Simple machines - Effort and load, mechanical advantage, velocity ratio, efficiency of machine, relationship between efficiency, velocity ratio and mechanical advantage

Exercise 1.9.44

Introduction:

A machine is a tool containing one or more parts that uses energy to perform an intended action. Machines are usually powered by mechanical, chemical, thermal, or electrical means, and are often motorized. Historically, a power tool also required moving parts to classify as a machine. However, the advent of electronics has led to the development of power tools without moving parts that are considered machines.

A simple machine is a device that simply transforms the direction or magnitude of a force, but a large number of more complex machines exist. Examples include

1 Levers

2 Screw Jack

3 Wheel and axle

4 Pulleys

5 Inclined plane, etc.,

Load (or) Weight

The force overcome by the effort is called load or weight (W).

Effort (or) power :

The force applied to lift the load is called effort or power (P).

Fulcurm :

It is a fixed point in the machine around which the machine rotates (F).

Mechanical advantage

In a simple machine when the effort (P) balances a load (W) the ratio of the load to the effort is called the mechanical advantage of the machine. It is simply expressed in a number.

$$\text{Mechanical advantage (M.A)} = \frac{\text{Load}}{\text{Effort}} = \frac{W}{P}$$

Velocity ratio

It is the ratio between the distances moved by the effort to the distance moved by the load. It is also experssed in a number.

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort (dp)}}{\text{Distance moved by the load (dw)}}$$

Efficiency of Machine

The ratio of output to the input of machine is known as efficiency. In simple machines, the ratio of mechanical advantage to the velocity ratio is also known as efficiency of machine. Efficiency is generally expressed in percentage.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$\boxed{\%\ \text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100\ \%}$$

Relation between M.A., V.R. and η

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Load x Distance moved by the load}}{\text{Effort x Distance moved by the effort}}$$

$$= \frac{\text{Load}}{\text{Effort}} \times \frac{\text{Distance moved by the load}}{\text{Distance moved by the effort}}$$

$$= \text{Mechanical advantage} \times \frac{1}{\text{Velocity ratio}}$$

$$\boxed{\text{Efficiency } (\eta) = \frac{\text{Mechanical advantage}}{\text{Velocity ratio}} = \frac{\text{M.A.}}{\text{V.R.}}\ \%}$$

Ideal Machine

In an ideal machine the mechanical advantage is equal to the velocity ratio. so, efficiency is 100% or unity.

Examples

1 Calculate, mechanical advantage, velocity ratio and efficiency if a machine mass of 120 kg is lifted to a height of 5 metre by a force of 60 kg. moving 15 m.

Load (w) = 120 kg

Distance moved by load = (dw) = 5 m

Power (P) = 60 kg

Distance moved by power (dp) = 15 m

$$MA = \frac{W}{P} = \frac{120\,kg}{60\,kg} = 2$$

$$VR = \frac{dp}{dw} = \frac{15}{5} = 3$$

$$\text{Efficiency}(\eta) = \frac{MA}{VR} \times 100\%$$

$$= \frac{2}{3} \times 100\%$$

= 66.66 %

2 Calculate the mechanical advantage and efficiency of machine, if effort applied 300 kg a load of 900 kg is lifted by a simple machine having a velocity ratio of 4.

Load (W) = 900 kg

Effort (P) = 300 kg

Velocity ratio (V.R) = 4

$$\text{Mechanical advantage (M.A.)} = \frac{\text{Load (W)}}{\text{Effort (P)}}$$

$$= \frac{900}{300}$$

$$= 3$$

$$\text{Efficiency } (\eta) = \frac{\text{M.A.}}{\text{V.R.}} \times 100\%$$

$$= \frac{3}{4} \times 100\%$$

$$= 75\ \%$$

3 Find Mechanical advantage. Calculate the work done and horse power required if it is required to be raised to a height of 6 m in 27 sec.and using a pulley block, a weight of 180 kg is raised with a force 15 kg.

W = 180 kg
P = 15 kg
M.A. = ?
Work done = ?
HP = ?
Height = 6 m
t = 27 second

M.A. $= \text{M.A.} = \frac{W}{P} = \frac{180\ \text{kg}}{15\ \text{kg}} = 12$

Work done = F x d (Force x Distance)
= 15 kg x 6 m
= **90 m - kg**

Power = Workdone / time
= 90 m - kg / 27 s
= 90/27m-kg/s [75m-kg/sec=1HP]
= 90/27 x 1/75 H.P.
= 0.04444 H.P.

4 Calculate the applied force if a Load of 400 kg is lifted by a machine having an η of 72%. If velocity ratio = 6?

W = 400 kg
η = 72 %
V.R. = 6

$$\eta = \frac{\text{M.A.}}{\text{V.R.}} \times 100\%$$

$$72 = \frac{\text{M.A.}}{6} \times 100\ \%$$

$$\text{M.A.} = \frac{72 \times 6}{100}$$

$$\frac{W}{P} = 4.32$$

$$\frac{400\ \text{kg}}{P} = 4.32$$

$$\text{Applied Force P} = \frac{400}{4.32} = 92.59\ \text{kg.}$$

Assignment

1 Calculate the efficiency of a machine having velociy ratio 5 if a force of 275 kg applied to lift a weight of 1100kg with the help of simple machine.

2 Calculate (i) Mechanical advantage (ii) Efficiency of machine if the effort applied is 250 kg and a load of 1000 kg is lifted by a simple machine having a velocity ratio of 5.

3 What effort would be required and what would be the mechanical advantage if a lifting machine having a velocity ratio of 25, lifts a load of 40 Kg with an efficiency of 54.4% ?

4 Find out the effort required if the velocity ratio of a weight lifting machine is 20. If the efficiency of the machine is 40%.

5 Find the mechanical advantage if using a pulley block a load of 350 N is raised with a force of 25N.

6 Calculate M.A. η of the machine, if the effort applied is 250 kg and a load of 1000 kg is lifted by a simple machine having a velocity ratio 5.

7 Find out the η of the machine of effort applied is 300 kg if load of 1200 kg is lifted using simple machine having a velocity ratio of 5.

8 Calculate M.A. and efficiency if in a simple machine the velocity ratio is found to be 20. An effort of 20 kg is required to lift a load of 400 kg.

9 What is the velocity ratio, if its efficiency is 0.75 and in a lifting machine an effort of 31 kg just raises a load of 1000 kg?

Lever

A lever is a rigid rod which rotates about a fixed point called the fulcrum.

E.g. : Cutting plier, A pair of scissors, Crow bar, Beam balance, Hand pump.

The distance of the load from the fulcrum is called the load arm. The distance of the effort from the fulcrum is called the effort arm.

Principle of Lever

- All levers are functioning in the following principle
  Load x Load arm = Effort x Effort arm
- **Classification of lever**

1. Straight lever
2. Curved lever

1. Straight lever

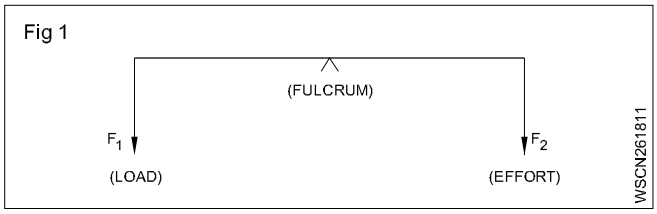
There are three types :

1. First order lever
2. Second order lever
3. Third order lever

First order lever

In this type the fulcrum lies between the load and the effort.

E.g : A pair of scissors, See-saw, Crow bar, Beam balance, Hand pump, etc.,

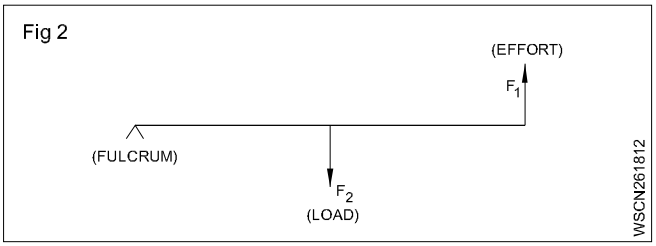


In this type of lever the mechanical advantage will be equal or less than or greater than 1 (M.A < = > 1)

Second order lever

In this type, the load lies between the fulcrum and the effort.

E.g : Nut crakers, Wheel barrow, Paper sheet cutter, Bottle openers, Lime squeezer, etc.,

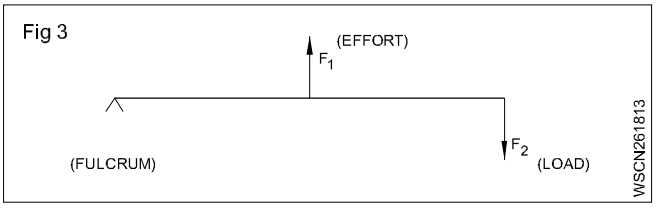


In this type of lever, the mechanical advantage will be greater than 1 (M.A. > 1). Less effort is used to lift more load.

Third order lever

In this type, the effort lies between the fulcrum and the load.

E.g. The human force arm, forceps, broom, fire tongs, fishing rod.



In this type of lever, the mechanical advantage will be less than 1 (M.A < 1) more effort is used to lift less load.

Bell cranked levers (Curved levers) (Fig 5)

In addition to the above types of levers, two rods may be joined together at an angle to increase leverage without utilising much space. Such levers are cranked levers and the special form inwhich included angle is 90°, is called the bell cranked lever.

E.g : Motor cycle breaks system clutch pedal.

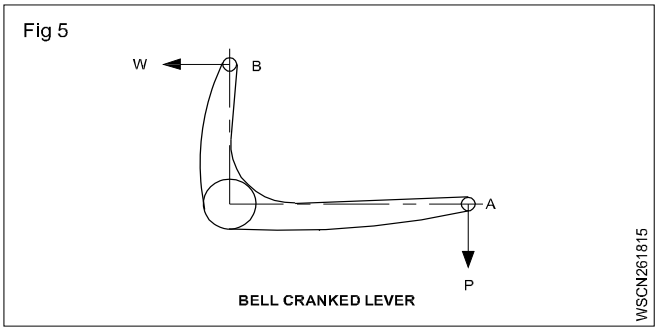
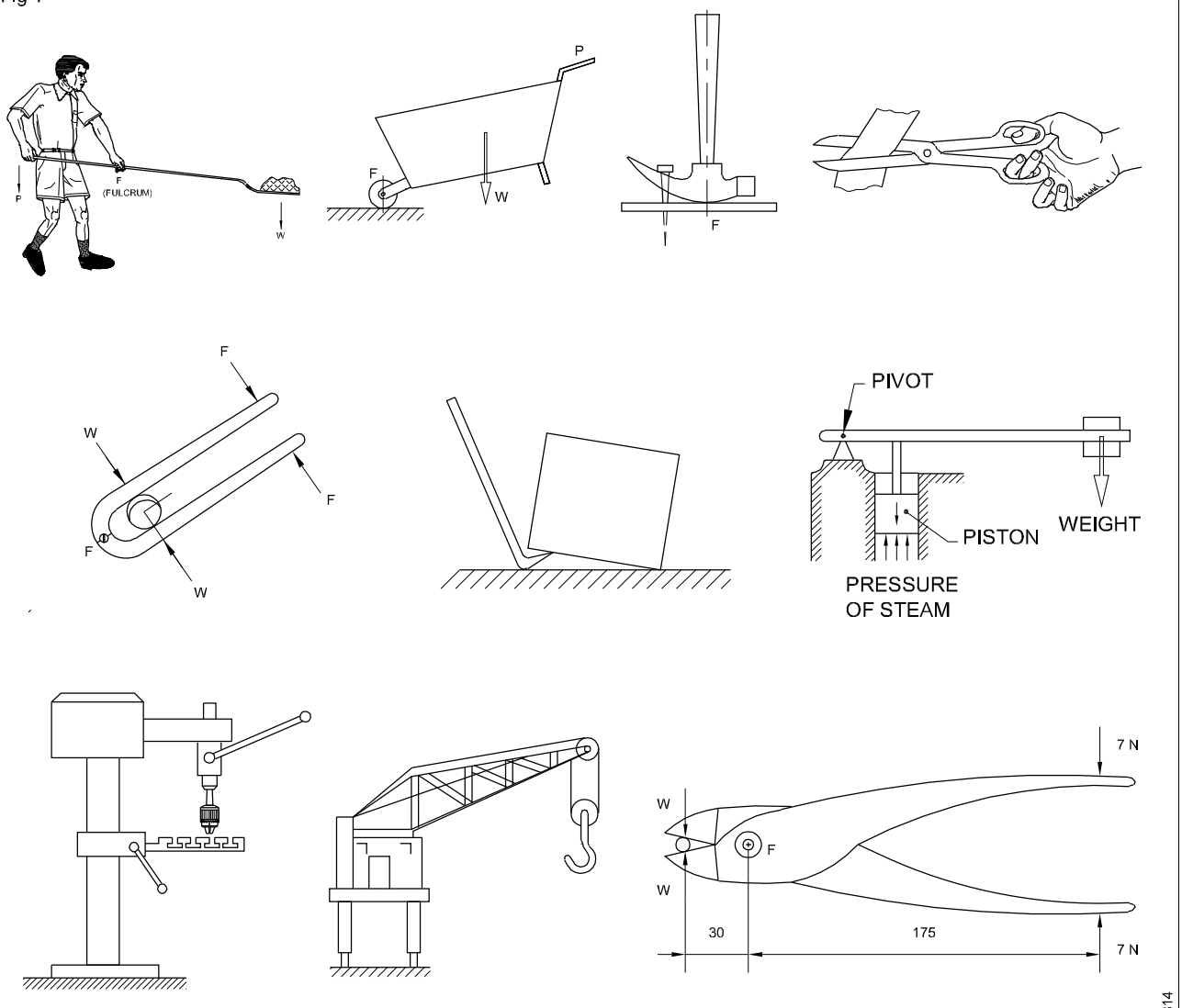


Fig 4



EXAMPLES OF SIMPLE LEVERS

Examples

1 Calculate the load at B, if the load is in the balance condition if a rod AB is 8 metre long and has got a weight of 10 kg at A. The fulcrum is 3 metre fromB.

Load x Load arm = Effort x Effort arm

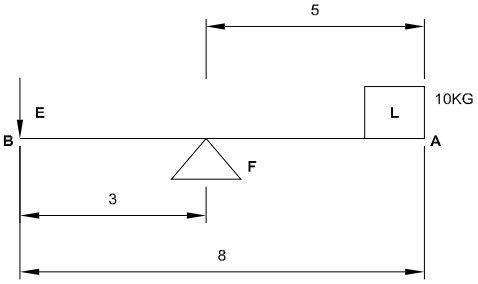
10 x 5 = P x 3

50 = 3 P

P = 50 / 3

= 16.67 kg

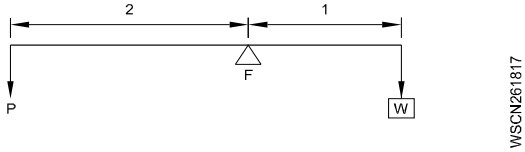
Fig 6



When load and effort are not given separately in the sum consider which one having more weight is as a load.

2 Find the effort required and mechanical advantage of the system if a weight of 3000 kg is to be lifted by a bar of length 3 metre. The load arm is 1 metre and the effort arm is 2 metre.

Fig 7



As per lever principle

Load x Load arm = Effort x Effort arm

3000 x 1 = P x 2

3000 = P x 2

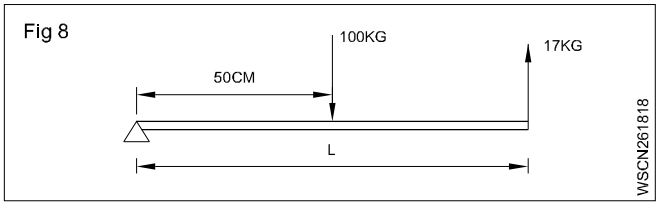
P = 3000/2

= 1500 kg

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}} = \frac{3000}{1500}$$

$$= 2$$

3 According to Fig. the lever has to support a 100 kg load with a 17 kg equivalent force supplied to it. Find the distance between the load and point of force.



Solution.

Load = 100 kg; Effort = 17 kg.

Load arm = 50 cm

Let effort arm = x cm

As per principle of levers:

Effort x Effort arm = Load x Load arm

$$17x = 100 \times 50$$

$$x = \frac{100 \times 50}{17} = 294.1 \text{ cm}$$

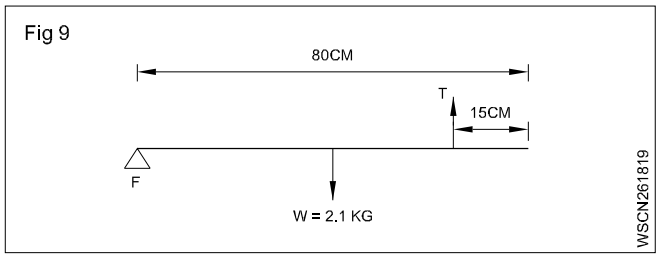
$$x = 294.1 \text{ cm}$$

Distance between the load and point of force = 294.1 - 50

$$= 244.1 \text{ cm}$$

$$= 2.4410 \text{ m}$$

4 Find the tension of the string if an uniform bar of length 80 cm and weighing 2.1 kg is supported on a smooth peg at one end and by a vertical string at a distance of 15 cm from the other end.



$$W = 2.1 \text{ kg}$$

$$\text{Tension} = T \text{ kg}$$

$$P \times dp = 2.1 \times dv$$

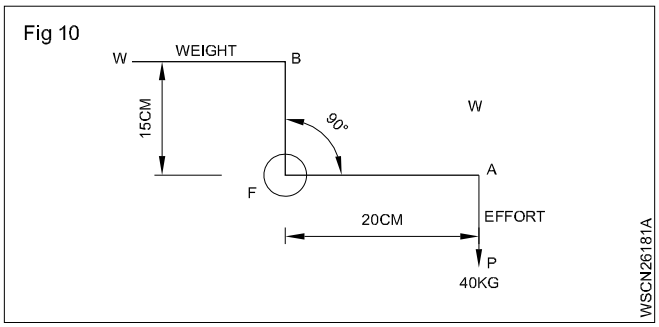
$$T \text{ kg} \times (80 - 15) \text{ cm} = 2.1 \text{ kg} \times \frac{80}{2} \text{ cm}$$

$$T \times 65 = 2.1 \times 40$$

$$T = \frac{2.1 \times 40}{65} \text{ kg.}$$

$$\text{Tension} = 1.292 \text{ kg}$$

5 In the figure given below in bell cranked lever AFB on perpendicular AF the force P is 40 kg. Weight W is on perpendicular FB. Find the measure of W.



Solution. By principle of momentum

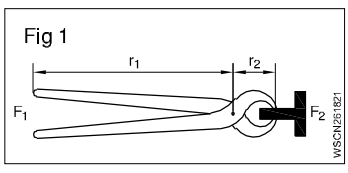
$$P \times AF = W \times BF$$

$$40 \times 20 = W \times 15$$

$$W = \frac{40 \times 20}{15} = \frac{160}{3} = 53.3 \text{ kg.}$$

Assignment

1



1st Order Lever (Pliers)

Data given

Effort at F_1 = 90 N

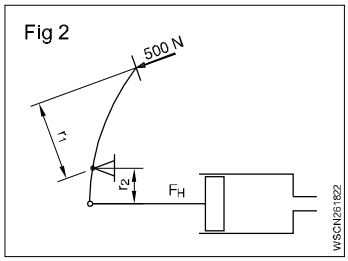
Arm r_1 = 380 mm

Arm r_2 = 36 mm

Find

Cutting Force F_2 = _____ N

2



Brake Lever

Foot force = 500 N

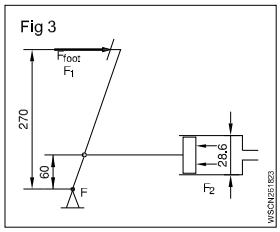
Arm r_1 = 210 mm

Arm r_2 = 70 mm

Find

Force on Master Cylinder = _____ N

3 2nd Order Lever (Brake lever)



Data given

Load Arm = 60 mm

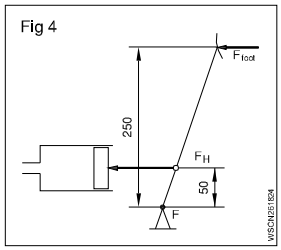
Effort Arm = 270 mm

Foot force F_1 = 600 N

Find

Force on MC Piston F_2 = _____ N

4 Brake Lever



Data given

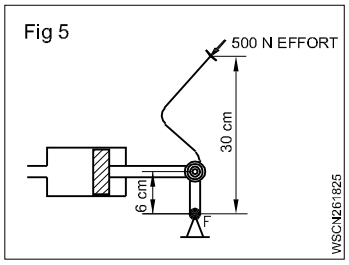
Lever Arm Ratio = 250:50

Force on MC Piston = 1800N

Find

Foot force = _____N

5 Brake Lever



Data given

Effort Arm = 30 cm

Load Arm = 6 cm

Pedal force = 500 N

Dia of MC Piston = 3.2 cm

Find

a Force on MC piston = _____ N

b Pressure in the line = _____ N/cm^2

6 a Which order both arms are equal in length.

b Which order Effort arm is longer.

c Which order Effort arm is shorter than load arm.

7 a Which order belongs to forearm of a human body.

b Which order belongs to a pair of sugar tongs.

c Which order belongs to carburettor Throttle Valve.

d Which order belongs to a common balance.

e Which order belongs to a pair of scissors.

f Which order belongs to a safety valve.

g Which order belongs to a Crow bar.

h Which order belongs to a Brake lever.

8 Find out the values aganist the question mark.

Types of lever	Load	Effort	Load arm	Effort arm	M.A.
Ist order	30 kg	20 kg	3 m	?	?
IInd order	25 kg	15 kg	?	2 m	?
Bell cranked lever	?	25 kg	1 m	2 m	?

9 a What is the principle of levers?

b Write two examples of first order lever.

c Write two examples of second order lever.

d Write two examples of third order lever.

e Which order belongs to bell cranked lever.

f What is the Mechanical advantage?

g What is the Velocity ratio?

h What is the Efficiency?

10 A forceps of 8 cm length is used to apply a foce of 100 gm. Find out the force required if the forceps are held at 5 cm from the fulcurm.