EXERCISE 3(A)

Solutions:

(a) A machine is a device by which we can either overcome a large resistive force (or load) at some point by applying a small force (or effort) at a convenient point and in a desired direction or by which we can obtain a gain in speed.

(b) machine whose parts are weightless and frictionless so that which there is no dissipation of energy in any manner is an ideal machine. The work output is equal to work input i.e its efficiency is 100%

Solutions:

Machines are useful to us in:

(a) Lifting a heavy load by applying a less effort

(b) Changing the point of application of effort to a convenient point

(c) Changing the direction of effort to a convenient direction

(d) For obtaining a gain in speed

Solutions:

(a) To multiply the force: a jack is used in lifting a car

(b) To change the point of application of force: a cycle's wheel is rotated with the help of a chain by applying the force on the pedal.

(c) To change the direction of force: to lift a bucket full of water from the well, a single fixed pulley is used by applying the effort in the downward direction instead of applying it upwards when the bucket is lifted up without the use of pulley.

(d) To obtain gain in speed: when a pair of scissors is used to cut the cloth, the blades of a scissors move longer on cloth while its handles move a little.

Solutions:
In lifting a car, the purpose of jack is to make the effort less than the load so that it works as a force multiplier.

Solutions:
A machine whose parts are weightless and frictionless so that which there is no dissipation of energy in any manner is an ideal machine. The work output is equal to work input which means its efficiency is 100%.

Ideal machine	Practical machine
Efficiency is 100%	Efficiency is less than 100%
Parts are weightless, elastic and perfectly smooth	Parts are not weightless, elastic or perfectly smooth
No loss in energy due to friction	Always some loss of energy due to friction
Work output is equal to the work input	Work output is always less than the work input

Question: 6
Explain the term mechanical advantage. State its unit.
Solutions:
The ratio of the load to the effort is known as mechanical advantage of the machine. Since mechanical advantage is the ratio of two similar quantities, so it has no unit.

Question: 7
Define the term velocity ratio. State its unit.
Solutions:
The term velocity ratio is defined as 'the ratio of the velocity of effort to the velocity of load is called the velocity ratio of machine'. Since the velocity ratio is also the ratio of two similar quantities, so it has no unit.

Question: 8
How is mechanical advantage related to the velocity ratio for
(i) an ideal machine,
(ii) a practical machine?
Solutions:
For an ideal machine, work output is equal to the work input that means its efficiency is 100% and the mechanical advantage is numerically equal to the velocity ratio

M.A. = V.R

The mechanical advantage for all practical machines is always less than its velocity ratio or the output work is always less than the input work.

M.A < V.R.

Question: 9

Define the term efficiency of a machine. Give two reasons for a machine not to be 100% efficient?

Solutions:

The term efficiency of a machine is defined as the ratio of the work done on load by the machine to the work done on machine by the effort or efficiency is the ratio of the work output to the work input.

There is always some loss of energy due to friction and weight of moving parts in practical machines. So, the output energy is less than the input energy.

Question: 10

When does a machine act as (a) a force multiplier and (b) a speed multiplier? Can a machine act as a force multiplier and speed multiplier simultaneously?

Solutions:

(a) When the effort arm is longer than the load arm then the machine acts as a force multiplier. The mechanical advantage of such machines is greater than 1.

(b) When the effort arm is shorter than the load arm then the machine acts as a speed multiplier. The mechanical advantage of such machines is less than 1

Machines which are force multipliers cannot gain in speed and vice-versa. So, it is not possible for a machine to act as a force multiplier and speed multiplier simultaneously.

Question: 11

A machine works as a (i) force multiplier, (ii) speed multiplier. In each case state whether the velocity ratio is more than or less than 1.

Solutions:

(i) Displacement of load is less than the displacement of effort for a machine working as a force multiplier. Hence, the velocity ratio is more than 1

(ii) Displacement of load is more than displacement of effort for a machine working as a speed multiplier. Hence, the velocity ratio is less than 1

Question: 12

(a) State the relationship between mechanical advantage, velocity ratio and efficiency.

(b) Name the term that will not change for a machine of a given design.

Solutions:

(a) The mechanical advantage of a machine is equal to the product of its efficiency and velocity ratio.

$M.A = V.R \times \eta$

(b) The velocity ratio does not change for a machine of a given design

Question: 13

Derive a relationship between mechanical advantage, velocity ratio and efficiency of a machine.

Solutions:

Let a machine overcomes a load L by the application of effort E. Let the displacement of effort be d_E and the displacement of load be d_L in time t.

Work input = effort × displacement of effort

$= E \times d_E$

Work output = load × displacement of load

$= L \times d_L$

Efficiency η = work output / work input

$\eta = (L \times d_L) / (E \times d_E)$

$= L / E \times d_L / d_E$

$= L / E \times 1 / (d_E / d_L)$

But $L / E = M.A.$

$d_E / d_L = V.R.$

$\eta = M.A. / V.R.$

$M.A. = V.R. \times \eta$

Hence, the mechanical advantage of a machine is equal to the product of its efficiency and velocity ratio.

Question: 14

How is the mechanical advantage related with the velocity ratio for an actual machine? State whether the efficiency of such a machine is equal to 1, less than 1 or more than 1.

Solutions:

For an actual machine, the mechanical advantage is equal to the product of its efficiency and velocity ratio.

$M.A. = V.R. \times \eta$

The efficiency of such a machine is always less than 1

Question: 15

State one reason why is mechanical advantage less than the velocity ratio for an

actual machine.

Solutions:

For an actual machine the output work is always less than the input work, so the efficiency is always less than 1 because there is loss of energy due to friction.

Question: 16

What is a lever? State its principle.

Solutions:

A lever is a rigid, straight or bent bar which is capable of turning about a fixed axis.

Principle: A lever works on the principle of moments. For an ideal lever, it is assumed that the rod is weightless and there is no friction at the fulcrum. In the equilibrium position of the lever, by the principle of moments,

Moment of load about the fulcrum = Moment of the effort about the fulcrum

Question: 17

Write down a relation expressing the mechanical advantage of a lever.

Solutions:

The expression of the mechanical advantage of a lever is -

M.A. = (Effort arm) / (Load arm)

Question: 18

Name the three classes of levers and state how are they distinguished. Give two examples of each class.

Solutions:

The following are the three classes of levers

(i) Class I levers: In this type of the levers, the fulcrum F is in between the effort E and the load L.

Example: claw hammer, beam of a physical balance, crowbar, a seesaw

(ii) Class II levers: In these type of levers, the load L is in between the effort E and the fulcrum F. Thus the effort arm is always longer than the load arm.

Example: a wheel barrow, a paper cutter, a door, a nut cracker

(iii) Class III levers: In these type of levers, the effort E is in between the fulcrum F and the load L. Thus the effort arm is always smaller than the load arm.

Example: fire tongs, knife, fishing rod, sugar tongs

Question: 19

Give one example each of a class I lever where mechanical advantage is (a) more than 1, and (b) less than 1.

Solutions:

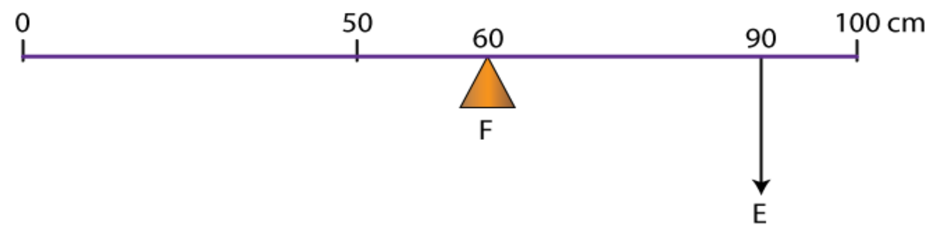
(a) For more than one mechanical advantage: shears used for cutting the thin metal sheets.
(b) For less than one mechanical advantage: a pair of scissors whose blades are longer than its handles.

Question: 20
What is the use of lever if its mechanical advantage is (a) more than 1, (b) equal to 1, and (c) less than 1?
Solutions:
(a) When the mechanical advantage is more the 1, the lever serves as force multiplier means it enables us to overcome a large resistive force by a small effort.
(b) When the mechanical advantage is equal to 1, the lever has effort arm and load arm of equal lengths.
(c) When the mechanical advantage is less than 1, the levers are used to obtain the gain in speed. This implies that the displacement of load is more as compared to the displacement of effort.

Question: 21
Both a pair of scissors and a pair of pliers belong to the same class of levers. Name the class of lever. Which one has the mechanical advantage less than 1?
Solutions:
A pair of scissors and a pair of pliers both belong to class I lever.
A pair of scissors has the mechanical advantage less than 1

Question: 22
Explain why scissors for cutting cloth may have blades longer than the handles, but shears for cutting metals have short blades and long handles.
Solutions:
A pair of scissors which is used to cut a piece of cloth has blades longer than the handles so that the blades move longer on the cloth when the handles are moved a little.
Shears used for cutting metals have short blades and long handles because it enables us to overcome large resistive force by a small effort.

Question: 23
Figure shows a uniform metre rule of weight W supported on a fulcrum at the 60 cm mark by applying the effort E at the 90 cm mark.



(a) State with reasons whether the weight *W* of the rule is greater than, less than or equal to the effort *E*.

(b) Find the mechanical advantage in an ideal case.

Solutions:

(a) The weight W of the scale is greater than E

The arm on the side of effort E is 30 cm and on the side of weight of scale is 10 cm. So, in order to balance the scale, weight W of scale should be more than effort E

(b) M.A. = Effort arm / Load arm

Effort arm = 30 cm

Load arm = 10 cm

Thus M.A. = 30 / 10

= 3

Question: 24

Which type of lever has a mechanical advantage always more than 1? Give reason with one example. What change can be made in this lever to increase its mechanical advantage?

Solutions:

The mechanical advantage of Class II levers are always more than 1

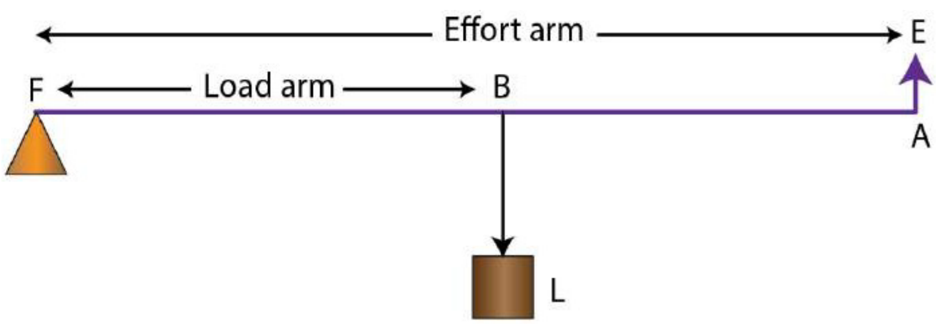
Example: a paper cutter

We can increase the length of effort arm in this lever to increase its mechanical advantage.

Question: 25

Draw a diagram of a lever which is always used as a force multiplier. How is the effort arm related to the load arm in such a lever?

Solutions:

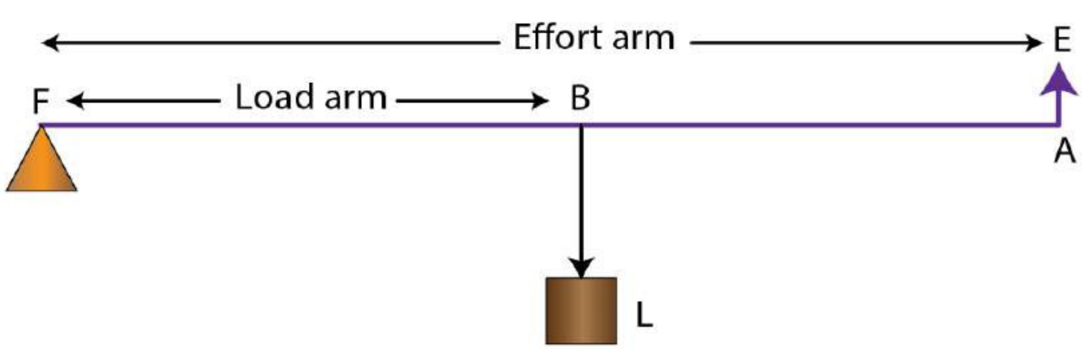


(b) Class II

In this type of lever the effort arm is longer than the load arm

Question: 26
Explain why the mechanical advantage of a class II type of lever is always more than 1.
Solutions:
In a Class II type of levers, the load L is in between the effort E and the fulcrum F. So, the effort arm is always longer than the load arm. Hence, M.A. > 1

Questions: 27
Draw a labelled diagram of a Class II lever. Give one example of such a lever.
Solutions:

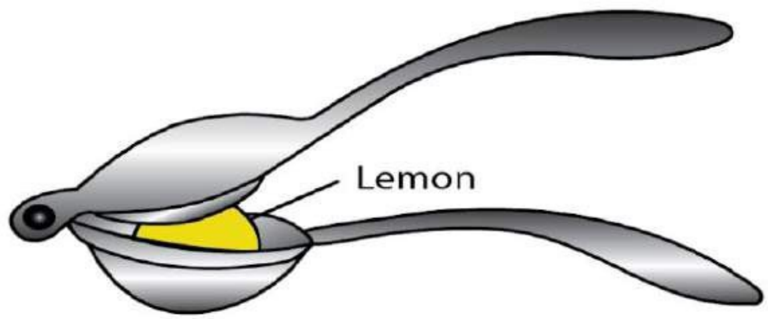


(b) Class II

Example: a wheel barrow

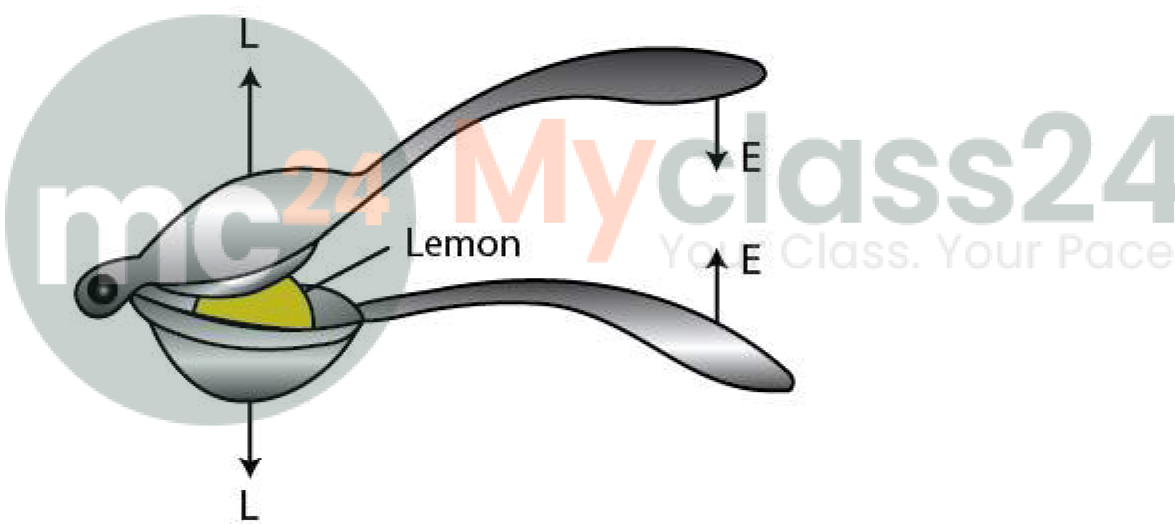
Question: 28
Shows a lemon crusher.

(a) In the diagram, mark the position of the directions of load L and effort E.
(b) Name the class of lever.



Solutions:

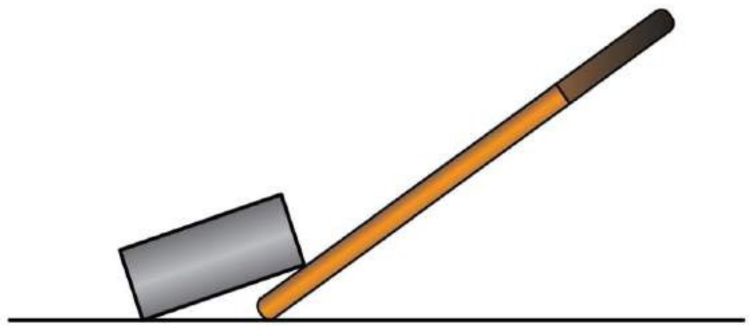
(a)



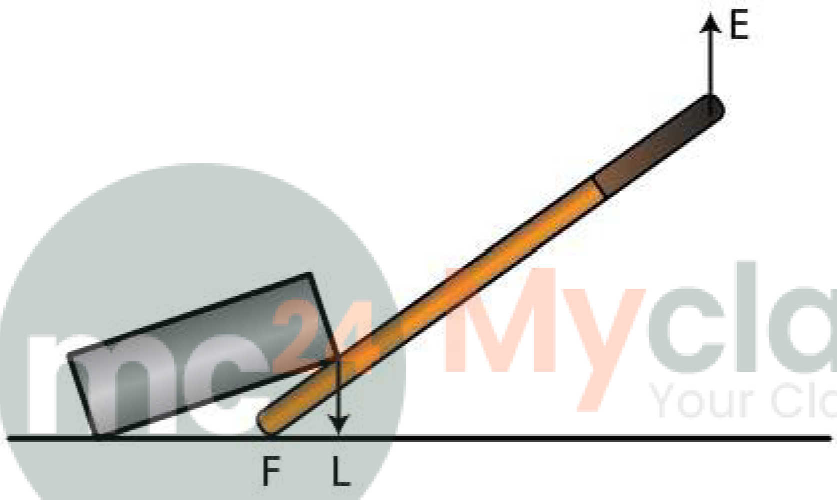
(b) It is a class II lever.

Question: 29

The diagram below shows a rod lifting a stone.
(a) Mark position of fulcrum F and draw arrows to show the directions of load L and effort E.
(b) What class of lever is the rod?
(c) Give one more example of the same class of lever stated in part (b).

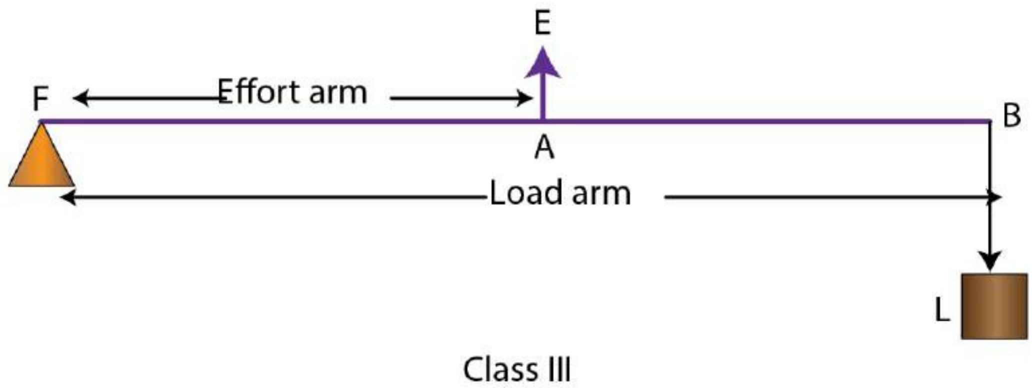


Solutions:



(b) Here the load is between fulcrum and effort. So, this rod is a class II lever.
(c) A wheel barrow is an example of class II lever.

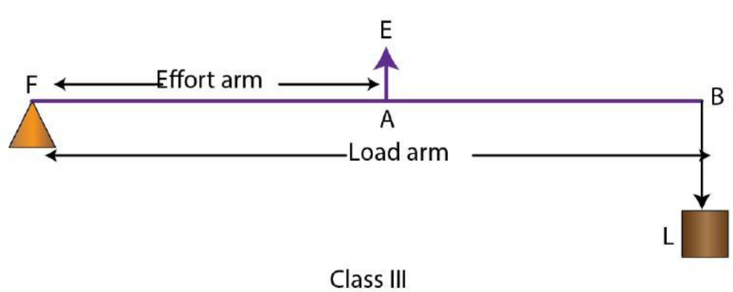
Question: 30
State the kind of lever which always has the mechanical advantage less than 1. Draw a labelled diagram of such a lever.
Solutions:
The mechanical advantage of Class III levers are always less than 1



Question: 31
Explain why the mechanical advantage of the class III lever is always less than 1.
Solutions:
In Class III lever, the effort E is in between the fulcrum F and the load L. So, the effort arm is always smaller than the load arm. Hence, M.A. < 1

Question: 32
Classes III levers have mechanical advantage less than 1. Why are they then used?
Solutions:
With levers of Class III, we do not get gain in force, but we get gain in speed, i.e a larger displacement of load is obtained by a smaller displacement of effort.

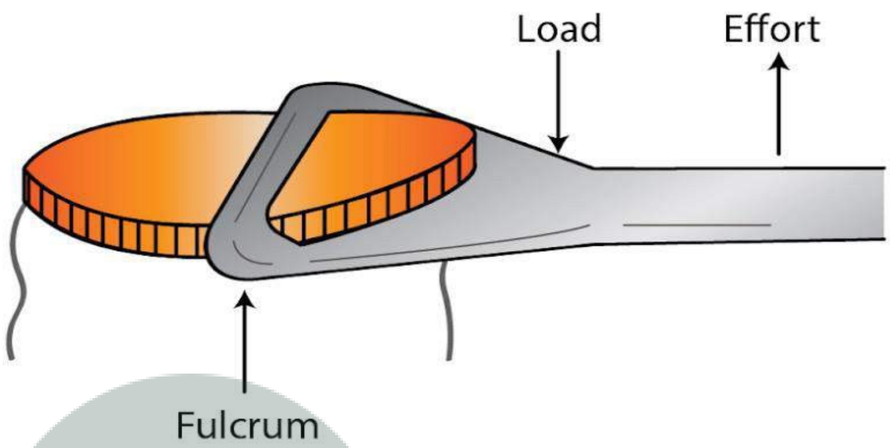
Question: 33
Draw a labelled sketch of a class III lever. Give one example of this kind of lever.
Solutions:



Example: Knife

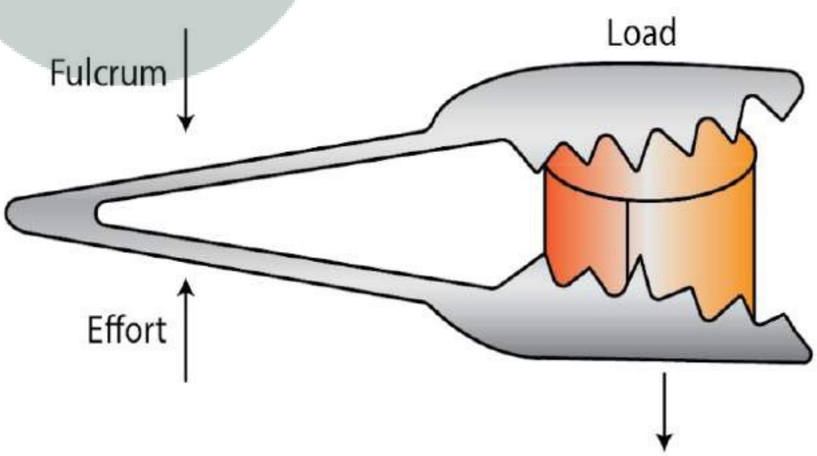
Question: 34
State the class of levers and the relative positions of load (*L*), effort (*E*) and fulcrum (*F*) in

(a) a bottle opener, and
(b) sugar tongs.
Solutions:
(a) A bottle opener is a lever of Class II, as the fulcrum F and the effort E are at the two ends of the lever and the load is in between the fulcrum F and the effort E.



Bottle opener

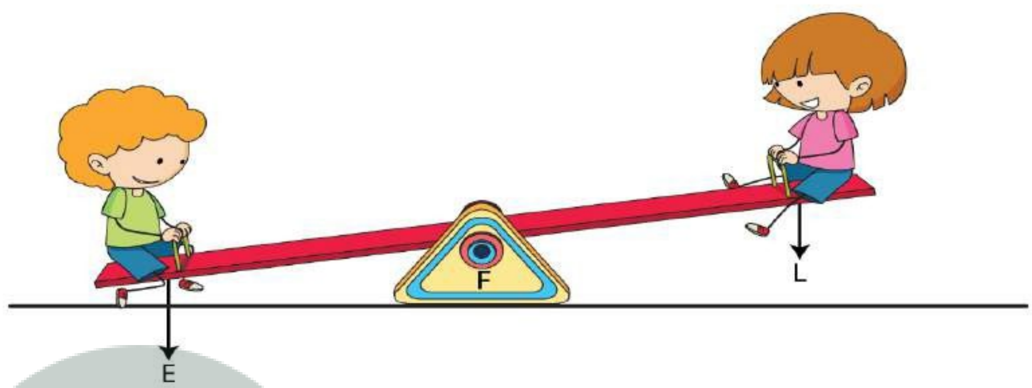
(b) Sugar tongs is a lever of Class III, as the fulcrum F and the load L are at the two ends of the lever and the effort E is in between the fulcrum F and the load L



Sugar tongs

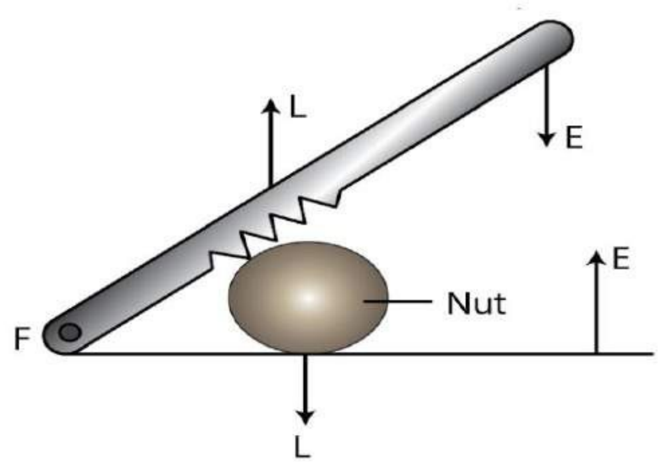
Question 35:
Draw diagrams to illustrate the position of fulcrum, load and effort, in each of the following:

(a) A seesaw
(b) A common balance
(c) A nut cracker
(d) Forceps.
Solutions:
(a) A seesaw

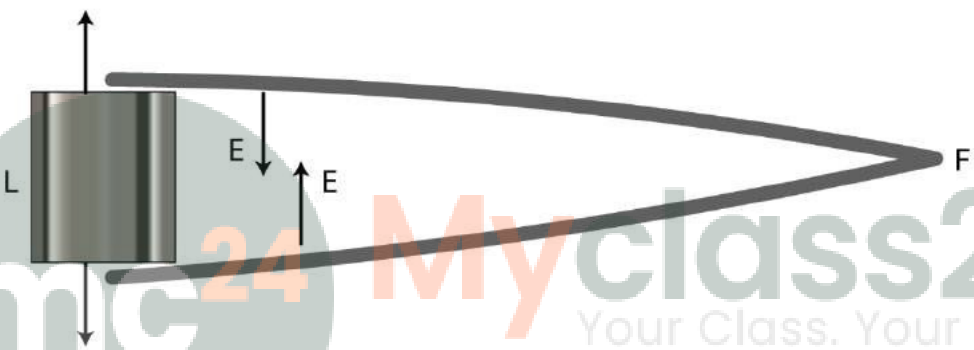


(b) A common balance

(c) A nut cracker



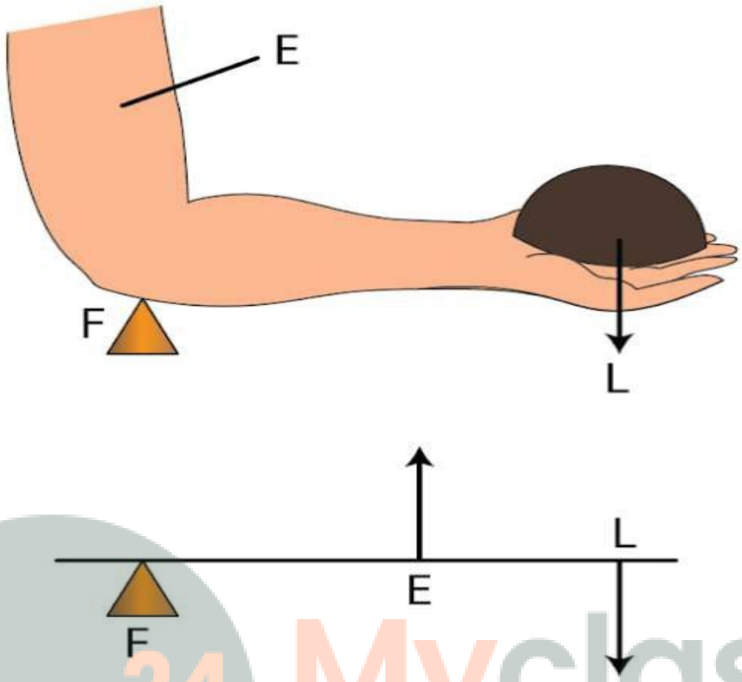
(d) Forceps



Question: 36
Classify the following into levers as class I, class II or class III:
(a) A door
(b) A catapult
(c) A wheel barrow
(d) A fishing rod.
Solutions:
(a) A door – Class II
(b) A catapult – Class I
(c) A wheel barrow – Class II
(d) A fishing rod – Class III

Question: 37
What type of lever is formed by the human body while (a) raising a load on the palm, and (b) raising the weight of body on toes?
Solutions:
(a) Raising a load on the palm is a Class III lever

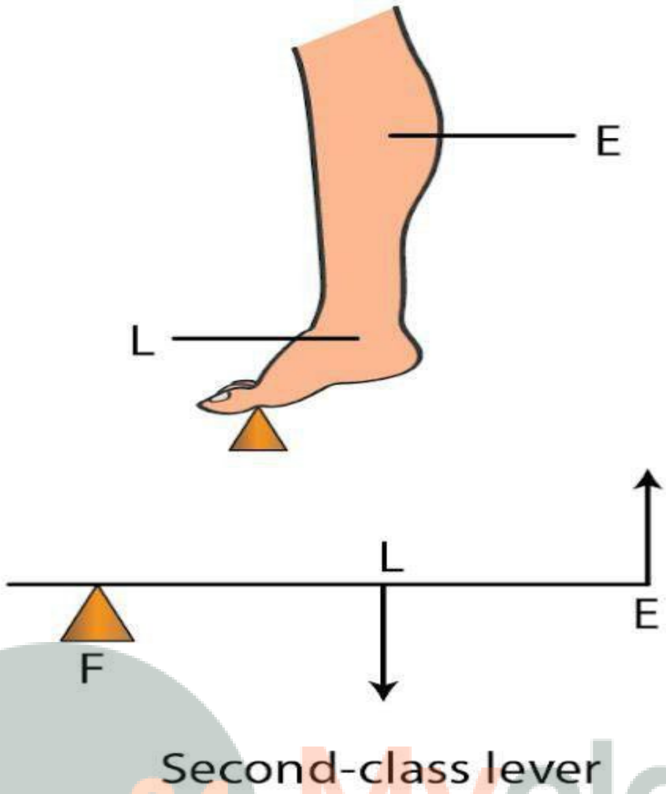
Here, the elbow of the human arm is the fulcrum. Biceps exert the effort in the middle and load on the palm is at the other end.



Third-class lever

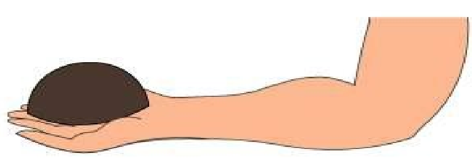
(b) Raising a weight of body on toes is a Class II lever

The fulcrum is at toes at one end, the load that is weight of the body is in the middle and the effort by muscles is at the other end.

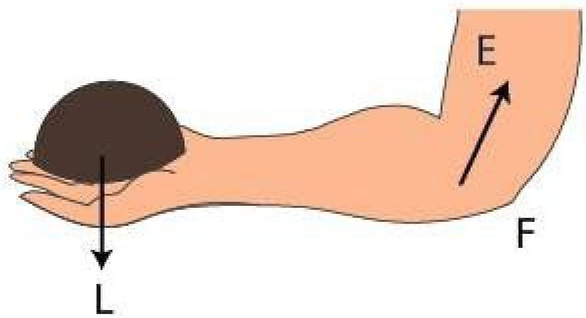


Question: 38

Indicate the positions of load L, effort E and fulcrum F in the forearm shown below. Name the class of lever.



Solutions:



It is a Class III lever

Question: 39
Give example of each class of lever in a human body.
Solutions:
The examples of each class of lever in a human body are as follows
(i) The action of nodding of the head is a Class I lever. Here the spine acts as the fulcrum, load is at its front part and effort is at its rear part.
(ii) Raising the weight of the body on toes is a Class II lever. Here the fulcrum is at toes at one end, the load is in the middle and effort by muscles is at the other end.
(iii) Raising a load by forearm is a Class III lever. Here the elbow joint acts as fulcrum at one end, biceps exerts the effort in the middle and a load on the palm is at the other end.

Question: 40
Complete the following sentences:
(a) Mechanical advantage = ___________ × velocity ratio
(b) In class II lever, effort arm is___________than the load arm.
(c) A scissors is a ___________multiplier.
Solutions:
(a) Mechanical advantage = efficiency × velocity ratio
(b) In Class II lever, effort arm is longer than the load arm.
(c) A scissors is speed multiplier

MULTIPLE CHOIC TYPE
Question: 1
Mechanical advantage (M.A.), load (L) and effort (E) are related as:
a. M.A. = L x E
b. M.A. x E = L

c. E = M.A. x L
d. None of these
Solutions:
Mechanical advantage (M.A.), load (L) and effort (E) are related as

$$M.A \times E = L$$

Question: 2
The correct relationship between the mechanical advantage (M.A.), velocity ratio (V.R.) and efficiency (η) is:
a. M.A. = η x V.R.
b. V.R. = η x M.A.
c. η = M.A. x V.R.
d. None of these
Solutions:
The correct relationship between the mechanical advantage (M.A), velocity ratio (V.R) and efficiency (η) is

$$M.A. = \eta \times V.R.$$

Question: 3
Select the incorrect statement:
(a) A machine always has the efficiency less than 100%.
(b) The mechanical advantage of a machine can be less than 1.
(c) A machine can be used as speed multiplier.
(d) A machine can have the mechanical advantage greater than the velocity ratio.
Solutions:
The incorrect statement is-
A machine can have the mechanical advantage greater than the velocity ratio.

Question: 4
The lever for which the mechanical advantage is less than 1 has the:
(a) Fulcrum at mid-point between load and effort.
(b) Load between effort and fulcrum.
(c) Effort between fulcrum and load.
(d) Load and effort acting at the same point.
Solutions:
The lever for which the mechanical advantage is less than 1 has the effort between fulcrum and load

Question: 5

Class II levers are designed to have:
a. M.A. = V.R.
b. M.A. > V.R.
c. M.A. > 1
d. M.A. < 1
Solutions:
Class II levers are designed to have-
M.A. > 1

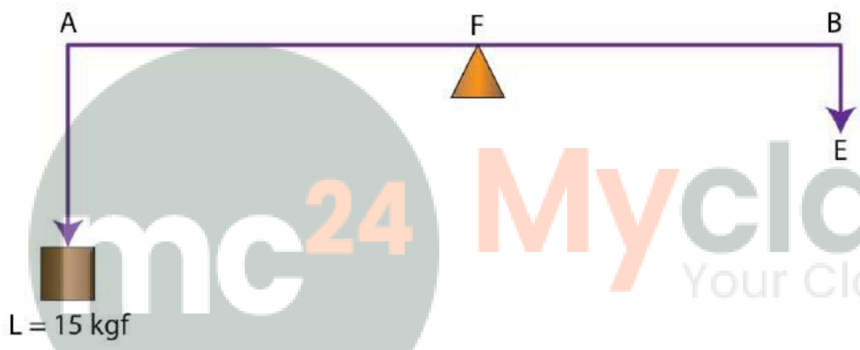
NUMERICALS
Question: 1
A crowbar of length 120 cm has its fulcrum situated at a distance of 20 cm from the load. Calculate the mechanical advantage of the crowbar.
Solutions:
Given
Total length of a crowbar = 120 cm
Load arm = 20 cm
Effort arm = 120 – 20
= 100 cm
Mechanical advantage M.A. = Effort arm / Load arm
M.A. = 100 / 20
= 5

Question: 2
A pair of scissors has its blades 15 cm long, while its handles are 7.5 cm long. What is its mechanical advantage?
Solutions:
Given
Effort arm = 7.5 cm
Load arm = 15 cm
Mechanical advantage M.A = Effort arm / Load arm
= 7.5 / 15
= 0.5

Question: 3
A force of 5kgf is required to cut a metal sheet. A shears used for cutting the metal sheet has its blades 5 cm long, while its handle is 10 cm long. What effort is needed to cut the sheet?
Solutions:

Given
Effort arm = 10 cm
Load arm = 5 cm
Mechanical advantage M.A. = Effort arm / Load arm
= 10 / 5
= 2
To find effort, we have
Effort = Load / M.A
= 5 / 2
= 2.5 kgf

Question: 4
The diagram below shows a lever in use.

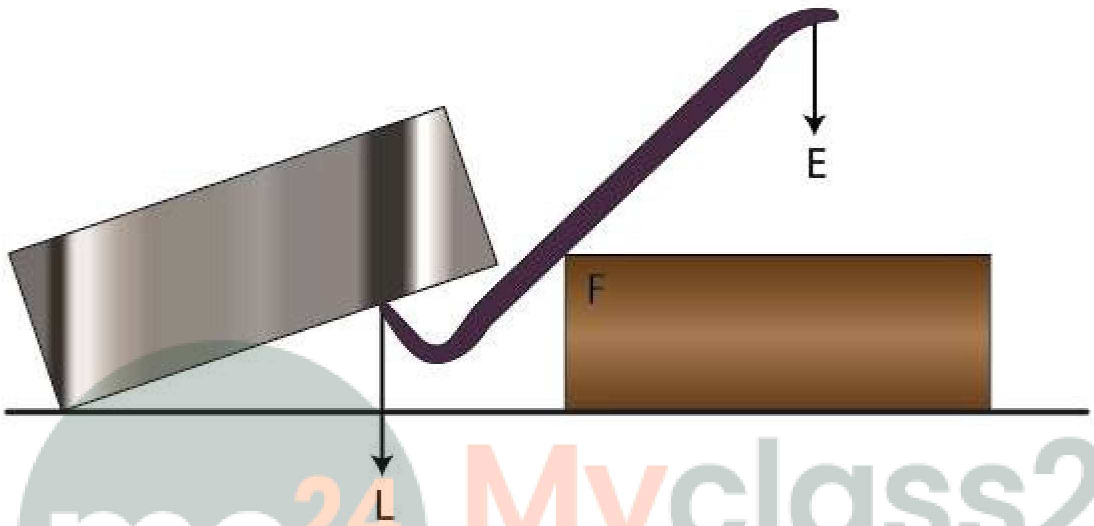


(a) To which class of lever does it belong?
(b) If AB =1 m, AF= 0.4 m, find its mechanical advantage.
(c) Calculate the value of E.
Solutions:
(a) This belongs to a Class I lever
(b) Given AB = 1m
AF = 0.4 m
BF = 0.6 m
Mechanical advantage M.A = BF / AF
= 0.6 / 0.4
= 1.5
(c) Given Load = 15 kgf
Effort = Load / M.A
= 15 / 1.5
= 10 kgf

Question: 5

A man uses a crowbar of length 1.5 m to raise a load of 75kgf by putting a sharp edge below the bar at a distance 1 m from his hand. (a) Draw a diagram of the arrangement showing the fulcrum (F), load (L) and effort (E) with their directions. (b) State the kind of lever. (c) Calculate: (i) load arm, (ii) effort arm, (iii) mechanical advantage, and (iv) the effort needed.

Solutions:



Crowbar is a class I lever

Given

(i) Total length of crowbar = 1.5 m

Effort arm = 1 m

Load arm = 1.5 – 1

= 0.5 m

(ii) Effort arm = 1 m

(iii) Mechanical advantage M.A. = Effort arm / Load arm

= 1 / 0.5

= 2

(iv) The effort needed

Effort = Load / M.A.

= 75 / 2

= 37.5 kgf

Question: 6

A pair of scissors is used to cut a piece of a cloth by keeping it at a distance 8.0 cm from its rivet and applying an effort of 10 kgf by fingers at a distance 2.0 cm from

the rivet.
(a) Find: (i) the mechanical advantage of scissors and (ii) the load offered by the cloth.
(b) How does the pair of scissors act: as a force multiplier or as a speed multiplier?
Solutions:

Effort arm = 2 cm
Load arm = 8.0 cm
Given effort = 10 kgf
(i) Mechanical advantage M.A. = Effort arm / Load arm
= 2 / 8
= 0.25
(ii) Load = M.A. × effort
= 0.25 × 10
= 2.5 kgf

The pair of scissors acts as a speed multiplier since mechanical advantage is less than 1 i.e M.A < 1

Question: 7
A 4 m long rod of negligible weight is to be balanced about a point 125 cm from one end and a load of 18 kgf is suspended at a point 60 cm from the support on the shorter arm.
(a) If a weight W is placed at a distance of 250 cm from the support on the longer arm, Find W.
(b) If a weight 5 kgf is kept to balance the rod, find its position.
(c) To which class of lever does it belong?
Solutions:

Given
Total length of rod = 4 m = 400 cm
(a) 18 kgf load is placed at 60 cm from the support.
W kgf weight is placed at 250 cm from the support.
According to the principle of moments
18 × 60 = W × 250
W = 4.32 kgf
(b) Given W = 5 kgf
18 kgf weight is placed at 60 cm from the support.
Let 5 kg of weight is placed at d cm from the support.
According to the principle of moments
18 × 60 = 5 × d
d = 216 cm from the support on the longer arm

(c) It belongs to class I lever

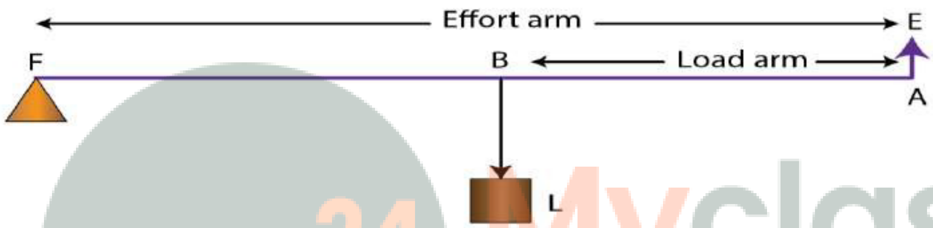
Question: 8

A lever of length 9 cm has its load arm 5 cm long and the effort arm is 9 cm long. (a) To which class does it belong? (b) Draw diagram of the lever showing the position of fulcrum F and directions of both the load L and effort E. (c) What is the mechanical advantage and velocity ratio if the efficiency is 100%? (d) What will be the mechanical advantage and velocity ratio if the efficiency becomes 50%?

Solutions:

(a) Length of the lever is equal to the effort arm. The effort arm is also more than the load arm. Hence this is a class II lever.

(b)



(b) Class II

(c) Mechanical advantage is

M.A. = Effort arm / Load arm

= 9 cm / 5 cm

M.A. = 1.8

Relation between mechanical advantage, efficiency and velocity ratio is

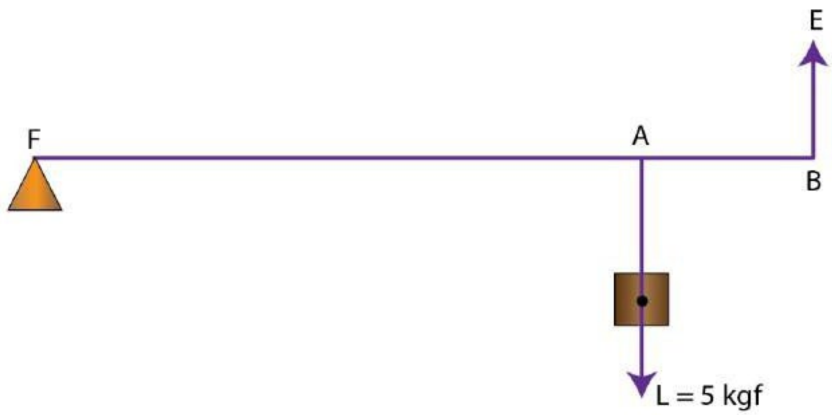
M.A. = $\eta \times$ V.R.

M.A.= V.R. (η = 100% = 1)

(d) When efficiency reduces, its mechanical advantage reduces and velocity ratio remains the same. So, when efficiency becomes 50%, M.A. = 0.9 and V.R. = 1.8

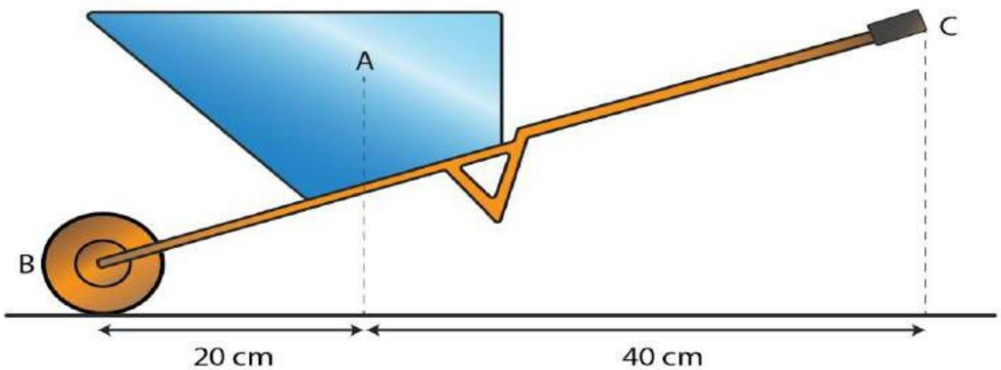
Question: 9

The diagram below shows a lever in use.



(a) To which class of lever does it belong?
(b) If FA = 80 cm, AB = 20 cm, find its mechanical advantage.
(c) Calculate the value of E.
Solutions:
(a) It belongs to class II lever.
(b) Given FA = 80 cm
AB = 20 cm
BF = FA + AB
= 100 cm
Mechanical advantage M.A. = BF / AF
= 100 / 80
= 1.25
(c) Effort (E) = Load (L) / M.A.
= 5 / 1.25
= 4 kgf

Question: 10
The figure shows a wheel barrow of mass 15 kg carrying a load of 30 kgf with its center of gravity at A. The points B and C are the centre of wheel and tip of the handle such that the horizontal distance AB = 20 cm and AC = 40 cm.



Find: (a) the load arm, (b) the effort arm, (c) the mechanical advantage, and (d) the minimum effort required to keep the leg just off the ground.

Solutions:

(a)

(i) Load arm AF = 20 cm

(ii) Effort arm CF = 60 cm

(iii) Mechanical advantage M.A. = CF / AF

= 60 / 20

= 3

(iv) Total load = 30 + 15

= 45 kgf

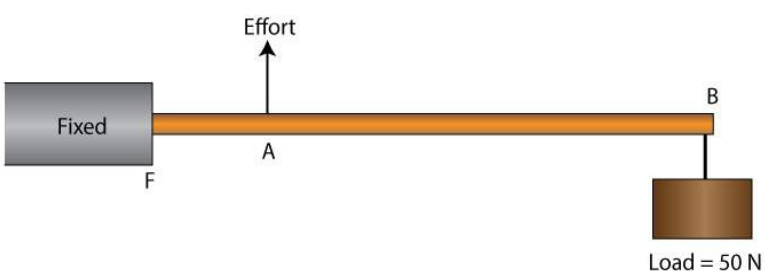
Effort = Load / M.A

= (30 + 15) / 3

= 15 kgf

Question: 11

The diagram below shows the use of a lever.



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

(b) To which class of lever does it belong? Give an example of this class of lever.

(c) If FA = 10cm, AB = 490cm, calculate: (i) the mechanical advantage, and (ii) the

minimum effort required to lift the load (= 50N).
Solutions:
(a) According to the principle of moments
Moment of the load about the fulcrum = moment of the effort about the fulcrum
load × FB = Effort × FA
(b) It belongs to Class III lever. The example of this lever is knife.
(c) Given FA = 10 cm
AB = 490 cm
BF = 490 + 10
= 500 cm
The mechanical advantage
M.A= AF / BF
= 10 / 500
= 1 / 50
The minimum effort required to lift the load
Effort = Load / M.A
= 50 / 1 / 50
= 50 × 50
= 2500 N

Question: 12
A fire tongs has its arms 20 cm long. It is used to lift a coal of weight 1.5kgf by applying an effort at a distance 15 cm from the fulcrum. Find: (i) the mechanical advantage of fire tongs and (ii) the effort needed.
Solutions:
Given
Fire tongs has its arms = 20 cm
Effort arm = 15 cm
Load arm = 20 cm
(i) Mechanical advantage M.A. = Effort arm / Load arm
= 15 / 20
= 0.75
(ii) Effort = Load / M.A
= 1.5 / 0.75
= 2.0 kgf