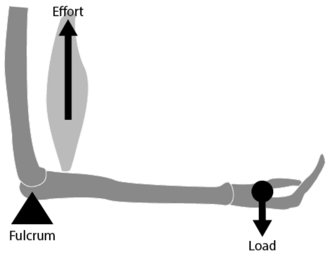
Name of Exp.: The forearm as a lever

The Aim: --

Theory

The forearm can be considered as a simple lever, actually a **third-class lever**. The pivot (or **fulcrum**) is at the elbow joint, the load is held in the palm of the hand and the **effort** is applied in the **biceps muscle**. In the arrangement shown in the figures, the forearm is horizontal and the force in the biceps muscle acts vertically. The system is in equilibrium for which:



$\Sigma \boldsymbol{F}_i = 0$ (where F_i are the forces)

$\Sigma \boldsymbol{\tau}_i = 0$ (where $\boldsymbol{\tau}_i$ are torques about any given point)

In Fig.(1),

a_e is the arm of the effort ($\boldsymbol{F}$),

a_m is the arm of the weight of the forearm ($m\boldsymbol{g}$),

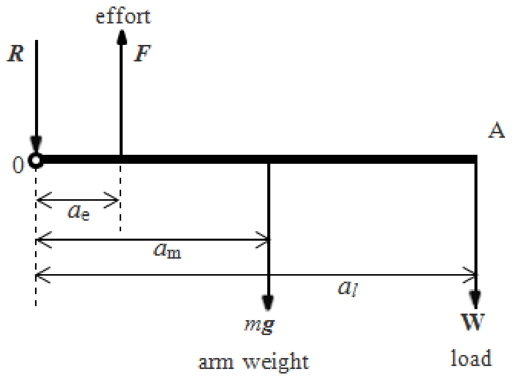
a_l is the arm of the load (**W**),

$\boldsymbol{F}$ is the force the biceps muscle exerts to hold the forearm ($m\boldsymbol{g}$) and its load (**W**),

$\boldsymbol{R}$ is the resistance force at the pivot 0 (fulcrum).

The forces in Fig.(1) form a system of parallel forces where,

$$F = W + mg + R \qquad (1)$$



`Fig.(1) The lever (arm) 0A is kept horizontal.

From the diagram and taking torques about the fulcrum (point 0):

Anticlockwise torque: τ_{acloc} = effort × a_e = $F \times a_e$

Clockwise torques: $\tau_{cloc} = mg\times a_m + W\times a_l$

With the arm being at equilibrium, we have:

$$\tau_{acloc} = \tau_{cloc}$$

Thus, the effort in biceps muscle to support the forearm and the load W in the hand is:

$$F = \frac{mga_m + Wa_l}{a_e} \qquad (2)$$

The mechanical advantage (M.A.) is defined as:

$$M.A = \frac{Output\ Force}{Input\ Force} \qquad (3)$$

$$M.A = \frac{Input\ arm\ force}{Output\ arm\ force} \qquad (4)$$

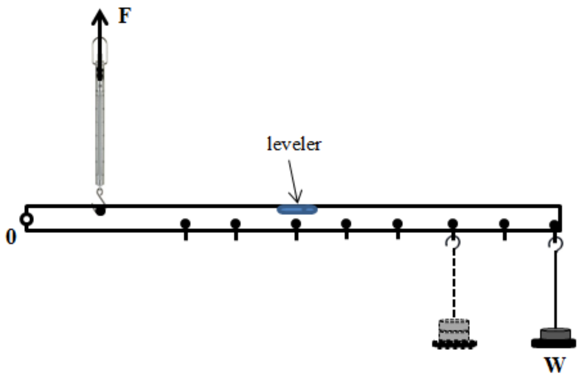


Fig.(2) Experiment setup.

Procedure

1. For a fixed a_l, change W and measure the effort F that makes the lever horizontal. Record as in **Table 1**. Plot a graph of F against W. Plot a graph of M.A. (Eq.3) against W.

2. For a fixed W, change a_l and measure the effort F that makes the lever horizontal. Record as in **Table 2**. Plot a graph of F against a_l. Plot a graph of M.A. (Eq.4) against a_l.

3. Discuss your results.

a_e = ……………... m, a_m = ……………... m, m = 241gm, mg = ………….. N,

Table 1 Constant Load's Arm (a_l)

a_l = ……… cm = ……..………… m

Load W (gm)	Load W (N)	Effort Force, F (N)	M.A. Eq.(3)

Table 2 Constant Load (W)

W = ……… gm = ……………….. N

Load distance a_l x10^{-3} (m)	Effort Force, F (N)	M.A. Eq.(4)

Questions

1. What is the effort? **Ans.:**

2. Consider the human forearm as a lever with the elbow as the fulcrum. When a body of given weight is held in the hand, the force exerted by the muscles on the arm is:

(a) less than the weight. (b) the same as the weight. (c) greater than the weight.

3. Define the third-class lever. **Ans.:**

4. Define the first-class lever. **Ans.:**

5. Define the second-class lever. **Ans.:**

6. What are the advantage(s) of third class levers? **Ans.:**

7. Define the mechanical advantage of a third-class lever. **Ans.:**

8. What are the sources of error? How can you reduce them? Explain.