Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 3
Section A

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.

For Examiner's Use	
Question	Mark
1	
2	
3	
TOTAL	

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.

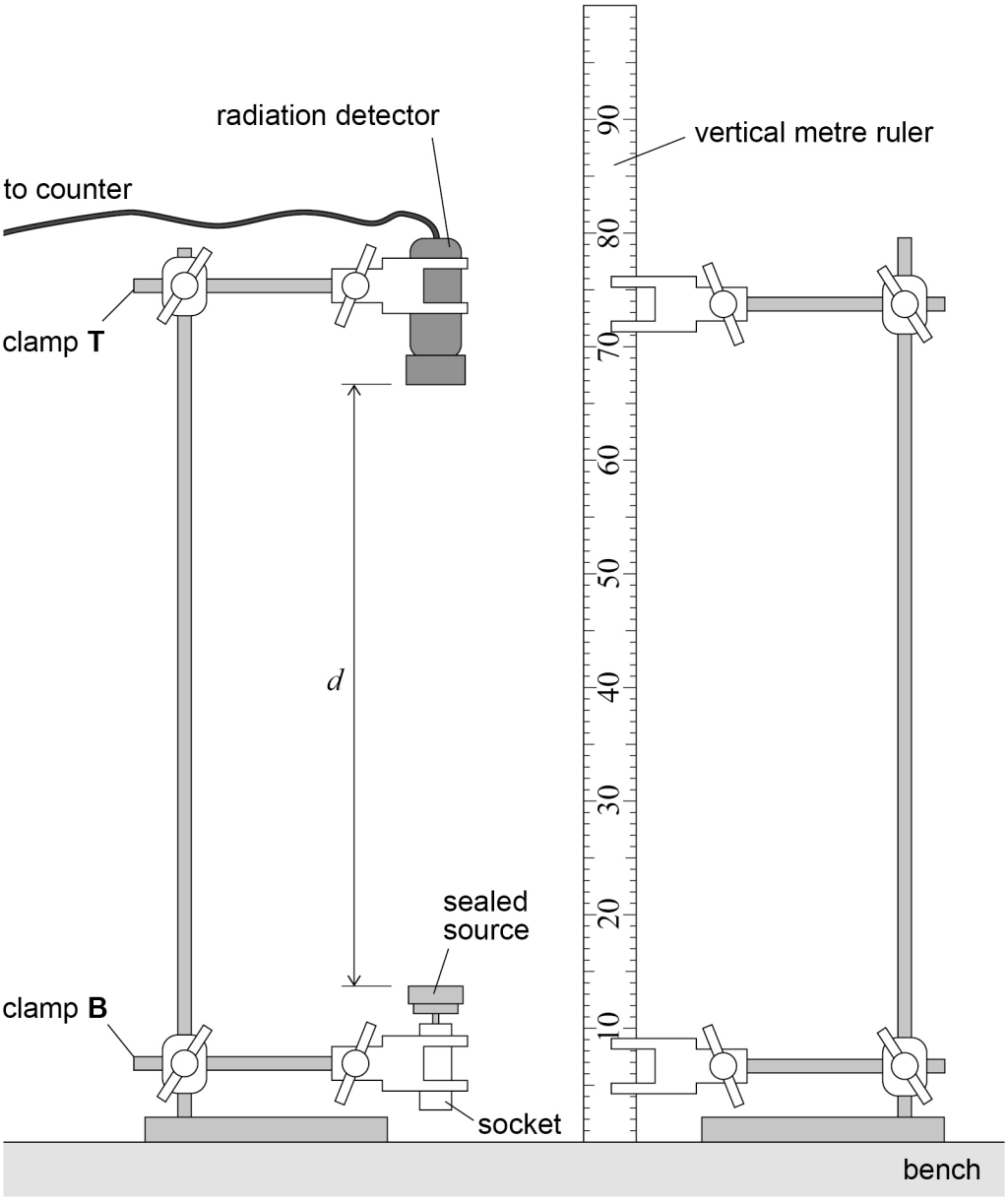
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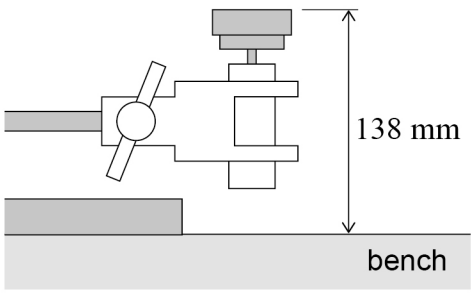
Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows apparatus used to investigate the inverse-square law for gamma radiation.

Figure 1





detail showing source, socket and clamp **B**

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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 $138\ \text{mm}$. 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 Before the source was brought into the room, a background count C_b was recorded.

$C_b = 630$ counts in 15 minutes

With the source and detector in the positions shown in **Figure 1**, $d = 530$ mm.
Separate counts C_1, C_2 and C_3 are recorded.

$C_1 = 90$ counts in 100 s
$C_2 = 117$ counts in 100 s
$C_3 = 102$ counts in 100 s

R_C is the mean count rate corrected for background radiation.

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

[2 marks]

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0 1 . 3 The apparatus is adjusted so that $d = 380$ mm.
Counts are made that show $R_C = 0.76\ s^{-1}$.

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]

0 1 . 4 Describe a safe procedure to reduce d. Give a reason for your procedure.

[2 marks]

Question 1 continues on the next page

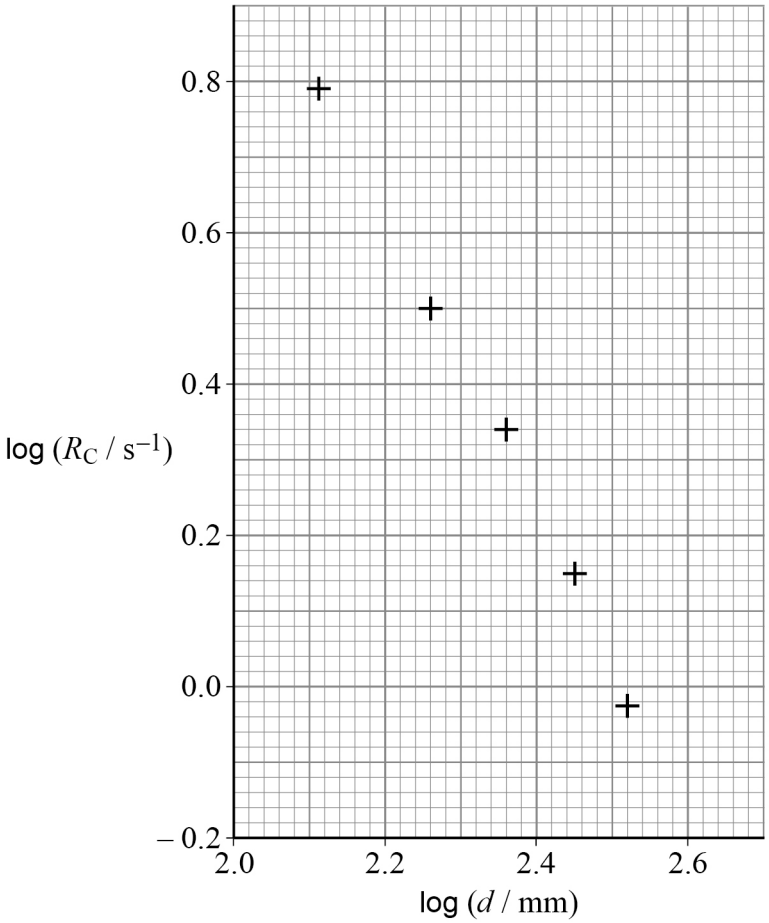
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The student determines R_C for further values of d.

The values of d change by the same amount Δd between each measurement.

Figure 2 shows these data.

Figure 2



0 1 . 5 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

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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.

0 1 . 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

0 1 . 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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Turn over for the next question

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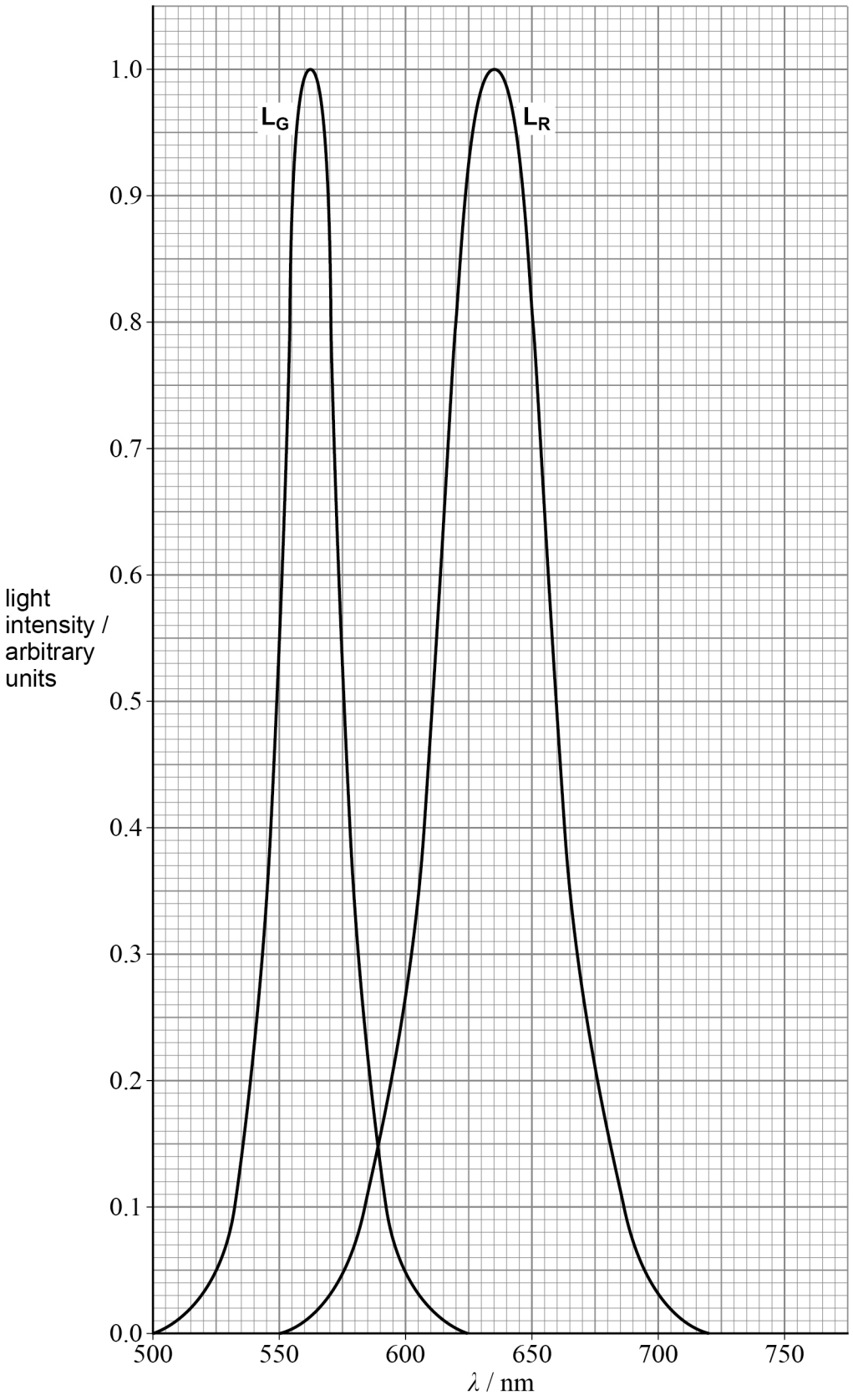
0 2 A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p.

Two LEDs $\mathbf{L_G}$ and $\mathbf{L_R}$ are adjusted to give the same maximum light intensity. $\mathbf{L_G}$ emits green light and $\mathbf{L_R}$ 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]

_____

_____

_____

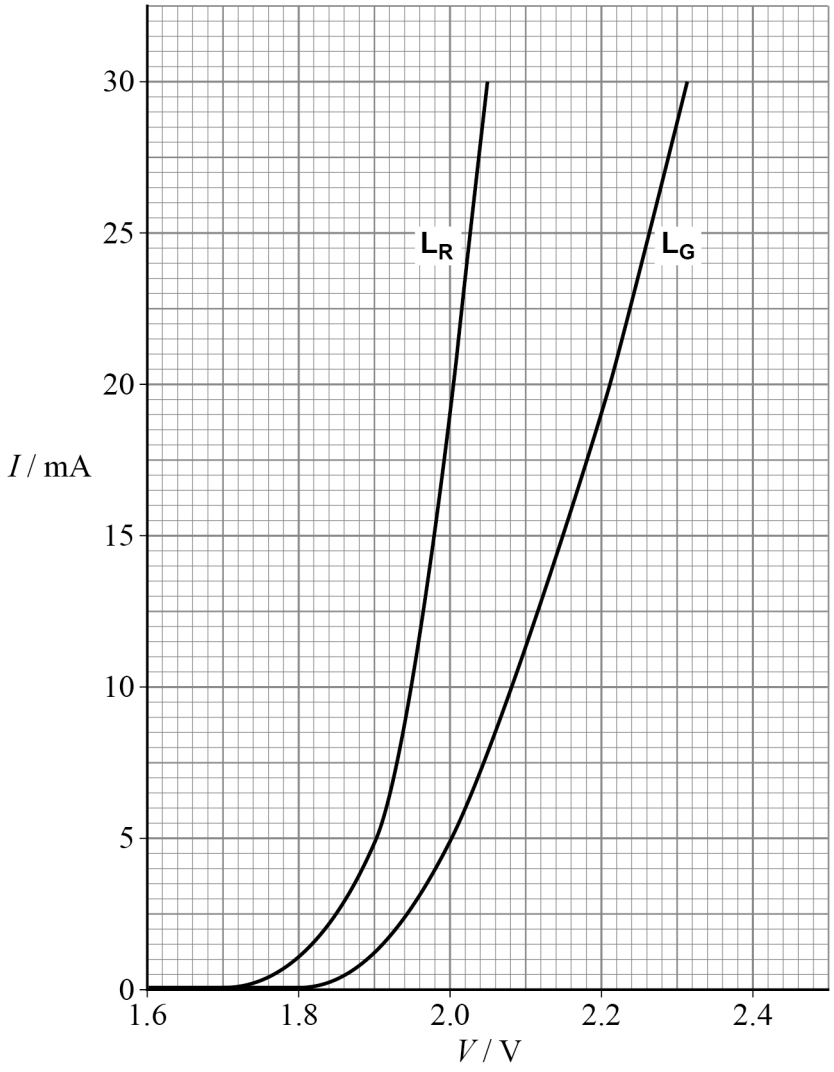
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0 2 . 3 **Figure 4** shows part of the current−voltage characteristics for $\mathbf{L_R}$ and $\mathbf{L_G}$.

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 $\mathbf{L_G}$ is 2.00 V.

Determine, using **Figure 4**, V_A for $\mathbf{L_R}$.

[2 marks]

V_A for $\mathbf{L_R}$ = _____ V

Question 2 continues on the next page

Turn over ►

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0 2 . 4 It can be shown that:

$$V_{\mathrm{A}} = \frac{hc}{e\lambda_{\mathrm{p}}}$$

where h = the Planck constant.

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

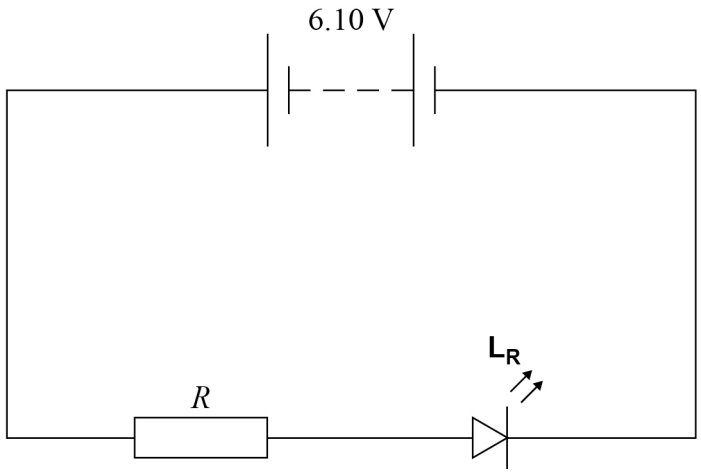
[2 marks]

$h =$ _____ J s

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0 2 . 5 **Figure 5** shows a circuit with $\mathbf{L_R}$ connected to a resistor of resistance R.

Figure 5



The power supply has emf $6.10\ \text{V}$ and negligible internal resistance.
The current in $\mathbf{L_R}$ must not exceed $21.0\ \text{mA}$.

Deduce the minimum value of R.

[2 marks]

minimum value of R = _____ Ω

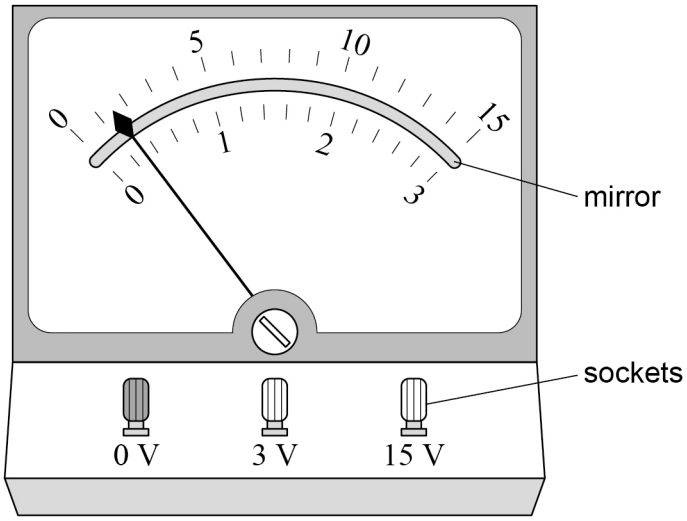
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0 3 An analogue voltmeter has a resistance that is much less than that of a modern digital voltmeter.
Analogue meters can be damaged if the full-scale reading is exceeded.
Figure 6 shows a dual-range analogue voltmeter with a zero error.

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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0 3 . 2 Explain the use of the mirror when reading the meter.

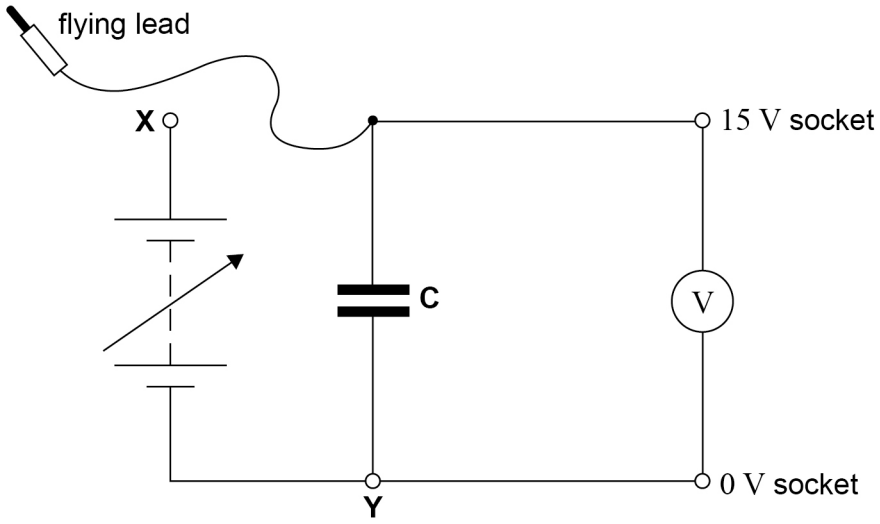
[2 marks]

Question 3 continues on the next page

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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 $T_{½}$ 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

$T_{½}$ / s	12.00	11.94	12.06	12.04	12.16

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0 3 . 3 Determine the percentage uncertainty in $T_{½}$.

[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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0 3 . 5 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 $3\ \text{V}$ range.
She expects $T_{½}$ to be about $2.5\ \text{s}$.

Explain:

- what the student should do, before connecting capacitor **C** to the $0\ \text{V}$ and $3\ \text{V}$ 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]

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The student wants to find the resistance of the voltmeter when it is set to the $15\ \text{V}$ range.
She replaces **C** with an $820\ \mu\text{F}$ capacitor and charges it to $15\ \text{V}$.
She discharges the capacitor through the voltmeter, starting a stopwatch when V is $14\ \text{V}$.
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 Suggest **two** reasons why the student selected the values of V shown in **Table 2**.
Explain each of your answers.

[4 marks]

1 _____

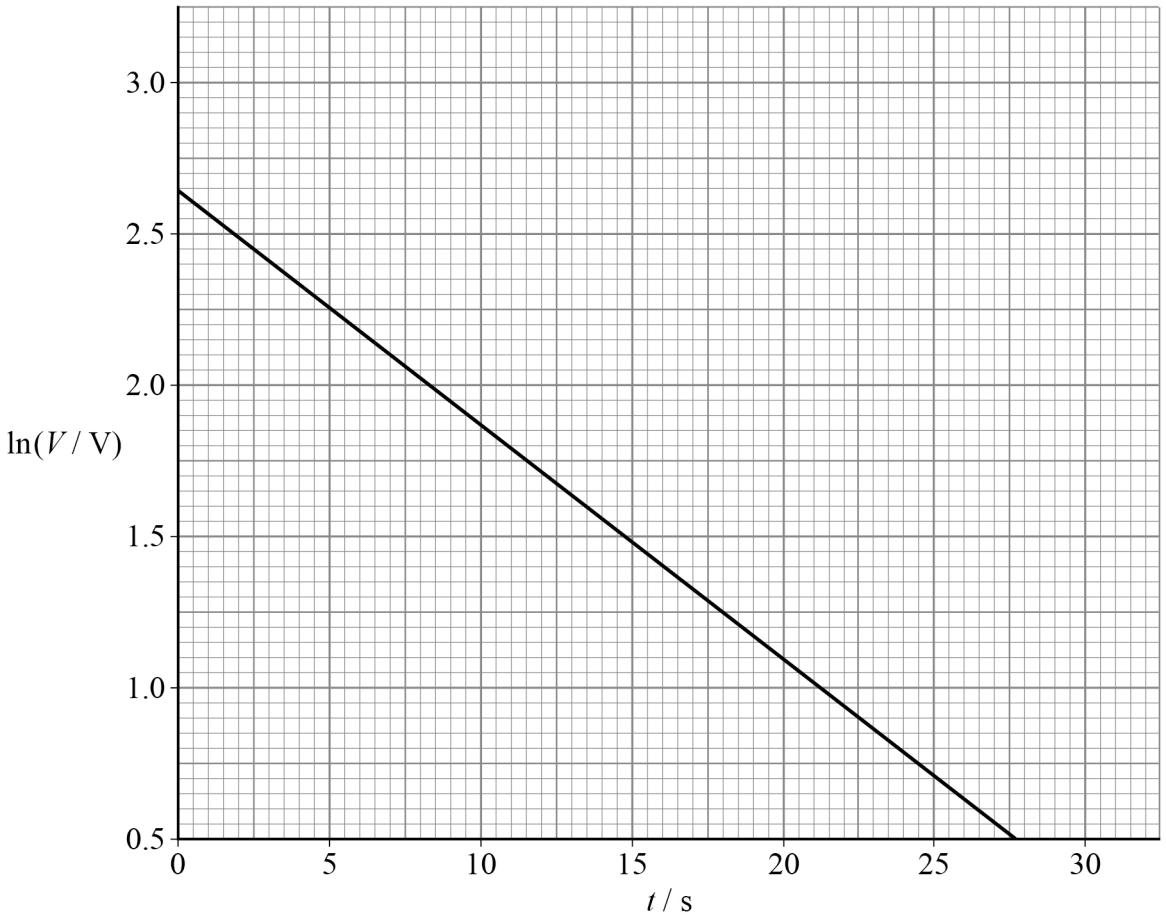
2 _____

Question 3 continues on the next page

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Figure 8 shows a graph of the experimental data.

Figure 8



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0 3 . 7 Show, using **Figure 8**, that the resistance of the voltmeter is about $16\ \text{k}\Omega$.

[3 marks]

0 3 . 8 Determine the current in the voltmeter at $t = 10$ s.

[2 marks]

current = _____ A

19

END OF QUESTIONS

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