Published

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Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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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 $k = 10^{y\text{-intercept}}$ [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 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>
<thead>
<tr>
<th>Mark</th>
<th>Expected Answer</th>
<th>Additional Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>A1 $\frac{4LF}{\pi E}$</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>T1 $\frac{1}{d^2} / 10^8 \text{ m}^2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T2 13 or 12.8</td>
<td>All values to 2 s.f. or 3 s.f. Allow a mixture of significant figures. Must be values in table.</td>
</tr>
<tr>
<td></td>
<td>9.8 or 9.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.9 or 6.93</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7 or 4.73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.2 or 3.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.9 or 1.93</td>
<td></td>
</tr>
<tr>
<td>U1</td>
<td>From $\pm 2$ to $\pm 0.1$</td>
<td>Allow more than one significant figure.</td>
</tr>
<tr>
<td>(c)</td>
<td>(i) G1 Six points plotted correctly</td>
<td>Must be within half a small square. Do not allow “blobs”. ECF allowed from table.</td>
</tr>
<tr>
<td></td>
<td>U2 Error bars in $\frac{1}{d^2}$ plotted correctly</td>
<td>All error bars to be plotted. Must be accurate to less than half a small square.</td>
</tr>
<tr>
<td></td>
<td>(ii) G2 Line of best fit</td>
<td>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).</td>
</tr>
<tr>
<td></td>
<td>G3 Worst acceptable straight line. Steepest or shallowest possible line that passes through all the error bars.</td>
<td>Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Lines must cross. Mark scored only if error bars are plotted.</td>
</tr>
<tr>
<td></td>
<td>(iii) C1 Gradient of line of best fit</td>
<td>The triangle used should be at least half the length of the drawn line. Check the read-offs. Work to half a small square. Do not penalise POT. (Should be about $9 \times 10^{-10}$.)</td>
</tr>
<tr>
<td></td>
<td>U3 Absolute uncertainty in gradient</td>
<td>Method of determining absolute uncertainty Difference in worst gradient and gradient.</td>
</tr>
<tr>
<td>(d)</td>
<td>(i) C2 $\frac{4LF}{\pi \times \text{gradient}} = 60.479$</td>
<td>Do not penalise POT. (Should be about $7 \times 10^{10}$.)</td>
</tr>
<tr>
<td></td>
<td>C3 N m$^{-2}$ or Pa</td>
<td>Allow in base units: kg m$^{-1}$ s$^{-2}$.</td>
</tr>
<tr>
<td></td>
<td>(ii) U4 Percentage uncertainty in $E$</td>
<td>Must be larger than 3%.</td>
</tr>
</tbody>
</table>
(e) C4

\[ e \text{ in the range } 15.5 \times 10^{-3} \text{ to } 18.0 \times 10^{-3} \text{ and given to 2 or 3 s.f.} \]

Allow mm.

U5

Absolute uncertainty in \( e \)

Note \( e = \frac{\text{gradient}}{d^2} \) is possible.

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]

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

\[
\text{max } E = \frac{4 \times \max L \times \max F}{\pi \times \min \text{ gradient}} = \frac{4 \times 2.51 \times 19.5}{\pi \times 2.50} = \frac{62.319}{\min \text{ gradient}}
\]

\[
\text{min } E = \frac{4 \times \min L \times \min F}{\pi \times \max \text{ gradient}} = \frac{4 \times 2.49 \times 18.5}{\pi \times 19.0} = \frac{58.652}{\max \text{ gradient}}
\]

(e) [U5]

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

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

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

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

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

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

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