Board – ICSE	Class – 10	Topic – MACHINES

1. Explain the term mechanical advantage and state its unit.

Ans:

The ratio between the useful load (resistance overcome) moved by a machine to the effort applied on it is called mechanical advantage. It is a pure number and has no unit.

2. Prove that efficiency of a machine is the ratio between actual mechanical advantage and velocity ratio.

Or

State the relationship between mechanical advantage velocity ratio and efficiency.

Ans:

Let 'l' be the useful load, which moves through a distance 'd', when an effort 'E' acts through a distance 'D'.

Input = E × D; Output = l × d

Now, Efficiency of machine

(η) = Output/Input

$$= \frac{l \times d}{E \times D} = \frac{l}{E} \div \frac{D}{d} = \frac{M.A}{V.R}$$

$$\eta = \frac{M.A}{V.R}$$

3. Name and define three classes of levers and give two examples for each kind.

Ans:

(i) **Lever of 1st order**

A lever in which the fulcrum acts in the middle, the load on one side and the effort on the other side is called lever of the 1st order. Scissors and crow-bar are the examples of lever of 1st order.

(ii) **Lever of 2nd order**

A lever in which the load acts in the middle, the effort on one side and fulcrum on the other side is called lever of 2nd order. A nut cracker and a wheel barrow are the examples of lever of 2nd order.

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(iii) **Lever of 3rd order**

A lever in which effort acts in the middle, the load on one side and fulcrum on the other side is called lever of 3rd order. A fire tong and fishing rod are examples of lever of 3rd order.

4. Explain
   (a) Why the lever of the second order has mechanical advantage more than one?
   (b) Why the lever of the third order has mechanical advantage less than one? Give one example of this class of lever.

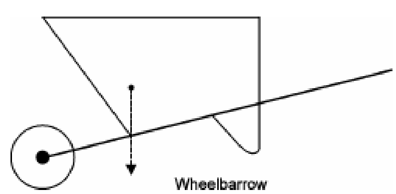
Ans:

The mechanical advantage of lever is given by the expression, effort arm ÷ load arm.

(a) In case of lever of second order, the effort arm is always longer than the load arm and hence, its mechanical advantage is more than 1.

(b) In case of lever of the third order, the effort arm is always smaller than the load arm and hence, its mechanical advantage is less than 1. For example, a fire tong is a lever of third order.

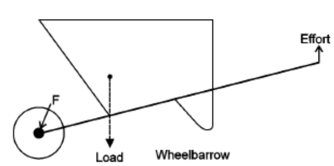
5. Explain the following :
   (a) The diagram shows a wheelbarrow. In the diagram mark fulcrum. Also draw arrows to show the direction of load and effort.



   (b) What class of lever is wheelbarrow?
   (c) Give one more example of same class of lever.

Ans:

(a) Shown in the diagram.



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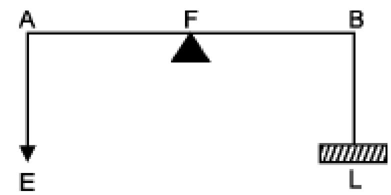
(b) Lever of the second order.

(c) Nut-cracker.

6. Diagram shows a weightless lever in equilibrium. Neglect friction at the fulcrum F.



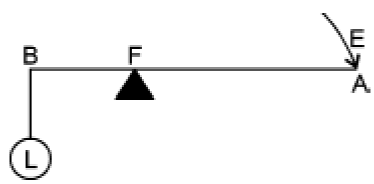
(i) State the principle of moments as applied to above lever.

(ii) Define mechanical advantage and calculate its value for given lever.

(iii) Name the type of lever, which has mechanical advantage greater than one.

Ans:

(i) Principle of moments states that, when a lever is in equilibrium, then the effort multiplied by the effort arm is equal to the load multiplied by the load arm.



(ii) The ratio between the useful load lifted to the effort applied is called mechanical advantage.

In the diagram L × BF = E × AF

$$\frac{L}{E} = \frac{AF}{BF} \quad \text{or} \quad M.A = \frac{AF}{BF}$$

(iii) Lever of the second order has mechanical advantage greater than one.

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7. Explain :
   (a) Define pulley. By drawing diagram calculate :
      (1) Mechanical advantage,
      (2) Velocity ratio of single fixed pulley.
   (b) Why is single fixed pulley commonly used, in spite of the fact that its mechanical advantage is less than one?

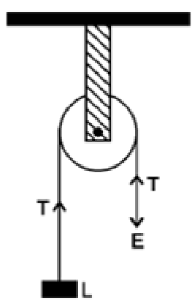
Ans:

(a) Pulley is a flat circular disc, having a groove in its edge and is capable of turning around a fixed point, passing through its centre and commonly called axle.

Let L be the load lifted by an effort E, such that T is the tension in the rope.

∴ L = T......... (i)

E = T ....(ii)



Comparing (i) and (ii) L = E; LE = 1

or M.A = 1

Let 'd' be the distance through which effort acts, as well as load lifted.

∴ V.R = Distance through which effort moves ÷ Distance through which load moves

= d ÷ d

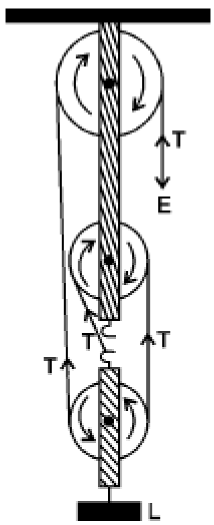
= 1.

(b) It helps in changing the direction of effort applied. As it is far easier, to apply effort in downward direction, therefore single fixed pulley is widely used.

8. Explain :
   (i) A pulley system has a velocity ratio 3. Draw a labelled diagram of the pulley system.
   (ii) What is the mechanical advantage of above system.

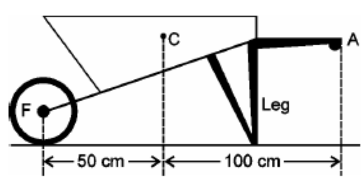
Ans:

(i) Shown in figure alongside.



(ii) M.A. = No. of pulleys in system = 3.

9. Figure shows a wheelbarrow with C as centre of gravity, such that its leg is in contact with ground.
   (i) What is the direction of force acting at C? Name the force.
   (ii) What is the direction of minimum force acting at A to keep the leg off the ground? What is the force called?
   (iii) The weight of wheel borrow is 15 kgf and it holds 60 kgf of sand. Calculate the minimum force to keep the leg off the ground?



Ans:

(i) The force is acting vertically downward. The force is called **LOAD.**

(ii) The minimum force acts vertically upward at A. The force is called **EFFORT.**

(iii) Weight of wheel barrow and sand

= (15 + 60) kgf

= 75 kgf

Load arm = 50 cm

Effort arm = (100 + 50) cm

= 150 cm.

By the principle of lever :

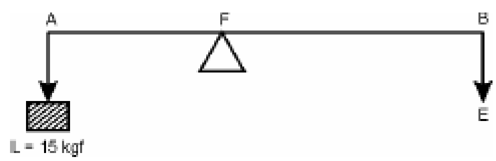
Effort × Effort arm = Load × Load arm

E × 150 cm = 75 kgf × 50 cm

$\therefore\ E = \frac{75 \times 50}{150\text{kgf}}$

= 25 kgf.

10. Diagram below shows a lever in use.



(i) To which class of lever does it belong?

(ii) If AB = 1 m, AF = 0.4 m, find its mechanical advantage.

(iii) Calculate the value of E.

Ans:

(i) It is class I lever.

(ii) Mechanical advantage

$= \frac{\text{Effort arm}}{\text{Load arm}}$

$= \frac{1\text{m} - 0.4\text{cm}}{0.4\text{m}}$

$= \frac{0.6\text{m}}{0.4\text{m}}$

=1.5

(iii) Mechanical advantage $= \frac{\text{Load}}{\text{Effort}}$

$1.5 = 15 \frac{\text{kgf}}{\text{Effort}}$

$\text{Effort} = 15 \frac{\text{kgf}}{1.5} = 10 \text{ kgf}$

11. A pulley system has velocity ratio 3 and an efficiency of 80%. Calculate :

(i) Mechanical advantage of system

(ii) Value of effort required to raise a load of 300 N.

Ans:

V.R = 3 ; η = 80% ; M.A. = ? ;

E = ? ; L = 300 N.

(i) M.A. = η × V.R = $\frac{80}{100}$ × 3 = 2.4.

(ii) $\frac{L}{E} = \text{M.A.} \quad \therefore\ E = \frac{L}{MA} = \frac{300N}{2.4} = 125\ N.$

12. A fixed pulley is driven by 100 kg mass falling at a rate of 8.0 m in 4 s. It lifts a load of 500 kgf. Calculate the power input to the pulley taking force of gravity on 1 kg = 10 N. If the efficiency of pulley is 75%, find the height to which load is raised in 4.0 s.

Ans:

(i) Force of 100 kg of falling mass

F = 100 × 10 N = 1000 N

$\text{Speed of fall (v)} = \frac{8.0m}{4s} = \frac{2m}{s}$

$\text{Power input} = F \times v = 100N \times \frac{2m}{s}$

= 2000 J

(ii) $\text{Efficiency} = \frac{\text{Power output}}{\text{Power input}}$

$\frac{75}{100} = \frac{\text{Poweroutput}}{2000J}$

$\text{Power output} = \frac{75 \times 2000J}{100}$

= 1500 J

Now, power output = Force × Velocity

1500 J = 500 kgf × Velocity

1500 J = 5000 N × Velocity

$\text{Velocity} = \frac{1500J}{5000N} = 0.3\ ms^{-1}$

Distance through which load moves in 4 s

= 0.3 ms^{-1} × 4 s = 1.2 m

13. A block and tackle system has velocity ratio 3. A man can exert a pull of 200 kgf. What is the maximum load he can raise with this pulley system, if its efficiency is 60%?

Ans:

Efficiency M.A (η)=V.R

$\therefore \frac{60}{100} = \frac{MA}{3}$

$\therefore \ MA = \frac{60 \times 3}{100} = 1.8$

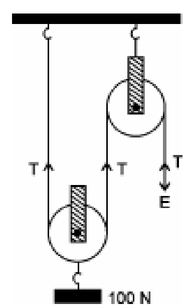
Now, $MA = \frac{l}{E}$

$1.8 = \frac{l}{200kgf}$

load (l) = 1.8 × 200 kgf = 360 kgf.

14. Diagram shows a pulley arrangement.
   (i) Copy the diagram, and mark direction of force due to tension acting on the movable pulley.
   (ii) What is the purpose of fixed pulley?
   (iii) If tension is T newton's, deduce the relation between T and E.
   (iv) Calculate the velocity ratio of the arrangement.
   (v) Assuming the efficiency to be 100%, what is the mechanical advantage?
   (vi) Calculate effort E.
   (vii) State two factors that will reduce efficiency of arrangement.

Ans:



(i) Shown in the diagram.

(ii) It changes the direction of effort from downward to upward direction.

(iii) T = E.

(iv) Let 'd' be the distance through which rope is pulled by the effort. In order to maintain equilibrium, the distance through which each segment of the rope shortens is d/2.

∴ V.R. = d ÷ = 2.

(v) $\eta = \frac{MA}{VR}$

$\frac{100}{100} = \frac{MA}{2} \ \therefore \ M.A. = \ 2.$

(vi) $M.A. = \frac{L}{E}$

$E = \frac{L}{MA} = \frac{100N}{2} = 50N$

(vii) (1) The friction of movable parts reduces efficiency.

(2) The weight of movable pulley reduces efficiency

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15. A crow bar of length 2.0 m is used as a machine, to lift a box of 100 kgf by placing a fulcrum at a distance of 0.1 m from the box. Calculate :
    (i) velocity ratio,
    (ii) mechanical advantage,
    (iii) effort required. What assumption has been made, in solving this problem?

Ans:

Length of crow bar = 2.0 m.

Length of load arm (d) = 0.1 m.

∴ Length of effort arm (D) = (2.0 – 0.1) = 1.9 m.

(i) Velocity ratio $= \frac{D}{d} = \frac{1.9m}{0.1m} = 19.$

(ii) Mechanical advantage = $\frac{L}{E}$ = V.R = 19

(iii) M.A. =$\frac{L}{E}$

∴ E = L ÷ M.A.

= 100 kgf ÷ 19

= 5.26 kgf.

It is assumed (i) The crow bar is weightless.

(ii) There is no friction at the fulcrum.