MACHINE

A machine is a device that transmits force or torque to accomplish a definite purpose.

The applications of simple machines are often for the purpose of multiplying force .

A machine cannot supply more output energy than it is given as input energy

i.e. the output energy is always less than or equal to the input energy.

This follows from the conservation of energy priciple.

Most machines have one or more of the following functions:

1. To exert a large force by application of a relatively small one.
2. To convert a slow movement into a rapid one or vice versa.
3. To enable a force to be applied at a more convenient point.

The Principles of Machines

The Effort (F_i)

The effort is the force that is applied to any machine.

F_i = input force

The Load (F_o)

The load is the force exerted by the machine.

F_o = output force

Mechanical Advantage (MA)

The ratio of load to effort is called the mechanical advantage of the machine.

$$\mathrm{MA} = \frac{\text{load}}{\text{effort}} = \frac{F_o}{F_i}$$

Most machines are designed with an intention of obtaining a MA greater than unity.(Why?)

Actual Mechanical Advantage(AMA)

The ratio of the force to overcome large resistance to the force applied is called the actual mechanical advantage of the machine.

$$AMA = \frac{F_0}{F_i} = \frac{\text{force overcome (resistance)}}{\text{force applied}} = \frac{\text{force output of the machine}}{\text{force input to the machine}}$$

Ideal Mechanical Advantage (IMA)

The ratio of the distance moved by the effort to the distance moved by the load neglecting energy dissipated in friction, etc.

$$\text{IMA} = \frac{s_i}{s_0} = \frac{\text{diatance moved by the effort}}{\text{distance moved by the load}}$$

Velocity Ratio (VR)

The ratio of the distance moved by the effort to that moved by the load is called the velocity ratio of the machine.

$$VR = \frac{s_i}{s_0} = \frac{\text{distance moved by the effort}}{\text{distance moved by the load}}$$

For an ideal machine, efficiency is 100 % and in that case **IMA = VR**

The VR of a machine only depends on the geometric construction of the machine.

The present of frictiojn does not alter the value of VR.

Efficiency

The efficiency as a percentage is defined by

$$\text{Efficiency (\%)} = \frac{\text{work output}}{\text{work input}} \times 100\%$$

The other forms of efficiency are

$$\text{Efficiency (\%)} = \frac{\text{power output}}{\text{power input}} \times 100\%$$

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

$$\text{Efficiency (\%)} = \frac{\text{AMA}}{\text{IMA}} \times 100\%$$

Principle of Work

work input = work output + energy dissipated in friction, etc.

The Simple Machines

(1) Pulley (2) lever (3) inclined plane (4) wedge

(5) screw and (6) wheel and axle (7) gear

The wheel and axle and the pulley can be looked upon as modified levers.

The wedge and the screw are adaptations of the inclined plane.

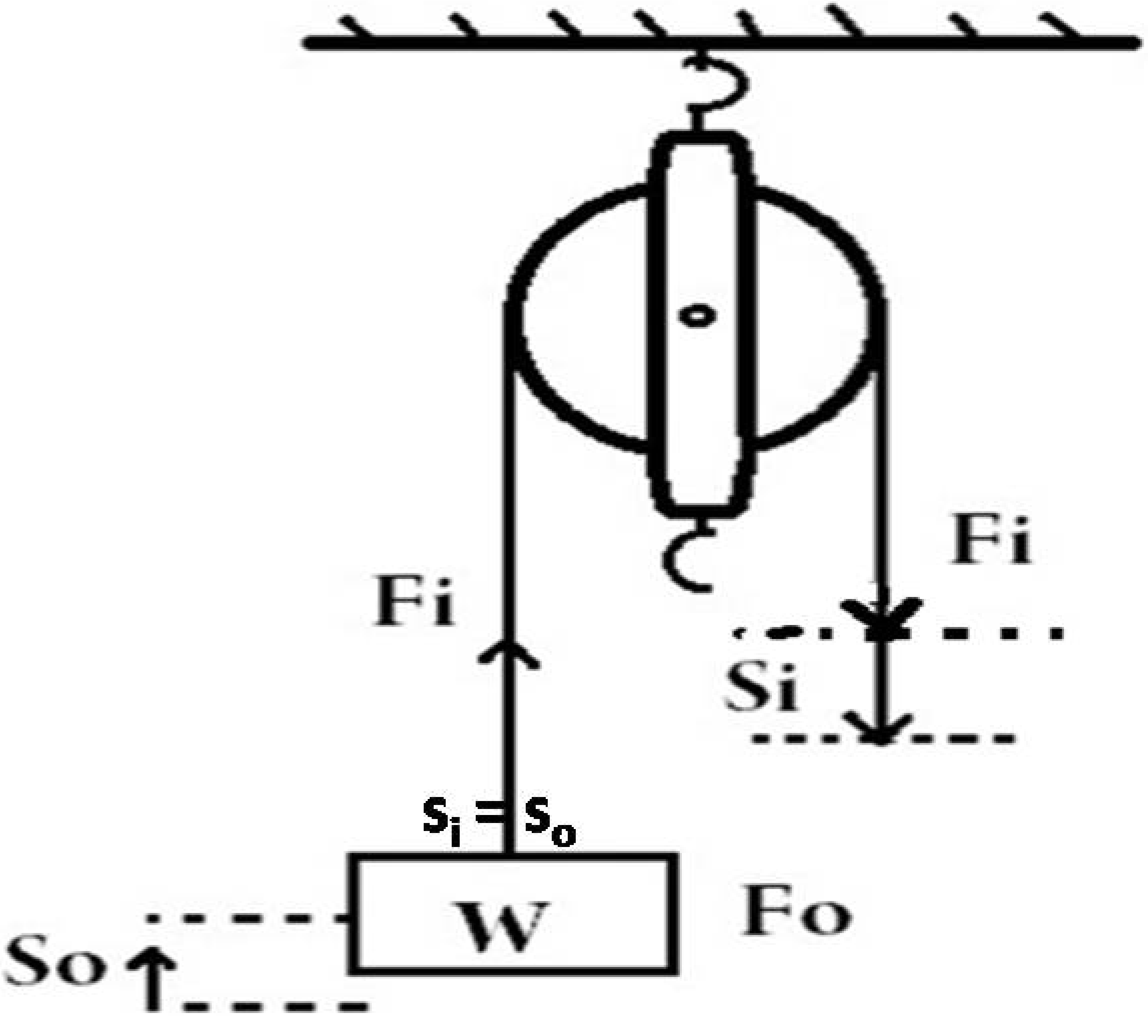
Pulley

A pulley simply consists of a grooved wheel on an axle with a cord or rope passed around the groove.

Two kinds of pulleys are encountered.

1. Fixed pulley
2. Movable pulley

Single Fixed Pulley



- By the principle of work

$$W_{in} = W_{out} + W_f$$

If friction is neglected, $W_f = 0$

$$W_{in} = W_{out}$$

$$F_i S_i = F_o S_o$$

$$\frac{F_o}{F_i} = \frac{S_i}{S_o}$$

$$MA = 1 (S_i = S_o)$$

$$IMA = 1$$

IMA = 2

By the 1st condition of a equilibrium,

$$\Sigma F_y = 0$$

$$(+2F_i) + (-F_o) = 0$$

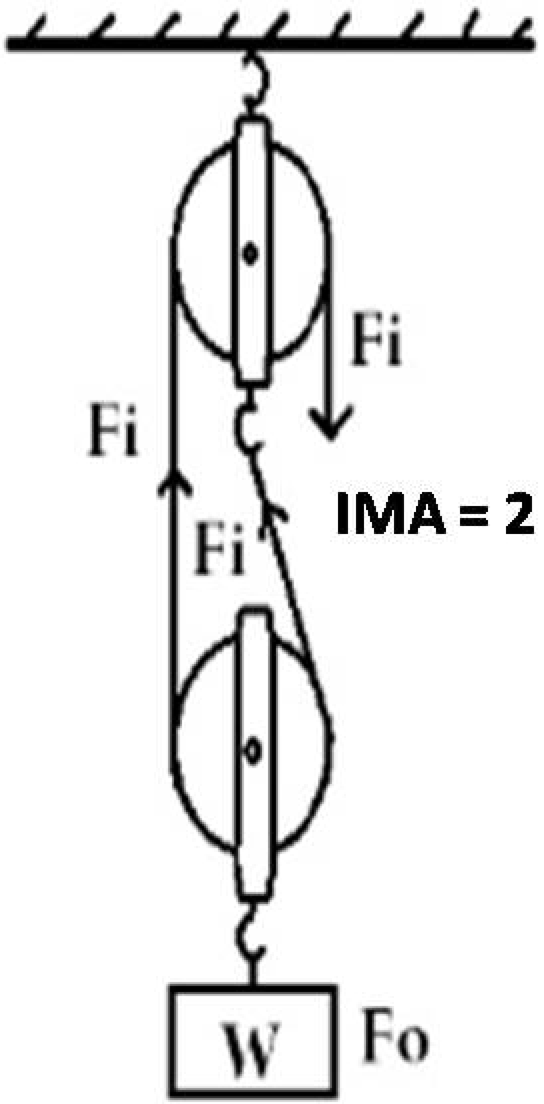
$$2F_i = F_o$$

$$\frac{F_o}{F_i} = AMA = 2$$

Friction is neglected.

$$IMA = AMA = 2$$

$$IMA = 2$$



IMA = 3

By the 1st condition of a equilibrium,

$$\Sigma F_y = 0$$

$$(+3F_i) + (-F_o) = 0$$

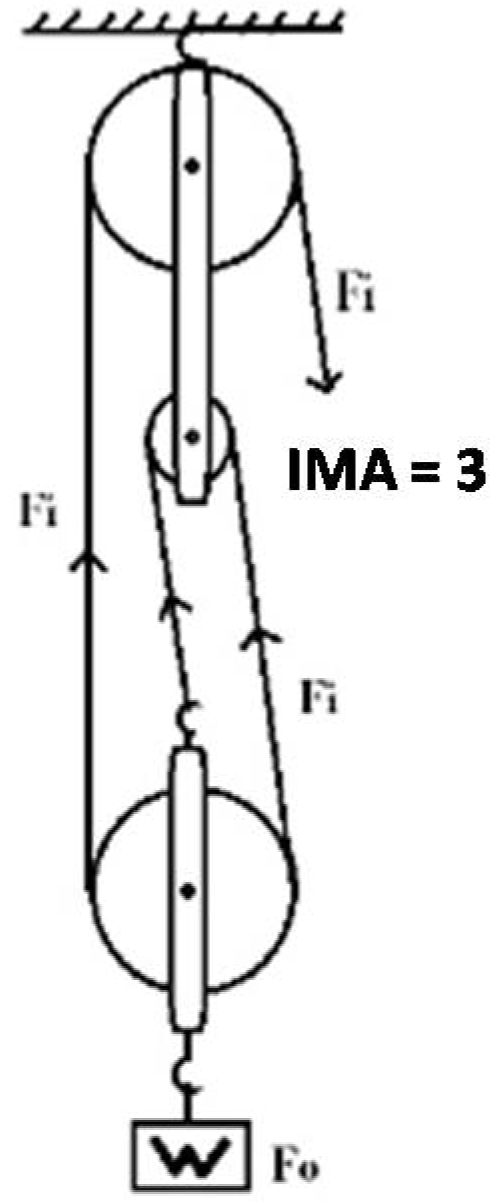
$$3F_i = F_o$$

$$\frac{F_o}{F_i} = AMA = 3$$

Friction is neglected.

$$IMA = AMA = 3$$

$$IMA = 3$$



Double Movable Pulleys

By the 1st condition of a equilibrium,

$$\Sigma F_y = 0$$

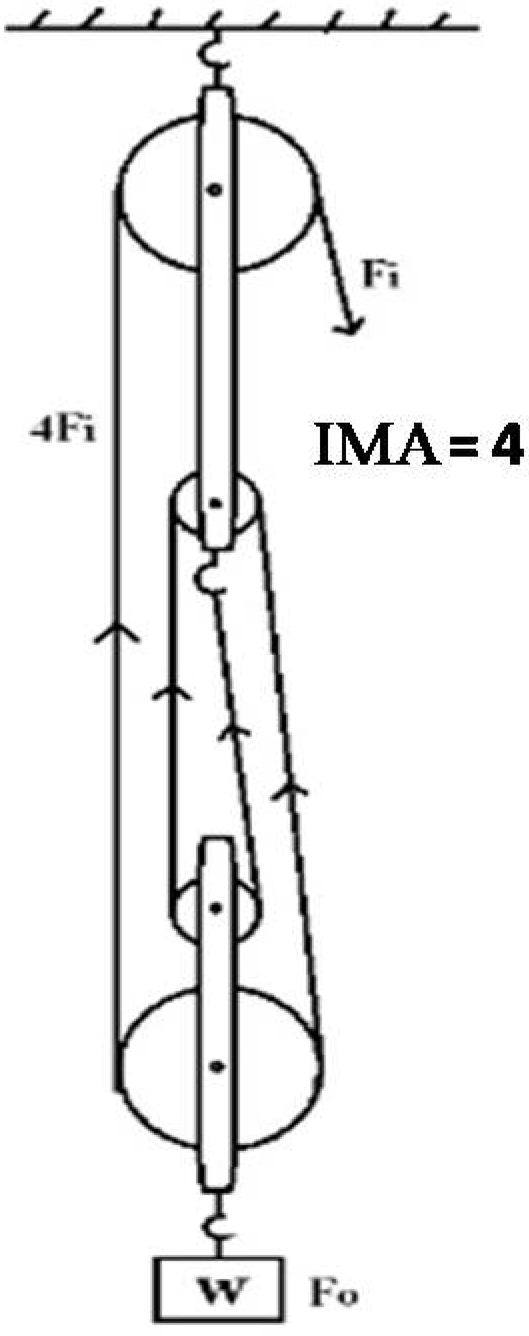
$$(+4F_i) + (-F_o) = 0$$

$$4F_i = F_o$$

$$\frac{F_o}{F_i} = AMA = 4$$

Friction is neglected.

IMA = AMA = 4



Applications

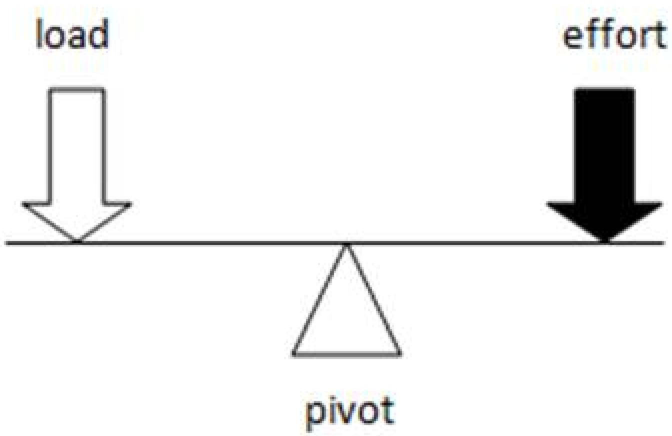
1. Traction
2. Exercises
3. Orthopaedic nursing

   (supporting injured limbs)

Lever

A lever consists of a pivot or fulcrum with a load at one end and an effort applied to move the load at the other end of a beam.

Levers are machines which operate on the principle of moments.



There are three knids of levers

First Order Lever

The pivot is situated between the load and the effort .

Its IMA values can be less than unity or equals to unity or greater than unity according to the position of the pivot.

Applications

Levers used in hospital work are scissors , bone elevator, etc.

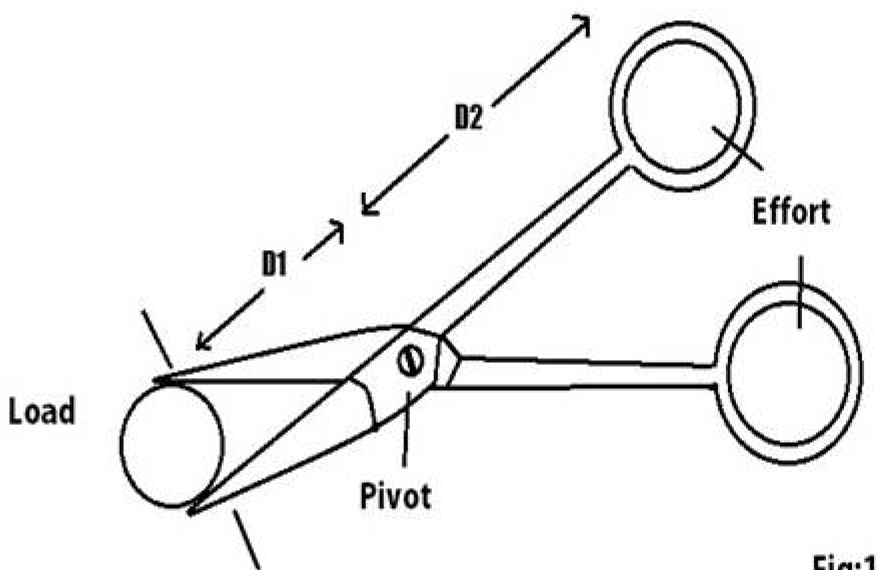


Fig:1.28

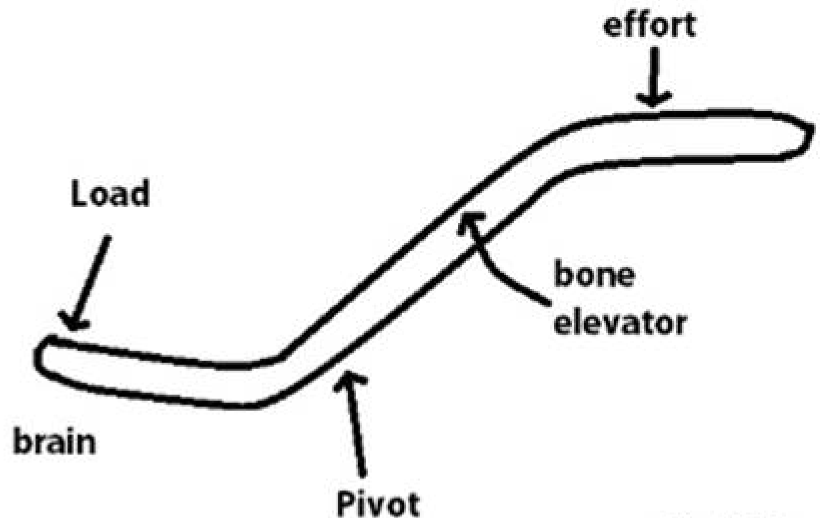


Fig:1.29

Lever found in the human body are

(i) the skull on its pivot , the atlas vertebra ,

(ii) the pedal action of the foot as in pressing a pedal in a car, etc.

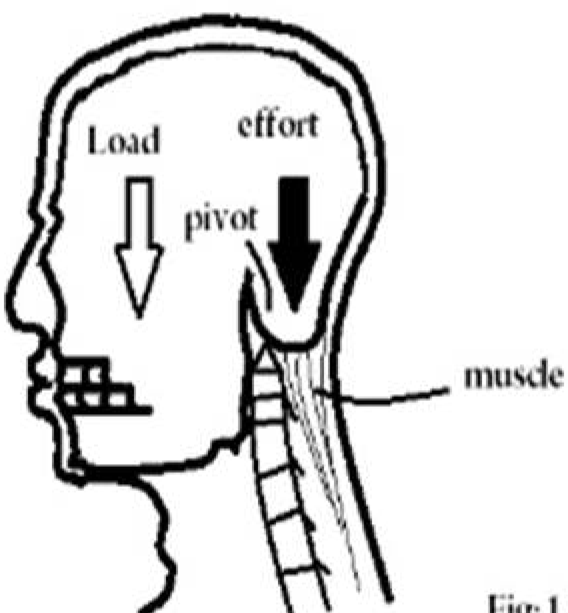


Fig: 1.30

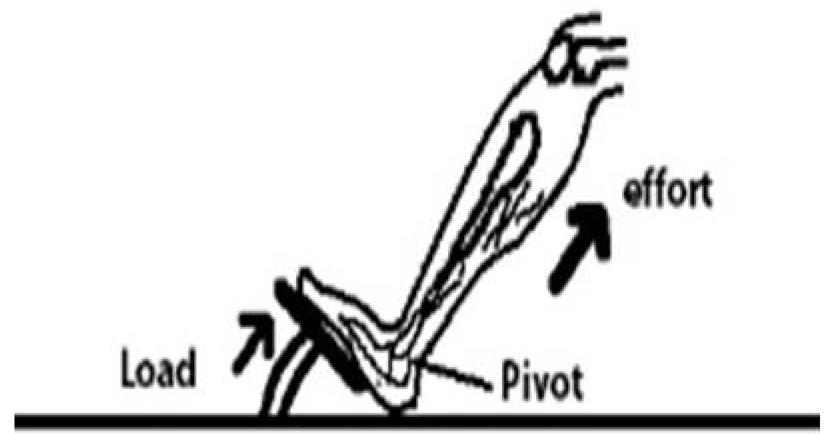
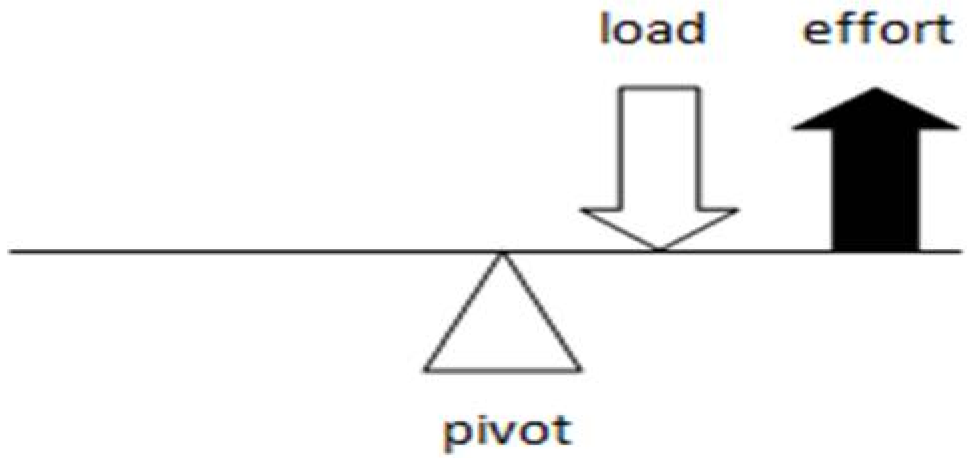


Fig:1.31

Second Order Lever

The load is situated between the pivot and the effort.

Its IMA value is always greater than unity.



Application

Ambulance carrying chairs (collapsible wheel chair) used in hospital.

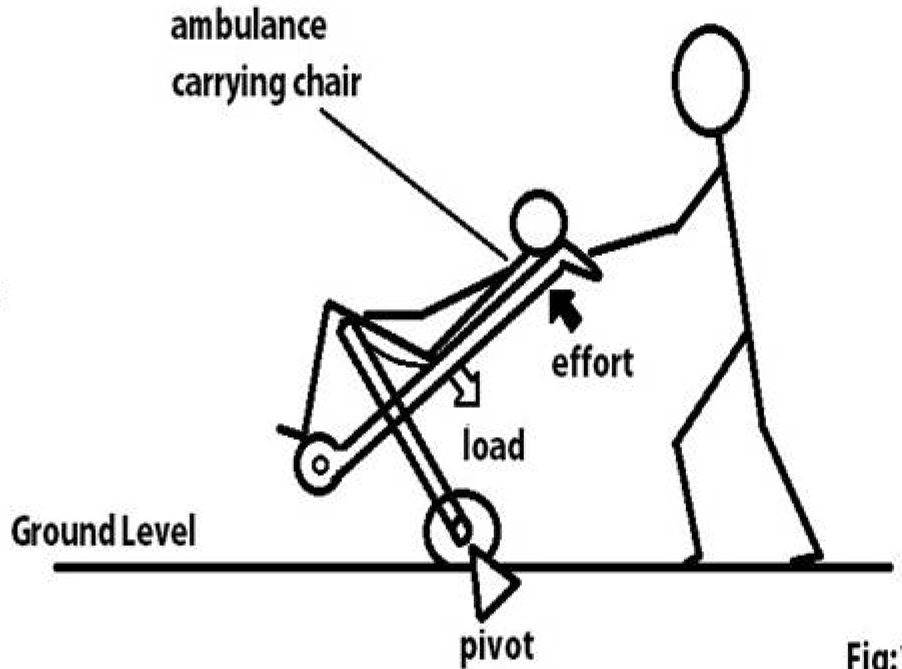


Fig:1.33

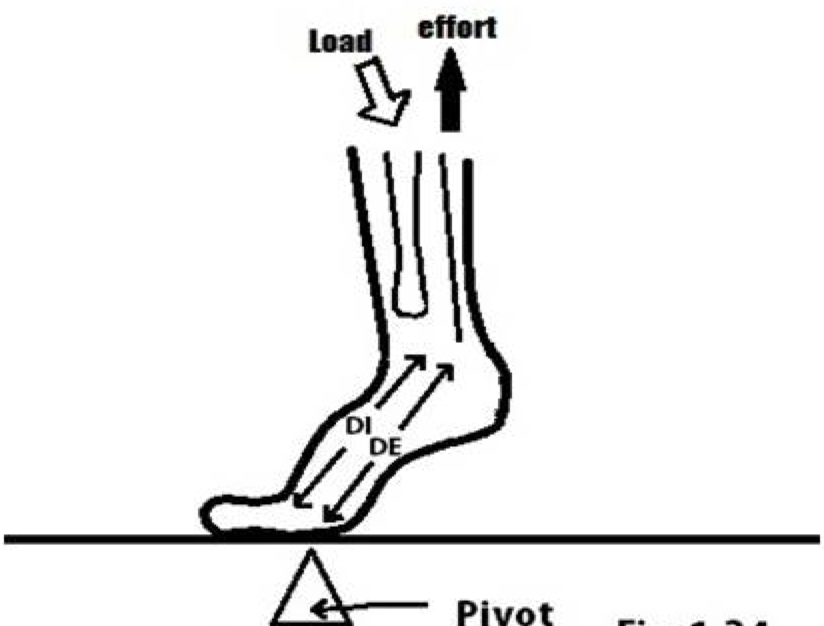


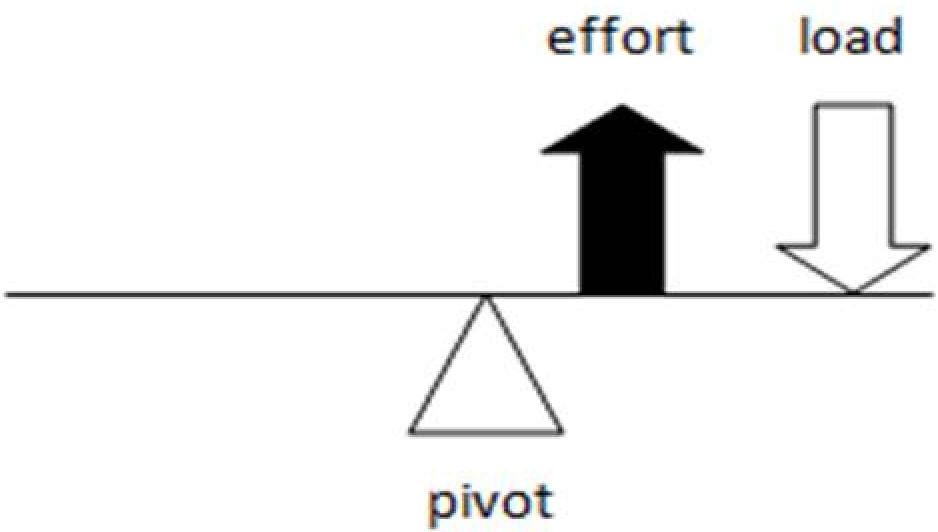
Fig:1.34

The second order lever is seen in the foot when a person stands on tiptoe.

Third Order Lever

The effort is situated between the pivot and the load.

Its IMA value is always less than unity.



Applications

Levers used in hospital work are forceps, surgical knives, nasal speculum, etc.

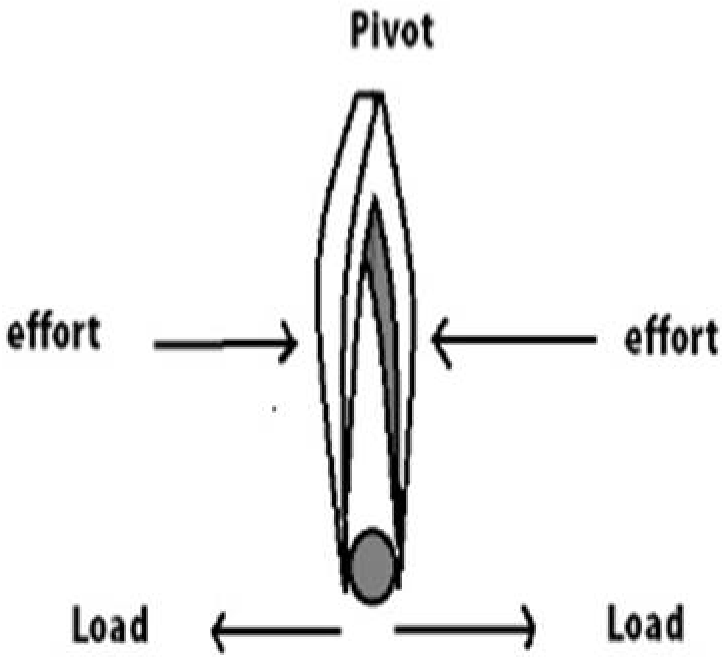


Fig:1.36

Forceps-third order lever

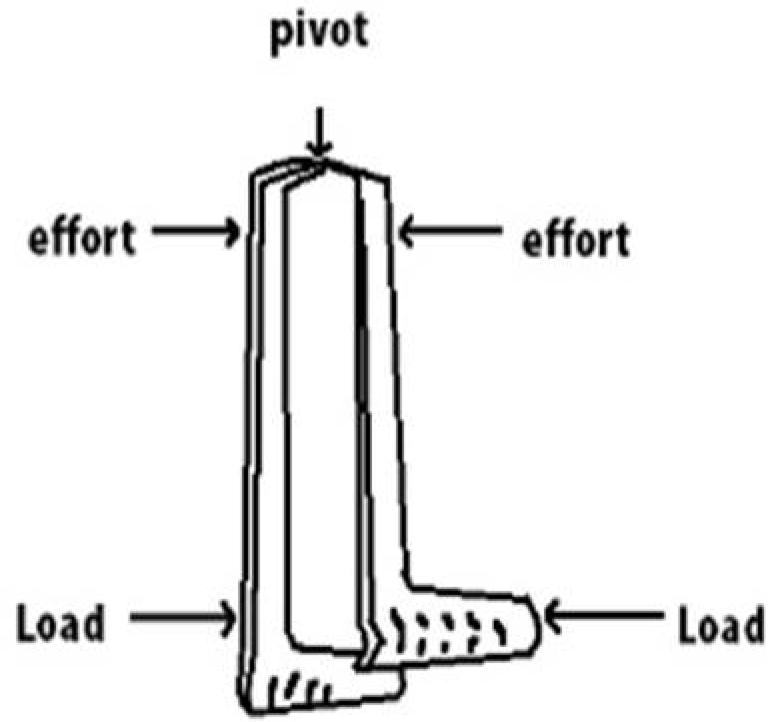


Fig:1.37

Nasal speculum third order lever

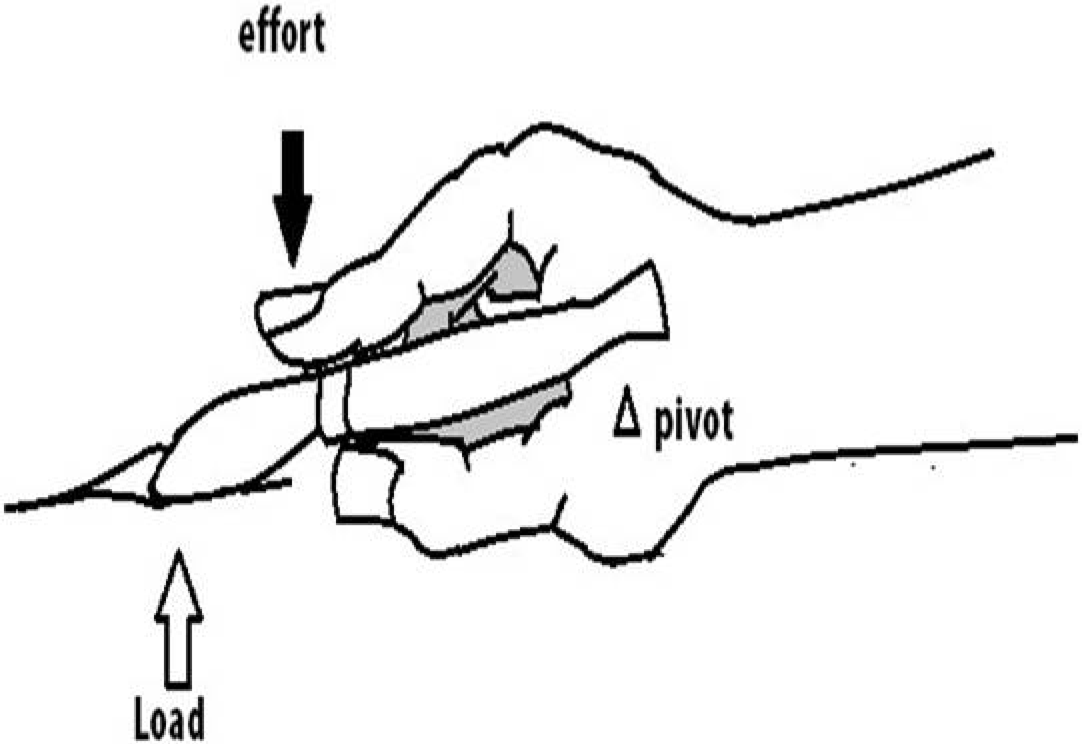


Fig:1.38

Surgical scalpel as a third order lever

Levers found in the human body are the forearm lifting weight in the horizontal position, the chewing action, etc.

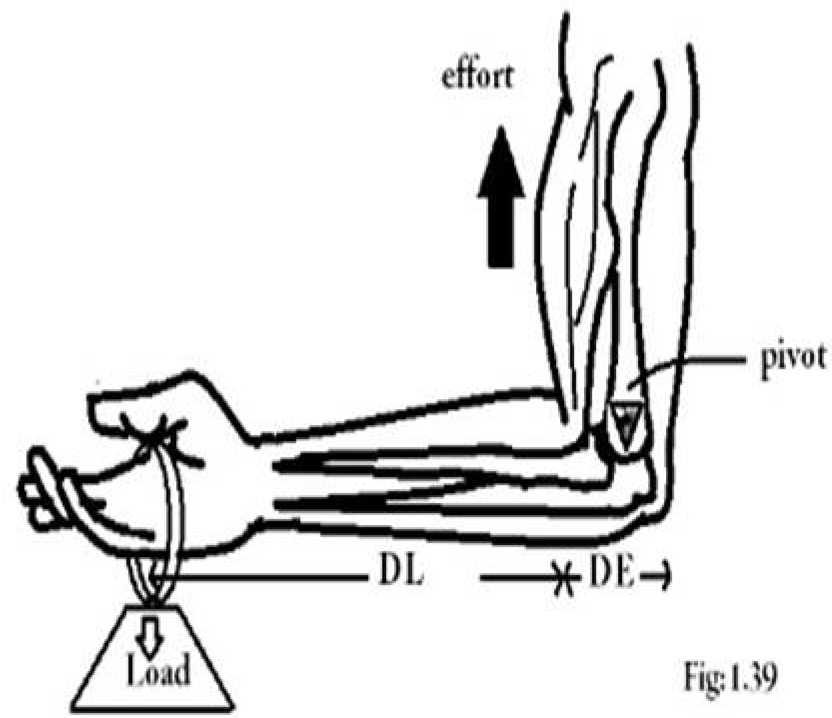


Fig:1.39

Forearm lifting weight-third order lever

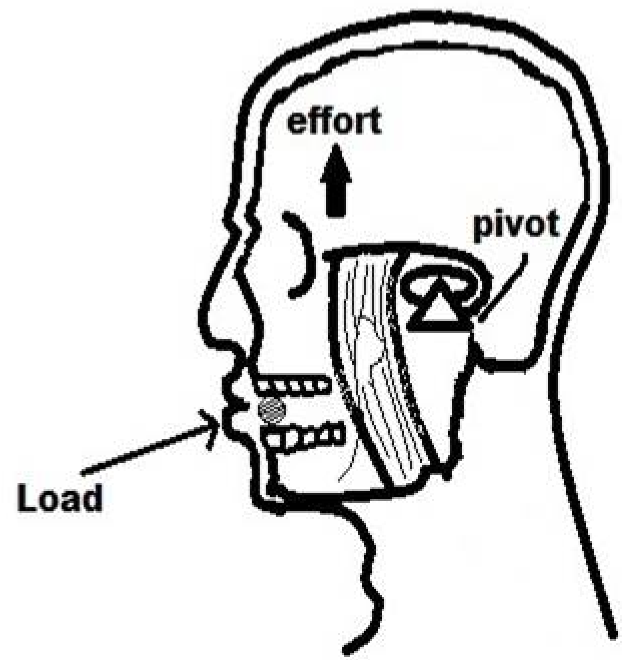


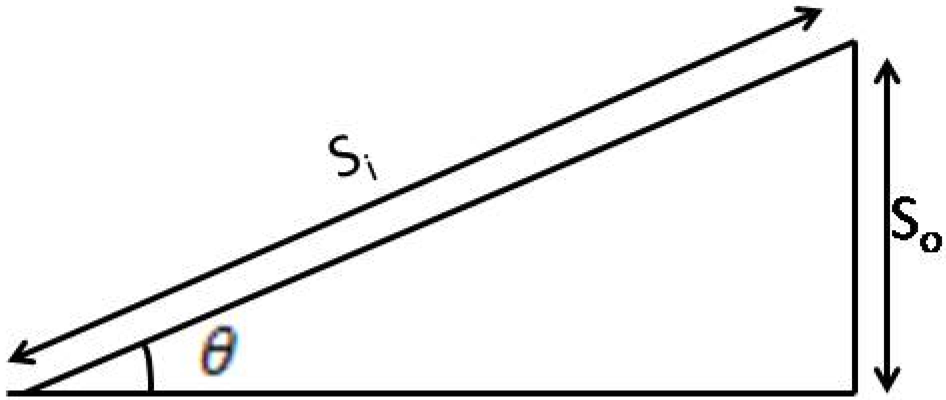
Fig:1.40

Chewing action-third order lever

An Inclined Plane

It is easier to ascend a slight incline than to ascend a vertical face. Disabled people in wheel chairs can propel themselves up a gentle slope of a ramp but find the effort too great or impossible to ascend a vertical step in a wheel chair.

$$IMA = \frac{s_i}{s_o} = \frac{1}{\frac{s_o}{s_i}} = \frac{1}{sin\theta}$$



1. (i) $IMA = ?, \; s_i = 3.3m, \; s_o = 8cm = 8 \times 10^{-2} m$

$$IMA = \frac{s_i}{s_o} = \frac{3.3}{8 \times 10^{-2}} = 41.25 \leftarrow$$

(ii) $Efficiency = 60\%, \; AMA = ?$

$$Efficiency = \frac{AMA}{IMA} \times 100\%$$

$$60\% = \frac{AMA}{41.25} \times 100\%$$

$$AMA = 24.75 \leftarrow$$

(iii) $F_o = ?$, $F_i = 50N$,

Efficiency $= 60\%$

$$AMA = \frac{F_o}{F_i}$$

$$24.75 = \frac{F_o}{50}$$

$$F_o = 1237.5 \text{ N} \quad \leftarrow$$

$3. F_o = 5 \text{ lb}, s_o = 15 \text{ in}, s_i = 3 \text{ in}, F_i = ?$

By the 2nd condition of equilibrium

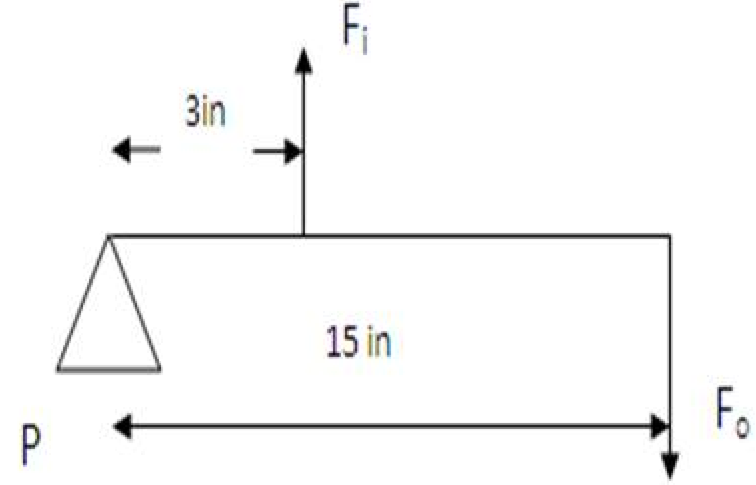
$$\Sigma\tau_P = 0$$

$$(+F_i s_i) + (-F_o s_o) = 0$$

$$F_i s_i = F_o s_o$$

$$F_i \times 3 = 5 \times 15$$

$$F_i = 25 \text{ lb}$$



4. $F_o = W = 90\ N$

$F_i = ?$ (Friction is neglected)

$s_i = 9\ cm,\ s_o = 3\ cm$

When friction is neglected,

$$W_{in} = W_{out}$$

$$F_i s_i = F_o s_o$$

$$F_i \times 9 = 90 \times 3$$

$$F_i = 30\ N$$

OR IMA=AMA

$$\frac{S_I}{S_O} = \frac{F_o}{F_i}$$

$$\frac{9}{3} = \frac{90}{F_i}$$

$$F_i = 30N$$

When friction is taken into account,

$$\text{IMA} = \frac{s_i}{s_o} = \frac{9}{3} = 3$$

$$\text{AMA} = \frac{F_o}{F_i} = \frac{90}{42} = 2.14$$

$$\text{Efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100\ \%$$

$$= \frac{2.14}{3} \times 100\ \%$$

$$= 71.33\ \%$$

5. $s_i = 15\ cm$, $s_o = 3\ cm$

$m = 20\ kg$, $g = 10ms^{-2}$

(i) $F_i = ?$ (Friction is neglected)

$F_o = w = mg = (20 \times 10)\ N$

$= 200\ N$

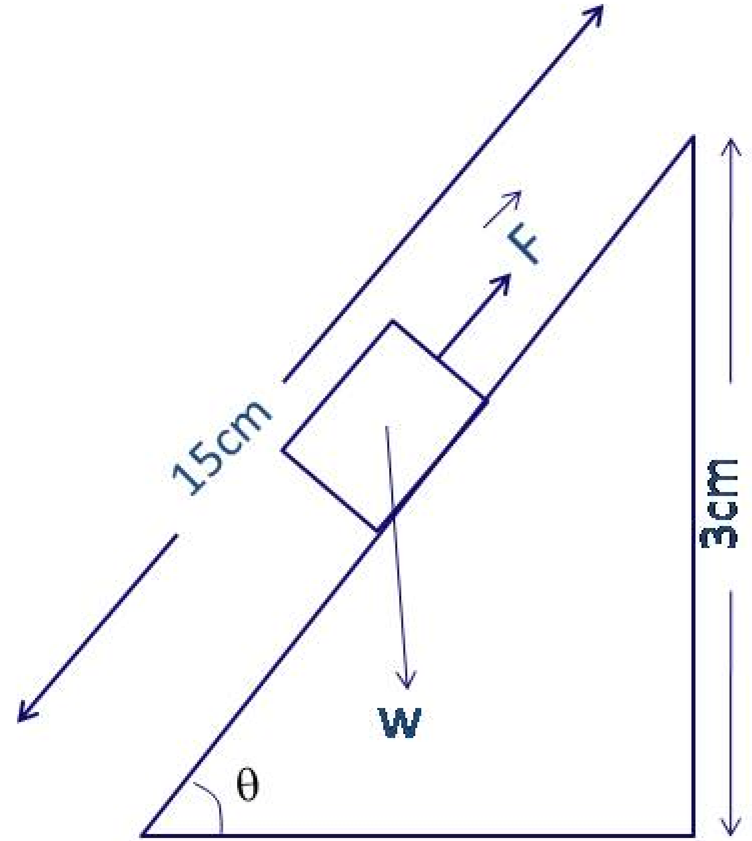
When friction is neglected,

$W_{in} = W_{out}$

$F_i s_i = F_o s_o$

$F_i \times 15 = 200 \times 3$

$F_i = 40\ N$



(ii) IMA = ? , AMA = ? , eff: = ?

$$F_i = 64 \text{ N}$$

$$\text{IMA} = \frac{s_i}{s_o} = \frac{15}{3} = 5$$

$$\text{AMA} = \frac{F_o}{F_i} = \frac{200}{64} = 3.125$$

$$\text{Efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100\,\%$$

$$= \frac{3.125}{5} \times 100\,\%$$

$$= 62.5\,\%$$

1 (*i*) IMA = ? $s_i = 3.3\ m$, $s_o = 8\ cm = 8 \times 10^{-2}\ m$

$$\text{IMA} = \frac{s_i}{s_o} = \frac{3.3}{8 \times 10^{-2}} = 41.25$$

(*ii*) Efficiency = 60 %, AMA = ?

$$\text{Efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100\ \%$$

$$60\ \% = \frac{\text{AMA}}{41.25} \times 100\ \%$$

$$\text{AMA} = 24.75$$

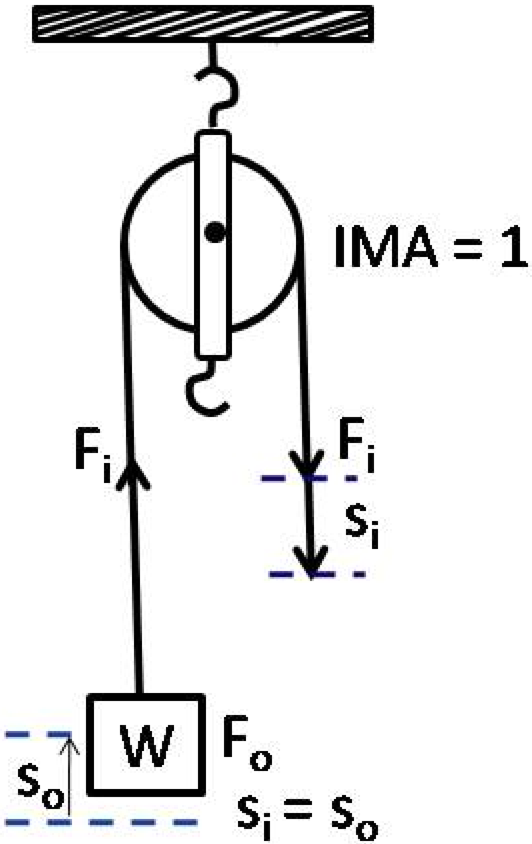
(iii) F_o = ? , F_i = 50 N , Efficiency = 60 %

$$\text{AMA} = \frac{F_o}{F_i}$$

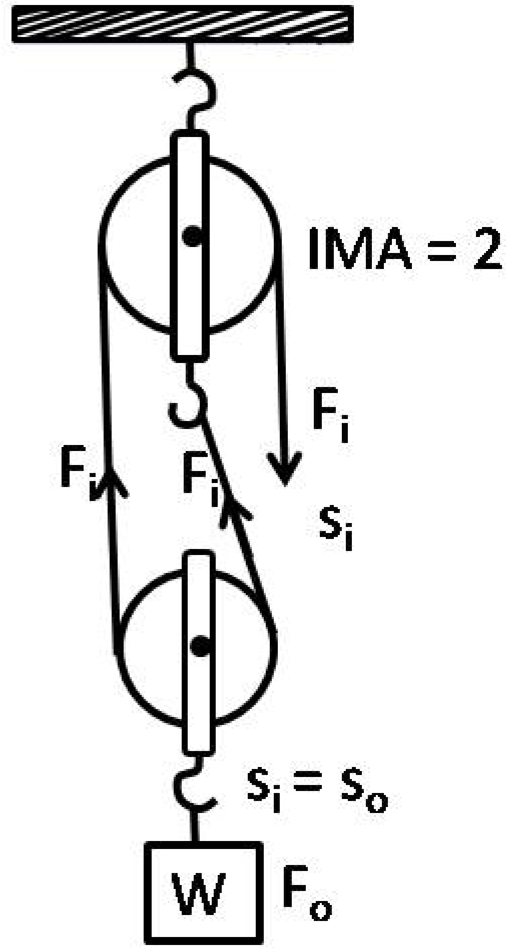
$$24.75 = \frac{F_0}{50}$$

$$F_o = 1237.5\ \text{N}$$

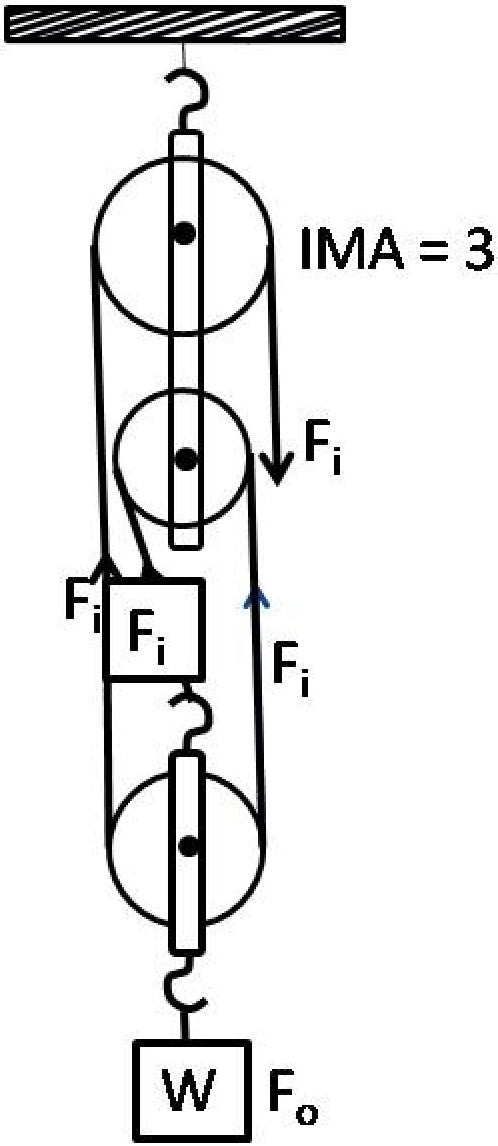
Single fixed pulley



Single movable pulley



Single movable pulley



Double movable pulleys