# Mark Scheme for Practical

| Qn | Marking Point | Marks |
|---|---|---|
| 1(a)(i) | Raw $L$ to the nearest 0.1 cm **and** final value in the range 11.5–12.5 cm. | 1 |
| 1(a)(ii) | Percentage uncertainty based on an absolute uncertainty $\Delta L$ in the range 2–5 mm.<br>If repeat readings have been taken, then the absolute uncertainty can be half the range (but not zero) if the working is clearly shown.<br>Correct method of calculation to obtain percentage uncertainty. | 1 |
| 1(b)(i) | All **raw times** measured either to the nearest 0.1 s or all to the nearest 0.01 s.<br>Evidence of measurement of $nT$ repeated where $nT \geqslant 10.0$ s.<br>Value of $T$ in the range 0.5 s $\leqslant T \leqslant$ 1.0 s. | 1<br>1<br>1 |
| 1(b)(ii) | Calculation of $T^2$ correct. | 1 |
| 1(b)(iii) | Justification of the number of significant figures in terms of the number of s.f. in **(raw) time** only. | 1 |
| 1(c)(i) | Raw $L$ to the nearest 0.1 cm **and** final value in the range 5.5–6.5 cm. | 1 |
| 1(c)(ii) | Second value of $T$ < first value of $T$. | 1 |
| 1(d)(i) | Calculated correctly two values of $k$ with unit and recorded to the least no. of sf among $T$ and $L$. The final $k$ values must not be fractions.<br>Unit: $cm^{0.5}\,s^{-1}$ or equivalent | 1<br>1 |
| 1(d)(ii) | Justification of Relationship<br>**Note: The given relation is valid for a compound pendulum.**<br>• Calculated correctly **%*k*uncertainty** = $\frac{\Delta k}{k_{ave}}$ x 100% **OR** **%*k*uncertainty** = $\frac{\Delta k}{k_{smaller}}$ x 100%<br>• $\Delta k = \lvert k_1 - k_2 \rvert$ **OR** $\Delta k = \lvert k_1 - k_2 \rvert / 2$<br>• Chose a criterion from the value in **(a)(ii)**.<br>• Concluded that **results do not support the suggestion** if **%*k*uncertainty** > the criterion chosen.<br>OR<br>Concluded **results support the suggestion** if **%*k*uncertainty** $\leq$ the criterion chosen. **(Expected)** | 1<br><br>1 |
| 1(e) | Correct calculation of $g$ using candidate's second $k$ **and** in range 9.0 m s$^{-2} \leqslant g \leqslant$ 11.0 m s$^{-2}$. | 1 |

| | number of oscns, *n* | time for *n* oscn, *t1* / s | time for *n* oscn, *t2* / s | *T* / s | *L* / m | *k* / m s^-1 | *g* / m s^-2 | %*L* / *L* | Comment |
|---|---|---|---|---|---|---|---|---|---|
| **(b)(ii)/ (b)(iii)** | 14 | 10.6 | 10.5 | 0.754 | 0.120 | 0.459 | **9.81** | 1.7 | this should be the more appropriate 2nd value of *k* used to find *g* due to smaller % error |
| **(c)(ii)** | 40 | 21.8 | 21.6 | 0.542 | 0.060 | 0.45 | 9.5 | 3.3 | |

**Fig. 1** Excel-Generated Theoretical Table for Q1

| | | | |
|---|---|---|---|
| | | | |
| | | **Total** | **14** |

<table>
<tr><th>Qn</th><th>Marking Point</th><th>Marks</th></tr>
<tr><td>2(a)</td><td>$R$ measured while resistor is in operation i.e., $R = \frac{V}{I}$</td><td>1</td></tr>
<tr><td></td><td>Value of $R_A$, $R_B$ and $R_C$ with unit in the range 64 - 72 Ω.</td><td>1</td></tr>
<tr><td></td><td>
<table>
<tr><th></th><th>V / V</th><th>I / mA</th><th>R / ohm</th><th>Nominal / ohm</th><th>Multimeter / ohm</th></tr>
<tr><td>R _A</td><td>2.03</td><td>29.9</td><td>67.9</td><td></td><td>68.2</td></tr>
<tr><td>R _B</td><td>2.02</td><td>30.1</td><td>67.1</td><td></td><td>67.8</td></tr>
<tr><td>R _C</td><td>2.02</td><td>30.2</td><td>66.9</td><td></td><td>67.5</td></tr>
<tr><td></td><td></td><td></td><td>67.3</td><td>68.0</td><td>67.8</td></tr>
</table>
Fig. 2a Excel-Generated Theoretical Table for Q2a</td><td></td></tr>
<tr><td>2(b)(i)</td><td>Value of $I$ with unit in the range 30.0–50.0 mA.</td><td>1</td></tr>
<tr><td>2(c)</td><td>Seven sets of readings of $R$:<br>22.7 Ω, 34.0 Ω, 45.3 Ω, 68.0 Ω, 102 Ω, 136 Ω & 204 Ω<br><br>Six sets of readings of $R$</td><td>2<br>or<br>1</td></tr>
<tr><td></td><td>Column headings:<br>Each column heading must contain a quantity, a unit, and a separating mark where appropriate.<br>The presentation of quantity and unit must conform to accepted scientific convention, e.g. $R$ / Ω, $I$ / mA and $\frac{1}{I}$ / mA$^{-1}$ .</td><td>1</td></tr>
<tr><td></td><td>Consistency of presentation:<br>All raw values of $I$ must be given to 0.1 mA or all to 0.01 mA.</td><td>1</td></tr>
<tr><td></td><td>Significant figures:<br>All values of $\frac{1}{I}$ must be given to the same number of s.f. as the number of s.f. in raw $I$.<br><br>Calculation: Values of $\frac{1}{I}$ are correct.</td><td>1</td></tr>
</table>

| | V / V | I / mA | R / ohm | 1/I / mA^-1 | |
|---|---|---|---|---|---|
| **R _A only** | 2.76 | 40.9 | 67.5 | 0.0244 | **(b)** |
| R _A and R _B in parallel | 2.07 | 61.3 | 33.8 | 0.0163 | |
| R _A, R _B and R _C in parallel | 1.65 | 73.6 | 22.4 | 0.0136 | |
| R _A and R _B in series | 3.32 | 24.5 | 135.5 | 0.0408 | |
| R _A. R _B and R _C in series | 3.56 | 17.5 | 203.4 | 0.0571 | |
| R _A and R _B in series w R _C in parallel | 2.36 | 52.7 | 44.8 | 0.0190 | |
| R _A and R _B in parallel w R _C in series | 3.11 | 30.7 | 101.3 | 0.0326 | |

**Fig. 2b** Excel-Generated Theoretical Table for Q2c

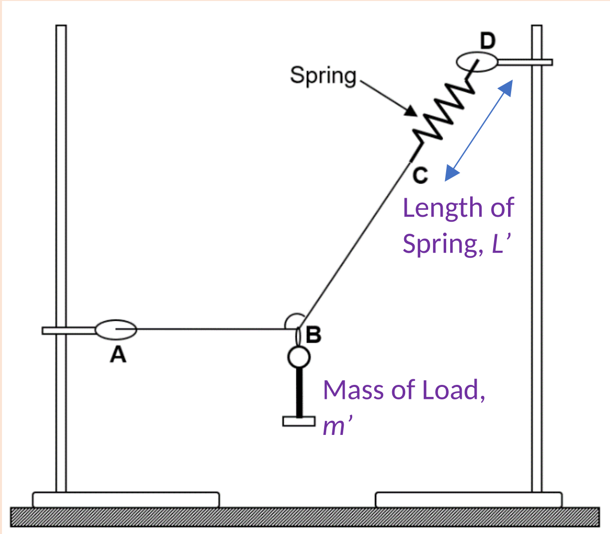
| | | |
|---|---|---|
| 2(d) | Stated appropriate graph $\left(\frac{1}{I} \text{ against } R\right)$ to be plotted. | **1** |
| | $E$ is determined by the inverse of the gradient.<br>$X$ is determined by product of $y$-intercept and $E$. | **1** |
| | **Total** | **10** |

| Qn | Marking Point | Marks |
|---|---|---|
| 3(a) | Value of $S$ with unit in the range 4.50 – 5.50 cm. | **1** |
| 3(b)(iii) | <u>Measurement and Observation</u><br>Recorded **two values** of $S_1$ and **two values** of $S_2$, and their **averages** to **nearest 0.001 m (i.e., 0.1 cm).** | **1** |
| 3(b)(iv) | $p$ and $q$ calculated correctly, and recorded to **nearest 0.001 m (i.e. 0.1 cm).** | **1** |
| 3(c) | Six (or more) sets of readings of $m$, including $m$ = 100 g and $m$ = 400 g | **1** |
| | Column headings:<br>Each column heading must contain a quantity, a unit, and a separating mark where appropriate.<br>The presentation of quantity and unit must conform to accepted scientific convention, e.g.<br>$m$ / g, $S_1$ / cm, $S_2$ / cm, $p$ / cm, $q$ / cm, $mg$ / N and $\sqrt{\frac{p^2}{4}+q^2}$ / cm. | **1** |
| | Consistency of presentation:<br>All raw values of $S_1$ and $S_2$ must be given to 0.1 cm.<br>All raw values of $m$ must have no d.p. in g. | **1** |
| | Decimal places:<br>All values of $p$ and $q$ must be given to the same number of d.p. as the number of d.p. in raw $S_1$ and $S_2$ respectively.<br><br>Significant figures:<br>All values of $mg$ must be given to the same number of s.f. as the number of s.f. in raw $m$.<br>All values of $\sqrt{\frac{p^2}{4}+q^2}$ must be given to the **least no. of s.f. among $p$ and $q$**<br>Calculation:<br>Values of $mg$ and $\sqrt{\frac{p^2}{4}+q^2}$ are correct. | **1** |

| *m* / g | *S* 1,1 / cm | *S* 2,1 / cm | *S* 1,2 / cm | *S* 2,2 / cm | *p* _ave / cm | *q* _ave / cm | *mg* / N | ((*p*^2)/4+*q*^2)^0.5 / cm |
|---|---|---|---|---|---|---|---|---|
| 400 | 27.8 | 18.0 | 27.8 | 18.0 | 17.8 | 13.0 | 3.9 | 15.8 |
| 350 | 24.8 | 16.5 | 24.8 | 16.5 | 14.8 | 11.5 | 3.4 | 13.7 |
| 300 | 22.5 | 15.0 | 22.5 | 15.0 | 12.5 | 10.0 | 2.9 | 11.8 |
| 250 | 19.8 | 13.2 | 19.8 | 13.2 | 9.8 | 8.2 | 2.5 | 9.6 |
| 200 | 17.1 | 11.5 | 17.1 | 11.5 | 7.1 | 6.5 | 2.0 | 7.4 |
| 100 | 13.2 | 8.4 | 13.2 | 8.4 | 3.2 | 3.4 | 1.0 | 3.8 |

**Fig. 3** Excel-Generated Theoretical Table for Q3c

| | | |
|---|---|---|
| 3(d) **(GRAPH)** | • Sensible scales must be used. Awkward scales (e.g., 3:10) are not allowed. Scales must be chosen so that plotted points occupy at least half the graph grids in both *x* and *y* directions.<br>• Axes must be labelled with the quantity which is being plotted. | **1** |
| | • Straight line of best fit- judge by scatter of points about the candidate's line. No curved lines allowed.<br>• There must be an even distribution of points on either side of the line along the full length.<br>• Allow maximum (correctly identified) one anomalous point if clearly indicated on graph i.e., circled or labelled. There must be at least five points left after the anomalous point is disregarded.<br>• Lines must not be kinked or thick. No hairy lines. (No curved lines allowed). | **1** |
| | All observations in table must be plotted.<br>Work to an accuracy of plot ≤ 0.5 small square. | **1** |
| 3(d) **(CALN)** | • Equation linearised correctly.<br>• Plot a sensible graph that allows for straight line to be drawn and *k* to be determined from the gradient. e.g. *mg* / N vs $\sqrt{\frac{p^2}{4}+q^2}$ / cm . | **1** |
| | • Gradient calculated correctly with clear working.<br>• The hypotenuse of the gradient triangle must be greater than half the length of the drawn line.<br>• Read-offs must be accurate to half a small square. | **1** |
| | • *k* determined correctly from gradient with unit. | **1** |
| 3(e) | Comments on whether there are any anomalous data - with the anomalous data clearly identified e.g.,<br><br>*"There are no anomalous points as all plotted points are evenly distributed on both sides of the best fit line and no point is significantly further from the best fit line compared to other points."*<br><br>Justifies whether there is any anomalous data based on deviation of the points from the linear trend e.g.,<br><br>*"Point (4.300, 7.00) is an anomalous point because point (4.300, 7.00) is significantly further from the best fit line as compared to other points."* | **1** |
| 3(f)(i) | Difficult to measure angle with reason e.g., hand shakes / curve at bottom / position of zero uncertain / parallax / holding set square without a stand | **1** |
| 3(f)(ii) | Trace on a card / use graph paper / project onto screen and measure angle / use trigonometry / take photo and measure angle / clamp set square | **1** |

| | | |
|---|---|---|
| 3(g) | <br>**Fig. I**<br><br>(a) Measure the provided masses, *m*' **using an electronic balance** and labelled them.<br>(b) Measure the natural length of spring CD, $L'_0$ using **a metre ruler**.<br>(c) Set up the apparatus as shown in Fig. I.<br>(d) Record the known mass *m*'.<br>(e) Record the angle $\theta$ **using a protractor** while **keeping AB horizontal**.<br>(f) Record the length *L'* using **a metre ruler**. Ensure it is **constant**.<br>(g) Repeat steps (d), (e) and (f) while varying the mass of the load *m'* to obtain 5 additional sets of readings.<br><br>(h) Resolving forces vertically,<br>$m'g = T_{CD}\sin(180^{\circ} - \theta) = k(L' - L'_0)\sin\theta$<br>where $T_{CD}$ is the tension in spring CD and<br>$g$ is the acceleration of freefall.<br><br>Plot a graph of $\sin\theta$ **against** $m'g$,<br><br>which is a straight-line graph through the origin with gradient<br>$\frac{1}{k(L' - L'_0)}$ is the gradient.<br><br>(i) $k = \frac{1}{\text{gradient}(L' - L'_0)}$ | [1] for diagram<br><br>[1] control of variables<br><br>[1] for process and how to determine *k* |
| | **Total** | **19** |

| Qn | Marking Point | Marks |
|---|---|---|
| **4** | **Mark Scheme** | |
| | Defining the problem<br>A1: identify independent (frequency $f$ of light, thickness of glass $t$) and dependent (ratio $A/A_0$) variables<br>A2: identify control variable<br>(e.g. keep distance between light source and sensor constant) | **1**<br>**1** |
| | Method of data collection<br>B1: labelled diagram showing a setup of laser, glass block(s) and light sensor in a line<br>B2: method to determine the different frequencies of laser (e.g. using diffraction grating and $n\lambda = d \sin \theta$<br>B3: method to determine thickness of glass $t$, using vernier calipers or metre rule<br>B4: method to measure intensity of light e.g. use light sensor / light intensity meter connected to datalogger and taking initial reading of $I_0$)<br>B5: determination of $A/A_0$ from the formula $I \propto A^2$<br>B6: identifying 2 runs required (run 1: vary thickness, keep frequency constant) (run 2: vary frequency, keep thickness constant) | **1**<br>**1**<br>**1**<br>**1**<br>**1**<br>**1** |
| | Method of Analysis<br>C1: linearization of relationship<br>$\ln(A/A_0) = \ln(k) + p\ln(t) + q\ln(f)$<br>C2:<br>Run 1: plot $\ln(A/A_0)$ against $\ln(t)$,<br>straight line with gradient $p$, y-intercept $\ln(k) + q\ln(f)$<br>Run 2: plot $\ln(A/A_0)$ against $\ln(f)$,<br>straight line with gradient $q$, y-intercept $\ln(k) + p\ln(t)$ | **1**<br>**1** |
| | Safety<br>D1: do not look directly into the light source. | **1** |
| | Additional details: (max 3)<br>E1: perform experiment in dark room to reduce noise in the form of ambient light<br>E2: detailed description to determine the angle of diffraction through the grating, by measuring distances and using trigonometry relations<br>E3: measure thickness of the glass blocks at different positions and average $t$.<br>E4: take preliminary measurements of the intensity with the largest thickness before the start of the experiment. If the intensity is too low, reduce the maximum thickness of glass block.<br>E5: ensure light reaches the light meter perpendicularly. | **1**<br>**1**<br>**1**<br>**1**<br>**1** |
| | **MAX** | **12** |