## UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS General Certificate of Education Advanced Subsidiary Level and Advanced Level

PHYSICS 9702/03

Paper 3 Practical Test

October/November 2006

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions.

## **READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer the one question.

You are expected to record all your observations as soon as they are made, and to plan the presentation of the records so that it is not necessary to make a fair copy of them. The working of the answers is to be handed in.

Marks are mainly given for a clear record of the observations actually made, for their suitability and accuracy, and for the use made of them.

Additional answer paper and graph paper should be submitted only if it becomes necessary to do so.

You are reminded of the need for good English and clear presentation in your answers.

At the end of the examination, fasten all your work securely together.

For Examiner's Use

## **BLANK PAGE**

## You may not need to use all of the materials provided.

- 1 In this experiment you will investigate how the length of a vibrating wire is affected by the tension in the wire.
  - (a) A mass of 150 g has been suspended using a copper wire as shown in Fig. 1.1.

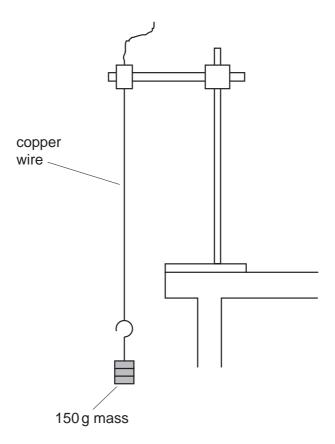


Fig. 1.1

(i) Clamp the U-shaped magnet so that the wire hangs mid-way between the pole pieces and is positioned about 25 cm below the point of suspension as shown in Fig. 1.2.

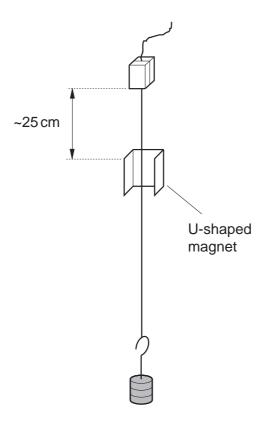
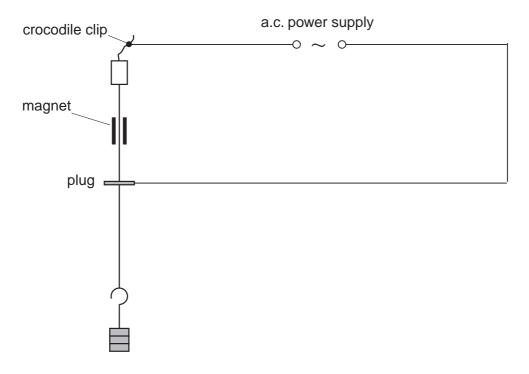


Fig. 1.2

(ii) Construct the circuit shown in Fig. 1.3. A connection to the top of suspended wire should be made using a crocodile clip. Connection to the lower end of the wire may be made by placing the metal end of a plug against the wire.



**Fig. 1.3** 9702/03/O/N/06

**(b) (i)** Adjust the position of the plug by gently sliding it up or down the wire until the wire performs large amplitude oscillations as shown in Fig. 1.4.

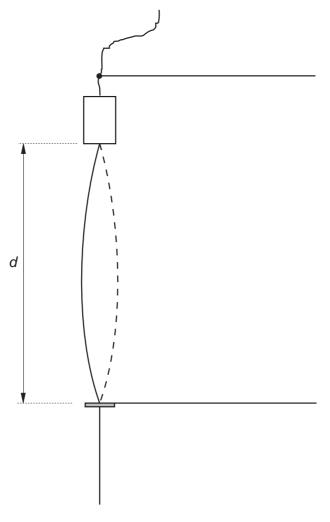


Fig. 1.4

(ii) Measure and record the length d and calculate the tension T in the wire.

The gravitational field strength  $g = 9.8 \,\mathrm{N \, kg^{-1}}$ .

| <i>d</i> = | <br> | ٠. | <br> |  | <br> |  |  |  |  |  |  |  |  |  |  |  |  |  | r | n |
|------------|------|----|------|--|------|--|--|--|--|--|--|--|--|--|--|--|--|--|---|---|
|            |      |    |      |  |      |  |  |  |  |  |  |  |  |  |  |  |  |  |   |   |

(c) Determine the percentage uncertainty in this value of d.

percentage uncertainty in *d* = .....

| (d) | (i)         | Change the value of $T$ by altering the mass and repeat <b>(b)</b> until you have six sets of values for $d$ and $T$ . Include values of $\sqrt{T}$ in your table of results. | Use |
|-----|-------------|---|-----|
|     |             |   |     |
|     |             |   |     |
|     |             |   |     |
|     |             |   |     |
|     |             |   |     |
|     | (ii)        | Justify the number of significant figures that you have given for $\sqrt{T}$ .  |     |
|     |             |   |     |
| (0) | /i\         | Diet a graph of d (v avia) against d T (v avia) and draw the line of heat fit   |     |
| (e) | (i)<br>(ii) | Plot a graph of $d$ ( $y$ -axis) against $\sqrt{T}$ ( $x$ -axis) and draw the line of best fit.  Determine the gradient of the line.  |     |
|     |             |   |     |
|     |             |   |     |
|     |             |   |     |
|     |             |   |     |
|     |             | gradient =  |     |
|     |             |   |     |

|   |                |         |              | _          | П        |                | _            |           | _       |                |                | _          |             | _            |             |               | _              |                |           | _       |          | П         |                |            |          |                |                |                | _            | П.        |           |             |              | 11             | _        |                | _            | _        |             | П              |                |              |          | П      |
|---|----------------|---------|--------------|------------|----------|----------------|--------------|-----------|---------|----------------|----------------|------------|-------------|--------------|-------------|---------------|----------------|----------------|-----------|---------|----------|-----------|----------------|------------|----------|----------------|----------------|----------------|--------------|-----------|-----------|-------------|--------------|----------------|----------|----------------|--------------|----------|-------------|----------------|----------------|--------------|----------|--------|
|   |                |         |              | ŧ          |          |                | #            | Ħ         | #       | Ħ              |                | t          |             | t            |             |               |                |                | Ħ         | Ţ       |          | Ħ         | $\pm$          |            |          |                |                |                | #            |           |           |             | Ħ            |                | Ŧ        |                | Ħ            | Ţ        |             |                |                |              |          |        |
| +++   | +              | +       | Н            | +          | H        | +              | +            | Н         | +       | Н              | H              | +          | $\vdash$    | +            | $\vdash$    | +             | +              | +              | Н         | +       | H        | H         | +              | +          |          | +              | +              | +              |              |           |           | Н           | H            |                | +        | Н              | +            | +        |             | +              | +              | +            |          | +      |
|   | $\blacksquare$ | $\perp$ |              | +          | Н        | +              | +            | Н         | +       | $\Box$         | Н              | F          | Н           | F            | Н           | $\mathbf{H}$  | +              | $\vdash$       | Н         | $\perp$ | Н        | Н         | $\blacksquare$ | +          |          |                | $\Box$         | +              | -            |           |           | Н           | Н            | $\blacksquare$ | +        | Н              | $\mathbf{H}$ | $\perp$  | Н           | $\mathbf{H}$   | $\mathbf{H}$   | +            |          | +      |
|   |                |         |              | $\pm$      |          |                | $\pm$        | П         | #       | П              |                | İ          |             |              |             |               |                |                |           |         |          |           |                |            |          |                |                |                |              |           |           |             | П            |                |          |                |              |          |             |                |                |              |          |        |
|   | +              | +       |              | +          | Н        | +              | +            | Н         | +       | +              | +              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          | _        | +              | +              | +              | +            | -         | +         | Н           | +            | ++             | +        | +              | +            | +        | Н           | +              | +              | +            |          | ++-    |
|   | ш              |         |              | $\pm$      |          |                | $\pm$        | П         | #       | П              |                |            |             |              |             |               | $\pm$          |                |           | $\pm$   |          | П         | $\pm$          |            |          |                |                |                | $\pm$        |           |           |             | $\pm$        |                |          |                | $\Box$       | $\pm$    |             | $\pm$          | $\pm$          | $\pm$        |          |        |
| +++   | +              | _       | Ш            | +          | Н        | +              | +            | Н         | +       | Н              | Н              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          |          | $\vdash$       | +              | +              | +            |           | $\vdash$  | Н           | +            |                | +        | Н              | +            | +        | Н           | +              | +              | +            |          | ++     |
|   |                |         | ш            |            |          |                |              | П         | 1       |                |                | t          | П           |              |             |               |                |                | П         |         |          | П         |                |            |          |                |                |                |              |           |           |             | П            |                |          |                | П            |          |             |                |                |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | +              | Н              | +          | Н           | +            | Н           | ++            | +              | +              | Н         | +       | $\vdash$ | Н         | +              | +          |          | -              | ++             | +              | +            |           | $\vdash$  | Н           | +            | +              | +        | Н              | +            | +        | Н           | +              | +              | +            |          | ++-    |
|   |                |         | ш            | $\pm$      |          |                | $\pm$        | П         | #       | $\pm$          |                | t          |             |              | ш           | $\Box$        | $\pm$          |                |           | $\pm$   |          |           | $\pm$          |            |          |                |                |                |              |           |           |             | $\Box$       |                | $\pm$    |                | $\Box$       |          |             | $\Box$         | $\pm$          | $\pm$        |          |        |
| +++   | +              | +       |              | +          | Н        | +              | +            | Н         | +       | +              | H              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          | -        | +              | ++             | +              | +            |           | $\vdash$  | Н           | +            | -              | +        | Н              | +            | +        | Н           | +              | +              | +            |          | ++-    |
|   |                |         |              |            |          |                | $\pm$        | П         |         | $\pm$          |                |            |             |              |             |               |                |                |           |         |          |           |                |            |          |                | $\Box$         |                |              |           |           |             | П            |                |          |                |              |          |             | $\Box$         |                |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | H              | +          | Н           | +            | Н           | ++            | +              | +              | Н         | +       | $\vdash$ | Н         | +              | +          | +        | +              | +              | +              | +            | +         | $\vdash$  | Н           | ₩            | +              | +        | $\vdash$       | ++           | +        | Н           | +              | +              | +            | Н        | ++     |
|   |                |         | ш            |            |          |                | 1            | П         | 1       | П              |                | t          |             |              | ш           |               |                |                |           |         |          | П         | Ш              |            |          |                |                |                |              |           |           |             | П            |                |          |                |              |          |             | ш              | Ш              |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | +              | H              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          |          | +              | +              | +              | +            |           | $\vdash$  | Н           | +            | ++             | +        | +              | +            | +        | Н           | +              | +              | +            |          | ++     |
|   |                |         |              | 1          |          |                | 1            |           | 1       | $\pm$          |                | İ          |             | t            |             |               |                |                |           |         |          | П         | $\blacksquare$ |            |          |                |                |                | #            |           |           |             | П            |                |          |                |              |          |             |                |                |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | H              | +          | Н           | +            | $\vdash$    | +             | +              | $\vdash$       | Н         | +       | H        | H         | +              | +          |          | +              | +              | +              | +            | +         | $\vdash$  | Н           | +            | +              | +        | +              | +            | +        | Н           | +              | +              | +            |          | +      |
|   |                |         |              |            |          |                | 1            | П         | T       | $\blacksquare$ |                | L          | П           | T            |             |               |                |                |           |         |          | П         | $\blacksquare$ |            |          |                | $\Box$         |                |              |           |           |             | П            |                |          |                | $\Box$       |          |             |                |                | T            |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | H              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          |          | $\vdash$       | +              | +              | +            |           | $\vdash$  | Н           | +            | ++             | +        | Н              | +            | +        | Н           | +              | +              | +            |          | ++     |
| +   | $\Box$         | $\perp$ | Ш            | $^{\pm}$   | Ħ        | Ħ              | $^{\dagger}$ | Ħ         | #       | Ħ              | T.             | T          | Ħ           | T            | Ħ           | Ħ             | $\top$         |                | Ħ         | 1       | Ħ        | Ħ         | $\mp$          | $\perp$    |          |                | $\Box$         | $\Box$         | #            |           |           |             | Ħ            | $\mp$          | 1        |                | Ħ            | #        | Ħ           | $\Box$         | $\mp$          | $\perp$      |          | Ħ      |
| +++   | +              | +       | H            | +          | Н        | $\mathbb{H}$   | +            | H         | +       | +              | +              | +          | +           | +            | +           | +             | +              | +              | $\forall$ | +       | +        | $^{+}$    | +              | +          | +        | +              | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | H            | +        | +           | ++             | +              | +            | +        | +      |
| $\Box$  | $\parallel$    | $\perp$ | ш            | #          | Ħ        | Ħ              | #            | Ħ         | #       | Ħ              | Ħ              | F          | Ħ           | T            | Ħ           | Ħ             | $\bot$         |                | Ħ         | Ŧ       | Ħ        | Ħ         | $\mp$          |            |          |                | $\pm$          | $\bot$         | #            | Ħ         |           | T.          | $\parallel$  | $\Box$         | ļ        | T.             | Ħ            | Ţ        | Ħ           | $\Box$         | $\Box$         | $\perp$      |          | Ħ      |
| +++   | +              | +       | H            | +          | H        | H              | +            | Н         | +       | +              | +              | +          | H           | +            | +           | +             | +              | +              | H         | +       | +        | H         | +              | +          | +        | +              | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | +            | +        | +           | +              | +              | +            | +        | +      |
| $\Box$  | Ħ              | $\perp$ | Ш            | Ŧ          | H        | П              | Ŧ            | П         | 1       | Ħ              | H              | F          | П           | Ŧ            | H           | H             | $\Box$         |                | П         | Ŧ       | H        | Ħ         | H              | Ŧ          |          |                | $\Box$         | $\Box$         | 1            |           | $\vdash$  | Ħ           | Ħ            | Ħ              | ļ        | Ħ              | Ħ            | Ŧ        | H           | $\Box$         | $\Box$         | Ŧ            | H        | H      |
| $\pm + +$   | ${\mathbb H}$  | +       | ₽₩           | +          | H        | H              | +            | H         | +       | H              | H              | $\pm$      | $\vdash$    | ╁            | $\vdash$    | $^{++}$       | ∄              | $\vdash$       | H         | +       | H        | $^{+}$    | ╁              | +          | $\vdash$ | ₩              | +              | _              | +            | ╁┼        | $\vdash$  | $\vdash$    | $\mathbb{H}$ |                | +        | $\vdash$       | +            | +        | $\vdash$    |                | ╫              |              | $\vdash$ | +      |
| $\blacksquare$                                    | Ħ              | $\perp$ | Ш            | +          | H        | П              | #            | Ħ         | #       | Ħ              | H              | F          | H           | 1            | H           | $\Box$        | $\Box$         |                | П         | +       | H        | H         | $\Box$         | Ŧ          |          | $\perp$        | $\Box$         | $\Box$         | +            | Н         |           | H           | Ħ            | $\Box$         | 1        | H              | H            | +        | H           | $\Box$         | $\Box$         | $\perp$      |          | H      |
| +++   | +              | +       | $\mathbb{H}$ | $\pm$      | H        | $\pm$          | $\pm$        | H         | $\pm$   | Н              | +              | $\pm$      | $\vdash$    | $\pm$        | $\vdash$    | $\pm \pm$     | +              | $\vdash$       | H         | $\pm$   | $\vdash$ | H         | +              | $\pm$      | +        | $\vdash$       | +              | $\pm$          | +            | +         | $\vdash$  | $\vdash$    | $\coprod$    | $\pm \pm$      | $\pm$    | $\vdash$       | $^{+}$       | $\pm$    | +           | $\pm \pm$      | +              | $\pm$        | $\vdash$ | $^{+}$ |
| $\Box$  | $\blacksquare$ | $\perp$ | Ш            | Ŧ          | H        | П              | Ŧ            | П         | 7       | Ħ              | Ħ              | F          | H           | Ŧ            | Ħ           | П             | П              |                | П         | Ŧ       | H        | Ħ         | Ħ              | Ŧ          |          |                | $\blacksquare$ | $\blacksquare$ | Ŧ            | H         |           | T           | П            | $\blacksquare$ | Ŧ        | T              | П            | Ŧ        | H           | $\Box$         | Ħ              | Ŧ            | H        | H      |
|   | Ħ              |         | Ш            | t          | H        | H              |              | H         | _       | H              | H              | t          | Н           | t            | H           | Ħ             | H              | Н              | H         |         | H        | Ħ         | Ħ              | $\pm$      | $\pm$    | H              | ∄              | H              | 1            | ┢         | H         | H           | Ħ            | 坩              | t        | H              | H            |          | H           | Ħ              | H              | $\pm$        | Н        | Ħ      |
|   |                |         |              | $\perp$    | П        |                | -            | Н         | 1       | $\blacksquare$ |                | F          |             | F            | Н           |               | $\blacksquare$ |                | Н         |         |          | Н         | $\blacksquare$ |            |          |                | $\blacksquare$ | $\blacksquare$ | -            |           |           | H           | Н            | $\blacksquare$ |          | $\blacksquare$ |              |          |             | $\blacksquare$ | $\blacksquare$ |              |          |        |
|   | $\pm$          | $\perp$ | Ш            | $\pm$      | Ħ        | $\sharp$       | $\pm$        | $\forall$ | 1       | $\pm$          | Ш              |            | $\Box$      | $\pm$        | $\parallel$ | $\Box$        | $\pm$          |                | $\Box$    | $\pm$   | ш        | $\exists$ | $\pm$          | $\pm$      |          | ш              | Ш              | $\pm$          | $\pm$        | ш         |           |             | $\parallel$  | $\pm$          | $^{\pm}$ | $\parallel$    | $\pm$        | $\pm$    |             | $\pm$          | $\pm$          | $\pm$        | Ш        | Ш      |
|   | +              | _       |              | +          | Н        | +              | +            | Н         | +       | +              | Н              | F          | Н           | +            | Н           | +             | +              | +              | Н         | +       | Н        | Н         | +              | +          | _        | +              | -              | +              | -            | -         | -         | Н           | $\mathbb{H}$ | -              | +        | $\Box$         | $\mathbf{H}$ | +        | $\Box$      | +              | +              | +            |          | -      |
|   | $\pm$          |         |              | 士          |          | $\pm$          | $\pm$        | Н         | $\pm$   | Н              | ш              | t          |             | $^{\dagger}$ | Н           | $\pm$         | $\pm$          |                | Н         | $\pm$   |          | Ш         | $\pm$          | $\pm$      |          |                | $\pm$          | $\pm$          | $^{\dagger}$ |           |           | Ш           | $\pm \pm$    |                | $\pm$    | $\Box$         | $\forall$    | $\pm$    | Н           | $\pm$          | $\pm$          | $\pm$        |          | $\Box$ |
|   | +              | -       | Ш            | +          | Н        | +              | +            | Н         | +       | +              | Н              | +          | Н           | +            | Н           | +             | +              |                | Н         | +       |          |           | Н              |            |          |                | +              | +              | +            |           |           | Н           | Н            |                | -        | Н              | Н            | +        | Н           | +              | +              | +            |          |        |
|   |                |         |              |            | Ħ        | $\pm$          |              | H         | $\pm$   | Ш              |                | t          |             |              | Н           | $\pm$         | $\pm$          |                | Н         |         |          | Н         | $\Box$         |            |          |                | $\Box$         |                |              |           |           |             | Ш            |                |          |                | $\Box$       |          |             | $\pm$          | $\forall$      | $^{\dagger}$ |          |        |
| +   | +              | -       |              | +          | Н        | +              | +            | Н         | +       | +              | $\perp$        | +          | Н           | +            | Н           | +             | +              | $\perp$        | Н         | +       | Н        | Н         | +              | +          |          | +              | +              | +              | +            | -         | Н         | Н           | $^{\rm H}$   | +              | +        | +              | +            | +        | Н           | +              | +              | +            |          | ++-    |
|   |                |         | ш            | $\pm$      |          | $\Box$         | $\pm$        | П         |         | $\pm$          |                | İ          |             | $^{\pm}$     |             | $\Box$        | $\pm$          |                | Ш         |         |          | Н         | Ш              |            |          |                |                | Ш              |              |           |           |             | Ш            |                |          |                | $\Box$       |          |             | $\pm$          | Ш              |              |          |        |
|   | +              | +       | Ш            | +          | Н        | +              | +            | Н         | +       | +              | H              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | H        | Н         | +              | +          | +        | +              | ++             | +              | +            | +         | $\vdash$  | Н           | +            | ++             | +        | Н              | +            | +        | Н           | +              | +              | +            |          | ++-    |
|   |                |         |              | $\pm$      |          |                | $\pm$        | П         | 1       | П              |                | İ          |             |              | ш           |               | $\perp$        |                |           |         |          |           | ш              |            |          |                |                |                | #            |           |           |             | П            |                |          |                |              |          |             | ш              | ш              |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | H              | +          | Н           | +            | Н           | +             | +              |                | Н         | +       | Н        | Н         | Н              | +          |          |                | +              | +              | +            |           |           | Н           | Н            | +              | +        | Н              | Н            | +        | Н           | +              | +              | +            |          | +      |
|   |                |         | ш            | ᆂ          |          |                | 1            | П         | 1       | $\blacksquare$ |                | İ          |             | 1            |             |               |                |                |           |         |          |           | $\perp$        |            |          |                | $\Box$         |                | #            |           |           |             | П            |                |          |                |              |          |             | ш              | ш              |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | +              | H              | +          | Н           | +            | Н           | +             | +              | +              | Н         | +       | +        | Н         | +              | +          | +        | +              | ++             | +              | +            | +         | $\vdash$  | Н           | +            | +              | +        | +              | +            | +        | Н           | +              | +              | +            | $\vdash$ | +      |
|   | $\Box$         |         |              | #          |          | $\blacksquare$ | #            | П         | #       | $\blacksquare$ | ш              | I          |             | T            |             | $\Box$        | $\bot$         |                |           | #       |          | $\Box$    | $\blacksquare$ | $\pm$      |          | $\blacksquare$ | $\Box$         |                | #            | I         |           |             | $\Box$       | $\blacksquare$ | #        |                | $\Box$       | #        |             | $\Box$         | $\blacksquare$ | #            |          |        |
| +++   | ++             | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | Н              | +          | Н           | +            | Н           | ++            | +              | +              | Н         | +       | $\vdash$ | Н         | +              | +          |          | +              | ++             | +              | +            |           | $\vdash$  | Н           | +            | -              | +        | Н              | +            | +        | Н           | ++             | +              | +            |          | ++     |
|   |                |         |              |            |          |                |              | П         | 1       | П              |                | F          | П           | L            |             |               |                |                | П         |         |          |           | П              |            |          |                | $\Box$         | П              |              |           |           |             | П            |                |          |                | П            |          |             | П              | П              |              |          |        |
| +++   | +              | +       | Н            | +          | Н        | +              | +            | Н         | +       | Н              | +              | +          | Н           | +            | Н           | ++            | +              | +              | Н         | +       | +        | Н         | +              | +          | +        | +              | ++             | +              | +            | +         | $\vdash$  | Н           | ++           | +              | +        | +              | ++           | +        | Н           | +              | +              | +            | $\vdash$ | ++     |
|   | $\blacksquare$ |         |              | $\perp$    | П        | $\blacksquare$ | $\perp$      | П         | 4       | $\blacksquare$ | $\blacksquare$ | F          |             | F            | П           | Н             | $\blacksquare$ | $\blacksquare$ | П         | $\perp$ |          | П         | $\blacksquare$ |            |          | 4              |                | $\blacksquare$ | $\perp$      |           |           |             | П            |                | -        | $\Box$         | $\square$    | $\perp$  |             | $\blacksquare$ | $\blacksquare$ | $\perp$      |          |        |
|   | $\pm$          |         |              | $\pm$      |          | $\pm$          | $\pm$        | Н         | $\pm$   | $\pm$          | $\pm$          | t          | $\Box$      | t            | $\forall$   | $\pm$         | $\pm$          |                | Н         | $\pm$   | $\pm$    | Н         | $\pm$          | $\pm$      |          | $\pm$          | +              | $\pm$          | $\pm$        | $\pm$     |           | $\vdash$    | $\pm \pm$    | $\pm$          | $\pm$    | $\pm$          | $\forall$    | $\pm$    | $\perp$     | $\pm$          | $\pm$          | $\pm$        |          | $\pm$  |
| +   | $\blacksquare$ | -       | Ш            | +          | П        | $\blacksquare$ | +            | Н         | $\perp$ | +              | 4              | F          | Н           | $\perp$      | Н           | $\mathbf{H}$  | +              | -              | Н         | +       | Н        | Н         | $\mathbf{H}$   | $\perp$    |          |                | $\Box$         | $\blacksquare$ | +            | -         | $\vdash$  | Н           | Н            | $\blacksquare$ | $\perp$  | $\perp$        | $\mathbf{H}$ | +        | Н           | +              | $\mathbf{H}$   | $\perp$      |          | +      |
| $\pm \pm \pm$                                     | Ħ              |         | Ш            | 1          | H        | Ħ              | 1            | Ħ         | _       | H              | ₽              | $^{\pm}$   | Ħ           | $\pm$        | H           | Ħ             | $\pm$          | H              | Ħ         | $\pm$   | ₽        | Ħ         | Ħ              |            | $\pm$    | H              | $\pm \dagger$  | Ħ              | $\pm$        | ┢         | H         | ₽           | Ħ            | 坩              |          | ₽              | Ħ            | $\pm$    | ∄           | Ħ              | Ħ              | $\pm$        | Н        | ₽      |
| + $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ $+$ | H              | +       | HI           | Ŧ          | H        | H              | +            | H         | Ŧ       | H              | H              | F          | H           | +            | H           | H             | +              | H              | H         | Ŧ       | H        | H         | +              | Ŧ          | H        | H              | $+$ $\top$     | 47             | +            | HF        | H         | H           | H            | $+ \mathbb{I}$ | Ŧ        | H              | H            | Ŧ        | H           | +T             | +              | Ŧ            | H        | H      |
|   | $\sharp$       | $\perp$ | Ш            | $_{\perp}$ | Ħ        | Ш              | $^{\pm}$     | Ħ         | #       | $\sharp$       | Щ              | $^{\perp}$ | H           | 1            | Ħ           | П             | $\perp$        |                | $\Box$    | #       | ш        | Ħ         | $\perp$        | $^{\perp}$ |          | H              | Ш              | $\perp$        | #            | ш         |           |             | $\sharp$     | $\pm$          | #        | $\parallel$    | $\parallel$  | #        | Ц           | $\pm$          | $\perp$        | $\perp$      |          | 井      |
| +++   | +              | +       | H            | +          | Н        | Н              | +            | Н         | +       | Н              | +              | +          | +           | +            | +           | +             | +              | +              | H         | +       | +        | $^{+}$    | +              | +          | +        | $\vdash$       | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | $\mathbb{H}$ | +        | +           | +              | +              | +            | +        | +      |
| $\Box$  | $\blacksquare$ | $\perp$ | ш            | #          | Ħ        |                | #            | Ħ         | #       | Ħ              | T.             | F          | H           | T            | Ħ           | Ħ             | $\bot$         |                | П         | 1       | Ħ        | Ħ         | $\mp$          | $\perp$    |          |                | $\Box$         | $\Box$         | #            |           |           |             | $\parallel$  | $\blacksquare$ | 1        | T.             | Ħ            | $^{+}$   |             | $\Box$         | $\Box$         | $\perp$      |          | Ħ      |
| ++  | +              | +       | $\mathbb{H}$ | +          | H        | H              | +            | Н         | +       | Н              | H              | +          | H           | +            | H           | +             | +              | H              | H         | +       | H        | H         | +              | +          | $\vdash$ | H              | +              | +              | +            | +         | $\vdash$  | H           | $\mathbb{H}$ | +              | +        | H              | $\mathbb{H}$ | +        | H           | +              | +              | +            | H        | +      |
| $\prod$   | П              | $\top$  | Ш            | Ŧ          | Ħ        | П              | Ŧ            | П         | Ŧ       | Ħ              | H              | F          | П           | Ŧ            | H           | H             | T              | H              | П         | Ŧ       | H        | П         | Ħ              | Ŧ          |          | H              | $\blacksquare$ | $\Box$         | Ŧ            | $\Box$    | H         | T           | П            | H              | Ŧ        | T              | П            | Ŧ        | П           | Ħ              | Ħ              | Ŧ            | H        | Ħ      |
| $\pm +$   | $\pm \dagger$  |         | Н            | $\pm$      | H        | $\pm$          | +            | H         | $\pm$   | H              | H              | $^{\perp}$ | H           | $\pm$        | $\vdash$    | $\pm \dagger$ | $\pm \pm$      |                | H         | $\pm$   | $\vdash$ | H         | $\pm \pm$      | $\pm$      |          | #              | +              | 1              | +            |           | $\vdash$  | H           | $^{+}$       | $\pm \pm$      | $\pm$    | H              | $^{+}$       | $\pm$    | $\vdash$    | $\pm \pm$      | _              |              |          |        |
| $\Box$  | П              | F       | П            | Ŧ          | П        | П              | Ŧ            | П         | Ŧ       | П              | Ŧ              | F          | П           | F            | H           | H             | Ŧ              | F              | П         | Ŧ       | H        | П         | Ŧ              | F          | Ŧ        | F              | $\blacksquare$ | H              | Ŧ            | F         | F         | T           | П            | $\Box$         | Ŧ        | Ŧ              | П            | Ŧ        | 1           | $\Box$         | $\Box$         | Ŧ            | H        | H      |
| Ш   | Ħ              |         | Ш            | $\pm$      | H        | Ħ              | 1            | Ħ         | $\pm$   | Ħ              | Ħ              | +          |             | $^{\pm}$     | Ħ           | Ħ             | $\pm$          | $\pm$          | Ħ         | $\pm$   | Ħ        | Ħ         | $\forall$      | $\pm$      |          | 士              | 坩              | $\pm$          |              | $\forall$ | $\forall$ |             | ∄            | $\pm$          | Ŧ        | H              | Ħ            | $\pm$    |             | $\forall$      | $\pm$          | $\pm$        | Ħ        | Ħ      |
| +   | П              | F       | Н            | F          | H        | П              | Ŧ            | П         | Ŧ       | A              | Ŧ              | F          | H           | F            | H           | H             | П              | H              | H         | Ŧ       | H        | H         | A              | Ŧ          | H        | H              | П              | П              | Ŧ            | H         | H         | H           | H            | П              | Ŧ        | H              | H            | Ŧ        | H           | #1             | П              | F            | H        | H      |
| Ш   | Ħ              | $\pm$   | Ш            | $\pm$      | Ħ        | Ħ              | 1            | Ħ         | 1       | Ħ              | Ħ              | t          | Ц           | $_{\perp}$   | Ħ           | Ħ             | $\pm$          | 世              | Ħ         | $\pm$   | 世        | Ħ         | $\forall$      | $\pm$      | $\pm$    | 世              | 坩              | $\pm$          | $\pm$        | 世         | 世         | Ш           | ∄            | ∄              | t        | Ħ              | Ħ            | $\pm$    | Ц           | $\pm$          | $\pm$          | $\pm$        | 世        | 廿      |
| $+\Pi$  | $\Box$         | +       | Н            | Ŧ          | H        | П              | +            | H         | -       | A              | H              | F          | H           | F            | H           | H             | $\Pi$          | H              | H         | F       | H        | H         | H              | H          | +        | H              | +I             | 47             | +            | H         | H         | H           | H            | H              | F        | H              | H            | 1        | H           | +T             | 47             | Ŧ            | H        | H      |
|   |                |         | Ш            | #          | Ħ        | П              | $\pm$        | Ħ         | #       | $^{\dagger}$   | ш              |            | $\parallel$ | #            | $\perp$     | Ħ             | $\perp$        |                | Ħ         | 1       | ш        | Ħ         | $\pm$          |            |          | ш              | $\pm$          | $\perp$        | $\pm$        |           |           | $\parallel$ | $\sharp$     | $\pm$          | 1        | $\parallel$    | $\pm$        |          | $\parallel$ | Ħ              | $\pm$          |              |          | Ħ      |
| ++  | +I             | +       | $\mathbb{H}$ | +          | H        | $\mathbb{H}$   | Ŧ            | H         | +       | $\mathbb{H}$   | $\mathbb{H}$   | +          | H           | +            | H           | +             | +              | +              | H         | +       | H        | H         | +              | +          | +        | +              | +              | +              | +            | +         | +         | H           | H            | +              | +        | H              | H            | +        | H           | +              | +              | +            | H        | +      |
|   | $\Box$         | $\perp$ | ш            | 1          | Ħ        | Ш              | #            | Ħ         | #       | Ħ              |                | t          | H           | 1            | H           | $\Box$        | ш              |                | Ħ         | $\perp$ | $\perp$  | Ħ         | $\bot$         |            |          | ш              | ш              | ш              | #            | ш         |           |             | $\parallel$  | $\bot$         | #        |                | Ħ            | $\perp$  | Ħ           | $^{\pm}$       | $\bot$         | $\perp$      | ш        | #      |
| ++  | +              | +       | H            | +          | Н        | +              | +            | Н         | +       | +              | H              | +          | H           | +            | H           | $^{+}$        | +              | H              | H         | +       | H        | H         | +              | +          | H        | H              | +              | +              | +            | +         | H         | H           | H            | +              | +        | H              | H            | +        | H           | +              | +              | +            | H        | H      |
| +   | $\Box$         |         | ш            | 1          | Ħ        | П              | 1            | П         | 1       | П              | Ħ              | þ          | Ц           | 1            | H           | $\Box$        | $\bot$         |                | Ħ         | #       | Ħ        | Ц         | $\Box$         |            |          |                | $\Box$         | $\perp$        | 1            |           |           |             | Ц            | $\Box$         | #        | Ħ              | П            | #        | Ц           | $\Box$         | $\Box$         |              |          | Ħ      |
| +++   | +              | +       | H            | +          | Н        | +              | +            | H         | +       | +              | +              | +          | +           | +            | +           | +             | +              | +              | $\forall$ | +       | +        | $^{+}$    | +              | +          | +        | +              | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | +            | +        | +           | +              | +              | +            | +        | +      |
|   | $\Box$         | $\perp$ | Ш            | #          | Ħ        | П              | #            | Ħ         | #       | Ħ              | T.             | I          | Ħ           | T            | Ħ           | Ħ             | $\bot$         |                | Ħ         | $\perp$ | I        | Ħ         | $\Box$         | $\perp$    |          |                | $\Box$         | $\perp$        | #            | ш         |           |             | Ħ            | $\Box$         | 1        |                | Ħ            | $^{\pm}$ | Ħ           | $\Box$         | $\Box$         | $\perp$      |          | Ħ      |
| +++   | 1.1            | +       | ++           | +          | Н        | +              | +            | H         | +       | +              | +              | +          | +           | +            | +           | +             | +              | +              | H         | +       | +        | $^{+}$    | +              | +          | +        | +              | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | $\forall$    | +        | +           | ++             | +              | +            | +        | +      |
| #   | $\top$         | +       | ш            | 1          | Ħ        | Ħ              | 1            | Ħ         | Ţ       | Ħ              |                | t          | П           | 1            | Ħ           | $\Box$        | $\Box$         |                | П         | $^{+}$  | Ħ        | Ħ         | $\Box$         |            |          |                | $\Box$         | $\perp$        | 1            | Ħ         |           |             | Ħ            | $\Box$         | 1        |                | Ħ            | $^{+}$   |             | $\Box$         | $\Box$         | $\perp$      |          | Ħ      |
|   | Н              | -       | $\vdash$     | +          | Н        | +              | +            | Н         | +       | +              | +              | +          | +           | +            | +           | +             | +              | +              | Н         | +       | +        | $^{+}$    | ₩              | +          | +        | +              | +              | +              | +            | +         | +         | +           | H            | +              | +        | +              | $\forall$    | +        | +           | +              | +              | +            | $\vdash$ | +      |
|   |                | +       | 1 1 1        | -          | $\vdash$ | $\top$         | +            | Н         | 1       | П              | $\vdash$       | +          | $\vdash$    | +            | 口           | $\Box$        | $\bot$         |                | Ħ         | #       | Ħ        | Ħ         | П              |            |          |                |                | $\perp$        | $\top$       | $^{++}$   | $\vdash$  | $\vdash$    | +            | +              | +        | $\vdash$       | +            | +        | +           | $\rightarrow$  |                | _            | $\vdash$ |        |
|   |                |         | Ш            | ┸          | ₩        |                | _            |           |         |                | -              | +          | -           |              |             |               | -1 ]           | 1 1 1          | r f       | 1.7     | i 1.     |           |                |            |          |                |                |                |              |           | $\vdash$  | -           | +            | $\rightarrow$  | -        | $\vdash$       | +            | -        | ш           | $\perp$        | ш              | $\perp$      | $\vdash$ |        |
|   |                |         |              | +          | H        | H              | +            | П         | +       | Н              |                | F          |             | Ŧ            | +           | +             | $\neg$         | $\vdash$       | H         | +       | +        | $\forall$ | +              | +          | +        | +              | +              | +              | +            |           |           | Ħ           | Ħ            | H              | Ŧ        | Ħ              | Ħ            |          |             |                |                | +            |          | +      |
|   |                |         |              |            |          |                |              |           | #       |                |                |            |             |              |             |               | $\blacksquare$ |                |           |         |          |           |                |            |          |                |                |                |              |           |           |             |              |                |          |                |              |          |             |                |                |              |          |        |
|   |                |         |              |            |          |                |              |           | +       |                |                |            |             |              |             |               |                |                |           | +       |          |           |                |            |          | #              |                |                |              |           |           |             |              |                |          |                |              |          |             |                |                |              |          |        |
|   |                |         |              |            |          |                |              |           |         |                |                |            |             |              |             |               |                |                |           |         |          |           |                |            |          |                |                |                |              |           |           |             |              |                |          |                |              |          |             |                |                |              |          |        |
|   |                |         |              |            |          |                |              |           |         |                |                |            |             |              |             |               |                |                |           |         |          |           |                |            |          |                |                |                |              |           |           |             |              |                |          |                |              |          |             |                |                |              |          |        |

(f) The formula which relates d and T is

$$d = \frac{1}{2f} \sqrt{\frac{T}{m}}$$

where m is the mass per unit length of the wire and f is the frequency of vibration of the wire.

Use your answer from **(e)** (ii) and the value of f (written on a card) to determine a value for m. Include an appropriate unit with your value.

| <i>m</i> = | <u> </u> |
|------------|----------|

**(g)** State one difficulty that you had when performing the experiment and one improvement that you would make if you had to repeat the experiment.

improvement

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

University of Cambridge International Examinations is part of the University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.

difficulty