

PLANNING

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe



1 The exact relationship between the temperature of an object and the amount of radiation emitted has been explored by a number of famous physicists. In 1879, the law that describes this relationship was first experimentally discovered Josef Stefan. Shortly later, Ludwig Boltzmann derived it theoretically.

The relationship between the power radiated P_{rad} by an object of temperature T (in kelvin), independently formulated by Stefan and Boltzmann states that

$$P_{\text{rad}} = \epsilon \sigma A T^4$$

where ϵ is the emissivity of the object

σ is the Stefan-Boltzmann constant and

A is the surface area of the object

The emissivity constant depends on the material of the object.

For practical purposes, the net power being radiated is more useful than the absolute radiated power. The net power radiated by an object at temperature T in an environment T_0 is given by

$$P_{\text{net}} = P_{\text{rad}} - P_{\text{absorb}}$$

This leads to

$$P_{\text{net}} = \epsilon \sigma A T^4 - \epsilon \sigma A T_0^4$$

For a given radiating body ϵ , σ and A are constant and if the room temperature T_0 (295K) is much lower than the object's temperature T (ranged from 1500 to 2000K), then P_{rad} is much greater than P_{absorb} . We can then assume that for a given radiating body power radiated is given by

$$P \propto T^4$$

Design a laboratory experiment to investigate how the power P radiated from a tungsten lamp at high temperature varies with its thermodynamic temperature T .

The equipment available includes the following:

- | | |
|-----------------------------------|---------------------------------|
| Leads/ connecting wires | Metre rule |
| 12 V 400 W Tungsten filament bulb | Retort stand, boss and clamp |
| A variable power supply 13 V MAX | Thermocouple |
| Radiation detector | Platinum Resistance thermometer |
| Voltmeter | Rheostat |
| Ammeter | Digital multimeters |

Data showing the temperature dependence of relative resistance for tungsten and resistivity of

tungsten as a function of temperature are provided and are shown in Fig 8.1 and Fig 8.2 respectively.

Fig 8.1: Temperature dependence of relative resistance for tungsten

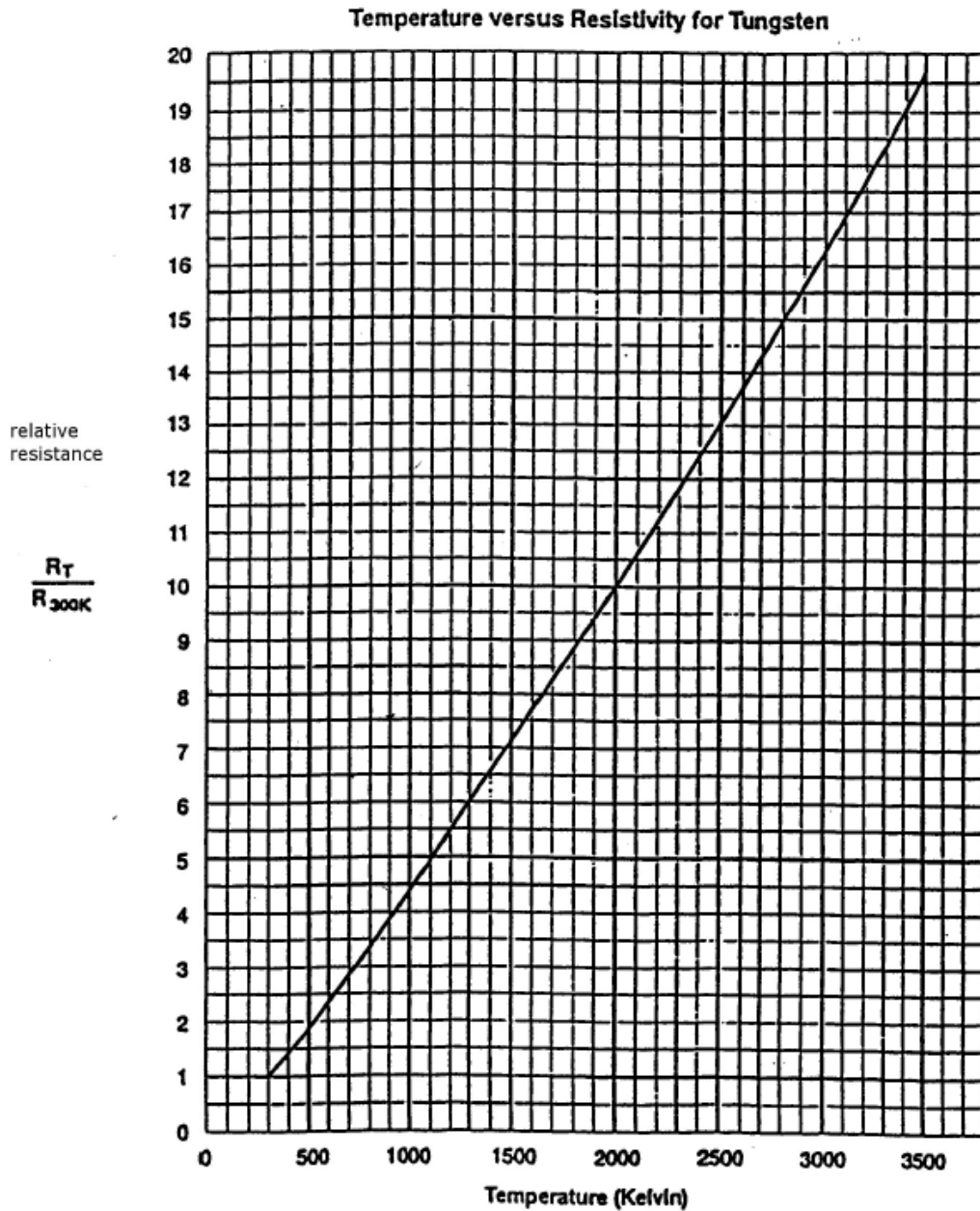


Fig 8.2 Resistivity of tungsten as a function of temperature

R/R_{ref}	Temperature / K	Resistivity / $\square \square \text{ cm}$
1.00	300	5.65
1.43	400	8.06
1.87	500	10.56
2.34	600	13.23
2.85	700	16.09
3.36	800	19.00
3.88	900	21.94
4.41	1000	24.93
4.95	1100	27.94
5.48	1200	30.98
6.03	1300	34.08
6.58	1400	37.19
7.14	1500	40.36
7.71	1600	43.55
8.28	1700	46.78
8.86	1800	50.05
9.44	1900	53.35
10.03	2000	56.67
10.63	2100	60.06
11.24	2200	63.48
11.84	2300	66.91
12.46	2400	70.39
13.08	2500	73.91
13.72	2600	77.49
14.34	2700	81.04
14.99	2800	84.70
15.63	2900	88.33
16.29	3000	92.04
16.95	3100	95.76
17.62	3200	99.54
18.28	3300	103.3
18.97	3400	107.2
19.66	3500	111.1
26.35	3600	115.0

You may also use any of the other equipment usually found in a Physics laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay attention to

- (a) The identification and control of variables,
- (b) the equipment you would use,
- (c) the procedure to be followed,
- (d) how the power radiated from a tungsten lamp could be determined ,
- (e) any precautions that you would take to improve the accuracy and safety of the experiment.

Diagram

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Ans

Basic procedure (2 marks)

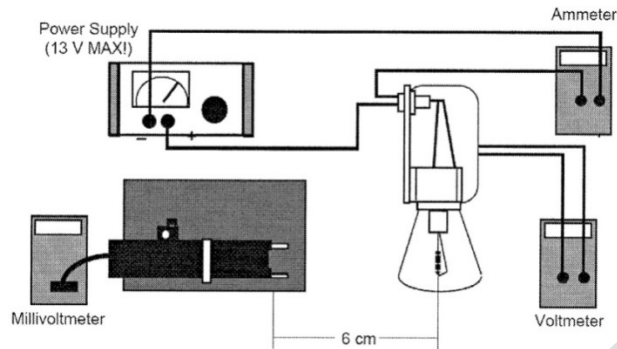
Radiation from lamp directed to radiation sensor

B1

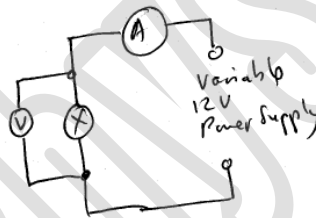
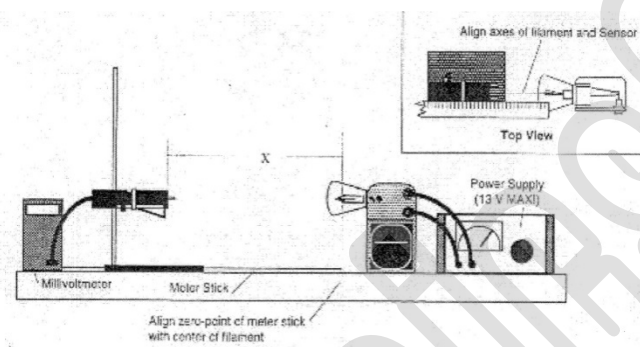
Vary Power/voltage supplied to lamp, find power radiated

B1 (max B2)

Diagram (2 marks)



OR



Sensor connect to DMM (voltmeter) / data logger /-Mentioned radiation meter gives direct reading

D1

Electrical circuit for lamp given (allow use of ohmmeter to measure resistance.)

D1

(max D2)

Measurements (2 marks)

Determination the resistance R and temperature T of the filament

1. For each voltage setting, using the corresponding values of I and V from the ammeter and voltmeter respectively, calculate the corresponding resistance R_T of the filament using $R_T = \frac{V}{I}$

M1

Or mention use of ohmmeter to give readings for each value of PS.

2. Calculate the ratio of $\frac{R_T}{R_{ref}}$; the corresponding temperature T can be determined from the graph of $\frac{R_T}{R_{ref}}$ against T.

Determination of Power Radiated from Bulb

For each T, record readings of Power radiated from the voltmeter which is a measure of the power radiated.

M1

Max 2

Analysis (1 mark)

Assuming that the power P radiated by the filament is proportional to T^n (or $(\frac{R_T}{R_{ref}})^n$) where n is a constant, plot a graph of

$\log P$ against $\log T$ (or $\log (\frac{R_T}{R_{ref}})$) to investigate how P depends on

T . The gradient will give n if a straight line graph is obtained.

A1

(Accept any other suitable analysis including)

(Do not accept if student only mentioned plotting of graph without equation involved)

(Max A1)

Control of variables (1 marks)

Radiation sensor should be kept at a fixed distance from the filament.

C1

Radiation sensor should be set at the same height as the filament.

C1

Alignment of filament with respect to sensor window that is angle of inclination of filament to the vertical should be kept fixed

C1

(Max C1)

Further details (3 marks)

mV range used to measuring o/p from sensor

F1

For each voltage setting of the power supply, be brisk when recording the data points and the sensor readings as lamp will begin to heat up the sensor.

F1

In between readings cover shield the sensor with aluminized foam-core board, with aluminized side facing the bulb.

F1

Remove all other objects in the vicinity of the radiation sensor to ensure that its output is not influenced by extraneous radiation sources.

F1

(Max F3)

Safety (1 mark)

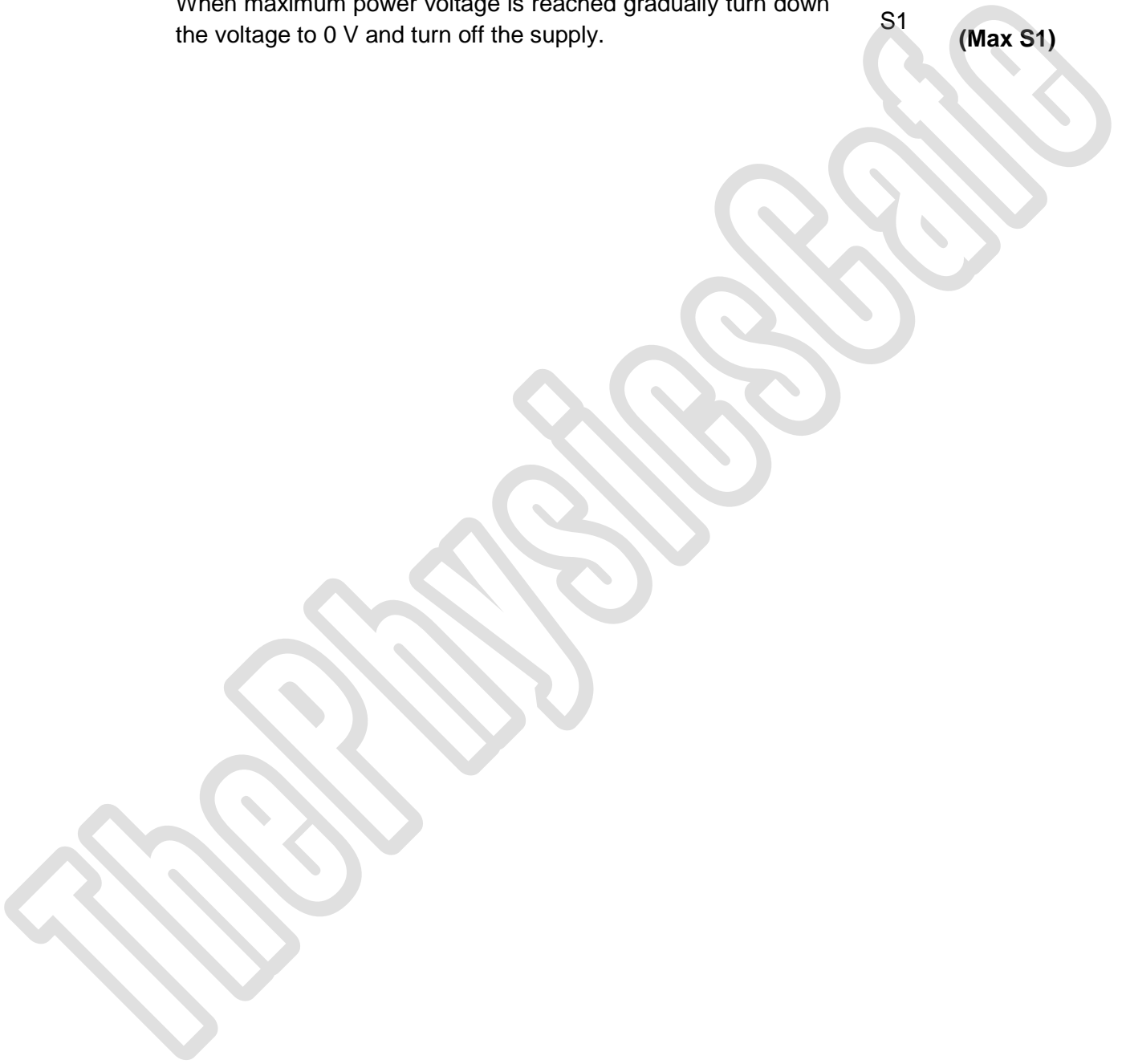
Bulb used in this experiment will cause burns if you touch it; do not move the bulb while it is on, but if necessary move it by the base only. S1

Place bulb on good footing as it is light and could tip over easily. S1

Do not exceed voltages of 12 V or currents of 3 A on the bulb filament. S1

When maximum power voltage is reached gradually turn down the voltage to 0 V and turn off the supply. S1

(Max S1)



- 2 Two flat circular coils carrying current can be used as Helmholtz coils to produce uniform magnetic field between the coils. Fig. 9.1 illustrates the magnetic flux pattern due to the Helmholtz coils.

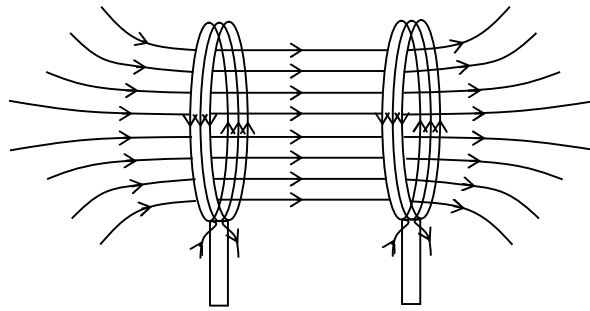


Fig. 9.1

The magnetic flux density B between the Helmholtz coils is thought to depend on the current I in the coils and may be written in the form, $B = kI^n$ where k and n are constants.

You are provided with two flat circular coils. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of n .

You should draw a labeled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

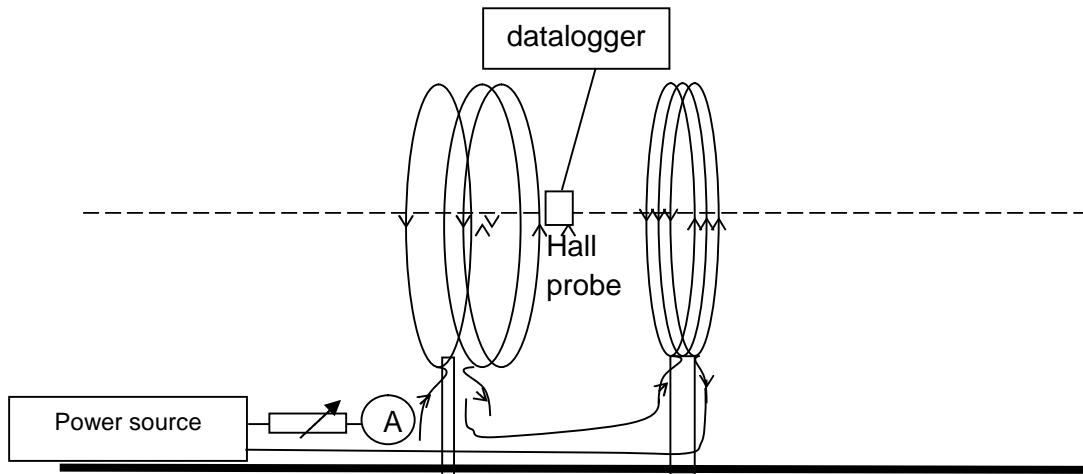
- (a) the identification and control of variables,
- (b) the equipment you would use,
- (c) the procedure to be followed,
- (d) how the magnetic flux density between the Helmholtz coils would be measured,
- (e) any precautions that would be taken to improve the accuracy of the experiment.

Diagram

Ans **Aim**

To investigate how the magnetic flux density B between the 2 circular coils varies with the current I in the coils

Procedure



- 1) Set up the apparatus as shown above.
- 2) Switch on the power source to pass a current through both coils to produce a magnetic field.
- 3) Record the value of I from the ammeter.
- 4) Place the hall probe between the coils. Record the value of the magnetic flux density B from the datalogger.
- 5) Repeat steps 2 to 4 to obtain further values of B for different I by changing the resistance of variable resistor.
- 6) From $B = kI^n \Rightarrow \lg B = n \lg I + \lg k$. Plot a graph of $\lg B$ against $\lg I$. The value of n can be obtained from the gradient of the graph.

Control of variables

- 1) The separation of the 2 coils should be kept constant by using the meter rule to check and adjust the separation before every reading.
- 2) The position of the hall probe between the 2 coils should be kept constant by clamping the hall probe to a fixed position between the coils.

Safety and Accuracy

- 1) The plane of the hall probe should be perpendicular to the magnetic field within the 2 coils.
- 2) The axes of the 2 coils must coincide to ensure that the magnetic field in the region between the 2 coils is uniform.
- 3) The coils are to be close to one another to ensure that the magnetic field between the coils is uniform.
- 4) The position of the hall probe is along the centre axis of the 2 coils and it is equidistant from the coils.
- 5) The range of the current used should be kept small to reduce heating effect in coils by using

the variable resistor.

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- 3 While a bar magnet is dropped vertically through a coil, there will be an induced e.m.f. in the coil. The maximum e.m.f. E is induced as the magnet leaves the coil with speed v . Fig. 6.1 shows the coil wrapped around a vertical plastic tube with a magnet above it. It is suggested that the relation between E and v is

$$E = kv^n$$

where k and n are constants.

[12]

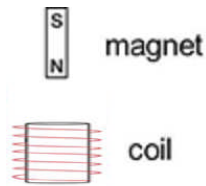


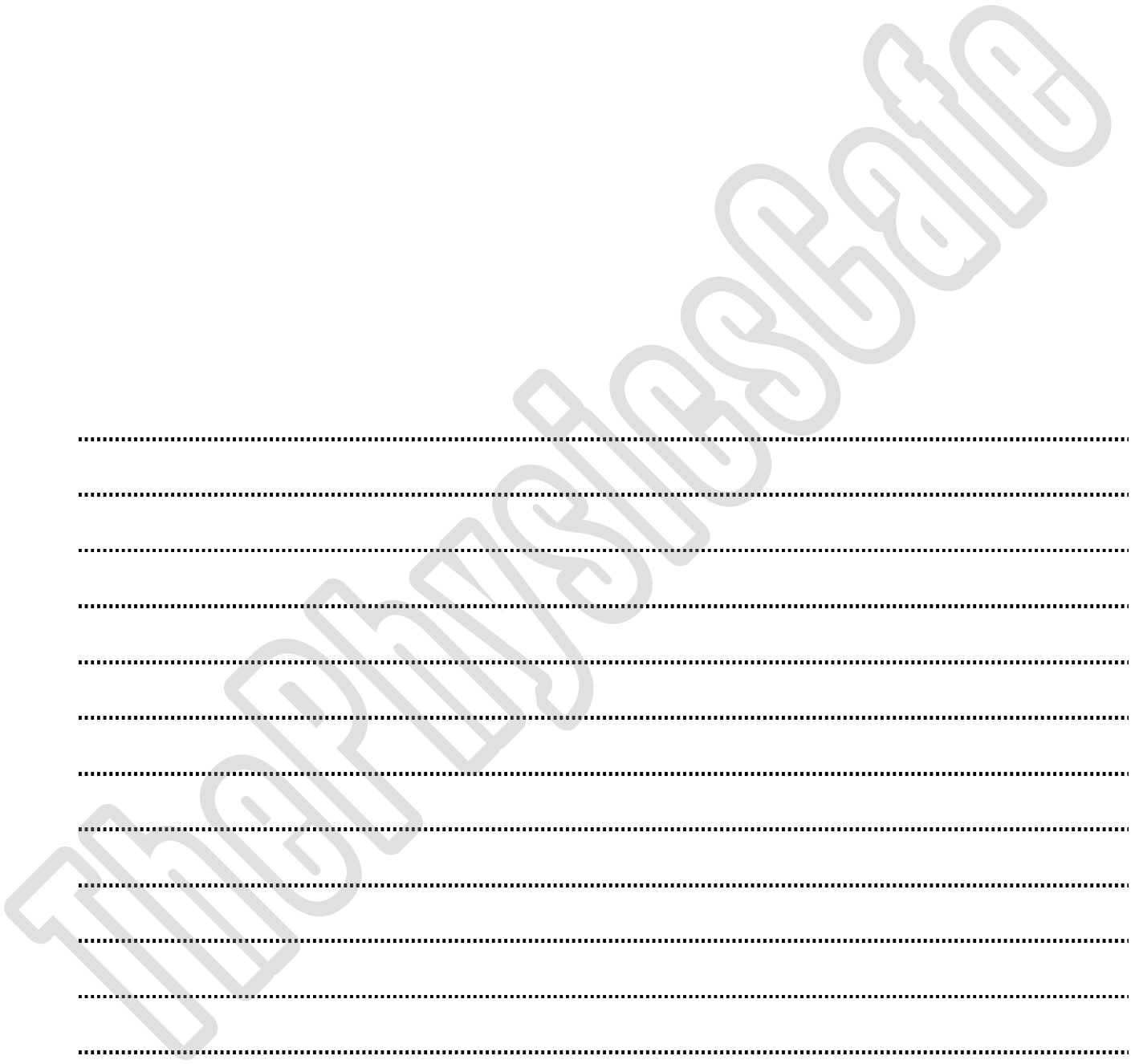
Fig. 6.1

Design an experiment to determine the value of n . You may use any other equipment usually found in a Physics laboratory. You should draw a labelled diagram to show the arrangement of your equipment.

In your account you should pay special attention to

- the equipment you would use,
- the procedure to be followed,
- the control of variables,
- how the speed and induced e.m.f. would be measured,
- any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram



A series of horizontal dotted lines spanning the width of the page, intended for drawing a diagram.

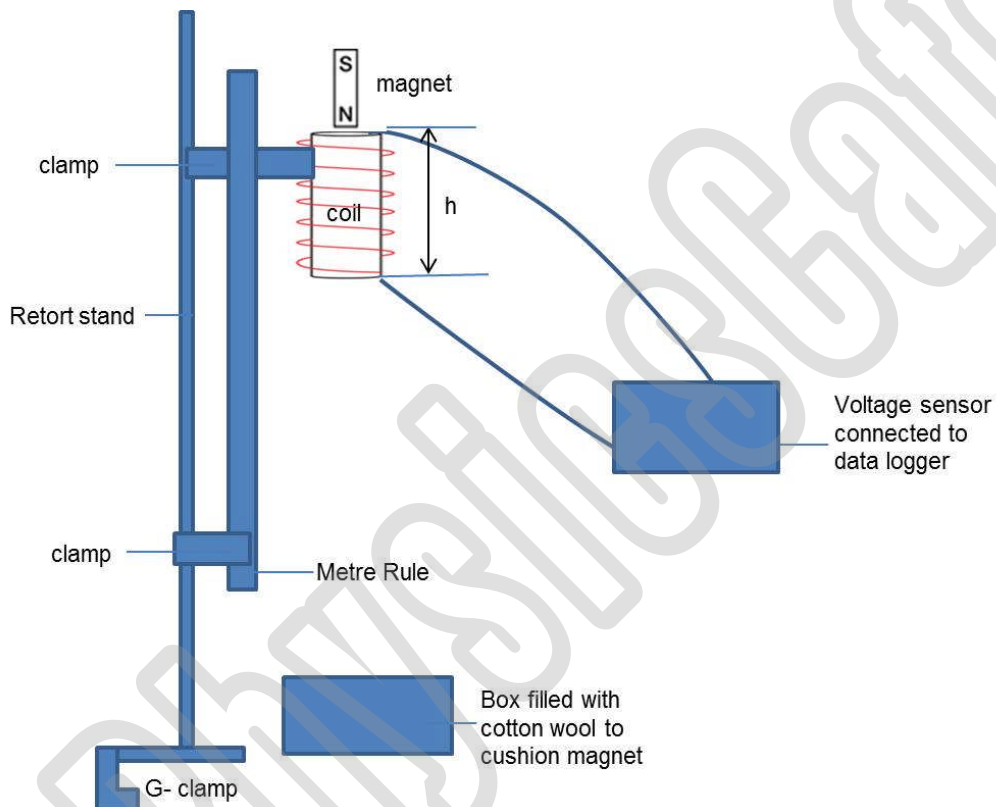
Ans **Defining the problem** (all need to be present for 1 mark)

Speed leaving the coil, v is the independent variable.

Max Induced e.m.f., E is the dependent variable

Keep the number of turns on the coil, N constant.

Diagram (Every component to be labelled)



Methods of data collection

1. Set up the apparatus as shown in the diagram.
2. Connect a voltage sensor to the coil which is connected to a data logger to measure the induced e.m.f. as the magnet falls through the coil.
Alternative: digital multimeter or CRO which can measure the peak value of a varying voltage.
3. Using a metre rule, measure the distance, h , travelled by the magnet from the point of its release till the point it leaves the tube.
4. Using $\frac{1}{2}mv^2 = mgh$ (gain in KE = loss in GPE since magnet is falling), determine the value of v from $v = \sqrt{2gh}$.
Alternative: Motion sensor + data logger. Have to explain how v can be obtained from the data logger.
5. In order to vary the speed v , change the distance h by raising the magnet higher above the tube.

Method of Analysis

1. Plot a graph of $\lg E$ against $\lg v$.
2. Determine the value of n from the gradient of the graph.

Safety:

1. Use a g-clamp to clamp the retort stand to the table so that the set up does not topple over and fall on the experimenter.
or
2. Collect the magnet with a box filled with cotton wool so that the magnet does not fall on the experimenter after passing through the tube.

Additional details:

1. Repeat experiment for each value of v and then find the average.
2. Use same magnet or magnet of same strength to ensure that B-field of magnet is constant.
Alternatively, collecting magnet with cotton to prevent magnet being demagnetised and changing value of B-field.
3. To ensure magnet is vertical when dropping into the coil, use a non-metallic vertical guide to direct orientation of magnet.
4. To ensure coil is vertical, check that the tube is vertical with a spirit level.
5. Use of short magnet so that v is (nearly) constant.