MACHINES.

A machine is a device which allows the supply of energy at one point to do work at another point.
A force called effort is applied on a machine to overcome a resisting force called load.
A machine is used to

- Convert energy from one form to another.
- It amplifies a force.
- Magnifies movements.

Terms used

Work in put

This is the work done by the effort and is equal to the product of effort and distance moved by the effort.

Work in put $=$ effort x distance moved by effort.

Work out put

This is the work done by the machine to overcome the load.

Work output $=$ load x distance moved by load.

Example.

A lady pulls a load that weighs 450N along an inclined plane through a distance of 30m which is 10m high. If she applies an effort of 200N. Find:

(i) The work input.
(ii) The work output.

Mechanical advantage (M.A)

Is the ratio of load to effort.

i.e.

$$\text{M.A.} = \frac{Load}{effort}.$$

It has no unit because it is a ratio of forces (quantity with the same units)

Example.

An effort of 50N is applied to a machine which overcomes a load of 800N. What is the mechanical advantage of this machine?

$\text{M.A.} = \frac{LOAD}{EFFORT.}$

=

Velocity ratio.

This is the ratio of the distance moved by the effort to the distance moved by the load in the same time interval.

It has no unit.

VR = $\frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load}$

Example.

A box was pushed up an inclined plane through a distance of 250 m which is 25 m high. What is the velocity ratio of the machine?

Efficiency.

This is the ratio of the work output to the work in put expressed as a percentage.

$$\tau = \frac{work\ output}{work\ in\ put} x100\%.$$

From $\tau = \frac{work\ output}{work\ in\ put}$ x 100%

$$\tau = \frac{L\ X\ dL}{E\ X\ dE}\ X100\%$$

$$\tau = \text{M.A X } \frac{1}{VR}\ X100\%$$

$$\tau = \frac{M.A}{V.R} \text{X100\%.}$$

The ratio of mechanical advantage to velocity ratio also gives efficiency.

(This one should not be used as a definition of efficiency.)

$$\tau = \frac{M.A}{VR} \text{X100\%}$$

Proof for $\tau = \frac{M.A}{VR}$ X100%.

PERFECT MACHINE.

This is a machine in which its mechanical advantage is equal to its velocity ratio.

OR

A machine in which the work output is equal to the work input.

Therefore in perfect machine, M.A = V.R.

A perfect machine is sometimes known as an ideal machine.

Therefore the efficiency of a perfect machine is 1 and its percentage efficiency is 100%.

AN IMPERFECT MACHINE.

This is a machine in which its mechanical advantage is not equal to its velocity ratio.

OR

A machine in which the work output is not equal to work input.

Therefore, all imperfect machines have efficiency less than 1 and its percentage efficiency is less than 100%.

Types of simple machines

These include levers, pulleys, inclined planes, wages, screws, wheel and axle, gears.

LEVERS.

This is a rigid rod free to turn about a fixed turning point (the pivot or fulcrum).

There are 3 classes of levers.

1st class levers.

These are levers that have pivot between load and effort.

E.g. pair of scissors, sea saws, pair of pliers, bottle opener etc.

2nd class lever.

This is the lever that has a load between the pivot and the effort.

E.g. wheelbarrow, Nut cracker, axe etc.

3rd class lever.

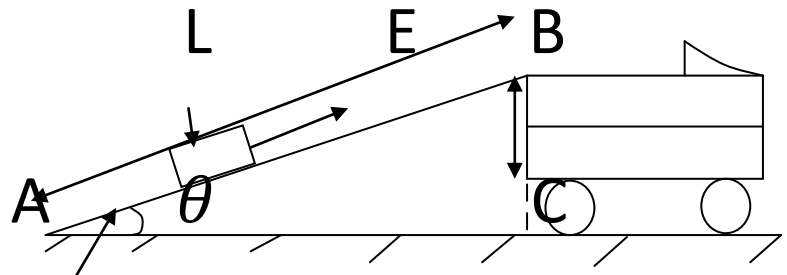
This is when the effort is between the pivot and load.

E.g. Fore arm, spade, pair of tongs, forceps, table knife, claw hammer, shovel.

A.F.ABBOTT Page 87 for the diagrams of each class of levers.

INCLINED PLANE.

It is a wooden plunk which is inclined to the ground at a certain angle, θ.



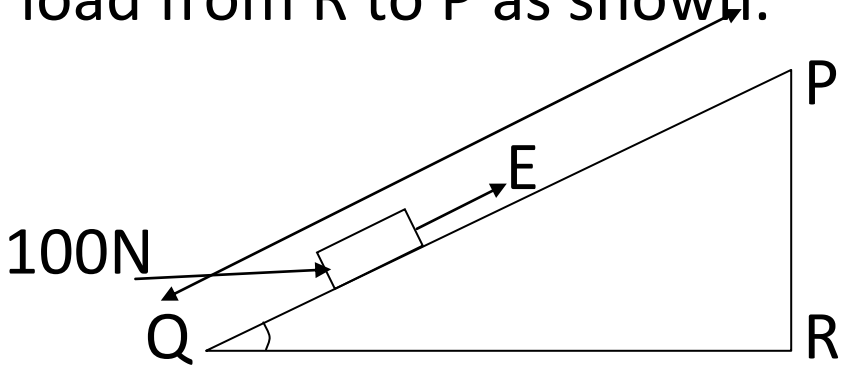
The effort (E) raises the load,L (box) through a vertical height BC by pulling it along the inclined plane from point A at the ground to point B at the required height.

AB – length of inclined plane.
L – Load / weight.
E – Effort (pull/push).
θ - Angle of inclination to the ground.
BC –vertical height.

$$V.R = \frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load} = \frac{l}{h}$$

Questions.

1. Below is an inclined plane used to lift a load from R to P as shown.



Given that E =90N, PR =5 m, and QP = 10m
Determine

i) Mechanical advantage.
ii) Velocity ratio.
iii) Efficiency of the machine.

2. i) What is meant by first class lever?

ii) By means of a lever, an effort of 50N moves a load of 200N through a distance of 3m. If the effort moves a distance of 16m; calculate

(i) The mechanical advantage
(ii) The efficiency.

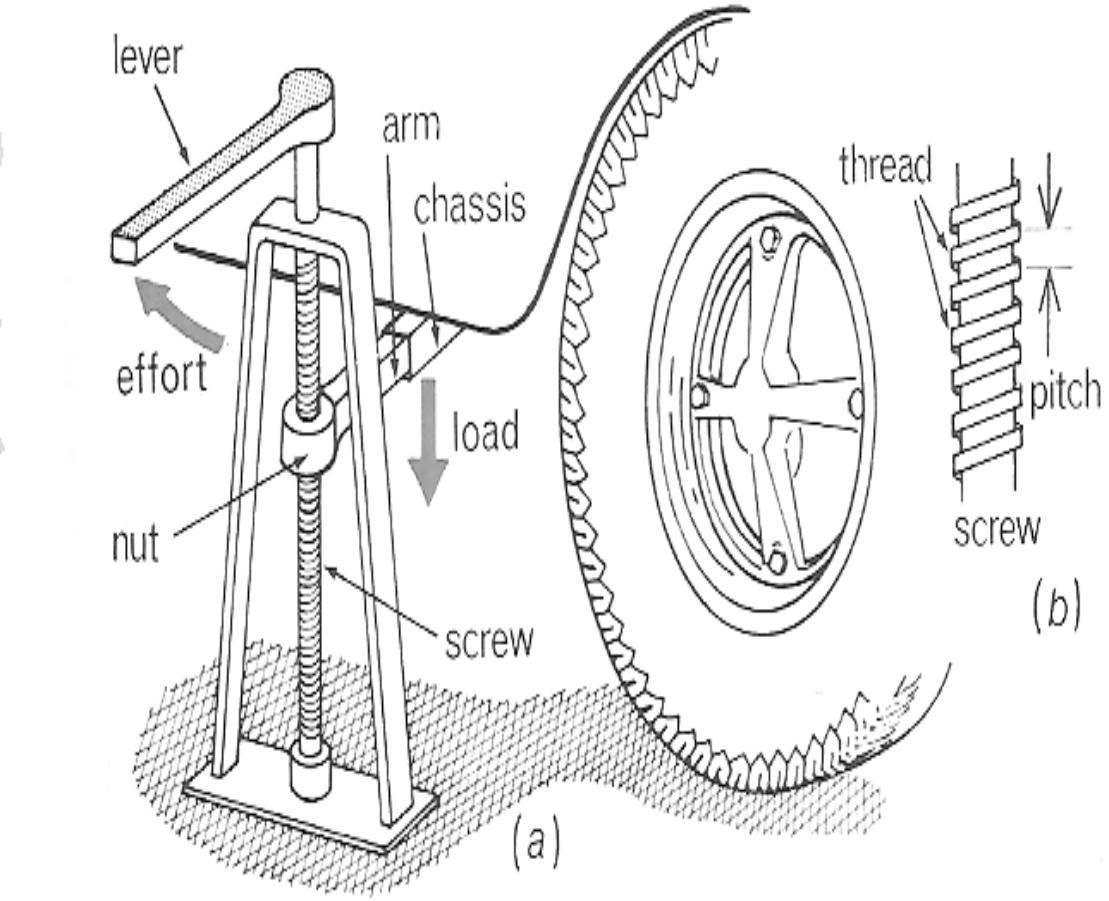
SOLUTION.

SCREW.

Pitch is the distance between one thread and the next measured along the axis of the screw.

It is equal to the distance moved by the load when the screw is rotated through one complete turn.

Examples of a screw jack.



P – Pitch.

a –radius of rotation (effort distance).

V.R of the screw = $\frac{dE\ in\ one\ rotation}{dL\ in\ one\ rotation.}$

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

Example

Given that the pitch of a screw is 5mm when an effort of 30N is rotated to lift a load of 750N in one turn and the length of the handle of the screw is 50cm. Calculate

i) M.A
ii) V.R
iii) Efficiency.

Solution:

(i) M.A = $\frac{Load}{Effort} = \frac{750}{30} = 25$

(ii)V.R = $\frac{2\pi a}{p}$

$= \frac{2\ x3.14\ x\ 50}{0.5}$

= 628

iii) $\tau = \frac{M.A}{V.R}$ X100% = 3.98%

Questions

1) A machine of velocity ratio 5 is used to raise a load whose weight is 2000N. The effort required is 500N. Calculate its:

(i) M.A (ii) Efficiency.

2) A trolley of weight 10N is pulled from the bottom to the top of the inclined plane by a steady force of 2N.If the height and distance moved by the force are2m and 20m respectively. Calculate

i) M.A
ii) V.R
iii) Efficiency.

PULLEYS.

A pulley is a grooved wheel mounted on a block. A string or rope passes around the pulley and it is held in place by the groove.

An effort E is applied on the rope to produce tension T in the rope such that effort = tension.

The tension in the rope is constant or uniform and acts in both directions along the rope. The load L is supported by the total tension in the sections of the rope attached to the pulley on which the load is fixed.

The tension in the section of the rope attached to the load directly is equal to the

number of sections of the rope attached to the load by tension.

Load L = n T where n is number of sections of the rope attached to the load.

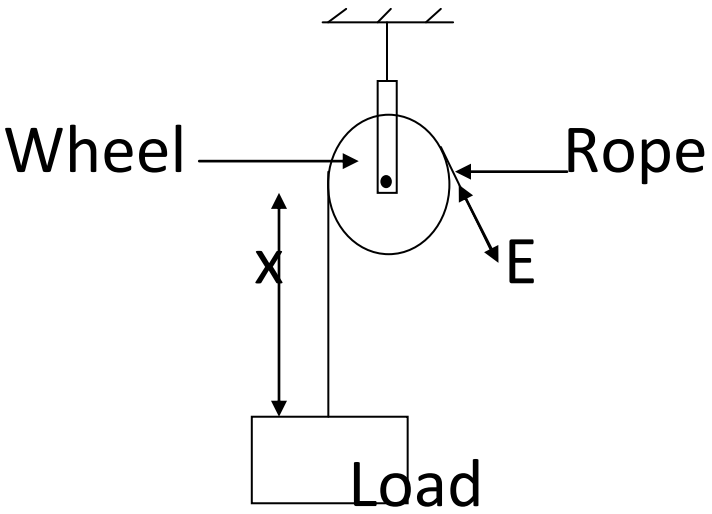
L can be less than n T (L < n T) due to the weight of the pulleys.

L + W = n T where W is weight of the pulleys.

Types of pulley systems.

Single fixed pulley.

It consists of only one pulley which is fixed.



Tension T = E

At equilibrium L =T

M.A = $\frac{Load}{effort}$ =$\frac{L}{E}$ but L=E

= $\frac{E}{E}$

= 1

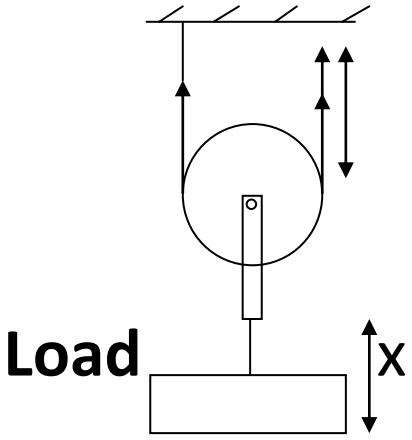
V.R = $\frac{Distance\ moved\ by\ effort}{Distance\ moved\ by\ load}$

= $\frac{x}{x}$

= 1

Single movable pulley

Consists of one moving pulley.



At equilibrium

Load L = 2 T

M.A = $\frac{L}{E} = \frac{2T}{T} = 2$

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

$= \frac{2x}{x} = 2$

Block and tackle single pulley system

It consists of one or more pulleys in two blocks mounted independently on the

same axle. One block is fixed and the other is moving. The load is fixed on the lower moving block, the upper fixed block has a number of pulleys as stated below in comparison with the lower block.

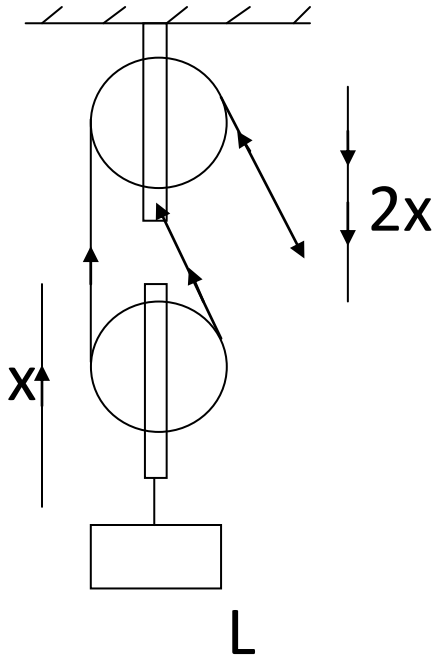
1. For total even number of pulleys -:

   Number of pulleys in the upper block = number of pulleys in the lower block.

2. For total odd number of pulleys.

Number of pulleys in the upper block exceeds number of pulleys in the lower block by 1.

System of 2 pulleys

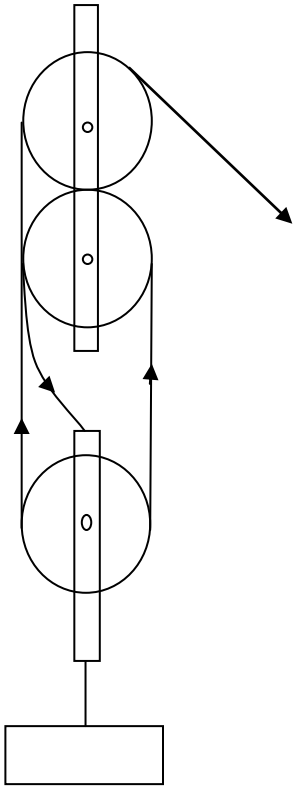


At Equilibrium , L = 2T, E = T

M.A $= \frac{L}{E} = \frac{2T}{T} = 2$

V.R $= \frac{dE}{dL} = \frac{2X}{X} = 2$

System of 3 pulleys



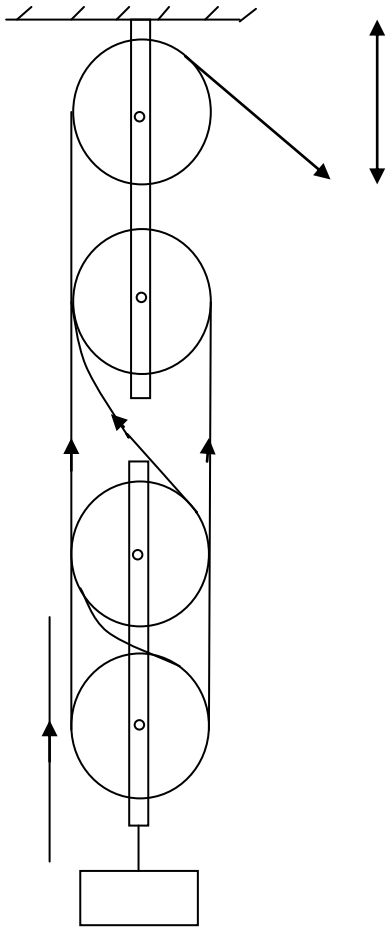
E

Load

At equilibrium L = 3T, E = T

M.A = $\frac{L}{E} = \frac{3T}{T} = \frac{3X}{X} = 3$

System of 4 pulleys



T

T

T

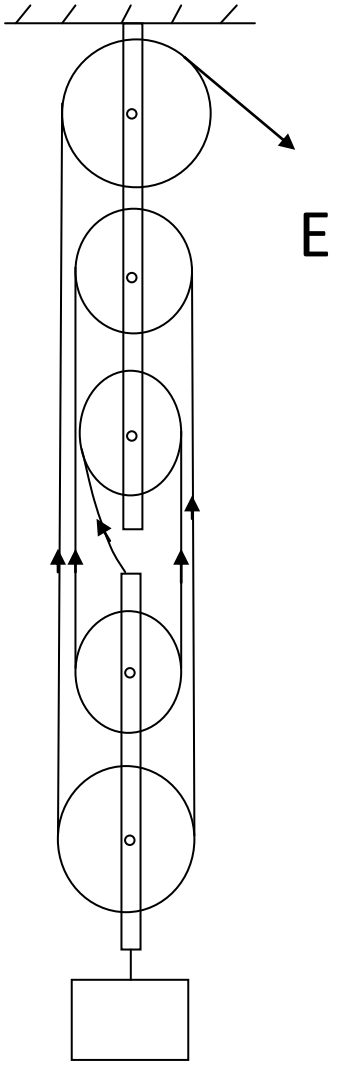
4x

At equilibrium ≡m

Load L = 4T and E = T

M.A $= \frac{L}{E} = \frac{4T}{T} = 4$

System of 5 pulleys



Load

equilibrium ≡ m, L = 5T and E = T

M.A = $\frac{L}{E} = \frac{5T}{T}$ = 5

V.R = $\frac{dE}{dL} = \frac{5X}{X}$

Example.

1. Example

A pulley system of V.R = 3 Supports a load of 20N, given that the tension in each section of the string is 8N. Calculate;

i) The effort required to raise a load.
ii) The mechanical advantage.
iii) The distance moved by the effort if the load moves through a distance of 2m.
iv) The weight of a pulley.

SOLUTION

i) $E = T = 8N$

$3E = L + W$

3 x 8 = 20 +W

Therefore weight of the pulley

W= 24-20 = 4

Weight of each pulley = 2N

ii) M.A = $\frac{L}{E} = \frac{20}{8}$ = 2.5

iii) V.R = $\frac{dE}{dL}$

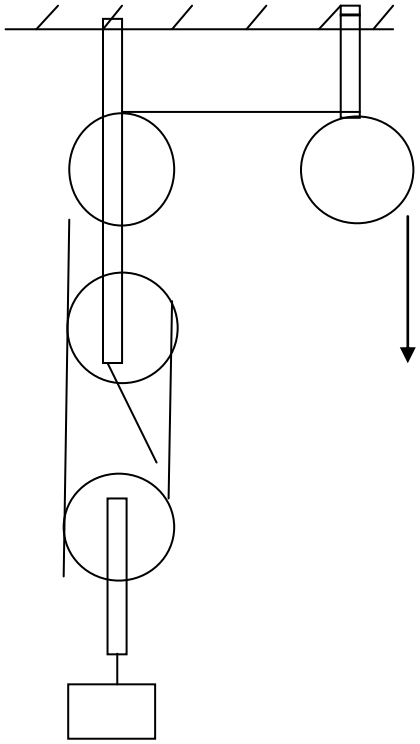
3 = $\frac{dE}{2}$ dE = 3 x 2 = 6m

Efficiency τ = $\frac{M.A}{V.R}$ x100%

= $\frac{2.5}{3.0}$ x100%

= 83⅓%

2) A single stringed pulley system shown below.



8N

20N

A load of 20N raised by an effort of 8N, If the system is friction less find the mass of the lower pulley.

Upward forces = down ward forces

$3T = 20 + W$

$3 \times 8 = 20 + W$

$W = (24 - 20)$

$W = 4N$

3. Mass of the lower pulley = $\frac{w}{g} = \frac{4}{10}$

=0.4kg.

An effort of 50N is required to raise a load of 200N using a pulley system of Velocity ratio 5.

a) Draw a diagram to show the pulley system.

i) Find the efficiency of the system.

ii) Calculate the work wasted when the load is raised through 120cm.

b) Give 2 reasons why efficiency of your pulley system is always less than 100%.

Solution

i) $\tau = \frac{M.A}{V.R}$ X100 = $\frac{4}{15}$ X100 = 80%

ii) dL = 120cm = 1.2m

Work in put = E X dE = 50 X 6 = 300J

Work output = L X dL= 200 x 1.2 = 240J

Work wasted = work in put – work output

= 300 – 240

= 60J

N.B.

Number of strings supporting a movable load is the velocity ratio.

Efficiency of a pulley system is always less than 100% because;

(i) work is wasted when overcoming friction force

(ii) Work is wasted in raising moving parts of the machine.

Work wasted = work input – work output.

Ways of improving on the efficiency of the machine.

- By lubricating moving parts of the machine
- By reducing on the weight of moving parts using light alloys.

Uses of pulleys

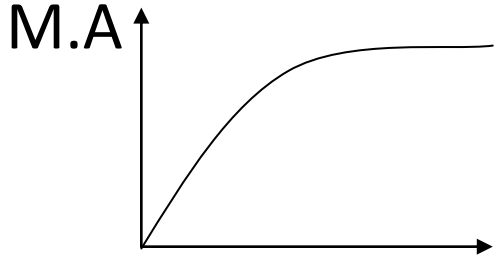
- Used in hoisting flags
- Used in cranes to lift the load.
- In construction of buildings.

Explain how a flag is hoisted.

A string is attached on the wheel of the pulley up the pole and the flag which acts as the load is attached to the string and pulled to hoist the flag.

The flag is tied on a string and the string is then passed over the pulley running. The rope is pulled down and the flag is hoisted.

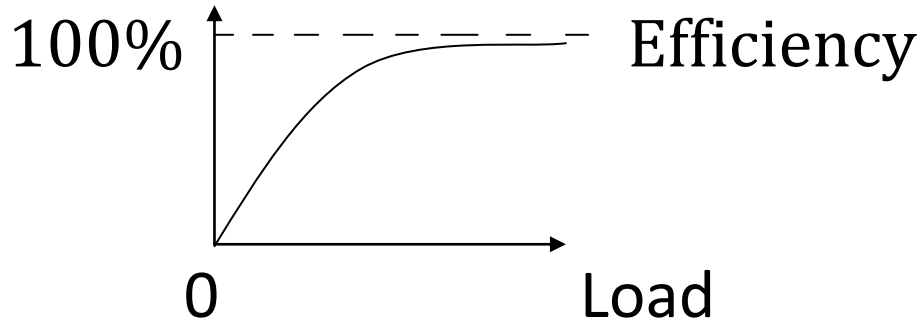
Variation of M.A with load



0 Load

- When the load is small, friction and unnecessary weight are also small. Therefore M.A is significant.
- When the load is increased friction and unnecessary weights are increased, decrease the efficiency and M.A of the machine.

Variation of efficiency with load



- When the load is small, friction and other necessary weights are significant

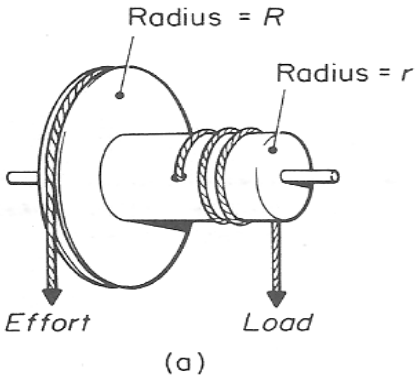
compared to the load. This makes both M.A and efficiency small.

- When the load becomes big friction and efficiency necessary weights become insignificant (very small) compared to the load. This increases the M.A and efficiency of the system.

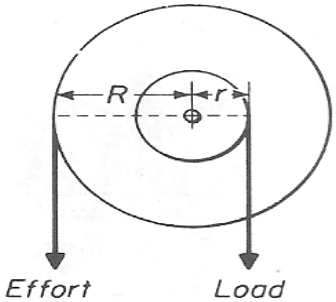
WHEEL AND AXLE

Wheels And Axles.mp4

It consists of a large diameter wheel and axle both of which are firmly attached to one another. A.F ABBOTT Page 95.



(a)



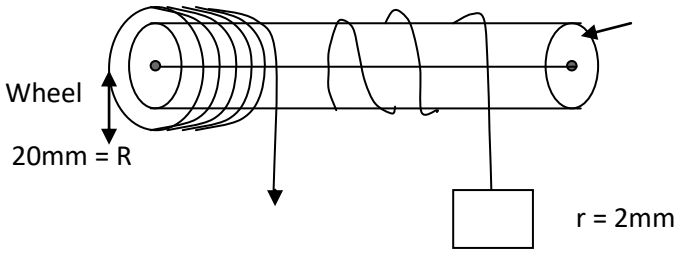
(b)

After a complete turn, Effort (E) moves through a distance equal to $2\pi R$ and the load is raised through a distance $2\pi r$.

Therefore;

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

V.R = $\frac{2\pi R}{2\pi r}$ = ...



Assuming that the efficiency of the above system is 45%. Find

a) The effort required to raise the load.

b) The energy wasted when the effort moves through one complete revolution
of 1760cm

Solution

a) V.R $= \frac{R}{r} = \frac{20mm}{2mm} = 10$

Efficiency = $\frac{M.A}{V.R}$ X100

45 = $\frac{M.A}{10}$ X100

M.A = $\frac{45\ X10}{100} = 4.5$

M.A = $\frac{Load}{effort} = \frac{1000}{E} = 4.5$

Effort E= $\frac{1000}{4.5} = 222.2N.$

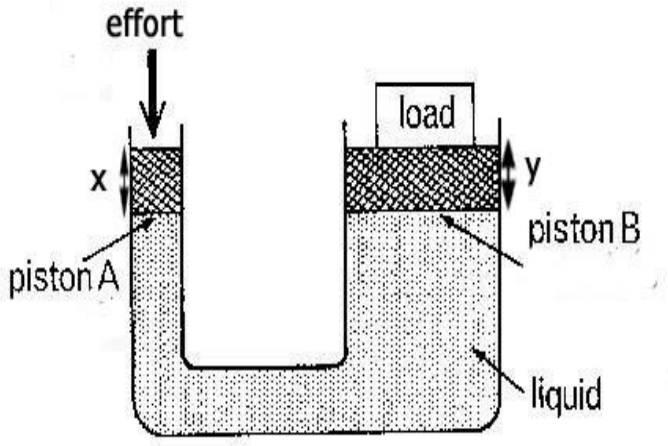
b) Work input = E x dE = 222.2 X $2\pi\ X\ \frac{20}{1000}$= 8.88πJ

Work output = L X dE = 1000 x$2\pi\ x\ \frac{2}{1000}$= 4πJ

Work wasted = (8.88 -4)π = 4.88πJ = 15.34J

HYDRAULIC PRESS

It works on the principle that pressure transmitted through an incompressible liquid/ fluid confined (enclosed) is the same everywhere in the fluid.



Pressure p = $\frac{force(F)}{area(A)}$

F = P X A

Therefore E = P X A_1= P X πr^2

And load L = P X A_2 = P X πR^2

M.A = $\frac{R2}{r2}$

M.A = $\frac{load}{effort}$ = $\frac{P\pi R2}{P\pi r2}$

When E and L move through a distance x and y respectively, the volumes are pressed

by small piston is equal to volume raised up in the; large piston.

$A_1 x = A_2 y \quad = \pi r^2 x = \pi R^2 = \frac{x}{y} = \frac{\pi R2}{\pi r2}$

$V.R = \frac{R^2}{r^2}$

Questions

1. A hydraulic hoist has a main cylinder diameter of 30cm and a pump cylinder diameter of 10cm.

Calculate

a) V.R (Ans 9)

b) M.A given that the force applied on the piston pump 70N and efficiency equal 80%) (Ans 7.2)

2. The efficiency of the hydraulic press is 60 %. Find the load raised if an effort of 200N is applied on a piston of

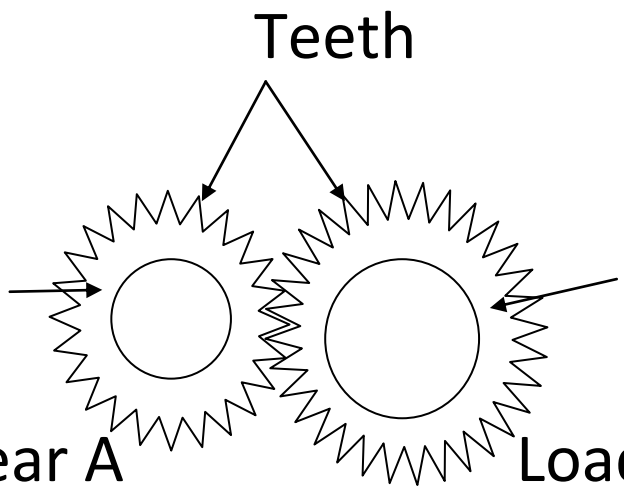
radius 5cm and the load is placed on the piston of radius 30cm. (Ans 4320N)

GEARS.

In gears, the effort is applied to one wheel which is called the driving wheel. The other wheel to which the load is connected is called the driven wheel.

For two gears in contact, it is observed that the speed of rotation is inversely proportional to the number of teeth.

Gear and Wheels Part 1.mp4



(Driving wheel) (Driven wheel)

Velocity ratio =

$$\frac{speed\ of\ rotation\ of\ driving\ wheel}{speed\ of\ rotation\ of\ driven\ wheel.}$$

V.R = $\frac{Number\ of\ teeth\ in\ a\ driven\ wheel}{number\ of\ teeth\ in\ driving\ wheel}$.

If gear A turns its teeth it interlocks with those of B and makes it turn in the opposite direction.

N.B

The fastest turning gear is that with the smallest number of teeth.

Example:

If gear A has 30 teeth and drives gear B with 75 teeth.

a) How many times does A rotate for each rotation of B?
b) Calculate the velocity ratio of the system.
c) Calculate the mechanical advantage of the gear system if its efficiency is 80%.
   Solution:
   - ✓ The number of times A rotates for each rotation of B is given by:

   No. of teeth in B divide by No. of teeth in A.

Example

A hydraulic machine has 120 teeth in the driven gear and 40 teeth in the driving gear. Calculate

i) Its V.R.
ii) Its M.A if the machine is 80% efficient.

Solution

i) V.R = $\frac{number\ ot\ teeth\ in\ driven\ gear}{over\ number\ of\ teeth\ in\ driving\ gear.}$

$= \frac{120}{40} = 3$

ii) Efficiency $\tau = \frac{M.A}{V.R}$ X100%

$$80 = \frac{M.A}{3} X100\%$$

$$M.A = \frac{80\ X3}{100} = 2.4$$

HEAT ENGINES

These are simple machines which turn chemical energy to kinetic energy and heat. There are two types of heat engines.

i) Petrol engine.
ii) Diesel engine.

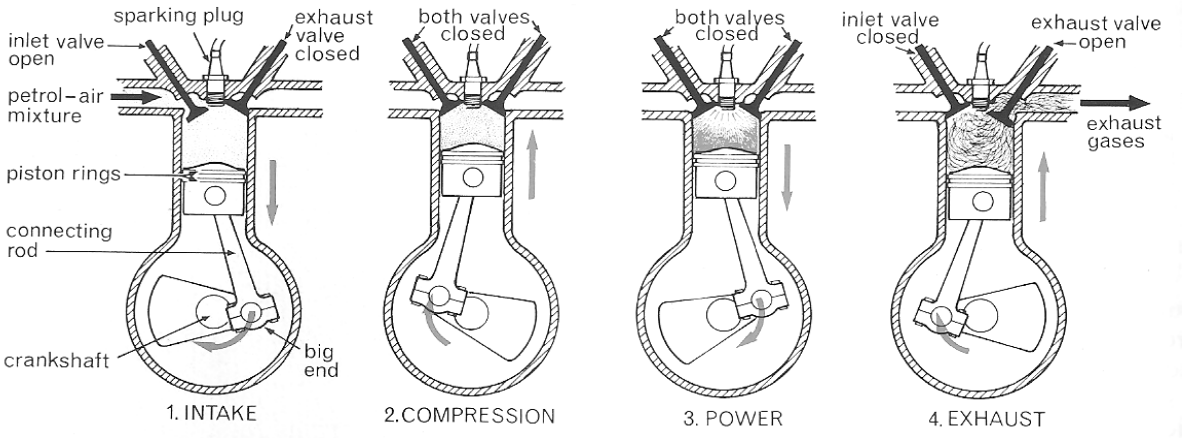
Petrol engine.

These are used to power cars, motor, bikes, vans etc.

Petrol is mixed with air and exploded inside the engine cylinder. The explosion is used to force down a closely fitting piston.

The crank shaft is used to turn the up and down movement of the piston into kinetic energy that drives the valve forward; in this way engine energy is obtained as a result of burning petrol inside it.

The four stroke petrol engine.



1. Intake stroke.

Air and petrol mixture enters the cylinder and the piston goes down as the exhausted valve closes hence pressure within decreases.

2. Compression and power stroke

-spark plug produces a spark which ignites the mixture. After very high compression an explosion occurs and the piston is pushed down.

Power is obtained plus some energy (chemical $\rightarrow mechanical \rightarrow heat$).

3. Exhaust stroke

The exhausted valve opens and unwanted gases are taken out while the in let valve is closed, after the piston has moved upwards.

N.B- four cylinders are used in four stroke engine for continuous power production in every quarter of the cycle.

Diesel engine

These are used to carry heavy Lorries, trailers etc.

They are efficient in pulling very heavy loads e.g. ships. The main difference between diesel and petrol engine is the way in which the fuel is burnt. The injector pump is compressed so much that it becomes hot enough to ignite the diesel fuel. The diesel engine must be made stronger than the petrol engine.

The diesel engine has no spark plug instead has a fuel injector.

In the diesel engine air is compressed to withstand extra compression required.

Differences between petrol and diesel engines.

PETROL ENGINE	DIESEL ENGINE
-fuel is ignited on /in the engine by electric spark plug.	- fuel is ignited by compression
-Has a carburetor for mixing air and petrol	Lacks a carburetor
Has spark plugs	Lacks spark plugs
-operates at lower compression ratio of 8:1and therefore less powerful.	Operates at higher compression and therefore ratio of 16:1 and therefore more powerful
Power occurs when petrol and air mixture is	Only diesel is ignited

ignited	
Has no injector pump	Has injectors which atomize diesel
Petrol engine is lighter	Its heavier
Produces less noise	Produces a lot of noise
Maintenance is more frequent and usually have problems in starting.	Maintenance is less frequent and causes no problem in starting.

END