A-Level Physics

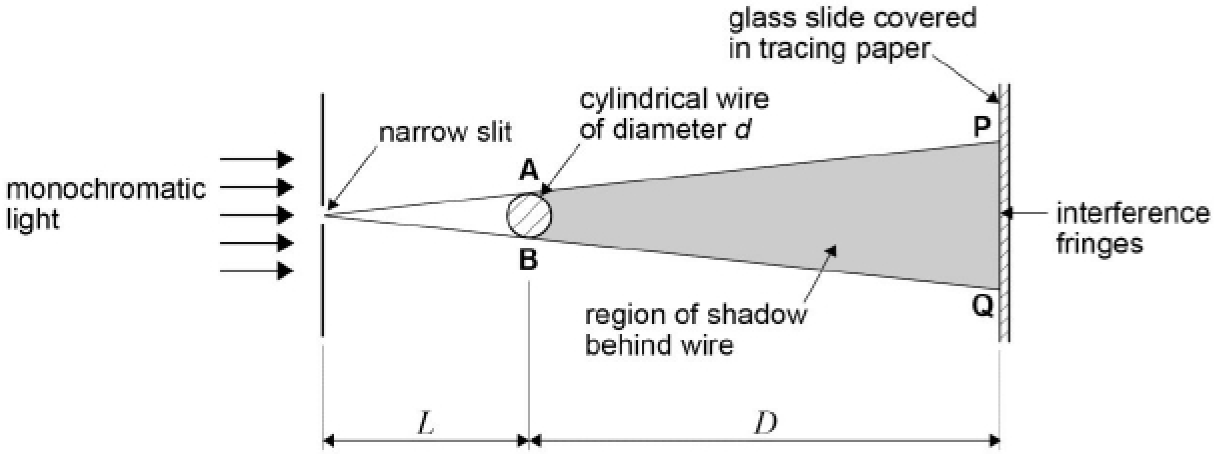
Young's Double Slits Experiment

Question Paper

Time available: 63 minutes
Marks available: 42 marks

1. 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**.

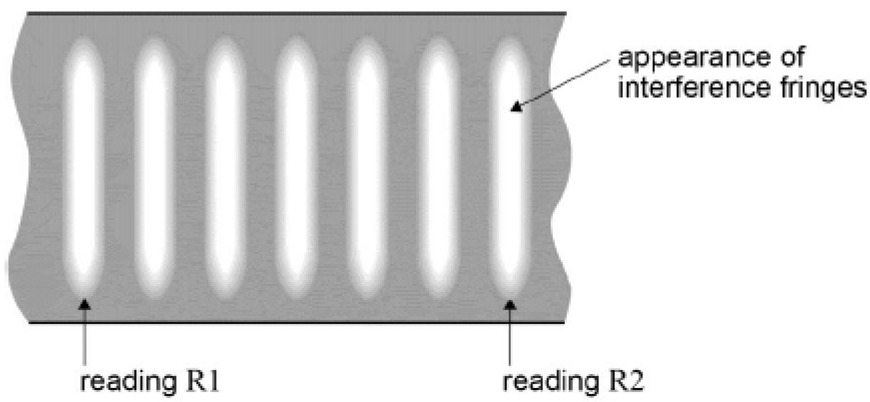
Figure 1



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

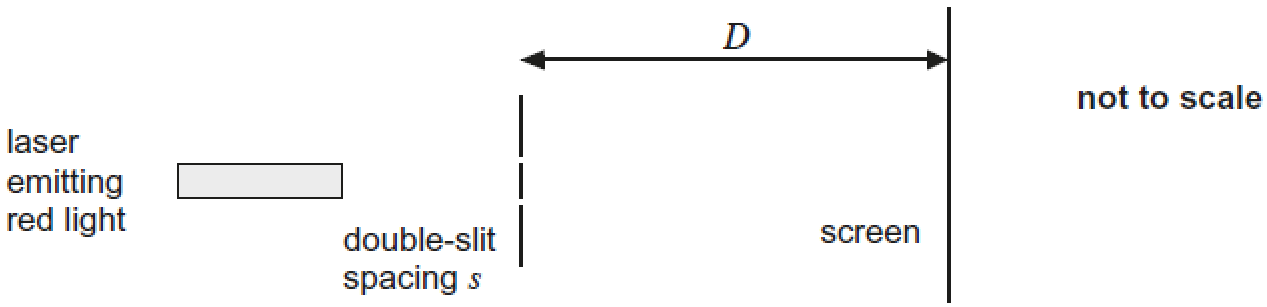
Use the data from **Table 2** to determine the percentage uncertainty in the student's result for d.

percentage uncertainty = ____________________ %

(2)

(Total 11 marks)

2. The diagram shows the arrangement of apparatus in an experiment to measure the wavelength of red light emitted by a laser. The light is incident on a double-slit so that an interference pattern is produced on the screen.



A student sets up the apparatus and measures the fringe width *w* of the interference pattern and the distance *D* between the double-slit and screen.

The student makes further measurements of *w* using the same laser but with different values of *D* and different slit spacing *s*.

The student's results are shown in the table below

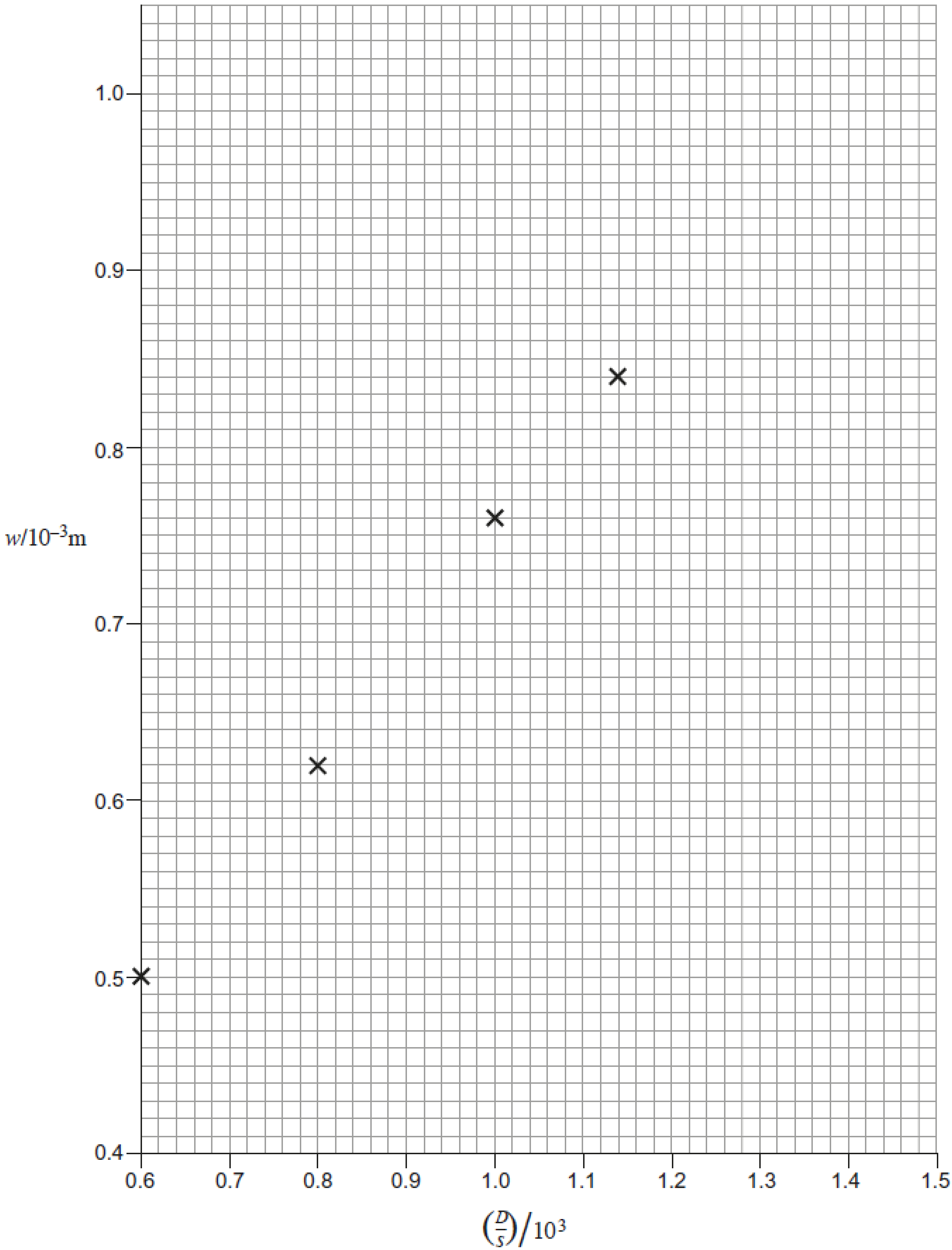
***D*/m**	$S/10^{-3}$ m	$\left(\frac{D}{S}\right)/10^{3}$	$w/10^{-3}$m
1.000	0.70		1.03
0.900	0.70		0.93
0.800	0.70	1.14	0.84
1.000	1.00	1.00	0.76
0.800	1.00	0.80	0.62
0.600	1.00	0.60	0.50

(a) Complete the table above.

(1)

(b) Complete the graph below by plotting the two remaining points and drawing a best fit straight line.

(2)



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(c) (i) Determine the gradient of the graph above.

(3)

(ii) Determine the wavelength of the red laser light used in this experiment.

(1)

(d) (i) Theory suggests that the graph above should go through the origin.

State and explain what this suggests about the relationship between *w* and $\frac{D}{S}$.

(2)

(ii) The student discovers that the best fit line drawn in the graph does not go through the origin.

Determine, using information from the graph above, the value of *w* corresponding to $\left(\frac{D}{S}\right) = 0$.

(2)

(iii) The graph suggests a systematic error in a measurement.

Identify the measurement.

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(1)

(e) The interference pattern produced on the screen is much brighter in the centre of the screen than at the edges.

State what causes this effect.

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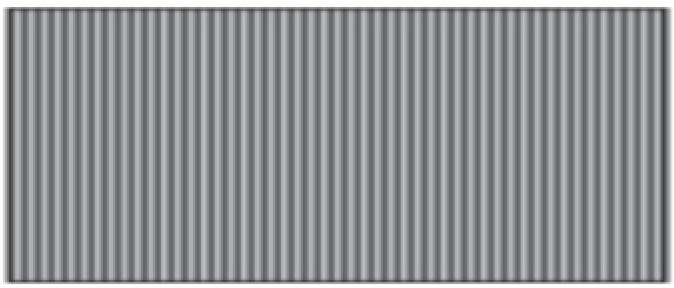
(1)

(Total 13 marks)

3. (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.

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(3)

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

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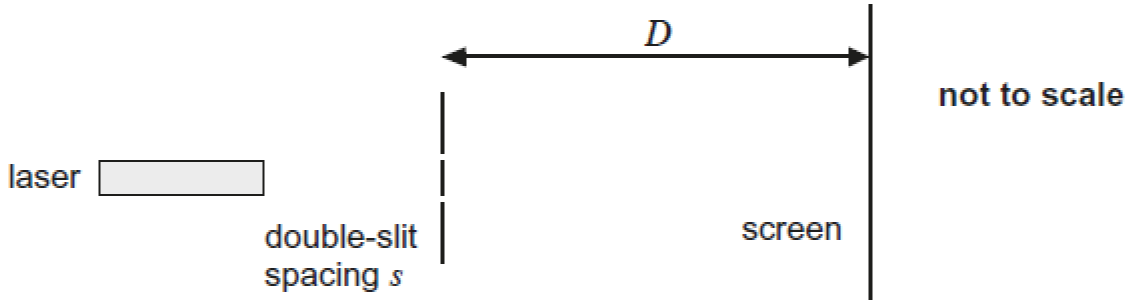
(2)

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



s = 0.60 ± 0.02 mm
D = 1.500 ± 0.002 m

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

(i) the wavelength of the laser light used

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(1)

(ii) the percentage uncertainty in this value of wavelength

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(1)

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

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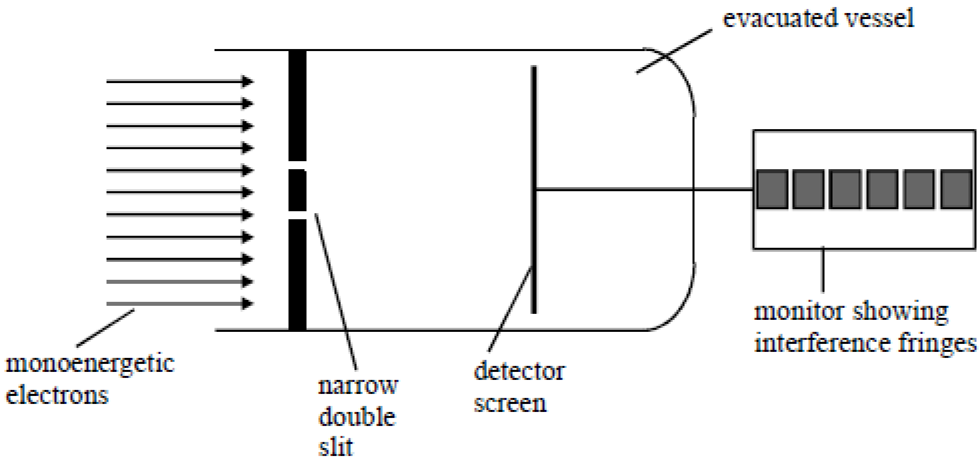
(1)

(Total 8 marks)

4. A beam of electrons travelling at 1.2×10^3 m s^{-1} inside an evacuated container is directed normally onto a double slit arrangement, as shown in the diagram. An array of detectors forms a screen which collects the electrons that pass through the slits for a selected period of time. The number of electrons collected by the detectors is displayed as a fringe pattern on a monitor.



(a) (i) Show that the de Broglie wavelength of the incident electrons is 6.1×10^{-7} m. Ignore relativistic effects.

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(ii) The monitor screen shows six bright fringes. Estimate the number of electrons that contribute to each bright fringe when the detector current is 4.8×10^{-13} A and the electrons are collected over a period of 1.0 m s.

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(4)

(b) (i) The intensity of the incident electron beam is reduced to a level where only one electron is travelling through the slits at a time. The collection time is increased to allow the original number of electrons to be collected. Compare the pattern observed on the monitor screen with that originally observed.

(ii) The speed of the electrons in the beam is reduced to half by reducing the anode potential of the electron gun that produced the beam. Describe and explain how the pattern observed on the monitor screen would differ from that originally observed in part (a).

(4)

(c) The electrons are replaced with a source of monochromatic light and the detector screen is replaced with a light-sensitive detecting screen. Determine the frequency of light that would produce fringes with the same fringe spacing as those originally observed using electrons.

(2)

(Total 10 marks)