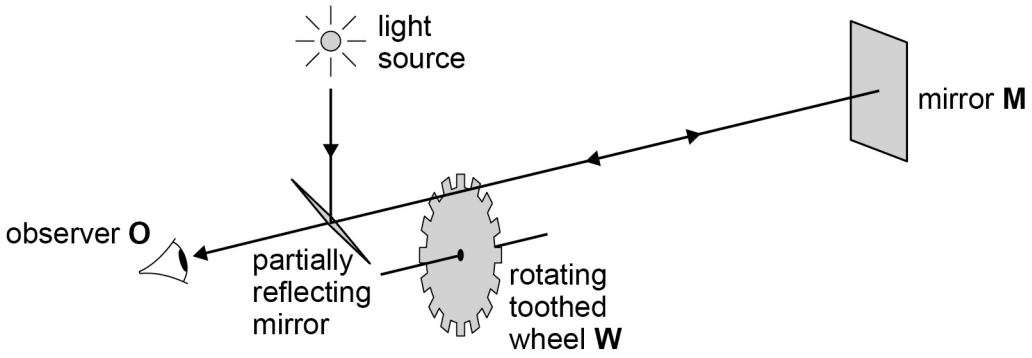
Give a reason for your answer.

[2 marks]

7

0 2 **Figure 2** shows the apparatus Fizeau used to determine the speed of light.

Figure 2



The following observations are made.

A When the speed of rotation is low the observer sees the light returning after reflection by the mirror **M**.

B When the speed of the wheel is slowly increased the observer continues to see the light until the wheel reaches a certain speed. At this speed the observer cannot see the light.

0 2 . 1 Explain these observations.

[2 marks]

Observation A

Observation B

0 2 . 2 **Table 1** shows data from Fizeau's experiment at the instant when observation B is made.

Table 1

d, distance from **M** to **W**	8.6 km
f, number of wheel revolutions per second	12
n, number of teeth in the wheel	720

It can be shown that the speed of light c is given by the equation

$$c = 4dnf$$

Discuss whether the data in **Table 1** are consistent with the present accepted value for the speed of light.

[2 marks]

0 2 . 3 The speed of the wheel is further increased.

Deduce the value of f when the observer would next be unable to see light returning from the mirror.

[2 marks]

Question 2 continues on the next page

0 2 . 4 Explain how the nature of light is implied by Maxwell's theory of electromagnetic waves and Fizeau's result.

[3 marks]

9

Turn over for the next question

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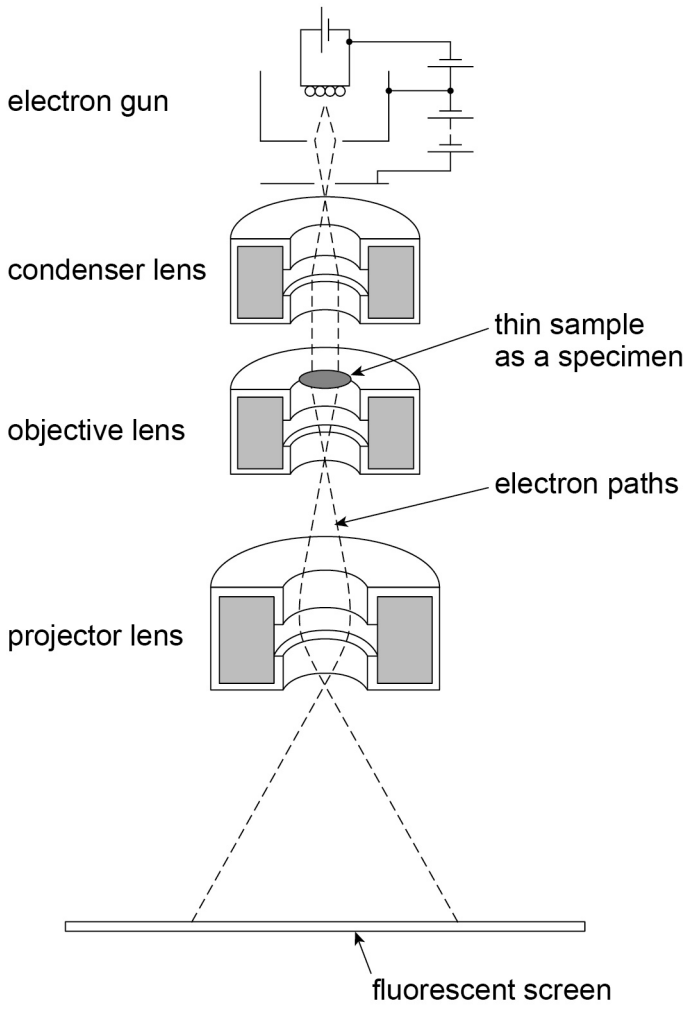
ANSWER IN THE SPACES PROVIDED

0 3 **Figure 3** shows the main parts of a transmission electron microscope (TEM).

Figure 3



0 3 . 1 What is the process by which electrons are produced in an electron gun?
Tick (✓) the correct box.

[1 mark]

Beta particle emission ☐

Electron diffraction ☐

Photoelectric effect ☐

Thermionic emission ☐

0 3 . 2 The electrons in a particular TEM have a kinetic energy of 4.1×10^{-16} J. Relativistic effects are negligible for this electron energy.

Suggest, with a calculation, whether the images of individual atoms can, in principle, be resolved in this TEM.

[3 marks]

Question 3 continues on the next page

0 3 . 3 A typical TEM can accelerate electrons to very high speeds and form high resolution images.

Explain:

- the process of image formation, and
- the factors that affect the quality of, and the level of detail in, the image.

[6 marks]

10

Turn over for the next question

0 4 . 1 A student models a spacecraft journey that takes one year. The spacecraft travels directly away from an observer at a speed of $1.2 \times 10^7 \text{ m s}^{-1}$. The student predicts that a clock stationary relative to the observer will record a time several days **longer** than an identical clock on the spacecraft.

Comment on the student's prediction. Support your answer with a time dilation calculation.

[4 marks]

0 4 . 2 In practice, the gravitational field of the Sun affects the motion of the spacecraft and it does not travel directly away from the Earth throughout the journey.

Explain why this means that the theory of special relativity cannot be applied to the journey.

[2 marks]

6

Cosmic rays detected on a spacecraft are protons with a total energy of 3.7×10^9 eV.

Calculate the velocity of the protons as a fraction of the speed of light.

[3 marks]

$3.7 \times 10^9 \times 1.6 \times 10^{-19} = 5.9 \times 10^{-10}$ J ✓

1.6×10^{-19}: charge on electron in coulombs

$m_{proton} = 1.67 \times 10^{-27}$ kg

$E = mc^2 = \dfrac{m_0 c^2}{\sqrt{1-}}$

E: energy; m: relativistic mass; c: speed of light

proton velocity = _____ c

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