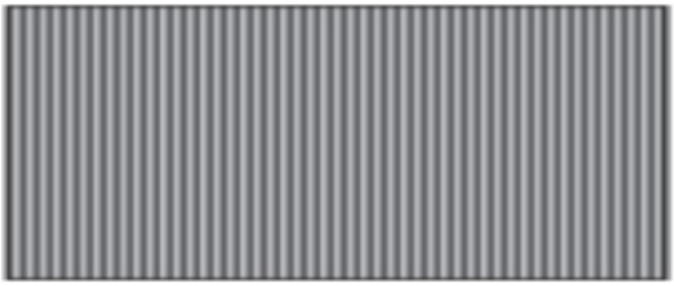
Q1.

(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.

___

___

___

___

(3)

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

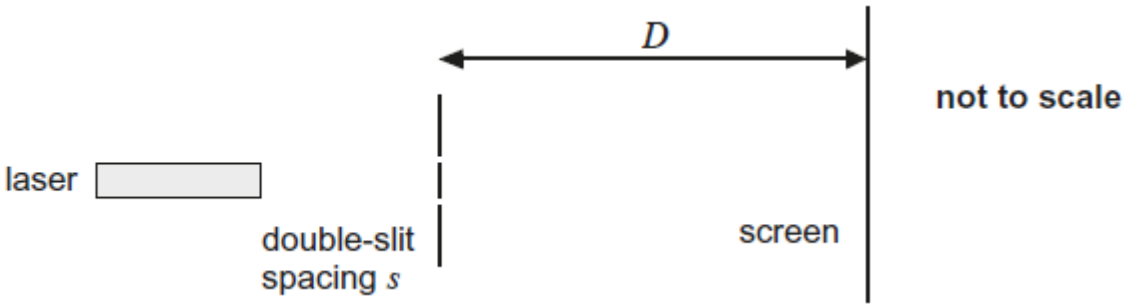
___

___

___

(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

(1)

(ii) the percentage uncertainty in this value of wavelength

(1)

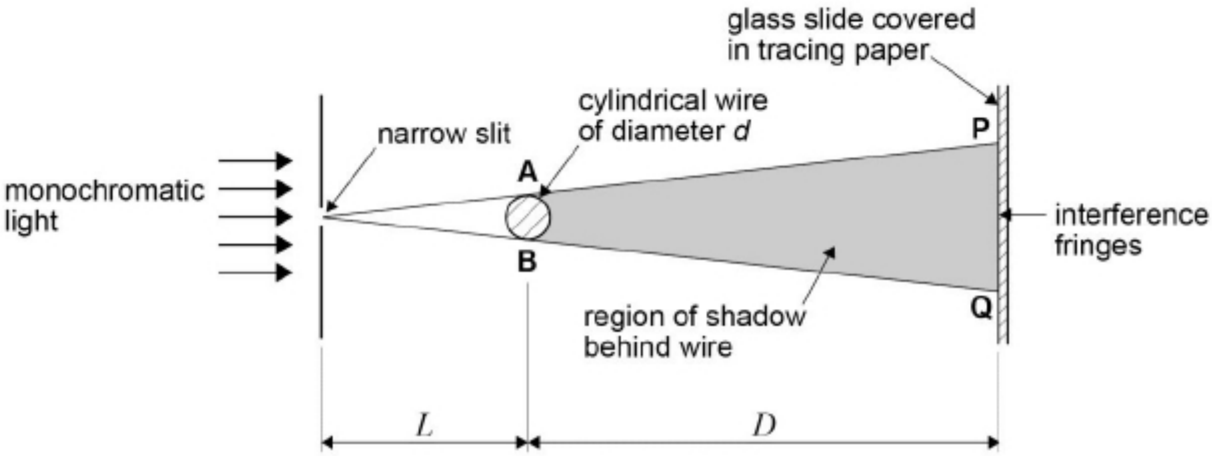
(iii) the absolute uncertainty in this value of wavelength.

(1)
(Total 8 marks)

Q2.

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**.

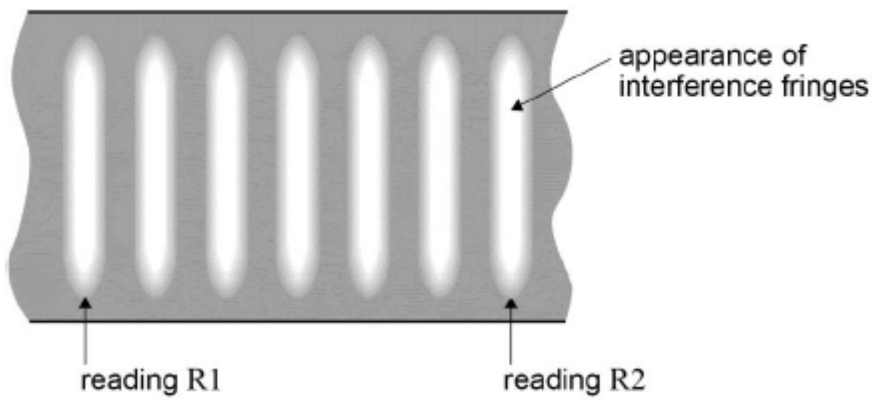
Figure 1



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.

____

____

____

____

(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)

Q3.

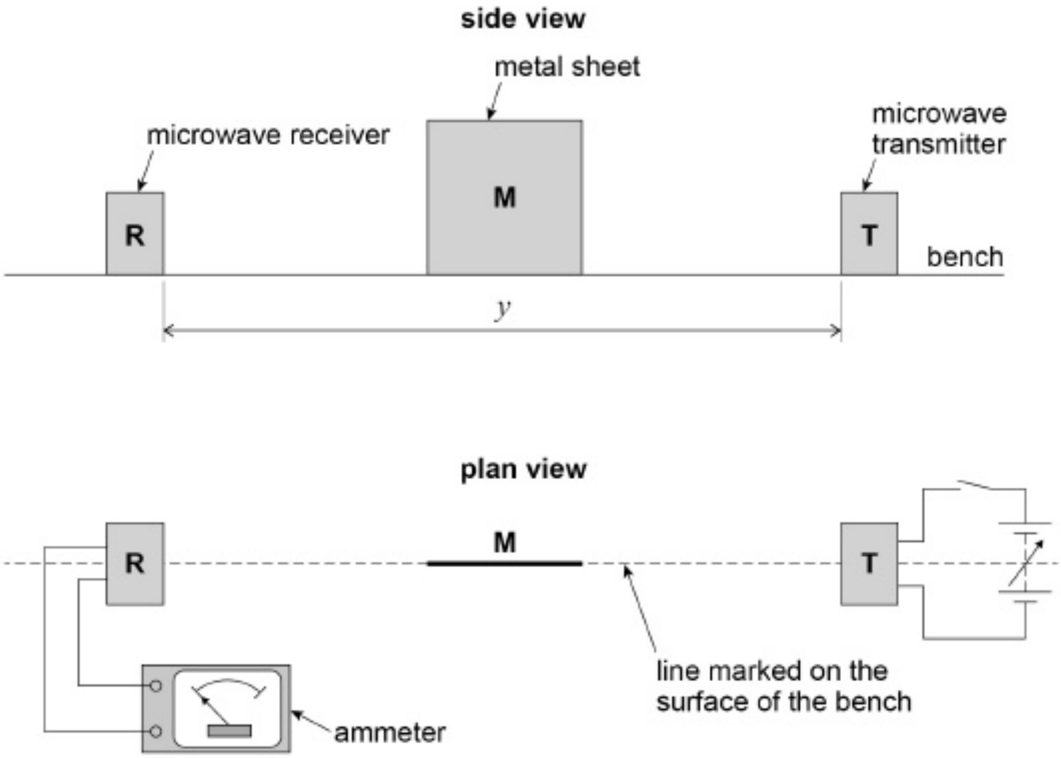
This question is about an experiment to measure the wavelength of microwaves.

A microwave transmitter **T** and a receiver **R** are arranged on a line marked on the bench.

A metal sheet **M** is placed on the marked line perpendicular to the bench surface.

Figure 1 shows side and plan views of the arrangement.
The circuit connected to **T** and the ammeter connected to **R** are only shown in the plan view.

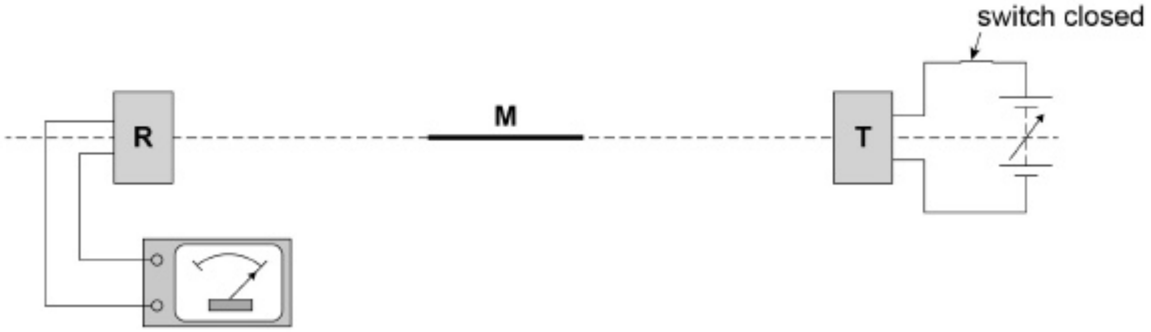
Figure 1



The distance y between **T** and **R** is recorded.

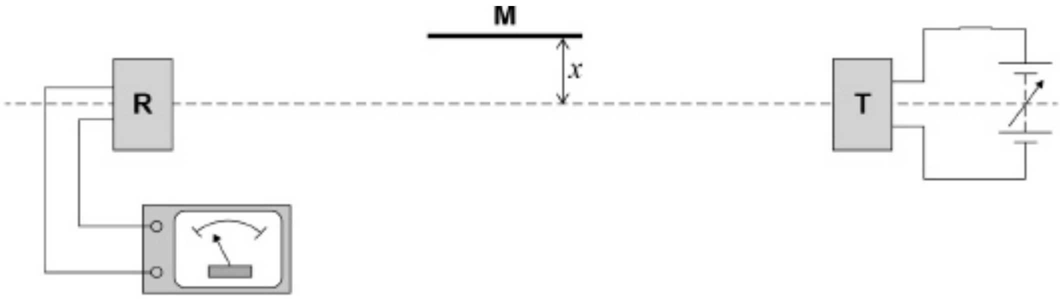
T is switched on and the output from **T** is adjusted so a reading is produced on the ammeter as shown in **Figure 2**.

Figure 2



M is kept parallel to the marked line and moved slowly away as shown in **Figure 3**.

Figure 3



The reading decreases to a minimum reading **which is not zero**.
The perpendicular distance x between the marked line and **M** is recorded.

(a) The ammeter reading depends on the superposition of waves travelling directly to **R** and other waves that reach **R** after reflection from **M**.

State the phase difference between the sets of waves superposing at **R** when the ammeter reading is a **minimum**.
Give a suitable unit with your answer.

____

(1)

(b) Explain why the minimum reading is **not** zero when the distance x is measured.

____

____

____

(1)

(c) When **M** is moved further away the reading increases to a maximum then decreases to a minimum.

At the first minimum position, a student labels the minimum n = 1 and records the value of x.
The next minimum position is labelled n = 2 and the new value of x is recorded.
Several positions of maxima and minima are produced.

Describe a procedure that the student could use to make sure that **M** is parallel to the marked line before measuring each value of x.

You may wish to include a sketch with your answer.

____

____

____

____

____

____

____

____

(2)

(d) It can be shown that

$$n\lambda = \sqrt{4x^2 + y^2} - y$$

where λ is the wavelength of the microwaves and y is the distance defined in **Figure 1**.

The student plots the graph shown in **Figure 4**.

The student estimates the uncertainty in each value of $\sqrt{4x^2 + y^2}$ to be 0.025 m and adds error bars to the graph.

Determine

- the maximum gradient G_{max} of a line that passes through all the error bars
- the minimum gradient G_{min} of a line that passes through all the error bars.

G_{max} = ____________________

G_{min} = ____________________

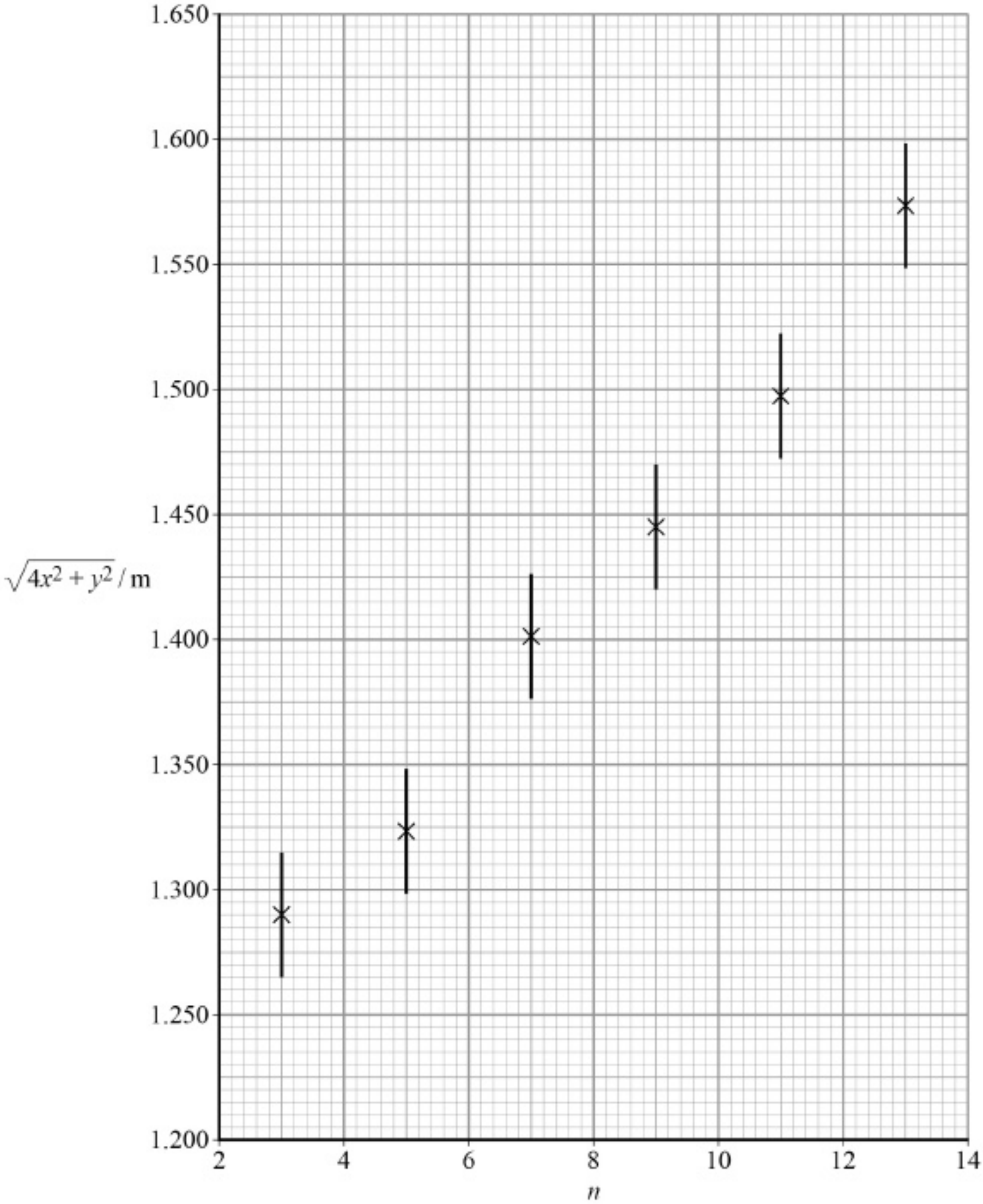
(3)

(e) Determine λ using your results for G_{max} and G_{min}.

λ = ____________________ m

(2)

Figure 4



(f) Determine the percentage uncertainty in your result for λ.

percentage uncertainty in λ = ____________________ %

(3)

(g) Explain how the graph in **Figure 4** can be used to obtain the value of y.
You are **not** required to determine y.

___

___

___

___

___

___

___

___

___

(2)

(h) Suppose that the data for n = 13 had not been plotted on **Figure 4**.

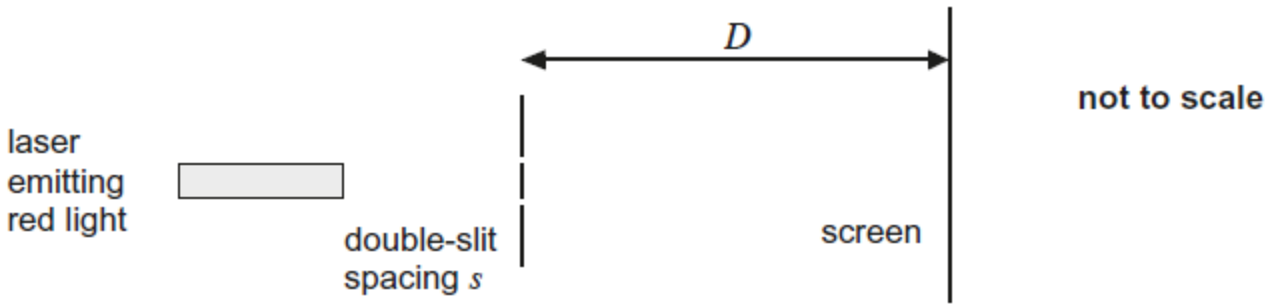
Add a tick (✓) in each row of the table to identify the effect, if any, on the results you would obtain for G_{max}, G_{min}, λ and y.

Result	Reduced	Not affected	increased
G_{max}			
G_{min}			
λ			
y			

(4)
(Total 18 marks)

Q4.

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

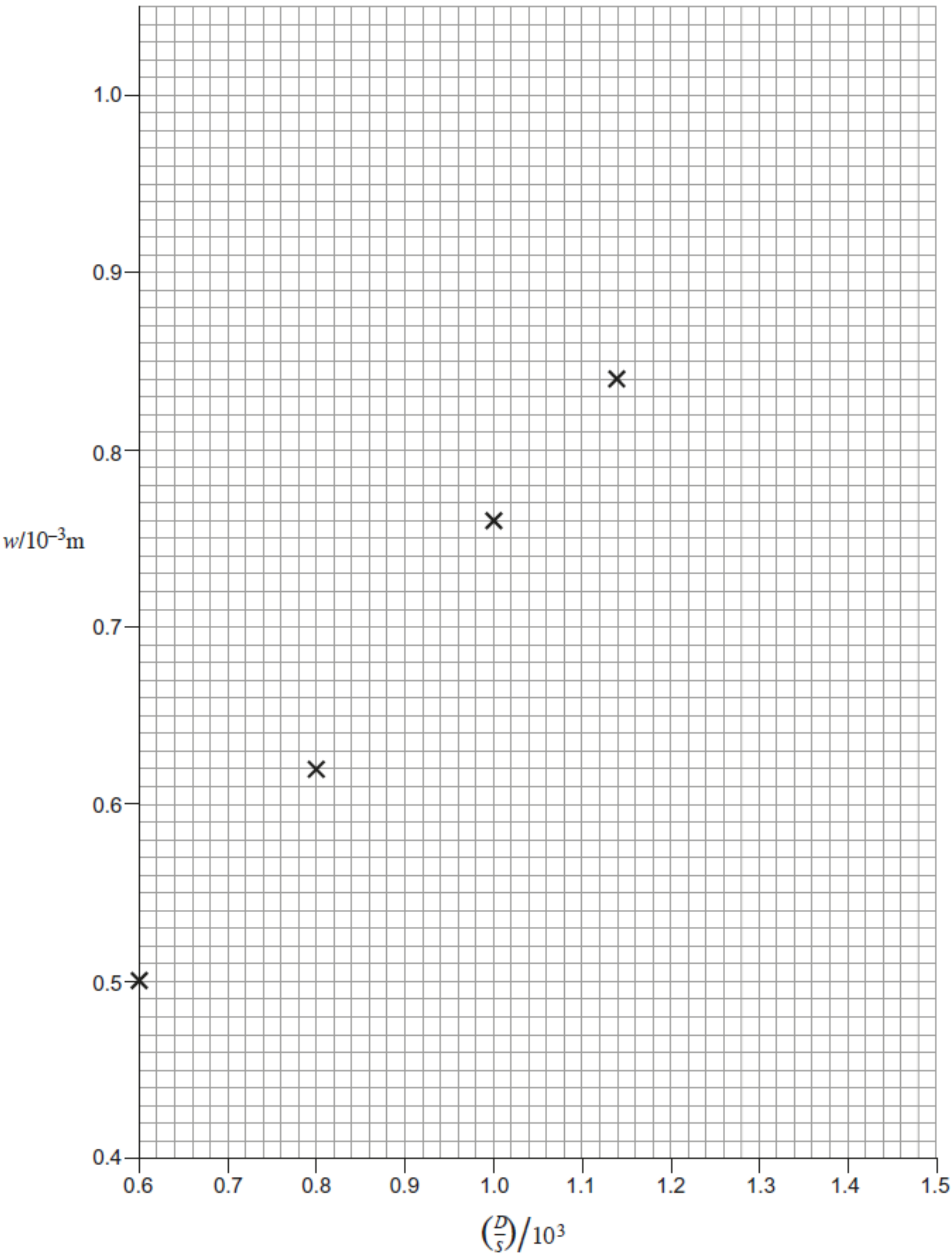
***D*/m**	$S/10^{-3}$ m	$\left(\frac{D}{S}\right)/10^{3}$	$w/10^{-3}$m
1.000	0.70		1.03
0.900	0.70		0.93
0.800	0.70	1.14	0.84
1.000	1.00	1.00	0.76
0.800	1.00	0.80	0.62
0.600	1.00	0.60	0.50

(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)



(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.

(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.

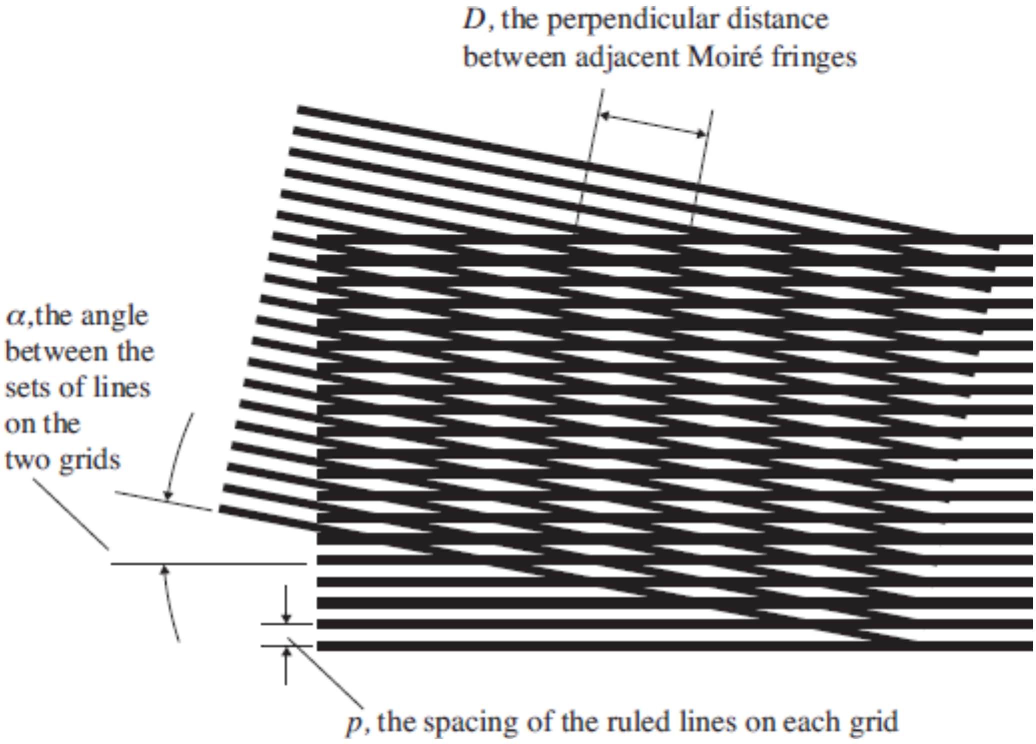
____

____

(1)
(Total 13 marks)

Q5.

Two grids of parallel ruled lines can be used to produce Moiré fringe patterns, as shown below.



A student obtains two diffraction gratings thought to be identical with a line spacing of about 3 × 10^{-6} m. The student finds that when these are placed together and viewed against a white background a Moiré fringe pattern is observed when one grating is rotated slightly. For small angles, the distance between the Moiré interference fringes, D, is given by the approximate equation, $D \simeq \frac{57p}{\alpha}$, where α is in degrees.

By assuming that p = 3.0 × 10^{-6} m, the student uses this equation in a spreadsheet to find D for values of α up to 16°.

The student's results are shown below.

α / °	D / mm
2	0.0855
4	0.0428
6	0.0285

8	0.0214
10	0.0171
12	0.0143
14	0.0122
16	0.0107

The student intends to view the Moiré fringes through a microscope to check the spreadsheet results for D by measuring D using the microscope directly.
The vernier scale on the microscope can measure to the nearest 0.01 mm.

(a) Explain using suitable calculations why this microscope is not suitable to check the results of the spreadsheet calculation.

(4)

(b) The equation for D can be rearranged to give $p \simeq \frac{\alpha D}{57}$.

The student suggests that if a better microscope can be provided and α can be set to produce values of D greater than 0.10 mm, the value of p can be found experimentally. Discuss whether the student’s suggestion is sensible.

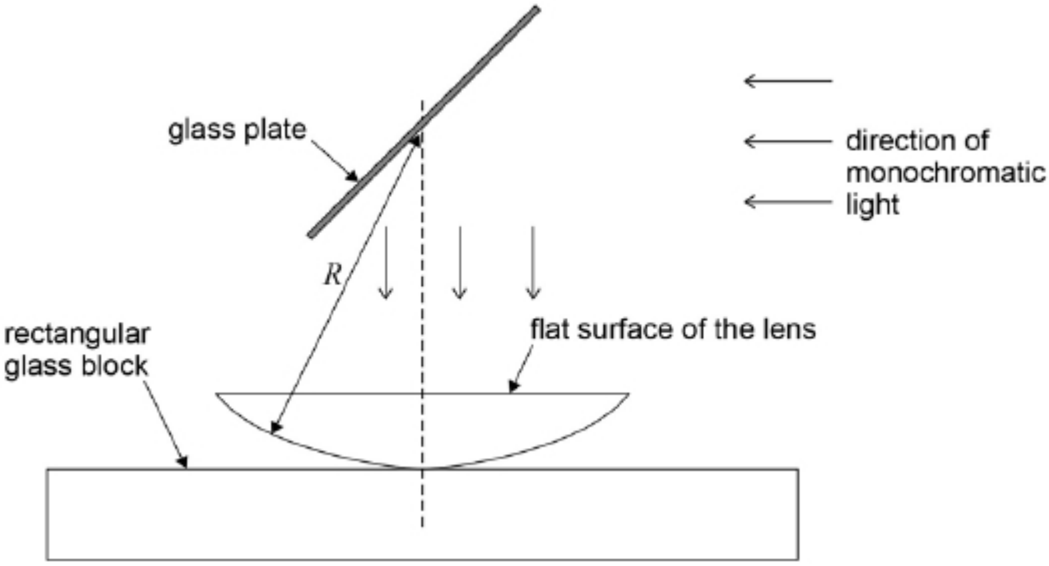
(2)

(c) The theoretical separation of the Moiré fringes when α = 2°, shows D = 0.0859 mm. Calculate the percentage difference between this value and the student's spreadsheet result for D when α = 2°.

Q6.

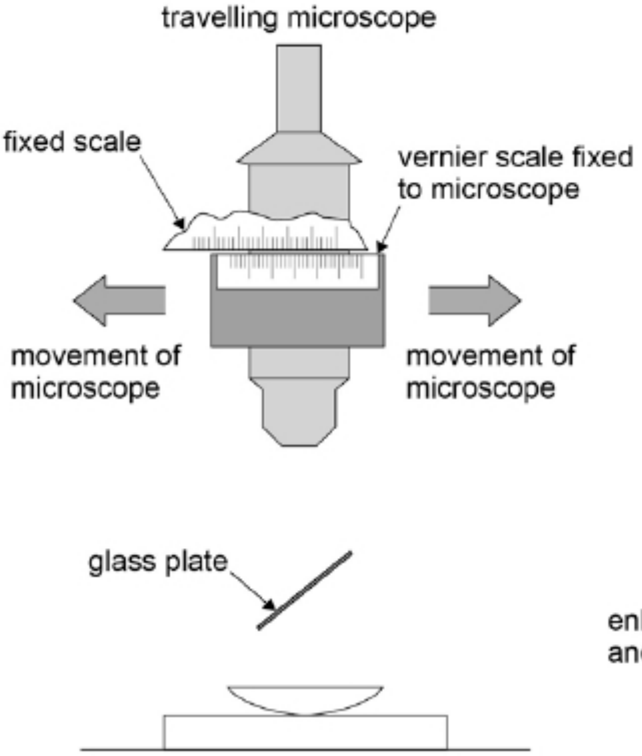
A lens has a flat surface and a curved surface. An experiment is carried out to determine the radius R of the curved surface of the lens. The lens is placed on a rectangular glass block with its flat surface upwards. The lens is illuminated with monochromatic light reflected from a glass plate as shown in **Figure 1**.

Figure 1



When the apparatus is viewed from above an interference pattern consisting of concentric dark and bright rings is seen. A travelling microscope positioned as shown in **Figure 2** is used to measure the diameter of the **bright** rings.

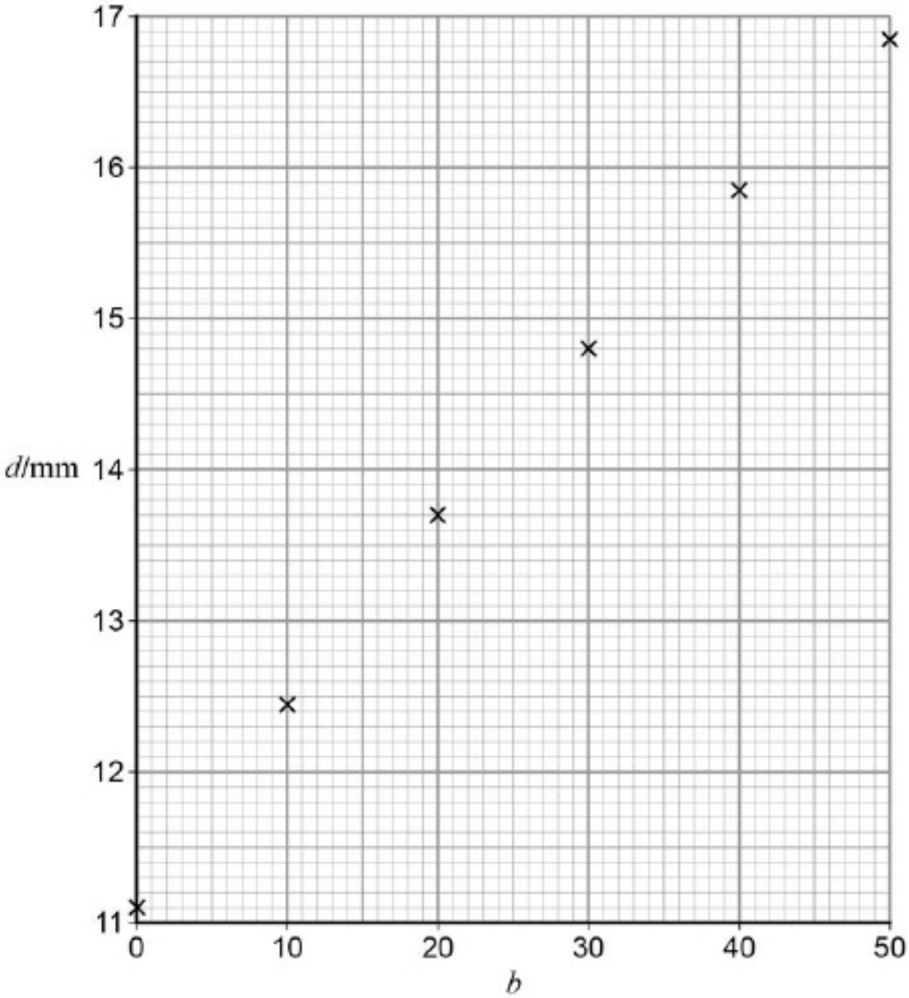
Figure 2



enlarged view of pattern of concentric dark and bright rings seen through the microscope

(a) A student chose a particular bright ring (not at the centre of the pattern) and measured its diameter. He called this ring number 0. Counting outwards from the centre, he measured the diameter of every tenth ring.

Below is a graph of ring number b against ring diameter d.



Draw a line of best fit on the graph above.

(1)

(b) Determine the gradient G corresponding to b = 25.

G = ____________________

(3)

(c) The radius of curvature R of the lens can be calculated using any point on the graph together with the formula

$$R = \frac{Gd}{2\lambda}$$

where λ = 589.3 nm.

Determine R.