



Please write clearly in block capitals.

Centre number

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Candidate number

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Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 3 Section A

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.

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.

For Examiner's Use	
Question	Mark
1	
2	
3	
TOTAL	



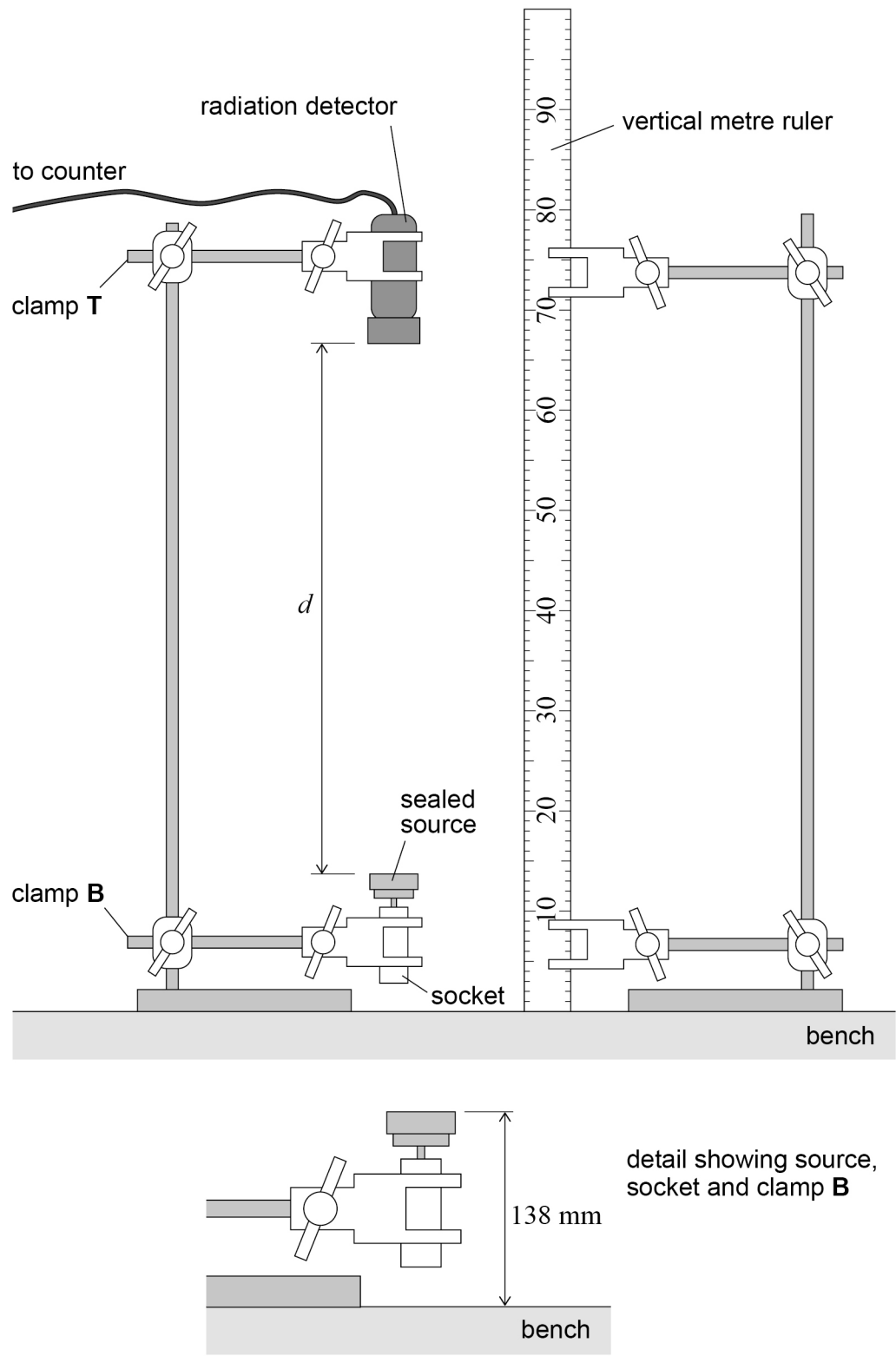
Section A

Answer **all** questions in this section.

0 1

Figure 1 shows apparatus used to investigate the inverse-square law for gamma radiation.

Figure 1



A sealed source that emits gamma radiation is held in a socket attached to clamp **B**. The vertical distance between the open end of the source and the bench is 138 mm. A radiation detector, positioned vertically above the source, is attached to clamp **T**.

A student is told **not** to move the stands closer together.

0 1 . 1

Describe a procedure for the student to find the value of d , the vertical distance between the open end of the source and the radiation detector.

In your answer, annotate **Figure 1** to show how a set-square can be used in this procedure.

[2 marks]

Question 1 continues on the next page

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0	1	.	2
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Before the source was brought into the room, a background count C_b was recorded.

$$C_b = 630 \text{ counts in 15 minutes}$$

With the source and detector in the positions shown in **Figure 1**, $d = 530 \text{ mm}$.

Separate counts C_1 , C_2 and C_3 are recorded.

$$C_1 = 90 \text{ counts in 100 s}$$

$$C_2 = 117 \text{ counts in 100 s}$$

$$C_3 = 102 \text{ counts in 100 s}$$

R_C is the mean count rate corrected for background radiation.

Show that when $d = 530 \text{ mm}$, R_C is about 0.3 s^{-1} .

[2 marks]



01.3

The apparatus is adjusted so that $d = 380 \text{ mm}$.
Counts are made that show $R_C = 0.76 \text{ s}^{-1}$.

The student predicts that:

$$R_C = \frac{k}{d^2}$$

where k is a constant.

Explain whether the values of R_C in Questions **01.2** and **01.3** support the student's prediction.

[2 marks]

01.4

Describe a safe procedure to reduce d . Give a reason for your procedure.

[2 marks]

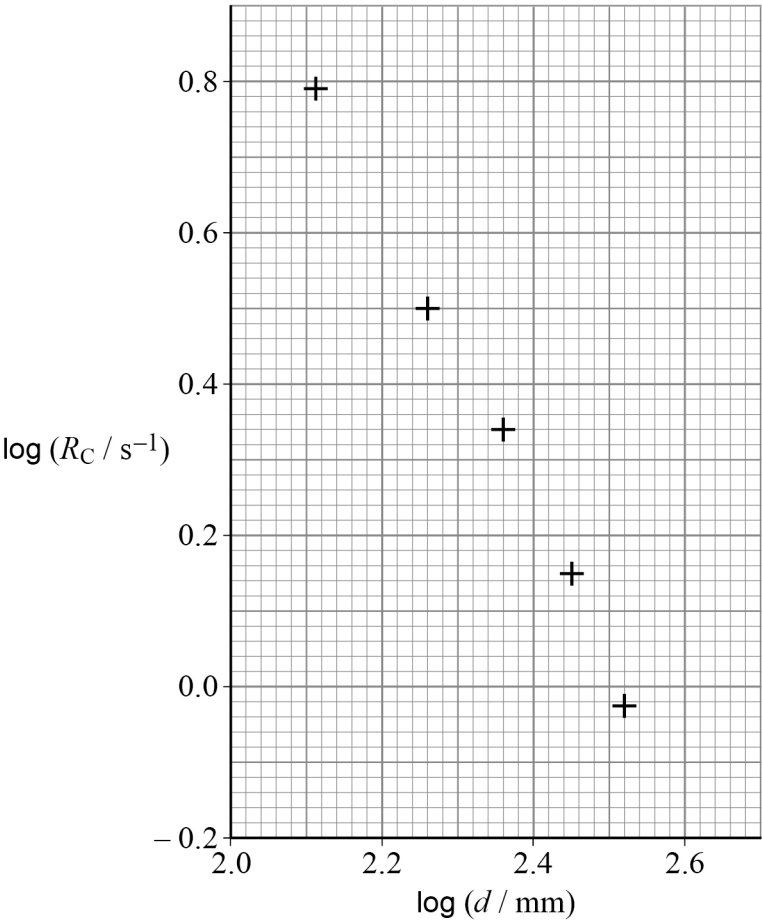
Question 1 continues on the next page

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The student determines R_C for further values of d .
The values of d change by the same amount Δd between each measurement.
Figure 2 shows these data.

Figure 2



0	1	5
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 Determine Δd .

[2 marks]

$\Delta d =$ _____ mm



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0 1 . 6

Explain how the student could confirm whether **Figure 2** supports the prediction:

$$R_c = \frac{k}{d^2}$$

No calculation is required.

[3 marks]

Question 1 continues on the next page

Turn over ►



When a gamma photon is detected by the detector, another photon cannot be detected for a time t_d called the dead time.

It can be shown that:

$$t_d = \frac{R_2 - R_1}{R_1 \times R_2}$$

where R_1 is the measured count rate
 R_2 is the count rate when R_1 is corrected for dead time error.

01.7

The distance between the source and the detector is adjusted so that d is very small and R_1 is 100 s^{-1} .
On average, two of the gamma photons that enter the detector every second are not detected.

Calculate t_d for this detector.

[1 mark]

$t_d =$ _____ s

01.8

A student says that if 100 gamma photons enter a detector in one second and t_d is 0.01 s, all the photons should be detected.

Explain, with reference to the nature of radioactive decay, why this idea is **not** correct.

[2 marks]



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0	2
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A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p .

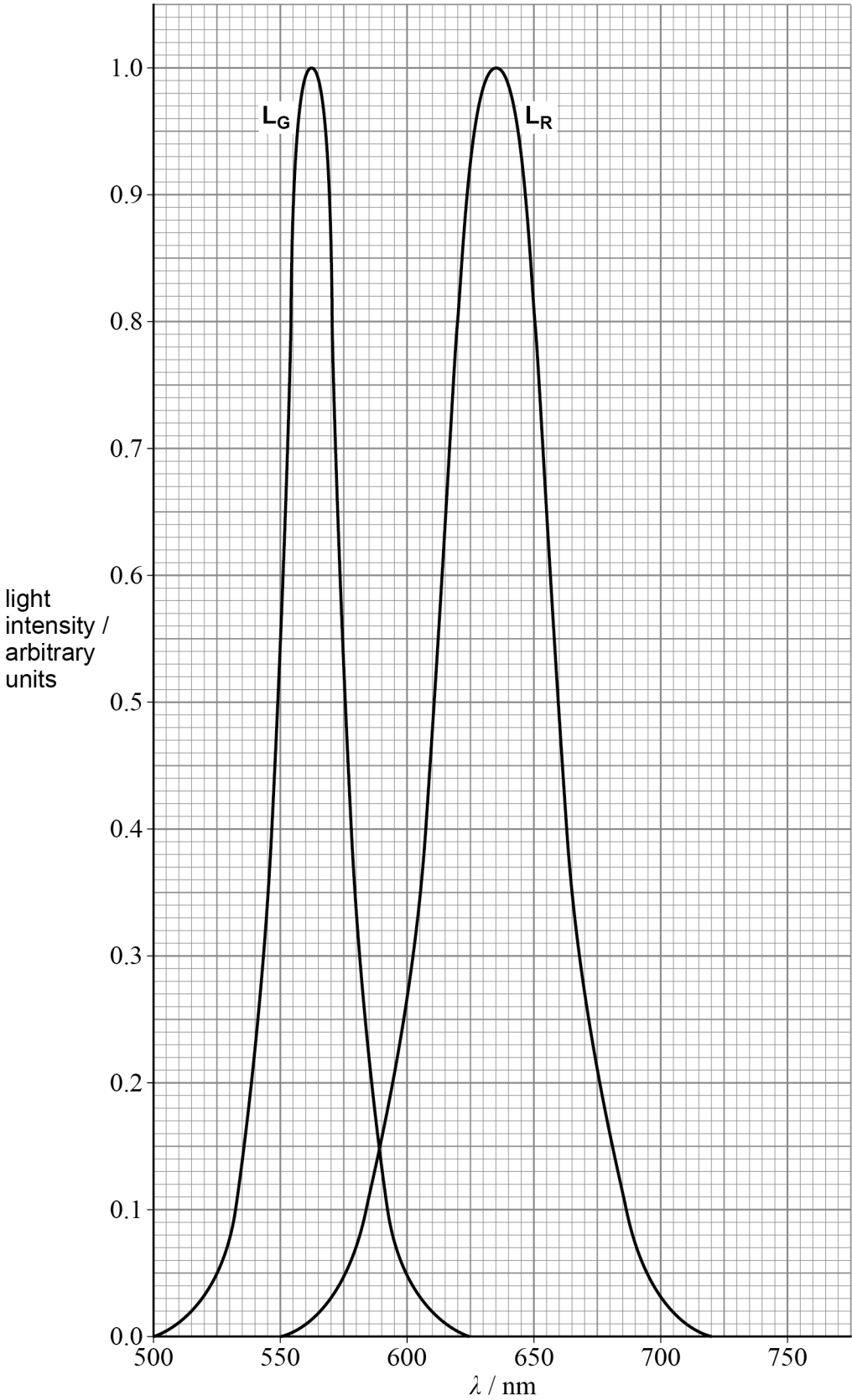
Two LEDs L_G and L_R are adjusted to give the same maximum light intensity. L_G emits green light and L_R emits red light.

Figure 3 shows how the light output of the LEDs varies with the wavelength λ .



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Figure 3



Question 2 continues on the next page

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0 2 . 1

Light from **L_R** is incident normally on a plane diffraction grating.
The fifth-order maximum for light of wavelength λ_p occurs at a diffraction angle of 76.3° .

Determine N , the number of lines per metre on the grating.

[3 marks]

$N =$ _____ m^{-1}

0 2 . 2

Suggest **one** possible disadvantage of using the fifth-order maximum to determine N .

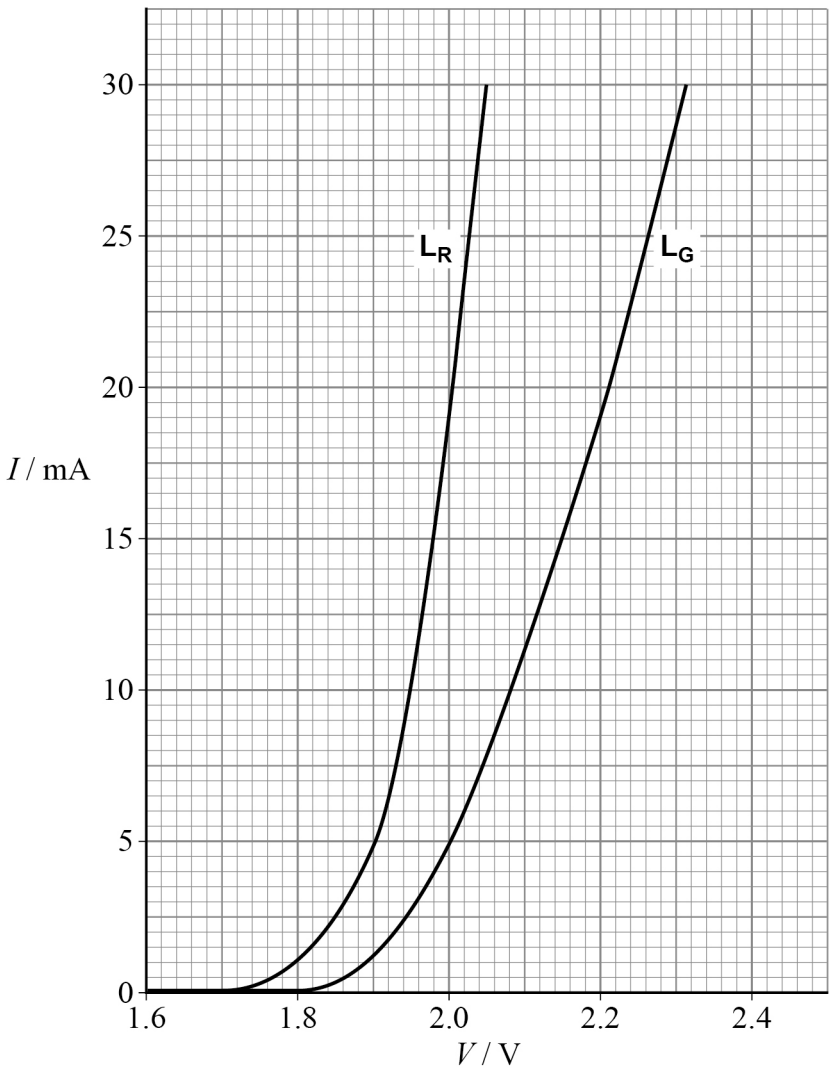
[1 mark]



0 2 . 3

Figure 4 shows part of the current–voltage characteristics for L_R and L_G .

Figure 4



When the linear part of the characteristic is extrapolated, the point at which it meets the horizontal axis gives the activation voltage V_A for the LED.

V_A for L_G is 2.00 V.

Determine, using **Figure 4**, V_A for L_R .

[2 marks]

V_A for L_R = _____ V

Question 2 continues on the next page

Turn over ►



0	2	.	4
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It can be shown that:

$$V_A = \frac{hc}{e\lambda_p}$$

where h = the Planck constant.

Deduce a value for the Planck constant based on the data given about the LEDs.

[2 marks]

$h =$ _____ J s

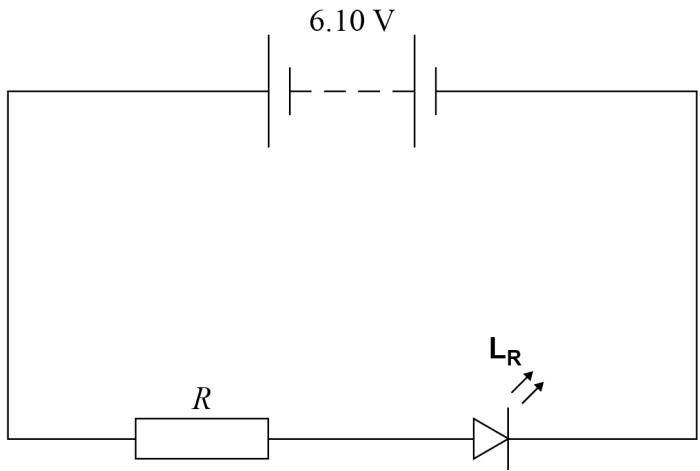


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0 2 . 5

Figure 5 shows a circuit with L_R connected to a resistor of resistance R .

Figure 5



The power supply has emf 6.10 V and negligible internal resistance.
The current in L_R must not exceed 21.0 mA.

Deduce the minimum value of R .

[2 marks]

minimum value of $R =$ _____ Ω

10

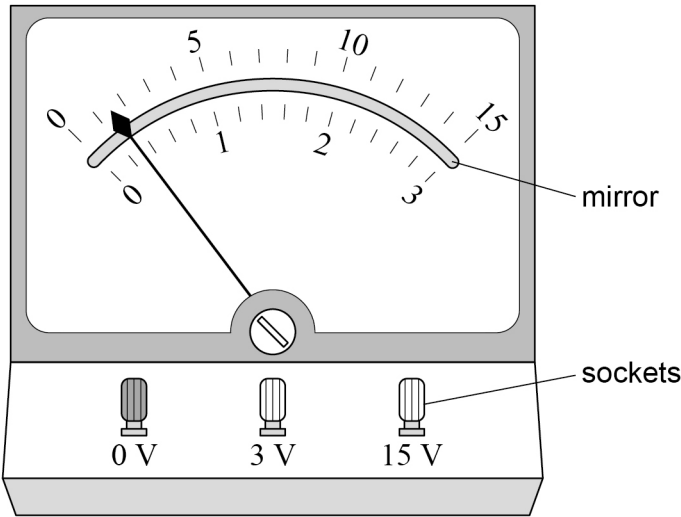
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0 3

An analogue voltmeter has a resistance that is much less than that of a modern digital voltmeter.
Analogue meters can be damaged if the full-scale reading is exceeded.
Figure 6 shows a dual-range analogue voltmeter with a zero error.

Figure 6



0 3 . 1

The voltmeter is set to the **more sensitive** range and then used in a circuit.

What is the potential difference (pd) between the terminals of the voltmeter when a full-scale reading is indicated?

Tick (✓) **one** box.

[1 mark]

2.7 V

☐

3.3 V

☐

13.5 V

☐

16.5 V

☐

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03.2

Explain the use of the mirror when reading the meter.

[2 marks]

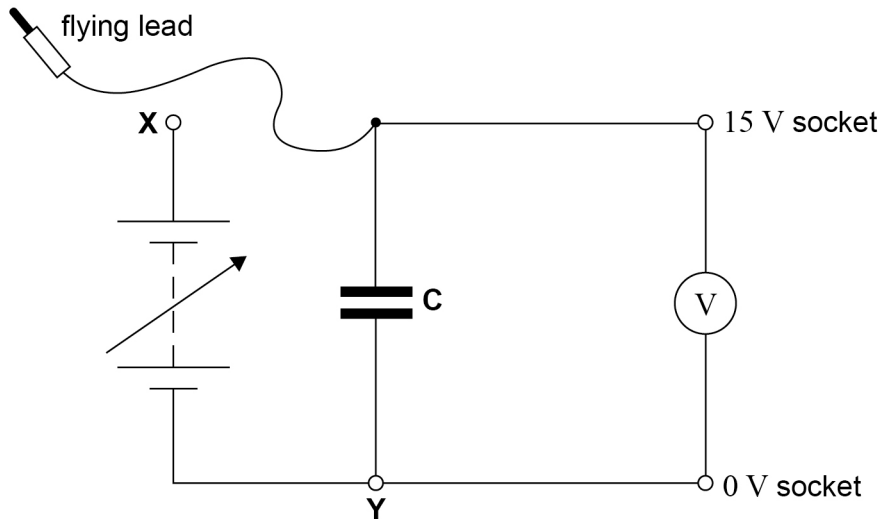
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A student corrects the zero error on the meter and then assembles the circuit shown in **Figure 7**.
The capacitance of the capacitor **C** is not known.

Figure 7



The output pd of the power supply is set to zero.
The student connects the flying lead to socket **X** and adjusts the output pd until the voltmeter reading is full scale (15 V).
She disconnects the flying lead from socket **X** so that **C** discharges through the voltmeter.

She measures the time $T_{\frac{1}{2}}$ for the voltmeter reading V to fall from 10 V to 5 V.

She repeats this process several times.

Table 1 shows the student's results, **none** of which is anomalous.

Table 1

$T_{\frac{1}{2}} / \text{s}$	12.00	11.94	12.06	12.04	12.16
------------------------------	-------	-------	-------	-------	-------



0 3 . 3 Determine the percentage uncertainty in $T_{1/2}$.

[2 marks]

percentage uncertainty = _____ %

0 3 . 4 Show that the time constant for the discharge circuit is about 17 s.

[1 mark]

Question 3 continues on the next page

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The student thinks that the time constant of the circuit in **Figure 7** is directly proportional to the range of the meter.
To test her theory, she repeats the experiment with the voltmeter set to the 3 V range.
She expects $T_{1/2}$ to be about 2.5 s.

Explain:

- what the student should do, before connecting capacitor **C** to the 0 V and 3 V sockets, to avoid exceeding the full-scale reading on the voltmeter
- how she should develop her procedure to get an accurate result for the time constant
- how she should use her result to check whether her theory is correct.

[4 marks]

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

The student wants to find the resistance of the voltmeter when it is set to the 15 V range.

She replaces **C** with an 820 μF capacitor and charges it to 15 V.

She discharges the capacitor through the voltmeter, starting a stopwatch when V is 14 V.

She records the stopwatch reading t at other values of V as the capacitor discharges.

Table 2 shows her results.

Table 2

V/V	14	11	8	6	4	3	2
t/s	0.0	3.1	7.2	11.0	16.2	19.9	25.2

0	3	.	6
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Suggest **two** reasons why the student selected the values of V shown in **Table 2**. Explain each of your answers.

[4 marks]

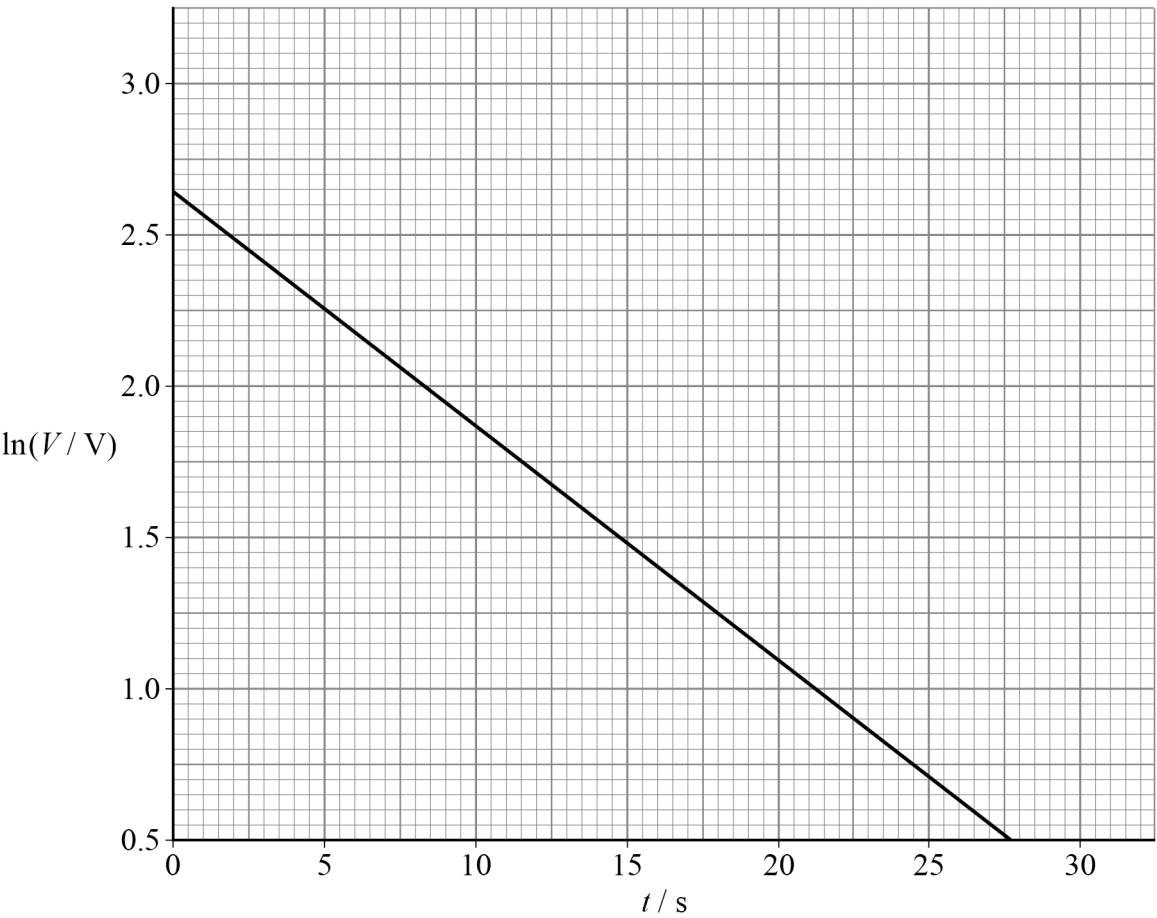
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Figure 8 shows a graph of the experimental data.

Figure 8



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03.7

Show, using **Figure 8**, that the resistance of the voltmeter is about 16 k Ω .

[3 marks]

03.8

Determine the current in the voltmeter at $t = 10$ s.

[2 marks]

current = _____ A

19

END OF QUESTIONS



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