Published

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Question 1 Planning (15 marks)

Defining the problem (2 marks)

P $\lambda$ is the independent variable, or vary $\lambda$. \[1\]

P $V$ is the dependent variable, or measure $V$. \[1\]

Methods of data collection (4 marks)

M Circuit diagram showing d.c. power supply in series with diode (correct symbol needed) and method to measure potential difference across diode. Circuit must be correct. \[1\]

M Instrument to change p.d. across LED e.g. variable power supply/potential divider/variable resistor. \[1\]

M Record wavelength of light of LED from data sheet or use Young’s slits/diffraction grating. \[1\]

M (Slowly) increase potential difference across LED until LED (just) emits light (or reverse procedure). \[1\]

Method of analysis (3 marks)

A Plot a graph of $\lg V$ against $\lg \lambda$ (allow natural logs). Allow $\lg \lambda$ against $\lg V$. \[1\]

A $n = \text{gradient}$ \[1\]

A $k = 10^{\text{intercept}}$ \[1\]

Additional detail (6 marks)

Relevant points might include: \[6\]

1 Use of a protective resistor (can be shown on the diagram).

2 Polarity of LED correct in circuit diagram.

3 Instrument to determine when LED just lights e.g. light meter/detector, LDR.

4 Method to use light detector/LDR to determine point at which LED emits light.

5 Expression that gives $\lambda$ (symbols need to be defined) from experimental determination of wavelength of light, e.g. Young’s slits/diffraction grating.

6 Perform experiment in a dark room/LED in tube.

7 Relationship is valid if graph is a straight line.

8 $\lg V = n \lg \lambda + \lg k$

9 Repeat $V$ and average for the same $\lambda$ or LED.

Do not allow vague computer methods.
### Question 2 Analysis, conclusions and evaluation (15 marks)

<table>
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<tr>
<th>Mark</th>
<th>Expected Answer</th>
<th>Additional Guidance</th>
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<tr>
<td><strong>(a)</strong></td>
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</table>
| A1 | \[
\frac{4LF}{\pi E}
\] | |
| **(b)** | | |
| T1 | \[
\frac{1}{d^2} \times 10^6 \text{ m}^{-2}
\] | |
| T2 |  | All values to 2 s.f. or 3 s.f. Allow a mixture of significant figures. Must be values in table. |
| 13 or 12.8 | |
| 9.8 or 9.77 | |
| 6.9 or 6.93 | |
| 4.7 or 4.73 | |
| 3.2 or 3.19 | |
| 1.9 or 1.93 | |
| **(c) (i)** | | |
| G1 | Six points plotted correctly | Must be within half a small square. Do not allow “blobs”. ECF allowed from table. |
| U1 | From ± 2 to ± 0.1 | Allow more than one significant figure. |
| **(c) (ii)** | | |
| G2 | Line of best fit | If points are plotted correctly then lower end of line should pass between (3.2, 3.0) and (3.6, 3.0) and upper end of line should pass between (11.2, 10.0) and (11.6, 10.0). |
| **(c) (iii)** | | |
| G3 | Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars. | Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Lines must cross. Mark scored only if error bars are plotted. |
| **(d) (i)** | | |
| C2 | \[
\frac{4LF}{\pi \times \text{gradient}} = 60.479 \text{ gradient}
\] | Do not penalise POT. (Should be about \(7 \times 10^{10}\).) |
| C3 | \(N \text{ m}^{-2}\) or \(\text{Pa}\) | Allow in base units: \(\text{kg m}^{-1} \text{s}^{-2}\). |
| **(d) (ii)** | | |
| U4 | Percentage uncertainty in \(E\) | Must be larger than 3%. |

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Uncertainties in Question 2

(c) (iii) Gradient [U3]

uncertainty = gradient of line of best fit – gradient of worst acceptable line

uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

percentage uncertainty = $\frac{\Delta \text{gradient} + 0.01 \times 0.01 + 0.5 \times 0.02}{2.50 \times 19.0} \times 100 = \left(\frac{\Delta \text{gradient}}{\text{gradient}}\right) \times 100 + 3.03\%$

$max E = \frac{4 \times \text{max} L \times \text{max} F}{\pi \times \text{min gradient}} = \frac{4 \times 2.51 \times 19.5}{\pi \times \text{min gradient}} = \frac{62.319}{\text{min gradient}}$

$min E = \frac{4 \times \text{min} L \times \text{min} F}{\pi \times \text{max gradient}} = \frac{4 \times 2.49 \times 18.5}{\pi \times \text{max gradient}} = \frac{58.652}{\text{max gradient}}$

(e) [U5]

percentage uncertainty = $\left(\frac{0.5}{19.0} + \frac{0.01}{2.50} + 2 \times \left(\frac{0.02}{0.23}\right)\right) \times 100 + %E = 20.4\% + %E$

percentage uncertainty = $\left(\frac{\Delta \text{gradient}}{\text{gradient}} + 2 \times \left(\frac{0.02}{0.23}\right)\right) \times 100$

$max e = \frac{\text{max gradient}}{d_{\text{min}}^2}$

$max e = \frac{4 \times L_{\text{max}} \times F_{\text{max}}}{\pi \times E_{\text{min}} \times d_{\text{min}}^2}$

$min e = \frac{\text{min gradient}}{d_{\text{max}}^2}$

$min e = \frac{4 \times L_{\text{min}} \times F_{\text{min}}}{\pi \times E_{\text{max}} \times d_{\text{max}}^2}$