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 $\theta$ is the independent variable and $a$ is the dependent variable, or vary $\theta$ and measure $a$. [1]

P Keep $F$ constant. [1]

Methods of data collection (4 marks)

M Diagram showing inclined plane with labelled support (not if a ruler used as the inclined plane or as vertical support). [1]

M Method to measure angle e.g. use a protractor to measure $\theta$ or use a ruler to measure marked distances from which $\sin \theta$ or $\theta$ may be determined. (Allow a labelled protractor in the correct position.) [1]

M Method to measure a time or velocity to determine $a$, e.g. measure the time using a stopwatch, light gate(s) connected to a timer, motion sensor connected to a time display. [1]

M Use a balance to measure the mass of the trolley. [1]

Method of analysis (3 marks)

A Plot a graph of $a$ against $\sin \theta$. or Plot a graph of $ma$ against $\sin \theta$. or Plot a graph of $ma$ against $mg \sin \theta$. [1]

A Relationship is valid if the graph is a straight line and does not pass through the origin [1]

A $k = F - m \times (y$-intercept) or $k = F - (y$-intercept) or $k = F - (y$-intercept) [1]

Do not allow $\lg$-$\lg$ graphs.

Additional detail (6 marks)

Relevant points might include: [6]

1 Keep mass of trolley constant/use same trolley.

2 Correct trigonometry relationship to determine $\sin \theta$ or $\theta$ using marked lengths.

3 Use ruler to measure appropriate distance to determine $a$, e.g. length of slope, length of card for light gate method, position of motion sensor.

4 Equation to determine $a$ from measurements taken appropriately with $a$ as the subject.

5 Measurement of $F$ for a valid method e.g. take reading from newton-meter or from stretched elastic/spring from extension (allow falling weight e.g. $F = mg$).

6 Use a constant extension to produce a constant force when using stretched spring/elastic.
7 Method to ensure the inclined plane is the same height each side of the plane or spirit level across plane or ensure force $F$ (or string) is parallel to the plane.

8 Safety precaution linked to falling mass/trolley or spring/elastic breaking (not string).

9 Rearrangement of relationship into $y = mx + c$ e.g. $ma = -mg \sin \theta + (F - k)$ or $a = -g \sin \theta + \frac{F - k}{m}$ or correct $y$-intercept (subject must be $y$-axis).

10 Repeat experiment for each angle $\theta$ to find average for $a$.

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{4 \rho L}{\pi} )</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>T1 ( \frac{1}{d^2} / 10^6 \text{ m}^{-2} )</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>T2 1.2 or 1.21</td>
<td>All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.</td>
</tr>
<tr>
<td></td>
<td>3.2 or 3.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7 or 4.73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.9 or 6.93</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.8 or 9.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 or 13.7</td>
<td></td>
</tr>
<tr>
<td>U1</td>
<td>From ± 0.03 to ± 1</td>
<td>Allow more than one significant figure. Allow zero for first uncertainty and up to 1.2 for largest uncertainty.</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. Length of bar must be accurate to less than half a small square and symmetrical.</td>
</tr>
<tr>
<td>(ii)</td>
<td>G2 Line of best fit</td>
<td>Lower end of line must pass between (2.6, 4.0) and (3.0, 4.0) and upper end of line must pass between (12.4, 18.0) and (13.0, 18.0).</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. Must be steepest/shallowest line. Mark scored only if error bars are plotted.</td>
</tr>
<tr>
<td>(iii)</td>
<td>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 ( 1.4 -1.5 \times 10^{-6} )).</td>
</tr>
<tr>
<td>U3</td>
<td>Absolute uncertainty in gradient</td>
<td>Method of determining absolute uncertainty: difference in worst gradient and gradient.</td>
</tr>
<tr>
<td>Mark</td>
<td>Expected Answer</td>
<td>Additional Guidance</td>
</tr>
<tr>
<td>------</td>
<td>-----------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>(d) (i) C2</td>
<td>$\frac{\pi \times \text{gradient}}{4L} = 0.7854 \times \text{gradient}$</td>
<td>Must use gradient value. Do not penalise POT (Should be about $1 \times 10^{-6}$.)</td>
</tr>
<tr>
<td>C3</td>
<td>$\Omega m$</td>
<td>Correct unit and correct power of ten.</td>
</tr>
<tr>
<td>(ii) U4</td>
<td>Percentage uncertainty in $\rho$</td>
<td>Percentage uncertainty in gradient + 1%.</td>
</tr>
<tr>
<td>(e) C4</td>
<td>$R$ in the range 25.5 to 28.4 and given to 2 or 3 s.f.</td>
<td>Allow 26 or 27 or 28. Allow ECF for POT error in (d)(i) e.g. $2.7 \times 10^7$.</td>
</tr>
<tr>
<td>U5</td>
<td>Absolute uncertainty in $R$</td>
<td>Percentage uncertainty must be greater than 8.6%.</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 = \( \frac{1}{2} \) (steepest worst line gradient – shallowest worst line gradient)

(d) (ii) [U4]

\[
\text{percentage uncertainty} = \left( \frac{\Delta \text{gradient}}{\text{gradient}} + \left( \frac{0.01}{1.00} \right) \right) \times 100 = \left( \frac{\Delta \text{gradient}}{\text{gradient}} \right) \times 100 + 1\%
\]

\[
\max \rho = \frac{\pi \times \max \text{gradient}}{4 \times \min L} = \frac{\pi \times \max \text{gradient}}{4 \times 0.99}
\]

\[
\min \rho = \frac{\pi \times \min \text{gradient}}{4 \times \max L} = \frac{\pi \times \min \text{gradient}}{4 \times 1.01}
\]

(e) [U5]

\[
\text{percentage uncertainty} = \left( \frac{\Delta \rho}{\rho} + 2 \times \left( \frac{0.01}{0.23} \right) \right) \times 100 = \left( \frac{\Delta \rho}{\rho} + 0.086 \right) \times 100
\]

\[
\text{percentage uncertainty} = \left( \frac{\Delta \rho}{\rho} + 0.01 \times \frac{2}{0.23} \times 0.01 \right) \times 100 = \left( \frac{\Delta \rho}{\rho} + 0.096 \right) \times 100
\]

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

\[
\max R = \frac{4 \times L_{\max} \times \rho_{\max}}{\pi \times d_{\min}^2}
\]

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

\[
\min R = \frac{4 \times L_{\min} \times \rho_{\min}}{\pi \times d_{\max}^2}
\]