Chapter Name: Simple Lifting Machines

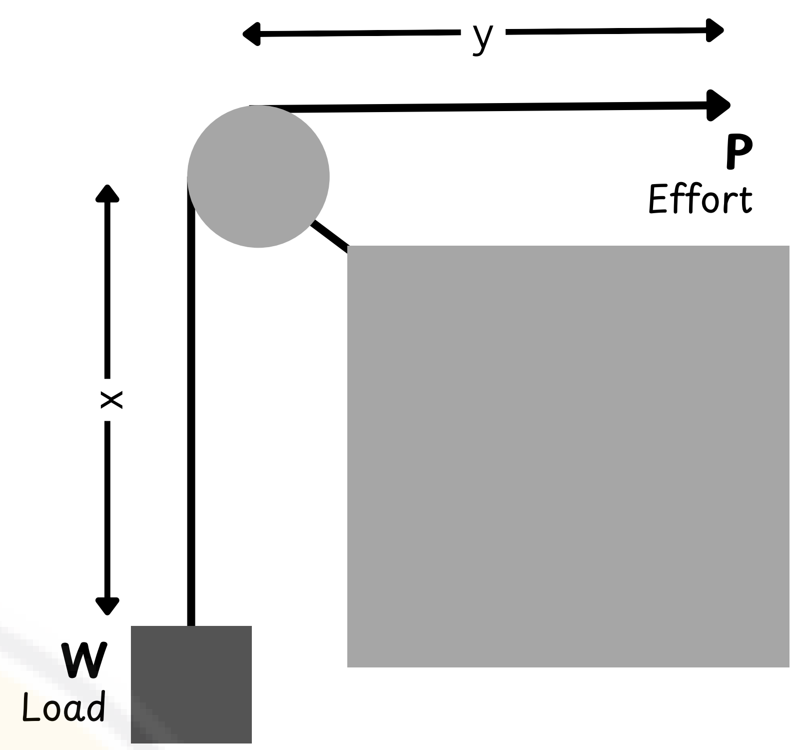
Definition of Lifting Machine

A lifting machine is a mechanical device used to lift heavy loads with the help of a comparatively smaller effort by applying the principles of mechanics.

Applications of Lifting Machines

Lifting machines are widely used in daily life and industries, such as:

- Lifting loads in construction sites
- Cranes for lifting heavy materials
- Jacks for lifting vehicles
- Pulleys in wells and workshops
- Winches and hoists in factories
- Elevators and lifts



y = distance moved by the effort
x = distance moved by the load

Advantages of Lifting Machines

- Reduce human effort
- Make lifting heavy loads easy and safe
- Save time and energy
- Increase work efficiency
- Enable precise and controlled lifting

Important Terms

(a) Load (W)

The weight or resistance lifted by the machine is called load.

(b) Effort (P)

The force applied to operate the machine and lift the load is called effort.

(c) Mechanical Advantage (M.A.)

Mechanical Advantage is the ratio of load lifted to effort applied.

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

👉 Higher M.A. means less effort is required.

(d) Velocity Ratio (V.R.)

Velocity Ratio is the ratio of distance moved by effort to the distance moved by load in the same time.

$$\text{V.R.} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

👉 It depends only on the design of the machine, not on friction.

(e) Efficiency (η)

Efficiency is the ratio of useful output to total input.

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

or in percentage,

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

👉 Efficiency is always less than 100% due to frictional losses.

Relationship between M.A., V.R., and Efficiency

$$\text{Efficiency} = \frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}}$$

or,

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

Law of Machine

The law of machine gives the relationship between effort (P) and load (W).

$$\boxed{P = mW + C}$$

Where:

- P = Effort
- W = Load
- m = Constant representing friction
- C = Effort required to overcome machine friction when load is zero

👉 This law shows that effort increases linearly with load.

Ideal Machine

An ideal machine is a machine:

- With no friction
- No loss of energy
- Efficiency = 100%

Characteristics:

- Mechanical Advantage = Velocity Ratio
- Efficiency is 100%
- Input of the machine = Output of the machine

Friction in a Machine

Friction is the resisting force between moving parts of a machine.

Effects of friction:

- Reduces efficiency
- Increases effort required
- Causes wear and tear
- Produces heat

👉 Due to friction:

$$\text{M.A.} < \text{V.R.}$$

Maximum Mechanical Advantage

For a given machine,

$$\text{Maximum M.A.} = \frac{1}{m}$$

(where mmm is the constant from the law of machine)

Maximum Efficiency

$$\eta_{\max} = \frac{1}{m \times \text{V.R.}}$$

👉 Maximum efficiency occurs when load is very large.

Reversible and Non-Reversible Machine

(a) Reversible Machine

A machine is reversible if:

- When the effort is removed, the load comes down automatically
- **Example:** Pulley system, wheel and axle

Condition for Reversibility

$$\eta > 50\%$$

(b) Non-Reversible (Self-Locking) Machine

A machine is non-reversible if:

- Load does not descend when effort is removed
- **Example:** Screw jack

Condition for Non-Reversibility

$$\eta < 50\%$$

Formulas of Common Lifting Machines

1. Simple Wheel and Axle

Velocity Ratio

$$\text{V.R.} = \frac{R}{r}$$

Where:

- R = Radius of wheel (effort wheel)
- r = Radius of axle (load axle)

2. Differential Wheel and Axle

Velocity Ratio

$$\text{V.R.} = \frac{2R}{r_1 - r_2}$$

Where:

- R = Radius of effort wheel
- r1 = Radius of larger axle
- r2 = Radius of smaller axle

3. Worm and Worm Wheel

Velocity Ratio

$$\text{V.R.} = \frac{T}{n}$$

Where:

- T = Number of teeth on worm wheel
- n = Number of starts (threads) on worm

4. Single Purchase Crab Winch

Velocity Ratio

$$\text{V.R.} = \frac{T \times R}{t \times r}$$

Where:

- T = Number of teeth on gear
- t = Number of teeth on pinion
- R = Radius of handle (length of crank)
- r = Radius of load drum

5. Double Purchase Crab Winch

Velocity Ratio

$$\text{V.R.} = \frac{T_1 \times T_2 \times R}{t_1 \times t_2 \times r}$$

Where:

- T1,T2 = Teeth on first and second gears
- t1,t2 = Teeth on first and second pinions
- R = Radius of handle
- r = Radius of load drum

6. Simple Screw Jack

Velocity Ratio

$$\text{V.R.} = \frac{2\pi R}{p}$$

Where:

- R = Length (radius) of handle
- p = Pitch of screw (distance moved by screw in one rotation)
- π = 3.142

7. Simple Pulley Block

Velocity Ratio

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

Where:

- n = number of pullies supporting the loads

www.polynoteshub.co.in