A

Surname ______________________

Other Names ______________________

Centre Number ______________________

Candidate Number ______________________

Candidate Signature ______________________

I declare this is my own work.

A-level

PHYSICS

Paper 3
Section A

7408/3A

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

JUN2174083A01

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 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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write 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.

DO NOT TURN OVER UNTIL TOLD TO DO SO

SECTION A

Answer ALL questions in this section.

0 1

FIGURE 1, on the opposite page, shows apparatus used to investigate the inverse-square law for gamma radiation.

FIGURE 1

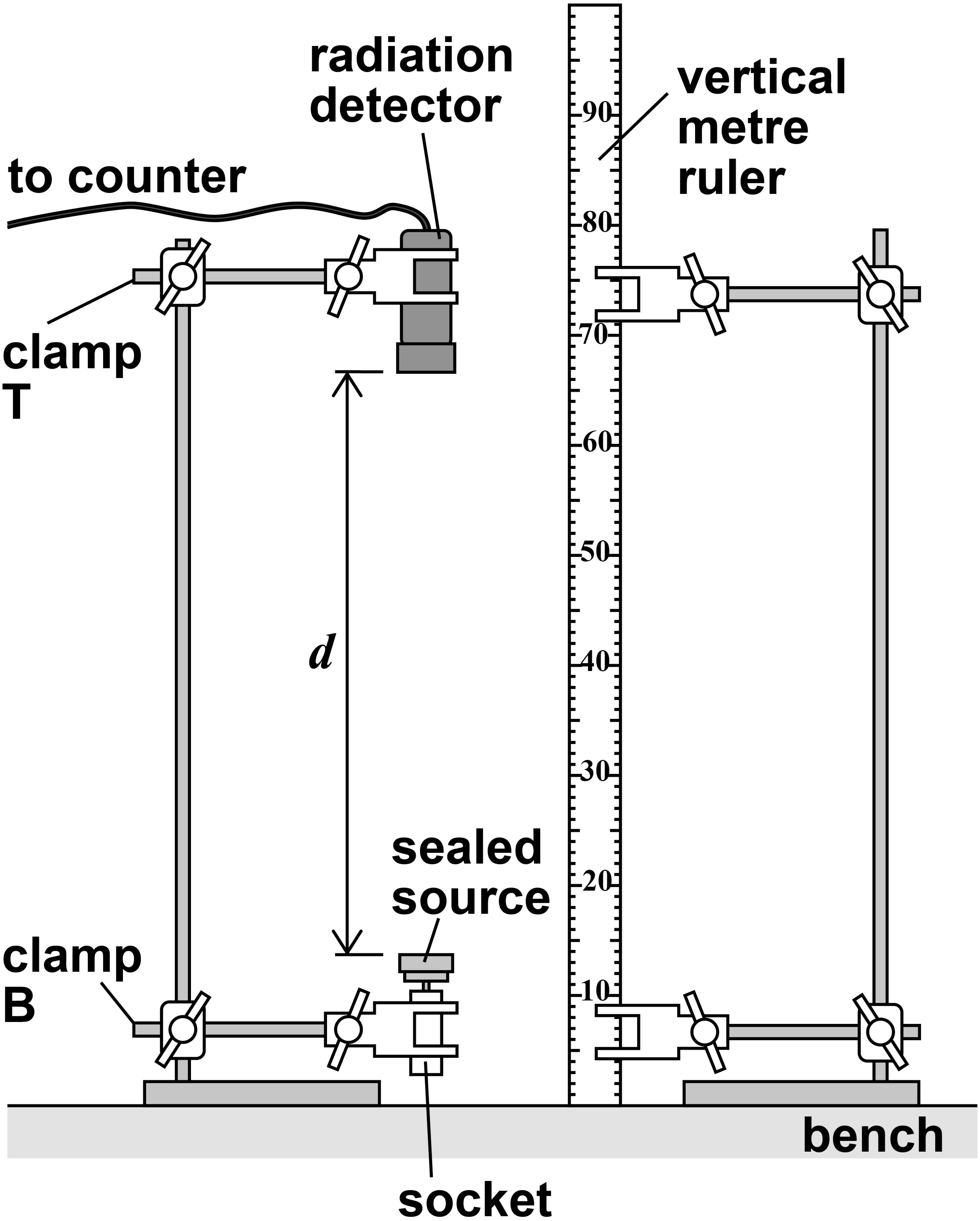
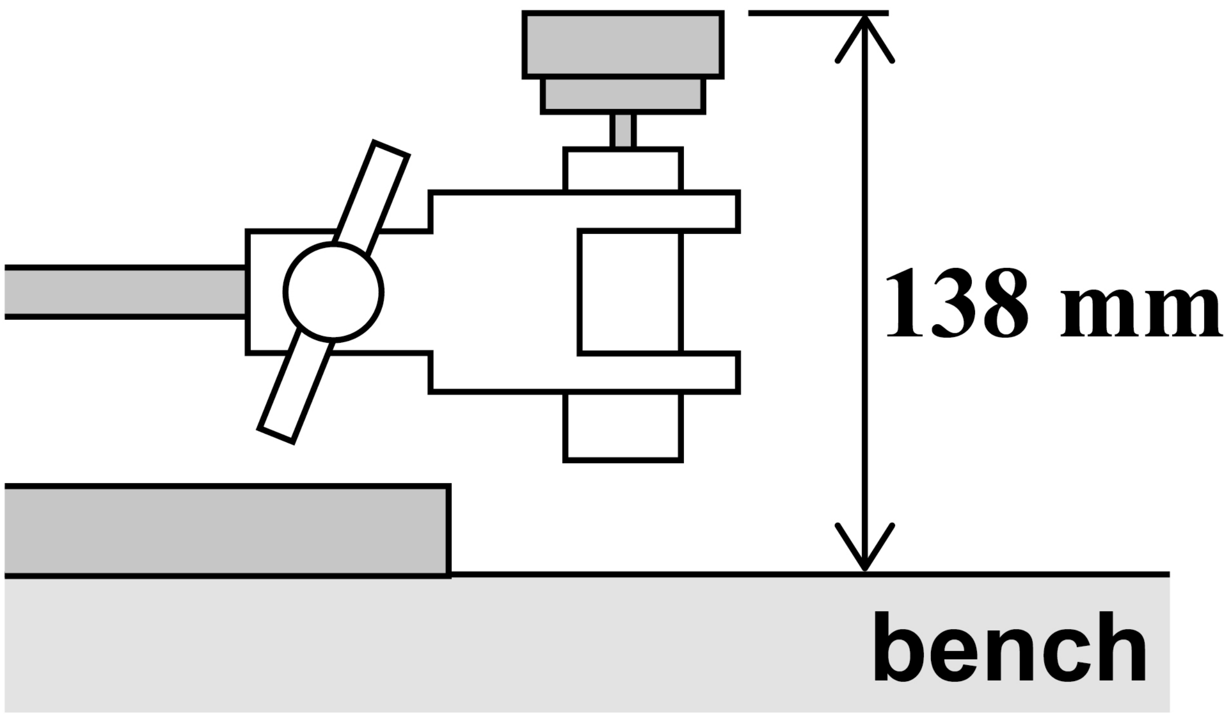


FIGURE 1 continues on page 6.

FIGURE 1 CONTINUED

detail showing source,
socket and clamp B



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, on pages 5 and 6, to show how a set-square can be used in this procedure. [2 marks]

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, on pages 5 and 6, $d = 530$ 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.

In the space on the opposite page, show that when $d = 530$ mm, R_C is about $0.3\ s^{-1}$.

[2 marks]

0 1 . 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]

[Turn over]

0 1 . 4

Describe a safe procedure to reduce d.
Give a reason for your procedure.
[2 marks]

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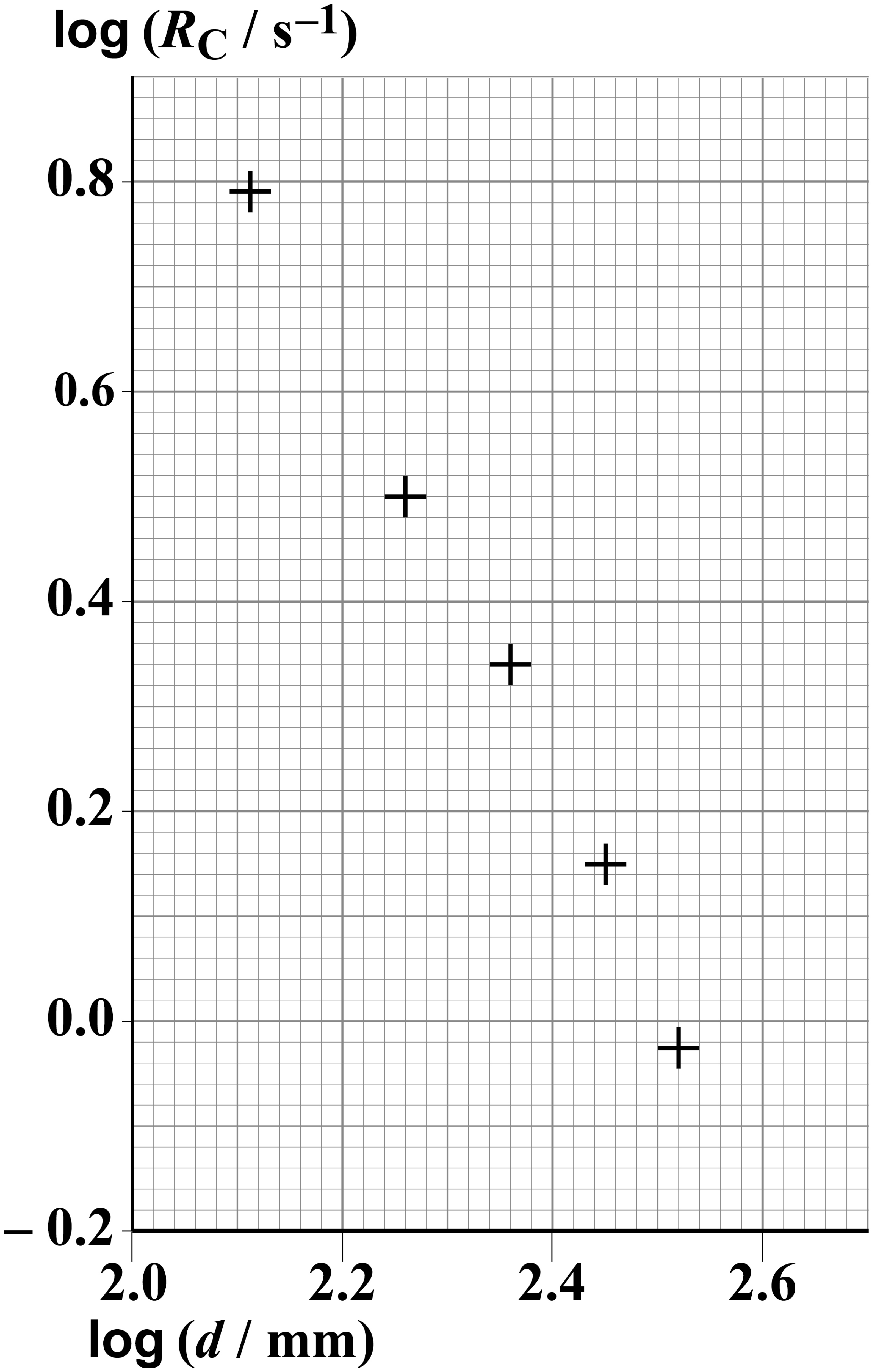
[Turn over]

The student determines R_C for further values of d.

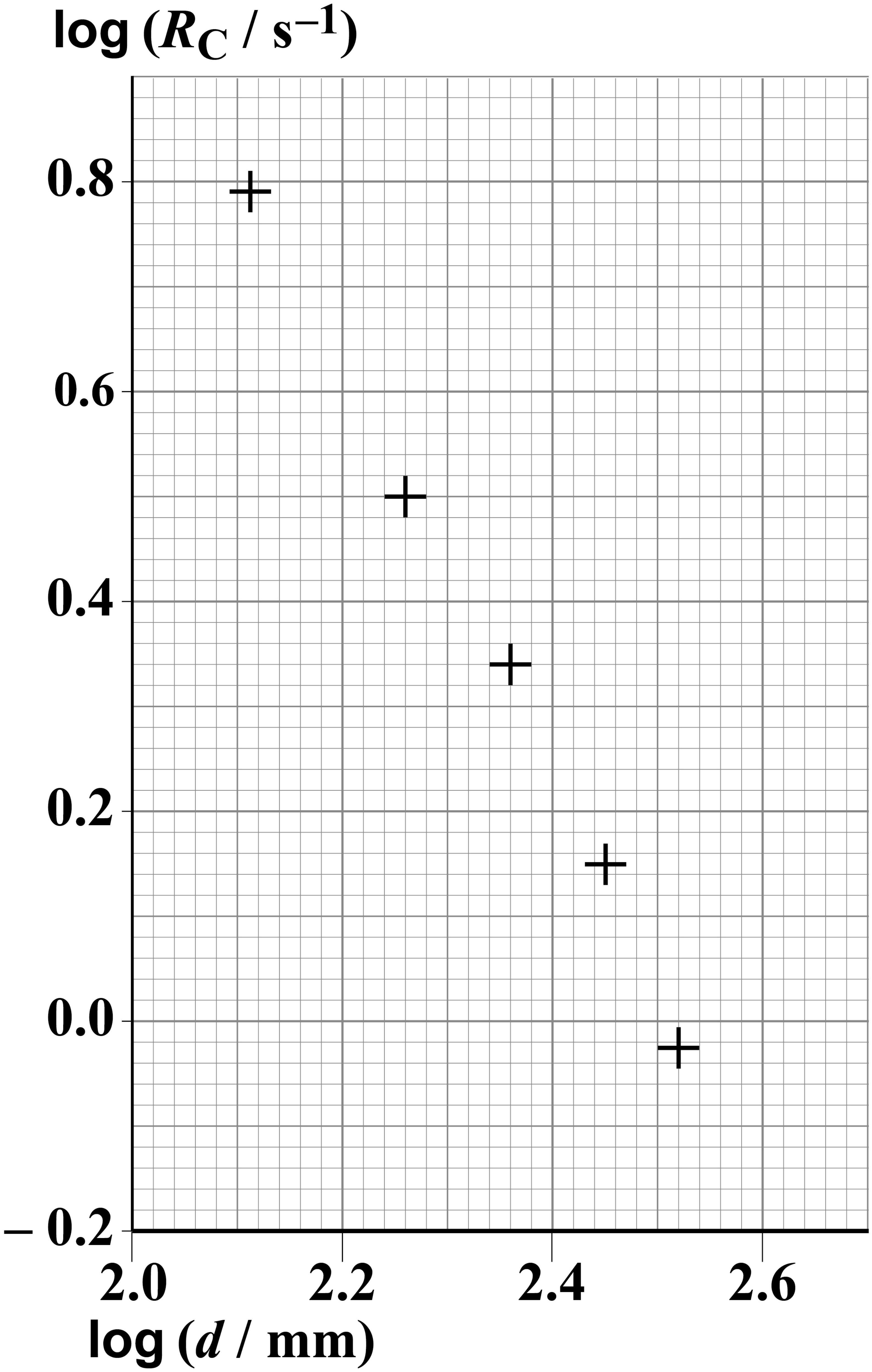
The values of d change by the same amount Δd between each measurement.

FIGURE 2, on the opposite page, shows these data.

FIGURE 2



REPEAT OF FIGURE 2

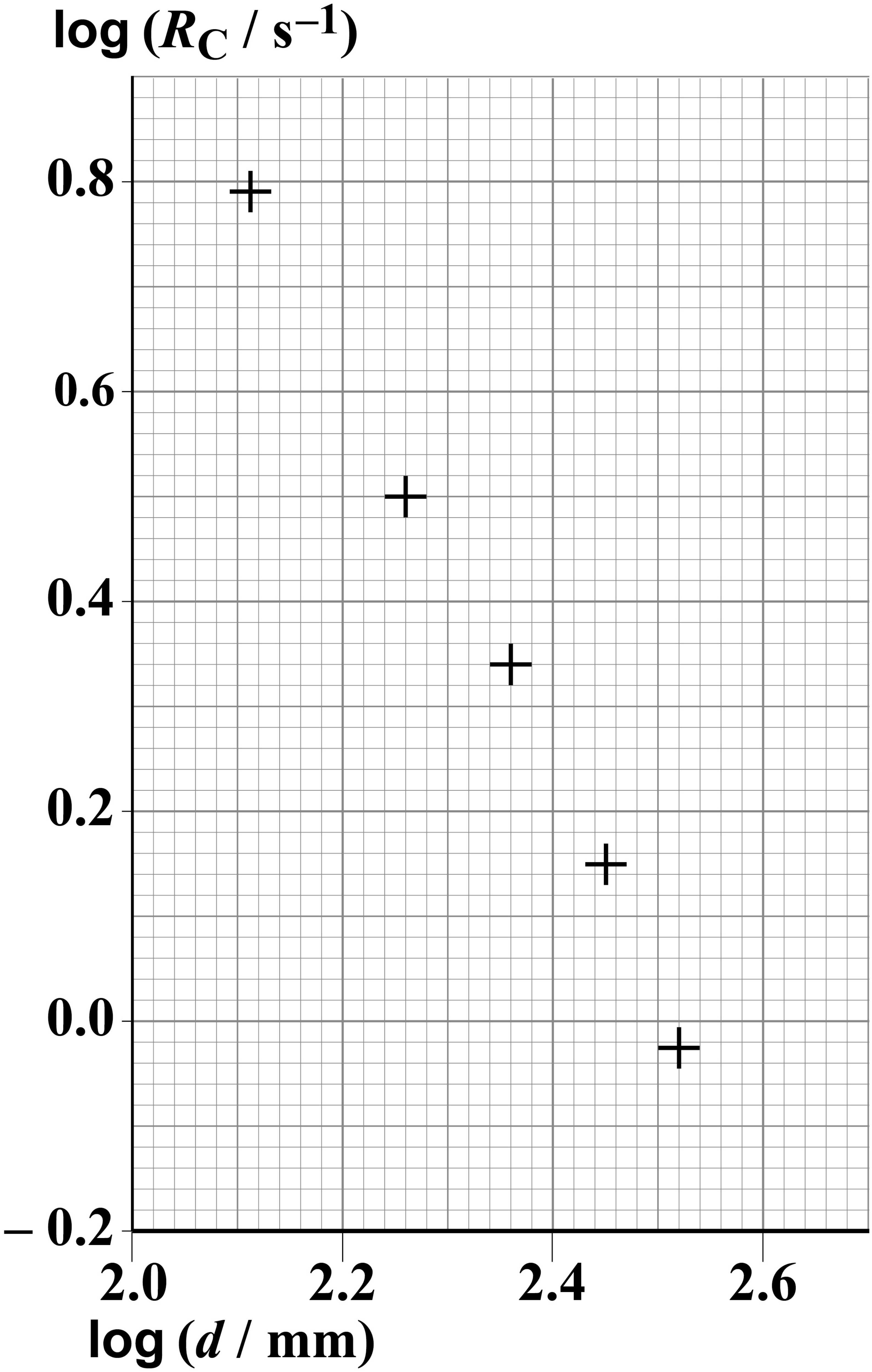


01.5

Determine Δd. [2 marks]

Δd = ______________________________ mm

REPEAT OF FIGURE 2



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]

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 $100\ \mathrm{s}^{-1}$.

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]

0 2

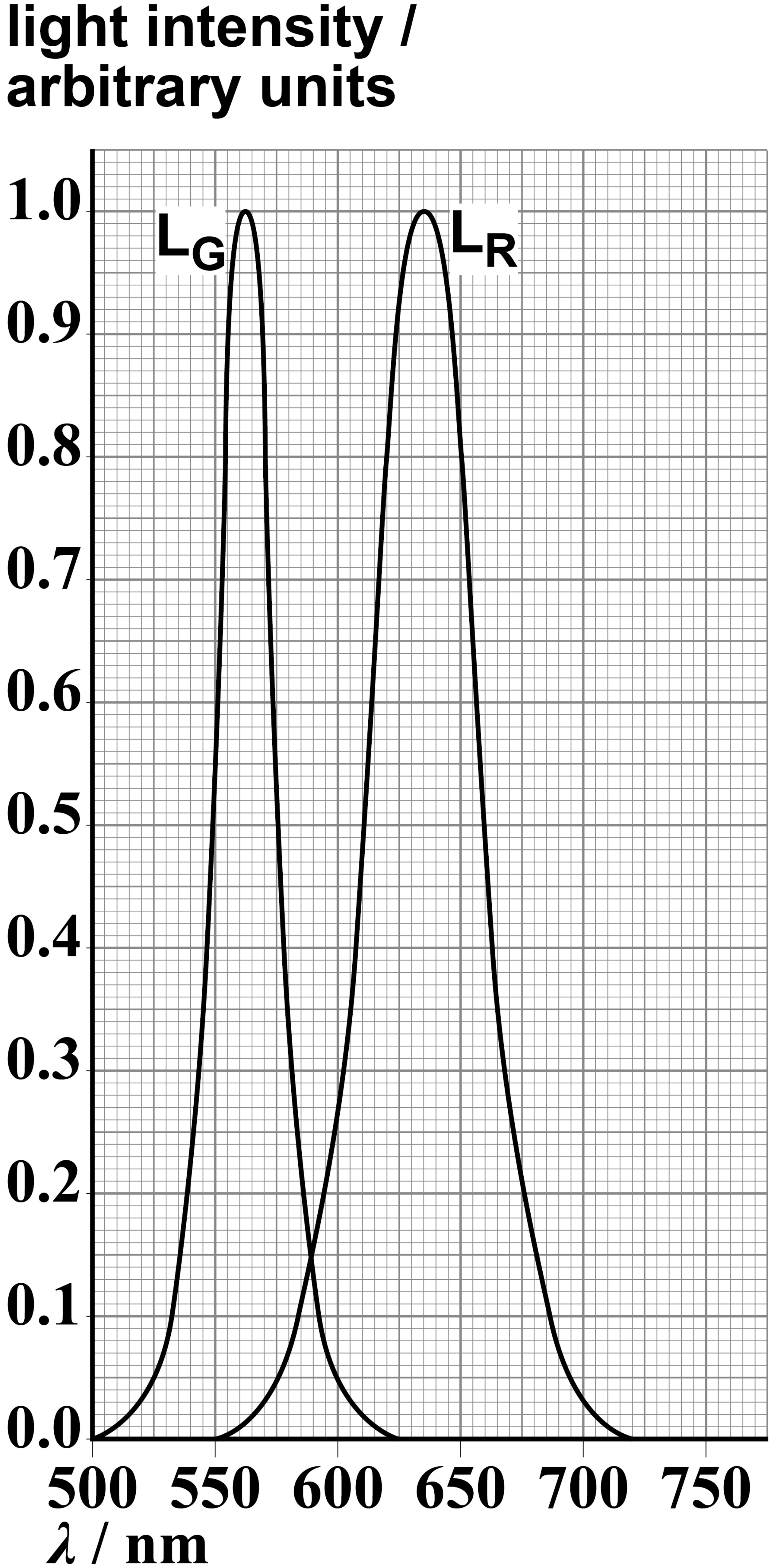
A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_{p}.

Two LEDs 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, on page 24, shows how the light output of the LEDs varies with the wavelength λ.

[Turn over]

FIGURE 3


light intensity /
arbitrary units
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
L_G
L_R
500
550
600
650
700
750
λ / nm

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]

BLANK PAGE

[Turn over]

0 2 . 3

FIGURE 4, on the opposite page, shows part of the current−voltage characteristics for L_R and L_G.

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.

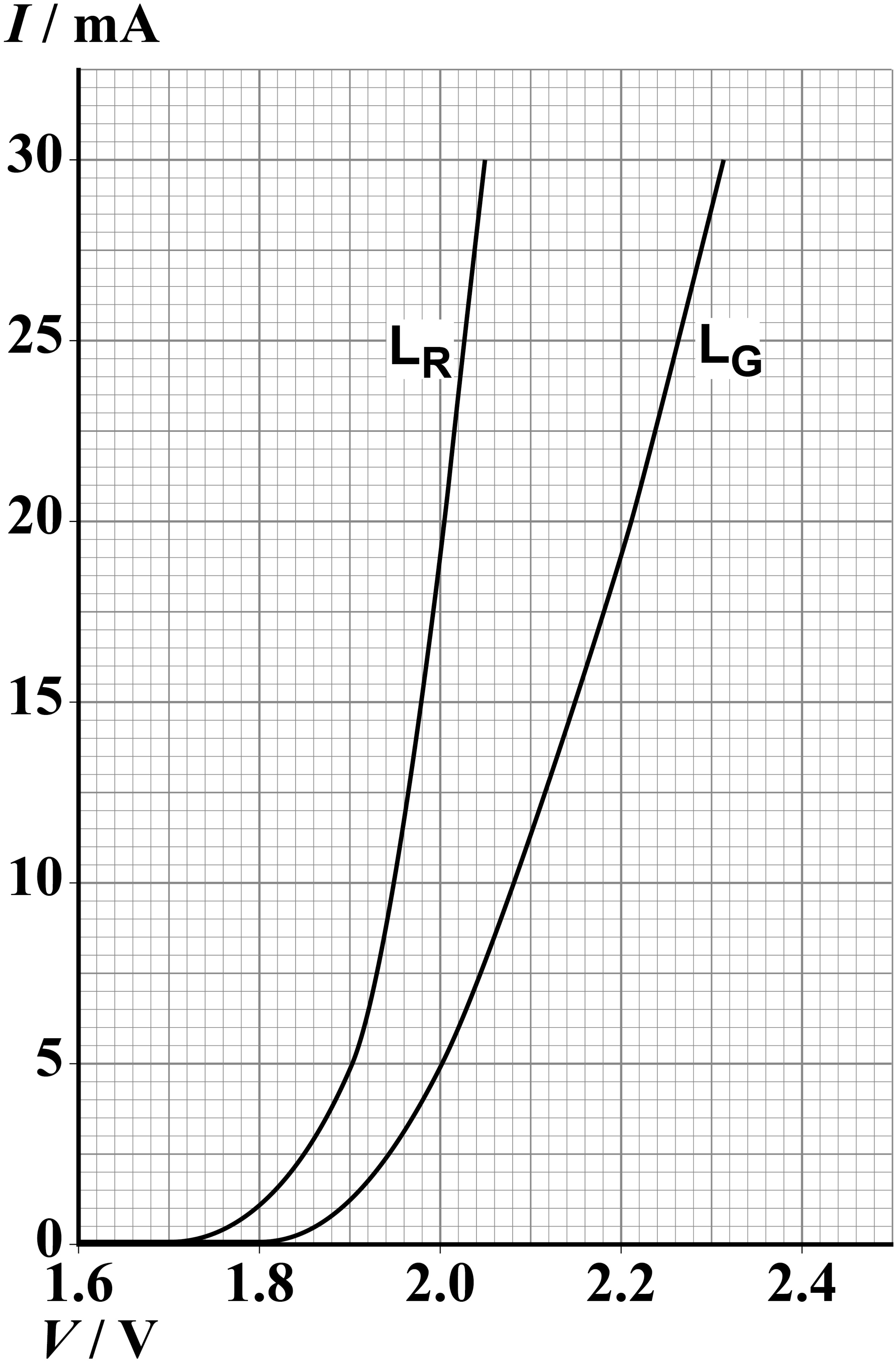
V_A for L_G is 2.00 V.

Determine, using FIGURE 4, V_A for L_R.

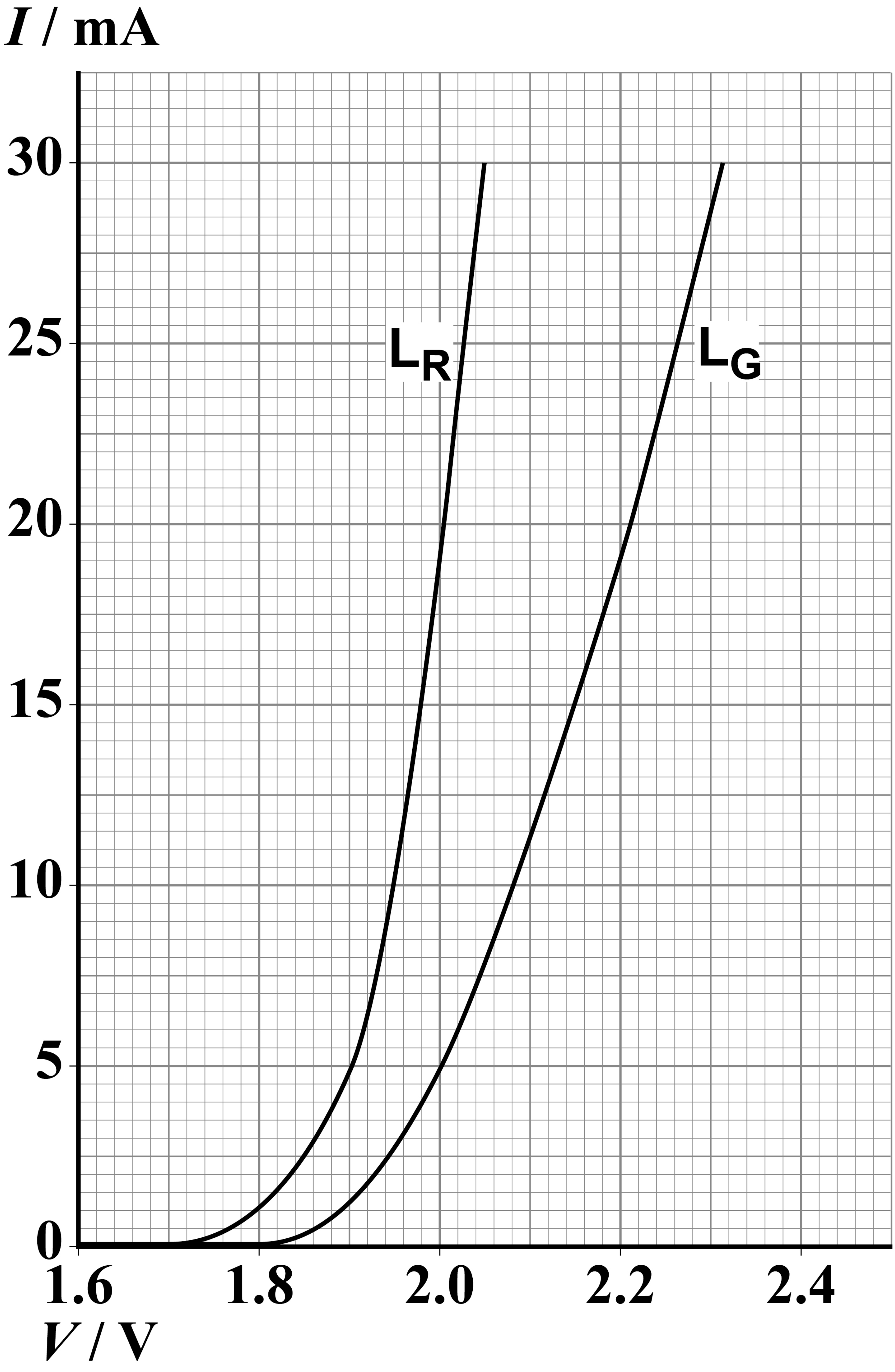
[2 marks]

V_A for L_R = ______________________________ **V**

FIGURE 4



REPEAT OF FIGURE 4



0 2 . 4

It can be shown that:

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

where h = the Planck constant.

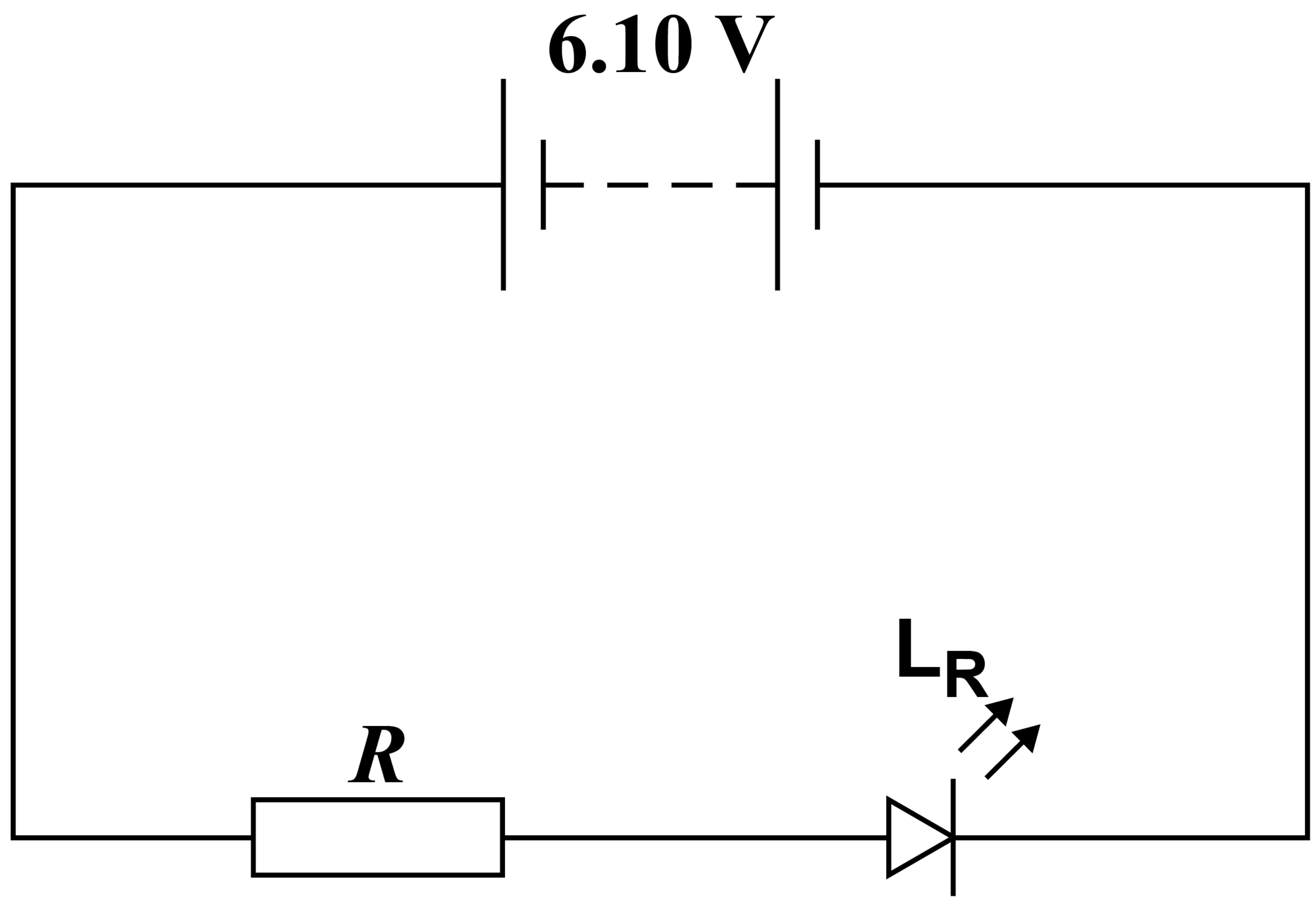
Deduce a value for the Planck constant based on the data given about the LEDs.
[2 marks]

h = ______________________________ J s

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

[Turn over]

10

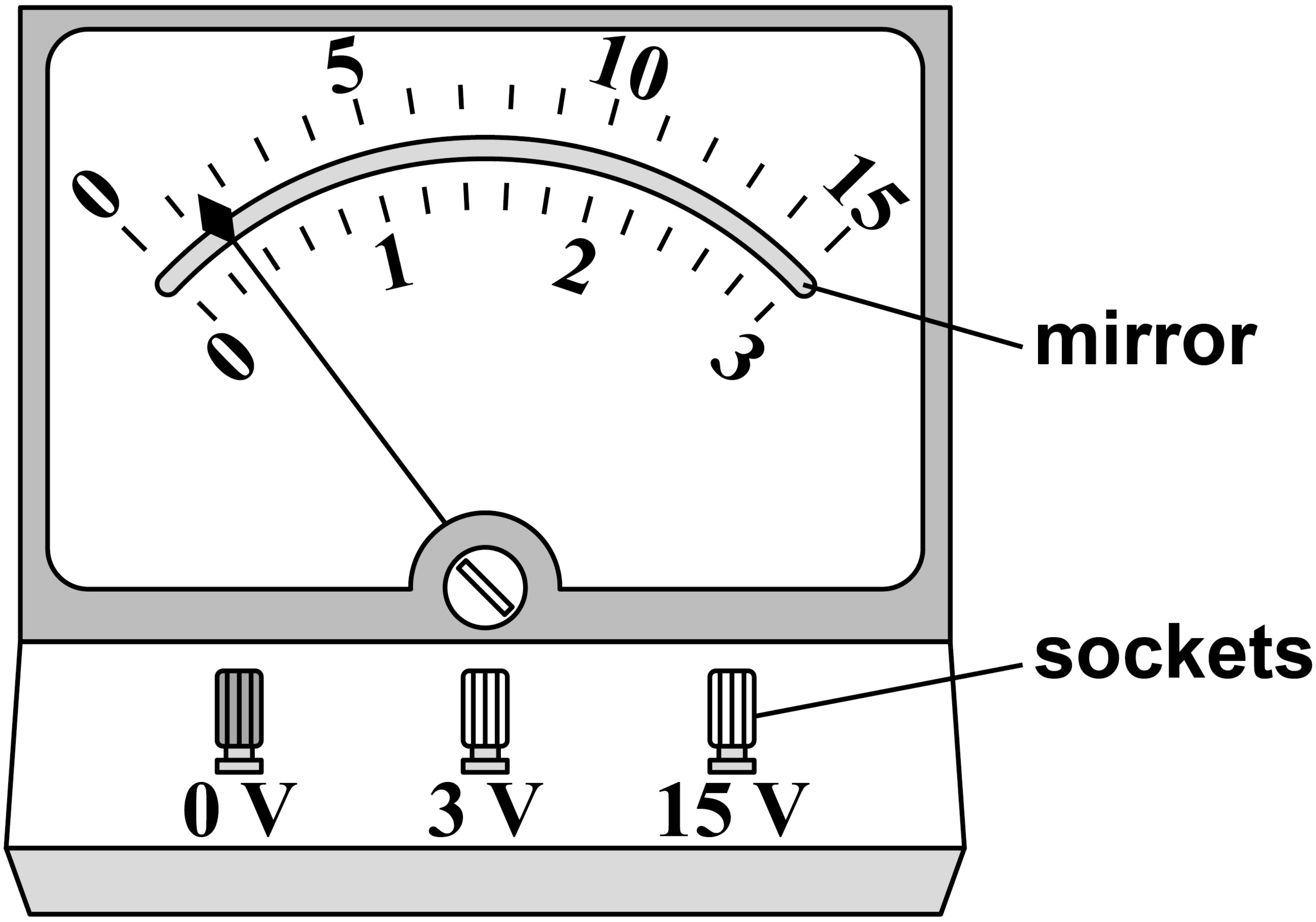
0 3

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



03.1

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

[Turn over]

0 3 . 2

Explain the use of the mirror when reading the meter. [2 marks]

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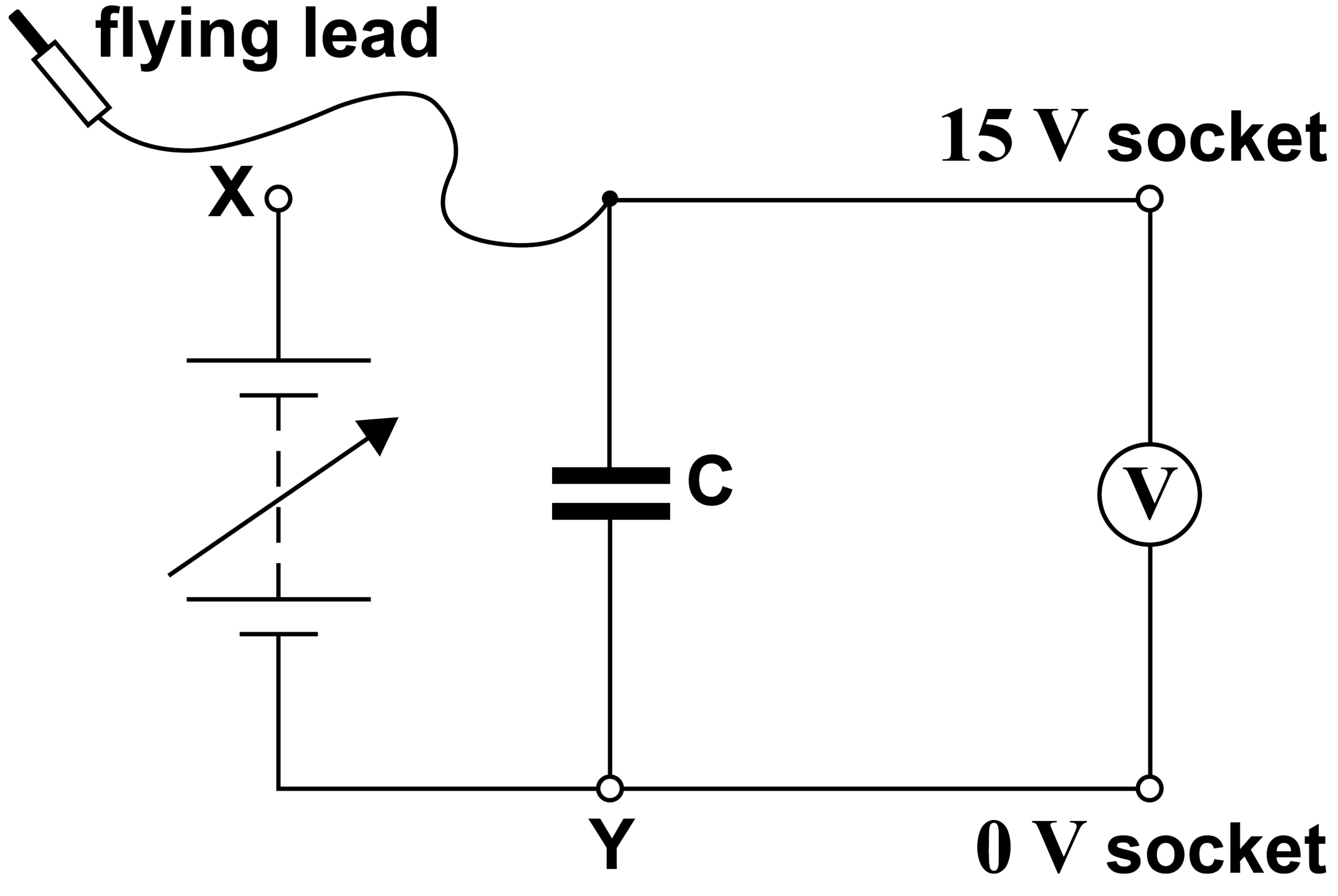
[Turn over]

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 $T_{1/2}$ 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

$T_{1/2}$ / s	12.00	11.94	12.06	12.04	12.16

[Turn over]

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03.3

Determine the percentage uncertainty in $T_{1/2}$. [2 marks]

percentage uncertainty = ______________ %

[Turn over]

0 3 . 4

Show that the time constant for the discharge circuit is about 17 s. [1 mark]

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[Turn over]

0 3 . 5

The student thinks that the time constant of the circuit in FIGURE 7, on page 38, 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]

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[Turn over]

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 ______________________________________

____

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2 ______________________________________

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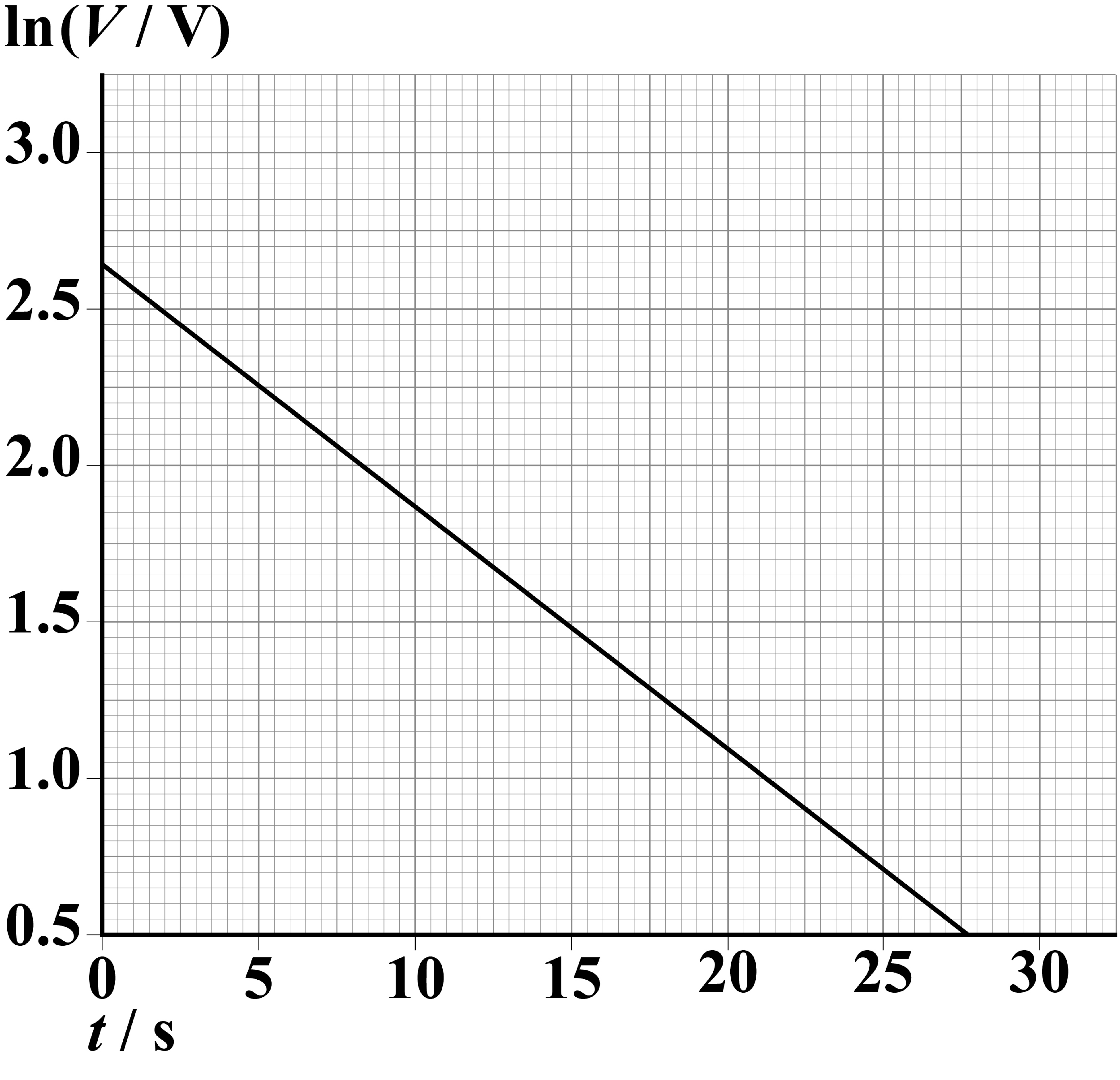
[Turn over]

FIGURE 8 shows a graph of the experimental data.

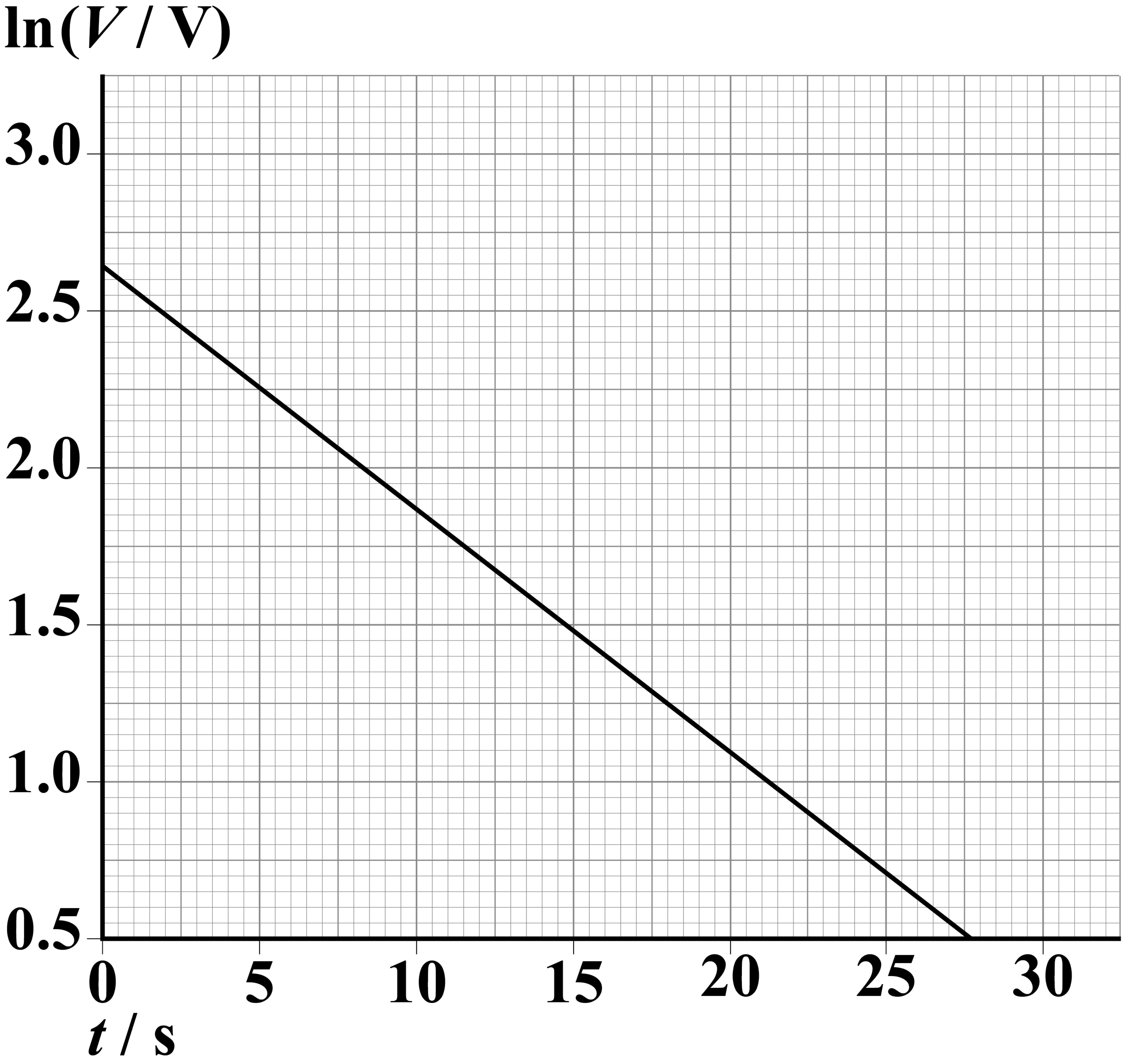
FIGURE 8



0 3 . 7

Show, using FIGURE 8, that the resistance of the voltmeter is about $16\ \mathrm{k\Omega}$. [3 marks]

REPEAT OF FIGURE 8



0 3 . 8

Determine the current in the voltmeter at t = 10 s. [2 marks]

current = ____________________________ A

END OF QUESTIONS

19

Additional page, if required.

Write the question numbers in the left-hand margin.

Additional page, if required.

Write the question numbers in the left-hand margin.

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For Examiner's Use	
Question	Mark
1	
2	
3	
TOTAL	

IB/M/SB/Jun21/7408/3A/E1

2 1 6 A 7 4 0 8 / 3 A