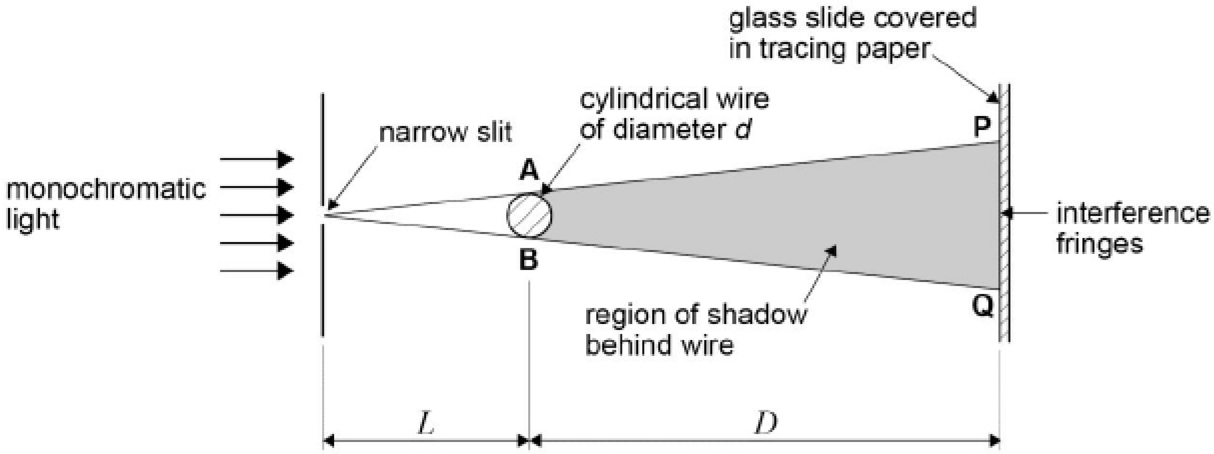
9 A student carries out an experiment to determine the diameter of a cylindrical wire based on the theory of Young's double−slit experiment, using the arrangement shown in **Figure 1**.

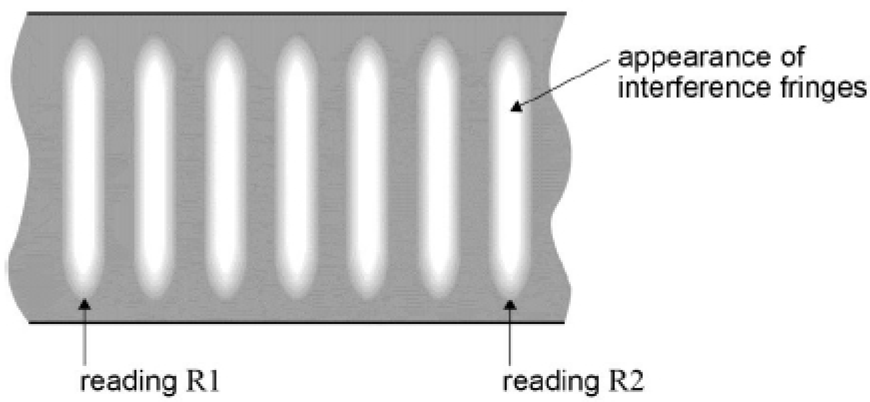
Figure 1



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.

6 sets of fringes separated by 11.16 − 8.71 mm

∴ 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 = fringe spacing
D = distance to screen
s = slit spacing ← same as d

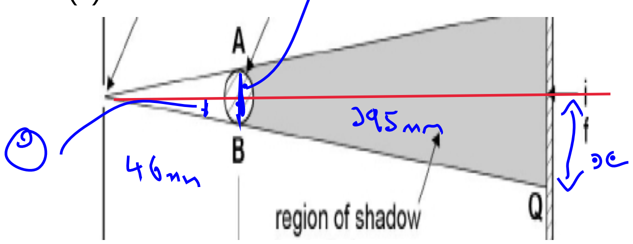
$W = \frac{\lambda D}{s} \Rightarrow s = \frac{\lambda D}{W}$

$= \frac{589.3 \times 10^{-9} \times 395 \times 10^{-3}}{4.08 \times 10^{-4}}$

$d = 5.71 \times 10^{-4}$ m

(2)

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



$\sin\theta = \frac{\left(\frac{5.71 \times 10^{-4}}{2}\right)}{46 \times 10^{-3}} \Rightarrow \theta = 0.356^\circ$

$\therefore \sin\theta = \frac{x}{(46+395) \times 10^{-3}} \Rightarrow x = 2.74 \times 10^{-3}$

∴ length of area with fringes = 5.48×10^{-3}

number of interference fringes = 13

(3)

∴ no of fringes = $\frac{5.48 \times 10^{-3}}{4.08 \times 10^{-4}} = 13.4$

So 13

(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 rachet right down but don't over tighten
- check for zero error

(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	— max
0.569	
0.571	
0.566	— min
0.569	

$\frac{1}{2}$ range = 4×10^{-3}

mean = 0.570

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

∴ % error = $\frac{4 \times 10^{-3}}{0.57 \times 10^{-3}} \times 100$ = 0.702%

percentage uncertainty = ____________________ %

(2)

(Total 11 marks)

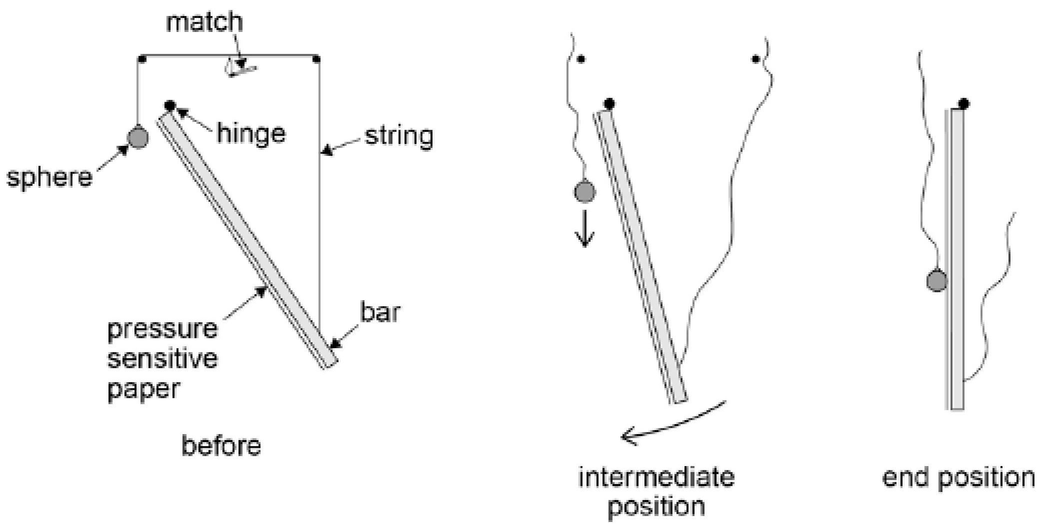
10 This question is about measuring the acceleration of free fall g.

Fab idea :-)

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

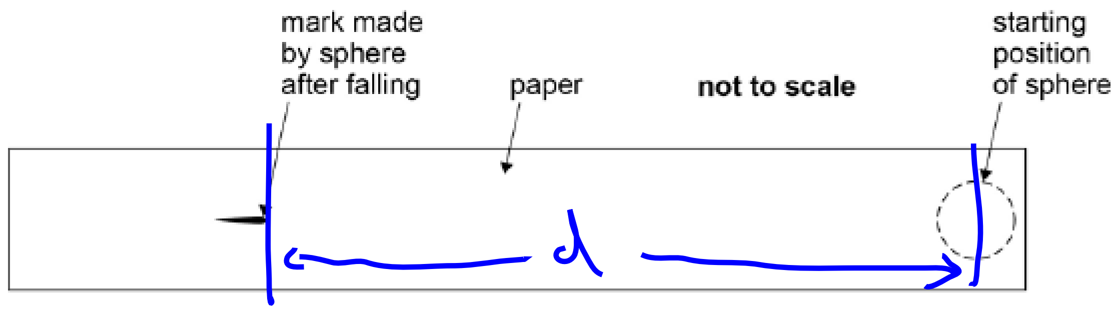
To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

(a) **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d.

Figure 2



(1)

(b) The student repeats the procedure several times.

Data for the experiment is shown in the table below.

d / m
0.752
0.758
0.746
0.701
0.772
0.769

min; wrong!; max

range = 0.772 − 0.746 = 0.026

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time *t* for the bar to reach the vertical position.

1 osc = 1.57 s ∴ 0.393 s

(only moves $\frac{1}{4}$ of an oscillation)

time____________________ s

(1)

(c) Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

15.7s for 10, so error 0.1s for 10 swings

$\frac{0.1}{15.7} \times 100 = 0.64$

uncertainty = 0.64 %

(2)

(d) Use the data from the table to calculate a value for d.

ignor outlier, find mean

d = 0.759 m

(2)

(e) Calculate the absolute uncertainty in your value of d.

spread = $\frac{0.026}{2}$ 0.013

uncertainty = ± 0.013 m

(1)

(f) Determine a value for g and the absolute uncertainty in g.

$s = ut + \frac{1}{2}at^2 \Rightarrow \frac{2 \times s}{t^2} = g$ (s = 0.759, t = 0.343)

g = 9.83 ms^{-2}

uncertainty = ______ ms^{-2}

See blank (r) page

(3)

(g) Discuss **one** change that could be made to reduce the uncertainty in the experiment.

______

______

______

______

(2)

uncertainty on $\underline{d}$ = 0.759 ± 0.013 → % error = 1.71 %

$g = \frac{2d}{t^2}$

uncert on t = 0.64%

∴ % on 2d = 1.71%

% on t^2 = %t × %t = 2 × 0.64 = 1.28%

+% when dividing

hence % = 1.28 + 1.71 = 2.99 %

(h) The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g.

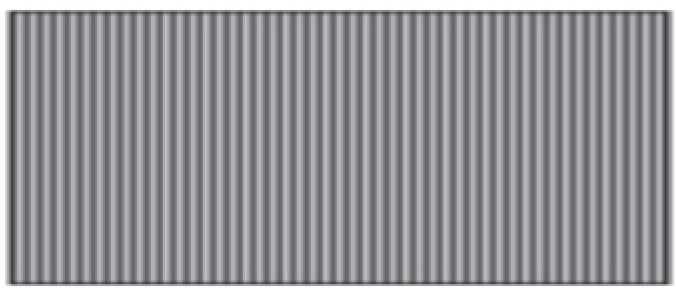
$s = \frac{1}{2}at^2 \Rightarrow$

we have a range of s vs t values. so plot a graph of t squared on the y and 2s on the x and look for gradient

(3)

(Total 15 marks)

11 (a) The image below shows a full-size photograph of a double-slit interference pattern, using a laser.



Determine the fringe width w using a ruler to take measurements from the image above. You may use a hand-lens to help you make this measurement.

Answer between 1.33 – 1.37 mm (from MS)

Gonna use 1.33mm measured as 40mm for 30 fringes.

(3)

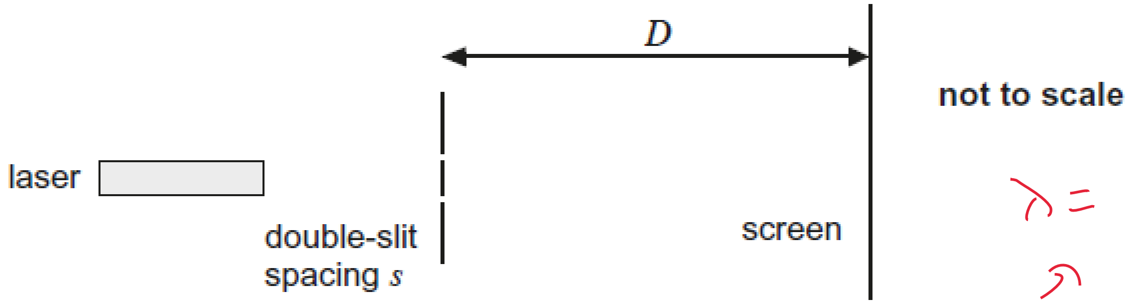
(b) Calculate the uncertainty in the value of w measured in part **(a)**.

$\frac{1\text{m}}{40} = 0.03 \text{ mm}$

$\% = \frac{0.03}{1.33} \times 100 = 2.26\%$

(2)

(c) In the experiment shown in the diagram below, the fringe pattern in the image in part **(a)** is produced.



$\lambda = \frac{ws}{D}$

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

$w = 1.33$ mm

$s = 0.60 \pm 0.02$ mm
$D = 1.500 \pm 0.002$ m

Using these data and your answers to part **(a)** and part **(b)**, determine

(i) the wavelength of the laser light used

$\lambda = \frac{1.33 \times 10^{-3} \times 0.6 \times 10^{-3}}{1.5} =$

532 nm

(1)

(ii) the percentage uncertainty in this value of wavelength

s = 3.3% %errors add when

D = 0.133% × or ÷

w = 2.26% so 5.7%

(1)

(iii) the absolute uncertainty in this value of wavelength.

$\frac{5.7}{100} \times 532 = \pm 30.3$ nm

= 30 nm

(some range expected)

(1)

(Total 8 marks)