This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners’ meeting before marking began, which would have considered the acceptability of alternative answers.

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

Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the May/June 2016 series for most Cambridge IGCSE®, Cambridge International A and AS Level components and some Cambridge O Level components.
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 $\log V$ against $\log \lambda$ (allow natural logs). Allow $\log \lambda$ against $\log V$. [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 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 $\log V = n \log \lambda + \log k$

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\varepsilon} )</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>T1 ( \frac{1}{d^2} \times 10^6 \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></td>
<td>U1 From ±2 to ±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 ( \text{N m}^{-2} ) or Pa</td>
<td>Allow in base units: ( \text{kg m}^{-1} \text{s}^{-2} ).</td>
</tr>
<tr>
<td></td>
<td>(ii) U4 Percentage uncertainty in ( \varepsilon )</td>
<td>Must be larger than 3%.</td>
</tr>
</tbody>
</table>
Uncertainties in Question 2

(c) (iii) Gradient [U3]

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

uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

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

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

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

(e) [U5]

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

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

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

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

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

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