

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

I declare this is my own work.

A-level PHYSICS

Paper 3 Section A

Monday 17 June 2024

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
- a protractor.

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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- 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	



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Section A

Answer **all** questions in this section.

0	1
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This question is based on a method to determine the resistivity of a wire (required practical activity 5).

Figure 1 shows a micrometer screw gauge.

Figure 1

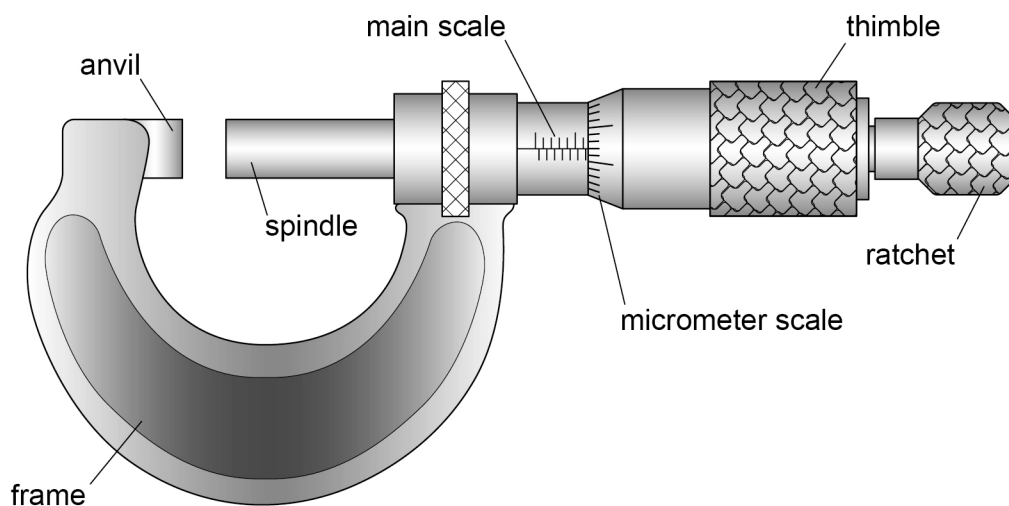
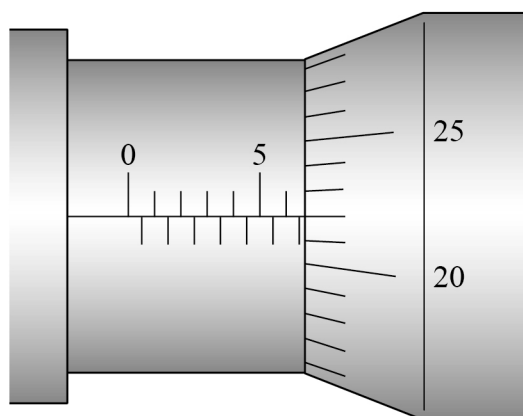


Figure 2 shows an enlarged view of the scales.

Figure 2



0 1 . 1 State, in mm, the resolution of the main scale.

[1 mark]

resolution = 0.50 mm

0 1 . 2 What is the reading on the micrometer?

Tick (✓) **one** box.

[1 mark]

6.22 mm

☐

6.72 mm

☒

6.78 mm

☐

8.22 mm

☐

0 1 . 3 A wire **X** is placed in the gap between the anvil and the spindle.

State and explain how this gap is closed just before taking a reading of the diameter of **X**.

[1 mark]

Turn the thimble until the spindle is nearly touching X, then close the gap using the ratchet, so X is not squeezed (crushed) by excessive force, which could change its diameter.

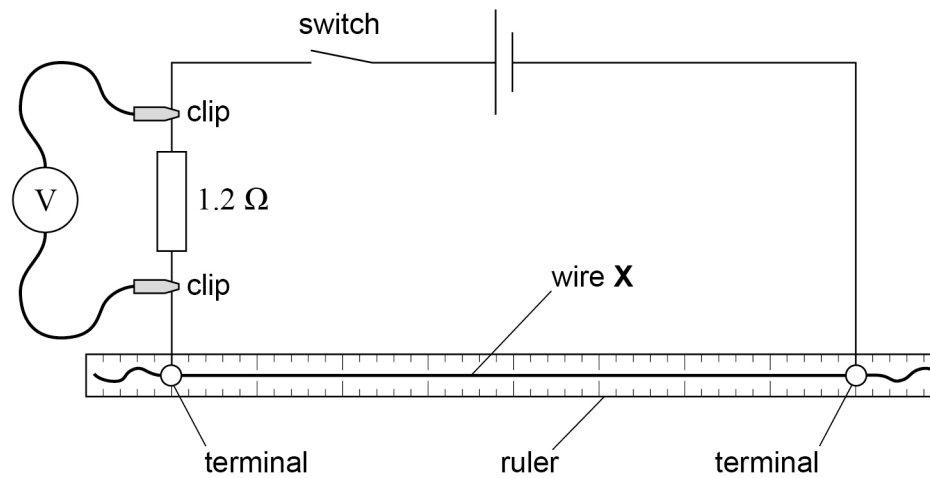
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Figure 3 shows a circuit used to determine the resistance per metre of wire **X**.

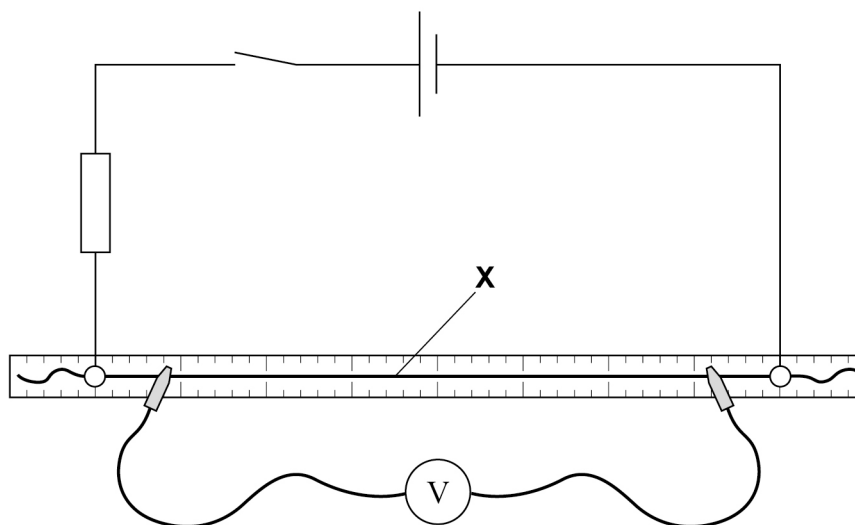
Figure 3



Two terminals are used to mount **X** on a ruler.
Clips are used to connect a voltmeter across the $1.2\ \Omega$ resistor.
When the switch is closed, the voltmeter reading is 931 mV.

The switch is then opened and the voltmeter is connected to **X** as shown in **Figure 4**.

Figure 4



0 1 . 4

When the switch is closed, the voltmeter reading is 397 mV.

Show that, for the arrangement in **Figure 4**, the resistance R of the wire between the clips is about 0.5Ω .

[2 marks]

Figure 3: current $I = V \div R = 0.931 \div 1.2 = 0.776 \text{ A}$

The same current flows through X (series circuit, and the voltmeter draws negligible current).

Figure 4: $R = V \div I = 0.397 \div 0.776$

$R = 0.512 \Omega$, which is about 0.5Ω

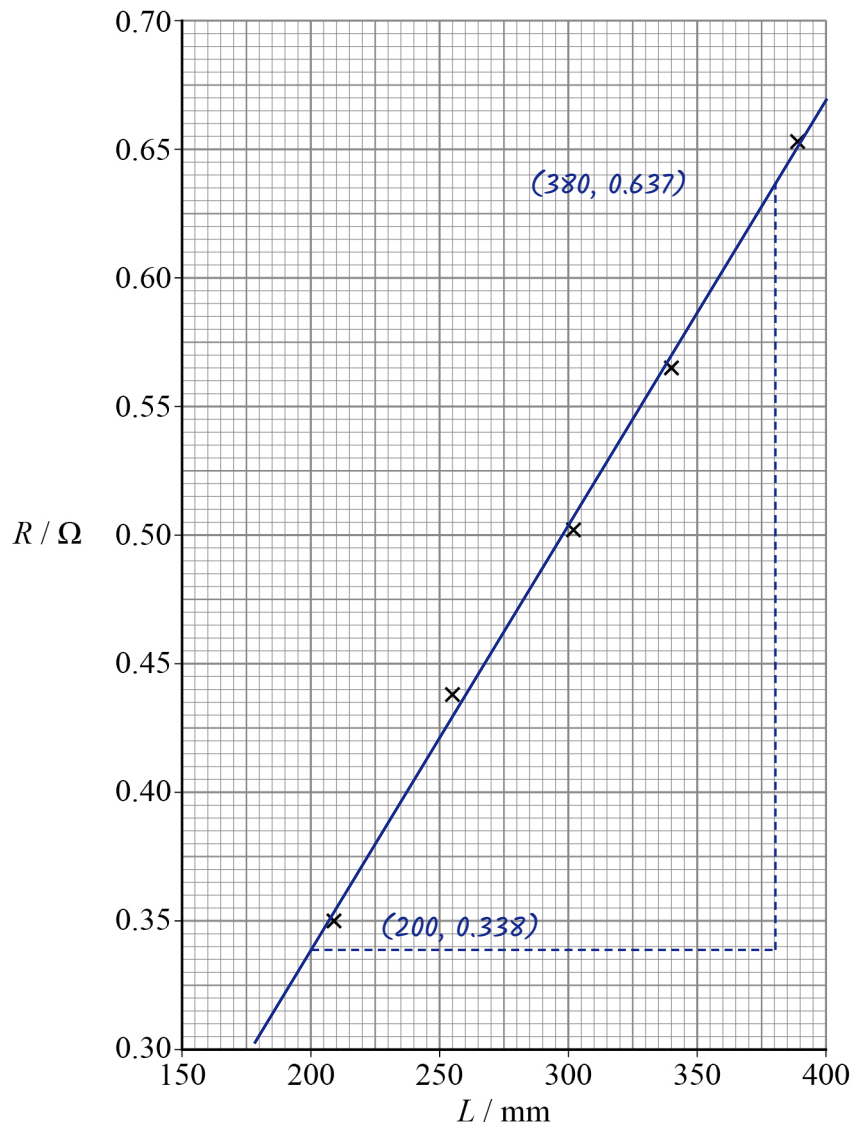
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The length of wire between the clips is L .
Values of R are determined for different values of L .
Figure 5 shows these data.

Figure 5



0 1 . 5 Determine the resistance per metre of **X**.

[2 marks]

$$\text{gradient} = \Delta R \div \Delta L = (0.637 - 0.338) \div (380 - 200) \times 10^{-3}$$

$$= 0.299 \Omega \div 0.180 \text{ m} = 1.66 \Omega \text{ m}^{-1}$$

resistance per metre = 1.66 $\Omega \text{ m}^{-1}$



0 1 . 6

Table 1 shows the resistance per metre of various metal wires.
The diameter of **X** is one of the values of d shown in **Table 1**.

Table 1

	Resistance per metre of wire / $\Omega \text{ m}^{-1}$			
d / mm	copper	tungsten	alumel	nichrome
0.38	0.151	0.504	3.15	9.73
0.93	0.0247	0.0824	0.515	1.59
1.63	0.00805	0.0268	0.168	0.518
2.08	0.00494	0.0165	0.103	0.318
3.66	0.00160	0.00532	0.0333	0.103

Identify the metal used for **X**.
Go on to determine the resistivity of the metal.
State an appropriate SI unit for your answer.

[4 marks]

$$R/L = 1.66 \Omega \text{ m}^{-1} \text{ is closest to nichrome with } d = 0.93 \text{ mm } (1.59 \Omega \text{ m}^{-1})$$

$$\rho = RA/L = (R/L) \times \pi d^2/4$$

$$A = \pi \times (0.93 \times 10^{-3})^2 \div 4 = 6.79 \times 10^{-7} \text{ m}^2$$

$$\rho = 1.66 \times 6.79 \times 10^{-7} = 1.13 \times 10^{-6} \Omega \text{ m}$$

metal used for **X** = nichrome

resistivity = 1.13×10^{-6} SI unit = $\Omega \text{ m}$

Question 1 continues on the next page

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0 1 . 7

A student adds error bars for R and L to each point on **Figure 5**.

She estimates that

- each value of R has a percentage uncertainty of 6%
- each value of L has an absolute uncertainty of 5 mm.

Compare her error bars for the point at $L = 209$ mm with her error bars for the point at $L = 388$ mm.

[2 marks]

The horizontal (L) error bars are the same length for both points: ± 5 mm, a total width of 10 mm.

The vertical (R) error bars at $L = 388$ mm are about twice as long: at $L = 209$ mm they are $\pm 0.021 \Omega$ (0.329 to 0.371 Ω), but at $L = 388$ mm they are $\pm 0.039 \Omega$ (0.614 to 0.692 Ω).



0 1 . 8

Outline how error bars are used to determine the uncertainty in the gradient of a linear graph.

[2 marks]

Draw the line of best fit, and also the steepest and the shallowest straight lines that pass through all of the error bars (maximum and minimum gradient lines). Find the gradient of each line.

Uncertainty in gradient = (maximum gradient – minimum gradient) ÷ 2, or the difference between the best gradient and the steepest (or the shallowest) gradient.

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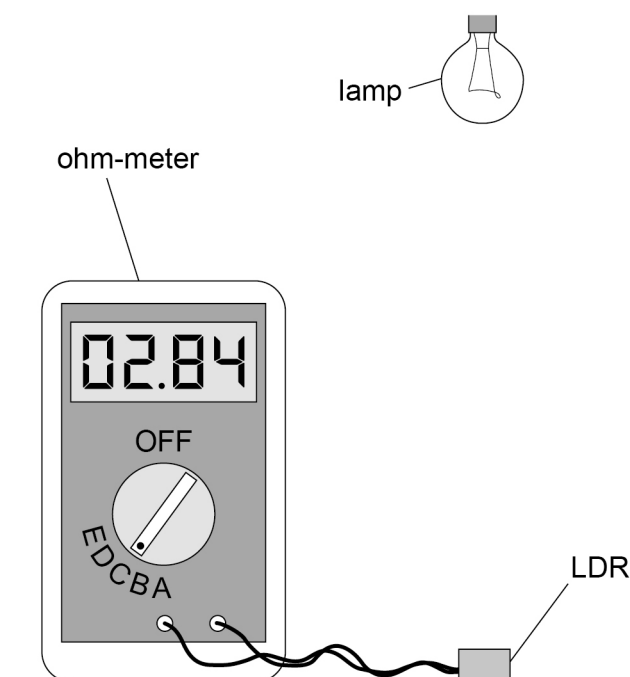
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0 2

Figure 6 shows apparatus used to investigate how the resistance R of a light-dependent resistor (LDR) varies with illumination.

Figure 6



The ohm-meter

- **always** displays a four-digit reading of R
- can be set to the different ranges **A** to **E** shown in **Table 2**.

Table 2

Setting	Maximum reading displayed	Minimum (non-zero) reading displayed	Unit
range A	199.9	000.1	Ω
range B	1999	0001	Ω
range C	19.99	00.01	$k\Omega$
range D	199.9	000.1	$k\Omega$
range E	1.999	0.001	$M\Omega$



0 2 . 1

Explain why the reading displayed in **Figure 6** shows that the ohm-meter is set to range **C**.

[1 mark]

The display reads 02.84, with the decimal point after the second digit (two digits after the decimal point, format XX.XX). Only range C displays readings in this format.

0 2 . 2

The quantity E_V is a measure of the intensity of the light incident on the LDR. The SI unit of E_V is the lux (lx).

The resistance R of the LDR is given by

$$\log(R / \Omega) = -0.772 \log(E_V / \text{lx}) + 5.09$$

Show that E_V for the arrangement shown in **Figure 6** is about 130 lx.

[2 marks]

$$R = 02.84 \text{ k}\Omega = 2840 \Omega, \text{ so } \log(R / \Omega) = \log 2840 = 3.453$$

$$3.453 = -0.772 \log(E_V / \text{lx}) + 5.09$$

$$\log(E_V / \text{lx}) = (5.09 - 3.453) \div 0.772 = 2.120$$

$$E_V = 10^{2.120} = 132 \text{ lx, which is about 130 lx}$$

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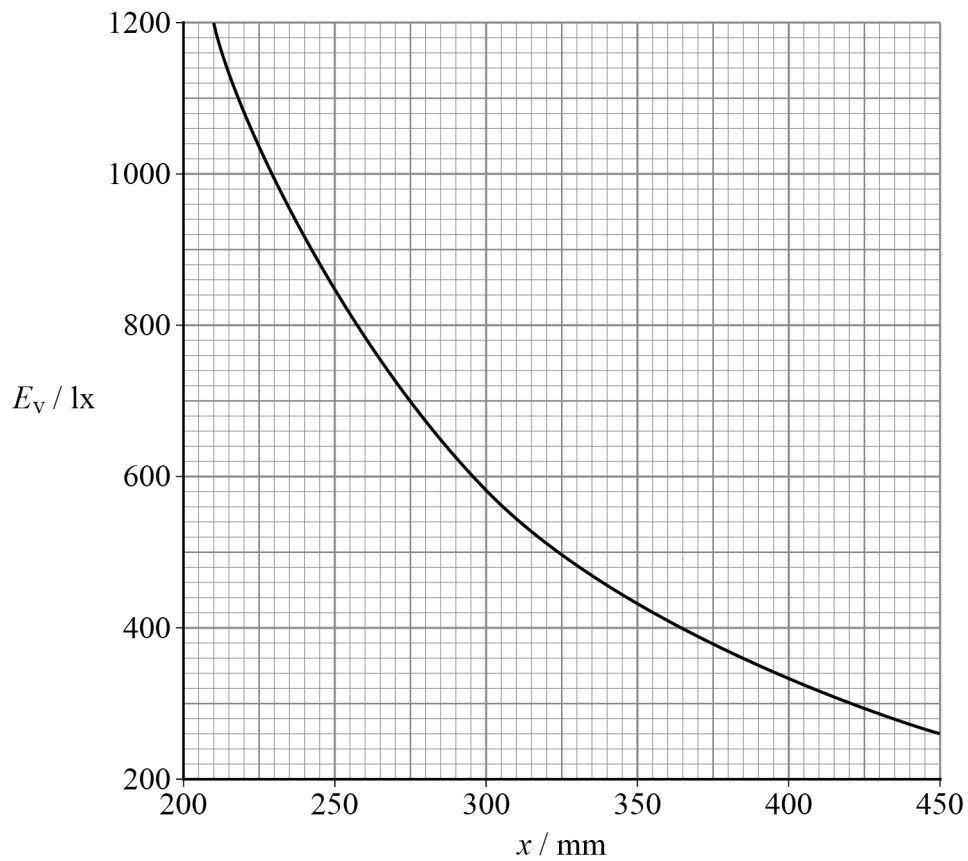


R is recorded for different values of the vertical distance x between the lamp and the LDR.

E_V is calculated for each value of R .

Figure 7 shows how E_V varies with x .

Figure 7



It can be shown that $E_V \propto \frac{1}{x^2}$

0 2 . 3

Describe a method to show that **Figure 7** confirms this relationship. You do not need to show any calculations.

[2 marks]

Read off values of E_V and x for at least three (e.g. five) different points spread along the curve in Figure 7.

Calculate $E_V \times x^2$ for each point. If the values are the same (constant, with only small percentage differences), this confirms $E_V \propto 1/x^2$.

(Or: plot E_V against $1/x^2$; a straight line through the origin confirms it.)

0 2 . 4

Deduce the value of x when $E_V = 130 \text{ lx}$.

[2 marks]

$E_V \times x^2 = \text{constant}$. From Figure 7, at $x = 400 \text{ mm}$, $E_V = 330 \text{ lx}$

$\text{constant} = 330 \times 400^2 = 5.28 \times 10^7 \text{ lx mm}^2$

$x^2 = 5.28 \times 10^7 \div 130 = 4.06 \times 10^5 \text{ mm}^2$

$x = \sqrt{(4.06 \times 10^5)} = 637 \text{ mm}$

$x =$ 637 mm

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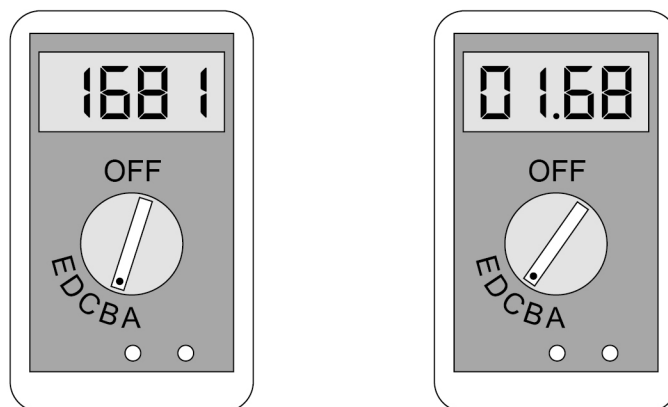


0 2 . 5

R is measured when $x = 450$ mm.

Figure 8 shows how the ohm-meter displays the values of R when set to range **B** and when set to range **C**.

Figure 8



The uncertainty of the reading on the ohm-meter is $\pm 2\%$ of the displayed reading plus ± 2 in the least significant digit.

This means that:

- using range **B** the **maximum** value of R is $1.02 \times 1681 + 2 = 1717 \, \Omega$
- using range **C** the **minimum** value of R is $0.98 \times 1.68 - 0.02 = 1.63 \, \text{k}\Omega$.



Complete **Table 3**.

Go on to explain whether range **B** or range **C** should be used to measure R .

[2 marks]

Table 3

Setting	Minimum R	Maximum R
range B	<u>1645</u> Ω	1717 Ω
range C	1.63 k Ω	<u>1.73</u> k Ω

Range B: $\text{max} - \text{min} = 1717 - 1645 = 72 \Omega$ ($\pm 36 \Omega$, about $\pm 2\%$).

Range C: $\text{max} - \text{min} = 1730 - 1630 = 100 \Omega$ ($\pm 50 \Omega$, about $\pm 3\%$).

*So range B should be used, because the spread of possible values of R
(and its percentage uncertainty) is smaller.*

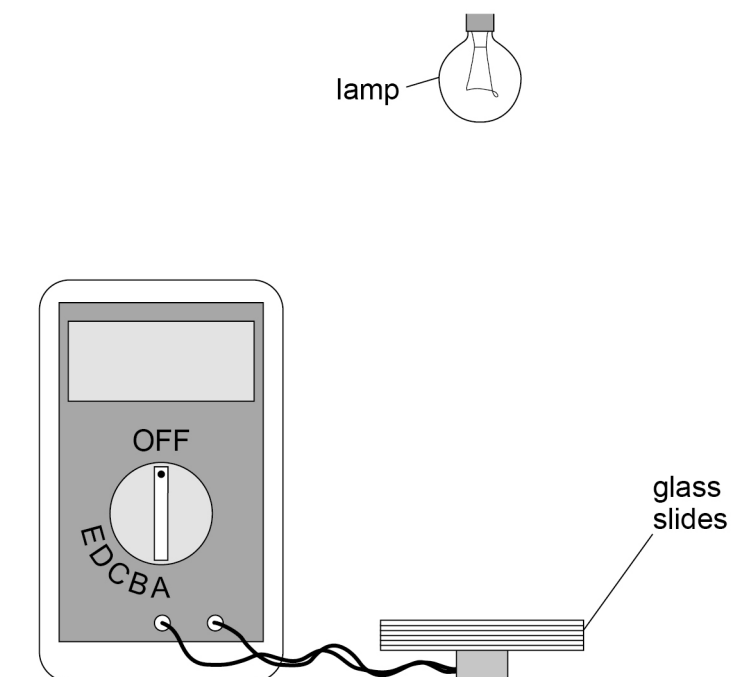
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Figure 9 shows the LDR being used to investigate the transmission of light through glass slides.

Figure 9



The lamp and ohm-meter are switched on.

R is recorded with different numbers of slides placed on the LDR.

E_V is calculated for each value of R .

0 2 . 6

The positions of the lamp and the LDR are not changed during the experiment.

Identify **two** other control variables.

[2 marks]

1 The brightness of the lamp: keep the voltage across (current in) the lamp constant.

2 The background light in the room: keep the room in blackout, with no external light sources.



0 2 . 7

For the arrangement in **Figure 9** it can be shown that

$$E_V = 400 e^{-\mu N}$$

where N is the number of slides
 μ is a constant.

Explain how μ can be determined from a linear graph.

[2 marks]

Take natural logs: $\ln E_V = -\mu N + \ln 400$

Compare with $y = mx + c$: plot $\ln E_V$ on the y-axis against N on the x-axis, which gives a straight line.

The gradient is $-\mu$, so $\mu = -\text{gradient}$ (the y-intercept is $\ln 400$).

0 2 . 8

In an experiment $\mu = 9.0 \times 10^{-2}$

Deduce the minimum number of slides needed to reduce E_V by 50%.

[2 marks]

Reducing E_V by 50%: $E_V = 200 \text{ lx}$, so $e^{-\mu N} = 0.5$

$$\ln 0.5 = -9.0 \times 10^{-2} \times N$$

$$N = 0.693 \div 0.090 = 7.7$$

The number of slides must be a whole number, so 8 slides

number of slides = 8

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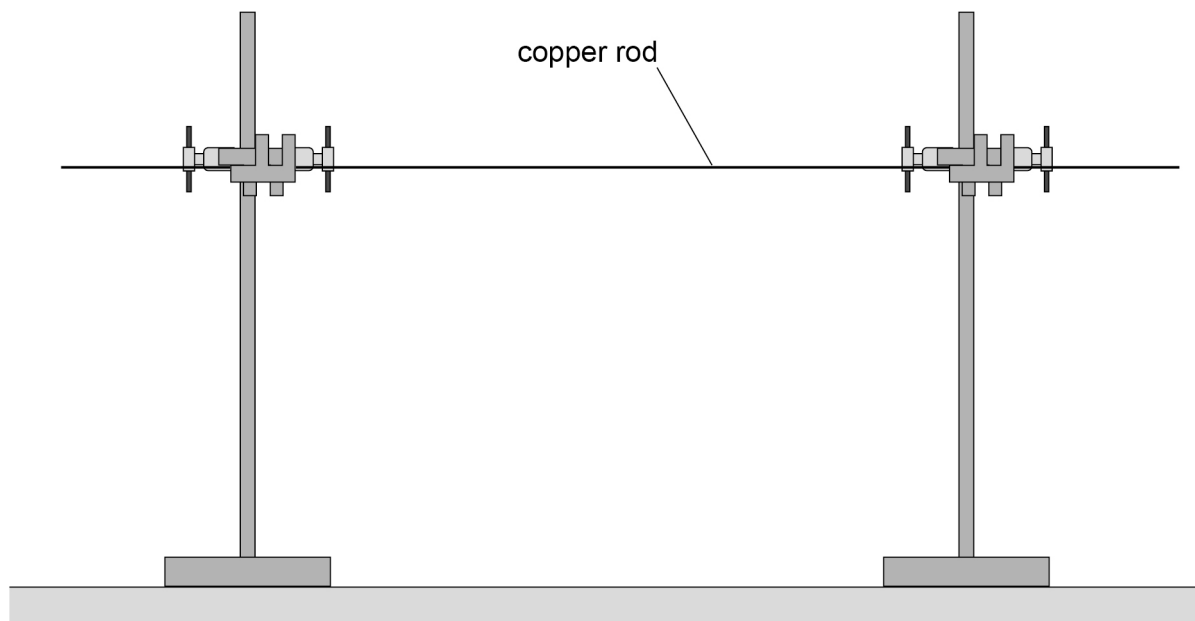


0 3

This question is about a method to investigate how the force on a conductor varies with flux density and current (required practical activity 10).

Figure 10 shows a copper rod clamped above a horizontal bench.

Figure 10



0 3 . 1

Describe a method to show that the copper rod is horizontal.
Your method must include the use of a metre ruler.
You may annotate **Figure 10**.

[3 marks]

Stand the metre ruler vertically on the bench, with its zero at the bench, next to the rod close to one clamp.

Make the ruler vertical with a set square: one edge of the set square resting flat on the bench and its other edge touching the upright ruler.

Measure the height of the rod (e.g. its lower edge) above the bench, with the eye level with the rod to avoid parallax.

Repeat the measurement at a second point near the other clamp (and in the middle). If the heights are all the same, the rod is parallel to the horizontal bench, so it is horizontal.

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Figure 11 shows the copper rod positioned above a digital balance.

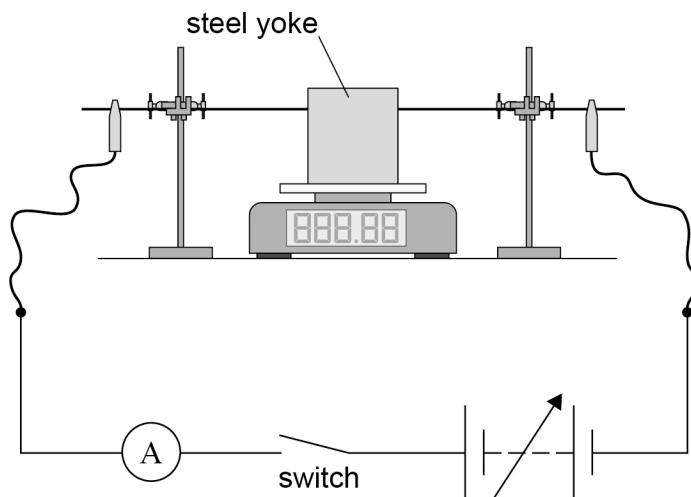
Two identical magnets are mounted on a steel yoke with their opposite poles facing each other.

The balance is zeroed.

The yoke is then placed on the balance so that a horizontal uniform magnetic field is applied perpendicular to the copper rod.

The ends of the rod are connected as shown.

Figure 11



0 3 . 2

When the switch is open, the reading on the balance shows the mass of the yoke and the two magnets.

When the switch is closed, the reading on the balance decreases.

Explain, with reference to **Figure 11**, the direction of the horizontal magnetic field.

[3 marks]

The reading decreases, so there is an upward force on the magnets; by Newton's third law the force on the rod is downwards. The current in the rod flows from left to right.

By Fleming's left-hand rule (thumb: force down, second finger: current to the right), the first finger points out of the page, so the field is directed out of the page.



The current I in the rod is varied.

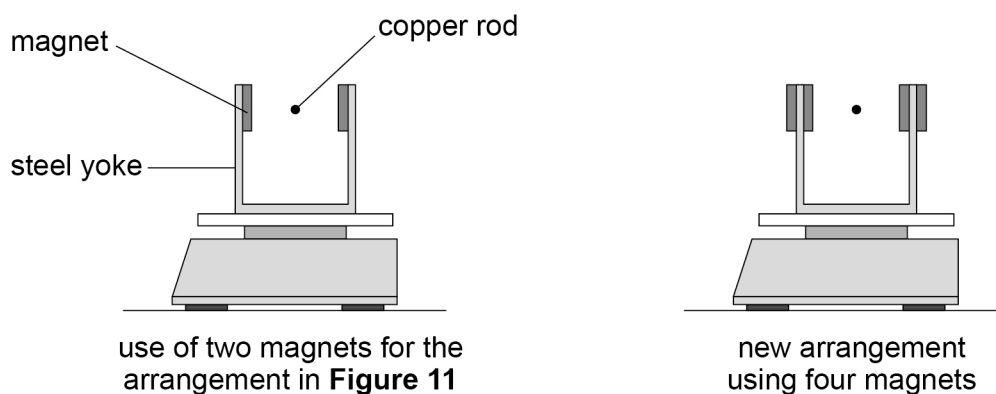
The balance reading M_1 is recorded for different values of I .

The switch is now opened.

Two additional magnets, identical to those used before, are attached to the yoke.

Figure 12 shows how this new arrangement compares with the arrangement in **Figure 11**.

Figure 12



The balance reading with four magnets attached to the yoke is M_2 .

With the switch open, M_2 is the mass of the yoke and the four magnets.

The switch is now closed.

M_2 is recorded for different values of I .

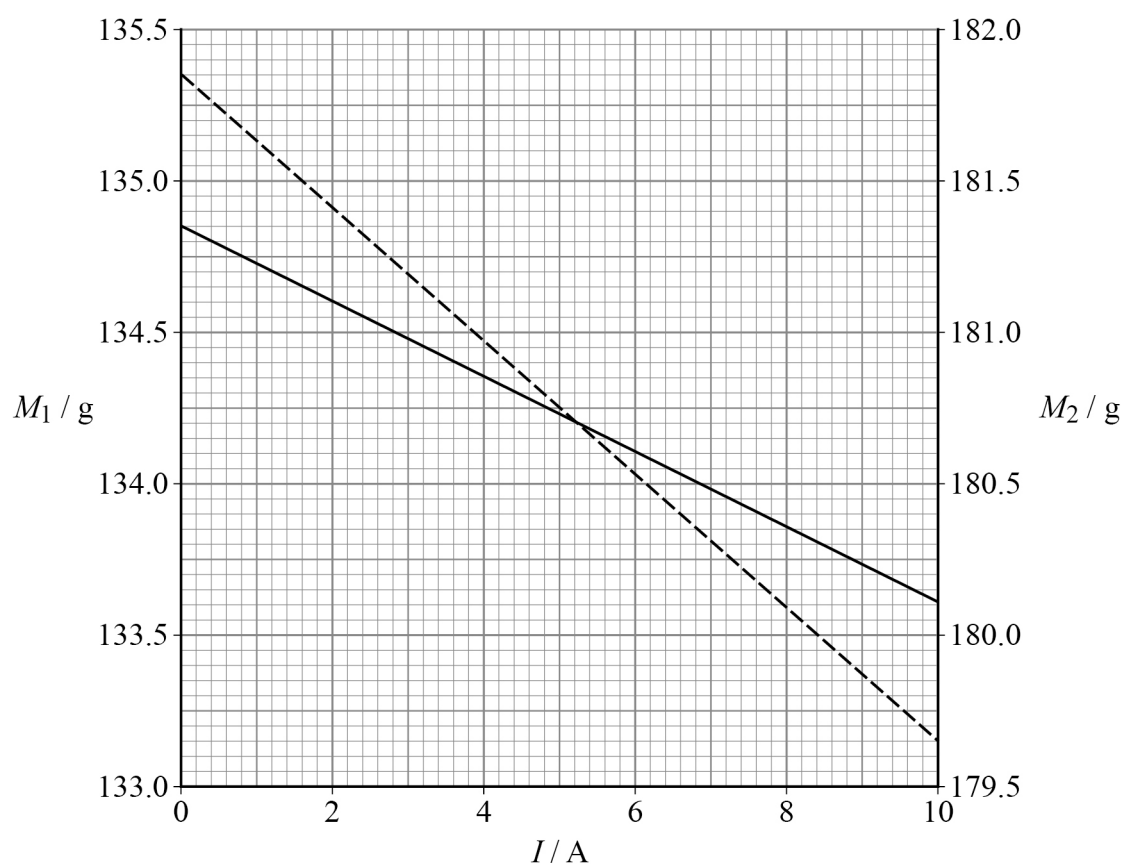
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Figure 13 shows data from both experiments.
Values of M_1 and M_2 are plotted using different vertical axes.

Figure 13



The solid line ——— shows the variation of M_1 with I

The dashed line - - - - - shows the variation of M_2 with I



It can be shown that

$$M = kBI + nZ + Y$$

where

M = balance reading when the current is I

B = magnetic flux density of the horizontal uniform magnetic field

n = number of magnets attached to the yoke

Z = mass, in g, of each magnet

Y = mass, in g, of the yoke

k is a constant.

0 3 . 3 Deduce the fundamental base units for k .

[3 marks]

kBI has the same units as mass M , so $kBI \equiv \text{kg}$

$F = BIL$ so $B = F/IL$: $T = \text{N A}^{-1} \text{m}^{-1}$

$\text{N} = \text{kg m s}^{-2}$, so $T = \text{kg s}^{-2} \text{A}^{-1}$ and $BI \equiv \text{kg s}^{-2}$

$k = M/(BI) \equiv \text{kg} \div \text{kg s}^{-2} = \text{s}^2$

fundamental base units = s^2

0 3 . 4 Determine Y .

[3 marks]

Intercepts at $I = 0$ (no force on rod): $M_1 = 134.85 \text{ g}$, $M_2 = 181.85 \text{ g}$

$134.85 = 2Z + Y$ and $181.85 = 4Z + Y$

Subtract: $2Z = 47.00 \text{ g}$, so $Z = 23.50 \text{ g}$

$Y = 134.85 - 47.00 = 87.85 \text{ g}$

$Y =$ 87.85 g

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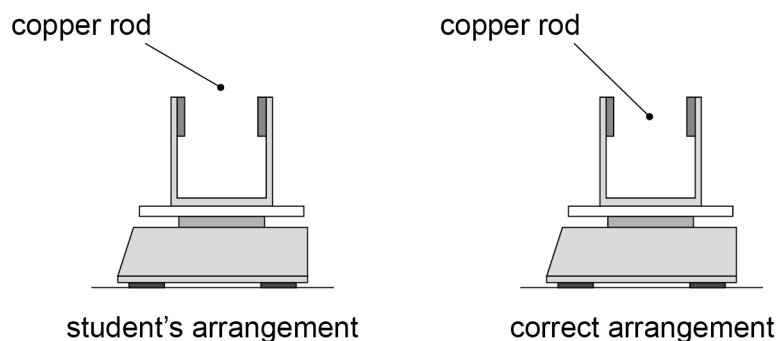


0 3 . 5

A student sets up the apparatus with the copper rod positioned incorrectly.

Figure 14 shows how the student's arrangement compares with the correct arrangement.

Figure 14



The student produces a graph of M_1 against I .

Compare the student's graph with the graph of M_1 against I (the solid line) in **Figure 13**.

Explain your answer.

[3 marks]

In the student's arrangement the rod is above the magnets rather than between them, so the magnetic flux density B at the rod is smaller (weaker field).

The intercept at $I = 0$ is the same (134.85 g), because with no current there is no force on the rod, so the reading is still the mass of the yoke and two magnets ($2Z + Y$), which has not changed.

The line is less steep (the gradient is less negative), because the gradient is kB : for each change in current the force BIL on the rod, and so the change in M_1 , is smaller.

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END OF QUESTIONS



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