# Simple Machines

**Definitions to know:**

**Work** – done when an applied force causes an object to move in the direction of the force

**Energy** – ability to cause change; can change the speed, direction, shape, or temperature of an object

**Load** – the weight being lifted by the simple machine

**Effort** – effort is the force placed on the simple machine to move the load. Also called applied force or input force

### What are simple machines?

Simple machines are tools that make work easier. They have few or no moving parts . These machines use energy to work . Do work with one movement. Make our work easier by letting us use less mechanical effort to move an object. Simple machines make work easier for us by allowing us to push or pull over increased distances. We move an object a greater distance to accomplish the same amount of work. Simple machines give us an advantage by changing the amount, speed, or direction of forces. They allow us to use a smaller force to overcome a larger force. The amount of effort saved when using machines is called mechanical advantage or MA

### What are Compound or Complex machines?

Two or more simple machines working together are known as compound machines. Most of the machines we use today are compound machines

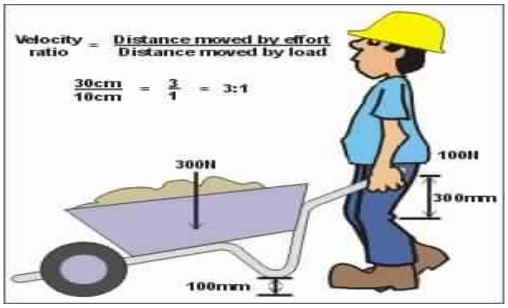
## Mechanical advantage

Mechanical advantage is defined as the ratio of resistance overcomes to the effort applied. The simple machine requires force to do work. The resistive force to be overcome is called load and the force applied to overcome the load is called effort.

$$\text{Mechanical Advantage (MA)} = \frac{\text{load (L)}}{\text{effort applied (E)}}$$

$$\text{MA} = \frac{\text{L}}{\text{E}}$$

## Velocity Ratio




Velocity ratio of simple machine is the ratio of distance travelled by the effort to the distance travelled by the load in the machine. As velocity ratio or ideal mechanical advantage is a simple ratio of two distances, it also does not have the unit. The friction is not involved in it.

If a machine overcomes a load 'L' and the distance travelled by the load is 'Ld'. Similarly, the effort applied in the machine is 'E' and the distance travelled by effort is 'Ed', and 'T' is the time taken then

$$\text{Velocity of load} = \frac{\text{Ld}}{\text{T}}$$

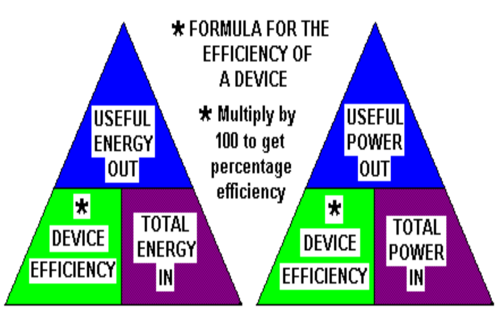
$$\text{Velocity of effort} = \frac{\text{Ed}}{\text{T}}$$

$$\frac{\text{Velocity of effort}}{\text{Velocity of load}} = \frac{\text{Ed/T}}{\text{Ld/T}}$$

$$\text{Velocity ratio (VR)} = \frac{\text{Distance moved by effort (Ed)}}{\text{Distance moved by load (Ld)}}$$

$$\text{Velocity ratio (VR)} = \frac{\text{Ed}}{\text{Ld}}$$

## Efficiency




If a machine overcomes a load 'L' and the distance travelled by the load is 'Ld.', the work done by the load is L × Ld. It is also called output work or useful work. Therefore,

**Output work** = L × Ld

Likewise, the effort applied to overcome the load is E and the distance covered by effort is Ed, the work done by effort is E × Ed. It is also called input work. Therefore,

**Input work** = E × Ed

**The efficiency** of a simple machine is defined as the ratio of useful work done by a machine (output work) to the total work put into the machine (input work).

$$\text{Efficiency}\ (\eta) = \frac{\text{output}}{\text{input}} = \frac{L \times Ld}{E \times Ed} \times 100\%$$

$$\text{Efficiency}\ (\eta) = \frac{L \times Ld}{E \times Ed} \times 100\%$$

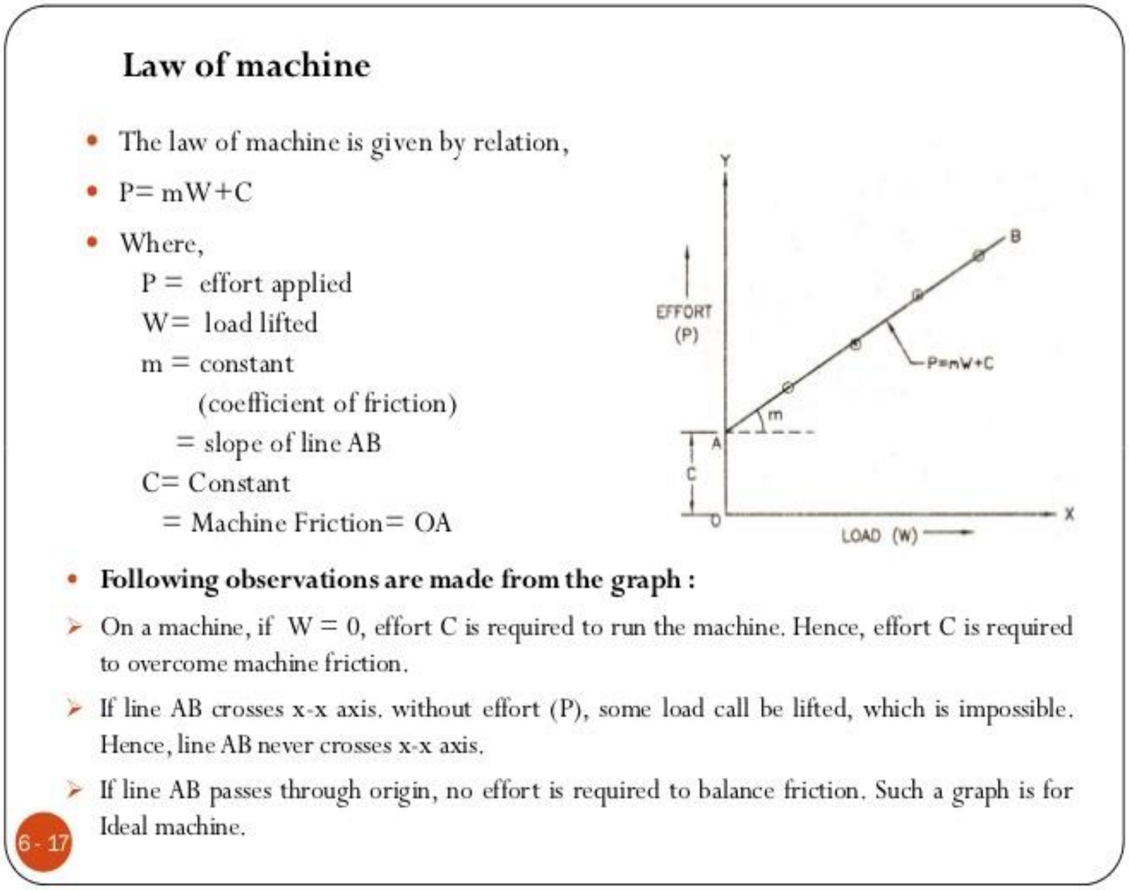
$$\eta = \frac{MA}{VR} \times 100\%$$

For **ideal machine**, work output is equal to the work input. Ideal machines are those imaginary machines which are frictionless. In practice, the work output of a machine is always less than work input due to the effect of friction. If the frictional force in the machine increases the efficiency decreases because machines are frictionless in practice, the efficiency of a machine can never be 100%.

**Reversible machine** : A machine which is capable of doing work in the reverse direction even after the removal of effort ,load get lifted is called Reversible machine. For reversible machine efficiency will be greater than 50%

**Non - Reversible machine** : A machine which is not capable of doing work in the reverse direction is called Non - Reversible machine. It is also called **self- locking machine** as if the frictional forces are high enough, no amount of load force can move it backwards, even if the input force is zero. For non-reversible machine efficiency will be less than 50%

## Law of machines



### Law of machine

- The law of machine is given by relation,
- $P = mW + C$
- Where,
  - P = effort applied
  - W = load lifted
  - m = constant
    - (coefficient of friction)
    - = slope of line AB
  - C = Constant
    - = Machine Friction = OA



- **Following observations are made from the graph :**

➢ On a machine, if W = 0, effort C is required to run the machine. Hence, effort C is required to overcome machine friction.

➢ If line AB crosses x-x axis. without effort (P), some load call be lifted, which is impossible. Hence, line AB never crosses x-x axis.

➢ If line AB passes through origin, no effort is required to balance friction. Such a graph is for Ideal machine.

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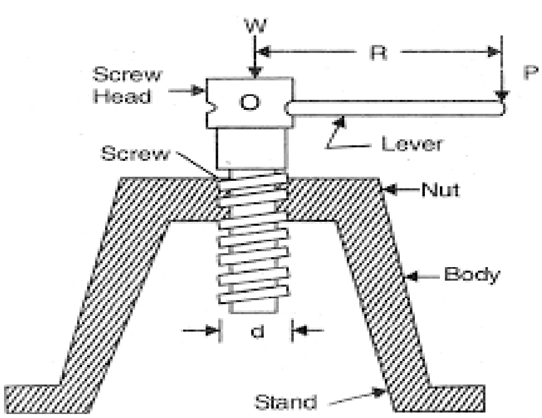
## SIMPLE SCREW JACK



A simple screw jack consists of a heavy-duty vertical screw with a load table mounted on its top, which screws into a threaded hole in a stationary support frame with a wide base resting on the ground. A rotating collar on the head of the screw has holes into which the handle, a metal bar, fits. When the handle is turned clockwise, the screw moves further out of the base, lifting the load resting on the load table. In order to support large load forces, the screw usually has either square threads or buttress threads.

## Principle

It works on the principle of inclined planes

## Advantages

An advantage of jackscrews over some other types of jack is that they are *self-locking*, which means when the rotational force on the screw is removed, it will remain motionless where it was left and will not rotate backwards, regardless of how much load it is supporting. This makes them inherently safer than hydraulic jacks, for example, which will move backwards under load if the force on the hydraulic actuator is accidentally released.

## Mechanical advantage

The ideal mechanical advantage of a screw jack, the ratio of the force the jack exerts on the load to the input force on the lever ignoring friction is

$$\frac{F\ load}{F\ in} = \frac{2\pi r}{l}$$

Where

F load is the force the jack exerts on the load

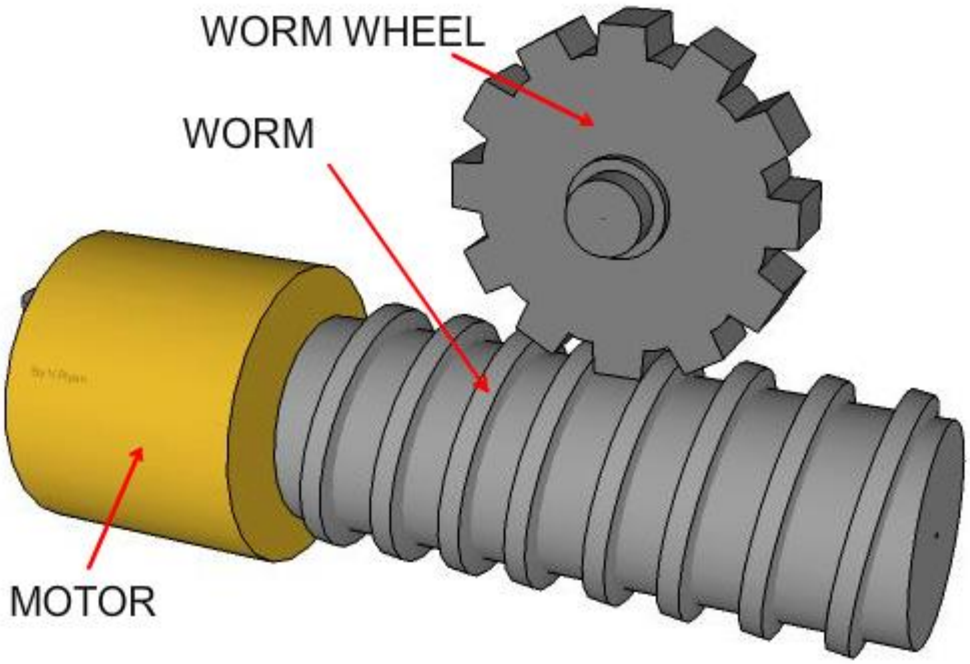
F in is the rotational force exerted on the handle of the jack

r is the length of the jack handle, from the screw axis to where the force is applied

l is the lead of the screw.

The screw jack consists of two simple machines in series; the long operating handle serves as a lever whose output force turns the screw. So the mechanical advantage is increased by a longer handle as well as a finer screw thread. However, most screw jacks have large amounts of friction which increase the input force necessary, so the actual mechanical advantage is often only 30% to 50% of this figure.

## Worm and worm wheel




Worm gears are special gears used in rudders, automobile steering mechanisms, hoists and rolling mills.

A worm gear drive consists of two elements:

1. Driving element → Screw
2. Driven element → Helical gear

Driving element (screw) is called worm and driven element (helical gear) is called worm gear or worm wheel.

Worm gear drives are typically used for transmission of power between two non-parallel and non-intersecting shafts.

### How worm gear works?

The worm (screw) continuously rotates and drives the worm wheel (meshed with it). Worm and worm gear form a lower pair as they have sliding contact with each other.

In a worm gear drive, power is always transmitted from worm to worm wheel. Power cannot be transmitted from worm wheel to worm. This phenomenon is called self-locking. It is highly useful in many applications.

Velocity ratio is determined by the number of teeth on worm gear and the number starts on worm. Power transmission decreases with increase in velocity ratio.

**Note:** A screw (worm) is said to have one start if it advances one groove (in linear direction), in one complete revolution. It is said to have have two starts if it advances two grooves (in linear direction) in one revolution. The worm shown in the animation above has four starts.

### Advantages of Worm Drives:

1. Worm gear drives operate silently and smoothly.
2. They are self-locking.
3. They occupy less space.
4. They have good meshing effectiveness.
5. They can be used for reducing speed and increasing torque.
6. High velocity ratio of the order of 100 can be obtained in a single step.

### Disadvantages of Worm Drives:

1. Worm gear materials are expensive.
2. Worm drives have high power losses and low transmission efficiency.
3. They produce a lot of heat.

### Applications of Worm Gear Drives:

Worm drives are used in:

1. Gate control mechanisms
2. Hoisting machines
3. Automobile steering mechanisms
4. Lifts
5. Conveyors
6. Presses