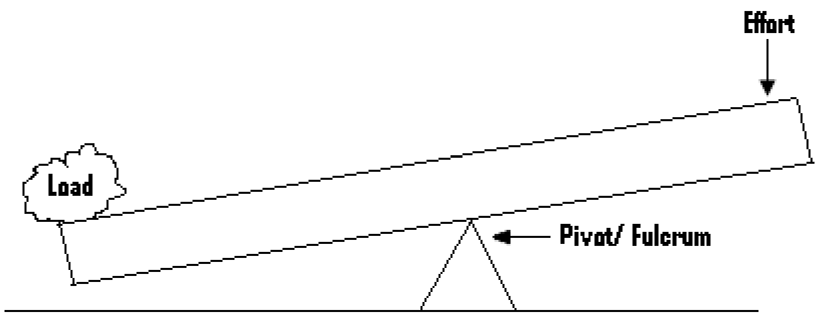
CHAPTER FOUR
MACHINES

Introduction:

A machine is a device by means of which a small force (effort) applied at one end, can be used to overcone a large force (load) at another end.A machine enables work to be done easily, and it does work by taking in energy at one end and feeding it out at another end, possibly in another form.

The Lever:



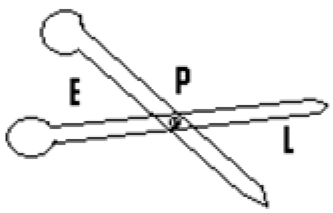
- The lever is a rigid straight bar, which has an immovable point called the pivot or the fulcrum.
- The force which is applied to the lever (machine) is called the effort, and the work it does or the force it overcomes, is referred to as the load.
- In the lever, a small force applied at one point (effort) is used to overcome a greater force or load at another point.

Mechanical advantage (M.A):

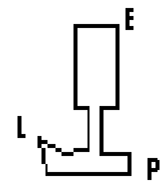
- This is given by the ratio of the load to the effort, i.e. M.A = $\frac{Load}{Effort}$
- When the mechanical advantage is greater than 1, then the implication is that a small effort has been used to overcome a bigger load or resistance.
- Some machines are designed to overcome a load much greater than the effort used, and an example is the car screw jack which is used in the lifting of motor car.
- In such cases, the mechanical advantage of the machine must be greater than 1.
- In certain machines, the mechanical advantage is less than 1 and for this reason, the effort is greater than the load and an example of such a machine is the bicycle.
- Under ordinary conditions, the resistance to the motion of the bicycle along a level road is comparatively small and as such a large mechanical advantage is unecessary.

The mechanical advantage of a lever, and types of levers:

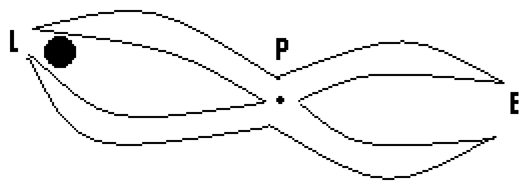
- There are three classes of levers, and these are:
  (1) The first class lever.
  (2) The second class lever.
  (3) The third class lever.
- In the first class lever, the pivot is between the load and the effort, and examples are the pair of scissors, the pincers and the hammer (used to remove nails).



Scissors

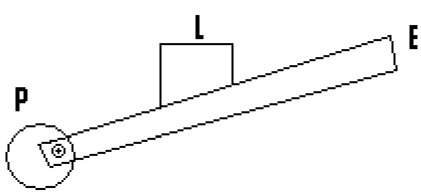


Hammer

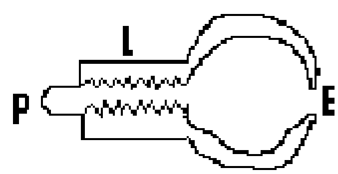


Pincers

- In the second class lever, the load is between the effort and the pivot, and examples are the wheelbarrow and the nut cracker.

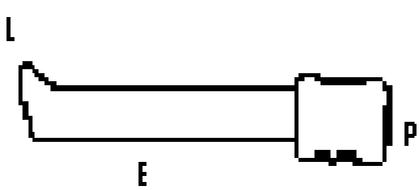


Wheelbarrow

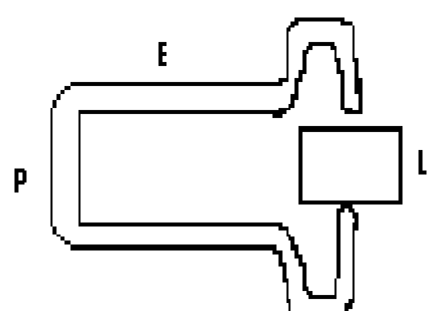


Nut cracker

- In the third class lever, the effort is between the load and the pivot, and examples are the tong and the knife.



KNIFE



TONG

- For a lever M.A = $\frac{L}{E}$
  where M.A = Mechanical advantage, L = Load and E = Effort.

(Q1) By means of a lever, an effort of 10N was applied to raise a stone of mass 20N. Calculate the mechanical advantage.

Soln:

E = Effort = 10N.

L = Load = 20N.

M.A = $\frac{L}{E}$ = $\frac{20}{10} = 2$.

(Q2) A simple machine has a mechanical advantage of 10. Find the effort which will be needed inorder to raise a load of 20N.

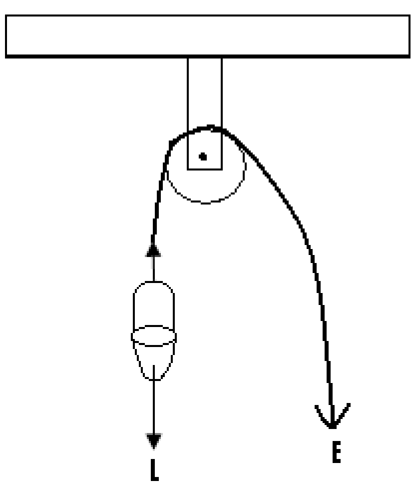
Soln:

From M.A = $\frac{L}{E}$ => E = $\frac{L}{M.A} = \frac{20}{10} = 2$.
=> Effort needed = 2N.

Pulleys:

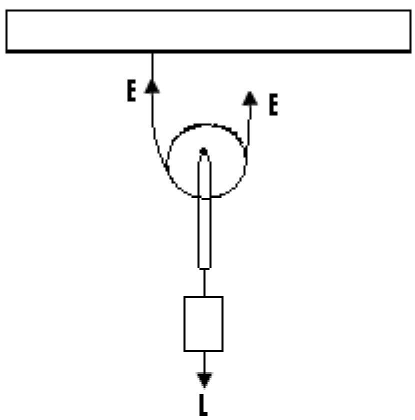
- A pulley is awheel with a grooved rim.
- Several of them may be mounted in a frame work called a block, and the effort is applied to a rope which passes over the pulleys.

The single fixed pulley:



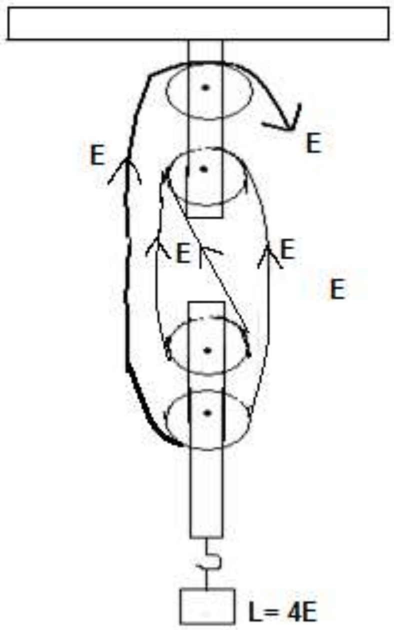
This is often used for the purpose of raising small loads contained in buckets or baskets, to the top of a building during construction or repair work.It can be used to change the direction of application of an effort, so as to make it more convenient to apply the force. For such a pulley, the load = the effort and the mechanical advantage = 1. Even though the effort applied is equal to the load raised, a greater convenience and the ease of being able to stand on the grounds and pull downwards, instead of having to haul the load upward to the top of the building is obtained.

The single moving pulley:



- For this, the tension in the string or rope is equal to the effort applied, so that the total upward pull on the pulley is twice the effort E.
- Suppose a load of 4kgf is supported by the pulley, then since the load is supported by the tension in two sections of the string, the effort needed to be applied must be 2kgf.
  M.A = $\frac{L}{E} = \frac{4}{2} = 2.$

The block and tackle:



- This is by far the most important pulley system of all, being commonly used for lifts and cranes.
- Two blocks are employed containing from two to eight pulleys in each, according to the mechanical advantage required and a single string is used to pass round each pulley.- If an effort E is applied to the free end of the string, then the total upward force on the load will be 4E.

- M.A = $\frac{4E}{E}$ = 4.
  - In practice, however, the practical mechanical advantage is always less than 4, since extra effort must be applied to overcome friction and the weight of the moving pulley block and string.

The velocity ratio (V.R):

- This is the ratio of the distance moved by the effort, to the distance moved by the load at the same time.
- The velocity (the speed) ratio of a machine = $\frac{distance\ moved\ by\ the\ effort}{distance\ moved\ by\ the\ load\ in\ the\ same\ time}$
- Also, V.R.= $\frac{effort\ distance}{load\ distance}$

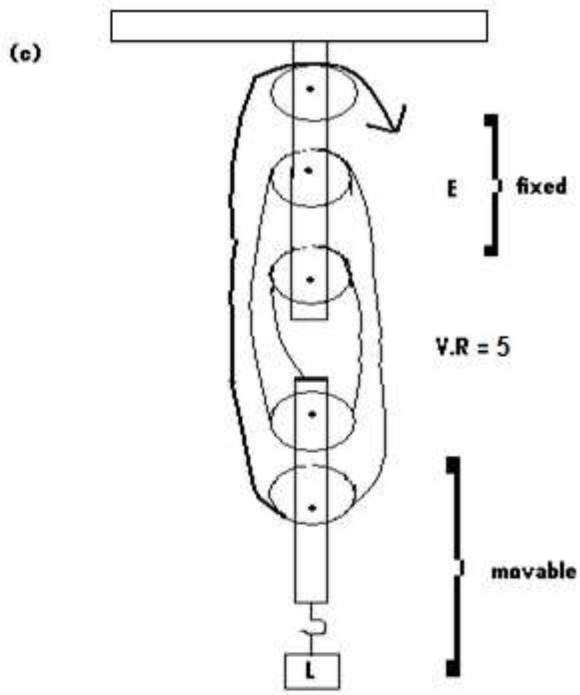
(Q1) During the use of a simple machine, the effort moved through a distance of 150cm, and the load moved through a distance of 30cm. Find the velocity ratio.oSoln:

V.R = $\frac{effort\ distance}{load\ distance} = \frac{150}{30} = 5.$

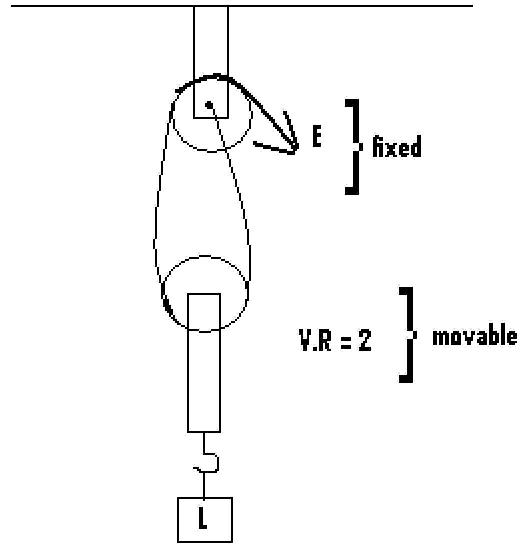
N/B: V.R has no units.

- The velocity ratio of a single pulley is 1, and that of a movable pulley is 2.

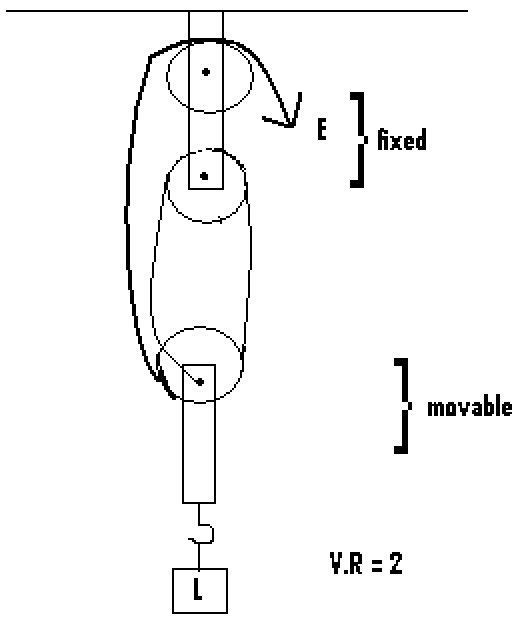
<u>The velocity ratio of the block and tackle:</u>



(a)



(b)



- The velocity ratio for a block and tackle system of pulleys, is obtained by counting the number of strings supporting the movable block of pulleys.
- In the first figure, the movable block is supported by two strings and for this reason, the velocity ratio = 2.
- In the second figure, the movable block is supported by three strings and as such it velocity ratio = 3.

- Because the effort has to overcome the weight of the movable block, the load as well as friction, the mechanical advantage of the block and tackle system is much less than the velocity ratio.
- However, the higher the velocity ratio, the higher the mechanical advantage.

The efficiency of a machine:

- The efficiency of a machine is the ratio of its work output to its work input.

- Efficiency = $\frac{work\ output}{work\ input} \times 100$

- Also the efficiency of a machine = $\frac{useful\ energy\ output}{energy\ input} \times 100$

- The efficiency is usually expressed as a percentage.

- The efficiency of a machine can never be 100%, because part of the work input is used to overcome the friction which operates between the moving parts.

- Apart from that, part of the work input is wasted or used in raising the moving parts of the machine.

- By reducing friction in a machine, its efficiency improves and as such energy is saved.

(Q1) A machine needs 100J of energy to produce an output of 80J. Calculate its efficiency.

Soln:

Work output = 80J.

Work input = 100J.

Efficiency = $\frac{work\ output}{work\ input} \times 100$

= $\frac{80}{100} \times 100$ = 80%.

(Q2) A man operating a machine puts in 60J of energy and gets an output of 50J of energy. Determine the machines efficiency.

Soln:

Efficiency = $\frac{work\ output}{work\ input} \times 100$

= $\frac{50}{60} \times 100$= 83%.

(Q3) The efficiency of a machine is 40%. If the output is 12J, find the work input.

Soln:

Efficiency = 40% = 0.4

Efficiency = $\frac{output}{input}$

=> 0.4 = $\frac{12}{input}$ $=> input = \frac{12}{0.4}$= 30J.

N/B:

- In calculating the efficiency, if the efficiency is not given, we use the formula Efficiency = $\frac{output}{input} \times 100$
- On the other hand if the efficiency is given, then we use efficiency = $\frac{work\ output}{work\ input}$