EXPERIMENT No. 5

(To be performed by group of 4-5 students)

1.0 Title :

Design and draw mechanical levers for given load.

2.0 Prior concepts:

Type of mechanical levers used in machines.

Types of stresses induced.

Knowledge of engineeringmechanics.

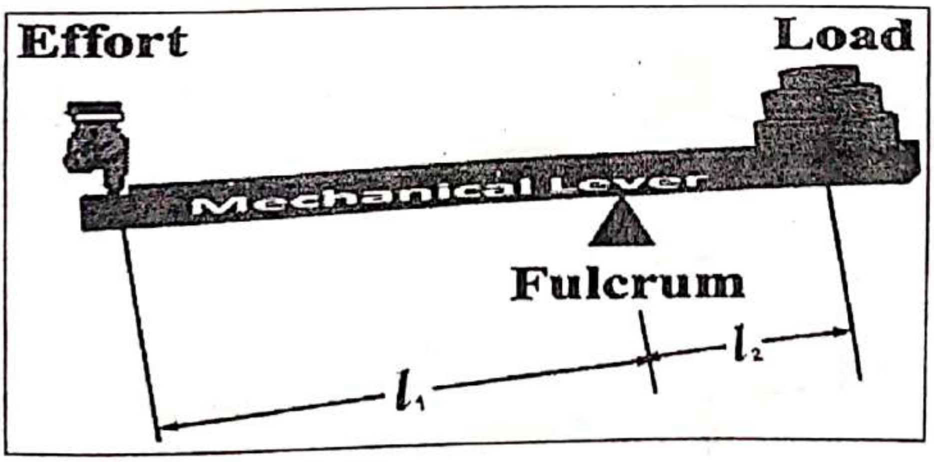
3.0 New concepts :

Proposition 1:Lever

It is rigid rod or bar capable of turning about a fixed point called fulcrum to multiply or transfer the force.

Concepts Structure:

Rigid rod or Bar	+	Turning about Fulcrum	+	To multiply or Transfer the force	=	Mechanical Lever



The construction of simple lever is as shown in above figure.

Where: F = Load.

P = Effort applied to lever.

l_1 = Perpendicular distance of the line of action of effort to fulcrum (or effort arm)

l_2 = Perpendicular distance of the line of action of load to fulcrum (or load arm)

Taking moment about fulcrum

$$F \times l_2 = P \times l_1$$

$$\frac{F}{P} = \frac{l_1}{l_2}$$

The ratio of load to effort i.e. (F/P) is called the **"mechanical advantage"**

The ratio of effort arm to load arm (l_1/l_2) is called **"leverage"**

Proposition 2: Types of levers

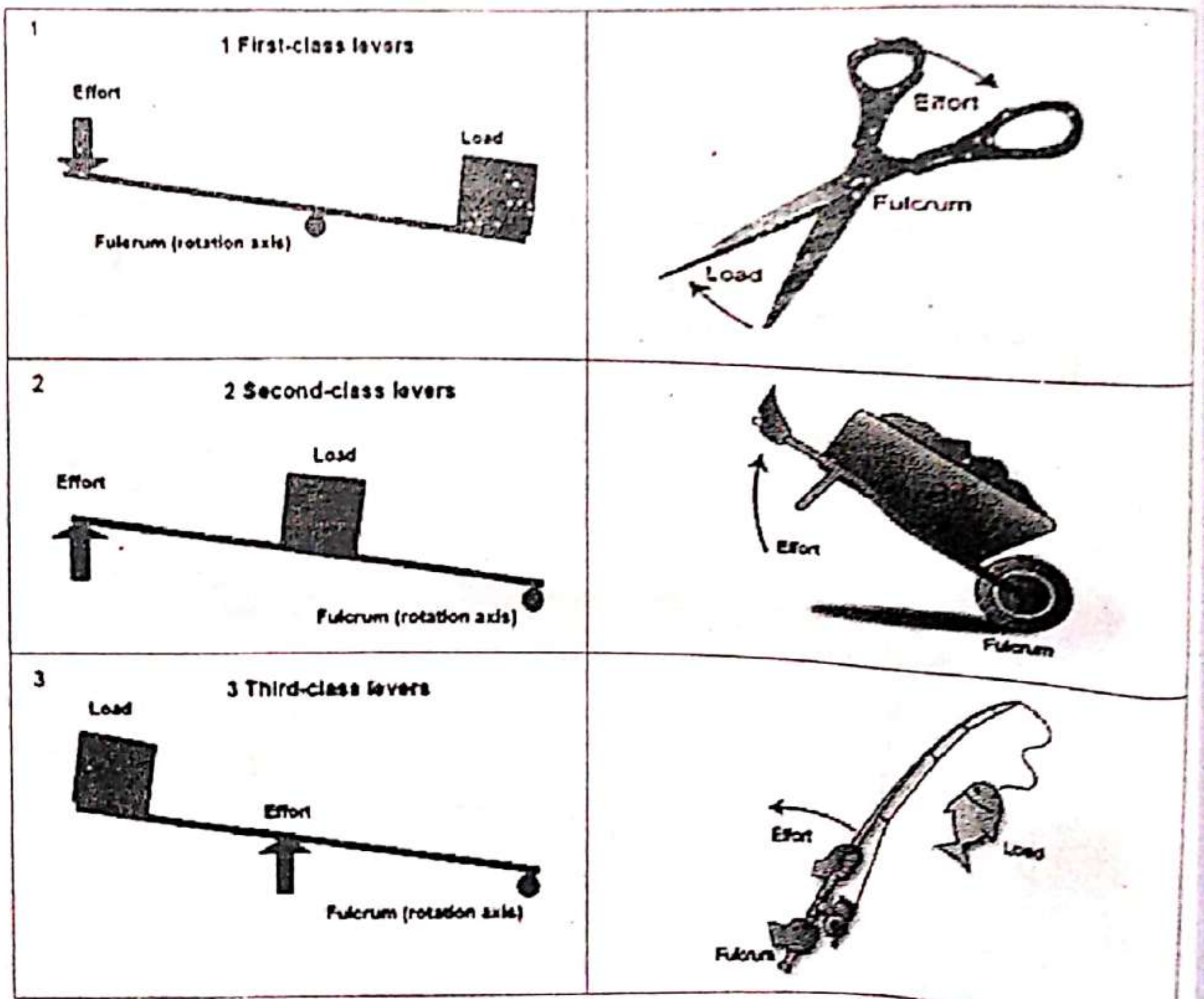
Levers are classified in three types depending upon the relative position of the effort point, the load point and the fulcrum. There are three types

Type 1: Those where the **fulcrum is placed between the effort and the load.**

Type 2: Those where the **load is placed between the fulcrum and the effort.**

Type 3: Those where the **effort is placed between the fulcrum and the load.**

Concepts Structure:



Applications of lever:

- **Type 1:** Pliers, Bell crank lever in railway signal mechanism.
- **Type 2:** Lever operated safety valve used in boilers. Nut cracker, Wheel barrow.
- **Type 3:** Paper punching machine, sugar tongs, weighing machine, tweezers.

4.0 Learning Objectives:

Intellectual Skills:

- Analyze and evaluate the loads, forces, stresses involved in lever and and decide the dimensions.
- Apply the basic knowledge of the earlier subject like Strength of Materials, Engineering Mechanics.
- Understand modes of failure in lever and decide the design criteria.

Motor Skills:

- Ability to draw and determine the area subjected to failure for given stress condition.
- Ability to calculate various dimensions of machine component under given load condition using appropriate criterion for failure.

5.0 Learning Aids:

- Working Model of Bell crank lever, Hand Lever, Foot lever.

6.0 Stepwise Procedure :

Teacher Activity:

1. Introduce the students about various types of mechanical leverswith practical examples.
2. Provide the value of load and Material strength to each group of students

Student Activity:

1. Observe in groups the given mechanical lever and Select the value of Load / Force to which the lever is subjected to, under the guidance of Teacher.
2. Observe in groups the given mechanical lever and identify the different stresses and draw two-dimensional diagram showing the area of failureunder the observation.
3. Observe in groups the given mechanical lever anddetermine the various dimensions of lever by writing the strength equations for particular stress conditions, under the observation.
4. Check the safety and reliability of component for the determined dimensions for other stresses considering other failure criterion, and note down the observations.
5. Draw the orthographic view of given Mechanical joint with the help of determined dimensions. Students may use appropriate scale to draw the orthographic views.

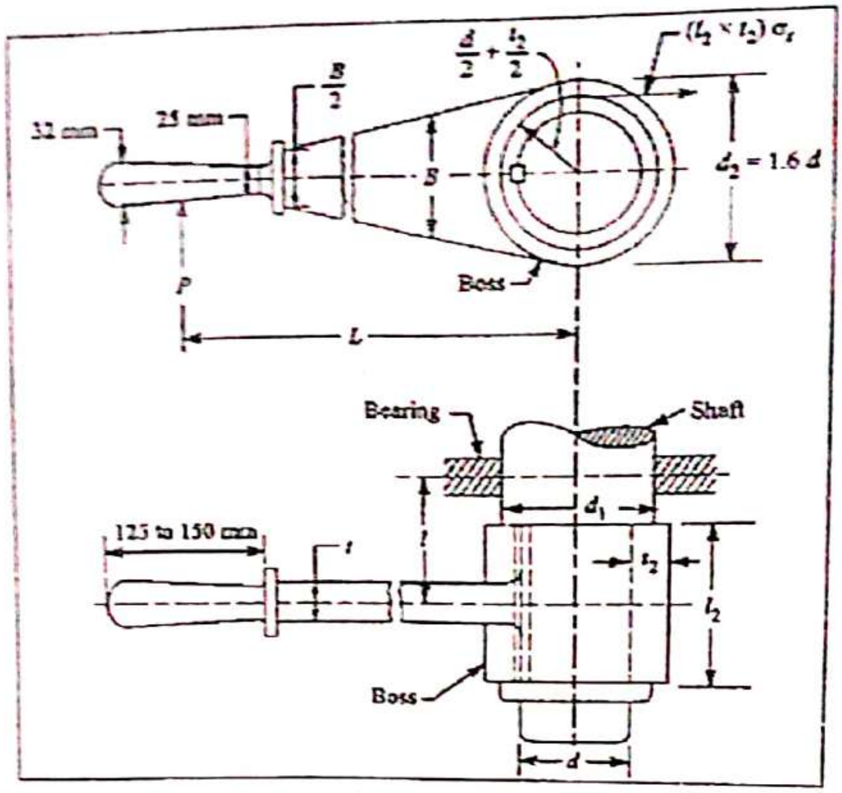
7.0 Observations :

1. **Design of Hand lever:**

A hand lever of a lever is 800 mm long from the centre of gravity of the spindle to the point of pull of ……..N. the effective Overhang from nearest bearing is 100 m. if the permissible stress in tension, shear, and crushing is not exceed to ……..N/mm^2. Design the spindle, key, lever and boss. Assume the arm of lever is to be rectangular having width as ……… times of thickness.

(Teacher shall provide the value of Force, Stress and Relation between width and thickness)

Solution:



Where:

P= Force applied at the handle.

L = Effective length of the lever

d = Diameter of the shaft.

d_1 = Diameter of shaft at centre of bearing.

d_2 = Diameter of boss.

l_1 = Length of key.

l_2 = Length of boss.

l = Overhang distance of bearing from the lever.

t = Thickness of lever near boss

B = Width or height of lever near boss = ...t

Step 1: Calculate diameter of shaft by considering shaft is under pure torsion.

i) Torque(T) = P X L

= .... × .... = ...N-mm

ii) When Shaft subjected to pure torsion then we know that

$$\text{Shear stress} = \frac{16T}{\pi d^3}$$

$$.............\ldots = \frac{16 \times \ldots\ldots\ldots}{\pi d^3}$$

d^3 = ...

d = ... mm

Modify the diameter of shaft at the centre of bearing (d) = ... mm.

Step 2: Calculate diameter of boss (d_2), length of boss (l_2), and thickness of boss (t_2) by using empirical relations.

- Diameter of boss (d_2) = 1.6 d = 1.6 X .... = ...mm
- Length of boss (l_2) = 0.3 d = 0.3 X .... = ...mm
- Thickness of boss (t_2) = 1.25 d = 1.25 X .... = ...mm

Step 3: Calculate diameter of shaft in bearing (d_1) by considering shaft is under combined twisting and bending moment

i) Calculate Bending moment(M) = P X l = ...X........=...............N-mm

ii) Calculate torque (T) = P X L = ...X........=...............N-mm

iii) Calculate equivalent twisting moment (T_e) = $\sqrt{M^2 + T^2}$

(T_e) = $\sqrt{\quad}$

(T_e) = ... N-mm

iv) Calculate (d_1)

Shear stress = $\frac{16T_e}{\pi d^3}$

.... = $\frac{16 \times \text{............}}{\pi d^3}$

d_1^3 =

d_1 =

Modify the diameter of shaft at the centre of bearing (d_1) = ...mm

Step 4: Design the key

i) If crushing stress greater than shear stress the select **square key.** Otherwise select rectangular key

ii) For Square key width (b) and height (h) both are same

b = h = 0.25d = 0.25 X .... = ...mm

OR

For rectangular key width (b) = 0.25d = 0.25 X .... =...............mm

Height (h) = 0.1667d = 0.1667 X .... =...............mm

iii) Length of key can be calculated by considering l = Length of boss l_1

Length of key (l) = ...mm

iv) Check the dimensions of key by considering Key subjected to

Calculate force applied on key (F)

Torque applied on Circumference of shaft (T) = Force applied on key (F) X Radius of shaft $\left(\frac{d}{2}\right)$

$$T = F \times \frac{d}{2}$$

$$F = \frac{2T}{d} = \ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots N$$

a) Shear failure of key

Area under shear failure of key = b X l = ... = ...mm^2

$$\text{Shear stress} = \frac{Force}{Area\ under\ shear\ failure}$$

....

....

....

If calculated value of shear stress is less than permissible shear stress of key then design is safe. Otherwise put the value of permissible shear stress and find the length (l) of key from above equation

b) Crushing failure of key

Area under shear failure of key = t X l = ... = ...mm^2

$$\text{Crushing stress} = \frac{Force}{Area\ under\ shear\ failure}$$

....

....

....

If calculated value of Crushing stress is less than permissible crushing or compressive stress of key then design is safe. Otherwise put the value of permissible compressive stress and find the length (l) of key from above equation

Step 5: Calculate Cross section of lever near boss

The cross section of lever near boss may be calculated by considering the lever in bending. It assumed that lever extends to the shaft which results in a stronger section of the lever.

Bending moment (M) = P X L = ... = ...N-mm

Section modulus (Z) = (1/6) X t X B^2 = ...

= ....mm^3

We know that

$$\sigma_b = \frac{M}{Z} = \frac{P \times L}{\frac{1}{6} \times t \times B^2} = \frac{6P \times L}{t \times B^2}$$ ***(In this equation put B = 4t or 5t)***

.... = ...

t^2 = ..., t = ...≈ ....mm

Thickness of lever = (t) =..............mm

Width or height of lever near boss =......X t = ...t = ...mm

(Space to draw Front view and Top viewof Hand lever by considering calculated dimensions)

8.0 Questions for confirmation of learning:

(Student shall write answers to the questions at the time of practical independently before completing the experiment to have self-feedback. He/ She may refer to the notes, etc. Teacher shall supervise.)

1. List four applications of Hand lever.

   i) .... ii) ....

   iii) .... iv) ....

2. Write the formula for failure of key under crushing and shear stress failure

   ....

   ....

   ....

   ....

3. Write the formula for failure of shaft under pure torsion.

   ....

9.0 Conclusion:

1. In case of hand leverdiameter of boss (d_2) is........................(1.6 or 0.5 or 3.2) times diameter of shaft (d).
2. Diameter of shaft at the centre of bearing (d_1) is calculated by considering {Equivalent twisting moment (T_e)/ pure torsion(T) / pure bending moment(M)}.
3. Write the relation for width and height of key for square and rectangular key in terms of diameter of shaft

For Square key

Width of key (b) = ... Height of key (h) = ...

For Rectangular key

Width of key (b) = ... Height of key (h) = ...

10.0 Student Activity (Field Visit)

(Teacher shall form a group of 4-5 students each. Each group shall perform only one allotted activity from the following. Teacher shall supervise these activities).

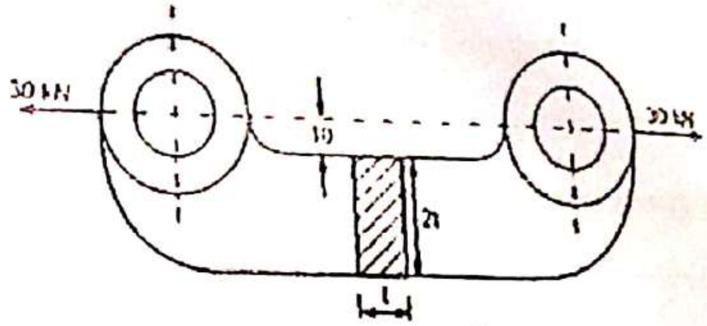
1. Observe the machine where bell crank lever is used and design the same.
2. Observe the machine pulley is used and design arm of pulley.
3. Observe the machine where Foot lever is used and design the same.

(Space for answer)

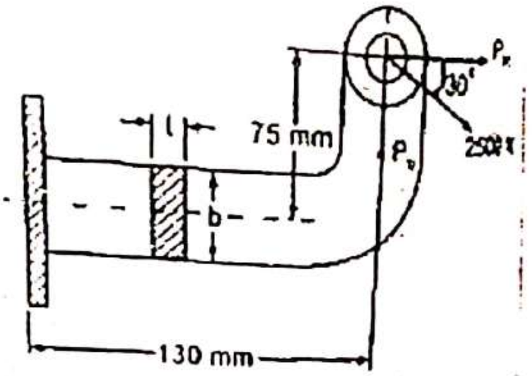
11.0 Questions:

Write answers to Q....Q....Q....Q.... (Teacher shall allot the question)

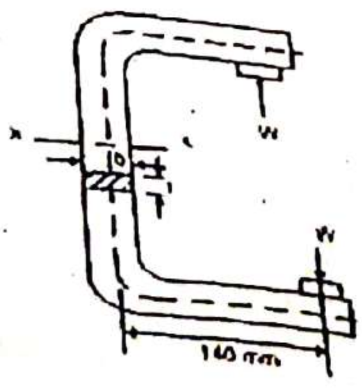
1. An offset link subjected to force of 30 kN is shown in fig. if the permissible tensile stress is 55 N/ mm^2. Determine the dimensions of cross-section of link.



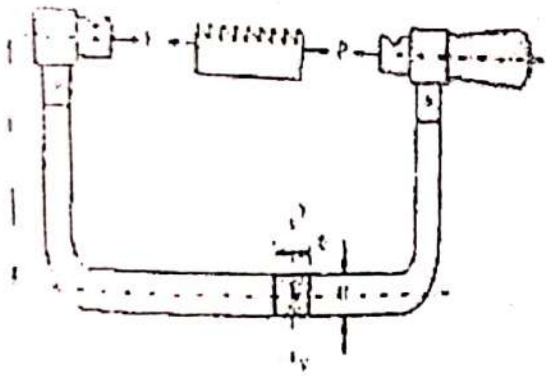
2. A mild steel bracket as shown in fig. is subjected to a pull of 2500 N acting at 30^0 to its horizontal axis. The bracket has rectangular section having b = 2t. find the cross sectional dimensions of the bracket, if the permissible stress for the bracket is 600MPa.



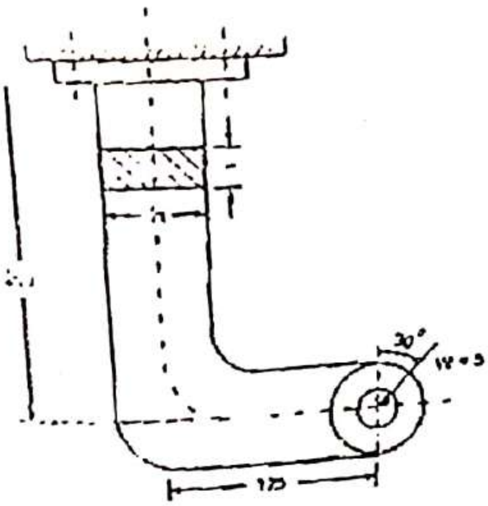
3. Design a C-clamp as shown in figure carries a load of 25 kN. The cross section of the clamp at X-X is rectangular having width equal to twice thickness. Assume the clamp is made of steel casting having an allowable stress of 100 MPa. find its dimensions



4. A frame of a hacksaw is shown in fig. the initial tension in the blade is 300 N. The frame is made of plain carbon steel with tensile yield strength 400 n/mm². Take factor of safety as 3. The cross section of frame is a rectangular with depth to width ratio (h/L) as 4. Determine the size of cross section of the frame.



5. A bracket made of steel FeE 200 (S_{yt}= 200 N/mm²) and subjected to a force of 5 kN acting at an angle of 30⁰ to the vertical, is shown in figure. The factor of safety is 4. Determine the dimensions of the cross section of the bracket.



6. A symmetric link shown n figure (a) carries load of 10 kN, breadth to thickness ratio is 4:1 and material used is 30C8 with yield strength 350 MPa, and factor of safety as 4. Find breadth (b) and its thickness (t) when the shape is modified to figure (b). determine increase in breadth (b) and thickness (t).

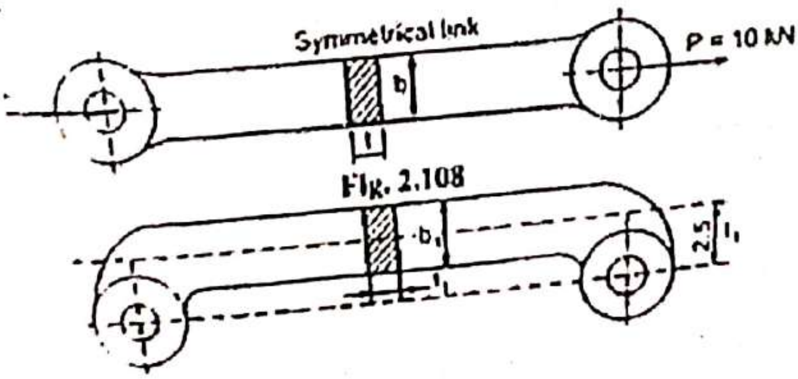
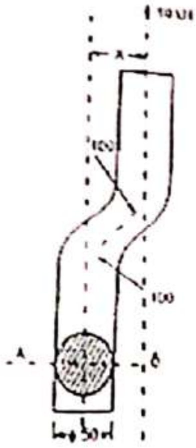


Fig. 2.108

7. An offset bar is loaded as shown in figure. The weight of bar is neglected. Find maximum offset, if allowable tensile is 70 MPa.



(Space for Answers)