

### EXERCISE 3(B)

**Solutions:**

Fixed pulley is defined as 'a pulley which has its axis of rotation stationary in position is called a fixed pulley. This type of pulley is used lifting a small load such as a water bucket.

**Solutions:**

The mechanical advantage of a single fixed pulley is 1. No, it cannot be used as a force multiplier.

**Solutions:**

In single fixed pulley there is no gain in mechanical advantage. A single fixed pulley is used only to change the direction of effort to be applied i.e with its use the effort can be applied in more convenient direction. It is difficult to lift a load up directly upwards.

**Solutions:**

The velocity ratio of a single fixed pulley is 1

**Solutions:**

The load rises with the distance  $x$  upwards.

**Question: 6**

**What is a single movable pulley? What is its mechanical advantage in the ideal case?**

**Solutions:**

A single pulley whose axis of rotation is movable is called a single movable pulley. The

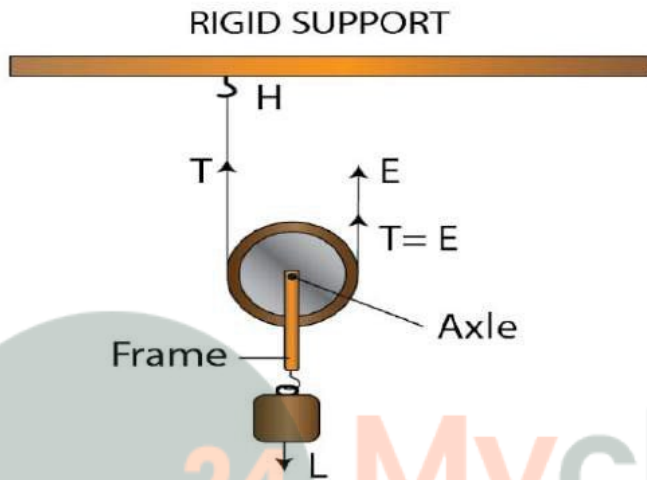
mechanical advantage in the ideal case is 2

**Question: 7**

**Name the type of single pulley that has an ideal mechanical advantage equal to 2. Draw a labeled diagram of the pulley mentioned by you.**

**Solutions:**

The single movable pulley acts as a force multiplier.



**Question: 8**

**Give two reasons why the efficiency of a single movable pulley system is not 100%.**

**Solutions:**

The efficiency of a single movable pulley system is not 100% because of the following reasons

- (i) The friction of the pulley bearing is not zero
- (ii) The weight of the pulley and string is not zero

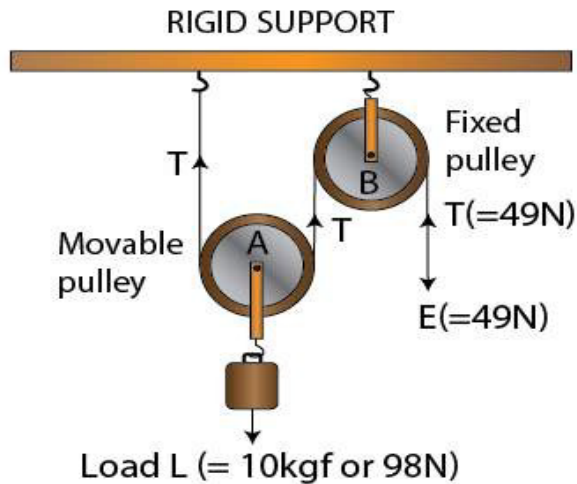
**Question: 9**

**In which direction the force need be applied, when a single pulley is used with a mechanical advantage greater than 1? How can you change the direction of force applied without altering its mechanical advantage? Draw a labelled diagram of the system.**

**Solutions:**

The force need to be applied in upward direction.

By using a single movable pulley along with a fixed pulley the direction of applied force can be changed without altering its mechanical advantage.



**Question: 10**

**What is the velocity ratio of a single movable pulley? How does the friction in the pulley bearing affect it?**

**Solutions:**

The velocity ratio of a single movable pulley is always 2. The friction in the pulley bearing has no effect.

**Question: 11**

**In a single movable pulley, if the effort moves by a distance  $x$  upwards, by what height is the load raised?**

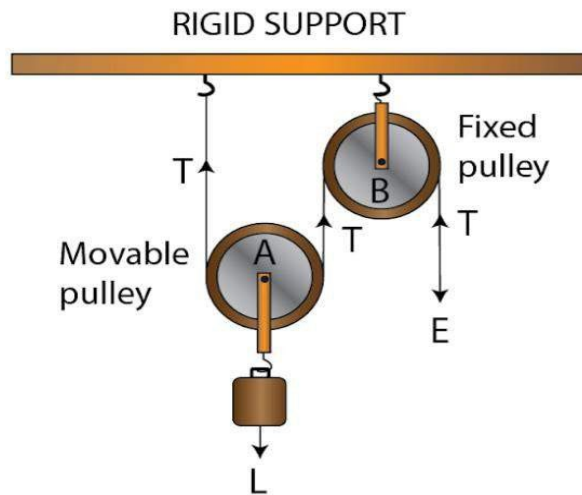
**Solutions:**

The load is raised to a height of  $x / 2$

**Question: 12**

**Draw a labelled diagram of an arrangement of two pulleys, one fixed and other moveable. In the diagram, mark the directions of all forces acting on it. What is the ideal mechanical advantage of the system? How can it be achieved?**

**Solutions:**

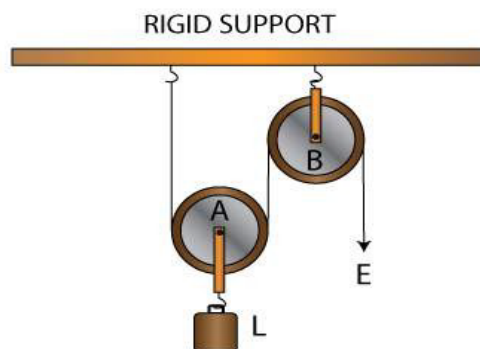


The ideal mechanical advantage of this system is 2. This can be achieved by assuming that string and the pulley are massless and also there is no friction in the pulley bearings between the string and surface of the rim of the pulley.

**Question: 13**

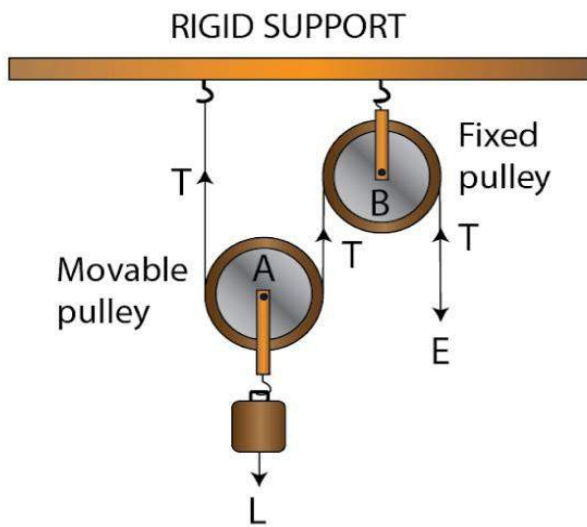
The diagram alongside shows a pulley arrangement.

- Name the pulleys A and B.
- In the diagram, mark the direction of tension on each strand of string.
- What is the purpose of the pulley B?
- If the tension is  $T$ , deduce the relation between (i)  $T$  and  $E$ , and (ii)  $E$  and  $L$ .
- What is the velocity ratio of the arrangement?
- Assuming that the efficiency of the system is 100%, what is the mechanical advantage?



**Solutions:**

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- (b) The purpose of fixed pulley B is to change the direction of effort to be applied from upward to downward  
 (c) At the free end, the effort E balances the tension T. So,  $E = T$   
 (d) The velocity ratio of this arrangement is 2  
 (e) If the efficiency of the system is 100%, the mechanical advantage is 2

**Question: 14**

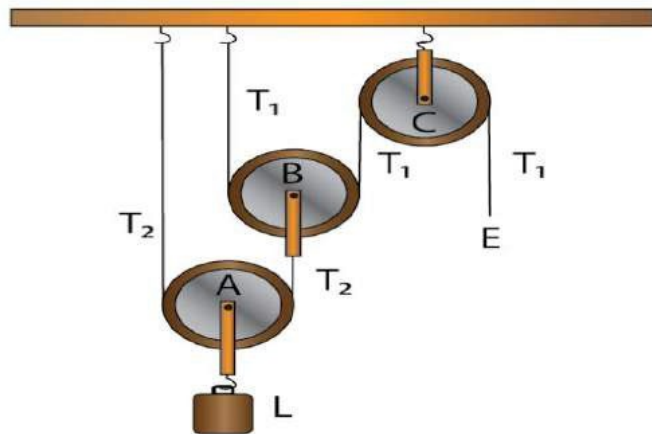
State four differences between a single fixed pulley and a single movable pulley.

**Solutions:**

Single fixed pulley	Single movable pulley
It is fixed to a rigid support	It is not fixed to a rigid support
Its ideal mechanical advantage is 1	Its ideal mechanical advantage is 2
Its velocity ratio is 1	Its velocity ratio is 2
The weight of pulley itself does not affect its mechanical advantage	The weight of pulley itself reduces its mechanical advantage
It is used to change the direction of effort from upwards to downwards	It is used as a force multiplier

**Question: 15**

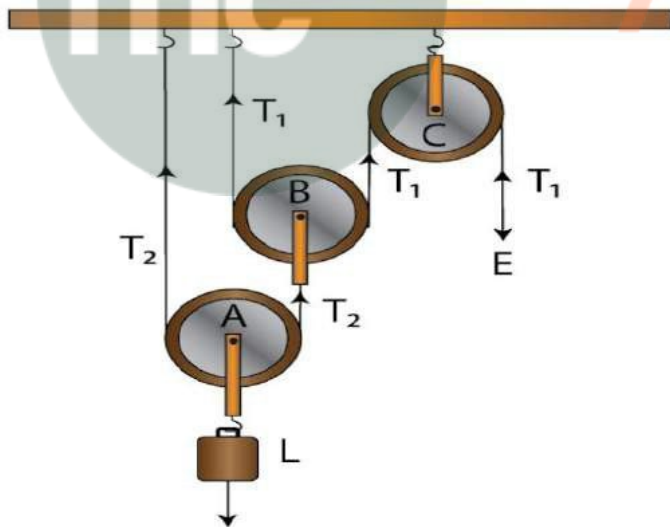
The diagram alongside shows an arrangement of three pulleys A, B and C. The load is marked as L and the effort as E.



- Name the pulleys A, B and C.
- Mark in the diagram the direction of load (L), effort (E) and tension  $T_1$  and  $T_2$  in the two strings.
- How are the magnitudes of L and E related to the tension  $T_1$ ?
- Calculate the mechanical advantage and velocity ratio of the arrangement.
- What assumptions have you made in parts (c) and (d)?

**Solutions:**

- Pulleys A and B are movable pulleys while pulley C is a fixed pulley.
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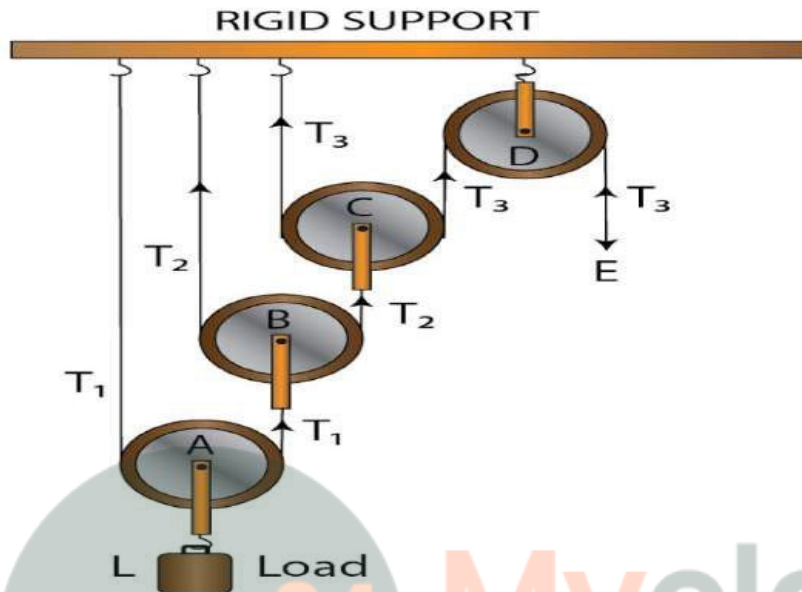
- The magnitude of effort  $E = T_1$  and the magnitude of  $L = 2^2 T_1 = 4T_1$
- The mechanical advantage  $= 2^2 = 4$  and the velocity ratio  $= 2^2 = 4$
- The pulleys A and B are weightless and there is no friction

**Question: 16**

**Draw a diagram of combination of three movable pulleys and one fixed pulley to lift**

up a load. in the diagram, show the directions of load, effort and tension in each strand. Find: (i) the mechanical advantage, (ii) velocity ratio and (iii) the efficiency of the combination in ideal situation.

Solutions:



Tension  $T_1$  in the string passing over the pulley A is given as

$$2T_1 = L$$

$$T_1 = L / 2$$

Tension  $T_2$  in the string passing over the pulley B is given as

$$2T_2 = T_1$$

$$T_2 = T_1 / 2$$

$$T_2 = L / 2^2$$

Tension  $T_3$  in the string passing over the pulley C is given as

$$2T_3 = T_2$$

$$T_3 = T_2 / 2$$

$$T_3 = L / 2^3$$

In equilibrium,  $T_3 = E$

$$E = L / 2^3$$

Mechanical advantage  $M.A = L / E = 2^3$

As one end of each string passing over a movable pulley is fixed, so the other end of string moves up twice the distance moved by the axle of the movable pulley.

If the load  $L$  moves up by a distance  $x$  i.e  $d_L = x$  and

The effort moves by a distance  $2^3x$  or  $d_E = 2^3x$

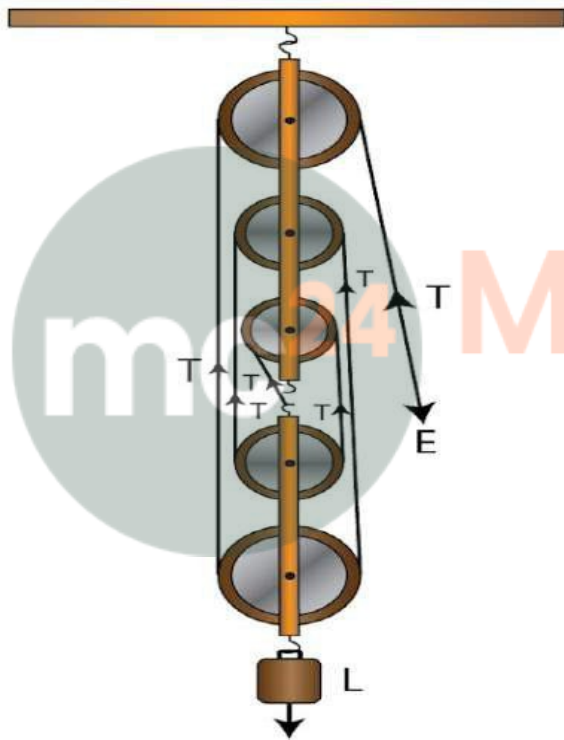
Velocity Ratio  $VR = (\text{Distance moved by the effort } d_E) / (\text{Distance moved by the load } d_L)$   
 $= 2^3x / x$

$$\begin{aligned} &= 2^3 \\ \text{Efficiency} &= \text{M.A} / \text{V.R} \\ &= 2^3 / 2^3 \\ &= 1 \text{ or } 100\% \end{aligned}$$

**Question: 17**

**Draw a diagram of a block and tackle system of pulleys having a velocity ratio of 5. In your diagram indicate clearly the points of application and the directions of the load L and effort E. Also mark the tension T in each strand.**

**Solutions:**



**Question: 18**

**Give reasons for the following:**

- In a single fixed pulley, the velocity ratio is always more than the mechanical advantage.**
- The efficiency of a movable pulley is always less than 100%.**
- In case of block and tackle system, the mechanical advantage increases with the increase in the number of pulleys.**
- The lower block of a block and tackle pulley system must be of negligible weight.**

**Solutions:**

- Some effort is wasted in a single fixed pulley in overcoming friction between the

strings and the grooves of the pulley. So, the effort needed is greater than the load and thus the velocity ratio is always more than the mechanical advantage

(b) The efficiency of a movable pulley is always less than 100% because some effort is wasted in overcoming the friction between the strings and the grooves of the pulley.

(c) The mechanical advantage increases with the increase in the number of pulleys because the mechanical advantage is equal to the total number of pulleys in both the blocks.

(d) The efficiency depends upon the mass of lower block, hence efficiency is reduced due to the weight of the lower block of pulleys.

**Question: 19**

**Name a machine which is used to:**

**(a) Multiply force**

**(b) Multiply speed, and**

**(c) Change the direction of force applied.**

**Solutions:**

(a) Multiply force – a movable pulley is used

(b) Multiply speed – Class III lever

(c) Change the direction of force applied – single fixed pulley

**Question: 20**

**State whether the following statements are true or false.**

**(a) The velocity ratio of a single fixed pulley is always more than 1.**

**(b) The velocity ratio of a single movable pulley is always 2.**

**(c) The velocity ratio of a combination of n movable pulleys with a fixed pulley is always  $2^n$ .**

**(d) The velocity ratio of a block and tackle system is always equal to the number of strands of the tackle supporting the load.**

**Solutions:**

(a) The velocity ratio of a single fixed pulley is always more than 1 (False)

(b) The velocity ratio of a single movable pulley is always 2 (True)

(c) The velocity ratio of a combination of n movable pulleys with a fixed pulley is always  $2^n$  (True)

(d) The velocity ratio of a block and tackle system is always equal to the number of strands of the tackle supporting the load (True)

**MULTIPLE CHOICE TYPE**

**Question: 1**

**A single fixed pulley is used because it:**

- (a) Has a mechanical advantage greater than 1
- (b) Has a velocity ratio less than 1
- (c) Gives 100% efficiency
- (d) Helps to apply the effort in a convenient direction.

**Solutions:**

A single fixed pulley is used because it helps to apply the effort in a convenient direction.

**Question: 2**

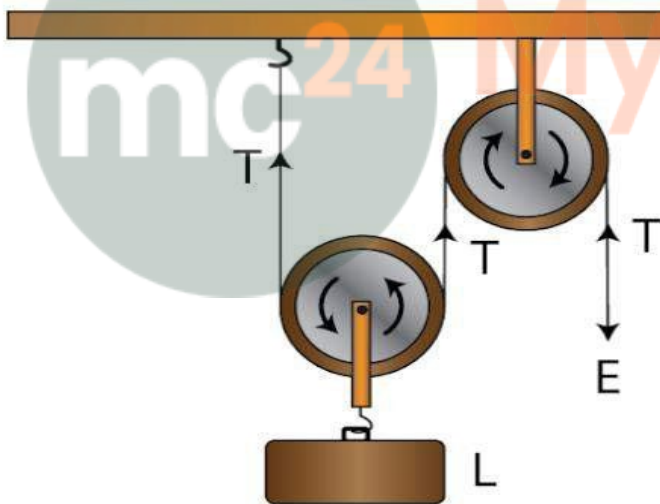
The mechanical advantage of an ideal single movable pulley is:

- (a) 1
- (b) 2
- (c) less than 2
- (d) less than 1.

**Solutions:**

The mechanical advantage of an ideal single movable pulley is 2

Derivation: Consider the diagram given below:



In the figure above, the load  $L$  is balanced by the tension  $T$  in two segments of the string and the effort  $E$  balances the tension  $T$  at the free end, so

$$L + L = 2T$$

$$E = T$$

Assumption: Weight of the pulley is negligible

$$\text{M.A.} = \text{Load } L / \text{Effort } E$$

$$= 2T / T$$

$$= 2$$

Hence, a single movable pulley has a M.A equal to 2

**Question: 3**

A movable pulley is used as :

- (a) a force multiplier
- (b) a speed multiplier
- (c) a device to change the direction of effort
- (d) an energy multiplier

**Solutions:**

A movable pulley is used as a force multiplier

Explanation: The mechanical advantage of movable pulley is greater than 1. Hence, using a single movable pulley, the load can be lifted by applying an effort equal to half the load i.e the single movable pulley acts as a force multiplier.

**NUMERICALS**

**Question: 1**

A woman draws water from a well using a fixed pulley. The mass of bucket and water together is 6 kg. The force applied by the woman is 70 N. calculate the mechanical advantage. (Take  $g = 10 \text{ m s}^{-2}$ ).

**Solutions:**

Given

The force applied by the woman is = 70 N

The mass of bucket and water together is = 6 kg

Total load =  $6 \times 10$

= 60 N

Mechanical advantage M.A = load / effort

=  $60 / 70$

= 0.857

**Question: 2**

A fixed pulley is driven by a 100 kg mass falling at a rate of 8.0 m in 4.0 s. It lifts a load of 75.0 kgf. Calculate:

- (a) The power input to the pulley taking the force of gravity on 1 kg as 10 N.
- (b) the efficiency of the pulley, and
- (c) the height to which the load is raised in 4.0 s.

**Solutions:**

(a) Effort driving the pulley is,

$E = mg$

=  $100 \times 10$

$$= 1000 \text{ N}$$

Input power is,

$$P_{\text{in}} = 2000 \text{ W}$$

(b) Load pulley by the pulley is,

$$L = 75 \times 10$$

$$= 750 \text{ N}$$

Hence, M.A is,

$$\text{M.A} = L / E$$

$$= 750 / 1000$$

$$= 0.75$$

When the effort moves by a distance  $d$  downwards, the load moves by the same distance upwards. Thus,

$$\text{V.R} = 1$$

Therefore efficiency is,

$$\eta = \text{M.A.} / \text{V.R.}$$

$$= 0.75 / 1$$

$$= 0.75$$

$$= 75\%$$

(c) The load moves by the same distance upwards when the effort moves by a distance  $d$  downwards. So, height to which the load moves is 8 m

### Question: 3

**A single fixed pulley and a movable pulley both are separately used to lift a load of 50 kgf to the same height. Compare the efforts applied.**

Solutions:

In case of a single fixed pulley, the effort i.e  $E_f$  needed to lift a load is equal to the load itself.

Hence,  $E_f = L$

$$E_f = L$$

The effort needed to lift a load is equal to half the load

$$E_m = 50 \text{ kgf} / 2$$

$$= 25 \text{ kgf}$$

Hence, the ratio of efforts applied by the respective pulley is

$$E_f / E_m = 2 / 1$$

Therefore  $E_f : E_m = 2 : 1$

### Question: 4

**In a block and tackle system consisting of 3 pulleys, a load of 75 kgf is raised with an effort of 25 kgf. Find: (i) the mechanical advantage, (ii) the velocity ratio, and (iii)**

the efficiency.

**Solutions:**

Given,

$$\begin{aligned}\text{Load} &= 75 \text{ kgf} \\ \text{Effort} &= 25 \text{ kgf} \\ n &= 3 \\ \text{M.A.} &= \text{Load} / \text{Effort} \\ &= 75 / 25 \\ &= 3 \\ \text{M.A.} &= n = 3 \\ \text{Velocity V.R.} &= n = 3 \\ \text{Efficiency } \eta &= \text{M.A.} / \text{V.R.} \\ &= 3 / 3 \\ &= 1 \text{ or } 100\%\end{aligned}$$

**Question: 5**

A block and tackle system has 5 pulleys. If an effort of 1000 N is needed in the downward direction to raise a load of 4500 N, calculate:

- (a) The mechanical advantage,
- (b) The velocity ratio and,
- (c) The efficiency of the system.

**Solutions:**

Given,

$$\begin{aligned}\text{A block and tackle system has 5 pulleys (} n = 5 \text{)} \\ \text{Effort} &= 1000 \text{ N} \\ \text{Load} &= 4500 \text{ N}\end{aligned}$$

- (a) The mechanical advantage

$$\begin{aligned}\text{M.A.} &= \text{Load} / \text{Effort} \\ &= 4500 / 1000 \\ &= 4.5\end{aligned}$$

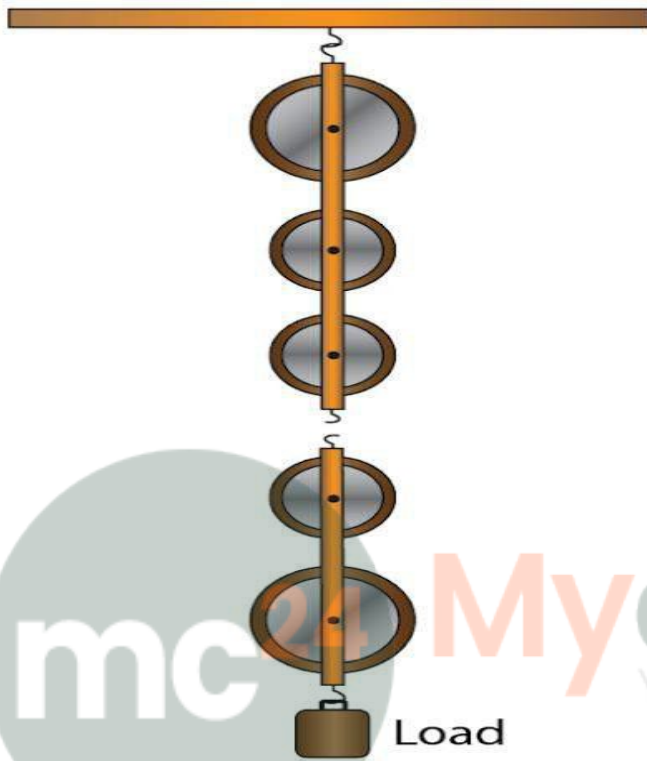
- (b) The velocity ratio =  $n = 5$

- (c) The efficiency of the system  $\eta = \text{M.A.} / \text{V.R.}$
- $$\begin{aligned}&= 4.5 / 5 \\ &= 0.9 \\ &= 90\%\end{aligned}$$

**Question: 6**

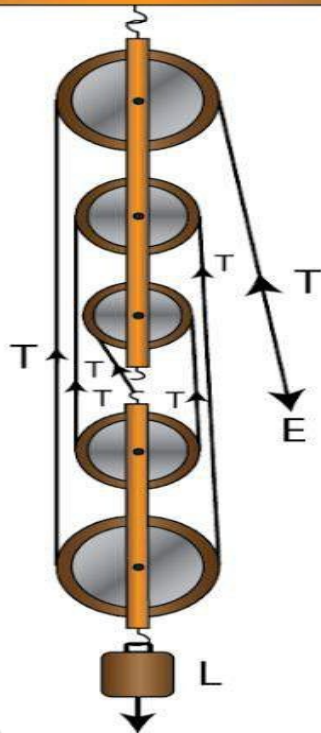
In figure draw a tackle to lift the load by applying the force in the downward direction.

- (a) Mark in the diagram the direction of load L and effort E.
- (b) If the load is raised by 1 m, through what distance will the effort move?
- (c) State how many strands of tackle are supporting the load.
- (d) What is the mechanical advantage of the system?



**Solutions:**

(a)



(b) If the load is raised by 1 m, the effort move =  $1 \times 5 = 5$  m

(c) Five strands of tackle are supporting the load

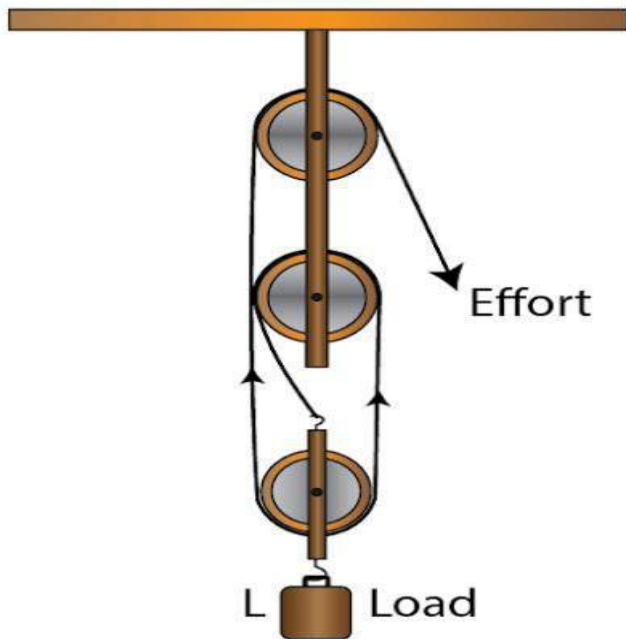
(d) Mechanical advantage of the system is given by

$$\begin{aligned} \text{M.A.} &= \text{Load} / \text{Effort} \\ &= 5T / T \\ &= 5 \end{aligned}$$

**Question: 7**

A pulley system has a velocity ratio 3. Draw a diagram showing the point of application and direction of load (L), effort (E) and tension (T). If lifts a load of 150 N by an effort of 60 N. Calculate its mechanical advantage. Is the pulley system ideal? Give reason.

**Solutions:**



Load = 150 N

Effort = 60 N

Mechanical advantage = Load / Effort

= 150 / 60

= 2.5

The pulley system is not ideal because the mechanical advantage is less than 3.

**Question: 8**

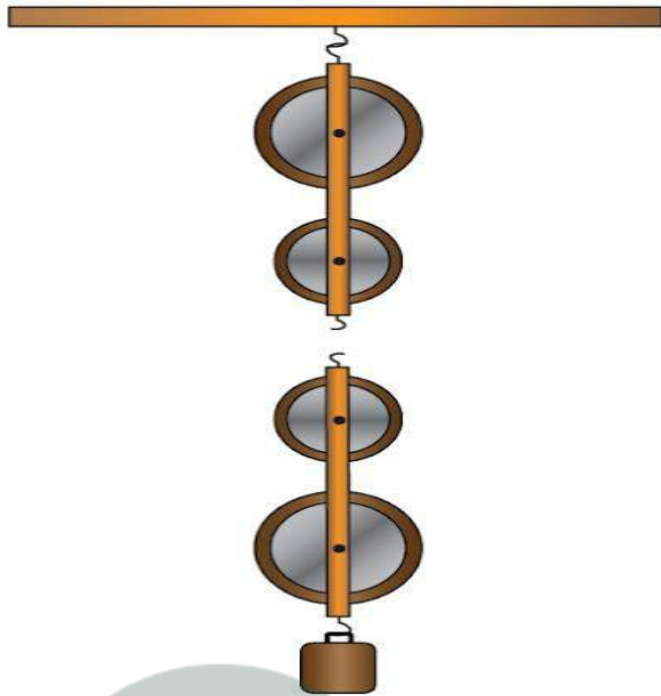
Figure shows a system of four pulleys. The upper two pulleys are fixed and the lower two are movable.

(a) Draw a string around the pulleys. Also show the point of application and direction in which the effort E is applied.

(b) What is the velocity ratio of the system?

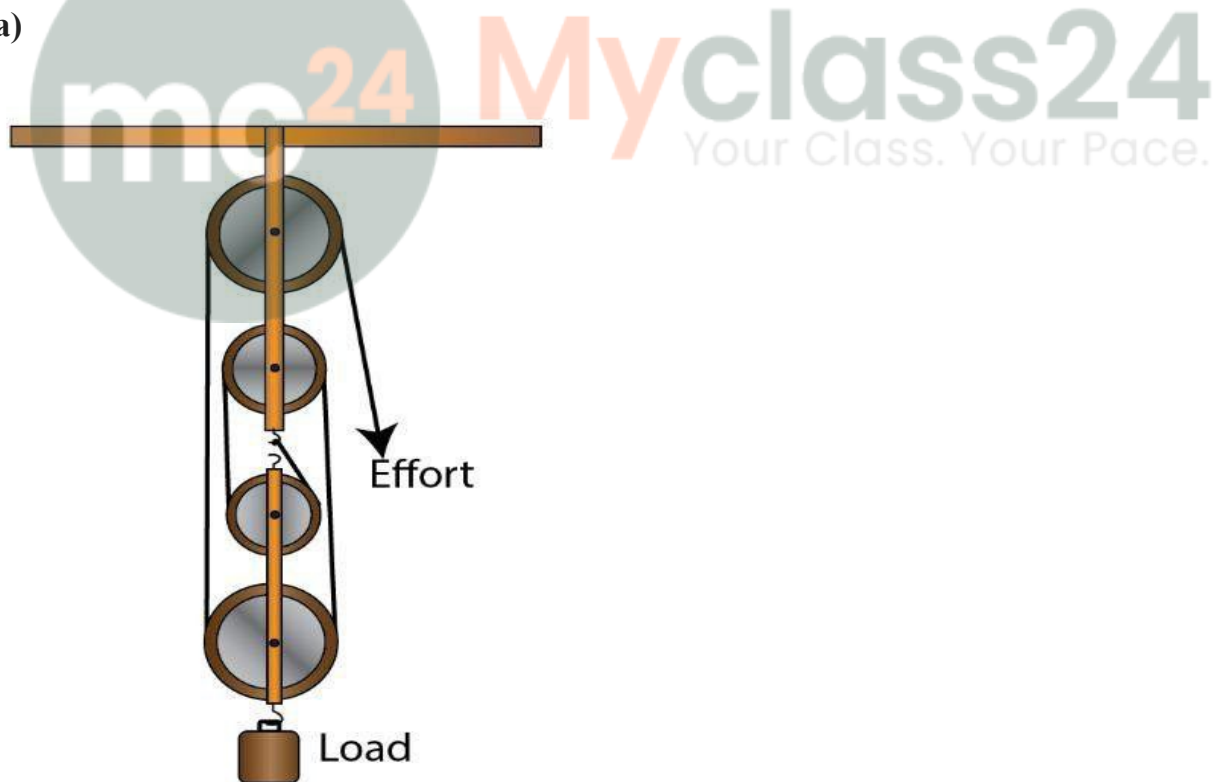
(c) How are load and effort of the pulley system related?

(d) What assumption do you make in arriving at your answer in part (c)?



Solutions:

(a)



- (b) Velocity ratio of the system =  $n = 4$   
(c) The relation between load and effort

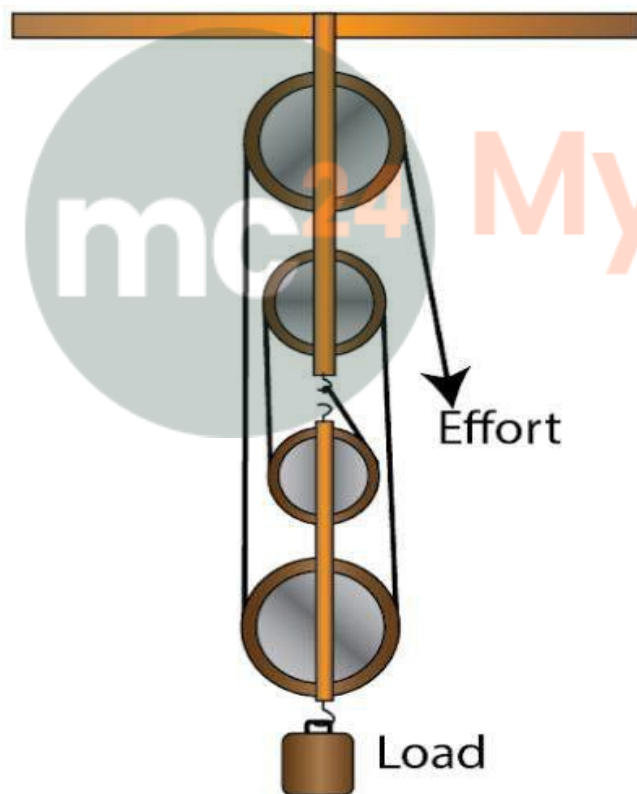
$$\text{M.A.} = \text{load} / \text{effort} = n = 4$$
$$\text{Load} = 4 \times \text{effort}$$

- (d)
- (i) There is no friction in the pulley bearings
  - (ii) Weight of lower pulleys is negligible and
  - (iii) The effort is applied downwards.

**Question: 9**

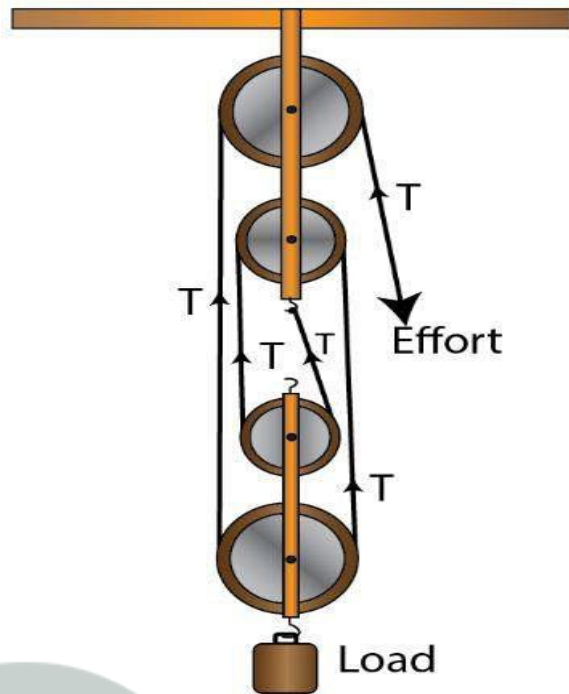
Figure shows a block and tackle system of pulleys used to lift a load.

- (a) How many strands of tackle are supporting the load?
- (b) Draw arrows to represent tension  $T$  in each strand.
- (c) What is the mechanical advantage of the system?
- (d) When load is pulled up by a distance 1 m, how far does the effort end move?
- (e) How much effort is needed to lift a load of 100 N?



**Solutions:**

- (a) There are 4 strands of tackle supporting the load.
- (b)



(c) The mechanical advantage of the system

$$\begin{aligned} \text{M.A.} &= \text{Load} / \text{Effort} \\ &= 4T / T \\ &= 4 \end{aligned}$$

(d) When load is pulled up by a distance 1 m, the effort end will move by a distance

$$= 1 \times 4 = 4\text{m}$$

(e) M.A = Load / Effort

$$4 = 100 / \text{effort}$$

$$\text{Effort} = 100 / 4$$

$$= 25 \text{ N}$$

### Question: 10

A block and tackle system has the velocity ratio 3. Draw a labelled diagram of the system indicating the points of application and the directions of load L and effort E. A man can exert a pull of 200 kgf. (a) What is the maximum load he can raise with this pulley system if its efficiency is 60%? (b) If the effort end moves a distance 60 cm, what distance does the load move?

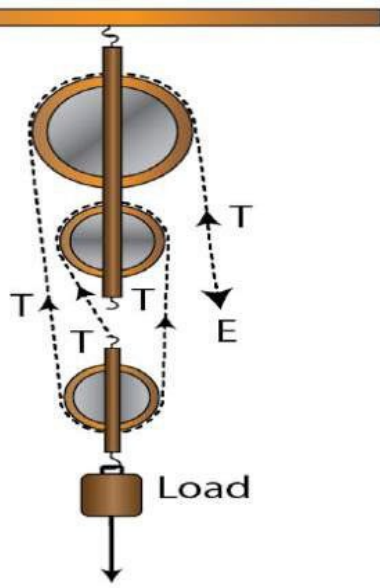
**Solutions:**

**Given,**

A block and tackle system has V.R = n (number of pulleys)

Hence, n = 3

The diagram is shown below



(b) The effort put by man is  $E = 200 \text{ kgf}$   
Efficiency  $\eta = 60\%$

For block and tackle system,

$$\eta = 1 - w / nE$$

$$0.6 = 1 - w / 3 \times 200$$

$$w / 600 = (1 - 0.6)$$

Thus  $W = (1 - 0.6) \times 600$

$$w = 240 \text{ kgf}$$

Hence, load is

$$L = nE - w$$

$$L = 600 - 240$$

$$= 360 \text{ kgf}$$

(b) The velocity ratio of system is  $V.R = 3$

Therefore, we get

$$V.R = d_E / d_L = n = 3$$

Therefore  $d_L = d_E / 3$

$$= 60 / 3$$

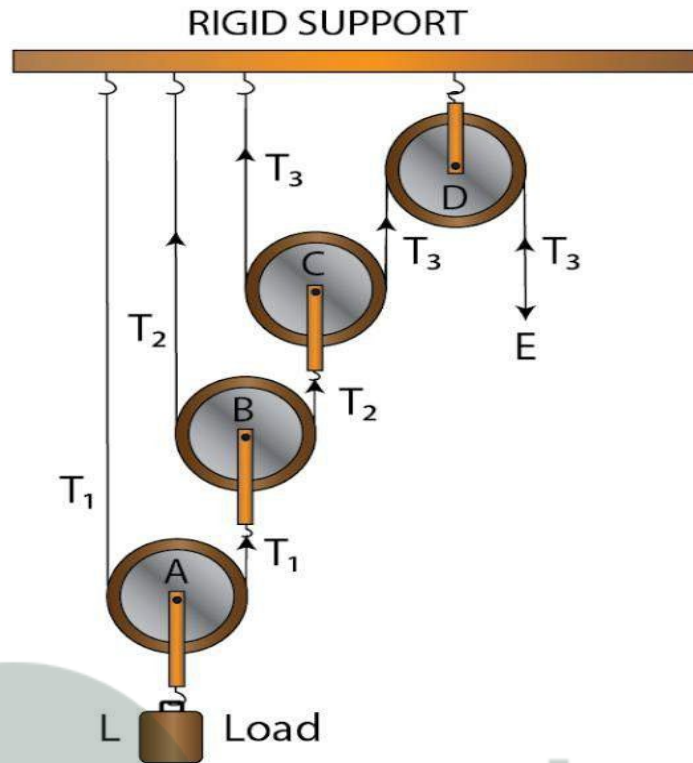
$$= 20 \text{ cm}$$

### Question: 11

You are given four pulleys and three strings. Draw a neat and labelled diagram to use them so as to obtain a maximum mechanical advantage equal to 8. In your diagram mark the directions of load  $L$ , effort  $E$  and tension in each strand.

What assumptions have you made to obtain the required mechanical advantage?

Solutions:



Assumptions are

- (i) There is no friction in the pulley bearing
- (ii) The pulleys and the string are massless





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