4 An aluminium ring is placed on a coil with the rod of a metal stand passing through their centres as shown in Fig. 4.1.

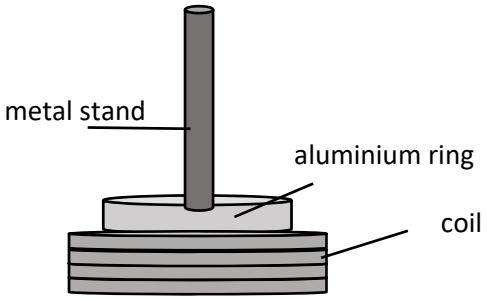

Fig. 4.1

When an alternating current of frequency *f* is applied to the coil of *n* turns per unit length, the ring rises until it is in equilibrium at a height *h* above the coil, as shown in Fig. 4.2.

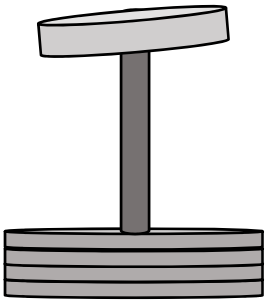

Fig. 4.2

It is suggested that the relationship between *h*, *f* and *n* is

$$h = kn^x f^y$$

*w*here *k, x* and *y* are constants.

Design an experiment to determine the values of *k, x* and *y.*

You should draw a diagram showing the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) the control of variables
(d) how the data would be analysed
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

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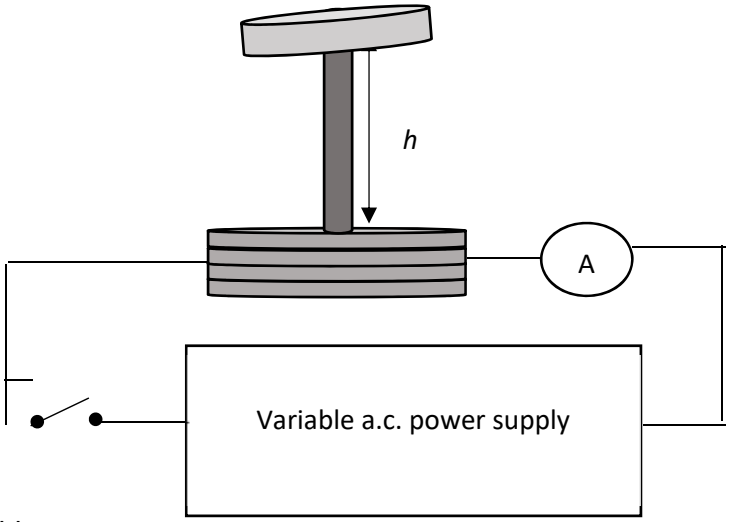
[Total: 12]

4 Planning	
Diagram [Max 1]	
Labelled diagram showing circuit with signal generator / (variable) ac supply, coil, stand and ring *h* must be indicated	**D1**
Basic Procedure [Max 2]	
Vary *n* by changing the number of coils per unit length and measure *h* (while keeping *f* constant) and Vary *f* by adjusting the variable ac supply / signal generator and measure *h* (while keeping *n* constant)	**B1**
Measure *h* after the ring has stabilized	**B1**
Methods and Measurements [Max 2]	
Method of measuring *h*, metre rule	**M1**
Method of measuring *f,* directly reading off signal generator / variable ac supply, or determined from graph shown on CRO	**M1**
Method of measuring *n*, count number of turns and divide by length measured with rule / vernier caliper	**M1**
Controlled Variables [Max 2]	
Keeping *f* constant when varying *n* and keeping *n* constant when varying *f*	**C1**
Ensure current in coil is kept constant by (varying the emf of the variable ac supply and monitoring with an ammeter).	**C1**
Analysis [Max 2]	
Linearise: ln $h = x\ ln(n) + ln(kf^y)$ where *x* is the gradient and ln(kf^y is the vertical intercept) Or ln $h = y\ ln(f) + ln(kn^x)$ where *y* is the gradient and ln(kn^x is the vertical intercept)	**A1**
Explain how *k* is obtained using graphs related to both equations.	**A1**
Further Details [Max 2]	
Perform trials/tests to determine suitable current to ensure measurable *h*. Or Ensure *h* is large enough to reduce uncertainty of *h* by using a large current	**F1**
Repeated readings of *h* to reduce random errors.	**F1**
Ensure surface of rod and ring is smooth to minimise friction between the two objects.	**F1**
Reading off *T* from time base of CRO and $f = 1/T$	**F1**
Coils are coiled to the same diameter	**F1**
Allow coils to cool down between experiments to prevent overheating of coils	**F1**
As height of the ring might fluctuate, take a picture or record a high speed video of the experiment with a ruler right beside the coil to determine the maximum height reached by the ring.	**F1**

Safety [Max 1]	
Wear insulating gloves to prevent electrocution / injury from touching hot coils	**S1**
Wear googles / shield / cap the stand to prevent injury due to ring flying off	**S1**

Sample Answer



1) Independent variable: *n*
   Dependent variable: *h*
   Measure the length of the coil with a pair of vernier calipers and count the number of turns of the coil. *n* can be determined by taking number of turns / length of coil.
2) Set up the experiment as shown in the above diagram.
3) Perform a trial run to determine the suitable voltage/current setting on the a.c power supply to ensure measurable *h*.
4) Turn on the power supply and measure the height, *h*, attained by the ring with a metre rule. Allow the ring to stabilize before measuring the height. Take repeated readings for *h* to reduce random error. Directly read off *f* from the a.c power supply and record the all readings in a table.
5) Repeat the experiment (step 4) to collect 6 sets of data keeping *f* constant but varying *n*. *n* is varied by replacing the existing coil with another coil made of the same material, but coiled to a greater number of turns at the same length.
6) Ensure that the current in the coil is kept constant by monitoring with the ammeter and adjusting the voltage setting on the power supply.
7) $\ln h = y \ln(f) + \ln(kn^x)$
   Plot a graph of $\ln h$ vs $\ln f$ where y is the gradient and $\ln(kn^x)$ is the vertical intercept.
8) Independent variable: *f*
   Dependent variable: *h*
   Repeat the experiment by varying *f* and keeping *n* constant. *f* can be varied by adjusting the a.c power supply. Collect 6 sets of data by adjusting the a.c power supply to vary *f*.

9) $\ln h = x\ ln(n) + ln(kf^y)$

Plot a graph of ln$h$ vs ln$f$ where x is the gradient and ln(kf^y) is the vertical intercept.

Substitute a point on the best fit line, the constant n value, x and y determined from the gradients of the two graphs to the following equation to determine k.

$$\ln k = \frac{\ln h - x \ln n}{y \ln f}$$

$$k = e^{\frac{\ln h - x \ln n}{y \ln f}}$$

10) To ensure safety, wear insulating gloves before touching apparatus to prevent electrocution.