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1 Planning (15 marks)

Defining the problem (3 marks)

P V is the independent variable, or vary V and f is the dependent variable, or measure f.
Or f is the independent variable, or vary f and V is the dependent variable, or measure V. [1]

P Change f (allow V) until the mass leaves/gap between plate. [1]

P Keep the position of the mass constant. (Do not allow keep mass constant.) [1]

Methods of data collection (5 marks)

M Labelled diagram showing signal generator/a.c. supply connected to vibrator with two wires with mass on plate. At least two labels needed. [1]

M Voltmeter/c.r.o. connected in parallel with vibrator in a workable circuit. [1]

M Measure f or T from signal generator/c.r.o. (Allow detailed use of motion sensor/stroboscope.) [1]

M Detail regarding mass leaving the plate: listen to noise, look for gap. [1]

M Repeat each experiment for the same value of V (allow f if consistent with above) and average. [1]

Method of analysis (2 marks)

Plot a graph of:

A $f^2$ against $1/V$

A $1/V$ against $f^2$

A $f$ against $1/\sqrt{V}$

A $1/\sqrt{V}$ against $f$

A $\lg V$ against $\lg f$

A $\lg f$ against $\lg V$

or or or or

A $V$ against $1/f^2$

A $1/f^2$ against $V$

A $\sqrt{V}$ against $1/f$

A $1/f$ against $\sqrt{V}$

[1]

A $k = \pi^2 \frac{\text{gradient}}{\text{gradient}^2 \times \pi^2}$

A $k = \pi \frac{\text{gradient}}{\text{gradient}^2 \times \pi}$

A $k = \frac{\pi^2}{\text{gradient}^2}$

A $k = \pi^2 \times 10^{-c}$

A $k = \pi^2 \times 10^{2c}$ [1]

Safety considerations (1 mark)

S Precaution linked to mass leaving vibrating plate, e.g. use safety screen/goggles/sand tray. [1]
Additional detail (4 marks)

D Relevant points might include
1 Wait for vibrator to oscillate evenly
2 Method to determine period of oscillation from c.r.o., i.e. one time period $\times$ time-base
3 Method to determine $f$ from c.r.o. having determined $T$, i.e. $f = 1 / T$
4 Method to determine $V$ from c.r.o, i.e. amplitude (height) $\times$ y-gain
5 Relationship is valid if the graph is a straight line passing through the origin
   [For lg – lg graph the gradient must be correct (–2 or –0.5)]
6 Determine $f$ (allow $V$ if consistent with above) by increasing and decreasing $V$ or $f$
7 Clean surfaces of metal plate/small mass
8 Spirit level to keep plate horizontal/eye level to look for gap

Do not allow vague computer methods.
## 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><strong>(a)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| A1 | gradient = \( m \)  
y-intercept = \( \log k \) | |
| **(b)** | | Allow a mixture of significant figures. T1 (first column) and T2 (second column) must be values in table. |
| T1 | T2 | |
| 1.70 or 1.699 | 1.312 or 1.3118 |
| 1.79 or 1.785 | 1.204 or 1.2041 |
| 1.85 or 1.851 | 1.114 or 1.1139 |
| 1.90 or 1.903 | 1.041 or 1.0414 |
| 1.95 or 1.954 | 0.98 or 0.978 |
| 2.00 or 1.996 | 0.90 or 0.903 |
| **U1** | From ±0.01 to ±0.03 | Allow more than one significant figure. |
| **(c) (i)** | | |
| G1 | Six points plotted correctly | Must be within half a small square. Do not allow “blobs”. \( P \) allowed from table. |
| **U2** | Error bars in \( \log P \) plotted correctly | All error bars to be plotted. Must be accurate to less than half a small square. |
| **(ii)** | | |
| G2 | Line of best fit | Upper end of line must pass between (1.75, 1.24) and (1.75, 1.255) and lower end of line must pass between (2.00, 0.900) and (2.00, 0.915). |
| 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. |
| **(iii)** | | |
| C1 | Gradient of line of best fit | Must be negative. 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 \(-1.35\).) |
| **U3** | Uncertainty in gradient | Method of determining absolute uncertainty: difference in worst gradient and gradient. |
| **(iv)** | | |
| C2 | \( y \)-intercept | Check substitution into \( y = mx + c \). Allow ecf from \((c)(iii)\). (Should be about 4.) Do not allow read-off of false origin. |
U4 Uncertainty in \( y \)-intercept

Uses worst gradient and point on worst acceptable line. Do not check calculation. Do not allow if false origin used.

(d) (i) C3 \( k = 10^{y \text{-intercept}} \)

C4 \( m = \text{gradient and given to 2 or 3 s.f. and in the range } -1.30 \text{ to } -1.44 \) Must be negative. Allow \(-1.3 \text{ or } -1.4 \) (2 s.f.)

(ii) U5 Percentage uncertainty in \( k \)

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)

(iv) [U4]

uncertainty = \( y \)-intercept of line of best fit – \( y \)-intercept of worst acceptable line

uncertainty = \( \frac{1}{2} \) (steepest worst line \( y \)-intercept – shallowest worst line \( y \)-intercept)

(d) (ii) [U5]

\[ \max k = 10^{\max y \text{-intercept}} \text{ and } \min k = 10^{\min y \text{-intercept}} \]

\[
\text{percentage uncertainty} = \frac{\max k - k}{k} \times 100 = \frac{\min k - k}{k} \times 100 = \frac{1}{2} \left( \frac{\max k - \min k}{k} \right) \times 100
\]