SIMPLE MACHINES

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 :

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

Relation between M.A., V.R. and η

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Load x Distance moved by the load}}{\text{Effort x Distance moved by the effort}}$$

$$= \frac{\text{Load}}{\text{Effort}} \times \frac{\text{Distance moved by the load}}{\text{Distance moved by the effort}}$$

$$= \text{Mechanical advantage} \times \frac{1}{\text{Velocity ratio}}$$

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

Ideal Machine

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

Examples

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

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

Fulcurm :
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 experssed in a number.

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

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
known as efficiency of machine. Efficiency is
generally expressed in percentage.

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

metre by a force of 60 kg. moving 15 m. Calculate, mechanical advantage, velocity ratio and efficiency.

Load (w) = 120 kg
Distance moved by load = (dw) = 5 m
Power (P) = 60 kg
Distance moved by power (dp) = 1.5 m

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

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

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

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

$$\mathbf{= 66.66\ \%}$$

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

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

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

$$= \frac{900}{300}$$

$$= 3$$

$$= 3$$

$$\text{Efficiency } (\eta) = \frac{M.A.}{V.R.} \times 100\%$$

$$= \frac{3}{4} \times 100\%$$

$$= 75\ \%$$

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

W	=	180 kg
P	=	15 kg
M.A.	=	?
Work done	=	?
HP	=	?
Height	=	6 m
t	=	27 second
M.A.	=	$M.A. = \frac{W}{P} = \frac{180\,kg}{15\,kg} = 12$
Work done	=	F x d (Force x Distance)
	=	15 kg x 6 m
	=	**90 m - kg**
Power	=	Workdone / time
	=	90 m - kg / 27 s
	=	90/27m-kg/s [75m-kg/sec=1HP]
	=	90/27 x 1/75 H.P.
	=	0.04444 H.P.

4. **A Load of 400 kg is lifted by a m/c having an h of 72%. If velocity ratio = 6, Calculate the applied force?**

W	=	400 kg
h	=	72 %
V.R.	=	6
η	=	$\frac{M.A.}{V.R.}$ x 100%
72	=	$\frac{M.A.}{6}$ x 100 %
M.A.	=	$\frac{72 \times 6}{100}$
$\frac{W}{P}$	=	4.32
$\frac{400\,kg}{P}$	=	4.32
Applied Force P	=	$\frac{400}{4.32}$ = 92.59 kg.

Lever

A lever is a rigid rod which rotates about a fixed point called the fulcrum.

E.g. : Cutting plier, A pair of scissors, Crow bar, Beam balance, Hand pump.

The distance of the load from the fulcrum is called the load arm. The distance of the effort from the fulcrum is called the effort arm.

Principle of Lever

Principle of Lever

- All levers are functioning in the following principle
  Load x Load arm = Effort x Effort arm

- Classification of lever

1. Straight lever
2. Curved lever

1. **Straight lever**

There are three types :

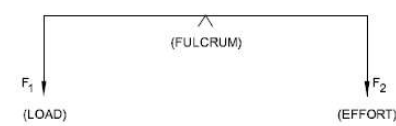
1. First order lever
2. Second order lever
3. Third order lever

First order lever

In this type the fulcrum lies between the load and the effort.

E.g : A pair of scissors, See-saw, Crow bar, Beam balance, Hand pump, etc.,

Fig 1



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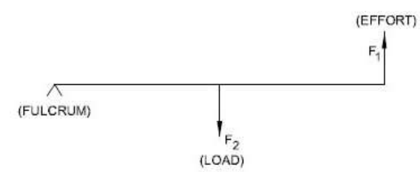
In this type of lever the mechanical advantage will be equal or less than or greater than 1 (M.A < = > 1)

Second order lever

In this type, the load lies between the fulcrum and the effort.

Fig 2



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E.g : Nut crakers, Wheel barrow, Paper sheet cutter, Bottle openers, Lime squeezer, etc.,

In this type of lever, the mechanical advantage will be greater than 1 (M.A. > 1). Less effort is used to lift more load.

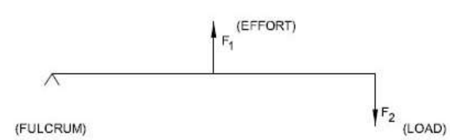
Third order lever

In this type, the effort lies between the fulcrum and the load.

E.g. The human force arm, forceps, broom, fire tongs, fishing rod.

In this type of lever, the mechanical advantage will be less than 1 (M.A < 1) more effort is used to lift less load.

Fig 3



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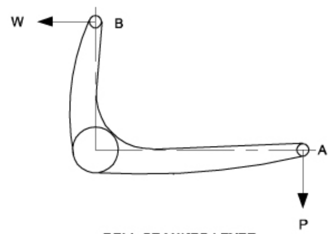
Bell cranked levers (Curved levers) (Figs. 5 & 6)

Fig 5



BELL CRANKED LEVER

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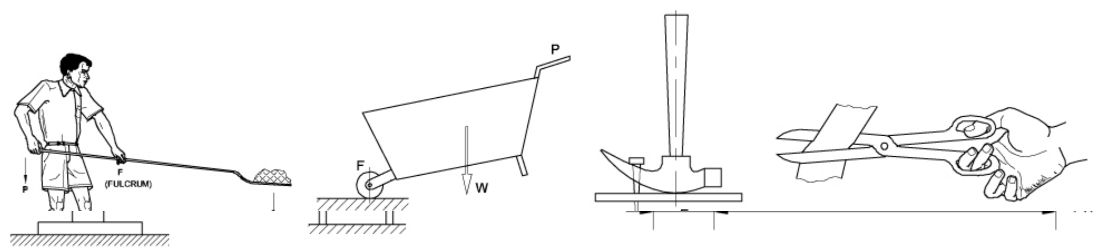
In addition to the above types of levers, two rods may be joined together at an angle to increase leverage without utilising much space. Such levers are cranked levers and the special form inwhich included angle is 90°, is called the bell cranked lever.

E.g : Motor cycle breaks system clutch pedal.

Fig 4



EXAMPLES IN SIMPLE LEVERS

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Examples

A rod AB is 8 metre long and has got a weight of 10 kg at A. The fulcrum is 3 metre from B. Calculate the load at B, if the load is in the balance condition.

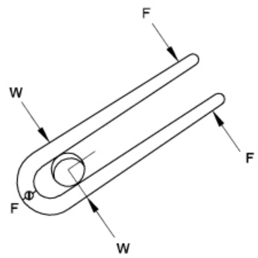
Load x Load arm = Effort x Effort arm

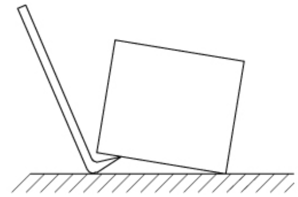
10 x 5 = P x 3

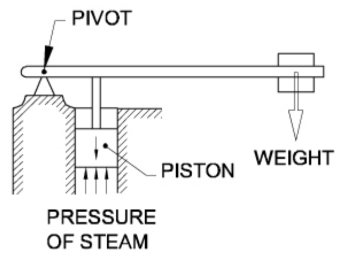
50 = 3 P

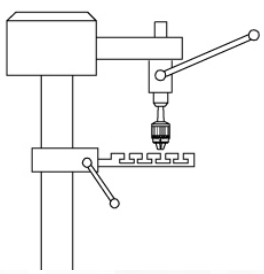
P = 50 / 3

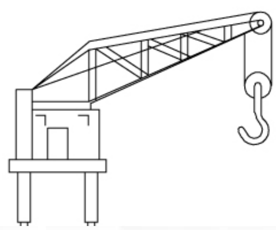
= 16.67 kg











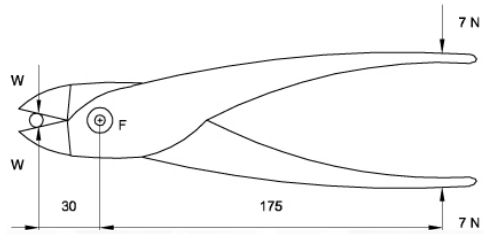
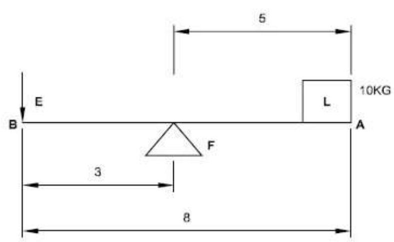


Fig 6



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When load and effort are not given separately in the sum consider which one having more weight is as a load.

2. **A weight of 3000 kg is to be lifted by a bar of length 3 metre. The load arm is 1 metre and the effort arm is 2 metre. Find the effort required and mechanical advantage of the system.**

As per lever principle

Load x Load arm = Effort x Effort arm

Fig 7

4. **An uniform bar of length 80 cm and weighing 2.1 kg is supported on a smooth peg at one end and by a vertical string at a distance of 15 cm from the other end. Find the tension of the string.**

W = 2.1 kg

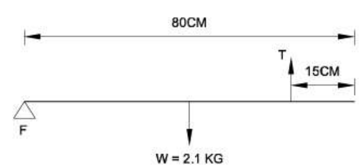
Tension = T kg

P x dp = 2 x dv

7 kg x (80 - 15) cm = 2.1 kg x (80/2)cm

T x 65 = 2.1 x 40

Fig 9



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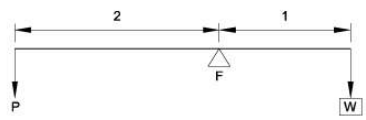
T = ((2.1 x 40) / 65) kg.

Tension = 1.292 kg

Fig 7



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3000 x 1 = P x 2

3000 = P x 2

P = 3000/2

= 1500 kg

Mechanical advantage = $\frac{\text{Load}}{\text{Effort}} = \frac{3000}{1500}$

= 2

3. **According to Fig. the lever has to support a 100 kg load with a 17 kg equivalent force supplied to it. Find the distance between the load and point of force. Solution.**

Load = 100 kg; Effort = 17 kg.

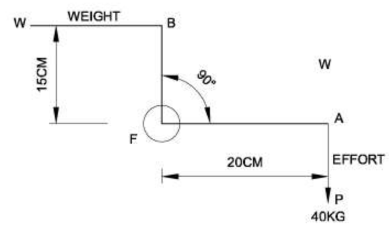
Load arm = 50 cm

Let effort arm = x cm

Tension = 1.292 kg

5. **In the figure given below in bell cranked lever AFB on perpendicular AF the force P is 40 kg. Weight W is on perpendicular FB. Find the measure of W.**

Fig 10



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Solution. By principle of momentum

P x AF = W x BF

40 x 20 = W x 15

W = (40 x 20) / 15 = 160 / 3 = 53.3 kg.

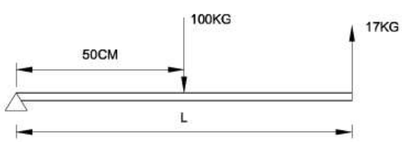
Simple Screw Jack

Working principle of simple screw jack is similar to that of an inclined plane. It

Load arm = 50 cm

Let effort arm = x cm

Fig 8



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As per principle of levers:

Effort x Effort arm = Load x Load arm

17x = 100 x 50

x = (100 x 50) / 17 = 294.1 cm

x = 294.1 cm

Distance between the load and point of force = 294.1 - 50

= 244.1 cm

= 2.4410 m

Simple Screw Jack

Working principle of simple screw jack is similar to that of an inclined plane. It consists of a screw fitted in a nut. Simple screw jack is shown in the figure. For lifting the load, an effort is applied at the end of the lever i.e effort arm.

Let l = Length of lever or effort arm (Tommy bar)

p = Pitch of screw

Velocity Ratio = $\frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$

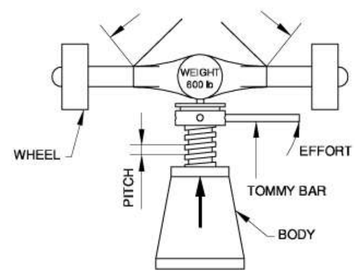
$= \frac{2\pi l}{p}$

Therefore Velocity Ratio of screw jack $= \frac{2\pi l}{p}$

Mechanical Advantage $= \frac{\text{Load}}{\text{Effort}} = \frac{W}{P}$

η Efficiency $= \frac{M.A.}{V.R.} \times 100\%$ %

Fig 11



SCREW JACK

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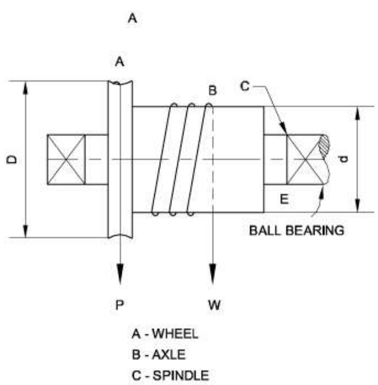
Simple wheel and axle (Fig 1)

Fig 12



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Wheel A and axle B are keyed to a common spindle C which is supported at the two ball bearings. Effort P is applied at the end of the rope wound round the wheel. Load W is attached to the free end of the rope wound round the axle. Both the ropes are wound in opposite directions as shown in the figure.

Let the dia. of wheel A = D

Dia. of axle B = d

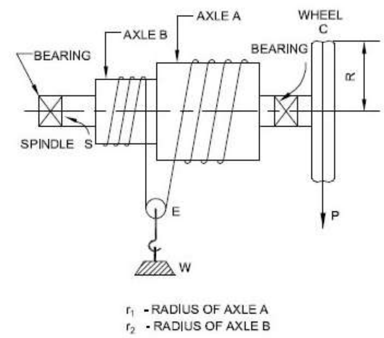
Distance moved by the effort in one revolution of wheel A = πD.

Distance through which the load is lifted = πd

Velocity ratio = πD = D

Differential wheel and axle (Fig 2)

Fig 13



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A rope is wound round A and then it passes round a pulley E carrying load W and then through the axle B. The winding of the rope through A and B is in opposite sense so that when the wheel revolves the rope is wound on one and unwound from the other. The effort P is applied by means of a rope on the wheel C of radius R.

Distance moved by C in its one revolution = $2\pi R$.

Length of rope wound on A = $2\pi r_1$ in one rotation .

Distance moved by C in its one revolution = $2\pi R$.

Length of rope wound on A = $2\pi r_1$ in one rotation .

Length of rope unwound from B in one rotation = $2\pi r_2$.

Net decrease in length= $2\pi r_1 - 2\pi r_2 = 2\pi(r_1 - r_2)$.

Distance through which load W is lifted

$$= \frac{2\pi(r_1 - r_2)}{2} = \pi(r_1 - r_2)$$

$$\text{Velocity ratio } = \frac{2\pi R}{\pi(r_1 - r_2)} = \frac{2R}{r_1 - r_2}$$

$$\text{M.A. } = \frac{W}{P}$$

$$\text{Therefore, efficiency } = \frac{M.A.}{V.R.} = \frac{\frac{W}{P}}{\frac{2R}{(r_1 - r_2)}}$$

$$= \frac{W(r_1 - r_2)}{P2R}$$

Examples

1. **A screw jack having 1.5 cm pitch and 30 cm long lever is used to lift up a load of 200 kg. If the effort applied to the lever is 20 kg then calculate the velocity ratio, the mechanical advantage and the efficiency of the screw jack.**

Solution . Given that :Load, W = 200 kg

Force, P = 20 kg

Screw pitch, h = 1.5 cm

Wheel A and axle B are keyed to a common spindle C which is supported at the two ball bearings. Effort P is applied at the end of the rope wound round the wheel. Load W is attached to the free end of the rope wound round the axle. Both the ropes are wound in opposite directions as shown in the figure.

Let the dia. of wheel A = D

Dia. of axle B = d

Distance moved by the effort in one revolution of wheel A = πD.

Distance through which the load is lifted = πd

$$\text{Velocity ratio} = \frac{\pi D}{\pi d} = \frac{D}{d}$$

$$\text{Mech. advantage} = \frac{W}{P}.$$

$$\text{Efficiency} = \frac{\text{Mechanical advantage}}{\text{Velocity ratio}}$$

$$= \frac{W}{P} \div \frac{D}{d}.$$

$$= \frac{W}{P} x \frac{d}{D}$$

$$= \frac{Wd}{PD}$$

$$= \frac{200}{20}$$

$$\text{And, Velocity ratio, V.R.} = \frac{2.\pi.l}{h}$$

$$= \frac{2 \times 3.14 \times 30}{1.5}$$

= **125.6**

$$\text{And, efficiency of teh screw jack} = \frac{M.A.}{V.R.} \times 100\%$$

$$= \frac{10}{125.6} \times 100$$

= **7.96 %**

2. **A simple screw jack having pitch = 1 cm and the effective length of the lever = 50 cm. What shall be the velocity ratio ? A force of 5 kg is applied on lever and lifts a load of 1100 kg. What is its efficiency?**

Length of lever l = 50 cm

Pitch of screw P = 1 cm

Load lifted = 1100 kg

Effort applied = 5 kg

$$\text{Velocity ratio of screw jack} = \frac{2\pi l}{P} = \frac{2\pi \times 50}{1}$$

Examples

1. **A screw jack having 1.5 cm pitch and 30 cm long lever is used to lift up a load of 200 kg. If the effort applied to the lever is 20 kg then calculate the velocity ratio, the mechanical advantage and the efficiency of the screw jack.**

Solution . Given that :Load, W = 200 kg

Force, P = 20 kg

Screw pitch, h = 1.5 cm

Length of the lever, l = 30 cm

Mechanical advantage, M.A. = W /P

3. **In a wheel and axle, the diameter of the wheel is 15 cm and that of the axle is 6 cm. If the efficiency of the machine is 75 %, what would be teh effort required to lift a load of 150 kg. ?**

Diameter of wheel D = 15 cm

Diameter of axle d = 6 cm

Load = 150 kg

Effort = say x kg = To Find

$$\text{Velocity ratio of wheel and axle} = \frac{D}{d} = \frac{15}{6} \text{..........(1)}$$

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}} = \frac{150}{x}$$

But, Mechanical Advantage= Efficiency x Velocity Ratio

$$= \frac{75}{100} \times \frac{15}{6} = \frac{15}{8}$$

$$\text{Mechanical Advantage} = \frac{15}{8} \text{..........................(2)}$$

By comparing Eq. (1) and Eq. (2), we can write

$$\frac{150}{x} = \frac{15}{8} \qquad \therefore x = \frac{150 \times 8}{15} = 80 \text{ kg}$$

Therefore x = 80 kg

Effort required = 80 kg

4. **In differential wheel and axle, the diameter of the wheel is 50 cm and diameters of the axles are 10 cm and 7.5 cm. If an effort of 70 kg can lift a load of 1,200 kg, find out the (i) velocity ratio, (ii) mechanical advantage and (iii) efficiency of machine.**

Velocity ratio of screw jack $= \dfrac{2\pi l}{P} = \dfrac{2\pi \times 50}{l}$

$= 2p \times 50 = 100p$

$= \dfrac{100 \times 22}{7} = \dfrac{2200}{7}$

$= 314\dfrac{2}{7}$

Velocity ratio of screw jack $= 314\dfrac{2}{7}$

Mechanical Advantage $= \dfrac{\text{Load}}{\text{Effort}} = \dfrac{1100}{5} = 220$

Mechanical Advantage $= 220$

Efficiency $= \dfrac{\text{Mechanical advantage}}{\text{Velocity ratio}}$

$= \dfrac{220}{2200/7}$

$= 220 \div \dfrac{2200}{7}$

$= 220 \times \dfrac{7}{2200}$

$= \dfrac{7}{10} = 0.7$

$=$ 70%

a load of 1,200 kg, find out the (i) velocity ratio, (ii) mechanical advantage and (iii) efficiency of machine.

Diameter of wheel D	=	50 cm
Diameter of larger load axle d_1	=	10 cm
Diameter of smaller load axle d_2	=	7.5 cm
Load	=	1200 kg
Effort	=	70 kg

(i) / Velocity Ratio of differential wheel and axle

$$= \frac{2D}{d_1 - d_2} = \frac{2 \times 50}{10 - 7.5} = \frac{100}{2.5} = 40$$

Velocity Ratio = 40

(ii) Mechanical Advantage $= \dfrac{\text{Load}}{\text{Effort}} = \dfrac{1200}{70} = 17\dfrac{1}{7}$

Mechanical Advantage $= 17\dfrac{1}{7}$

(iii) Efficiency of machine $= \dfrac{\text{Mechanical advantage}}{\text{Velocity ratio}}$

$$= \frac{1200/70}{40} = \frac{1200}{70} \div 40$$

$$= \frac{1200}{70 \times 40} = 0.42857$$

= 42.857 % = say 42.86 %

Velocity Ratio	=	40
Mechanical Advantage	=	17 (1/7)
Efficiency of Machine	=	42.86 %

5. **The two diameter of the top pulley block of a differential pulley block are 225 mm and 230 mm respectively. For raising a load of 200 N, a pull of 9.4 N has to be applied. Find out its mechanical advantage and velocity ratio.**

Solution

Larger diameter of wheel D	=	230 mm
Smaller diameter of wheel	=	225 mm
Load lifted	=	200 N
Effort applied	=	9.4 N
Mechanical Advantage	=	Load / Effort

$= \dfrac{200N}{9.4N}$

$= \dfrac{200}{9.4}$

$\log 200 = 2.3010$

$\log 9.4 = 0.9731$

Subtracting 1.3279

$\text{Antilog } 1.3279 = 21.27$

$=$ 21.27

Mechanical Advantage = 21.27

Velocity ratio of pulley block $= \dfrac{2D}{D - d}$

Fixed pulley

If the block of a pulley is fixed, then it is called fixed pulley. The load is attached to one end of the rope and effort is applied at the other end. The distance moved by the effort and load are equal.

$$\text{Load} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the load}\end{pmatrix} = \text{Effort} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the effort}\end{pmatrix}$$

Load x d $=$ Effort x d

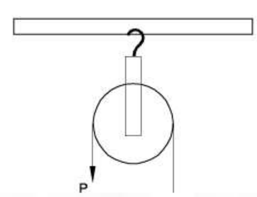
$= \dfrac{\text{Load}}{\text{Effort}} = \dfrac{d}{d} = 1$

Mechanical advantage $= \dfrac{\text{Load}}{\text{Effort}} = 1$

Velocity Ratio $= \dfrac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$

$= \dfrac{d}{d} = 1$

Fig 14



Velocity ratio of pulley block $= \frac{2D}{D-d}$

$= \frac{2 \times 230}{230-225}$

$= \frac{2 \times 230}{5}$

$= 92$

Velocity ratio of pulley block = **92**

Pulley

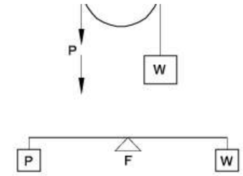
A pulley is simple machine used for lifting goods. It consists of small wheel made of metal or wood with a groove cut on its circumference. A light rope passes over the grooved rim. It can rotate about an axle passing through its centre. The axle of the pulley is supported on a frame known as the block. The load is attached to one end of the rope which passes over the pulley and the effort is applied at the other end. The effort applied is equal to the load to be lifted.

Types of pulley

1. Fixed pulley
2. Movable pulley

Types of pulley

1. Fixed pulley
2. Movable pulley



WS24T114

Movable pulley

If the block of a pulley is movable, then it is called movable pulley. In a movable pulley one end of the rope is attached to a fixed support and other end first passes through the movable pulley and then fixed pulley.

The effort is applied at free end of the rope. The load is attached to block of the movable pulley.

In this type of pulley, effort has to move twice the distance by which the load is moved.

$$\text{Load} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the load}\end{pmatrix} = \text{Effort} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the effort}\end{pmatrix}$$

$$\text{Load} \times d = \text{Effort} \times 2d$$

$$\text{Load} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the load}\end{pmatrix} = \text{Effort} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the effort}\end{pmatrix}$$

$$\text{Load} \times d = \text{Effort} \times 2d$$

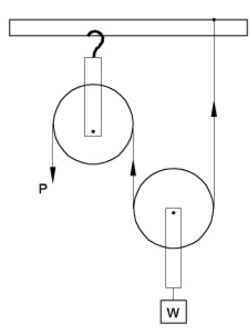
$$\frac{\text{Load}}{\text{Effort}} = \frac{2d}{d} = 2$$

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}} = 2$$

$$\text{Velocity Ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$= \frac{2d}{d} = 2$$

Fig 15



WS24T115

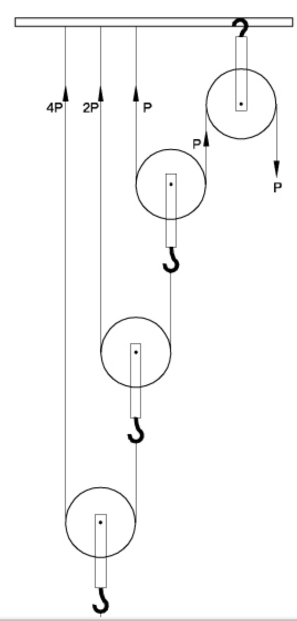
Weight of the pulley, rope and frictional resistance of pulley are not taken into consideration. In these

Types of multi movable pulley

A combination of fixed and movable pulleys is called a pulley block. They are

1. First system of pulley

Fig 16



2. Second system of pulley

3. Third system of pulley

1. **First system of pulley**

In this type, same size of one fixed pulley and more than one number of movable pulleys are there.

Each movable pulley is supported by an individual rope. One end of the rope is attached to a fixed support with the other end passing round a movable pulley, and then fixed to the fixed support through the next top movable pulley.

The rope passing round the last movable pulley then passes round a fixed pulley and effort is applied on free end. Load is attached to the last movable pulley.

For a single movable pulley mechanical advantage = 2

Mechanical advantages for 'n' number of moved pulley = 2^n

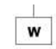
Mechanical advantage = $2^n = 2^3 = 2 \times 2 \times 2 = 8$

n = no. of movable pulley

Taking into consideration of pulley weight.

Mechanical advantage = $2^n - \frac{(2^n - 1)w}{P}$

(W = weight of single pulley)



P + P + 2P + 4P = 8P

WS24T116

Second system of pulley

In this particular system there are two pulley blocks, one of which is used as the fixed block while the other is used as a movable block. If the numbers of pulleys in the two blocks are equal then, one end of the rope is tied to the upper block and the effort is applied at the free end of the rope. If there are 'n' number of pulleys in both the blocks, then mechanical advantage = n.

Mechanical advantge $= \frac{W}{P} = n$

(n = total number of pulleys)

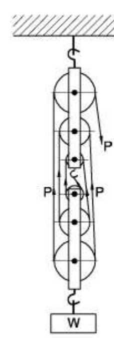
It 'w' is the weight of pulley connected with load then

Mechanical advantage $= \frac{W}{P} = n - \frac{W}{P}$

$= \frac{W}{P} + \frac{W}{P} = n$

$= \frac{W + w}{P} = n$

Fig 17



WS24T117

Third system of pulley

This is the reciprocal of first sysem of pulley.

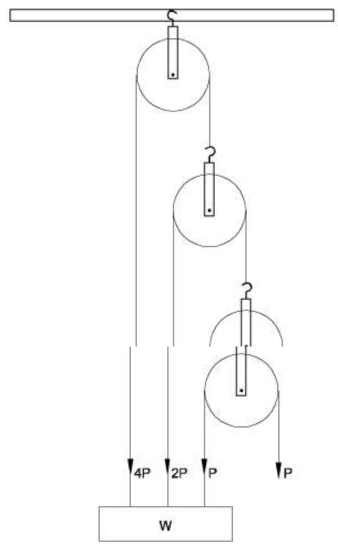
$$\text{Mechanical advantage} = \frac{W}{P} = 2^n - 1$$

(n = Total no. of pulley)

'w' is the weight of each pulley

$$\text{Mechanical advantage} = \frac{W}{P}$$
$$= 2^n - 1 + w\,(2^n - n - 1)$$

Fig 18



WS24T118

Pulley Block/Western Differential pulley block

It consists of larger wheel and smaller wheel attached with the same axis. Same rope is rounded through all wheels. In some cases, instead of rope, chain is used, when the wheels have teeth.

Let D = Larger diameter of wheel

d = Smaller diameter of wheel

Therefore Distance moved by effort = $\pi.D$

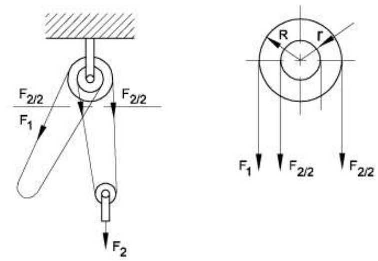
$$\text{Distance moved by load} = \pi\left(\frac{D-d}{2}\right)$$

Therefore Velocity ratio of pulley block

$$= \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$= \frac{(\pi.D)}{(D-d)} = \frac{D}{(D-d)}$$

Fig 19



WS24T119

Example

1. An arrangement of pulley block with six pulleys is used to lift a mass of 108 kg. If it has to be lifted through 2 metres find the effort needed and the distance through which it has to move mass = 108 kg.
   The load or weight force = 1080 N.

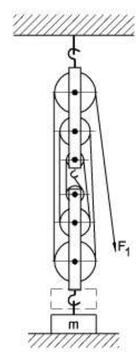
$$\text{Effort } F_1 = \frac{F_2}{n}$$

$$= \frac{1080\text{N}}{6} = 180\text{ N.}$$

The distance through which effort is to be moved = 2 metres x 6 = 12 metres.

The distance through which effort is to be moved = 2 metres x 6 = 12 metres.

Fig 20



WS24T120

2. A pulley block has 3 pulleys in the upper block and two pulleys in the lower block whose weight is 5 kgf. Determine the load that can be raised with an effort of 25 kgf. Determine the M.A., V.R. and efficiency.

Total number of pulleys in the system = 3 + 2 = 5

F_1 = 25 kgf.

Distance moved by the load

$$= \frac{(\pi . D)}{\pi . \left(\frac{D-d}{2}\right)} = \frac{D}{\frac{(D-d)}{2}}$$

$$= \frac{2D}{D - d}$$

If N_1 = No. of teeth of larger pulley

N_2 = No. of teeth of smaller pulley, then

$$\text{Velocity Ratio} = \frac{2N_1}{N_1 - N_2}$$

Total number of pulleys in the system = 3 + 2 = 5

F_1 = 25 kgf.

= n

Therefore $\frac{F_2}{25} = 5 \quad \therefore F_2 = 125$ kgf.

Weight of the lower pulley block is 5 kgf.

Therefore The load that can be lifted by this effort will be = 125 kgf – 5 kgf = 120 kgf.

Therefore Mechanical Advantage = $\frac{\text{load}}{\text{effort}} = \frac{120}{25} = 4.8$

The Velocity Ratio = 5

Therefore Efficiency = $\frac{M.A}{V.R} = \frac{4.8}{5} = \frac{48}{50} \times 100 = 96\%$

3. The two diameters of the top fixed pulley block of a differential pulley arrangement are 225 mm and 230 mm. If a load of 200 N is raised by applying an effort of 9.4 N, determine its M.A., V.R. and efficiency.

   Load raised = 200 N

   Effort applied = 9.4 N

4. The efficiency of a pulley block is 72% and the Velocity ratio is 28:1. What effort should be needed to raise a load of 1000 N.

   Efficiency =

   $\frac{72}{100} = \frac{M.A}{28} \qquad \therefore M.A = \frac{28 \times 72}{100}$

   $M.A = \frac{\text{load}}{\text{effort}} \text{ or } \frac{F_2}{F_1} = \frac{28 \times 72}{100}$

   Therefore Effort = $F_1 = \frac{1000 \text{ N} \times 100}{28 \times 72} = 49.6$ N.

Inclined Plane

A sloping surface is called an inclined plane, From the folloiwng figure

Principle of Inclined Plane (Fig 22)

- The inclined plane is a slope. It is a basic mechanical device to lift a body to a certain height with less effort.

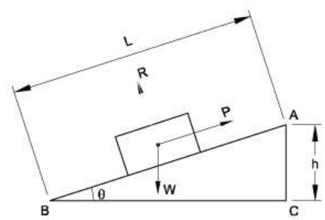
Fig 22

WS24T122

- To lift a body to a certain height, we have to apply a force on the body. Now in an inclined plane only pushing force parallel to the inclined plane is used.
- Study the figure and it may be seen that a force of F = 600N is applied as pushing force. Here friction is neglected.

i) Force parallel ot the inclined plane

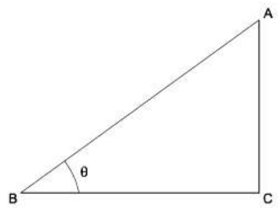
Fig 23



BC - Horizontal plane, BA - Inclined plane

The angle between the inclined and horizontal plane.

Fig 21



WS24T121

By applying a suitable effort, a load can be raised up the slope or lowered down the slope of the plane.

E.g. : Ladder, an escalator, a stair case

WS24T123

$$\text{Effort} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the effort}\end{pmatrix} = \text{Load} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the load}\end{pmatrix}$$

$$P \times L = W \times h$$

$$P = W \times \frac{h}{L}$$

$$= W \times \frac{\text{Opposite side}}{\text{Hypotenuse}}$$

$$P = W \sin\theta$$

$$= \frac{W}{P} = \frac{W}{W \sin\theta} = \frac{1}{\sin\theta}$$

$$= \frac{1}{\frac{\text{Opposite side}}{\text{Hypotenuse}}}$$

$$= 1 \times \frac{\text{Hypotenuse}}{\text{Opposite side}}$$

$$= \frac{L}{h} = \frac{\text{Length of the inclined plane}}{\text{height of the inclined plane}}$$

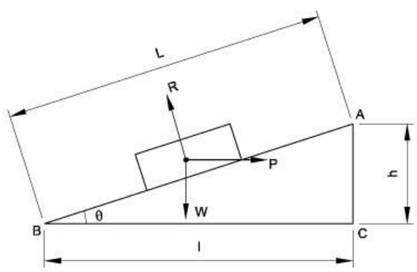
$$\text{Velocity Ratio (V.R)} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{L}{h}$$

Considering friction,

$$\text{Mechanical advantage (M.A)} = \frac{1}{\sin(\alpha+\theta)}$$

ii. **Force parallel to horizontal plane**

Fig 24



WS24T124

$$\text{Effort} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the effort}\end{pmatrix} = \text{Load} \times \begin{pmatrix}\text{Distance moved}\\ \text{by the load}\end{pmatrix}$$

$$P \times l = W \times h$$

$$P = W \times \frac{h}{l}$$

Force parallel to the incline

$= W \sin \alpha$

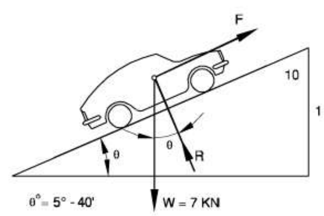
$= 7 \times 0.1$

$= 0.7$ KN

$= 700$ N

(sin 5°40' = 0.1 from tables)

Fig 25



VEHICLE ON AN INCLINED

WS24T125

Force perpendicular to the incline

$$P = W \times \frac{h}{l}$$

$$= W \times \frac{\text{Opposite side}}{\text{Adjacent side}}$$

$$P = W \tan\theta$$

$$\text{Mechanical advantage (M.A)} = \frac{W}{P} = \frac{W}{W\tan\theta} = \frac{1}{\tan\theta}$$

$$= \frac{\text{Adjacent side of the inclined plane}}{\text{Opposite side of the inclined plane}} = \frac{l}{h}$$

$$\text{Therefore MA} = \frac{l}{h}$$

$$\text{Velocity Ratio (V.R)} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{l}{h}$$

Considering friction,

$$\text{Mechanical advantage (M.A)} = \frac{1}{\tan(\alpha + \theta)}$$

Example(Fig 25)

A vehicle has a mass of 700 kg and stands at the top of a hill having a gradient of 1 in 10. Taking g = 10 N. Calculate the

- Force parallel to the incline

- Weight force perpendicular to the incline.

Sine value of 1 in 10

Sine value of 1 in 10

1 /10 = 0.1

For 0.1 sine of the angle = 5°-40'

Solution

Taking g = 10 N, we get

Weight of the vehicle = mg

= Mass of vehicle x g

= 700 x 10 N = 7000 N

W = 7 KN

Force perpendicular to the incline

= W cos α

= 7KN x Cos 5°40'

(Cos 5°40' = 0.996 from tables)

= 7 x 0.996

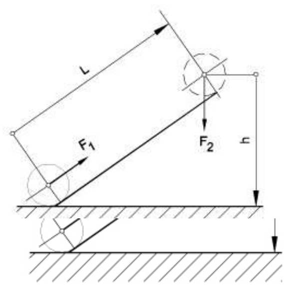
= 6.972 KN

= 6972 N

Example

- A mass of 300 kg is to be pulled up an inclined plane having 30° of angle of inclination. Calculate the pulling force. (Fig 26)

Fig 26



WS24T126

Mass to be pulled	=	300 kg
Weight force to be pulled	=	3000 N.
$(F_2 / F_1) = (1 / \sin)$ or F_1	=	F_2sina
Therefore F_1	=	3000 x sin 30°
	=	3000 x (1/2) = 1500N.
Therefore Pulling force	=	1500 N.

A. ASSIGNMENT

1. A force of 275 kg applied to lift a weight of 1100 kg with the help of simple machine. Calculate the efficiency of a machine having velociy ratio 5.

2. A load of 1000 kg is lifted by a simple machine having a velocity ratio of 5. Calculate the (i) Mechanical advantage (ii) Efficiency of machine if the effort applied is 250 kg.

3. If a lifting machine having a velocity ratio of 25, lifts a load of 40 Kg with an efficiency of 54.4%. What effort would be required and what would be the mechanical advantage?

4. The velocity ratio of a weight lifting machine is 20. If the efficiency of the machine is 40%. Find out the effort required.

5. By using a pulley block a load of 350 N is raised with a force of 25N. Find the mechanical advantage.

6. A load of 1000 kg is lifted by a simple machine having a velocity ratio 5. Calculate M.A. η of the machine, if the effort applied is 250 kg.

7. A load of 1200 kg is lifted using simple machine having a velocity ratio of 5. Find out the η of the machine of effort applied is 300 kg.

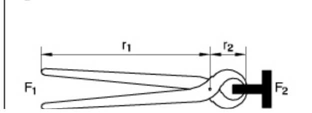
8. In a simple machine the velocity ratio is found to be 20. An effort of 20 kg is required to lift a load of 400 kg. Calculate M.A. and efficiency.

9. In a lifting machine an effort of 31 kg just raises a load of 1000 kg. What is the velocity ratio, if its efficiency is 0.75 ?

10. In a lifting machine having a V.R. of 25 lifts a load of 40 kg with an efficiency of 54.4%. What effort would be required and what would be the M.A.?

B. ASSIGNMENT

1. **Fig 1**

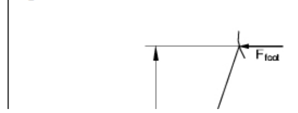


1st Order Lever (Pliers)

Data given

Effort at F_1 = 90 N

4. **Fig 4**

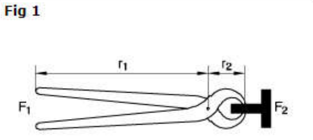


Brake Lever

Data given

Lever Arm Ratio = 250:50

1. **Fig 1**



WS24A101

1st Order Lever (Pliers)

Data given

Effort at F_1 = 90 N

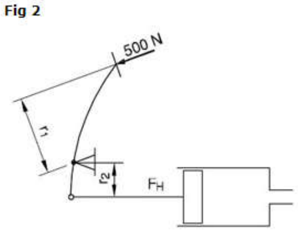
Arm r_1 = 380 mm

Arm r_2 = 36 mm

Find

Cutting Force F_2 = _______ N

2. **Fig 2**



WS24A102

Brake Lever

Foot force = 500 N

Arm r_1 = 210 mm

Arm r_2 = 70 mm

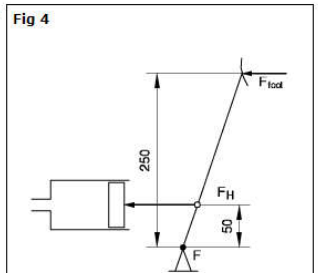
Find

Force on Master Cylinder = _______ N

3. **Fig 3**

2nd Order Lever (Brake lever)

4. **Fig 4**



WS24A104

Brake Lever

Data given

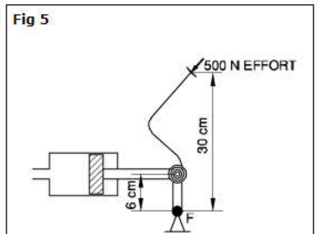
Lever Arm Ratio = 250:50

Force on MC Piston = 1800 N

Find

Foot force = _______N

5. **Fig 5**



WS24A105

Brake Lever

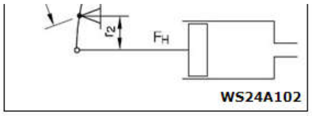
Data given

Effort Arm = 30 cm

Load Arm = 6 cm

Pedal force = 500 N

Dia of MC Piston = 3.2 cm

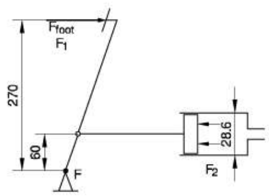


WS24A102

Find

Force on Master Cylinder = ______ N

3. Fig 3



WS24A103

2nd Order Lever (Brake lever)

Data given

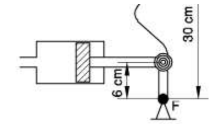
Load Arm = 60 mm

Effort Arm = 270 mm

Foot force F_1 = 600 N

Find

Force on MC Pist on F_2 = _______ N



WS24A105

Load Arm = 6 cm

Pedal force = 500 N

Dia of MC Piston = 3.2 cm

Find

a. Force on MC piston = _______ N

b. Pressure in the line = ______ N/cm^2

6. State True or False

a. In the first order Lever both arms are equal in length.

b. In the II order Lever Effort arm is longer.

c. In the III order Lever Effort arm is shorter than load arm.

d. The III order Lever is disadvantageous.

7. Fill up the blanks.

1. The forearm of a human body belongs to _______ order of lever.

2. A pair of sugar tongs belong to ________ order of lever.

3. Carburettor Throttle Valve belongs to ________ order of lever.

4. A common balance belongs to ________ order of lever.

5. A pair of scissors belongs to ________ order of lever.

6. A safety valve belongs to __________ order of lever.

7. A Crow bar (as shown) belongs to _________ order of lever.

8. A Brake lever (as shown) belongs to __________ order of lever.

8. Fill up the values against the question marks.

Types of lever	Load	Effort	Load arm	Effort arm	M.A.
Ist order	30 kg	20 kg	3 m	?	?
IInd order	25 kg	15 kg	?	2 m	?
Bell cranked lever	?	25 kg	1 m	2 m	?

9. **Fill up the blanks:**

a. The principle of levers is ____________.

b. Application of the Ist order of lever. Examples

i. __________

ii. __________

c. Application of the 2nd order of lever. Examples

a. __________

b. __________

d. Application of the 3rd order of lever. Example _________.

e. Application of bell cranked lever. Example __________.

f. Mechanical advantage __________.

g. Velocity ratio =

h. Efficiency =

10. A forceps of 8 cm length is used to apply a foce of 100 gm. Find out the force required if the forceps are held at 5 cm from the fulcurm.

C. ASSIGNMENT

1. Fig 1

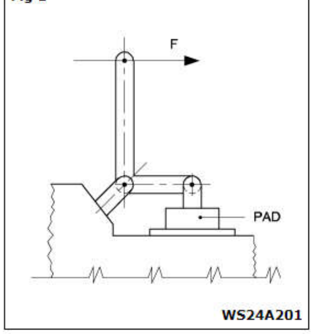
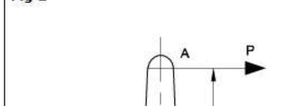


Figure 1 shows part of a small clamping device. The arms of the bell-cranked lever are at 90° and measure 160 mm and 75 mm respectively between centres, the longer arm being vertically upright. Find the force acting on the bottom of the pad of diameter 20 mm, when a force F of 240 N is exerted at right angles to the end of the longer arm.

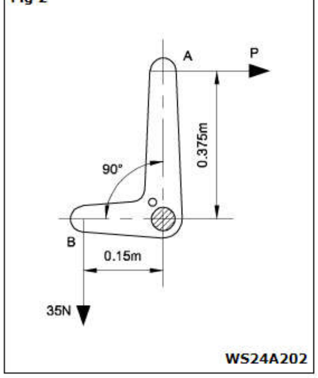
2. Fig 2



A bell cranked lever is shown in Fig 2, carrying a force of 35 N at B. (Fig 2)

Calculate ...... the

2. Fig 2

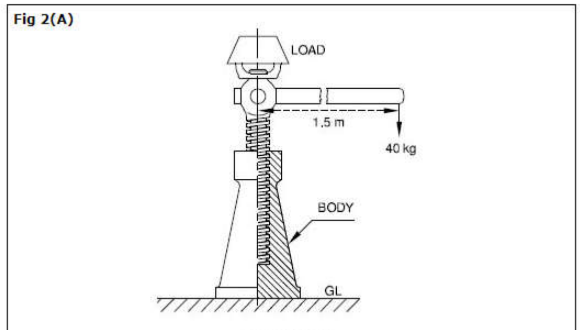


A bell cranked lever is shown in Fig 2, carrying a force of 35 N at B. (Fig 2)

Calculate the magnitude of a force which is required to be applied at A in order to balance the lever.

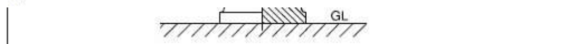
3. A screw jack has a screw with a pitch of 12 mm. A force of 40 kg is applied at the end of 1.5 m long lever to lift a specified load. Find the specified load if the efficiency is 12.7% (Fig 2A)

Fig 2(A)



SCREW JACK

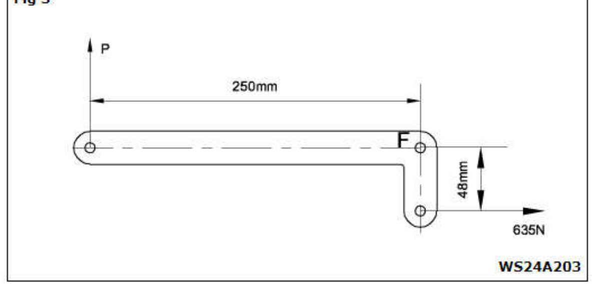
4. The crank lever shown in Fig 3 is pivoted at F. Calculate the value of force F to be applied.



SCREW JACK

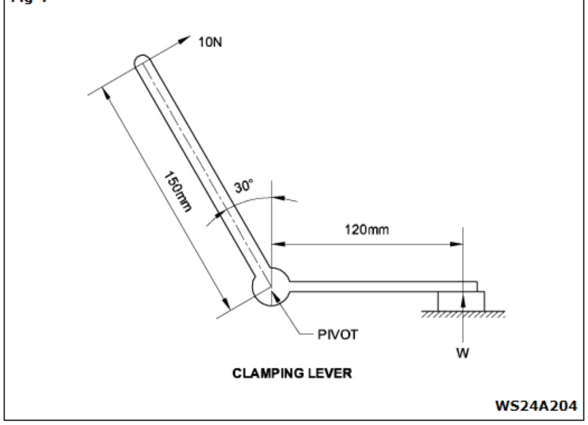
4. The crank lever shown in Fig 3 is pivoted at F. Calculate the value of force F to be applied.

Fig 3

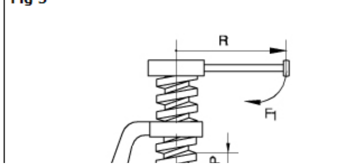


5. If the force applied by the operator on a clamping lever is 10 N, as shown in Fig 4, find the clamping force W.

Fig 4



6. Fig 5



m = 2500 kg

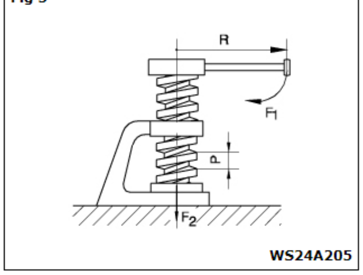
F_1 = 200 N

R = 400 mm

Efficiency (h)= 50%

Pitch (P) = ______ mm

6. Fig 5



m = 2500 kg

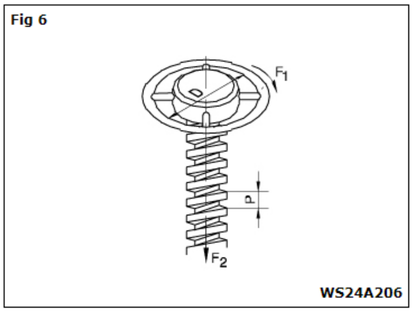
F_1 = 200 N

R = 400 mm

Efficiency (h)= 50%

Pitch (P) = ______ mm

7. Fig 6



D = 400 mm

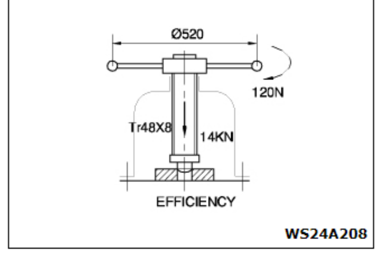
F_1 = 160 N

F_2 = 12 kN

P = 8 mm

h = ______ %

9. Fig 8



D = 520 mm

F_1 = 120 N

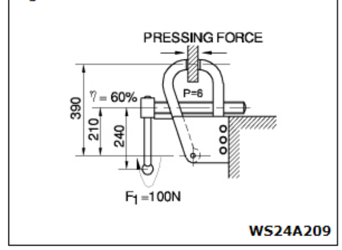
F_2 = 14 kN

P = 8 mm

thread OD = 48 mm

h = ______ %

10. Fig 9



P = 6 mm

F_1 = 100 N

h = 60%

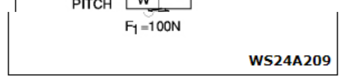
Pressing force = ______ N

11. Fig 10

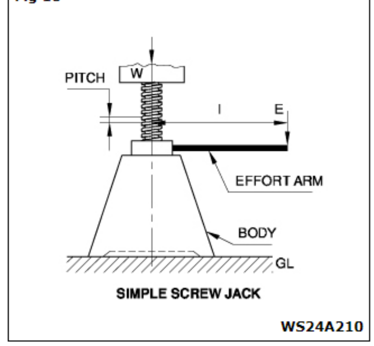
Screw Jack

VR = 60

Efficiency = 30%



11. Fig 10



Screw Jack

VR = 60

Efficiency = 30%

W = Load = 2200 N

Find
Effort = _______ N

12. Screw Jack

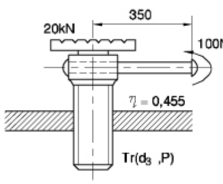
Thread lead = 6 mm

Distance effort applied = 420 mm

Find

VR = _________

8. **Fig 7**



WS24A207

F_2 = 20 kN

F_1 = 100 N

R = 350 mm

h = 0.455

Pitch `P' = ______ mm

13. Screw Jack

Pitch = 12.5 mm

Handle length = 500 mm

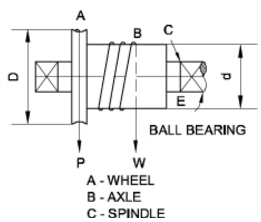
W = Load = 3 Tones

Efficiency = 60%

Find
Effort applied = ________ kg

D. ASSIGNMENT

1. **Fig 1**



Effort = 5 N

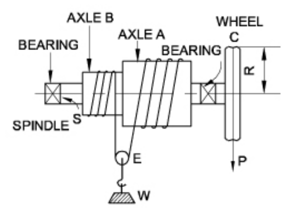
Load = 7.5 N

Radius of axle = 150 mm

Efficiency = 90%

Radius of wheel = ?

2. **Fig 2**



Load = 1220 N

Length of handle = 450 mm

Radius 1 = 88 mm

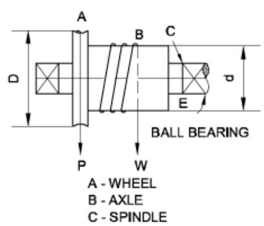
Radius 2 = 63 mm

Efficiency = 100%

Effort = ?

D. ASSIGNMENT

1. **Fig 1**



WS24A301

Effort = 5 N

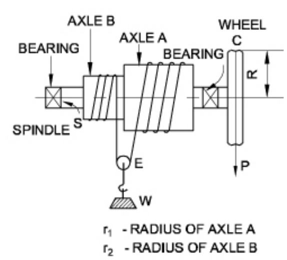
Load = 7.5 N

Radius of axle = 150 mm

Efficiency = 90%

Radius of wheel = ?

2. **Fig 2**



WS24A302

Load = 1220 N

Length of handle = 450 mm

Radius 1 = 88 mm

Radius 2 = 63 mm

Efficiency = 100%

Effort = ?

3. In a wheel and differential axle, the dia. of the wheel is 30 cm and the dia. of the axles are 9 cm and 8 cm. If an effort of 25 kg can lift a load of 1500 kg, find the efficiency of the machine.

4. The wheel and axle diameters of a simple machine are 300 mm and 62 mm respectively. Calculate M.A, V.R & η, if it needs an effort of 9 N to lift a load of 19 N.

E. ASSIGNMENT

a. A lineman has a pulley block with mechanical advantage of 30 : 1. How much force is applied by him to pull a load of 900 Kg?

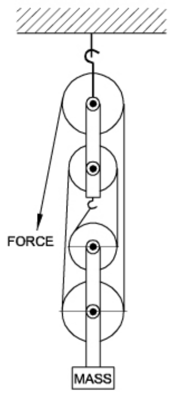
b. A lineman has a pulley block with mechanical advantage of 30 : 1. How much force is applied by him to pull a load of 900 Kg?

c. In a western pulley block the larger pulley has 15 teeth and the smaller 14 teeth. If the efficiency is 75%. What effort is required to lift a load 1250 Kg?

d. What is the force required to push a load of 2 tonne up a slope inclined at 20°. What will be the HP of the truck engine required to carry the load at a speed of 15 cm/sec on the inclination?

F. ASSIGNMENT

1. **Fig 1**

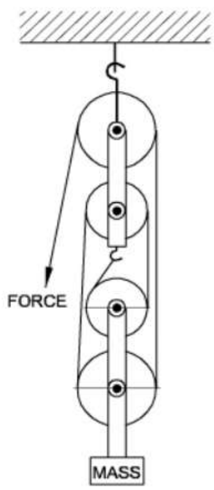


WS24A401

m = 172 kg

F_1 = ______ N.

2. **Fig 2**



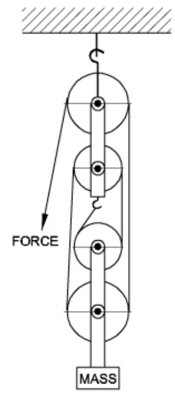
WS24A402

s_2 = 1.2 metres

n = 4

s_1 = ______

3. **Fig 3**



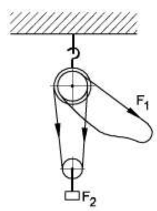
WS24A403

m = 72 kg

F_1 = 180 N

n = ______

4. **Fig 4**



WS24A404

m = 600 kg

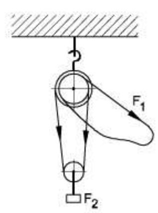
D = 180 mm

d = 170 mm

F_1 = ______ N

h = ______ %

5. **Fig 5**



WS24A405

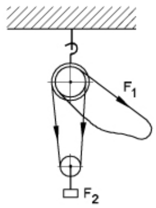
F_1 = 150 N

m = 960 kg

D = 160 mm

d = ______ mm

6 **Fig 6**



WS24A406

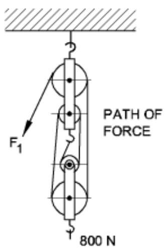
$F_1 + F_2$ = 8125 N

$D : d$ = 64:62

F_1 = ______ N

F_2 = ______ N

7 **Fig 7**



WS24A407

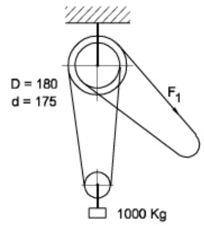
F_2 = 800 N

Weight of loose pulley block = 20 N

s_2 = 1.5 metres

F_1 = ______ N

8 **Fig 8**



WS24A408

D = 180 mm

d = 175 mm

m = 1000 kg

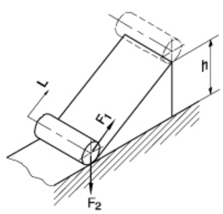
F_1 = ______ N

V.R. = ______

M.A. = ______

n = ______ %

1. **Fig 1**



WS24A501

m = 212 kg

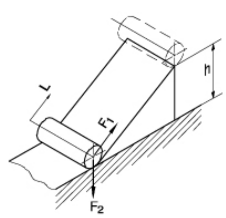
h = 0.8 metres

L = 1.4 metre

F_1 = _______ N

---

2. **Fig 2**



WS24A502

h = 1.2 metres

F_1 = 140 N

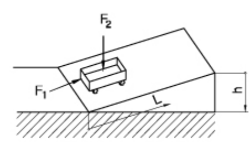
L = 3.4 metres

F_2 = ______ N

m = ______ kg

---

4. **Fig 4**



WS24A504

m = 350 kg

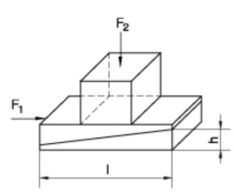
F_1 = 250 N

= 0.8

M.A . = ______

---

5. **Fig 5**



WS24A505

m = 4200 kg

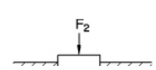
l = 120 mm

h = 12 mm

F_1 = ______ N

---

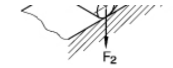
6. **Fig 6**



F_1 = 530 N

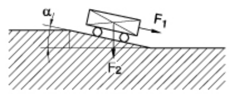
(h / l) = (1 / 20)

m = ______ kg



WS24A502

3. **Fig 3**



WS24A503

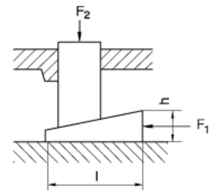
a = 12°

m = 950 kg

F_2 = ______ N

F_1 = ______ N

6. **Fig 6**



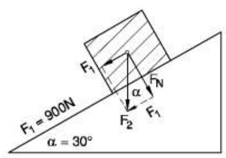
WS24A506

F_1 = 530 N

(h / l) = (1 / 20)

m = ______ kg

7. **Fig 7**



WS24A507

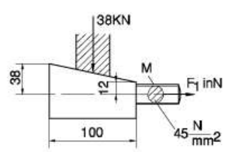
a = 30°

F_1 = 900 N

F_2 = ______ N

F_N = ______ N

8. **Fig 8**



WS24A508

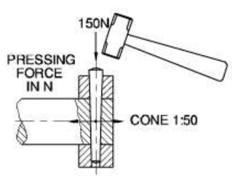
Applied Pressure = 45 N/mm²

F_2 = 38 kN

F_1 = ______ N

M (Dia of the thread) = ______ mm

9. **Fig 9**



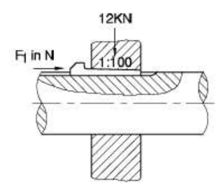
WS24A509

Tapor pin taper = 1:50

F_1 = 150 N

Pressing force F_2 = ______ N

10. **Fig 10**



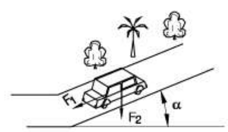
WS24A510

Taper ratio of key = 1:100

F_2 = 12 kN

F_1 = ______ N

11. **Fig 11**



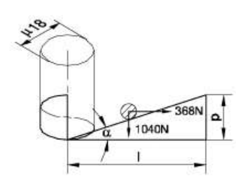
WS24A511

m = 1800 kg

F_1 = 3 kN

a = ______ °

Fig 12



WS24A512

F_1 = [illegible] N

F_2 = 1040 N

Pitch 'p' = ______ mm

a = ______ °