Ratna Sagar

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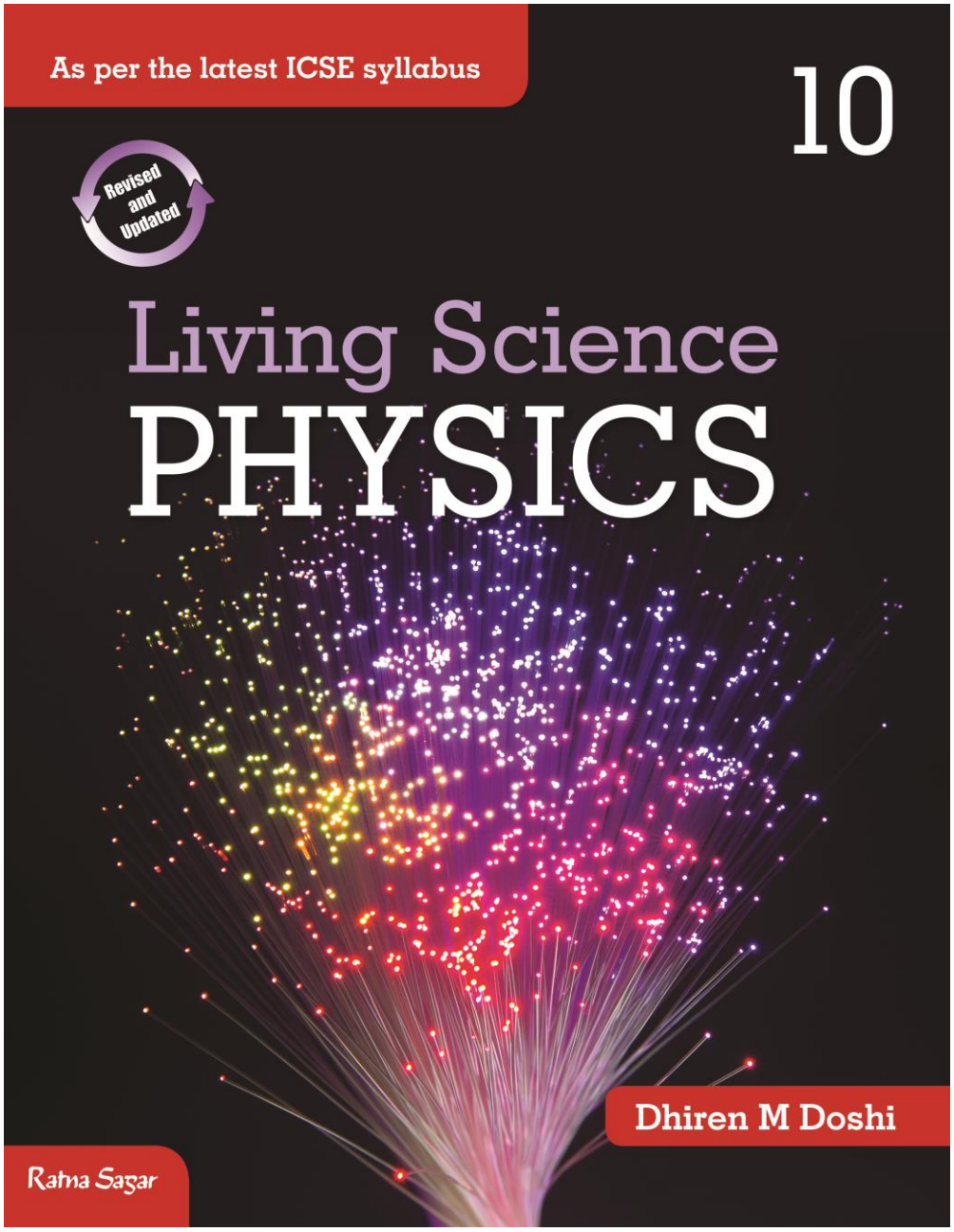
ICSE
Living Science
Physics

Class 10

Chapter-3 Simple Machine


As per the latest ICSE syllabus
10
Revised and Updated
Living Science
PHYSICS
Dhiren M Doshi
Ratna Sagar

LEARNING OBJECTIVES

Machines

- ❖ Technical Terms Related to Machines
- ❖Principle of a Machine

Levers

- ❖ Classification of Levers
- ❖ Velocity Ratio of Three Types of Levers

Pulley

- ❖ Single Fixed Pulley
- ❖ Single Movable Pulley
- ❖ Combination of a Single Fixed Pulley and Movable Pulley
- ❖ Combination of Pulleys: Block and Tackle System

What is a machine?

A simple machine is a device which is used to do work more conveniently and more quickly.

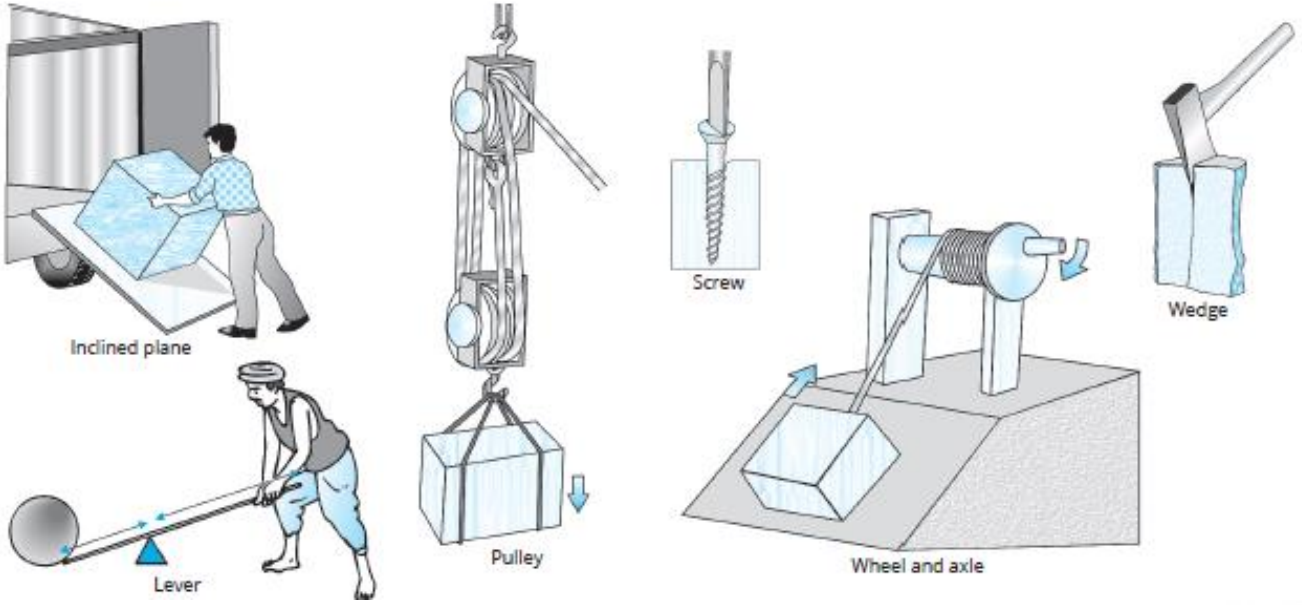
Machines

Simple machines are devices through which either the magnitude or the direction of application of force is changed to achieve a certain advantage or by which we can obtain a gain in speed.

The six basic simple machines commonly used are:

1. The lever **2.** The pulley **3.** The inclined plane **4.** The screw

5. The wedge **6.** The wheel and the axle



Technical Terms Related to Machines

1. Effort (*E*): The effort is the force applied to a machine to do mechanical work.

2. Load (*L*): The load is the force applied by the machine on the body on which the work is done.

3. Mechanical advantage (*MA*): The ratio of the load to the effort is called the mechanical advantage of the machine.

Mechanical advantage (*MA*) = Load (L)/ Effort (E)

a. If the load lifted is greater than the effort applied, the mechanical advantage is greater than one ($MA > 1$).

A machine having mechanical advantage greater than one, works as a force multiplier like in the case of crowbar and car jack.

b. If the load lifted is less than the effort applied, the mechanical advantage is less than one ($MA < 1$).

A machine having mechanical advantage less than one gives the gain in speed like in the case of knife and scissors.

c. If the load lifted is equal to the effort applied, the mechanical advantage is equal to one.

A machine having the mechanical advantage equal to one is generally used to change the direction of effort like in the case of pulley.

Unit: Since mechanical advantage is the ratio of two similar quantities, **it has no units**.

4. Velocity ratio (*VR*): The velocity ratio of a machine is the ratio of the velocity of the effort to the velocity of the load.

Velocity ratio (*VR*) = Velocity of effort /Velocity of load

= *VE* /*VL*

Velocity ratio (*VR*) is also defined as **the ratio of the displacement of the effort to the displacement of the load**. Velocity ratio (*VR*) = d*e*/*dl*

5. Work input or input (*W*i): The energy supplied to the machine or the work done on the machine by the effort is called work input or input (***W*i**).

6. Work output or output (*W* º): The useful energy obtained from the machine or the useful work done by the machine on the load is called work output or output (*W*o).

7. Efficiency (h): Efficiency of a machine is the ratio of the useful work done by the machine to the work done on the machine. In other words, it is the ratio of the work output to the work input. It is denoted by the Greek letter η (eta).

Efficiency = Work output/ Work input

Since efficiency is usually expressed in percentage, we can write:

Efficiency = Work output /Work input × 100%

Unit: Efficiency has no unit as it is a ratio.

Principle of a Machine

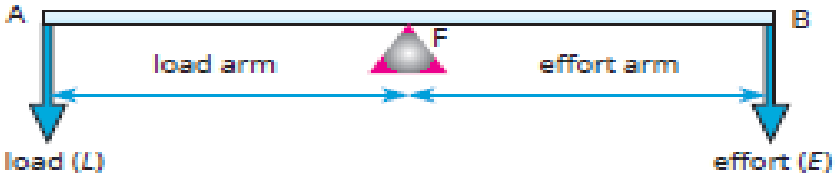
For an **ideal machine**, in which there is no loss of energy in any manner, the work output will be equal to the work input, i.e. the efficiency of an ideal machine is 100%.

For an ideal machine: η = 1

or, **Work output = Work input**

Levers

A lever is a rigid, straight or bent bar which is capable of turning about a fixed point or an axis commonly called its fulcrum.



Effort Arm : The perpendicular distance of the effort from the fulcrum is called the effort arm. FB is effort arm.

Load Arm: The perpendicular distance of the load from the fulcrum is called the load arm. FA is load arm.

Law of Lever

Load × Load arm = Effort × Effort arm

or Load/ Effort = Effort arm/ Load arm

But we know: Load/ Effort = *MA*

∴ *MA* = Effort arm/ Load arm

So we can conclude that **the mechanical advantage of a lever is equal to the ratio of the length of the effort arm to the length of the load arm**.

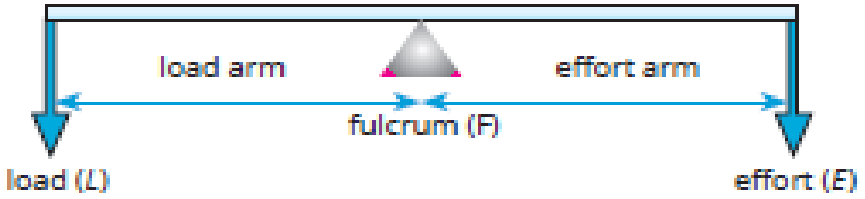
We can infer the following: **1.** If effort arm = load arm, *MA* = 1

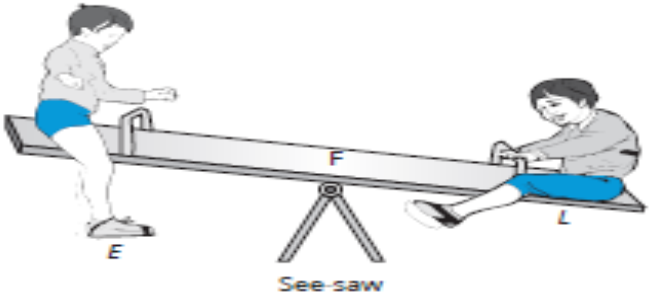
2. If effort arm > load arm, *MA* > 1 **3.** If effort arm < load arm, *MA* < 1.

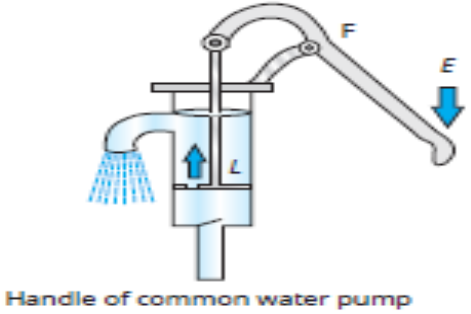
Classification of Levers

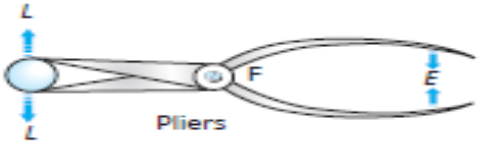
Class I Levers

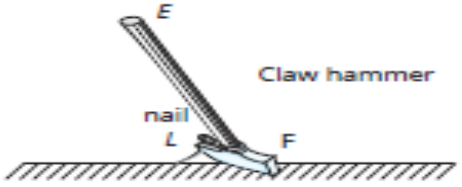
In class I levers, the fulcrum F is situated between the effort (*E*) and the load (*L*).







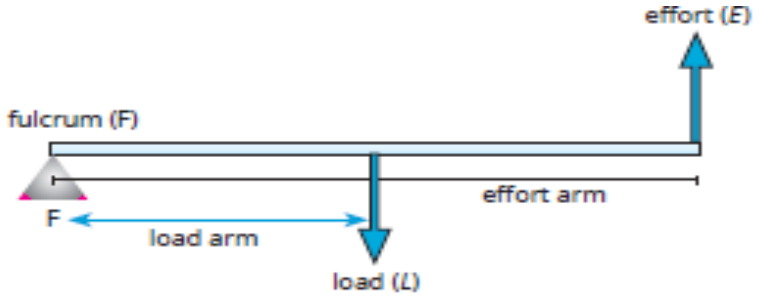




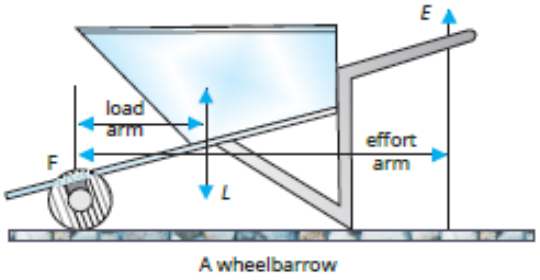
Examples of Class I Levers

Class II levers

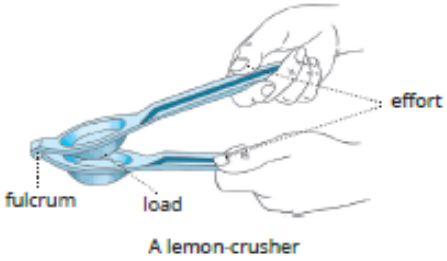
In class II levers, the load (*L*) is situated between the effort (*E*) and the fulcrum (F).



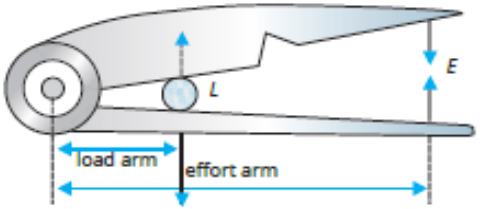
Examples of Class II Levers



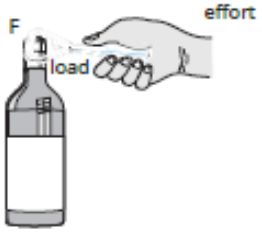
A wheelbarrow



A lemon-crusher



A nutcracker

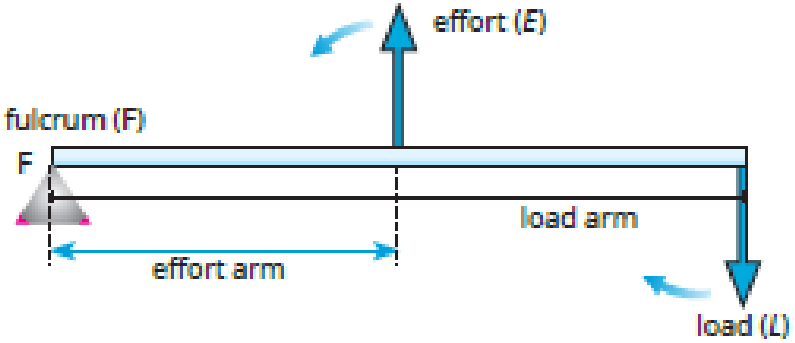


Bottle-opener

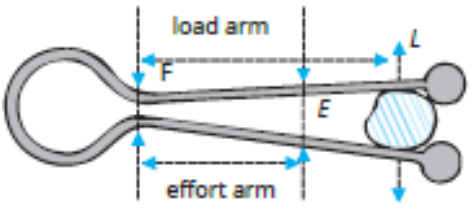
The mechanical advantage of a class II lever is always more than 1.

Class III levers

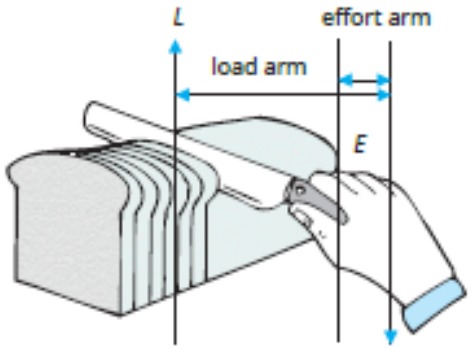
In class III levers, the effort (*E*) is situated between the fulcrum (F) and the load (*L*) . The mechanical advantage of class III levers is always less than 1. Class III levers act as speed multipliers.



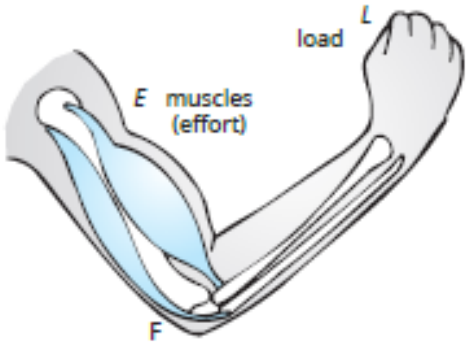
Examples of Class III Levers



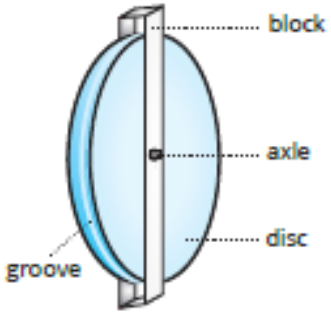
Fire tongs



Bread knife

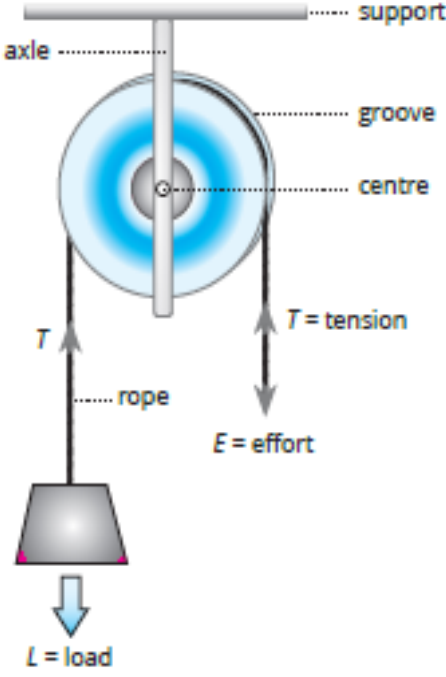


The human forearm



Pulley

A pulley is a metallic (or wooden) circular disc having a groove along its rim and capable of rotating about a rod called the axle which passes through its centre.



Single fixed pulley

A single fixed pulley is one which is fixed to a support so that its axis of rotation remains fixed.

Tension (*T*) in single fixed pulley acts upwards in the string on both the sides of the pulley and is equal throughout the string.

We have L= T and E = T (when the pulley is not rotating)

MA = Load/Effort = L/E =T/T =1

Velocity Ratio = Distance moved by effort/ Distance moved by load = d/d =1

Hence, efficiency, η = *MA* /*VR* = 1 or 100%

Single Movable Pulley

When load *L* is balanced by the effort *E*,

Load *L* = *T* + *T* = 2*T* and effort *E* = *T*

∴ Mechanical advantage, *MA* = Load (L) / Effort (E)

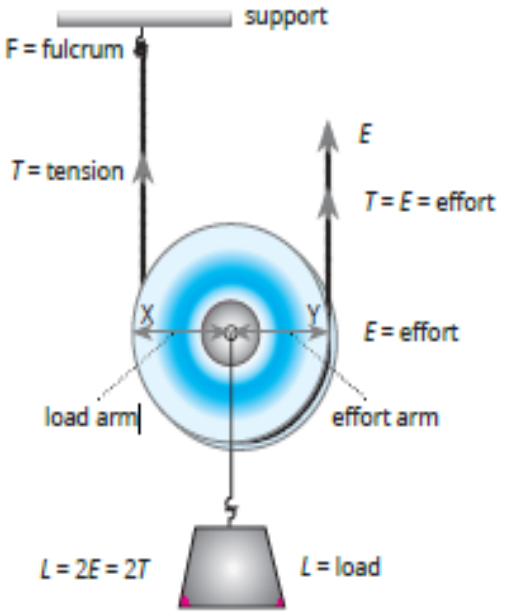
= 2*T*/ *T* = 2

∴ Load = 2 × Effort

Load is equal to twice the effort.

Thus, a movable pulley doubles the effort we exert.

When the load is pulled through a distance *d*, the string is pulled up by the effort through a distance 2*d*.



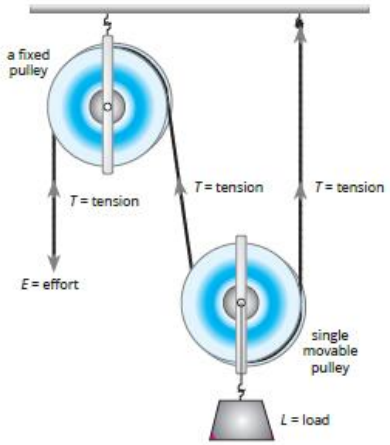
VR = Distance travelled by effort / Distance travelled by load

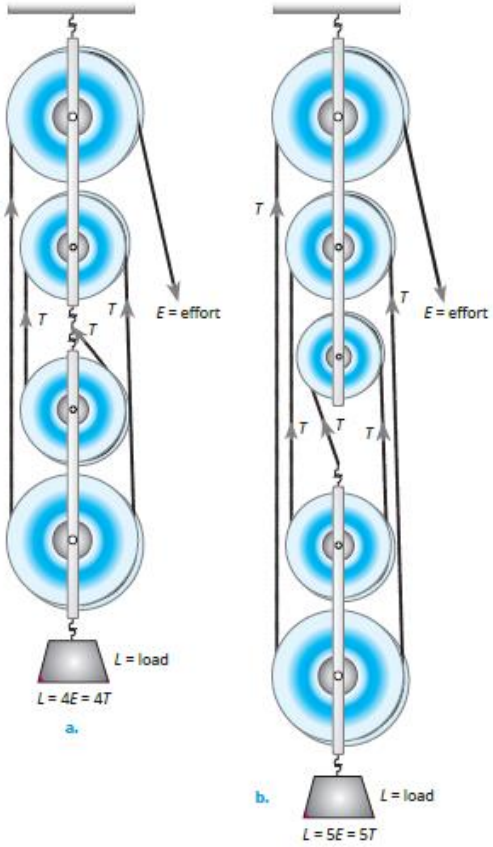
= 2*d* /*d* = 2

Efficiency, η = *MA* / *VR* = 2/2 = 1 or 100%

Combination of a single fixed and a movable pulley

A movable pulley is usually used in combination with a single fixed pulley. Single fixed pulley allows the effort to be applied in the downward direction whereas the movable pulley doubles the effort force, i.e. it has *MA* = 2.





Combination of pulleys: Block and tackle system

The block and tackle system of pulley consists of two sets of pulleys, each set containing two or more pulleys. These pulleys are mounted on a common axle and are of same radius.

The set of pulleys fixed to the rigid support is called block whereas the set of pulleys which are movable and attached to the load is called tackle.

1. The number of pulleys in the lower movable tackle is equal to the number of pulleys in the upper fixed block .

2. The number of pulleys in the lower movable tackle is one less than the number of pulleys in the upper fixed block .

SUMMARY

1. **Simple machine:** It is a device through which either the magnitude or the direction of application of force is changed to achieve a certain advantage or by which we can obtain a gain in speed.

2. **Functions of simple machine: a.** As a force multiplier **b.** Applying a force in a convenient direction **c.** Applying a force at a convenient point **d.** To obtain gain in speed.

3. **Mechanical advantage:** The ratio of the load to the effort is called the mechanical advantage. It has no units.

4. **Velocity ratio:** It is the ratio of the velocity at which an effort is applied to the velocity at which the load moves.

5. **Efficiency:** It is the ratio of the useful work done by the machine to the work done on the machine.

6. **Lever:** It is a rigid straight or bent bar which is capable of turning about a fixed point or an axis called its fulcrum.

7. **Principle of lever:** When a lever is in equilibrium, Load × Load arm = Effort × Effort arm

8. Pulley: It is a metallic (or wooden) circular disc having a groove in its edges and capable of rotating about a rod called the axle which passes through its centre.

9. Single movable pulley: It is one whose axis of rotation is not fixed.

10. Block and tackle system: It consists of two sets of pulleys. One block is fixed and the other block is movable. The mechanical advantage is equal to the total number of pulleys in the two blocks.

Formulae

1. Mechanical advantage = Load (*L*) / Effort (*E*)

2. Velocity ratio = Displacement of the effort (*D*) / Displacement of the load (*d*)

3. Efficiency = (Work output × 100%) / Work input

4. Efficiency, η = Mechanical advantage (*MA*) / Velocity ratio (*VR*)

5. Mechanical advantage of lever = Effort arm/ Load arm

6. Velocity ratio of lever = Effort arm (dE) / Load arm (dL)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