PROJECT 9

AIM

To study of the spring constant of a helical spring from its load-extension graph.

APPARATUS AND MATERIAL REQUIRED

Helical spring with a pointer attached at its lower end and a hook/ring for suspending a hanger; a rigid support/clamp stand; five or six slotted masses (known) for hanger; a metre scale.

PRINCIPLE

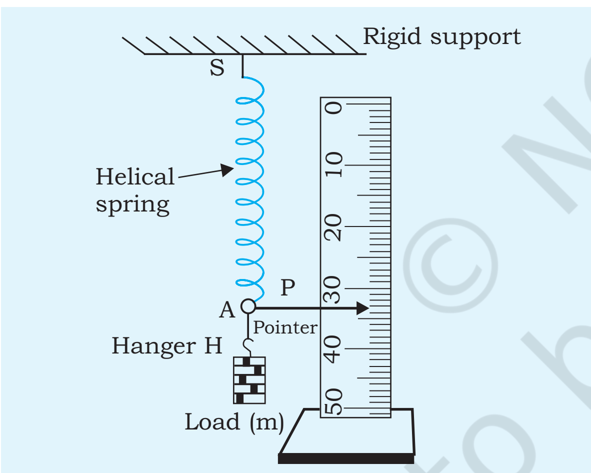

Fig. P 9.1: *Measurement of extension of a helical spring due to a load*

When an external force is applied to a body, the shape of the body changes or deformation occurs in the body. Restoring forces (having magnitude equal to the applied force) are developed within the body which tend to oppose this change. On removing the applied force, the body regains its original shape.

For small changes in length (or shape/dimensions) of a body (wire), within the elastic limit, the magnitude of the elongation or extension is directly proportional to the applied force (Hooke's law).

Following Hooke's law, the spring constant (or force constant) of a spring is given by

$$\text{Spring constant, } K = \frac{\text{Restoring force, } F}{\text{Extension, } x} \quad \text{(P 9.1)}$$

Thus, the spring constant is the restoring force per unit extension in the spring. Its value is determined by the elastic properties of the spring. A given load is attached to the free end of the spring which is suspended from a rigid point support (a nail fixed to a wall). A load (slotted weight) is placed in the hanger and the spring gets extended/elongated due to the applied force. By measuring the extensions, produced by the forces applied by different loads (slotted mass) in the spring and plotting the load (force) extension graph, the spring constant of the spring can be determined.

PROCEDURE

1. Suspend the helical spring, SA, having a pointer, P, at its lower free end, A, freely from a rigid point support, as shown in Fig. P 9.1.
2. Set the metre scale close to the spring vertically. Take care that the pointer moves freely over the scale without touching it and the tip of the pointer is in front of the graduations on the scale.
3. Find out the least count of the metre scale. It is usually 1 mm or 0.1 cm.
4. Record the initial position of the pointer on the metre scale, without any slotted mass suspended from the hook.
5. Suspend the hanger, H (of known mass, say 20 g) from the lower free end, A, of the helical spring and record the position of the pointer, P on the metre scale.
6. Put a slotted mass on the hanger gently. Wait for some time for the load to stop oscillating so as to attain equilibrium (rest) position, or even hold it to stop. Record the position of the pointer on the metre scale. Record observations in a table with proper units and significant figures.
7. Put another slotted mass on the hanger and repeat Step 6.
8. Keep on putting slotted masses on the hanger and repeat Step 6. Record the position of the pointer on the metre scale every time.
9. Compute the load/force $F\,(=\ mg)$ applied by the slotted mass, M and the corresponding extension (or stretching), x in the helical spring. Here g is the acceleration due to gravity at the place of the experiment.
10. Plot a graph between the applied force F along x-axis and the corresponding extension x (or stretching) on the y-axis. What is the shape of the curve of the graph you have drawn?
11. If you find that the force-extension graph is a straight line, find the slope (F/x) of the straight line. Find out the spring constant K of helical spring from the slope of the straight line graph.

OBSERVATIONS

Least count of the metre scale= ... mm= ... cm

Mass of the hanger = ... g

Table P 9.1: Computing spring constant of the helical spring

S. No.	Mass suspended from the spring, *M*	Force, $F = mg$	Position of the pointer	Extension, x	Spring constant, K (= F/x)
	(10^{-3} kg)	(N)	(cm)	(10^{-2} m)	(N m^{-1})
1	0				
2	20				
3	.				
4	.				
5	.				
6	.				
.	.				
.	.				
.	.				
.	.				

Mean Spring constant K = ... N/m

Plotting load - extension graph for a helical spring

Take force, F along the x-axis and extension, x along the y-axis. Choose suitable scales to represent F and x. Plot a graph between F and x (as shown in Fig. P 9.2). Identify the shape of the load-extension graph OA.

CALCULATIONS

Choose two points, O and A, wide apart on the straight line OA obtained from load extension graph, as shown in Fig. P 9.2. From the point A, draw a perpendicular AB on x-axis. Then, from the graph,

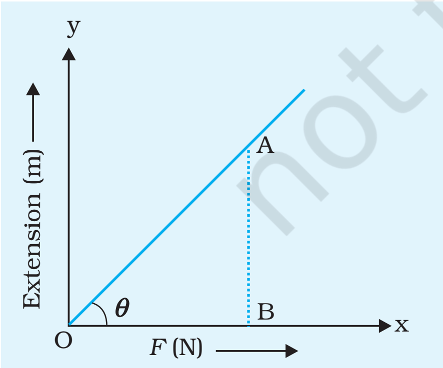

Fig. P 9.2: *Load-extension graph for a helical spring*

$$\text{Slope of the straight line graph} = \tan\theta = \frac{AB}{OB} = x/F$$

$$\text{Spring constant, } K = \frac{F}{x} = \frac{1}{\text{(slope of the graph)}}$$

$$\text{Spring constant, } K = \frac{OB}{AB} = \frac{F_B - F_O}{x_A - x_B} = \ldots \text{Nm}^{-1}$$

where x_A and x_B are the corresponding extensions at points A and B (or O) respectively where F_B and F_O are the loads (forces) at points B and O.

RESULT

The spring constant of the given helical spring = ... Nm^{-1}

PRECAUTIONS

1. The spring should be suspended from a rigid support and it should hang freely so that it remains vertical.
2. Slotted weights should be chosen according to elastic limit of the spring.
3. After adding or removing the slotted weight on the hanger, wait for sometime before noting the position of the pointer on the scale because the spring takes time to attain equilibrium position.

SOURCES OF ERROR

1. If support is not perfectly rigid, some error may creep in due to the yielding of the support.
2. The slotted weights may not be standard weights.

DISCUSSION

1. A rigid support is required for suspending the helical spring with load (or slotted mass) from it. The slotted masses may not have exact values engraved on them. Some error in the extension is likely to creep in due to the yielding (sometimes) of the support and inaccuracy in the values of the masses of loads.
2. The accuracy of the result depends mainly on the measurement of extension produced by the force (load) within the elastic limit. Take special care that the slotted mass is put gently on the hanger as the wire of the helical spring takes sometime to attain its new-equilibrium position.
3. If the elastic limit is crossed slightly, what changes will you expect in the spring and your result?

SELF ASSESSMENT

1. Two springs A (of thicker wire) and B (of thinner wire) of the same material, loaded with the same mass on their hangers, are suspended from a rigid support. Which spring would have more value of spring constant?
2. Soft massive spring of mass M_s and spring constant K has extension under its own weight. What mass correction factor for

the extension in the spring would you suggest when a mass, M is attached at its lower end?

[**Hint:** Extension X_m of the spring of mass M_s with the mass M attached at its lower end would be $X_m \frac{F}{K} = (M + \frac{M_s}{2})(\frac{g}{K})$]

3. What other factors affect spring constant, e.g. length.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Take spring of the same material but of different diameters of the wires. See how the spring contant varies.
2. Take springs of the same diameters of the wires but of different materials. See how the spring constant varies. What inference do you draw from your result?