NEW ZEALAND
MARITIME SCHOOL

STCW 1978 III/2
(as amended in 2010)

MECHANICAL TECHNOLOGY 1

COURSE CODE: 942. 594

ELEMENT 6: LIFTING MACHINES

Chapter 8:

Lifting Machines

8.Lifting Machines

Mechanical Advantage A machine is a device which changes the value of a force and its line of action and is designed to lift heavy loads by comparatively small effort forces. No more work can be got out of a machine than is put into it and in fact most machines will incur some losses due to friction in moving parts.

A machine is usually designed so that the load overcome is greater than the effort applied. The ***ratio of load to effort*** is known as the ***Mechanical Advantage*** thus;

$$\textbf{Mechanical Advantage} = \frac{\textit{Load lifted}}{\textit{Effort applied}}$$

$$\text{Or} \quad \textbf{M.A.} = \frac{W}{E}$$

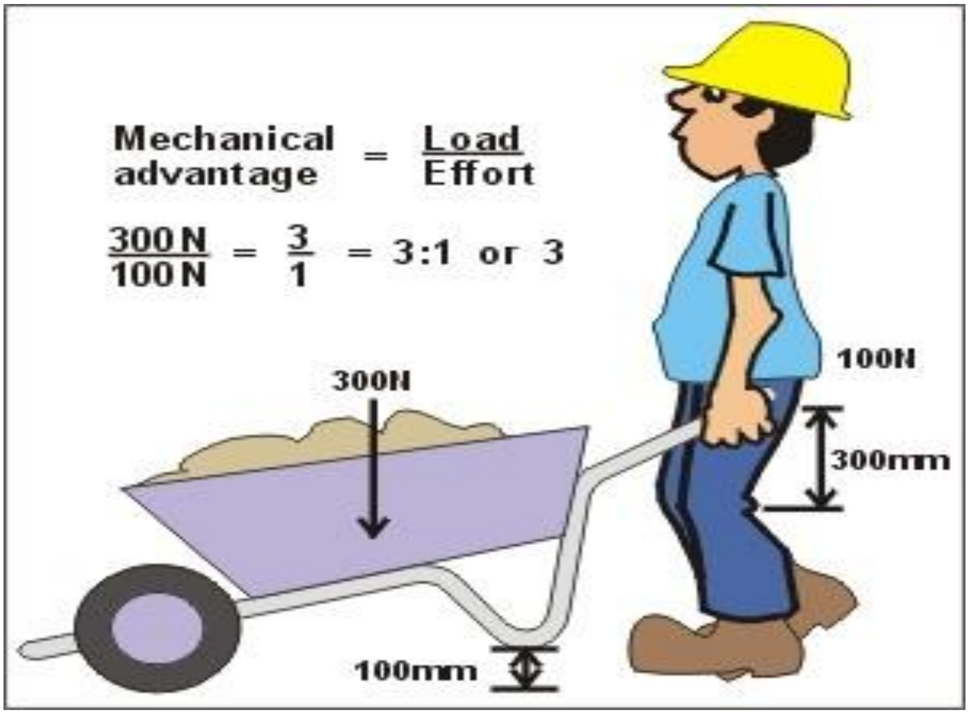
Since both W and E have the same units, mechanical advantage has no units and is only a number which varies with the load.

In an ideal machine there is no friction and the ratio $\frac{Load}{Ideal\ Effort}$ is then the *Ideal Mechanical Advantage* but in practice it is always less than the ideal and is usually obtained by experiment.

Work put into a Machine = work lost in friction + useful work done

Work is the product of effort applied and the distance it is lifted.

If the magnitude of effort is to be small compared with the load lifted then the distance the effort moves must be great compared with the distance the load moves.



The ratio of the distance moved by the effort to the distance moved by the load is called the "***Velocity Ratio***"

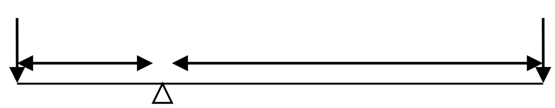
Therefore; **Velocity Ratio (VR) =** $\frac{\textbf{Distance moved by effort}}{\textbf{Distance moved by load}}$ **and**

Therefore Velocity Ratio = Ideal M.A.

Simplest VR is a crow bar;

Load Effort

$d_1 d_2$



$d_1$isthe distance moved by t

d_2 is the distance moved b

Therefore the VR of crow bar = $\frac{d_1}{d_2}$

The **Efficiency** of a machine is the ratio of output to input and is therefore;

Efficiency (Symbol η Greek letter 'eta') =

$$\frac{\boldsymbol{Output}}{\boldsymbol{Input}} = \frac{\boldsymbol{work\ done\ on\ load}}{\boldsymbol{work\ done\ at\ input}}$$

$$= \frac{\boldsymbol{load\ x\ distance\ moved}}{\boldsymbol{effort\ x\ distance\ moved}}$$

$$= \frac{\boldsymbol{load}}{\boldsymbol{effort}} \boldsymbol{x} \frac{\boldsymbol{distance\ moved\ by\ load}}{\boldsymbol{distance\ moved\ by\ effort}}$$

$$= \boldsymbol{M.A.\ x}\ \frac{\boldsymbol{1}}{\boldsymbol{VR}}$$

Hence; **Efficiency, η,** $= \frac{\boldsymbol{M.A.}}{\boldsymbol{V.R.}}$ **x 100 %**

And Efficiency**also** $= \frac{\textbf{work done in moving load}}{\textbf{work done by the effort}}$

Ideal Effort is that effort required to raise the load if the machine were 100% efficient.

At 100% efficiency the Mechanical Advantage will equal the Velocity Ratio from;

$$100\%\ \text{Efficiency} = \frac{\text{M.A.}}{\text{V.R.}} = 1$$

$$\text{Therefore M.A.} = \text{V.R.}$$

$$\text{Hence; ideal effort} = \frac{Load}{M.A.} = \frac{Load}{V.R.}$$

Example 2

A lifting machine has a velocity ratio of 4 and can lift a load of 100kg when the effort applied is 327N. Find (a) the efficiency, (b) the effort required to overcome friction at this load, (c) the work done against friction when the load is lifted 2m.

Solution;

First work in the same units for MA:= therefore 100kg × 9.81 = 981 N.

(a) **mechanical advantage** $= \frac{\boldsymbol{load.}}{\boldsymbol{effort.}} = \frac{98\mathbf{1}}{\mathbf{327.}} = 3$

$$\text{Efficiency} = \frac{M.A.}{V.R.} = \frac{\mathbf{3}}{\mathbf{4.}} = 75\%$$

(b) **Ideal effort** $= \frac{load}{V.R.} = \frac{980}{4} = 245\text{N}$

Friction effort = actual – ideal

= 327 -245 = 82N

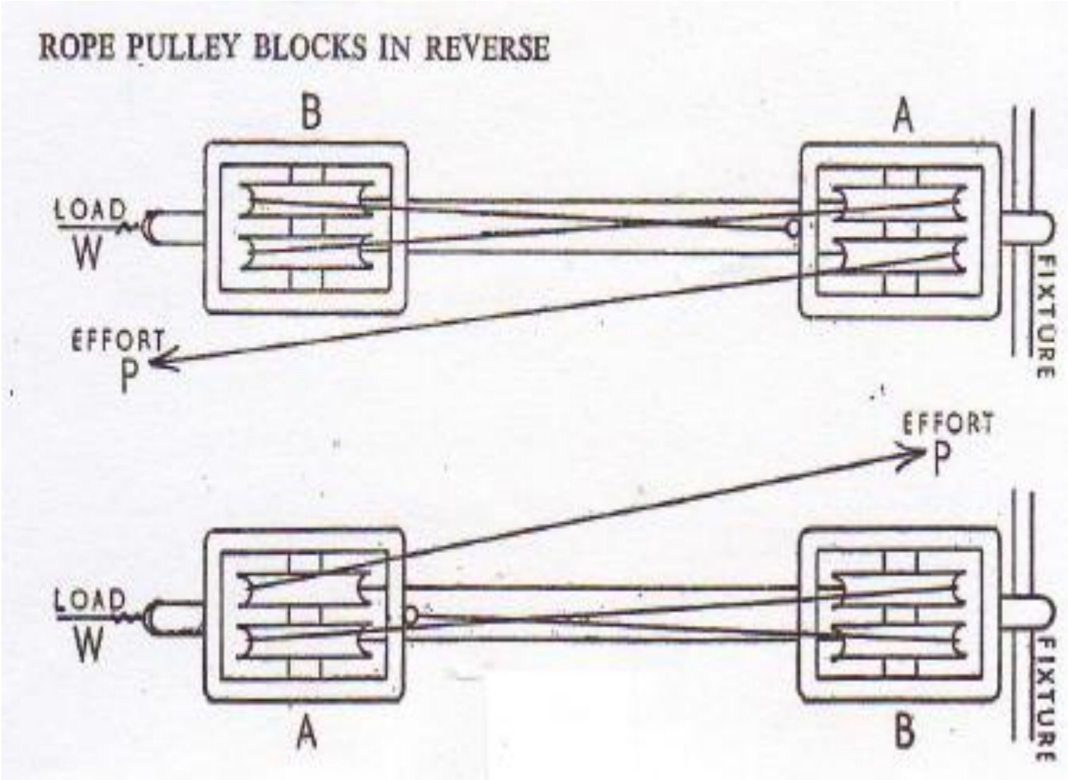
(c) Distance moved by effort = 2 x4 = 8m

Work done by effort against friction

= 82 x 8 = 656 Nm = **656 J**

8.1 VR s for different types of machines

8.1.1 Rope and Pulley System



The key to determining the VR of a pulley block system is to look at how it is rigged and count the number of ropes that support the load. The principle being that for every metre that the effort rope moves, each of the supporting ropes will also move one metre.

If the load moves in the opposite direction to which the effort is being applied (rigged to disadvantage) the VR is normally equal to the number of sheaves in the system but will depend on whether the rope is connected to the top or bottom sheave block.

If the load moves in the same direction as the effort is being applied the VR will still be equal to the number of ropes supporting the load and in the case below will equal the number of sheaves plus 1.

ie; for the system shown in the lower diagram; VR = 4 + 1 = 5

Efficiency of Each Pulley of Rope Blocks;

Assume all pulleys to have same efficiency, therefore Overall efficiency = product of efficiency of each block;

$$= eff_1 \text{ x } eff_2 \text{ x } eff_3 \text{ x etc = overall efficiency}$$

Example:

1). The set of rope pulley block which has 3 pulleys in the top block and 2 in the bottom, and effort of 300N is required to lift a load of 1.26 kn. Find the velocity ratio, mechanical advantage and the efficiency when lifting this load.

Solution:

V R. = number of ropes supporting load block.

= total number of pulleys

= 5 Ans (i).

M A. $= \frac{\text{Load}}{\text{Effort}} = \frac{1260}{300}$ **= 4.2 Ans (ii)**

Effic. $= \frac{\text{MA}}{\text{VR}} \times 100 \quad \frac{4.2}{5}$ **= 0.84 = 84 % Ans (ii)**

Example:

A set of rope pulley blocks has three pulleys in each blocks. Find the % efficiency when lifting a load of 448 N if the effort required is 90 N.

Total number of pulleys = 6

∴ **V R.** = 6

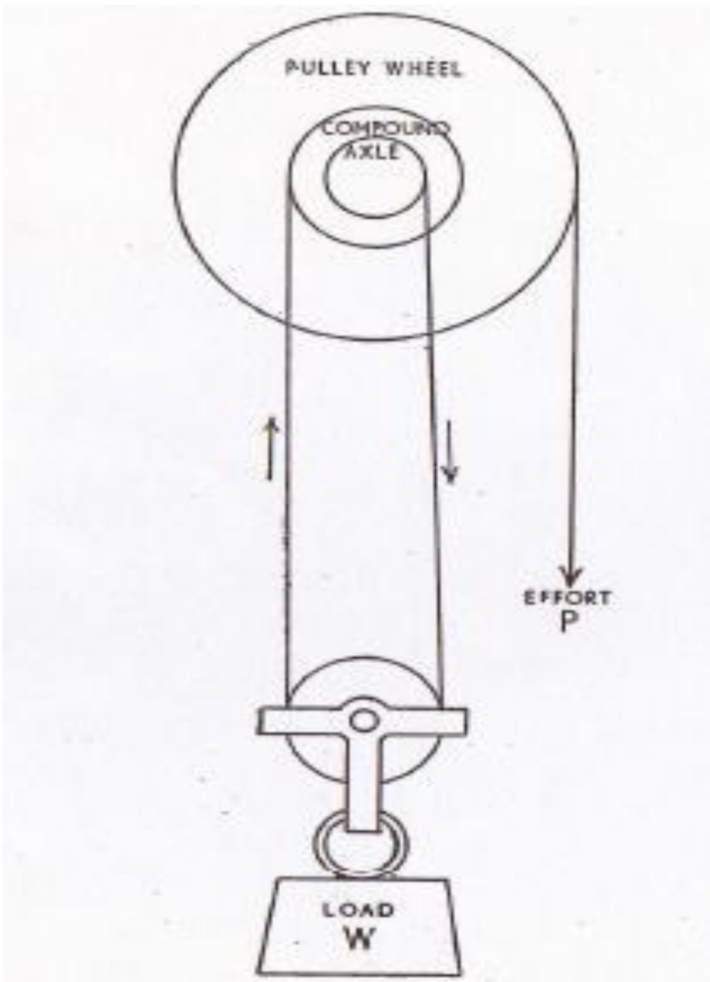
Mechanical advantage $= \frac{\text{Load}}{\text{Effort}}$

$= \frac{448}{90}$

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

$= \frac{448}{90 \times 6} \times 100$

8.2 Wheel and Differential Axle



Let D = diameter of pulley wheel

d_1 = diameter of large part of axle

d_2 = diameter of small part of axle.

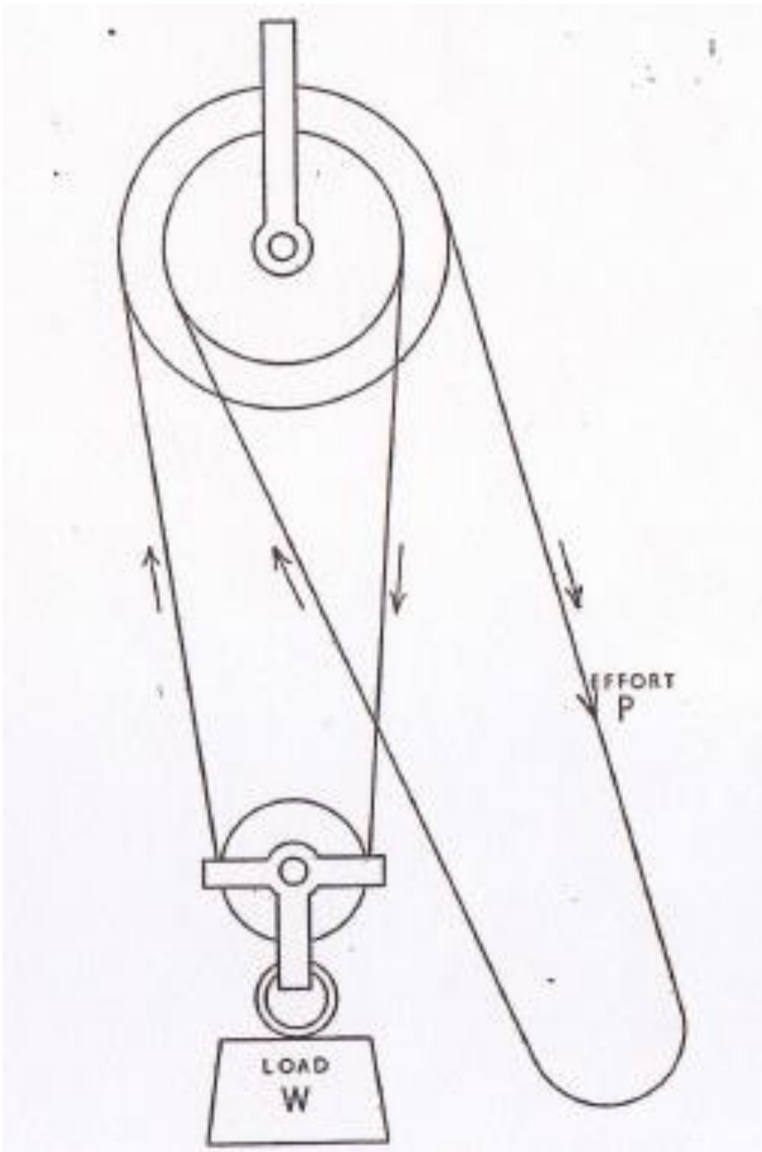
$$\text{V.R.} = \frac{\textit{Distance moved by effort}}{\textit{Distance moved by load}}$$

$$\text{V.R.} = \frac{\pi D}{0.5\,(\pi d1 - \pi d2)}$$

$$\text{V.R.} = \frac{2D}{d1 - d2}$$

Hence the effect of fitting a snatch block to a lifting machine is to halve the movement and therefore double the VR of the machine.

8.3 Weston Differential Pulley Blocks



Sometimes referred to as a "**Differential Pulley Block".**

Applying effort to compound sheave, one side of the load chain is pulled up onto the larger pulley, the other side is lowered off the smaller pulley, the movement of the load is half of this difference between the lifting and lowering effects due to the chain passing around the snatch block.

Let D = diameter of larger pulley in compound sheave

Let d = dia of smaller pulley in compound sheave

In one revolution;

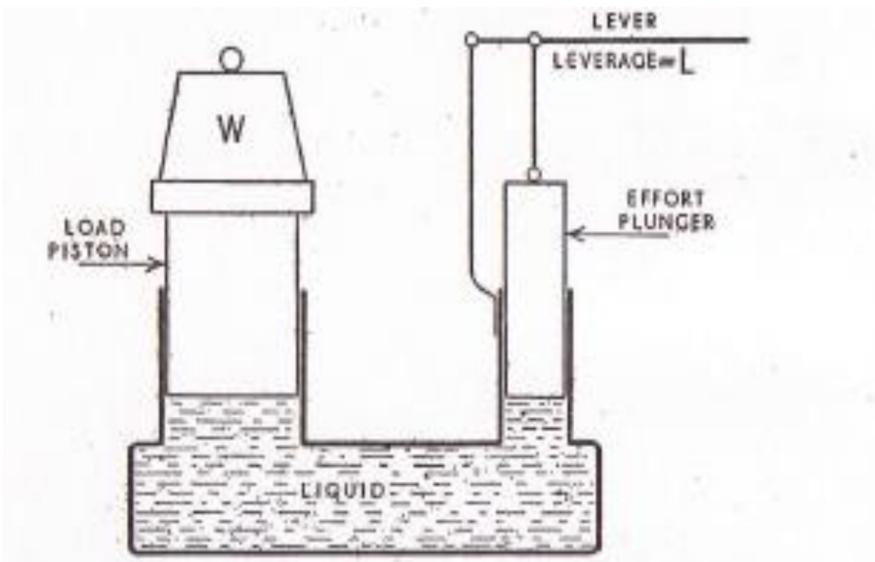
Distance moved by effort = πD

Distance moved by load $= \frac{1}{2}(\pi D - \pi d)$

Therefore VR = $\frac{2\pi D}{\pi D - \pi d}$ or **VR** = $\frac{\mathbf{2D}}{\mathbf{D-d}}$

8.5 Hydraulic Jack;

From the sketch below



Let A = area of load piston

Let a = area of effort piston

Since oil is usually used as the hydraulic medium and we consider a fluid as being not able to be compressed and we know that from work done by Pascal that the pressure must be equal on all surfaces within the hydraulic jack. Therefore moving the effort plunger down a distance of x the volume of liquid displaced is a xa and the load piston must move up an equal volume.

Therefore the distance the load piston moves = $\frac{\boldsymbol{a \times x}}{\boldsymbol{A}}$

And Velocity Ratio $= \frac{\textbf{Distance moved by effort}}{\textbf{Distance moved by load}}$

$$= \mathbf{x} \div \frac{a \times x}{A}$$

$$= \frac{x \times A}{a \times x}$$

$$= \frac{A}{a}$$

If a **lever arm** is fitted to the effort plunger, which is normal, then this leverage is represented by **L** and the VR then becomes;

$$\textbf{V.R.} = \frac{A}{a} \times \textbf{Lever arm ratio}$$

Example:

The diameter of the load ram of a hydraulic jack is 50mm and the diameter of the effort plunger is 20 mm. The plunger is operated by the handle whose effective leverage is 18 to 1. Assuming an efficiency of 80 %, find the load that can be lifted by an effort of 120 N applied. To the handle.

Solution:

$$\textbf{V R.} = \frac{\text{Area of load ram}}{\text{Area of effort Plunger}} \times \textbf{leverage}$$

$$= \frac{0.7854 \times 50^2}{0.7854 \times 20^2} \times 18$$

$$= 112.5$$

M.A. = V.R. $\times$ Efficiency

= 112.5 $\times$ 0.8 = 90

Load = Effort $\times$ M.A.

= 120 $\times$ 90

= 10,800 N = 10.8 kn Ans.

Example:

1) ***The third Engineer is required to use a Hydraulic Jack to remove the retaining nut of the piston from the cross head. Find the load, when an effort of 120 N is applied to lift it , the***

efficiency is 80% and the handle whose effective leverage ratio is 18 to 1.The Diameter of the effort plunger and load piston are 20 mm and 50mm

8.6 Experimental Results of a Machine

Choosing serious loads for a lifting machine and in each case measuring the effort required to just cause the machine to move and lift the load without acceleration, experimental values can be tabulated and drawn on a graph to show how the quantities are related. Let us now use the following demonstration.

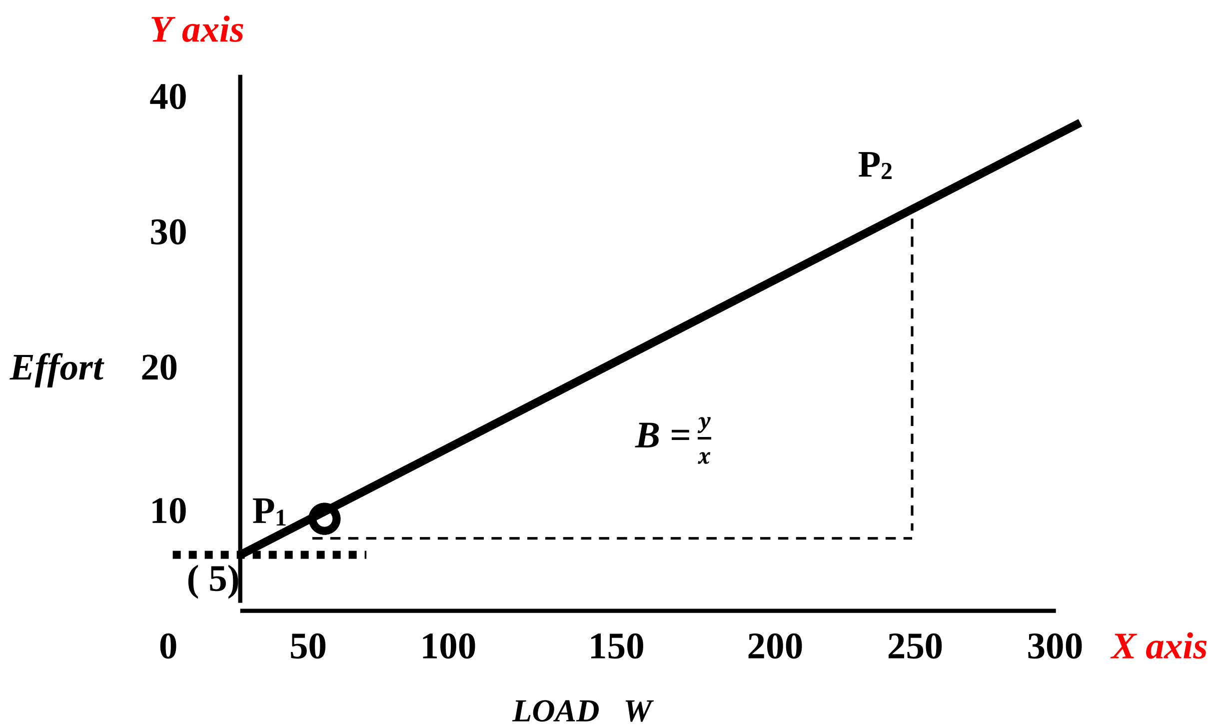
Example:

In an experiment on a lifting machine the following data were recorded:

Load [newton]	***50***	***100***	***150***	***200***	***250***	***300***
Effort [newton]	***9.8***	***15.0***	***20.3***	***25.0***	***30.4***	***34.7***

From the above values plot a graph and find the relationship between effort and load.

Solution:



The graph shows a straight line and also shows that when there is no load on the machine, a small effort is still required to lift the machine hook. This is the value **'*b*'** shown (i.e. the intercept of the y axis)

The slope of the graph, '***a***' is constant and is given by the change in effort divided by the corresponding change in load as shown.

The effort required to lift any load within the range of the machine is given

Effort, P = *a* + *bW* (Newton's)

Where

P is = the effort,

W is = the load or mass g,

a and ***b*** are constants (***b*** is y axis intercept and ***a*** is the gradient

Choosing any two points on the graph such as $\mathbf{P_1}$ and $\mathbf{P_2}$ slope of the line shows that the effort increases by shows **20 N** when the load is increased by **200 N.** Therefore for one newton increase of load the increase of effort must be

$$20 \div 200 = 0.1 \text{ N}$$

Note from the graph above here the value of *a* measures 5 N (this is to move the machine with no load),

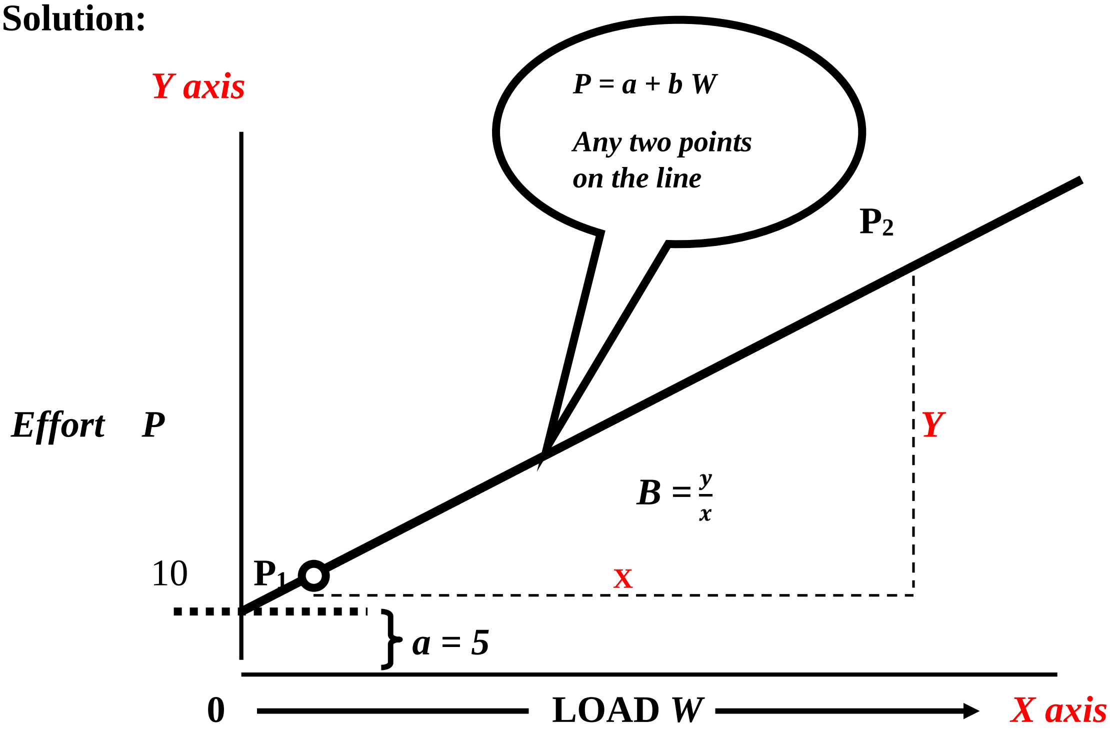
plus **0.1 N** for every newton of load above zero

$\therefore$ $P = 5 + 0.1\ W$

$P = a + b\ W$

This is the linear law of the machine.

Solution:



Y axis
P = a + b W
Any two points
on the line
P2
Effort P
Y
B = y/x
10
P1
X
a = 5
0
LOAD W
X axis