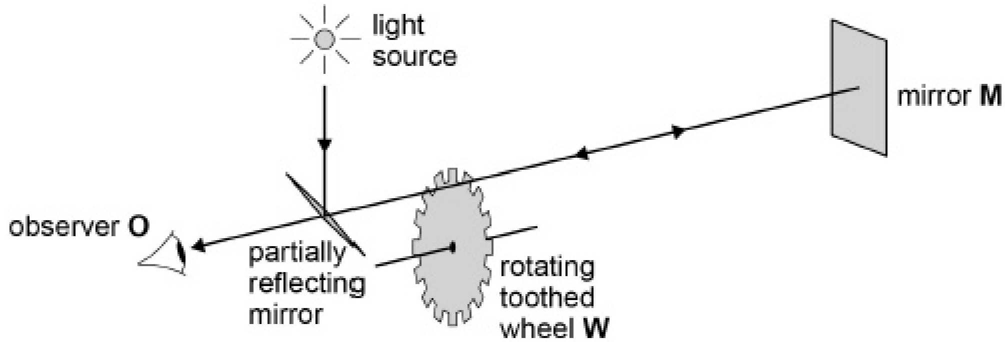
6 The diagram shows the apparatus Fizeau used to determine the speed of light.



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.

(a) Explain these observations.

Observation A

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Observation B

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(2)

(b) The table shows data from Fizeau's experiment at the instant when observation B is made.

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 the table are consistent with the present accepted value for the speed of light.

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(2)

(c) 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.

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(2)

(d) Explain how the nature of light is implied by Maxwell's theory of electromagnetic waves and Fizeau's result.

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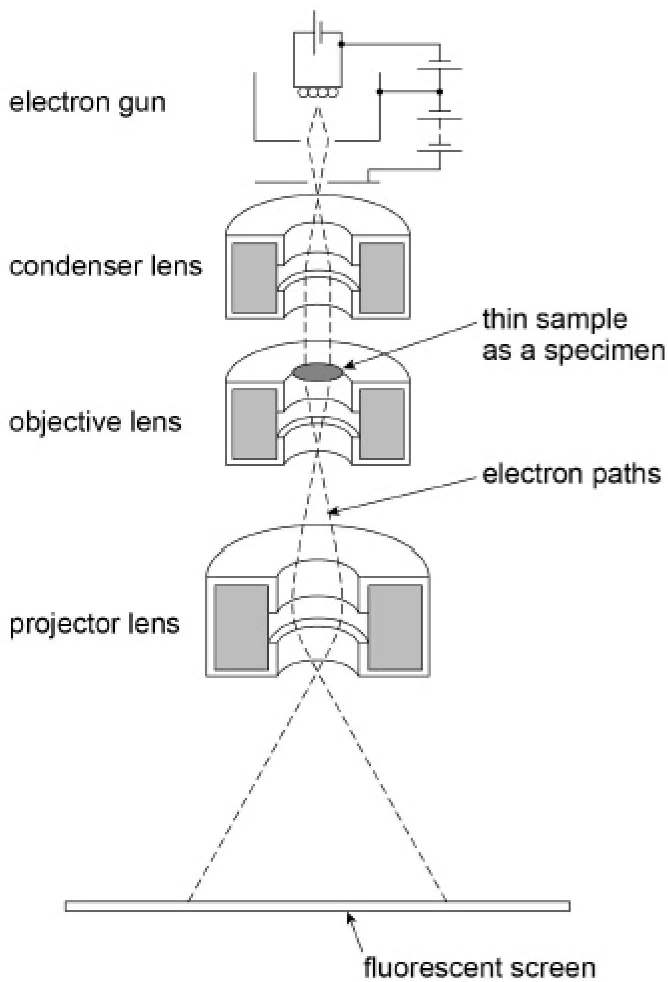
(3)
(Total 9 marks)

7 The diagram shows the main parts of a transmission electron microscope (TEM).



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

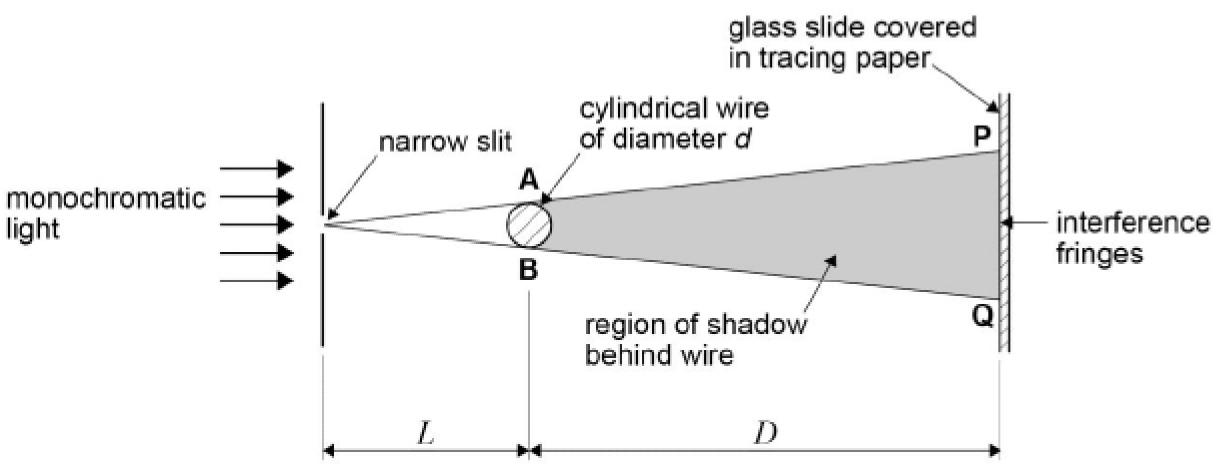
Calculate the velocity of the protons as a fraction of the speed of light.

proton velocity = ____________________ c

(Total 3 marks)

10 A student carries out an experiment to determine the diameter of a cylindrical wire based on the theory of Young's double−slit experiment, using the arrangement shown in **Figure 1**.

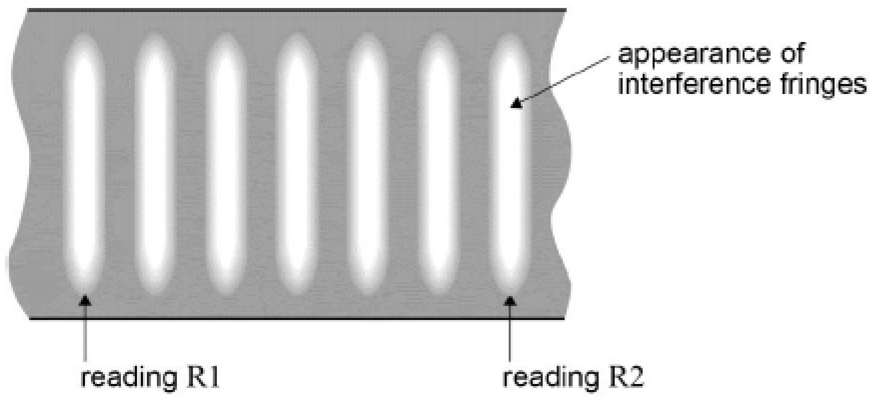
Figure 1



The wire is mounted vertically in front of a single narrow slit which is illuminated by monochromatic light. The wire produces a shadow between points **P** and **Q** on a glass slide covered with tracing paper. The light diffracts as it passes the wire. Points **A** and **B** act as coherent sources causing interference fringes to be seen between **P** and **Q**.

The student uses a metre ruler to measure the distances L and D shown in **Figure 1**. **Figure 2** shows the pattern of interference fringes between **P** and **Q**. The student takes readings from a vernier scale to indicate the positions of the centres of two of the fringes.

Figure 2



The student's measurements are shown in **Table 1**.

Table 1

L/mm	D/mm	R1/mm	R2/mm
46	395	8.71	11.16

(a) Determine the spacing of the interference fringes w using **Figure 1** and the data in **Table 1**.

Give your answer to an appropriate number of significant figures.

w ____________________ m

(2)

(b) Determine the diameter d of the wire.

wavelength of the monochromatic light = 589.3 nm

d = ____________________ m

(2)

(c) Estimate the number of interference fringes seen between **P** and **Q**.

number of interference fringes = ____________________

(3)

(d) The student uses a micrometer screw gauge to confirm his result for d.

Describe a suitable procedure that the student should carry out before using the micrometer to ensure that the measurements are not affected by systematic error.

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(2)

(e) To reduce the impact of random error, the student takes several measurements of the diameter at different points along the wire so that he can calculate a mean value for d.

These measurements are shown in **Table 2**.

d/mm
0.572
0.574
0.569
0.571
0.566
0.569

Use the data from **Table 2** to determine the percentage uncertainty in the student's result for d.

percentage uncertainty = ____________________ %

(2)

(Total 11 marks)