

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

A-level PHYSICS

Paper 3 Section A

Thursday 29 June 2017

Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 70 minutes on this section.

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae booklet.

Instructions

- Use **black ink** or **black ball-point pen**.
- **Fill** in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do **all** rough work in this book. Cross through any work you do not want to be marked.
- Show **all** your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 45.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
TOTAL	



J U N 1 7 7 4 0 8 3 A 0 1

Section A

Answer **all** questions in this section.

0	1
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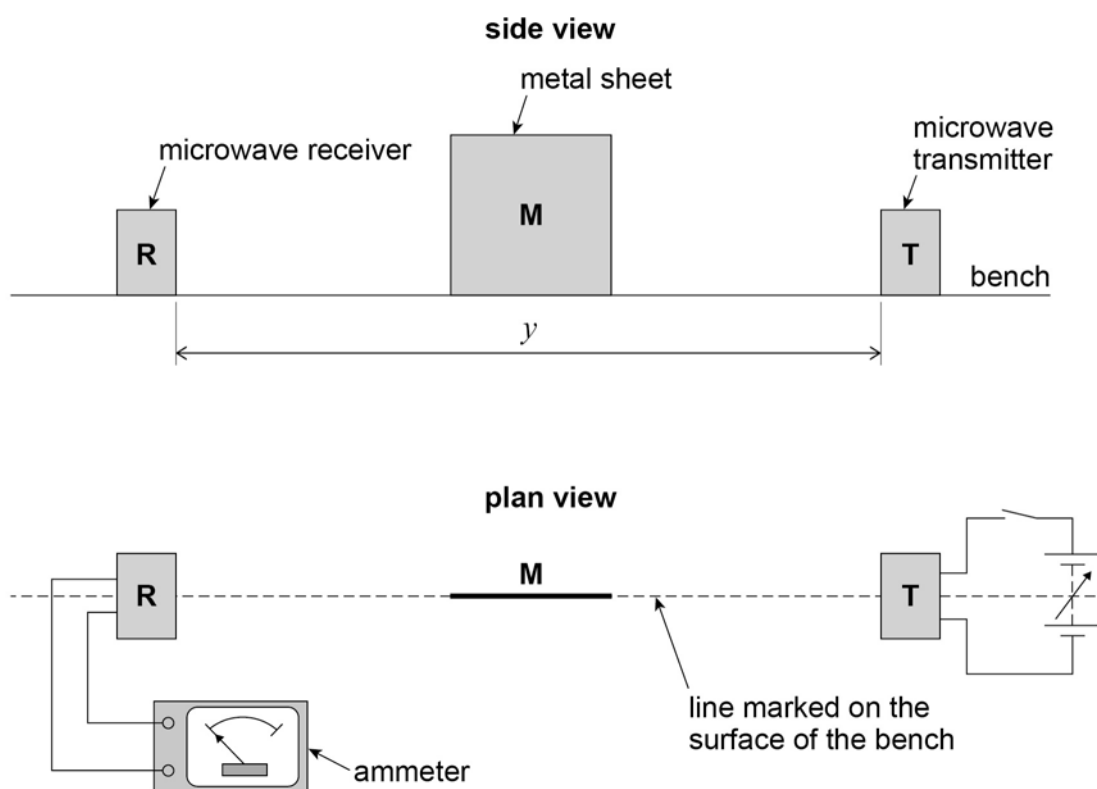
This question is about an experiment to measure the wavelength of microwaves.

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

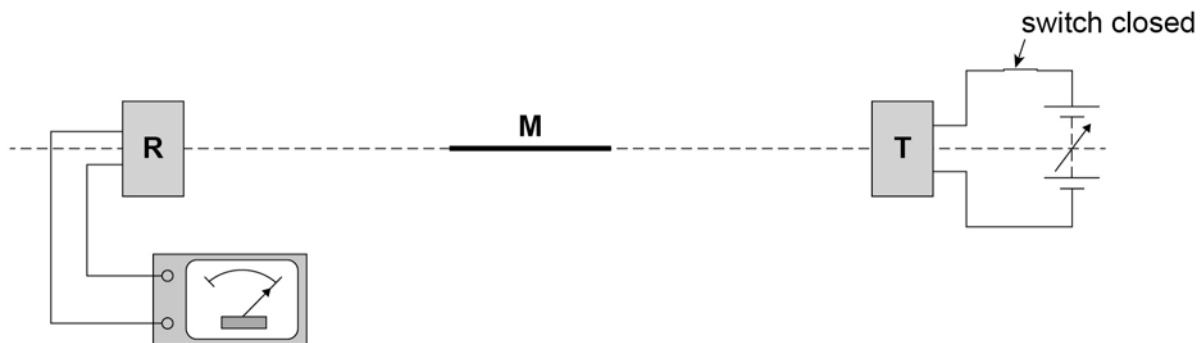


The distance y between **T** and **R** is recorded.



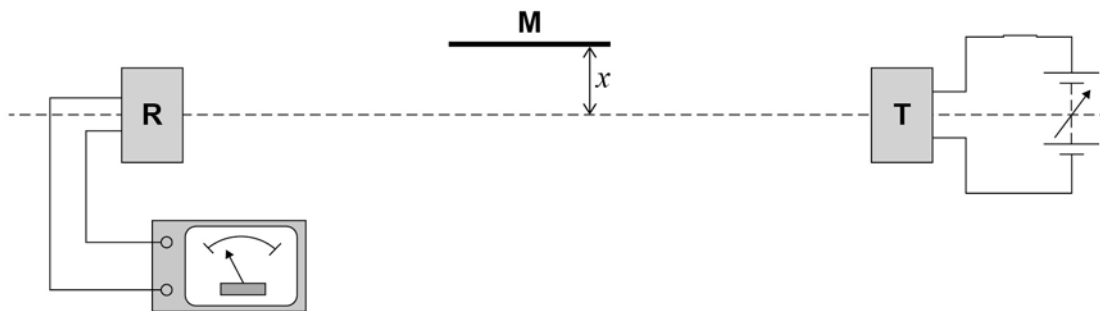
T is switched on and the output from **T** is adjusted so a reading is produced on the ammeter as shown in **Figure 2**.

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.

0 1 . 1

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 mark]

180° (π radians)

Question 1 continues on the next page

Turn over ►



0 1 . 2

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

[1 mark]

The two sets of waves do not have the same amplitude (some energy is absorbed at M on reflection), so they cannot cancel out completely.

0 1 . 3

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

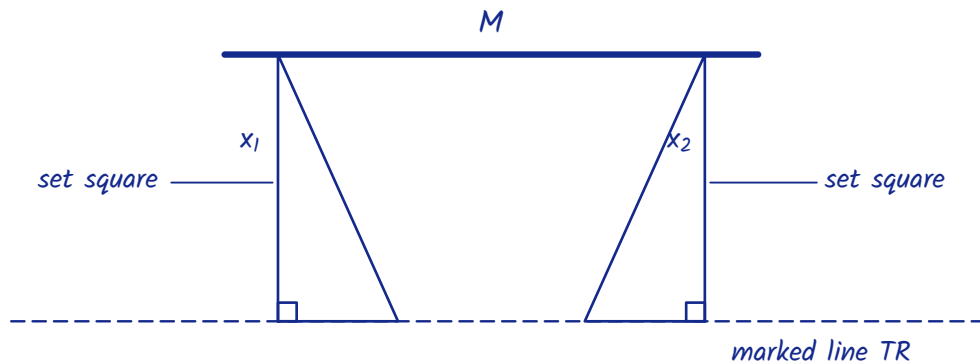
At the first minimum position, a student labels the minimum $n = 1$ and records the value of x .

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 marks]



Place a set square with one edge along the marked line TR (so the other edge is perpendicular to TR) and measure x along it at one end of M.

Repeat at a different point, at the other end of M. Adjust M until the two distances are the same; then M is parallel to the marked line.



Question 1 continues on the next page

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0 1 . 4

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.

[3 marks]

$G_{\max}$ line: through bottom of $n = 3$ bar and top of $n = 11$ bar

$$G_{\max} = (1.522 - 1.265) \div (11 - 3) = 0.257 \div 8 = 0.0321$$

$G_{\min}$ line: through top of $n = 5$ bar and bottom of $n = 13$ bar

$$G_{\min} = (1.548 - 1.348) \div (13 - 5) = 0.200 \div 8 = 0.0250$$

$$G_{\max} = 3.21 \times 10^{-2}$$

$$G_{\min} = 2.50 \times 10^{-2}$$

0 1 . 5

Determine λ using your results for $G_{\max}$ and $G_{\min}$.

[2 marks]

$$n\lambda + y = \sqrt{4x^2 + y^2}, \text{ so gradient} = \lambda$$

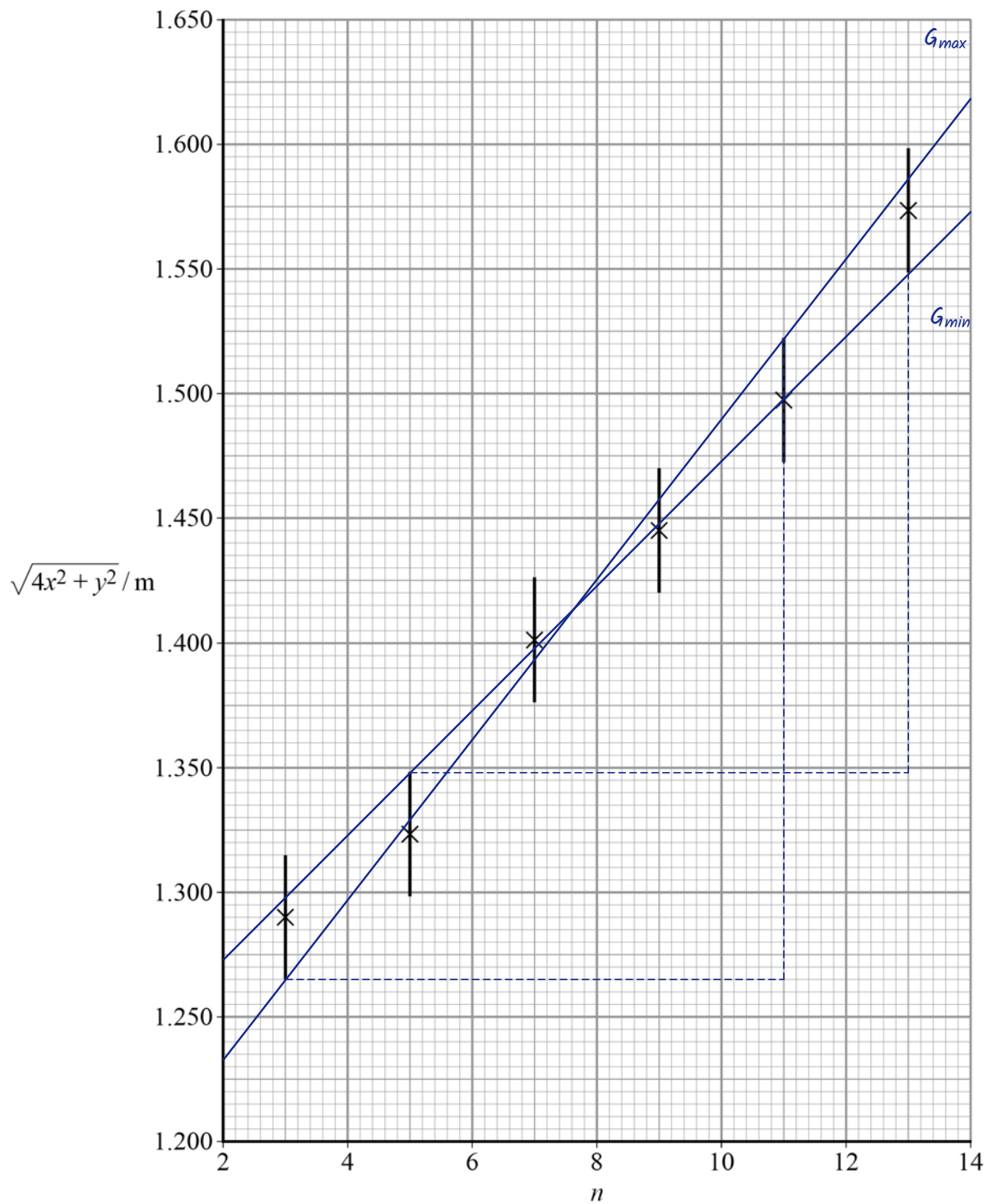
$$\lambda = (G_{\max} + G_{\min}) \div 2 = (0.0321 + 0.0250) \div 2$$

$$\lambda = 0.02855 \text{ m}$$

$$\lambda = 2.86 \times 10^{-2} \text{ m}$$



Figure 4



Question 1 continues on the next page

Turn over ►



0 1 . 6

Determine the percentage uncertainty in your result for λ .

[3 marks]

$$\Delta\lambda = (G_{\max} - G_{\min}) \div 2 = (0.0321 - 0.0250) \div 2 = 0.00355 \text{ m}$$

$$\% \text{ uncertainty} = (\Delta\lambda \div \lambda) \times 100 = (0.00355 \div 0.02855) \times 100 = 12.4 \%$$

percentage uncertainty in $\lambda = 12.4 \%$

0 1 . 7

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

[2 marks]

Since $\sqrt{4x^2 + y^2} = n\lambda + y$, y is the (vertical) intercept of the line at $n = 0$. The n axis does not start at 0, so the intercept must be calculated.

For each of the $G_{\max}$ and $G_{\min}$ lines, read a point (n , value) and calculate $\text{intercept} = \text{value} - \text{gradient} \times n$. Then find the average of the two intercepts to get y .

0 1 . 8

Suppose that the data for $n = 13$ had not been plotted on **Figure 4**.Add a tick (✓) in each row of **Table 1** to identify the effect, if any, on the results you would obtain for $G_{\max}$, $G_{\min}$, λ and y .

[4 marks]

Table 1

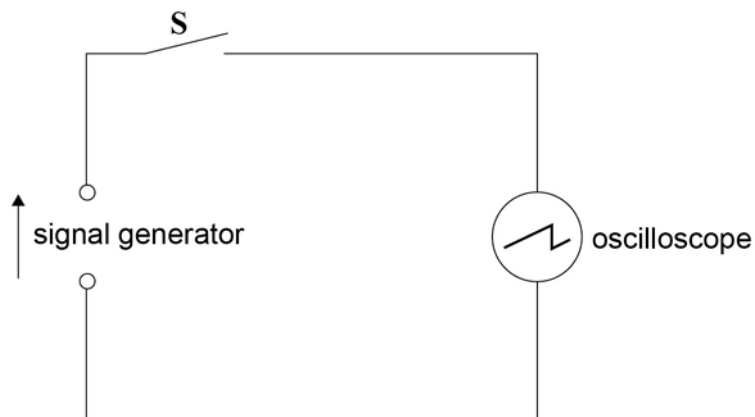
Result	Reduced	Not affected	Increased
$G_{\max}$		✓	
$G_{\min}$	✓		
λ	✓		
y			✓



0 2

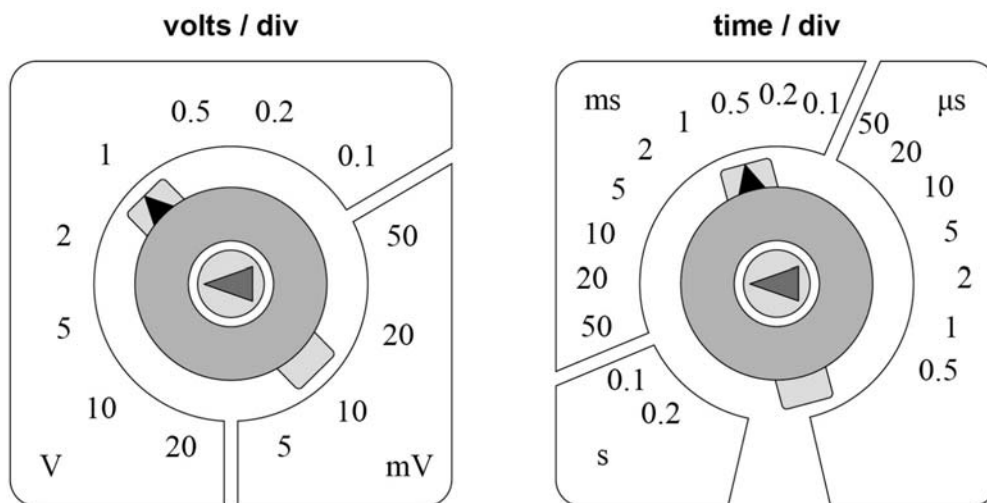
A signal generator is connected to an oscilloscope, as shown in **Figure 5**.

Figure 5



The Y-voltage gain and time-base settings of the oscilloscope are shown in **Figure 6**.

Figure 6



Question 2 continues on the next page

Turn over ►



When switch S is open (off) the oscilloscope displays the waveform shown in **Figure 7**.

When S is closed (on) the oscilloscope displays the waveform shown in **Figure 8**.

0 2 . 1

Determine the peak-to-peak voltage V of the waveform shown in **Figure 8**.

[1 mark]

Peak-to-peak height on Figure 8 = 6.3 divisions

Y-gain = 1 V div⁻¹, so $V = 6.3 \times 1 = 6.3$ V

$V =$ 6.3 V

0 2 . 2

Determine the frequency f of the waveform shown in **Figure 8**.

[2 marks]

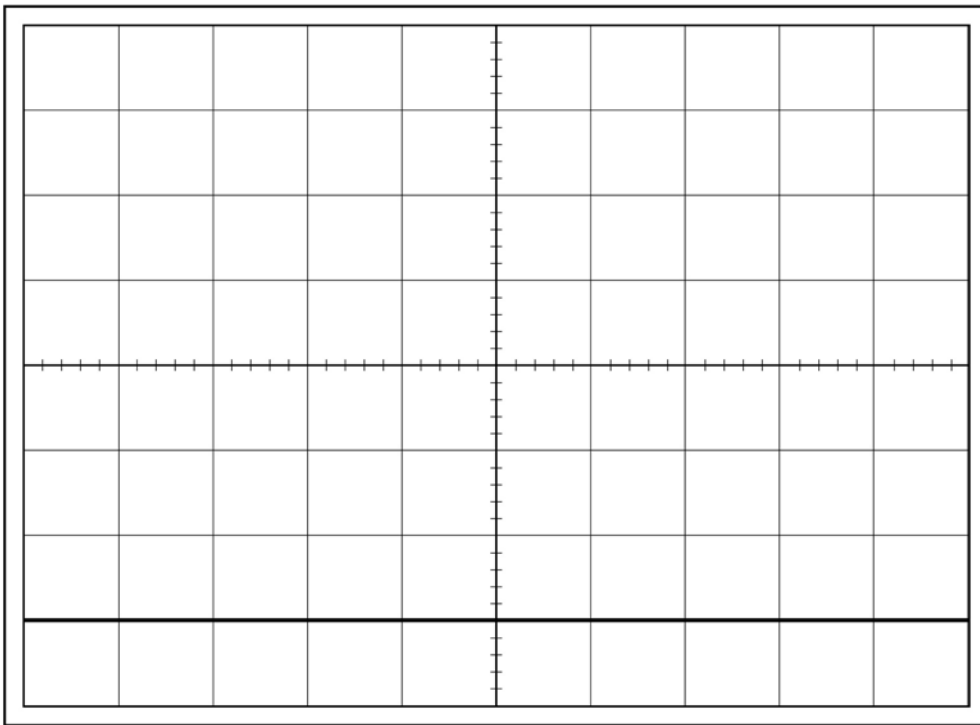
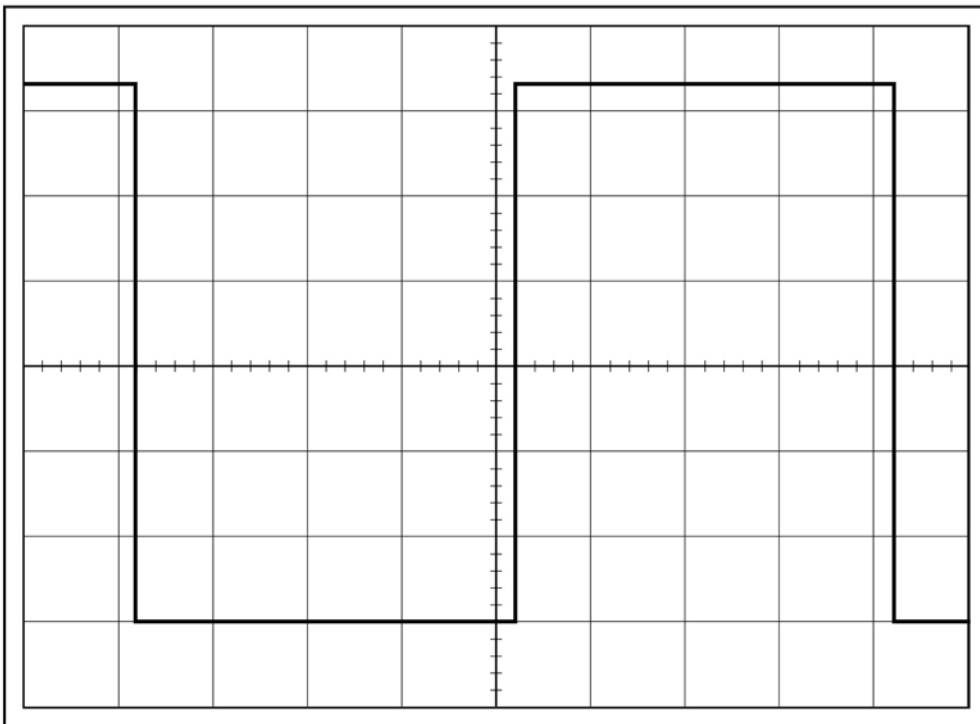
One cycle (period) = 8 divisions

Time-base = 0.5 ms div⁻¹, so $T = 8 \times 0.5 \text{ ms} = 4.0 \text{ ms} = 4.0 \times 10^{-3} \text{ s}$

$f = 1 \div T = 1 \div (4.0 \times 10^{-3})$

$f =$ 250 Hz



Figure 7**Figure 8**

Question 2 continues on the next page

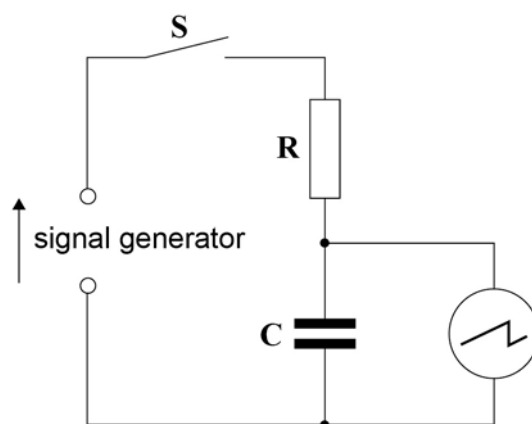
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0 2 . 3

Figure 9 shows the signal generator connected in series with a resistor **R** and a capacitor **C**.

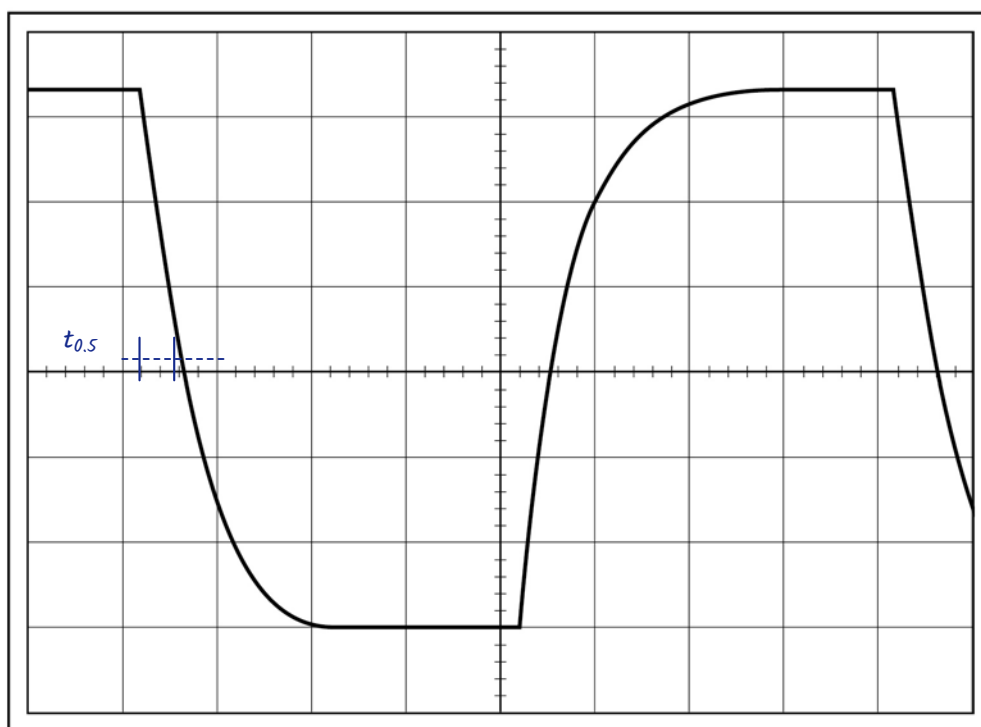
Figure 9



The oscilloscope is connected across the capacitor.
The Y-voltage gain and time-base settings are still the same as shown in **Figure 6**.

When **S** is closed (on) the oscilloscope displays the waveform shown in **Figure 10**.

Figure 10



Determine the time constant of the circuit in **Figure 9**.

[2 marks]

Discharge starts at the top level; V falls to half its initial value (3.15 V below the top) after 0.37 divisions.

$$t_{0.5} = 0.37 \times 0.5 \text{ ms} = 0.185 \text{ ms} = 1.85 \times 10^{-4} \text{ s}$$

$$t_{0.5} = RC \ln 2, \text{ so } RC = t_{0.5} \div \ln 2$$

$$RC = 1.85 \times 10^{-4} \div 0.693 = 2.7 \times 10^{-4} \text{ s}$$

time constant = 2.7 × 10⁻⁴ s

0 2 . 4

A student suggests that setting the time-base to 0.2 ms division⁻¹ might reduce uncertainty in the determination of the time constant.

State and explain any possible advantage or disadvantage in making this suggested adjustment.

[3 marks]

Advantage: the waveform will stretch horizontally by a factor of 2.5

(0.5 ÷ 0.2), so half a cycle now covers the 10 horizontal divisions of the screen.

So the resolution of the time axis is increased: the time interval

(half-life) is measured across a larger distance / more divisions, which reduces the (percentage) uncertainty in reading the time.

The whole cycle is not seen at once, but the X-shift can bring the discharge into view.

Question 2 continues on the next page

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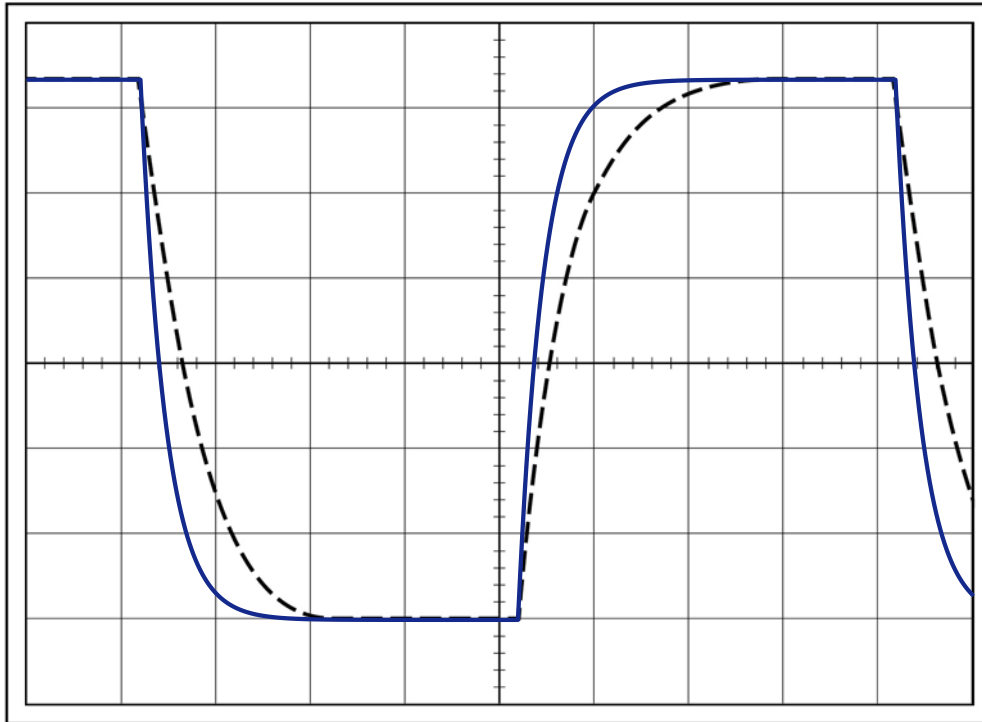
0 2 . 5

The student connects an identical resistor in parallel with R and uses the oscilloscope to display the waveform across C .

Draw on **Figure 11** the waveform you expect the student to see.

The waveform of **Figure 10** is shown as a dashed line to help you show how the waveform changes.

Figure 11



Explain the change in the waveform.

[2 marks]

Connecting an identical resistor in parallel with R halves the total resistance of the circuit, so the time constant RC halves.

So the capacitor charges and discharges faster: it reaches 0 V and the peak voltage in a shorter time.



0 2 . 6

Figure 12a is a graph of voltage against time showing the output of the signal generator. **Figure 12b** shows the voltage across **C** during the same time interval.

The student interchanges the positions of **R** and **C** and connects the oscilloscope across **R**.

Complete **Figure 12c** to draw the voltage across **R** during the time interval.

[2 marks]

Figure 12a

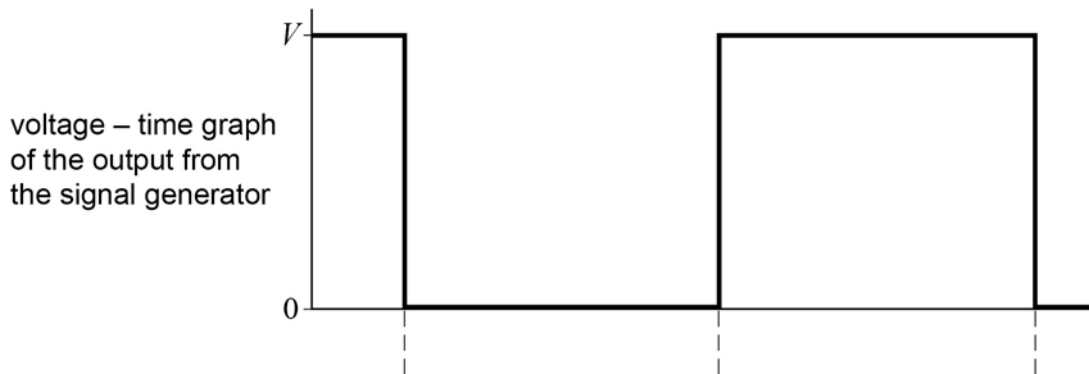


Figure 12b

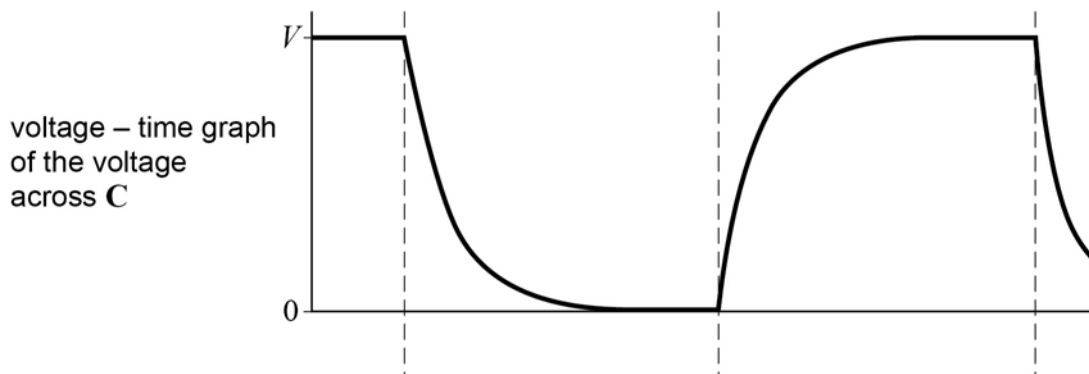
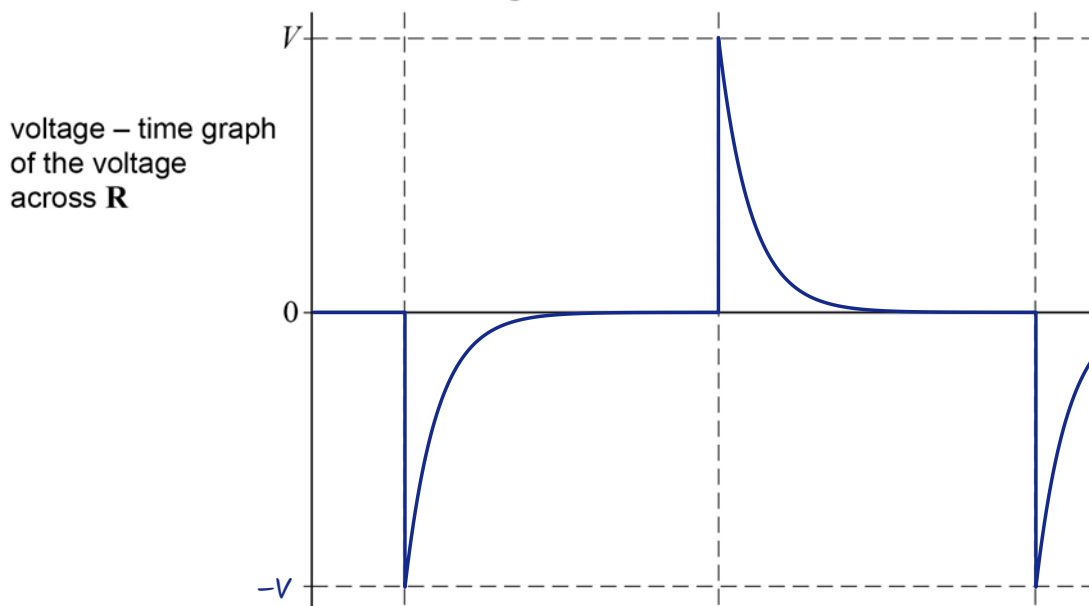


Figure 12c



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0 2 . 7

State and explain what changes, if any, the student needs to make to the settings of the oscilloscope so the waveform across **R** is fully displayed.

[2 marks]

Reduce the Y-gain (increase the volts per division) to 2 V division⁻¹.

The voltage across R now swings from +6.3 V to -6.3 V (12.6 V peak to peak), which would need 12.6 divisions at 1 V division⁻¹, more than the 8 on the screen; at 2 V division⁻¹ it fits.

Adjust the Y (vertical) shift so the trace is centred on the screen.

14



Turn over for the next question

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0 3

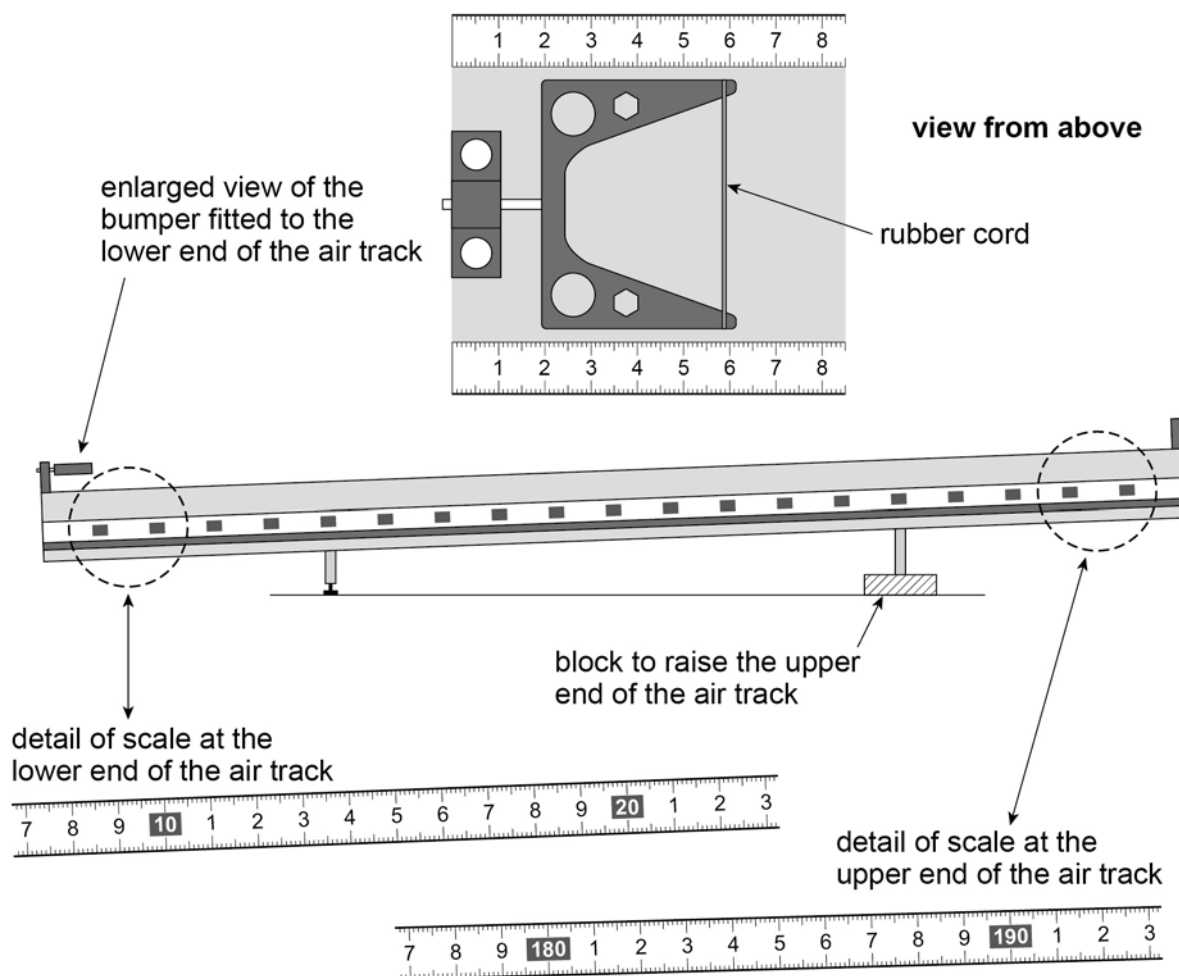
This question is about an experiment with a linear air track.

A block is used to raise one end of the track.

A bumper fitted with a rubber cord is attached at the lower end of the track.

The air track has a length of 2 m and there is a scale with major divisions marked in centimetres along the side; the zero of the scale is at the lower end, as shown in **Figure 13**.

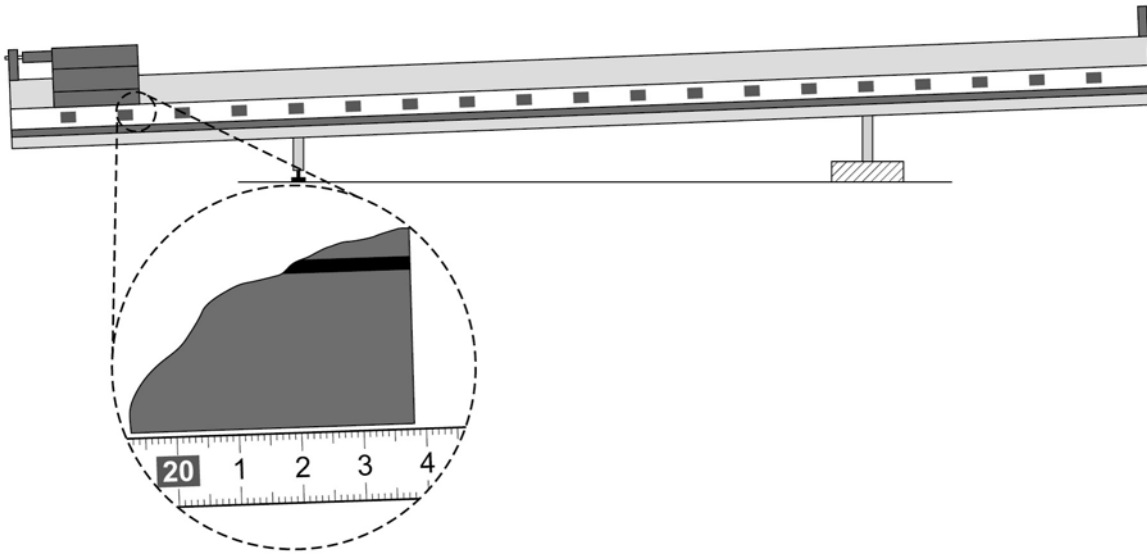
Figure 13



A glider is placed in contact with the rubber cord on the bumper at the lower end of the track. The position of the glider relative to the fixed scale can be determined using **Figure 14**.

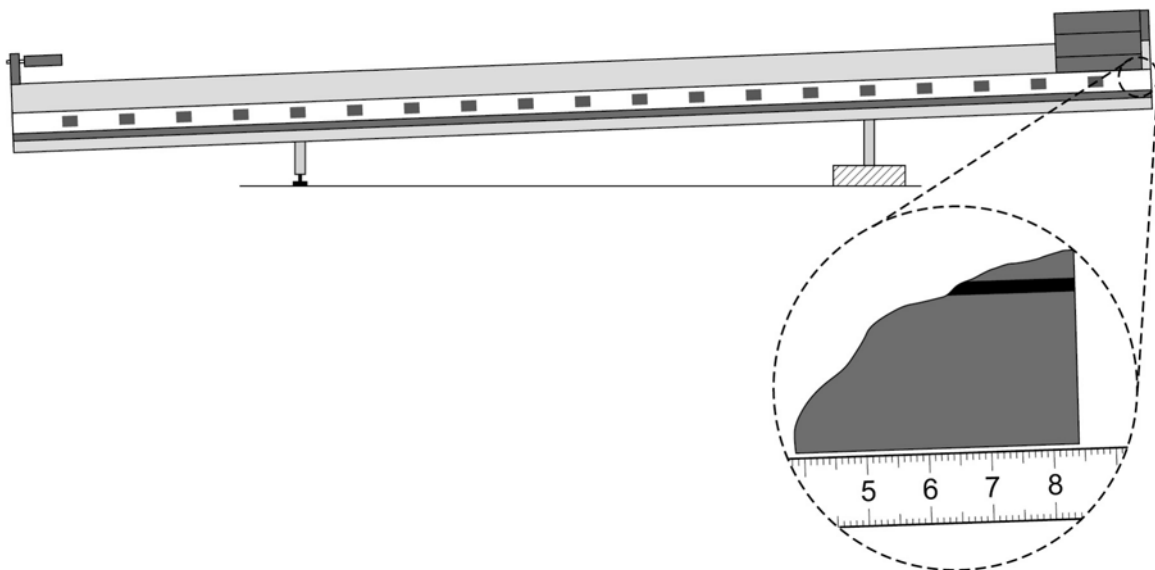


Figure 14



The glider is then moved to the position shown in **Figure 15**.

Figure 15



The air supply to the track is turned on and the glider is released. The glider accelerates down the track, strikes the rubber cord on the bumper and rebounds back up the track. The glider is allowed to bounce off the rubber band 20 times before it is stopped.

A student reads and records the highest position p of the glider after each rebound n .

Some of the student's data are shown in **Table 2**.

Additional columns have been provided to allow you to complete question **03.2** and question **03.3**.

Question 3 continues on the next page

Turn over ►



Table 2

n	p/cm	x/cm	$\ln(x/\text{cm})$
0	198.4	174.6	5.162
2	157.0	133.2	4.892
4	125.4	101.6	4.621
6	101.3	77.5	4.350
9	75.4	51.6	3.944
13	53.8	30.0	3.401

0 3 . 1

The value of p corresponding to $n = 0$ is the glider's initial position at the top of the track.

Deduce this value of p using **Figure 13** and **Figure 15**.
Write this result in **Table 2**.

[1 mark]

0 3 . 2

As it travels from the lower end of the track to each position p the glider moves through a distance x .

Deduce x for **all** the values of n using **Figure 14**.
Write these results in **Table 2**.

[1 mark]

0 3 . 3

Plot on **Figure 16** a graph of $\ln(x/\text{cm})$ against n .

Record your values of $\ln(x/\text{cm})$ in **Table 2**.

[3 marks]

0 3 . 4

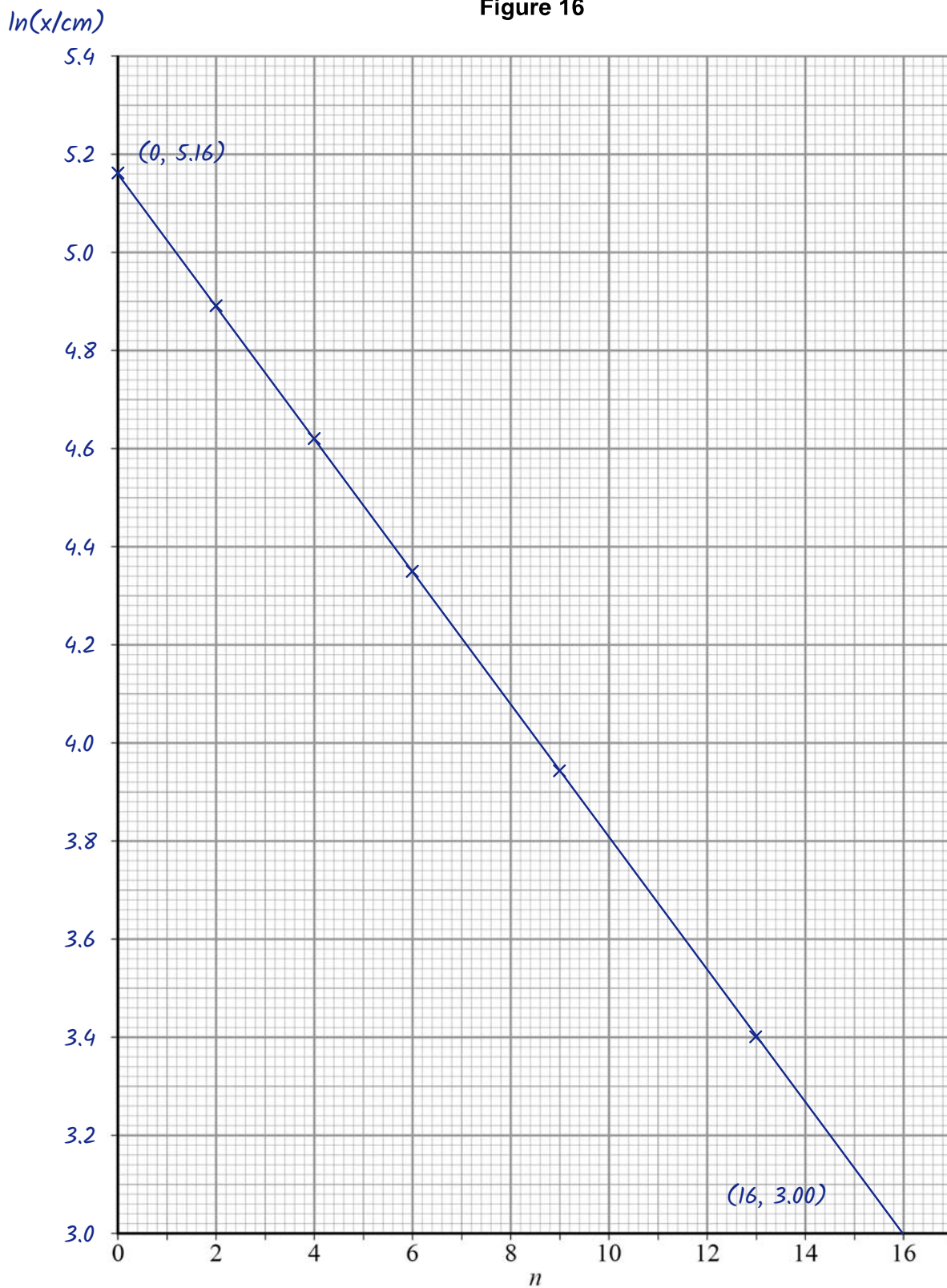
Explain why the graph you plotted confirms that x decreases exponentially with n .

[1 mark]

The graph of $\ln x$ against n is linear (a straight line) with a negative gradient, so $\ln x = \ln x_0 - kn$, i.e. $x = x_0 e^{-kn}$; x decreases exponentially with n .



Figure 16



Question 3 continues on the next page

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0 3 . 5

Determine, using your graph in **Figure 16**, the value of x when n is 20.**[3 marks]***Gradient (from line, (0, 5.16) to (16, 3.00)):*

$$\text{gradient} = (3.00 - 5.16) \div (16 - 0) = -2.16 \div 16 = -0.135$$

 $\ln x = 5.16 - 0.135n$, so at $n = 20$:

$$\ln x_{20} = 5.16 - 0.135 \times 20 = 5.16 - 2.70 = 2.46$$

$$x_{20} = e^{2.46} = 11.7 \text{ cm}$$

 x when n is 20 = 11.7 cm

0 3 . 6

Describe and explain **two** procedures the student should take to reduce uncertainty in the measurements of p .**[4 marks]**

procedure 1 View the glider at eye level, with the line of sight at right angles to the scale, when it reaches its highest point.

This reduces (eliminates) parallax error when reading the position p on the scale.

procedure 2 Use a video camera to record the glider as it reaches the top of the track, then replay frame by frame to read p .

The glider is only momentarily at rest, so this reduces random (human) error in judging the highest position.

END OF QUESTIONS

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