ACTIVITY 13

AIM

To study the effect of load on depression of a suitably clamped metre scale loaded (i) at its end; and (ii) in the middle.

A. Bending of a metre scale loaded at its end

APPARATUS AND MATERIAL REQUIRED

Metre scale (or a thick wooden strip of about 1 m length), thread, slotted weights with hanger (10 g, 20 g, 50 g, 100 g), another graduated scale to be used to measure depression, a pin, cellotape and clamp.

THEORY

The depression 'y' of a cantilever of length 'L' clamped at one end and loaded at the free end with a load M (weight Mg) is given by relation

$$y = \frac{MgL^3}{3Y(bd^3/12)}$$

where L, b and d are length, width and thickness of the rectangular cantilever respectively and Y is the modulus of elasticity of the material of the rod.

or $$y = \frac{4MgL^3}{Ybd^3}$$

The readings of depression 'y' of the cantilever, in this case with variation of load suspended at the other end, are taken. The variation of depression with load is expected to be linear.

PROCEDURE

1. Clamp the metre scale firmly to the edge of the table. As shown in Fig. A 13.1 ensure that the length and breadth of the scale are in horizontal plane and 90 cm of the length of the scale is projected out. Fix a pin with a tape at the free end of the metre scale along its length to act as a pointer.

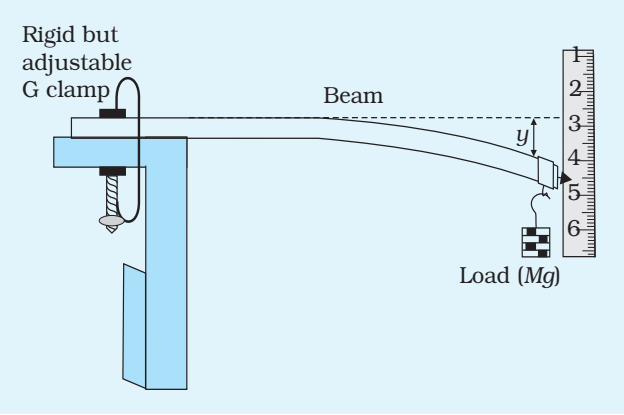

Fig. A 13.1: *Experimental set up to study depression of metre scale (used as cantilever) with load suspended at free end of the cantilever*

2. Fix a graduated scale vertically near the free end of the clamped metre scale and note its least count. Ensure that the pointed end of the pin is just above the graduation marks of the scale but do not touch it.
3. Read the pointer 'p' when metre scale cantilever is without any load.
4. Suspend a hanger of known mass for keeping slotted weights to depress the free end of the cantilever.
5. Read the pointer on vertical scale and record the observation.
6. Keep on adding 20 g masses to the hanger and record the reading of the pointer everytime when it stops vibrating.
7. After taking 6-7 observations with increasing load, gradually remove the slotted weights one by one and record the reading while unloading.
8. Plot a graph between the depression and the load.

OBSERVATIONS

Length of the cantilever L = ... cm

Width of the metre scale cantilever b = ... cm

Thickness of the metre scale d = ... cm

Reading of the free end of the cantilever with no load, l_0=

Table A 13.1: Effect of load on depression of cantilever

S. No.	Load M (g)	Reading of free end of cantilever			Depression $y = l_m - l_o$
		l_1 (cm) when load is increasing	l_2 (cm) when load is decreasing	Mean $l_m = \frac{l_1 + l_2}{2}$ (cm)	
1					
2					
3					
4					
5					
6					
7					

RESULT

The depression 'y' is directly proportional to the load M.

PRECAUTIONS

1. The beam should be rigidly clamped at one end.
2. Loading and unloading of the slotted weights should be done carefully without disturbing the position of the hanger on the beam.
3. The vertical scale should be adjusted close to the pointer in such a way that the pointer moves along it freely.

SOURCES OF ERROR

1. The scale should not be loaded beyond its elastic limit.

   (This can be easily checked by comparing the zero load reading after removing the maximum suspended load with that taken at the beginning of the experiment).
2. There should be no vibratory motion of the beam when reading is recorded.
3. While noting down the observation, the eye should be normal to the tip of the pin and the graduated scale.
4. Observations should be repeated while removing masses.

B. Bending of metre scale loaded in the middle

APPARATUS AND MATERIAL REQUIRED

Metre scale, two wedges to rest the ends of the metre scale, thread, slotted weights 200 g each, hanger for slotted weights, a graduated scale with a stand to hold the scale vertical, a plane mirror, a pointer and plasticine.

DESCRIPTION OF THE DEVICE

Fig. A 13.2 shows the arrangement. A horizontal metre scale is held on two wedges, a hanger is provided at the middle of the metre scale for applying load. A pointer is fixed at the mid point to measure the dipression. A graduated (least count 1 mm) scale with a plane mirror strip attached to it is held in vertical position in a stand behind the horizontal metre scale.

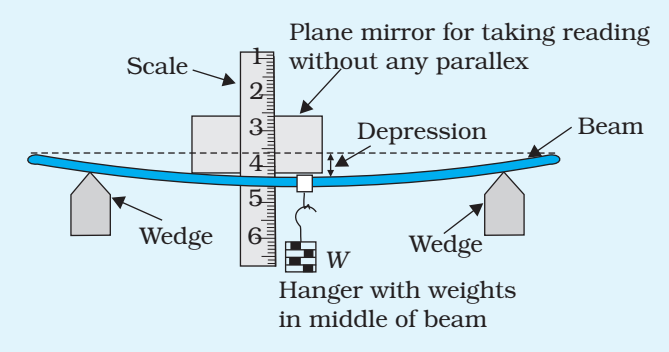

Fig. A 13.2: *Experimental set up to study depression, i.e., sag of a beam with load in the middle*

THEORY

Let a beam be loaded at the centre and supported near its ends as shown in Fig A 13.2. A bar of length '*L*', breadth '*b*' and thickness '*d*' when loaded at the centre by a load '*W*' sags by an amount given by

$$y = \frac{W l^3}{4 b d^3 Y}$$

where '*Y*' is the Young's modulus of the material of the rod/ beam, *W*, the load (= mg), where 'm' is the mass of the hanger with weights.

The depression '*y*' is directly proportional to the load.

PROCEDURE

1. Place the metre scale on two wedges with (5–10 cm) length projecting out on either side. Metre scale supported at both ends is like a beam.
2. Tie a loop of thread in the middle of the load such that a hanger to support slotted weights each of 200 g can be suspended on it. Ensure that the thread is tied tightly with the rod and does not slip.
3. Place a graduated scale (with least count 0.1 cm) vertically in a stand at the centre of the metre scale used as beam. To facilitate readings the vertical scale should be kept on the far side of the metre scale. Fix a pin to the hanger such that its pointed end is close to the edge of the vertical scale which has graduation marks on it.
4. Suspend the hanger of mass 200 g and record the position of the pointer fixed to the hanger. The mirror strip on the vertical scale should be used to remove any parallax.

5. Keep on adding 200 g slotted masses to the hanger and record the readings of the pointer each time.
6. Take about six observations.
7. Now, remove masses of 200g one by one recording the position of the pointer each time while unloading.
8. Calculate the depression for the load M gram and hence depression per unit load.
9. Plot a graph between the values of depression y against corresponding values of load and interpret the result.

OBSERVATIONS

Width of the beam, b =

Thickness of the beam, d =

Length of the beam between the wedges, L =

Table A 13.2 Depression of the beam for different loads

S. No.	Load M (g)	Reading of the centre of cantilever			Depression for load M (g), y (cm)	Depression per unit load y/M (cm/g)	Mean y/M (cm/g)
		Load increasing r_1' (cm)	Load decreasing r_2' (cm)	Mean reading $r = \frac{r_1' + r_2'}{2}$ (cm)			
1	0			r_0	0		
2	200			r_1	$r_1 - r_0$		
3	400			r_2	$r_2 - r_0$		
4							
5							
6							

RESULT

The depression of the metre scale at its middle is ... mm/g. The depression 'y' is directly proportional to the load M.

SOURCES OF ERROR

1. The rod should not be loaded beyond elastic limit.

2. There should be no vibratory motion of the rod when reading is recorded.
3. While taking readings, the eye should be normal to tip of the pointer and the metre scale.
4. The beam should be of uniform thickness and density throughout its length.
5. The masses used must have standard value as engraved on them.

PRECAUTIONS

1. The beam should be symmetrical on the knife edges.
2. Loading and unloading of the slotted weights should be done carefully without disturbing the centre point.
3. Mirror strip used to eliminate parallax error should not disturb the experimental setup.