Machines

- A simple machine is a device that makes work easier, faster and more convenient.
- Terms used in simple machines are:
    - Effort: force applied to the machine.
    - Load: body on which work is done.
    - Fulcrum: fixed point about which the machine can turn.
    - Input energy: energy supplied to the machine.
    - Output energy: useful work done by a machine.
    - Principle of machine: for an ideal machine the output is equal to its input.
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    - Velocity ratio=VEVL=dEtdLt=dEdL
    - **Relation between mechanical advantage and velocity ratio**
    - η=M.A.V.R.M.A.=η×V.R.
    -
    - Efficiency= $\frac{\text{Output energy}}{\text{Input energy}}$

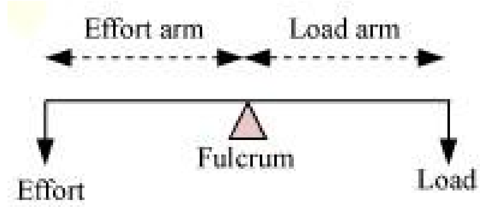
CARE OF MACHINE:

- Should be kept away from dust and moisture
- Proper lubrication should be used to avoid wear and tear
- Iron parts should be painted to avoid rusting.

- **Types of Simple Machines:**
    - **Lever**
    - **Inclined plane**
    - **Pulley**
    - **Wheel and axle**
    - **Screw**
    - **Wedge**

- **LEVER: It is a rod which moves freely about a fixed point called the fulcrum.**

- **Parts of a lever**

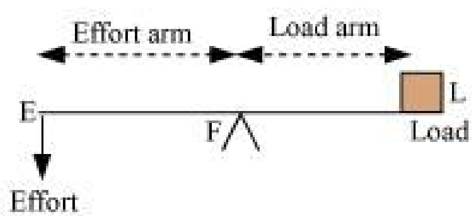


- Load × Load arm = Effort × Effort arm

$$\frac{\text{load}}{\text{effort}} = \frac{\text{effort arm}}{\text{load arm}},$$

$$\text{Mechanical advantage} = \frac{\text{effort arm}}{\text{load arm}}$$

- **Types of lever:** Levers are of three types depending on the position of the fulcrum, load and effort.
    - **Lever of first order:** Fulcrum is situated between the load and the effort. E.g., see-saw, crowbar, beam balance



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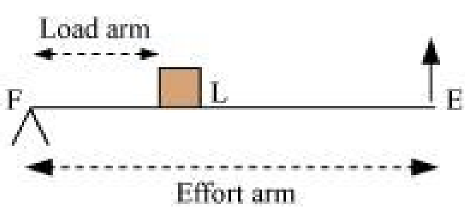
    - **Lever of second order:** Load is situated between the fulcrum and the effort. E.g., mango-cutter, wheel barrow, nut cracker



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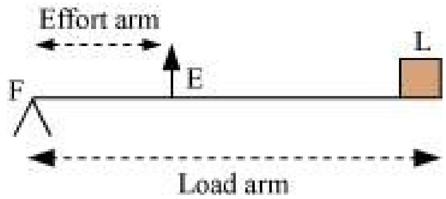
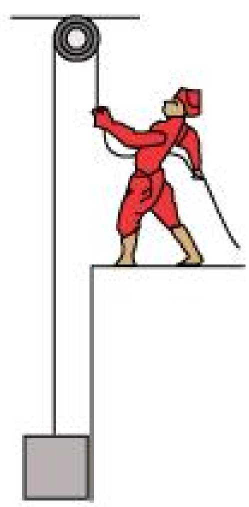
    - **Lever of third order:** Effort is situated between load and the fulcrum. E.g, pair of tongs, fishing rod



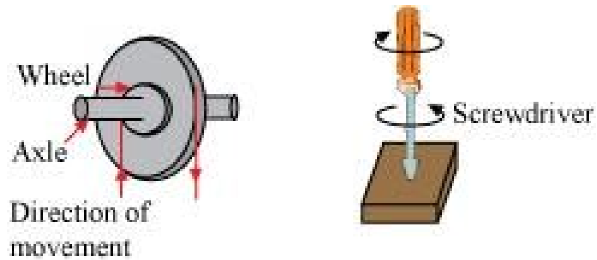
Order of Levers found in Human Body

(1) First order lever: Nodding of head
(2) Second order lever: Raising the weight of the body on toes
(3) Third order lever: Raising a load by forearm

- **PULLEY:**
    - **It consists of a circular disc made of metal or wood with a groove cut along its rim.**
    - **A rope passes around the groove; the groove prevents it from slipping off.**
    - **Pulley rotates about an axle fixed to a support called the block.**
    - **Load is attached to one end and the effort is applied to the other end.**
    - **Pulley allows us to apply force in a convenient direction.**



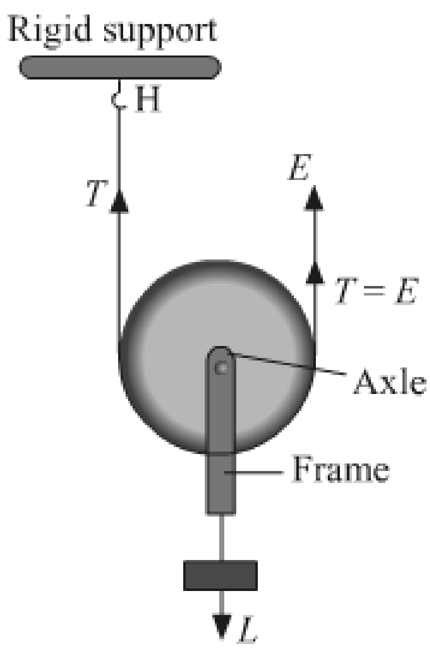
- **WHEEL AND AXLE:**



- Wheel with a rod attached to it is known as a wheel and axel arrangement.
- When a wheel is turned the axel also turns.
- E.g, steering wheel of a car, drill used by a carpenter.

Movable pulley

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



Single movable pulley

Mechanical advantage (M.A.), Velocity ratio (V.R.) and Efficiency (η) of single movable pulley:

Assumptions:
(1) Friction free pulley bearings or axle
(2) Negligible weight of pulley and string

The load is getting balanced by the tension in each segment of the string and the effort balances the tension at the free end of the string as is shown in the above figure.
So,

$L = 2T$ and $E = T$

$\Rightarrow E = L/2$

Hence, single movable pulley acts as a force multiplier as effort required to lift the load is half of the load.

M.A.=LoadEffort=2TT=2

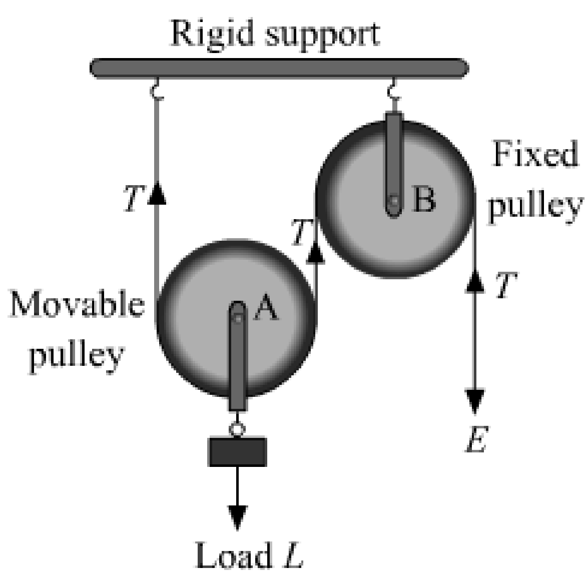
Now, when effort E pulls the free end of the string through a distance of $2d$, the load only moves up by a distance of d. This is because the segment of string on both sides of the pulley moves up a distance d. Therefore,

V.R.=Distance moved by effortDistance moved by load=2dd=2

Efficiency of the single movable pulley,

η=M.A.V.R.=22=1=100%

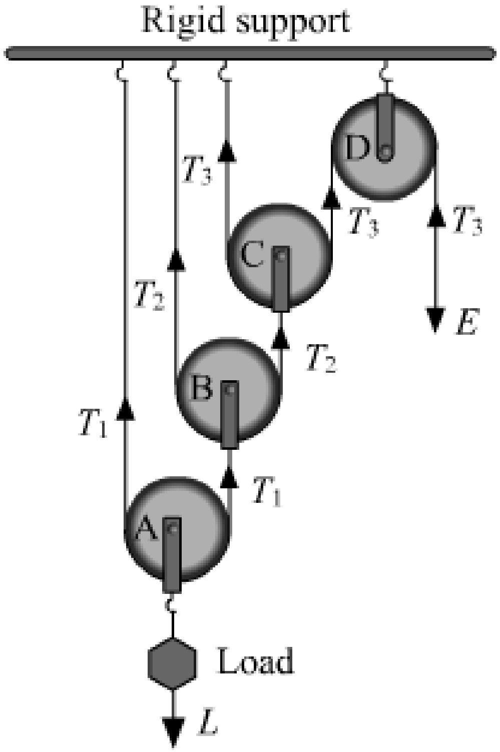
A new arrangement in which the movable pulley is paired with a fixed pulley so as to change the direction of effort from upward (as in the single movable pulley) to downward is shown below. However, the mechanical advantage (M.A.), velocity ratio (V.R.) and efficiency (η) of this arrangement or system are same as that of single movable pulley.



Single movable pulley with
a fixed pulley

To lift heavy loads or to shift them from one place to another, we need combination of pulleys which can provide us mechanical advantage greater than 2. Two such systems are:
(1) System with one fixed pulley and several movable pulleys attached to a same rigid

support



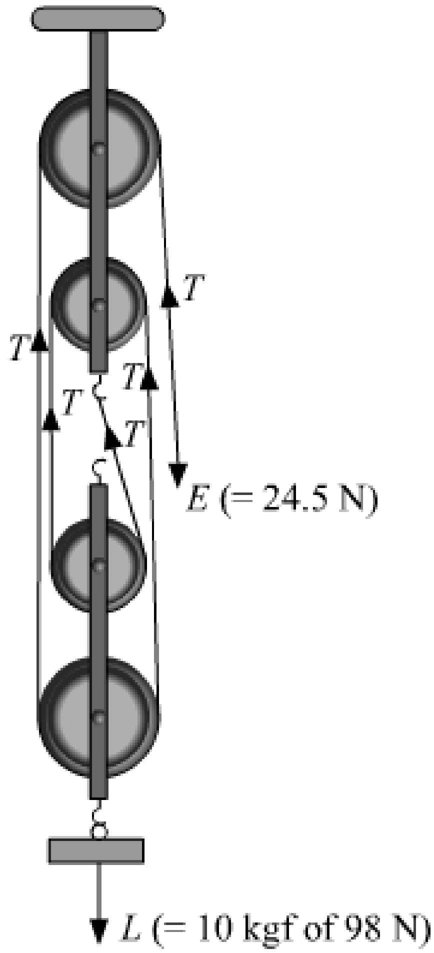
System of one fixed pulley and three movable pulleys

M.A.=loadeffort=23×T3T3=23
If there are ***n*** movable pulleys with one fixed pulley, then the mechanical advantage of such system is 2^n .

V.R.=distance moved by effortdistance moved by load=23xx=23

Efficiency =M.A.V.R.=2n2n=1 or 100%

(2) System with two blocks several pulleys, in which lower block is movable and the upper block is fixed to a rigid support (also known as block and tackle system)



Block and tackle
for 4 pulleys

$M.A. = \frac{Load (L)}{Effort (E)} = \frac{nT}{T} = n$

$\therefore V.R. = \frac{nd}{d} = n$

Efficiency is 100% as M.A. and V.R. are equal.

Effect of the weight of pulleys (*w*) on mechanical advantage, velocity ratio and efficiency
$M.A. = \frac{L}{E} = \frac{nE - w}{E} = n - \frac{w}{E}$

From the above equation, we figure out that the mechanical advantage is less than the ideal value *n*.

The velocity ratio does not change; it remains the same. However, efficiency will change because M.A. changes.

$\eta = \frac{M.A.}{V.R.} = \frac{n - \frac{w}{E}}{n} = 1 - \frac{w}{nE}$

From the above relation of efficiency, we see that efficiency increases if the pulleys in the lower block are made as light as possible.