A student wishes to determine the Young modulus $E$ of wood from the period of oscillation of a loaded wooden rule, as shown in Fig. 1.1.

An equation relating the period of oscillation $T$ to the overhanging length $l$ of the rule is

$$T^2 = \frac{kl^3}{E}.$$ 

The constant $k$ is given by

$$k = \frac{16\pi^2 M}{wd^3}$$

where $M$ is the mass of the load, $w$ is the width of the rule and $d$ is the thickness of the rule.

Design a laboratory experiment to determine the Young modulus of wood. You should draw a diagram showing the arrangement of your equipment. In your account, you should pay particular attention to

(a) the procedure to be followed,
(b) the measurements to be taken,
(c) the control of variables,
(d) how to analyse the data,
(e) how to determine $E$,
(f) the safety precautions to be taken.

[15]
An experiment is carried out to investigate how the current $I$ required to melt a wire varies with the diameter $d$ of the wire.

The equipment is set up as shown in Fig. 2.1.

**Fig. 2.1**

Question 2 continues on the next page.
It is suggested that $I$ and $d$ are related by the equation

$$I = pd^q$$

where $p$ and $q$ are constants.

(a) A graph is plotted with $\lg I$ on the $y$-axis and $\lg d$ on the $x$-axis. Express the gradient and $y$-intercept in terms of $p$ and $q$.

gradient = …………………………………

$y$-intercept = ………………………………… [1]

(b) Values of $d$ and $I$ are given in Fig. 2.2.

<table>
<thead>
<tr>
<th>$d/10^{-5}$ m</th>
<th>$I$ A</th>
<th>$\lg (d/10^{-5}$ m)</th>
<th>$\lg (I/A)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2.6 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>3.5 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>4.4 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>5.4 ± 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>6.4 ± 0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2.2

Calculate and record values of $\lg (d/10^{-5}$ m) and $\lg (I/A)$ in Fig. 2.2. Include in the table the absolute errors in $\lg (I/A)$. [3]

(c) (i) Plot a graph of $\lg (I/A)$ against $\lg (d/10^{-5}$ m). Include error bars for $\lg (I/A)$. [2]

(ii) Draw the line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the error in your answer.

gradient = ………………………………… [2]
1.15 1.20 \lg\left(\frac{d}{10^{-5}\text{ m}}\right)

1.25 1.30 1.35 1.40 1.45 1.50

0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85

\lg\left(\frac{I}{A}\right)
(iv) Determine the $y$-intercept of the line of best fit. Include the error in your answer.

$y$-intercept = ………………………………… [2]

(d) Using your answers to (c)(iii) and (c)(iv), determine the values of $p$ and $q$. Include the error in your values. You need not give the units of $p$ and $q$.

$p = …………………………………$
$q = ………………………………… [3]$