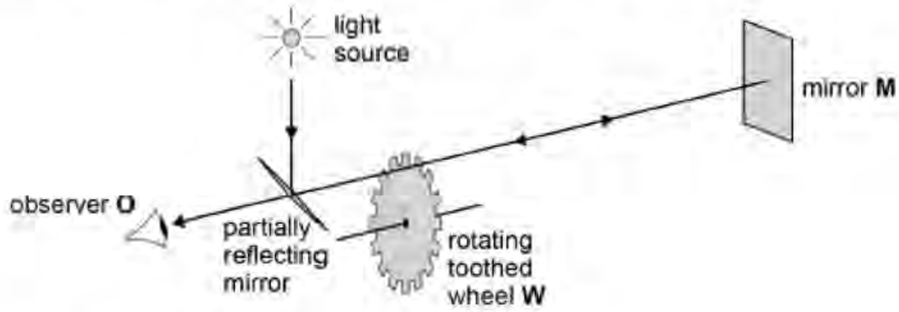
6 The diagram shows the apparatus Fizeau used to determine the speed of light.



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

light goes through gap, hits mirror & bounces back, again through the same gap to observer

Observation B

as above but now the wheel has moved so ~~that~~ lights reflected off M strikes a tooth

(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.

$C = 4 \times 8.6 \times 10^3 \times 720 \times 12$

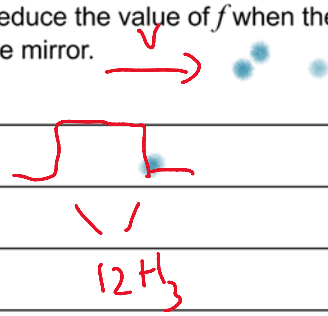
$= 2.97 \times 10^8$ m/s

if 3×10^8 m/s is correct, this is very close

(2)

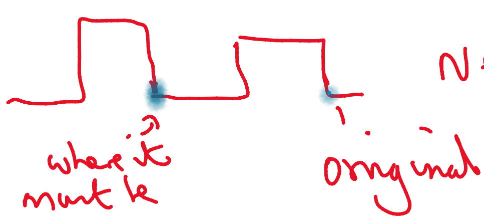
(c) The speed of the wheel is further increased.

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

① 

distance between the dots is how far it has to turn.

(2)

② 

Next

we know that at 12 Hz it just disappears so at 24 Hz it will just appear & at 36 Hz will just disappear again

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

Maxwell's theory predicted all EM waves go at $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Fizeau got a figure very close to this with light

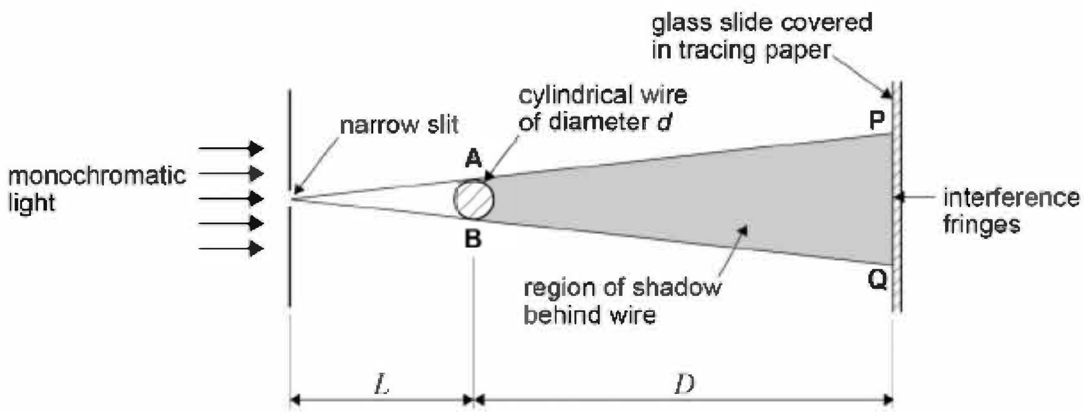
suggests light follows $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

(3)

(Total 9 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**.

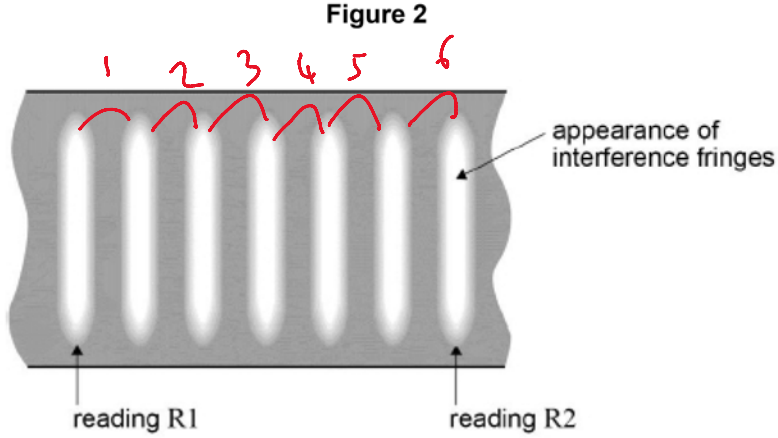
Figure 1



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.

$\frac{11.16 - 8.71}{6} = 0.408$ mm

w = 4.08×10^{-4} m

(2)

(b) Determine the diameter d of the wire.

wavelength of the monochromatic light = 589.3 nm

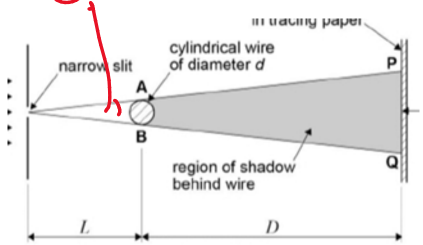
$w = \frac{\lambda D}{s}$ – slit → screen (395 mm); fringe spacing; slit width

$\frac{\lambda D}{w} = s$

$d =$ 5.7×10^{-4} m

(2)

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



similar triangles:

$\tan(\frac{\theta}{2}) = \frac{AB/2}{L}$ & $\tan(\frac{\theta}{2}) = \frac{PQ/2}{L+D}$

$\therefore \frac{AB/2}{L} = \frac{PQ/2}{L+D} \Rightarrow \frac{AB}{2L} = \frac{PQ}{2(L+D)} \Rightarrow \frac{AB(L+D)}{L} = PQ = 5.467 \times 10^{-3}$ m

50

$\frac{5.467 \times 10^{-3}}{4.08 \times 10^{-4}} = 13.3$

number of interference fringes =

$\therefore$ 13 (can't have 0.3 of a fringe)

(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.

close jaw

ensure its reading zero

(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

mean = 0.570

range = 0.574 − 0.566
= 0.008

∴ absolute uncertainty = (range / 2)
0.004

∴ 0.570 ± 0.004

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

$\% = 100 \times \frac{0.004}{0.57} = 0.702\%$

percentage uncertainty = ____________________ %

(2)

(Total 11 marks)