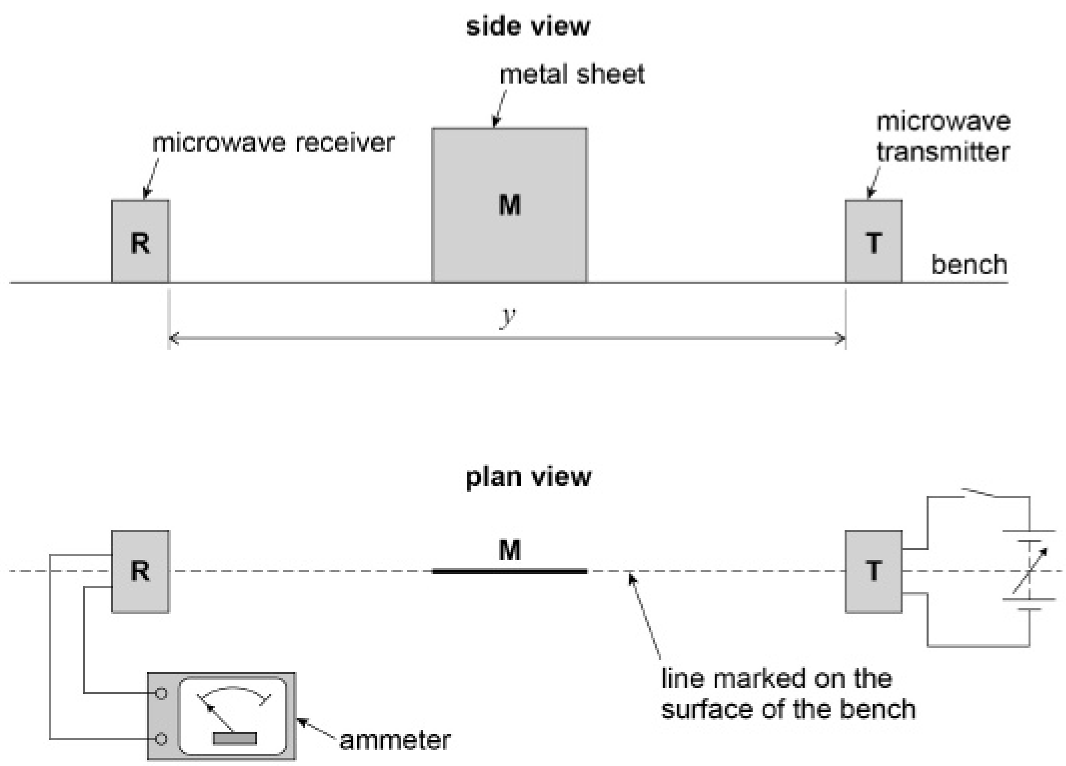
4 This question is about an experiment to measure the wavelength of microwaves.

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.

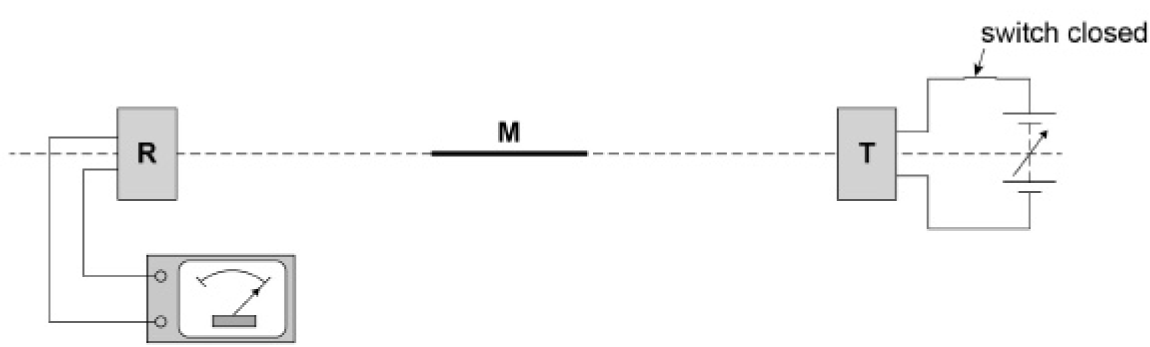
Figure 1



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

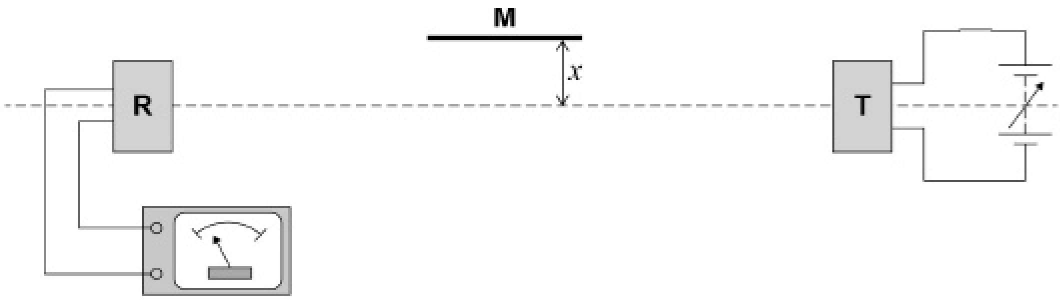
T is switched on and the output from **T** is adjusted so a reading is produced on the ammeter as shown in **Figure 2**.

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.

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(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} = ______________________

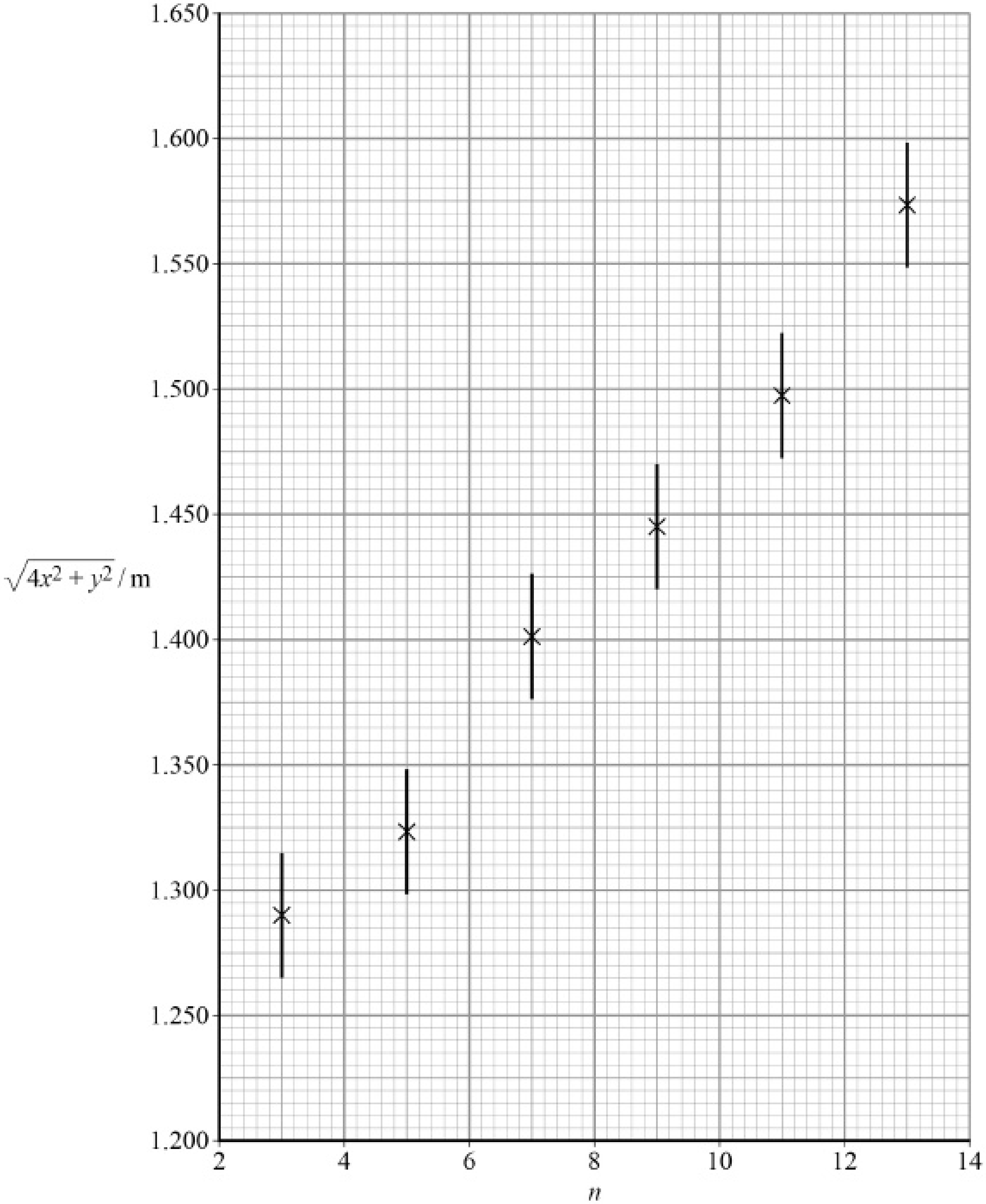
(3)

(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.

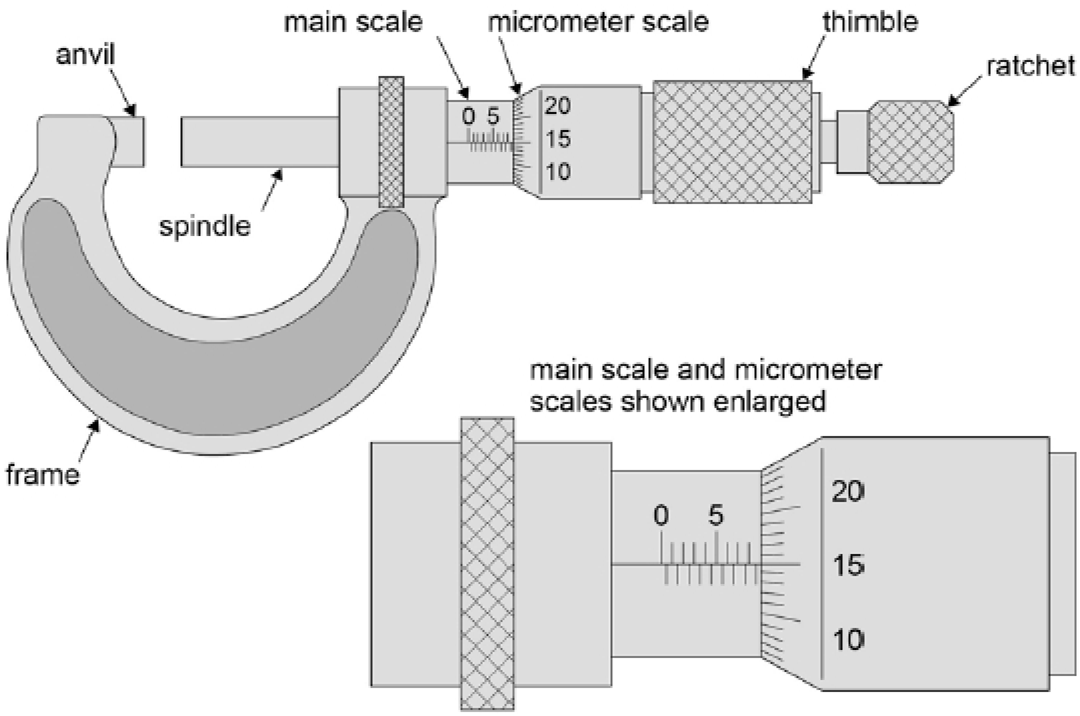
Result	**Reduced**	**Not affected**	**increased**
G_{max}			
G_{min}			
λ			
y			

(4)
(Total 18 marks)

5 This question is about the determination of the resistivity of a wire.

Figure 1 shows a micrometer screw gauge that is used to measure the diameter of the wire.

Figure 1



(a) State the resolution of the **main scale** on the micrometer in **Figure 1**.

resolution = ____________________ mm

(1)

(b) Determine the distance between the anvil and the spindle of the micrometer in **Figure 1**.
State any assumption you make.

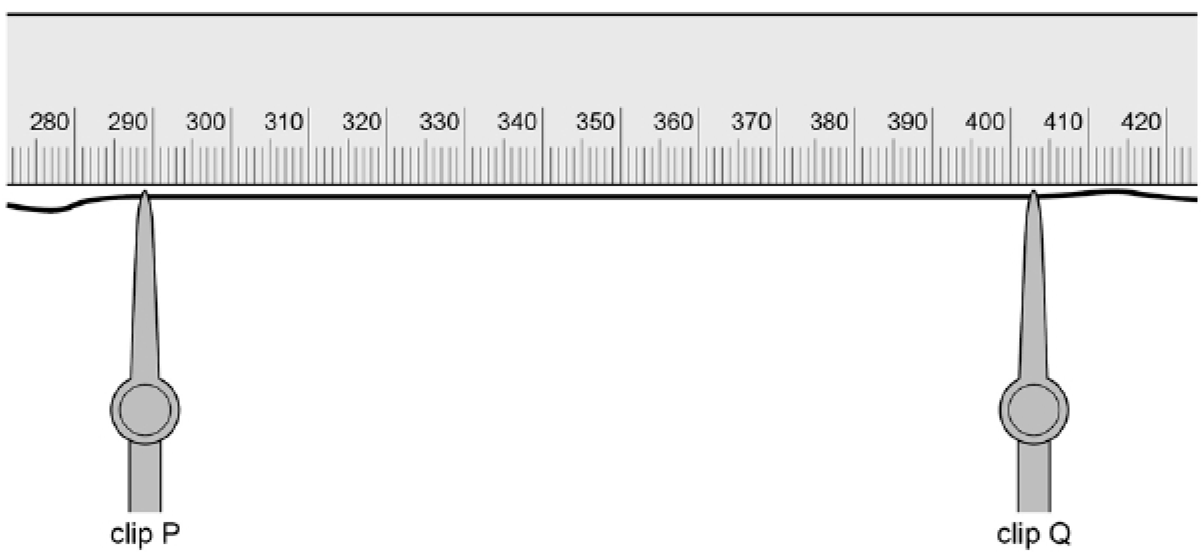
distance = ____________________mm

(2)

(c) A student must also determine the length L of the wire between clips P and Q that will be connected into a circuit.

Figure 2 shows the metre ruler being used to measure L.

Figure 2



Determine L

L = __________________________ mm

(1)

(d) Calculate the percentage uncertainty in your result for L.

percentage uncertainty = ____________________ %

(2)

(e) State and explain what the student could have done to reduce uncertainty in the reading for L.

____

____

____

(1)

(f) The student intends to make measurements that will allow her to determine the resistance of one metre of the wire. She uses an ohm-meter to measure the resistance R for different lengths L of the wire. The student's measurements are shown in the table below.

L/cm	R/Ω	
81.6	8.10	
72.2	7.19	
63.7	6.31	
58.7	5.85	
44.1	4.70	

Determine the value that the student should record for the resistance per metre of the wire.

Use the additional column in the table above to show how you arrived at your answer.

resistance of one metre of wire = ________________ Ω

(2)

(g) Determine the resistivity of the wire. Give a suitable unit for your answer.

mean diameter of the wire = 0.376 mm

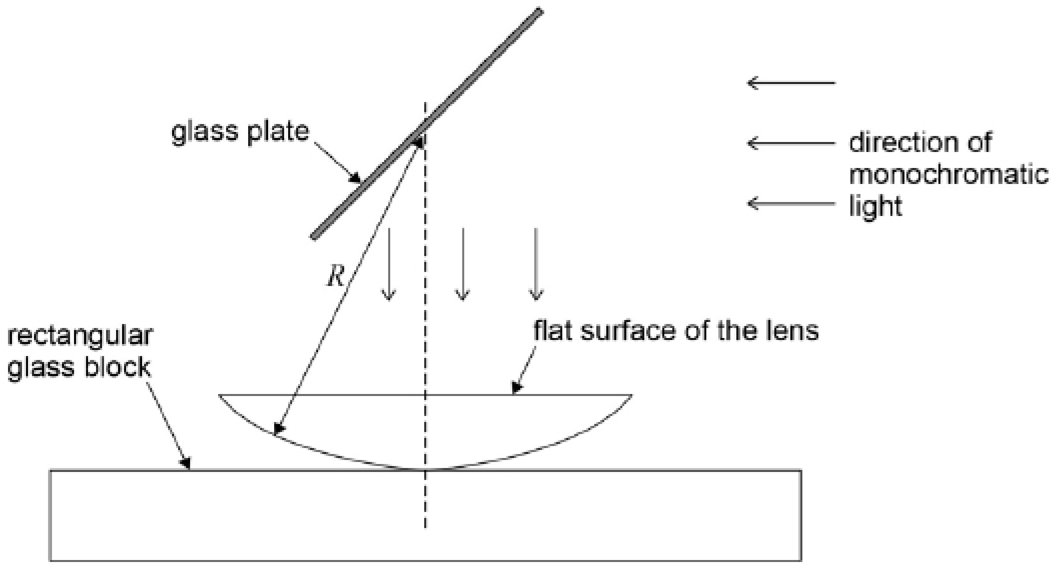
resistivity = ________________ unit = ____________

(4)

(Total 13 marks)

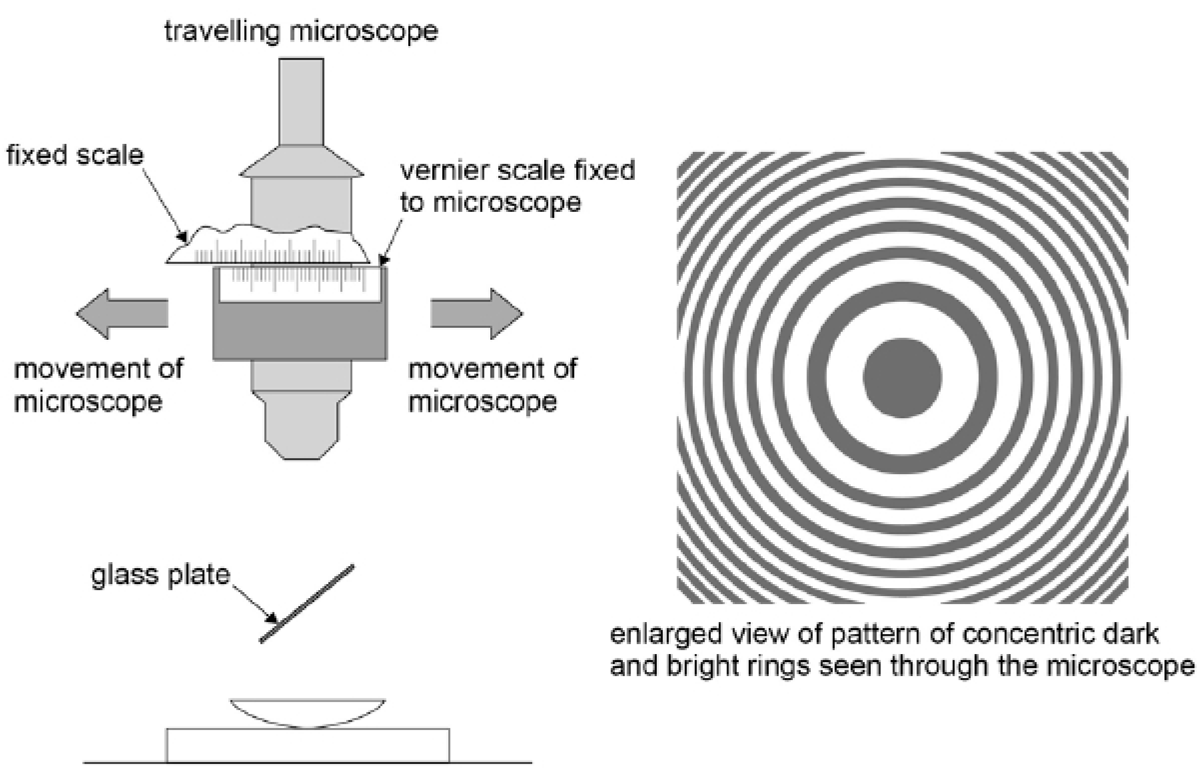
6 A lens has a flat surface and a curved surface. An experiment is carried out to determine the radius R of the curved surface of the lens. The lens is placed on a rectangular glass block with its flat surface upwards. The lens is illuminated with monochromatic light reflected from a glass plate as shown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

Figure 1



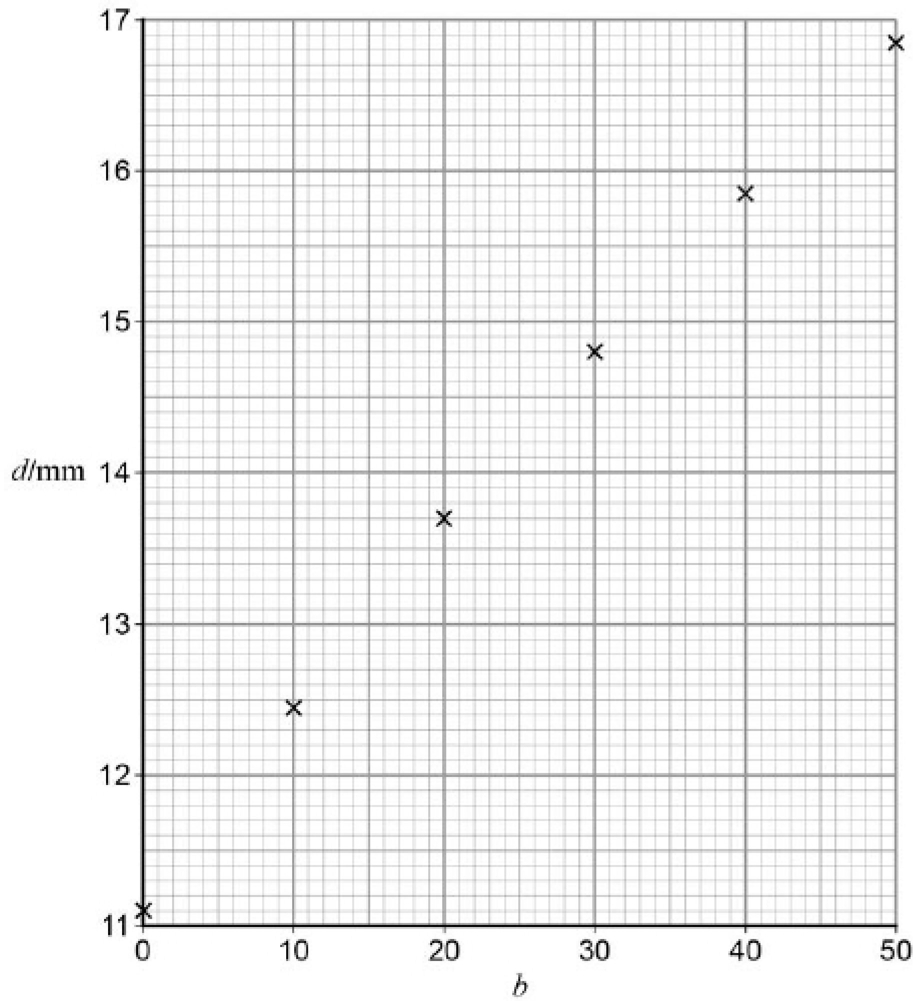
When the apparatus is viewed from above an interference pattern consisting of concentric dark and bright rings is seen. A travelling microscope positioned as shown in **Figure 2** is used to measure the diameter of the **bright** rings.

Figure 2



(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.

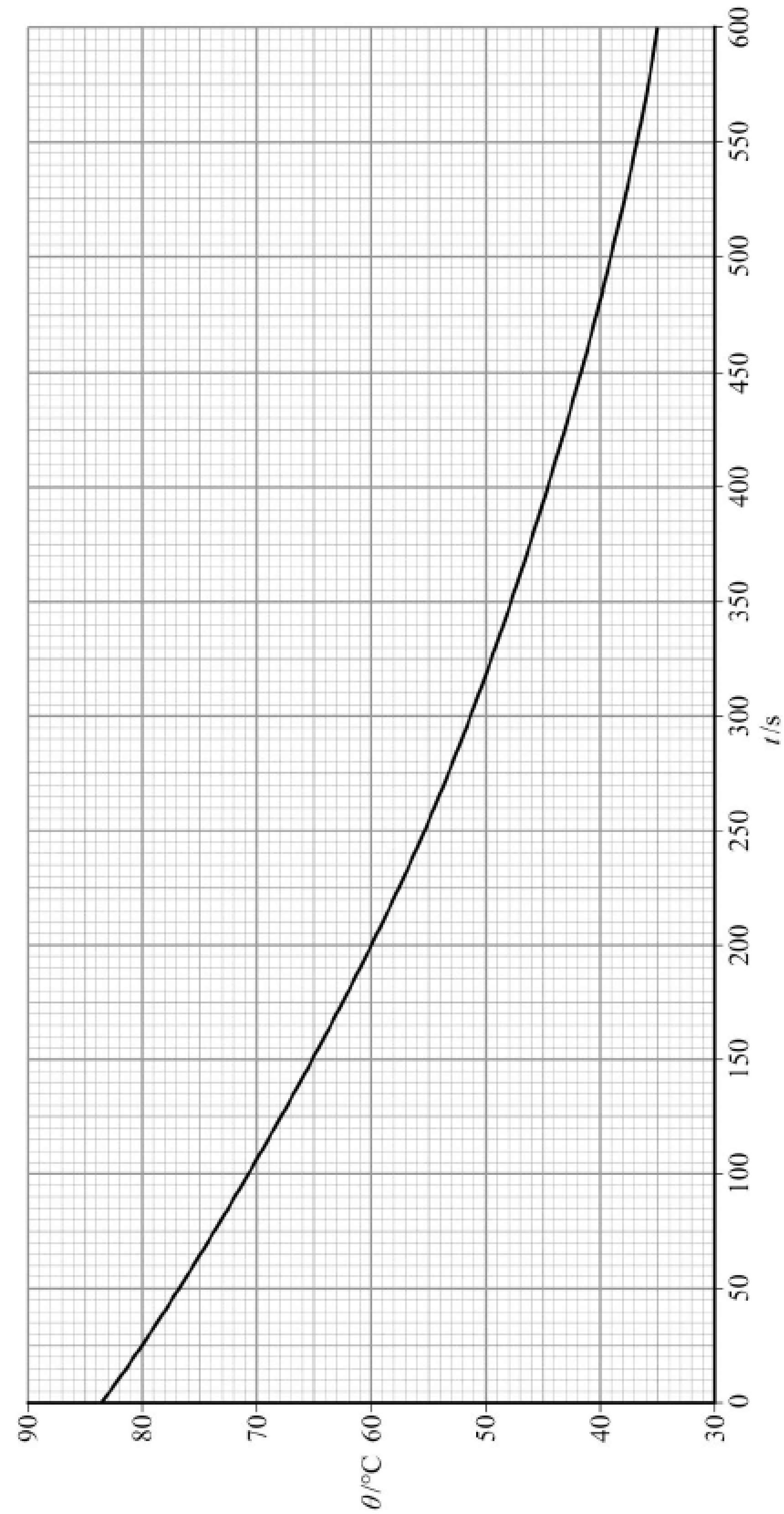
R = ______________________ m

(3)

(Total 7 marks)

8 A temperature sensor is connected to a data logger to monitor how the temperature θ of a fixed mass of recently−boiled water varies with time t, over an interval of 600 s. These data are processed to produce the graph shown in **Figure 1**.

Figure 1



(a) Determine the temperature θ_1 of the water when t is 190 s.

θ_1 = ____________________ °C

(1)

(b) Determine the gradient G_1 of the graph at t is 190 s.

G_1 ________________________

(3)

(c) When t = 370 s the temperature θ_2 = 46.6 °C and the gradient G_2 = − 0.0645.

The room temperature θ_R is given by $\dfrac{G_1\theta_2 - G_2\theta_1}{G_1 - G_2}$

Evaluate θ_R.

θ_R = ____________________ °C

(1)

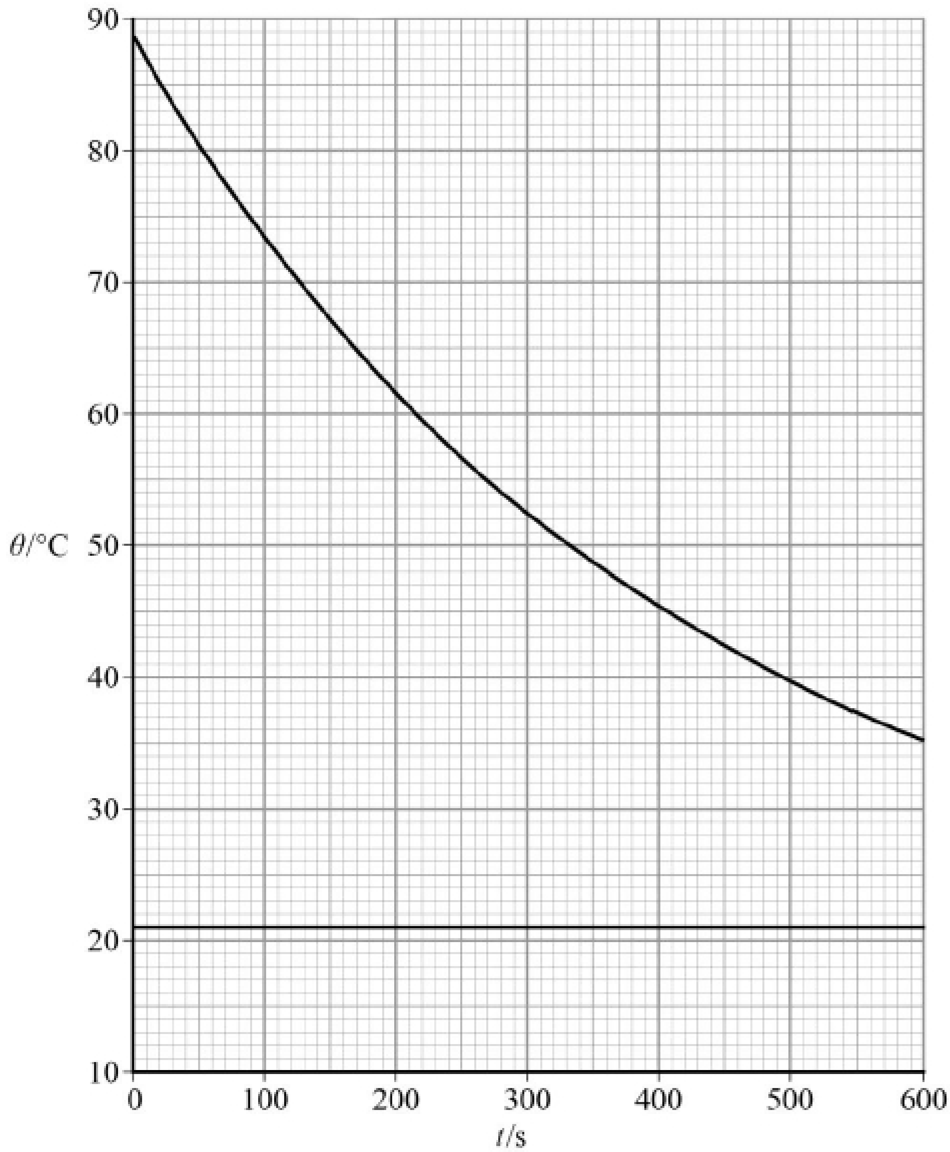
(d) It can be shown that when a hot object at a temperature θ is allowed to cool in a draught, the rate at which the temperature decreases is directly proportional to the temperature difference $(\theta - \theta_R)$ between the object and the surroundings.

A student realises that $(\theta - \theta_R)$ will decrease exponentially with time and designs an experiment in which two temperature sensors are connected to a data logger.

- Sensor 1 is placed in a beaker of recently−boiled water.
- Sensor 2 measures the air temperature in the room.
- The data logger is programmed to record the output from the sensors as the water cools for 600 s.

The output data from the sensors are processed to produce the graph shown in **Figure 2**.

Figure 2



($\theta - \theta_R$) will decrease exponentially in the same way that the potential difference (pd) across a discharging capacitor decreases with time.

When a capacitor discharges, the pd across the capacitor falls to $\frac{1}{e}$ of an initial value in a time called the **time constant**. Electronic engineers assume that a capacitor becomes fully discharged in a time equal to **5 time constants**.

Estimate the time taken for the water to cool down to room temperature.

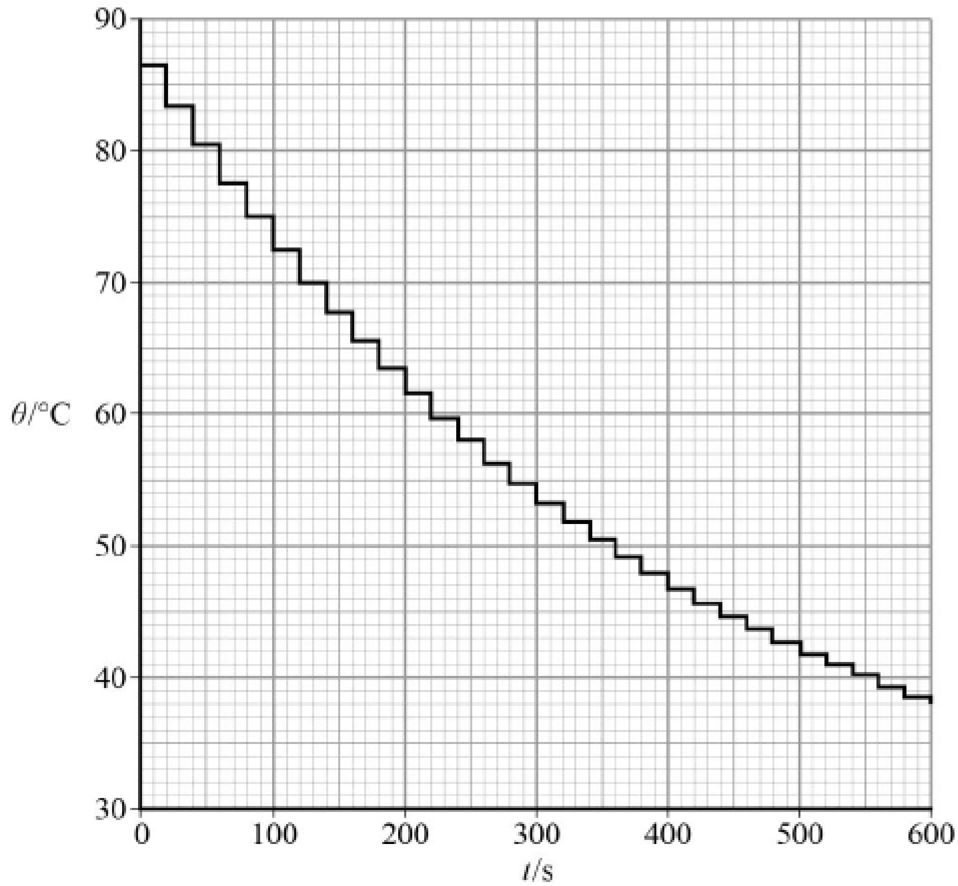
time taken = ____________________ s

(4)

(e) Another student carries out the experiment using the same mass of recently−boiled water and beaker as before.

The output data for sensor 1 from this student's experiment are shown in **Figure 3**.

Figure 3



Account for the differences between these results and the way they are displayed, with those shown in **Figure 2**.

You should include appropriate quantitative detail in your answer.

(5)

(Total 14 marks)