1 A student investigates stationary waves with an elastic cord of circular cross-section attached to a load, as shown in Fig. 1.1.

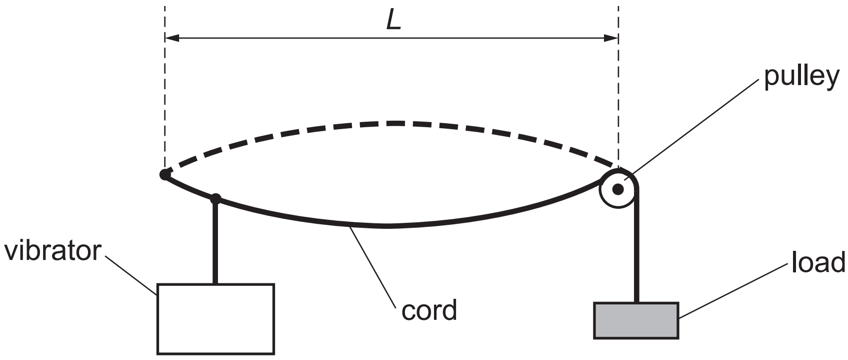


Fig. 1.1

When the frequency of the vibrator is f, the cord vibrates with the stationary wave pattern shown. The student investigates how f varies with the cross-sectional area A of the cord.

It is suggested that the relationship between f and A is

$$f = \frac{1}{2L}\sqrt{\frac{M}{kA}}$$

where L is the distance between the two nodes, M is the mass of the load and k is a constant.

Design a laboratory experiment to test the relationship between f and A.
Explain how your results could be used to determine a value for k.

You should draw a diagram, on page 3, showing the arrangement of your equipment.
In your account you should pay particular attention to:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

2 A student is investigating stationary waves on a stretched elastic cord. A vibrator attached to the cord is connected to a signal generator.

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

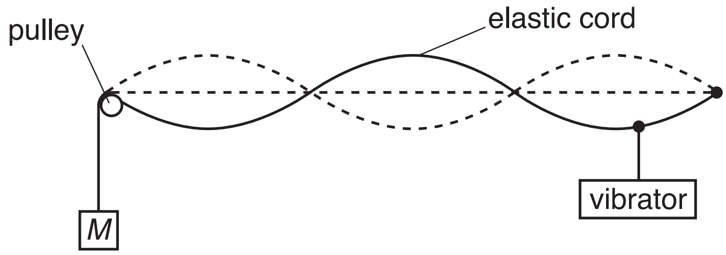


Fig. 2.1

The mass M attached to the cord is adjusted until resonance is obtained. The number n of antinodes on the stationary wave is recorded.

The experiment is repeated with different masses to obtain different values of n.

It is suggested that M and n are related by the equation

$$f = \frac{n}{2L}\sqrt{\frac{Mg}{\mu}}$$

where f is the frequency of the vibrator, g is the acceleration of free fall, L is the length of the elastic cord and μ is the mass per unit length of the elastic cord.

(a) A graph is plotted of M on the y-axis against $\frac{1}{n^2}$ on the x-axis.

Determine an expression for the gradient.

gradient = ... [1]

(b) Values of n and M are given in Fig. 2.2.
The percentage uncertainty in each value of M is ±10%.

n	M/g	$\frac{1}{n^2}$
3	850 ±	
4	500 ±	
5	300 ±	
6	200 ±	
7	150 ±	
8	100 ±	

Fig. 2.2

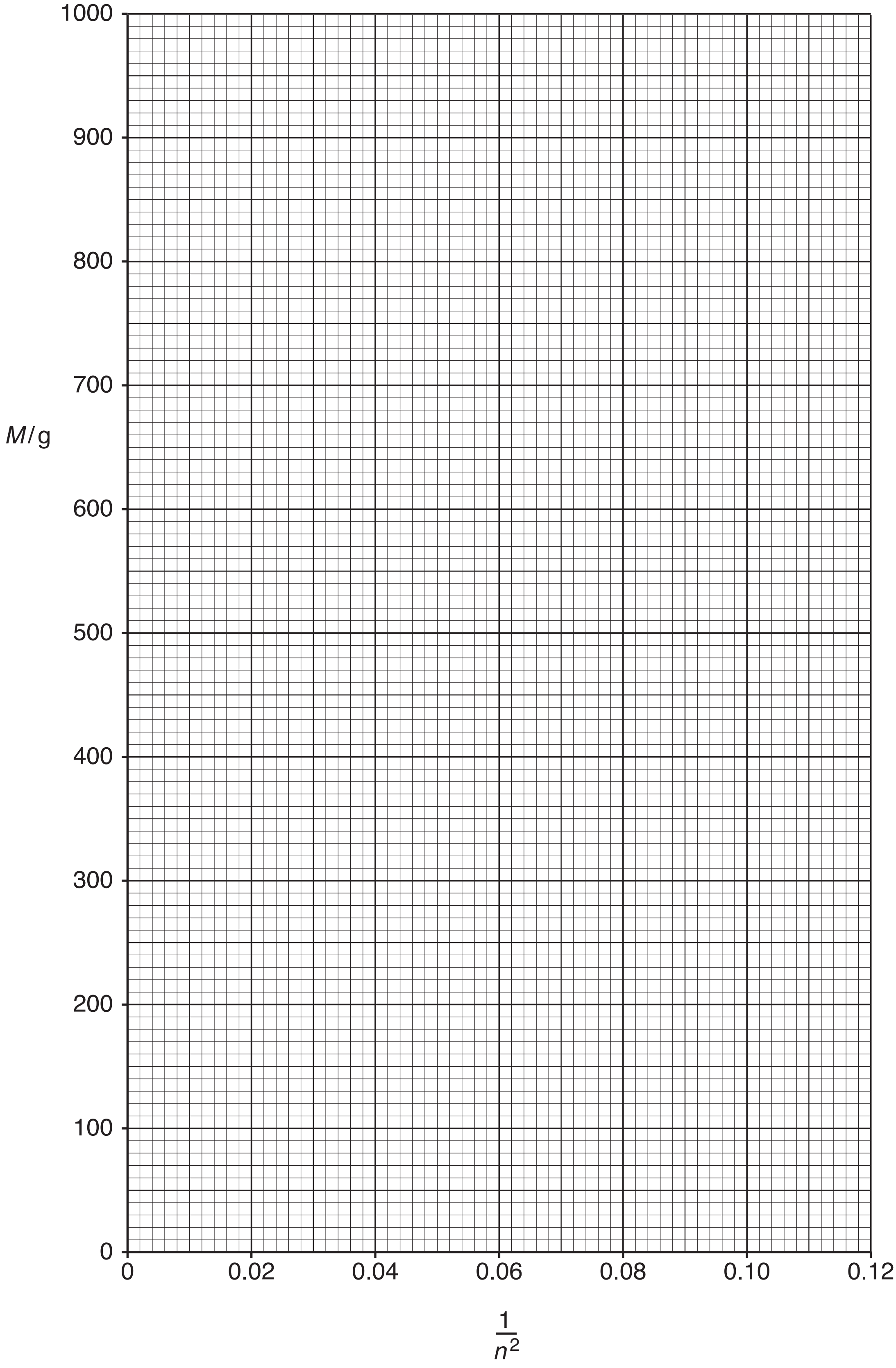
Calculate and record values of $\frac{1}{n^2}$ in Fig. 2.2.
Determine the absolute uncertainties in M. [2]

(c) **(i)** Plot a graph of M/g against $\frac{1}{n^2}$.
Include error bars for M. [2]

(ii) Draw the straight 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 absolute uncertainty in your answer.

gradient = ...[2]


1000
900
800
700
600
500
400
300
200
100
0
M / g
0
0.02
0.04
0.06
0.08
0.10
0.12
$\frac{1}{n^2}$

(d) **(i)** Using your answers to **(a)** and **(c)(iii)**, determine the value of μ. Include an appropriate unit.

Data: $g = 9.81\,\text{m}\,\text{s}^{-2}$, $L = 1.54 \pm 0.01\,\text{m}$ and $f = 120 \pm 5\,\text{Hz}$.

μ = ... [3]

(ii) Determine the percentage uncertainty in μ.

percentage uncertainty in μ = ... % [1]

(e) The experiment is repeated using the same cord. The frequency is changed to $180 \pm 5\,\text{Hz}$. Determine the mass M required to produce a wave with two antinodes. Include the absolute uncertainty in your answer.

M = ... kg [2]

[Total: 15]