

Levers and Simple machines - Simple machines - Effort and load, mechanical advantage, velocity ratio, efficiency of machine, relationship between efficiency, velocity ratio and mechanical advantage

Introduction

A machine is a tool containing one or more parts that uses energy to perform an intended action. Machines are usually powered by mechanical, chemical, thermal, or electrical means, and are often motorized. Historically, a power tool also required moving parts to classify as a machine. However, the advent of electronics has led to the development of power tools without moving parts that are considered machines.

A simple machine is a device that simply transforms the direction or magnitude of a force, but a large number of more complex machines exist. Examples include

- 1 Levers
- 2 Screw Jack
- 3 Wheel and axle
- 4 Pulleys
- 5 Inclined plane, etc.,

Load (or) Weight

The force overcome by the effort is called load or weight (W).

Effort (or) power

The force applied to lift the load is called effort or power (P).

Fulcrum

It is a fixed point in the machine around which the machine rotates (F).

Mechanical advantage

In a simple machine when the effort (P) balances a load (W) the ratio of the load to the effort is called the mechanical advantage of the machine. It is simply expressed in a number.

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

Velocity ratio

It is the ratio between the distances moved by the effort to the distance moved by the load. It is also expressed in a number.

$$\text{Velocity ratio} = \frac{\text{Distance moved by effort (dp)}}{\text{Distance moved by load (dw)}}$$

Efficiency of Machine

The ratio of output to the input of machine is known as efficiency. In simple machines, the ratio of mechanical advantage to the velocity ratio is also known as efficiency of machine. Efficiency is generally expressed in percentage.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

$$\% \text{ Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

Relation between M.A., V.R. and η

$$\begin{aligned} \text{Efficiency} &= \frac{\text{Output}}{\text{Input}} = \frac{\text{Load} \times \text{Distance moved by load}}{\text{Effort} \times \text{Distance moved by effort}} \\ &= \frac{\text{Load}}{\text{Effort}} \times \frac{\text{Distance moved by load}}{\text{Distance moved by effort}} \\ &= \text{Mechanical advantage} \times \frac{1}{\text{Velocity ratio}} \end{aligned}$$

$$\text{Efficiency } (\eta) = \frac{\text{Mechanical advantage}}{\text{Velocity ratio}} = \frac{\text{M.A.}}{\text{V.R.}} \times 100$$

Ideal Machine

In an ideal machine the mechanical advantage is equal to the velocity ratio. so, efficiency is 100% or unity.

Examples

1 Calculate the mechanical advantage, velocity ratio and efficiency if a machine mass of 120 kg is lifted to a height of 5 metre by a force of 60 kg. moving 15m.

- Load (w) = 120 kg
- Distance moved by load = (dw) = 5 m
- Power (P) = 60 kg
- Distance moved by power (dp) = 15 m

$$MA = \frac{W}{P} = \frac{120 \text{ kg}}{60 \text{ kg}} = 2$$

$$VR = \frac{dp}{dw} = \frac{15}{5} = 3$$

$$\text{Efficiency}(\eta) = \frac{MA}{VR} \times 100\%$$

$$= \frac{2}{3} \times 100$$

$$= 66.66 \%$$

2 Calculate the mechanical advantage and efficiency of machine, if effort applied 300 kg a load of 900 kg is lifted by a simple machine having a velocity ratio of 4.

- Load (W) = 900 kg
- Effort (P) = 300 kg
- Velocity ratio (V.R) = 4

$$\begin{aligned} \text{Mechanical advantage (M.A.)} &= \frac{\text{Load (W)}}{\text{Effort (P)}} \\ &= \frac{900}{300} \\ &= 3 \\ \text{Efficiency } (\eta) &= \frac{\text{M.A.}}{\text{V.R.}} \times 100\% \\ &= \frac{3}{4} \times 100\% \\ &= 75\% \end{aligned}$$

3 Calculate Mechanical advantage, work done and horse power required if it is raised to a height of 6 m in 27 sec. and using a pulley block, a weight of 180 kg is raised with a force 15 kg.

$$\begin{aligned} W &= 180 \text{ kg} \\ P &= 15 \text{ kg} \\ \text{M.A.} &= ? \\ \text{Work done} &= ? \\ \text{HP} &= ? \\ \text{Height} &= 6 \text{ m} \\ t &= 27 \text{ second} \end{aligned}$$

$$\begin{aligned} \text{M.A.} &= \frac{W}{P} = \frac{180 \text{ kg}}{15 \text{ kg}} = 12 \\ \text{Work done} &= F \times d \text{ (Force} \times \text{Distance)} \\ &= 15 \text{ kg} \times 6 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Work done} &= 90 \text{ m} \cdot \text{kg} \\ \text{Power} &= \frac{\text{Workdone}}{\text{time}} \\ &= \frac{90 \text{ m kg}}{27 \text{ s}} \\ &= \frac{90}{27} \text{ m kg/s [75m kg/sec=1HP]} \\ &= 90/27 \times 1/75 \text{ H.P.} \\ &= 0.04444 \text{ H.P.} \end{aligned}$$

4 Calculate the applied force if a Load of 400 kg is lifted by a machine having an η of 72%. If velocity ratio = 6?

$$\begin{aligned} W &= 400 \text{ kg} \\ \eta &= 72\% \\ \text{V.R.} &= 6 \\ \eta &= \frac{\text{M.A.}}{\text{V.R.}} \times 100 \\ 72 &= \frac{\text{M.A.}}{6} \times 100 \\ \text{M.A.} &= \frac{72 \times 6}{100} \\ &= 4.32 \\ \frac{W}{P} &= 4.32 \\ \frac{400 \text{ kg}}{P} &= 4.32 \\ \text{Applied Force } P &= \frac{400}{4.32} = 92.59 \text{ kg.} \end{aligned}$$

Assignment

- Calculate the efficiency of a machine having velocity ratio 5 if a force of 275 kg applied to lift a weight of 1100kg with the help of simple machine.
- Calculate (i) Mechanical advantage (ii) Efficiency of machine if the effort applied is 250 kg and a load of 1000 kg is lifted by a simple machine having a velocity ratio of 5.
- What effort would be required and what would be the mechanical advantage if a lifting machine having a velocity ratio of 25, lifts a load of 40 Kg with an efficiency of 54.4% ?
- Find out the effort required if the velocity ratio of a weight lifting machine is 20. If the efficiency of the machine is 40%.
- Find the mechanical advantage if using a pulley block a load of 350 N is raised with a force of 25N.
- Calculate M.A. η of the machine, if the effort applied is 250 kg and a load of 1000 kg is lifted by a simple machine having a velocity ratio 5.
- Find out the η of the machine of effort applied is 300 kg if load of 1200 kg is lifted using simple machine having a velocity ratio of 5.
- Calculate M.A. and efficiency if in a simple machine the velocity ratio is found to be 20. An effort of 20 kg is required to lift a load of 400 kg.
- What is the velocity ratio, if its efficiency is 0.75 and in a lifting machine an effort of 31 kg just raises a load of 1000 kg?