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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

Friday 5 June 2020

Afternoon

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.
- 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	



Section A

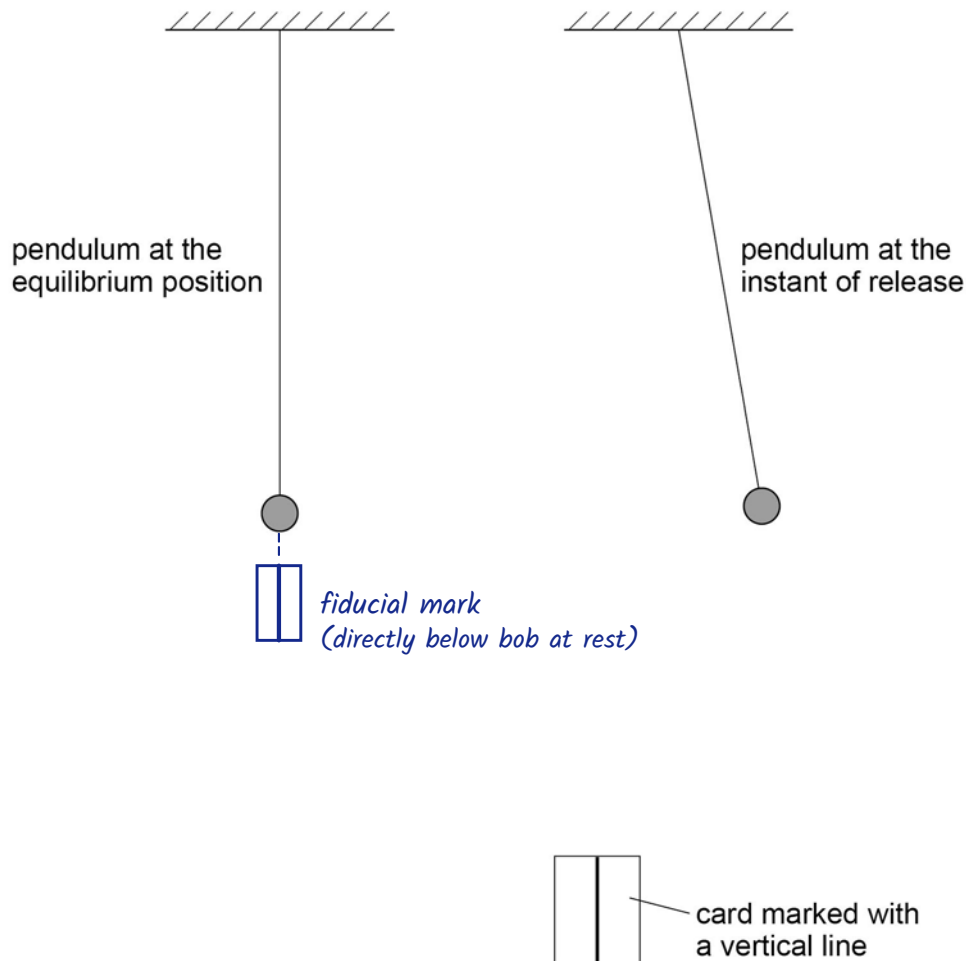
Answer **all** questions in this section.

0 1

A simple pendulum performs oscillations of period T in a vertical plane.

Figure 1 shows views of the pendulum at the equilibrium position and at the instant of release. **Figure 1** also shows a rectangular card marked with a vertical line.

Figure 1



0 1 . 1

The card can be used as a fiducial mark to reduce uncertainty in the measurement of T .

Annotate **Figure 1** to show a suitable position for the fiducial mark.
Explain why you chose this position.

[2 marks]

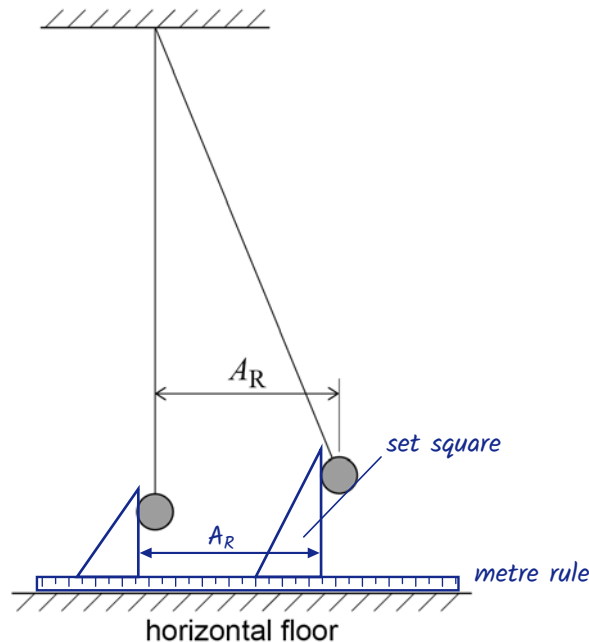
Directly below the bob at the equilibrium position, because the bob moves fastest here, so its transit time past the mark is least (the timing is most precise).



0 1 . 2

The period of the pendulum is constant for small-amplitude oscillations. **Figure 2** shows an arrangement used to determine the maximum amplitude that can be considered to be small, by investigating how T varies with amplitude.

Figure 2



Describe a suitable procedure to determine A_R , the amplitude of the pendulum as it is released.

You may add detail to **Figure 2** to illustrate your answer.

[2 marks]

Place a metre rule (horizontal scale) on the floor under the pendulum.

Put a set square on the rule with one edge vertical, touching the left-hand edge of the bob at rest, and read the scale; the vertical edge removes parallax error.

Repeat with the set square touching the left-hand edge of the displaced bob just before release.

A_R = difference between the two readings; using the same edge of the bob each time allows for the bob's radius.

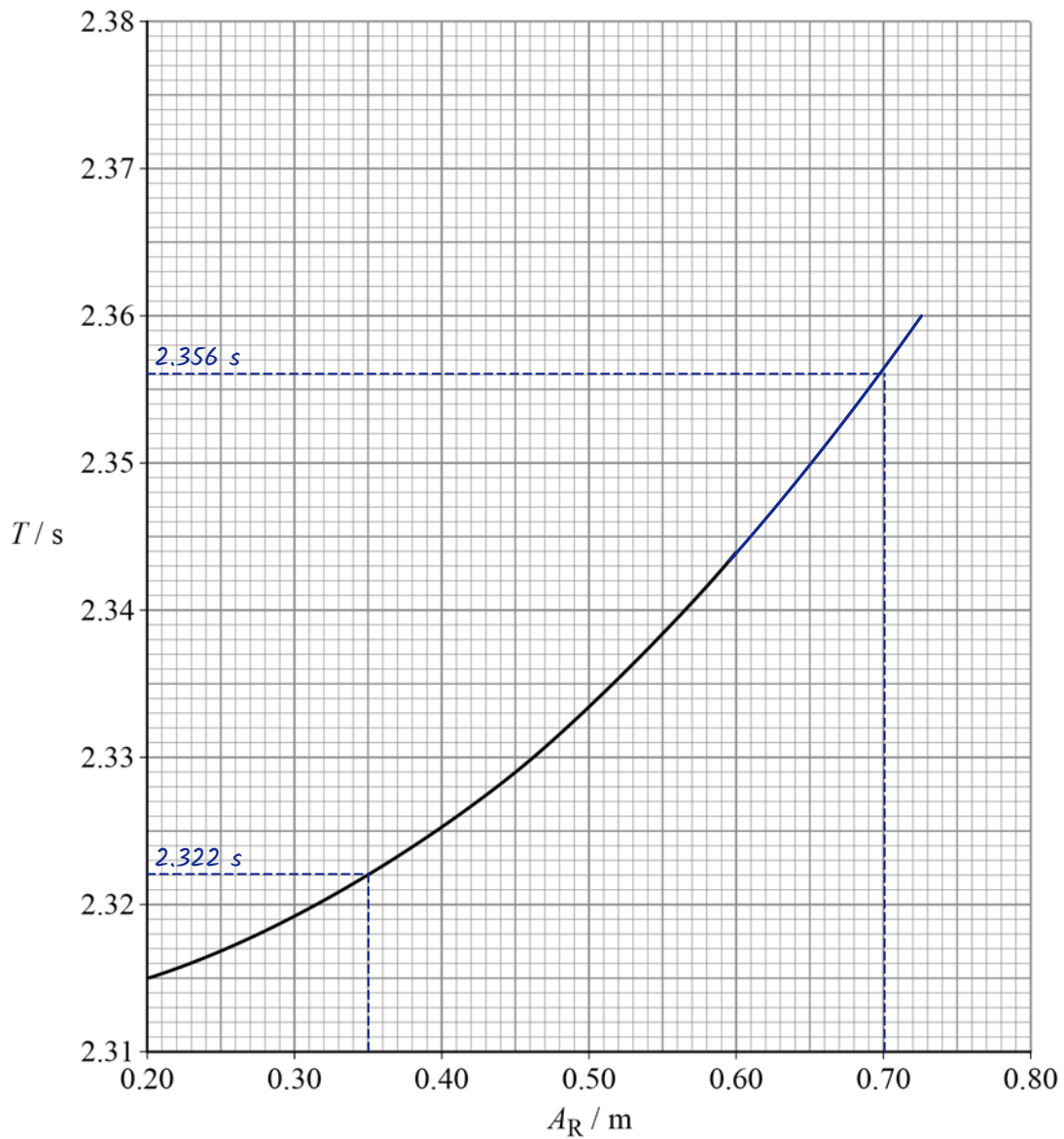
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0 1 . 3 Figure 3 shows some of the results of the experiment.

Figure 3



Estimate, using **Figure 3**, the expected percentage increase in T when A_R increases from 0.35 m to 0.70 m.

Show your working.

[3 marks]

From the extrapolated curve on Figure 3:

at $A_R = 0.35$ m, $T = 2.322$ s; at $A_R = 0.70$ m, $T = 2.356$ s

% increase = $(2.356 - 2.322) / 2.322 \times 100$

= $0.034 / 2.322 \times 100 = 1.46$ %

percentage increase = 1.46 %

Question 1 continues on the next page

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In another experiment the pendulum is released from a fixed amplitude.
The amplitudes A_n of successive oscillations are recorded, where $n = 1, 2, 3, 4, 5 \dots$.

Table 1 shows six sets of readings for the amplitude A_5 .

Table 1

A_5 / m	0.217	0.247	0.225	0.223	0.218	0.224
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0 1 . 4

Determine the result that should be recorded for A_5 .
Go on to calculate the percentage uncertainty in this result.

[3 marks]

0.247 m is anomalous, so it is rejected.

mean = $(0.217 + 0.225 + 0.223 + 0.218 + 0.224) / 5 = 0.2214 \text{ m}$

uncertainty = half range = $(0.225 - 0.217) / 2 = 0.004 \text{ m}$

% uncertainty = $0.004 / 0.2214 \times 100 = 1.81 \%$

$A_5 =$ 0.2214 m

percentage uncertainty = 1.81 %

0 1 . 5

Table 2 shows results for A_n and the corresponding value of $\ln(A_n / \text{m})$ for certain values of n .

Table 2

n	A_n / m	$\ln(A_n / \text{m})$
2	0.238	-1.435
4	0.225	-1.492
7	0.212	-1.551
10	0.194	-1.640
13	0.183	-1.698

Complete **Table 2**.

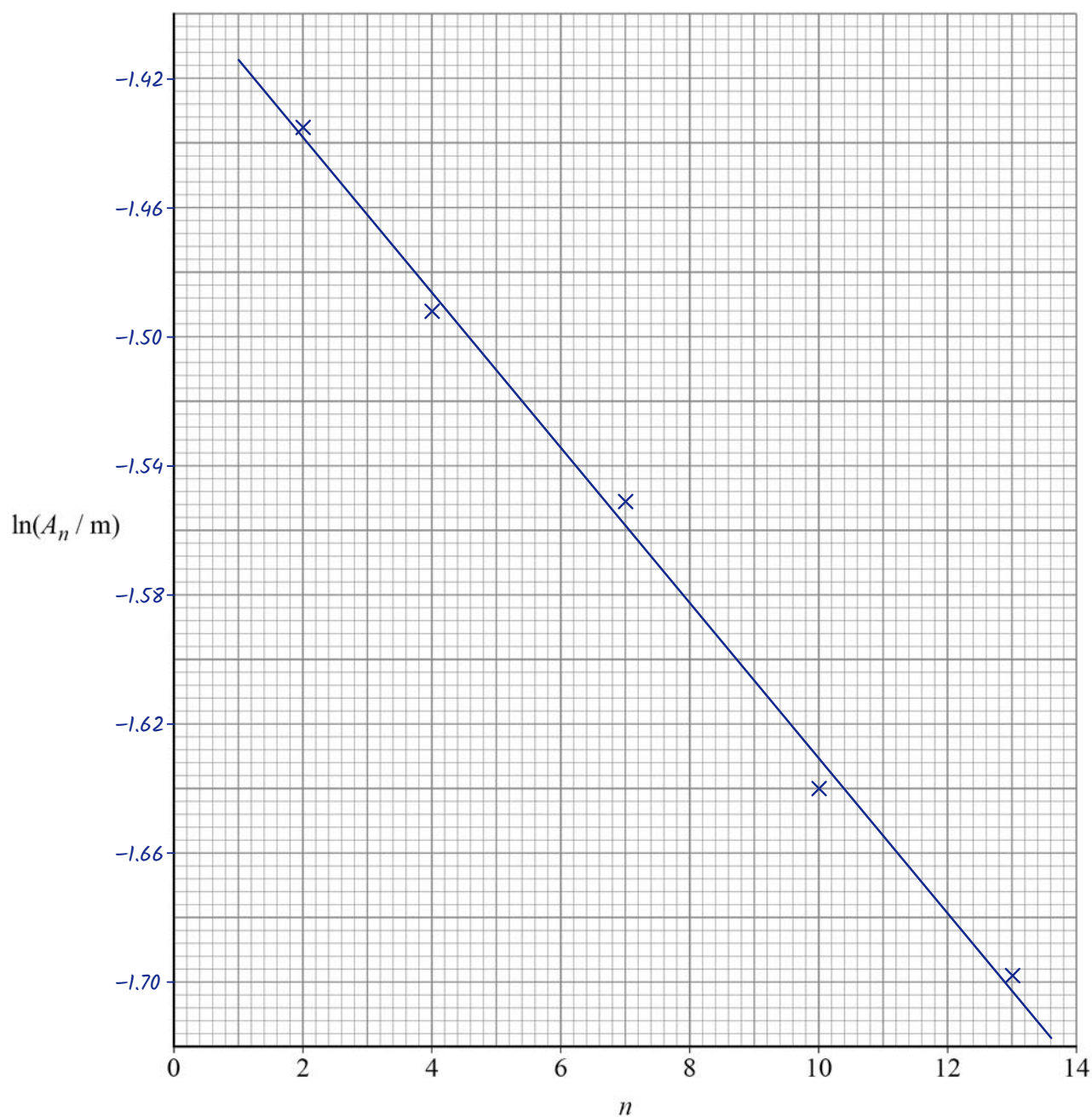
[1 mark]



0 1 . 6 Plot on **Figure 4** a graph of $\ln(A_n / m)$ against n .

[2 marks]

Figure 4



Question 1 continues on the next page

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0 1 . 7

It can be shown that

$$A_n = A_0 \delta^{-n}$$

where A_0 is the amplitude of release of the pendulum
 δ is a constant called the damping factor.

Explain how to find δ from your graph.
 You are **not** required to determine δ .

[2 marks]

Taking natural logs of $A_n = A_0 \delta^{-n}$: $\ln A_n = -n \ln \delta + \ln A_0$

*This has the form $y = mx + c$, so the graph of $\ln(A_n/m)$ against n is
 a straight line with gradient $= -\ln \delta$ (and intercept $\ln A_0$).*

Find the gradient of the best-fit line using a large triangle;

then $\delta = e^{-\text{gradient}}$.



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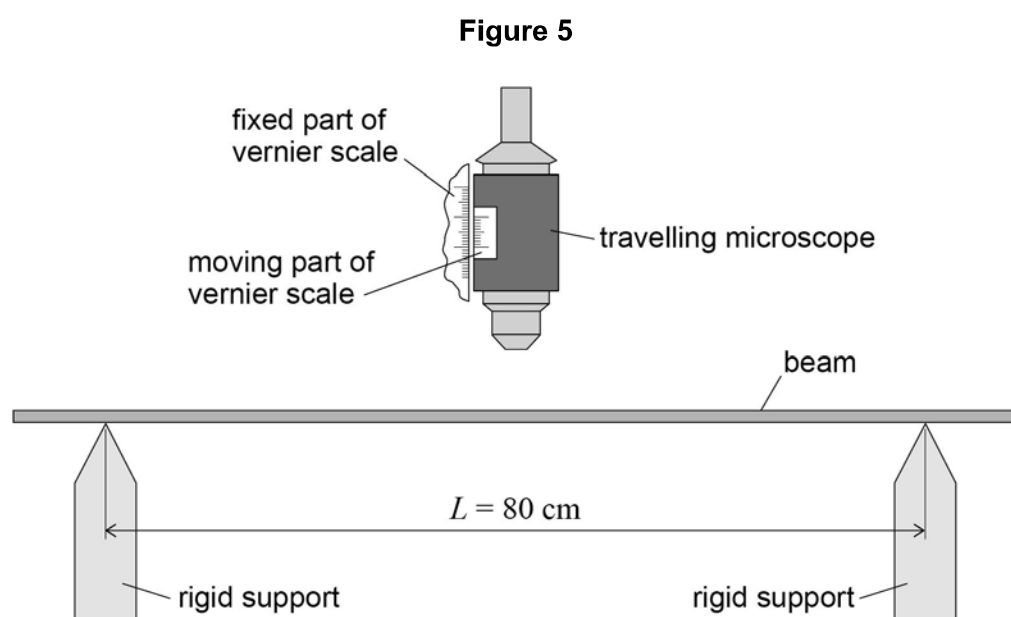
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0 2

Figure 5 shows apparatus used to investigate the bending of a beam.



The beam is placed horizontally on rigid supports.
The distance L between the supports is 80 cm.

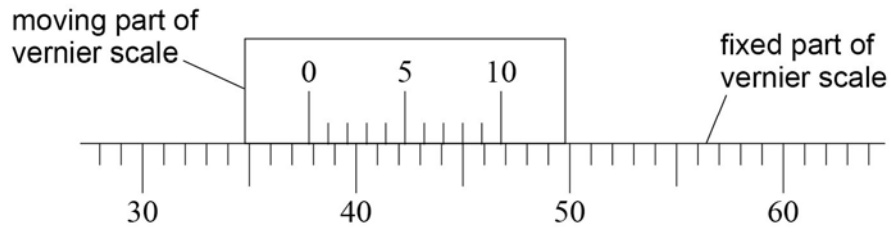
A travelling microscope is positioned above the midpoint of the beam and focused on the upper surface.



0 2 . 1

Figure 6 shows an enlarged view of both parts of the vernier scale.

Figure 6



The smallest division on the fixed part of the scale is 1 mm.

What is the value of the vernier reading R_0 in mm?

Tick (✓) **one** box.

[1 mark]

34.8

☐

37.8

☒

45.8

☐

49.8

☐

Question 2 continues on the next page

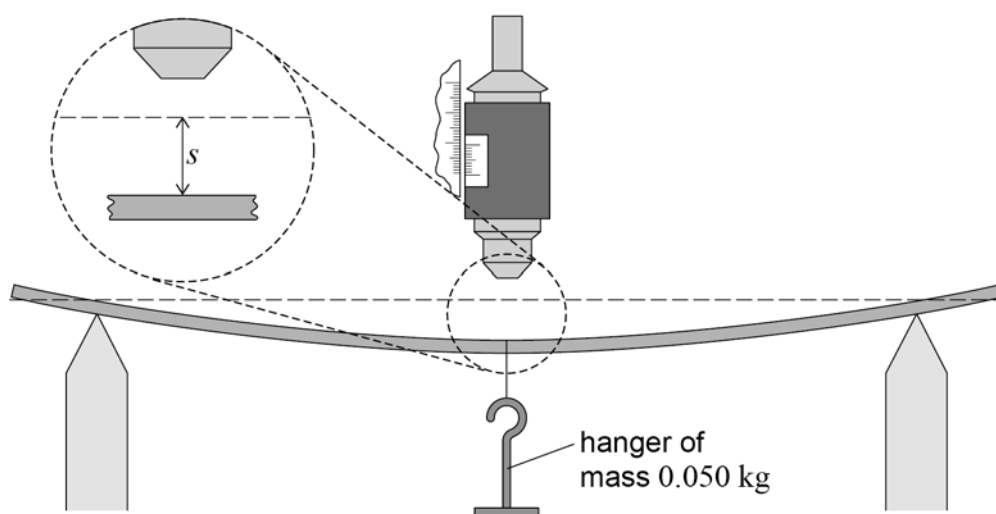
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0 2 . 2

Figure 7 shows the beam bending when a hanger of mass 0.050 kg is suspended from the midpoint.

Figure 7



The microscope is refocused on the upper surface and the new vernier reading R is recorded.

The vertical deflection s of the beam is equal to $(R - R_0)$.

The total mass m suspended from the beam is increased in steps of 0.050 kg.

A value of s is recorded for each m up to a value of $m = 0.450$ kg.

Further values of s are then recorded as m is decreased in 0.050 kg steps until m is zero.

Student **A** performs the experiment and observes that values of s during unloading are **sometimes** different from the corresponding values for loading.

State the type of error that causes the differences student **A** observes.

[1 mark]

Random error



0 2 . 3

Student **B** performs the experiment using a thinner beam but with the same width and made from the same material as before.

Discuss **one** possible advantage and **one** possible disadvantage of using the thinner beam.

[3 marks]

Advantage *The same load produces a larger deflection s (the thinner beam bends more),
so the percentage uncertainty in each value of s is reduced.*

Disadvantage *The thinner beam may go past its elastic limit and undergo plastic deformation (be permanently deformed),
so the graph of s against m would become non-linear (a curve).*

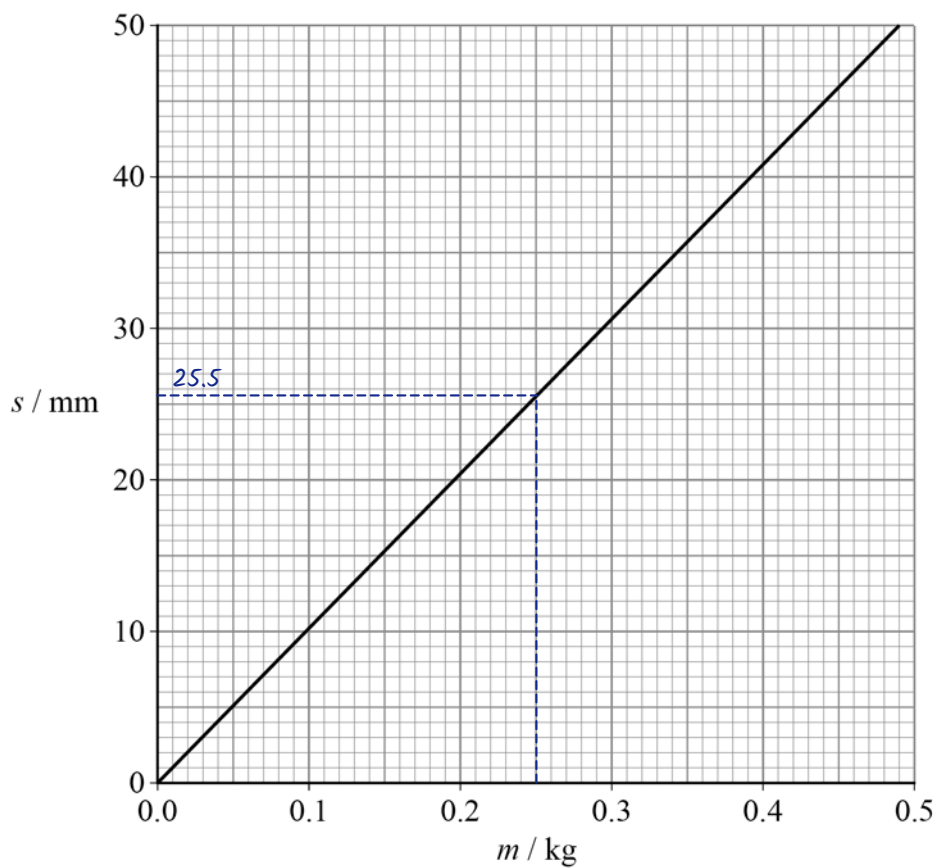
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0 2 . 4 Figure 8 shows the best-fit line produced using the data collected by student A.

Figure 8



It can be shown that $s = \frac{\eta m}{E}$

where E is the Young modulus of the material of the beam and η is a constant.



Deduce in s^{-2} the order of magnitude of η .

$$E = 1.14 \text{ GPa}$$

[4 marks]

$$E = 1.14 \text{ GPa} = 1.14 \times 10^9 \text{ Pa} \quad (\approx 10^9 \text{ Pa})$$

$$\text{From Figure 8: when } m = 0.25 \text{ kg, } s = 25.5 \text{ mm} = 25.5 \times 10^{-3} \text{ m}$$

$$s = \eta m / E \quad \text{so} \quad \eta = Es / m$$

$$\eta = (1.14 \times 10^9 \times 25.5 \times 10^{-3}) / 0.25$$

$$= 1.16 \times 10^8 \text{ s}^{-2}$$

order of magnitude of $\eta =$ 10⁸ s^{-2}

Question 2 continues on the next page

Turn over ►



0 2 . 5

Student **C** performs a different experiment using the same apparatus shown in **Figure 5** on page 10.

A mass M is suspended from the midpoint of the beam.

The vertical deflection s of the beam is measured for different values of L .

Figure 9 shows a graph of the results for this experiment.

Figure 9

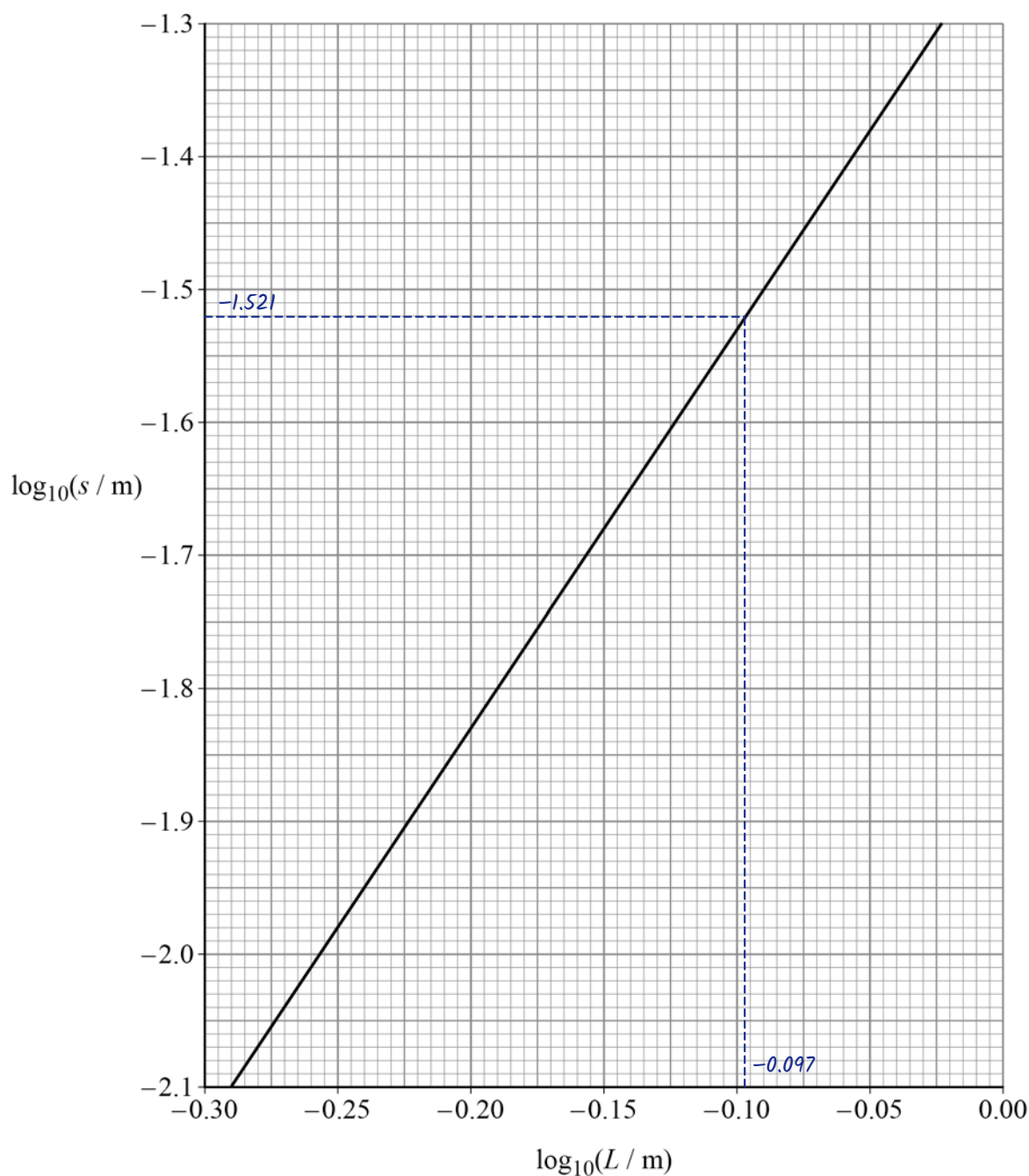


Figure 9 shows that $\log_{10}(s / \text{m})$ varies linearly with $\log_{10}(L / \text{m})$.

State what this shows about the mathematical relationship between s and L .
You do **not** need to do a calculation.

[1 mark]

s and L are related by a power law: $s = kL^n$ ($s \propto L^n$), where k and n are constants; the gradient is about 3, so $s \propto L^3$.

0 2 . 6

Deduce, using **Figure 9**, the value of s when $L = 80 \text{ cm}$.

[2 marks]

$$L = 80 \text{ cm} = 0.80 \text{ m}, \log_{10}(L / \text{m}) = \log_{10} 0.80 = -0.097$$

$$\text{From Figure 9: } \log_{10}(s / \text{m}) = -1.521$$

$$s = 10^{-1.521} = 0.0301 \text{ m}$$

$$s = \underline{3.0 \times 10^{-2}} \text{ m}$$

0 2 . 7

Determine M using **Figure 8**.

[1 mark]

$$\text{Gradient of Figure 8} = 25.5 \times 10^{-3} \text{ m} / 0.25 \text{ kg} = 0.102 \text{ m kg}^{-1}$$

$$M = s / \text{gradient} = 0.0301 / 0.102 = 0.295 \text{ kg}$$

$$M = \underline{0.295} \text{ kg}$$

13

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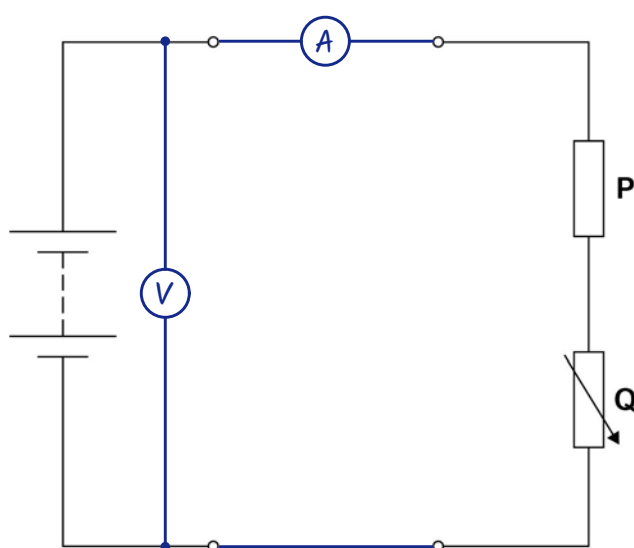


0 3

Figure 10 shows a partly-completed circuit used to investigate the emf $\mathcal{E}$ and the internal resistance r of a power supply.

The resistance of **P** and the maximum resistance of **Q** are unknown.

Figure 10



0 3 . 1

Complete **Figure 10** to show a circuit including a voltmeter and an ammeter that is suitable for the investigation.

[1 mark]



0 3 . 2

Describe

- a procedure to obtain valid experimental data using your circuit
- how these data are processed to obtain ε and r by a graphical method.

[4 marks]

Set Q to its maximum resistance, connect the circuit and record the ammeter reading I and the voltmeter reading V (the terminal pd).

Adjust (vary) the resistance of the variable resistor Q to change the current, and record V and I each time, giving at least 6 sets of readings over as wide a range of current as possible.

Repeat the set of readings and calculate mean values of V for each I .

Disconnect the circuit between readings so the supply does not heat up and r stays constant.

Since $V = \varepsilon - Ir$, plot a graph of V (vertical axis) against I (horizontal axis) and draw a straight line of best fit.

ε = the intercept on the V (vertical) axis.

r = $-$ gradient of the line (the gradient is $-r$).

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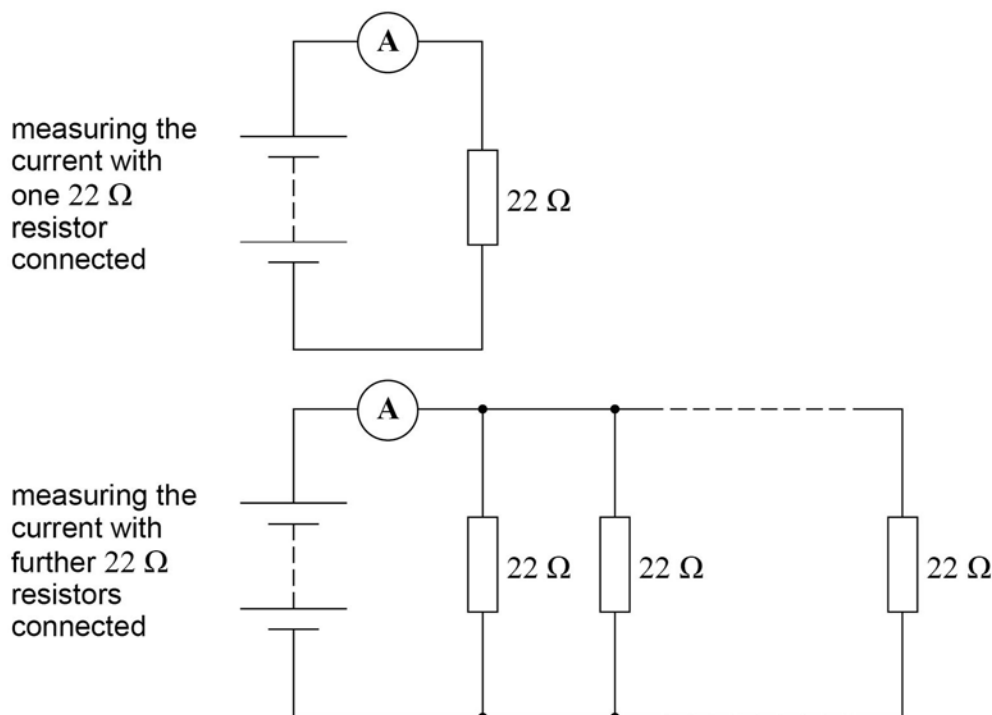
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Figure 11 shows a different experiment carried out to confirm the results for ε and r .

Figure 11



Initially the power supply is connected in series with an ammeter and a 22 Ω resistor. The current I in the circuit is measured.

The number n of 22 Ω resistors in the circuit is increased as shown in **Figure 11**. The current I is measured after each resistor is added.

It can be shown that

$$\frac{22}{n} = \frac{\varepsilon}{I} - r$$

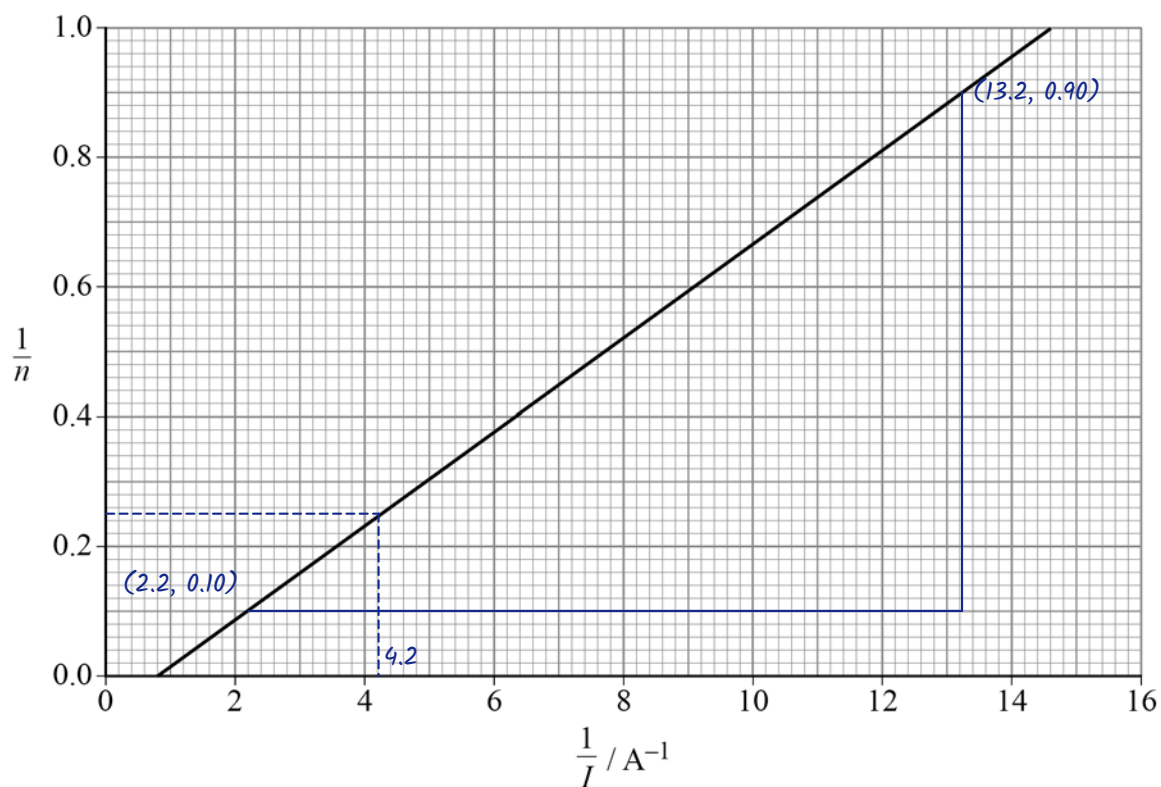
Figure 12 on page 22 shows a graph of the experimental data.

Question 3 continues on the next page

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Figure 12



0 3 . 3 Show that ε is about 1.6 V.

[2 marks]

$$22/n = \varepsilon/I - r \quad \text{so} \quad 1/n = (\varepsilon/22)(1/I) - r/22, \quad \text{gradient} = \varepsilon/22$$

$$\text{gradient} = \Delta(1/n) / \Delta(1/I) = (0.90 - 0.10) / (13.2 - 2.2)$$

$$= 0.80 / 11.0 = 0.0727 \text{ A}$$

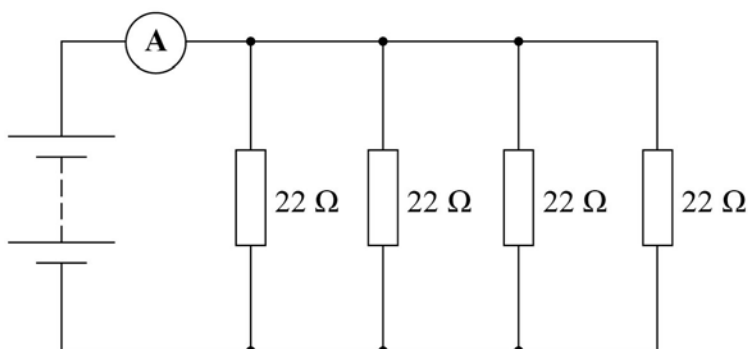
$$\varepsilon = 22 \times \text{gradient} = 22 \times 0.0727 = 1.60 \text{ V (about 1.6 V)}$$



0 3 . 4

Figure 13 shows the circuit when four resistors are connected.

Figure 13



Show, using Figure 12, that the current in the power supply is about 0.25 A.

[1 mark]

Four resistors: $n = 4$, so $1/n = 0.25$

From Figure 12: $1/I = 4.2 \text{ A}^{-1}$, so $I = 1 / 4.2 = 0.238 \text{ A} (\approx 0.25 \text{ A})$

0 3 . 5

Deduce, for the circuit shown in Figure 13,

- the potential difference (pd) across the power supply
- r .

[4 marks]

Total external resistance $R = 22 / 4 = 5.5 \Omega$

$pd = IR = 0.238 \times 5.5 = 1.31 \text{ V}$

lost volts $= \epsilon - pd = 1.60 - 1.31 = 0.29 \text{ V}$

$r = \text{lost volts} / I = (1.60 - 1.31) / 0.238 = 1.2 \Omega$

pd = 1.31 V

r = 1.2 Ω

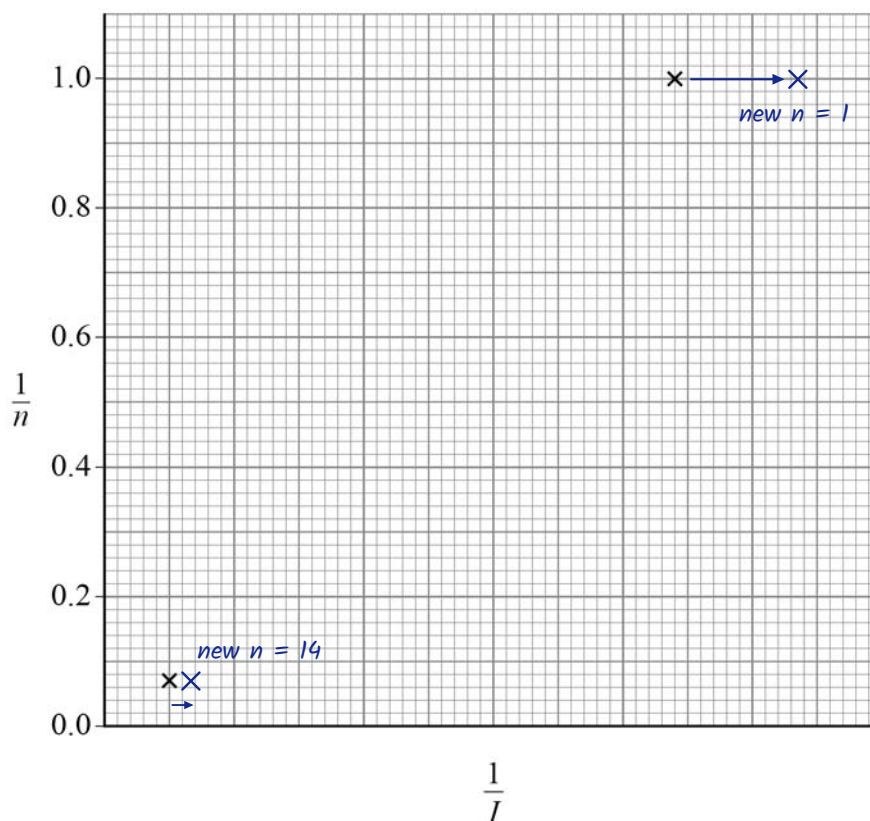
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0 3 . 6 Figure 14 shows the plots for $n = 1$ and $n = 14$

Figure 14



Three additional data sets for values of n between $n = 1$ and $n = 14$ are needed to complete the graph in **Figure 14**.

Suggest which additional values of n should be used.
Justify your answer.

[3 marks]

$n = 2, n = 3$ and $n = 6$

These give $1/n = 0.50, 0.33$ and 0.17 , which fill the large gap between the plots at $1/n = 1.0$ and $1/n = 0.071$ (data for larger n would bunch up near $1/n = 0$).

This improves the distribution of points along the line, so they are spread out as uniformly as possible.



03.7

The experiment is repeated using a set of resistors of resistance $27\ \Omega$.

The relationship between n and I is now

$$\frac{27}{n} = \frac{\varepsilon}{I} - r$$

Show on **Figure 14** the effect on the plots for $n = 1$ and $n = 14$
You do **not** need to do a calculation.

[2 marks]

17

END OF QUESTIONS



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