For Examiner's Use

4 A student is investigating the motion of a small cube on a turntable connected to an electric motor as shown in Fig. 4.1.

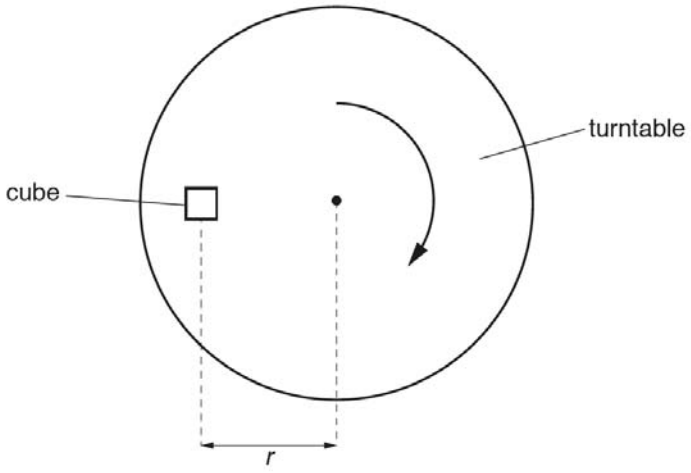

Fig. 4.1

The cube is placed at a distance r from the centre of the turntable. It is suggested that the relationship between r and the maximum frequency f of the turntable for which the cube does not move relative to the turntable is

$$K = 4\pi^2 mfr$$

where m is the mass of the cube and K is a constant.

Design a laboratory experiment to test the relationship between f and r. Explain how your results could be used to determine a value for K. You should draw a diagram 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 variables to be kept constant
- the analysis of the data,
- any safety precautions to be taken.

.

Diagram

For Examiner's Use

……

……

……

……

……

……

……

……

……

……

For Examiner's Use

For Examiner's Use

[12]

For Examiner's Use

4

Defining the problem

A1: identify independent (length *r*) and dependent (frequency *f* of turntable) and keeping mass *m* constant [1]

Comments: using the same cube as the variable to keep constant is not acceptable as the reason for using the same cube i.e. to keep m constant need to be mentioned.

Method of data collection

B1: labelled diagram showing power supply connected to motor (two leads) within turntable; circuit must be workable [1]

B2: method to change frequency of rotation of turntable e.g. adjust output of variable power supply or adjust variable resistor [1]

B3: increase frequency until the cube moves (relative to the turntable) [1]

B4: method to determine the period of rotation of turntable e.g. stopwatch, light gate attached to a timer/data-logger or stroboscope [1]

Comments: Marks will not be awarded if light gate with data logger are not correctly set up for use.

Method of Analysis

C1: plot a graph of *f* against 1 / *r* (allow log *f* against log *r*) [1]
relationship valid if a straight line produced passing through the origin
(for log *f* vs log *r*, straight line of gradient −1)

C2: K = gradient x $4\pi^2 m$ (for log *f* vs log *r*, $K = 10^{\text{y-intercept}} \times 4\pi^2 m$) [1]

Comments: Statement about validity of relationship is often left out or wrongly written.

Safety

D1: to protect against flying cube e.g. use safety screen [1]

Comments: use of googles to protect eyes is not good enough and as the face can also be hurt by flying cube.

Additional details: (max 4)

E1: time of oscillations >= 15.0 s and repeated time measurements and correct determination of period of rotation of turntable or fiducial marker to aid in counting the number of oscillations [1]

Comments: It is important that the time of oscillation be at least 15 s to minimise the random error due to human reaction time, and thus decide on the number of oscillations required.

E2: $f = 1 / T$ or detailed use of stroboscope AND repeat experiment for each r and average f [1]

E3: use balance to measure mass of cube [1]

E4: use a spirit level to check that turntable is horizontal or clean cube/surface [1]

E5: use a ruler to measure r [1]

E6: method to ensure that r is measured to the centre of the cube e.g. put a mark on the cube or align front or back of cube by a set distance [1]

E7: method to determine the centre of the turntable [1]

E8: wait for turntable to rotate steadily before increasing frequency or gradual/incremental/slowly increase in frequency [1]

Independent variable: distance *r* of the mass from the centre of turntable
Dependent variable: frequency *f* of the turntable
Variable to be kept constant: mass *m* of the cube.

Labeled diagram:

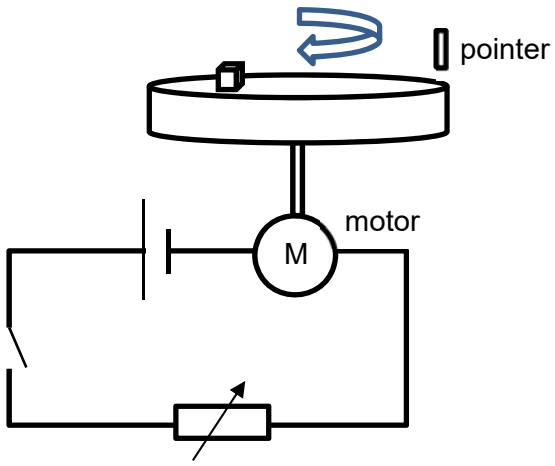

Fig. B

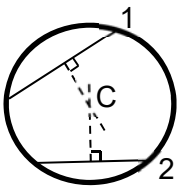

Fig. A

Procedures:

1. Put a mark on the centre of the cube using a marker.
2. Determine the centre of the turntable. This can be done by drawing 2 chords on the turntable. At the mid-point of each chord, draw a perpendicular line using a set-square. This is shown by the dotted lines in Fig. A. The intersection of the dotted lines gives the centre C of the turntable.
3. Set up the apparatus as shown in Fig. B.
4. Use a ruler to measure the distance *r*, from the centre of the cube to the centre of the turntable.
5. When the switch is closed, the cell supplies current to the motor which causes the turntable to rotate. Gradually increase the frequency of rotation by adjusting the variable resistor until the cube moves relative to the turntable.
6. A fiducial marker is used to aid in counting the number of rotations *N* of the pointer on the turntable. Measure the time taken *t* to complete *N* rotations using a stopwatch. The frequency *f* of the turntable can be found using $f = 1 / T = N / t$.
7. Repeat steps 4 to 7 to obtain at least 10 sets of readings for *r* and *f*, until *r* is about the full radius of the turntable.

<u>How to improve accuracy</u>:

1. Ensure that the total time taken to measure the rotations is ≥ 20 s and repeat the measurements.
2. The average *f* is obtained for each value of *r*.
3. Use a spirit level to check that the turntable is horizontal.
4. The mass *m* of the cube is measured using a weighing balance.

<u>Data analysis:</u>

$f = K / 4\pi^2 mr$
Plot a graph of *f* vs 1 / *r*
The relationship is valid if a straight line graph passing through the origin is obtained.
K = gradient x $4\pi^2 m$

<u>Safety Precautions:</u>

1. Use a safety screen or wear googles so that the flying cube does not accidentally hit the eyes.