EXPERIMENT 9

AIM

To determine Young's modulus of the material of a given wire by using Searle's apparatus.

APPARATUS AND MATERIAL REQUIRED

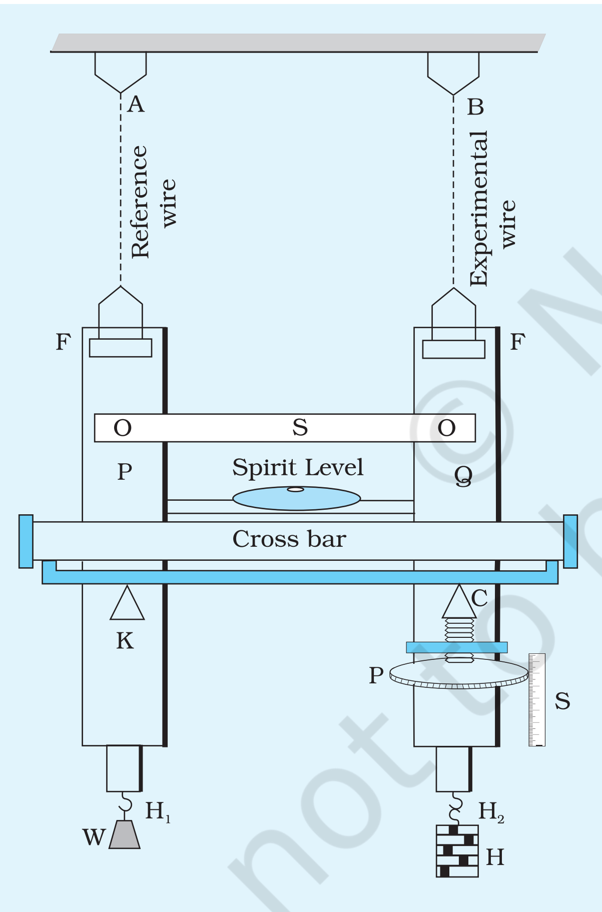

Fig. E 9.1: *Searle's apparatus for determination of Y*

Searle's apparatus, slotted weights, experimental wire, screw gauge and spirit level.

SEARLE'S APPARATUS

It consists of two metal frames P and Q hinged together such that they can move relative to each other in vertical direction (Fig. E9.1).

A spirit level is supported on a rigid crossbar frame which rests on the tip of a micrometer screw C at one end and a fixed knife edge K at the other. Screw C can be moved vertically. The micrometer screw has a disc having 100 equal divisions along its circumference. On the side of it is a linear scale S, attached vertically. If there is any relative displacement between the two frames, P and Q, the spirit level no longer remains horizontal and the bubble of the spirit level is displaced from its centre. The crossbar can again be set horizontal with the help of micrometer screw and the spirit level. The distance through which the screw has to be moved gives the relative displacement between the two frames.

The frames are suspended by two identical long wires of the same material, from the same rigid horizontal support. Wire B is called the experimental wire and wire A acts as a reference wire. The frames, P and Q, are provided with hooks H_1 and H_2 at their lower ends from which weights are suspended. The hook H_1 attached to the reference wire carries a constant weight W to keep the wire taut.

To the hook H_2 is attached a hanger on which slotted weights can be placed to apply force on the experimental wire.

PRINCIPLE

The apparatus works on the principle of Hookes' Law. If l is the extension in a wire of length L and radius r due to force F (=Mg), the Young's modulus of the material of the given wire, Y, is

$$Y = \frac{MgL}{\pi r^2 l}$$

PROCEDURE

1. Suspend weights from both the hooks so that the two wires are stretched and become free from any kinks. Attach only the constant weight W on the reference wire to keep it taut.
2. Measure the length of the experimental wire from the point of its support to the point where it is attached to the frame.
3. Find the least count of the screw gauge. Determine the diameter of the experimental wire at about 5 places and at each place in two mutually perpendicular directions. Find the mean diameter and hence the radius of the wire.
4. Find the pitch and the least count of the miocrometer screw attached to the frame. Adjust it such that the bubble in the spirit level is exactly in the centre. Take the reading of the micrometer.
5. Place a load on the hanger attached to the experimental wire and increase it in steps of 0.5 kg. For each load, bring the bubble of the spirit level to the centre by adjusting the micrometer screw and then note its reading. Take precautions to avoid backlash error.
6. Take about 8 observations for increasing load.
7. Decrease the load in steps of 0.5 kg and each time take reading on micrometer screw as in step 5.

OBSERVATIONS

Length of the wire (L) = ...

Pitch of the screw gauge = ...

No. of divisions on the circular scale of the screw gauge = ...

Least count (L.C.) of screw gauge = ...

Zero error of screw gauge = ...

Table E 9.1: Measurement of diameter of wire

S. No.	Reading along any direction			Reading along perpendicular direction			Mean diameter $d = \frac{d_1 + d_2}{2}$ (cm)
	Main scale reading S (cm)	Circular scale reading n	Diameter $d_1 = S + n \times$ L.C.	Main scale reading S (cm)	Circular scale reading n	Diameter $d_2 = S + n \times$ L.C. (cm)	
1							
2							
3							
4							
5							

Mean diameter (corrected for zero error) = ...

Mean radius = ...

MEASUREMENT OF EXTENSION *l*

Pitch of the micrometer screw = ...

No. of divisions on the circular scale = ...

Least count (L.C.) of the micrometer screw = ...

Acceleration due to gravity, g = ...

Table E 9.2: Measurement of extension with load

S. No.	Load on experimental wire M (kg)	Micrometer reading		Mean reading $\frac{x + y}{2}$ (cm)
		Load increasing x (cm)	Load decreasing y (cm)	
1	0.5			a
2	1.0			b
3	1.5			c
4	2.0			d
5	2.5			e
6	3.0			f
7	3.5			g
8	4.0			h

CALCULATION

Observations recorded in Table E 9.2 can be utilised to find extension of experimental wire for a given load, as shown in Table E 9.3.

Table E 9.3: Calculating extension for a given load

S. No.	Load (kg)	Mean extension (cm)	Load (kg)	Mean extension (cm)	Extension l for 1.5 kg
1.	0.5	(a)	2.0	(d)	d – a
2.	1.0	(b)	2.5	(e)	e – b
3.	1.5	(c)	3.0	(f)	f – c

$$\therefore \text{Mean } l = \frac{(a-d)+(b-c)+(c-f)}{3}$$

$$= \ldots \text{ cm for 1.5 kg}$$

Young's modulus, Y, of experimental wire $Y = \dfrac{MgL}{\pi r^2 l} = \ldots \mathrm{N/m^2}$

GRAPH

The value of Y can also be found by plotting a graph between l and Mg. Draw a graph with load on the x-axis and extension on the y-axis. It should be a straight line. Find the slope $= \dfrac{\Delta l}{\Delta M}$ of the line. Using this value, find the value of Y.

RESULT

The Young's modulus Y of the material of the wire

(using half table method) $= Y \pm \Delta Y \ \mathrm{N/m^2}$

(using graph) $= Y \pm \Delta Y \ \mathrm{N/m^2}$

ERROR

Uncertainty, ΔM, in the measurement of M can be determined by a beam/physical balance using standard weight box/or by using water bottles of fixed capacity.

Find the variation in M for each slotted weight of equal mass say ΔM_1 and ΔM_2. Find the mean of these ΔM. This is the uncertainity (ΔM) in M.

ΔL – the least count of the scale used for measuring L.

Δr – the least count of the micrometer screw gauge used for measuring r.

Δl – least count of the device used for measuring extension.

PRECAUTION

1. Measure the diameter of the wire at different positions, check for its uniformity.
2. Adjust the spirit level only after sufficient time gap following each loading/unloading.

SOURCES OF ERROR

1. The diameter of the wire may alter while loading.
2. Backlash error of the device used for measuring extension.
3. The nonuniformity in thickness of the wire.

DISCUSSION

Which of the quantities measured in the experiment is likely to have maximum affect on the accuracy in measurement of Y (Young's modulus).

SELF ASSESSMENT

1. If the length of the wire used is reduced what will be its effect on
   (a) extension on the wire and (b) stress on the wire.
2. Use wire of different radii (r_1, r_2, r_3) but of same material in the above experimental set up. Is there any change in the value of Young's modulus of elasticity of the material? Discuss your result.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Repeat the experiment with wires of different materials, if available.
2. Change the length of the experimental wire, of same material and study its effect on the Young's modulus of elasticity of the material.