AQA

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.

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	

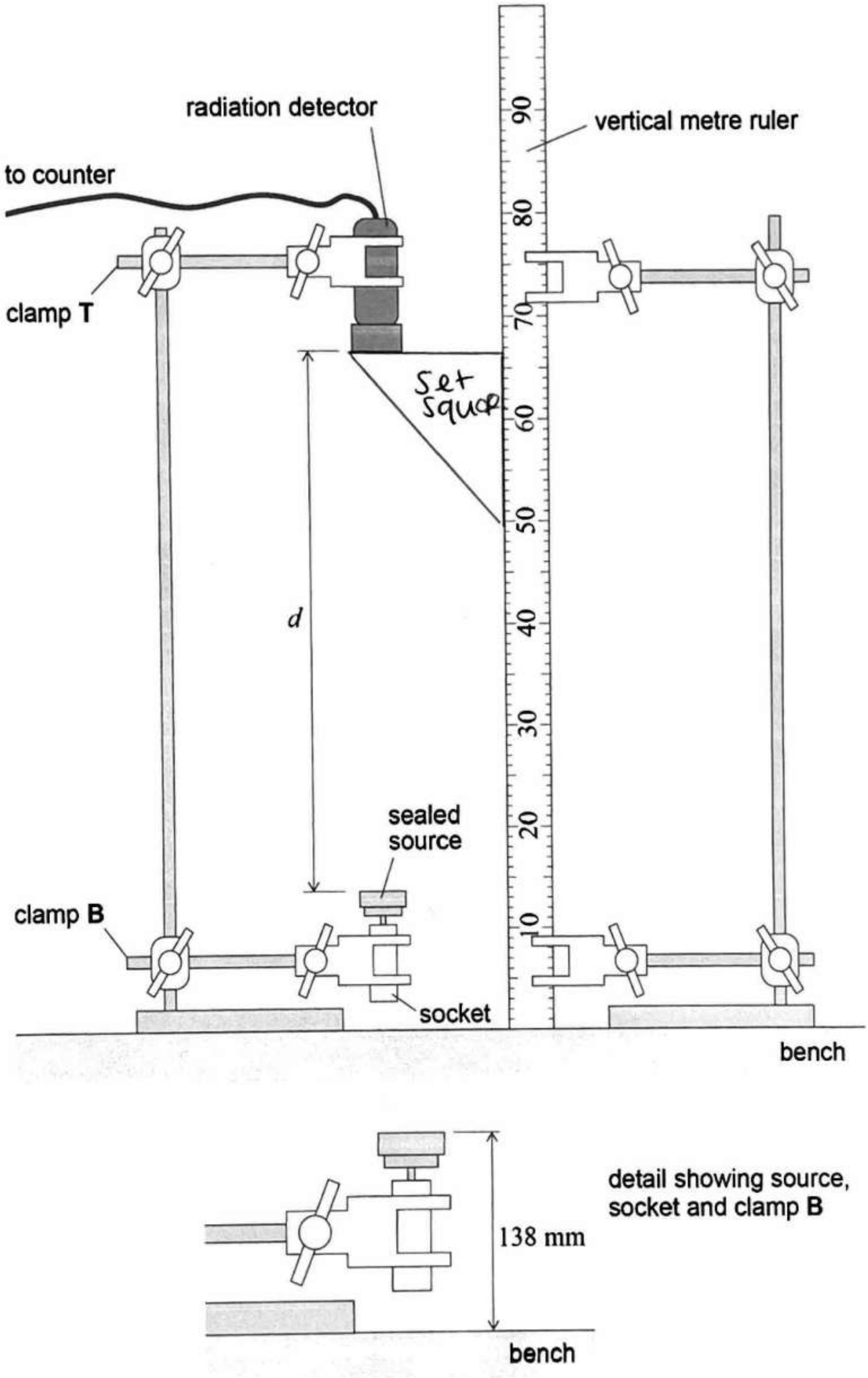
Do not write outside the box

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]

find d by reading the position of the detector using a set square then subtract 138 mm.

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]

$C_b = \frac{630}{15 \times 60} = 0.7$ counts s^{-1}

$C_{av} = \frac{90+117+102}{3} \times \frac{1}{100} = 1.03$ counts s^{-1}.

$R_c = C_{av} - C_b$

$= 1.03 - 0.7 = \underline{\underline{0.33\ s^{-1}}}$

0 1 . 3 The apparatus is adjusted so that $d = 380$ 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]

~~R~~ for $d = 530$ mm
$k = R_C d^2 = 0.33 \times (0.53)^2 = 0.093$

for $d = 380$ mm
$k = 0.76 \times (0.38)^2 = 0.110$

% difference $= \dfrac{0.110 - 0.093}{0.093} \times 100 = 18\%$

The large percentage difference suggests that the prediction is not correct.

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

[2 marks]

adjust the position of the detector using the clamp to maximise the distance between the experimenter and the source.

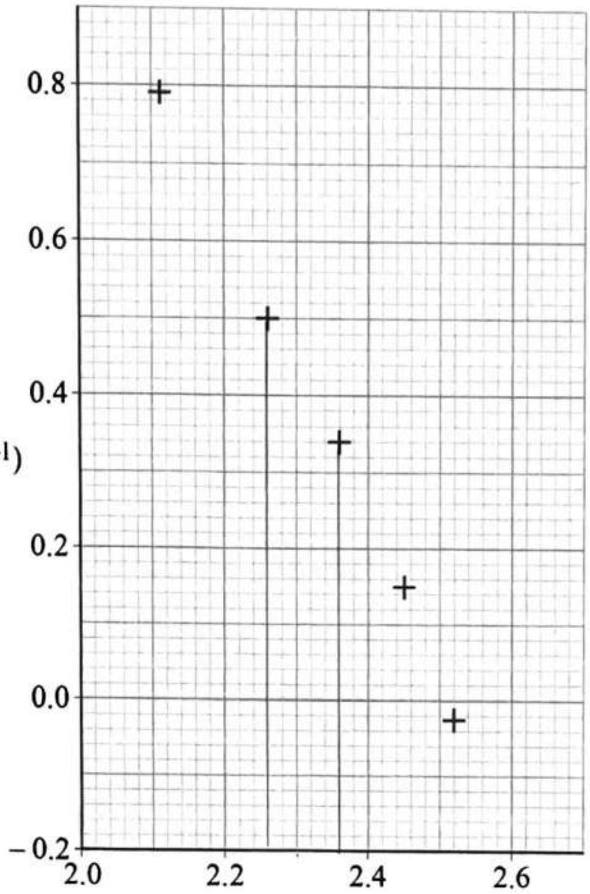
Question 1 continues on the next page

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]

$\Delta d = (10^{2.36} - 10^{2.26}) \div 1$

$= 47.1$ mm.

$\Delta d =$ 47.1 mm

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]

$\log R_C = -2\log d + \log k$ so they should draw a line of best fit and measure the gradient. If the gradient is approximately equal to -2 then the prediction is correct

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.

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]

$R_1 = 100s$
$R_2 = 102$

$$t_d = \frac{102-100}{100 \times 102} = 1.96 \times 10^{-4}\ s$$

t_d = 1.96×10^{-4} 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]

decay is random and so more than one photon may arrive at a detector within a 0.01s interval.

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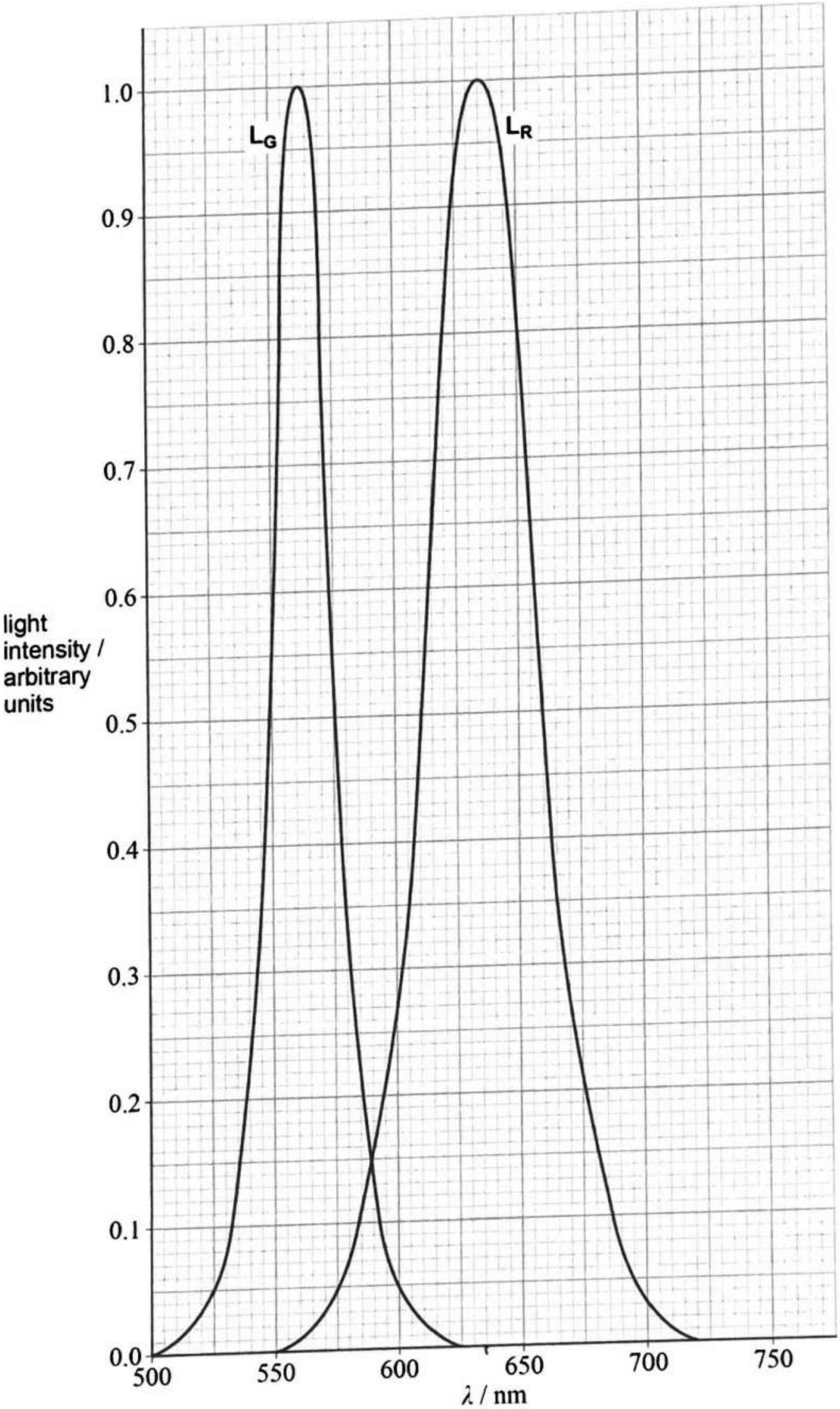
0 2 A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p.

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.

Figure 3



Question 2 continues on the next page

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]

$\lambda p = 635 \text{ nm}$ from Figure 3.

$n\lambda = d \sin\theta$

$d = \frac{n\lambda}{\sin\theta} = \frac{5 \times 635 \times 10^{-9}}{\sin 76.3} = 3.27 \times 10^{-6} \text{ m}$

$N = \frac{1}{3.27 \times 10^{-6}} = 3.06 \times 10^{5}$

$N =$ 3.06×10^5. m^{-1}

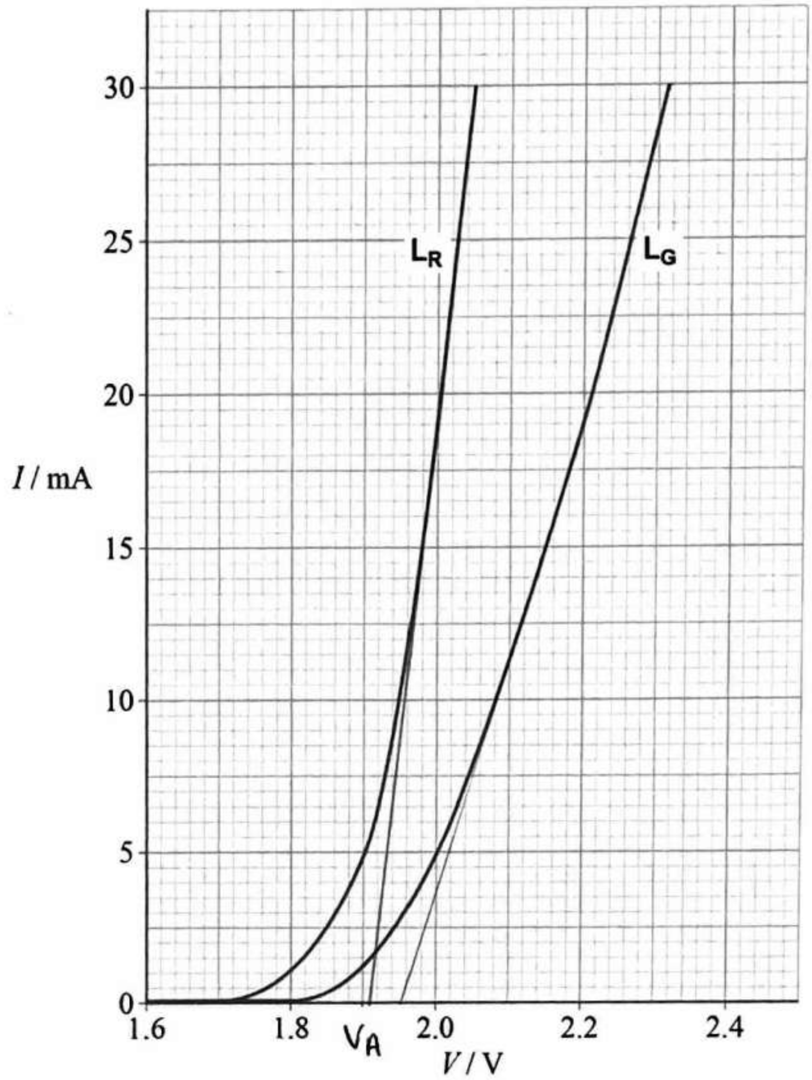
0 2 . 2 Suggest **one** possible disadvantage of using the fifth-order maximum to determine N.

[1 mark]

The centre of the fifth-order maximum is difficult to locate because it has a reduced intensity.

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** = 1.91 V

Question 2 continues on the next page

Turn over ▶

0 2 . 4 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]

$$h_r = \frac{eV_A \lambda_p}{c}$$

$$= \frac{1.6\times10^{-19} \times 1.91 \times 635\times10^{-9}}{3.0\times10^{8}}$$

$$= 6.47\times10^{-34}$$

$$h_G = \frac{1.6\times10^{-19} \times 1.93 \times 553\times10^{-9}}{3.0\times10^{8}}$$

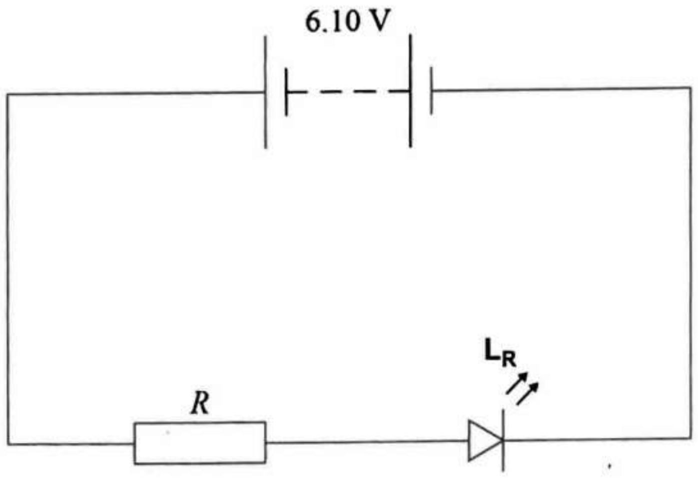
$$= 5.70\times10^{-34}$$

average = 6.1×10^{-34}

h = 6.1×10^{-34} J s

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 V and negligible internal resistance.
The current in $\mathbf{L_R}$ must not exceed 21.0 mA.

Deduce the minimum value of R.

[2 marks]

for $I = 21\text{mA}$, $V = 2.1\text{V}$ (from Figure 4)

$$R = \frac{6.1 - 2.1}{21 \times 10^{-3}} = 190\,\Omega$$

minimum value of R = 190 Ω

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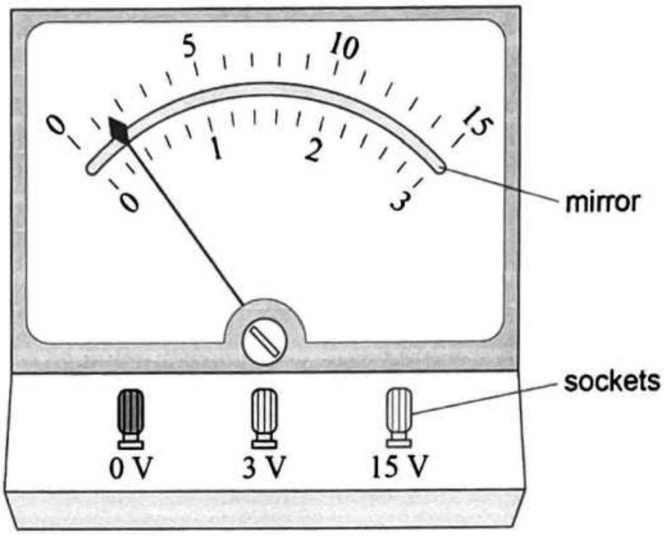
Turn over ▶

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 ☐

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

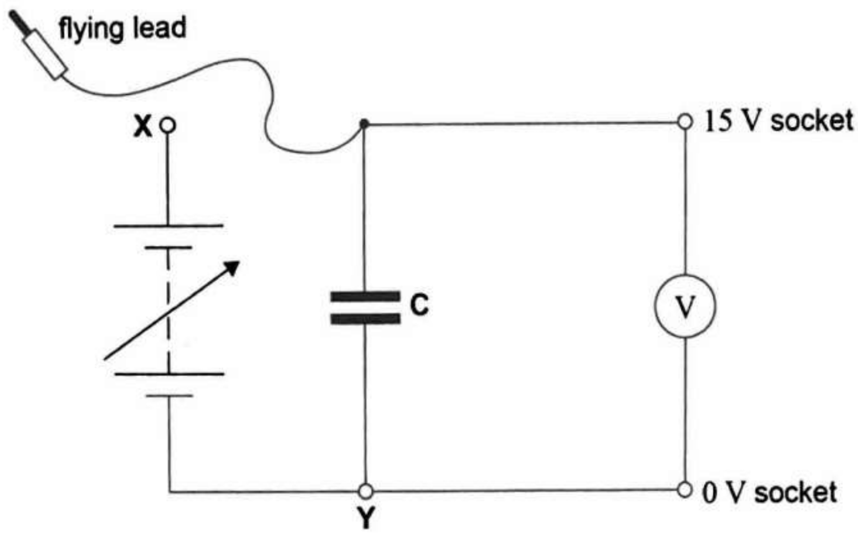
[2 marks]

move position until the needle is aligned with its reflection in the mirror before taking a reading. This reduces parallax error.

Question 3 continues on the next page

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

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

[2 marks]

average $T_{1/2} = \dfrac{12.00 + 11.94 + 12.06 + 12.04 + 12.16}{5}$

$= 12.04 s.$

uncertainty $= \frac{1}{2}(12.16 - 11.94) = 0.11$

% uncertainty $= \dfrac{0.11}{12.04} \times 100 = 0.91\%$

percentage uncertainty = 0.91 %

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

[1 mark]

$\tau = \dfrac{T_{1/2}}{\ln 2}$

$= \dfrac{12.04}{\ln 2}$

$= 17.4 s$

Question 3 continues on the next page

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 V range.
She expects $T_{½}$ 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]

Discharge C by connecting flying lead to Y
and reduce the output PD to ≤3V
before connecting C to X. To improve the procedure, increase the timing interval and take repeated readings then calculate a mean average. Correct for any zero error on the voltmeter for each reading. The theory will be correct if the time constant is approximately 20% the initial value.

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

[4 marks]

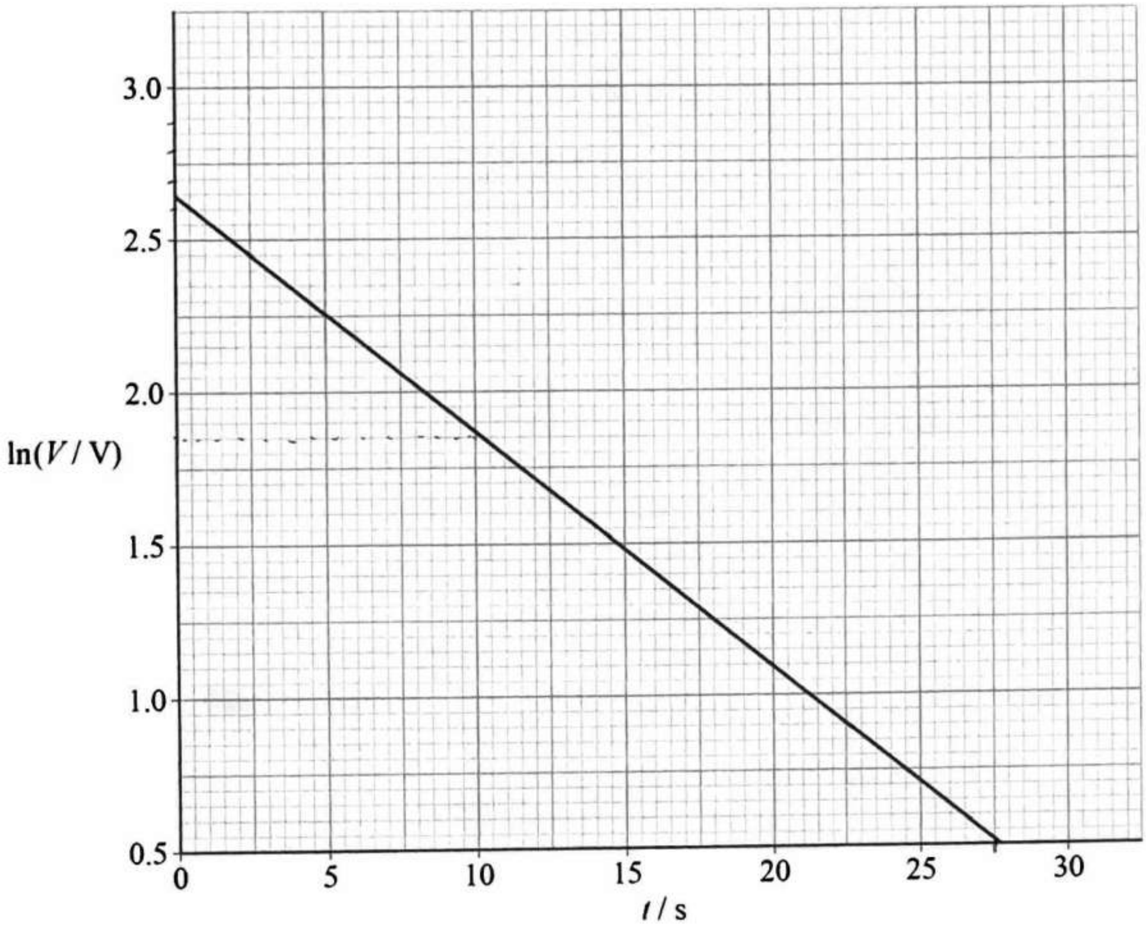
1 V data over a wide range. to test if the relationship changes in different ranges of V.

2 decreasing intervals between lower values of V because timings are shorter for lower Vs and hence less accurate.

Question 3 continues on the next page

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]

$$\text{gradient} = \frac{2.65 - 0.5}{27.5} = 0.0782$$

$$|\text{gradient}| = \left|\frac{-1}{R \times C}\right|$$

$$R = \frac{1}{\text{grad} \times C} = \frac{1}{0.0782 \times 820 \times 10^{-6}}$$

$$= 15.6 \times 10^{3}\ \Omega$$

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

[2 marks]

for $t = 10$ s, $\ln\left(\frac{V_{10}}{V}\right) = 1.85$

$V_{10} = V_0 e^{\frac{-10}{CR}} \Rightarrow V_{10} = 6.37$

$$I = \frac{V}{R} = \frac{6.37}{15.6 \times 10^{3}} = 4.1 \times 10^{-4}\ \text{A}$$

current = 4.1×10^{-4} A

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END OF QUESTIONS