4rth Semester

Kinematics and Dynamics Of Machine

Module 1(a)

Department of Mechanical Engineering
Government College Of Engineering Kalahandi, Odisha

16/03/14

Mechanical Engg.

Engg. of Mechanics

↓

Study of Motion

Study of Motion without considering the basic cause of motion i.e, forces

Kinematics

$$\vec{v} = \frac{d\vec{s}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$(\text{Jerk}) \quad \vec{j} = \frac{d\vec{a}}{dt}$$

Study of motion with the help of basic cause of motion i.e, forces

Dynamics

In Dynamics Newton's II^{nd} law of motion

$$\vec{F}_{ext} = \frac{d}{dt}(m\vec{v})$$

m → mass.

For example

Dynamic viscosity (μ)

$$\frac{N-s}{m^2}$$

Kinematic viscosity (ν) = m^2/s

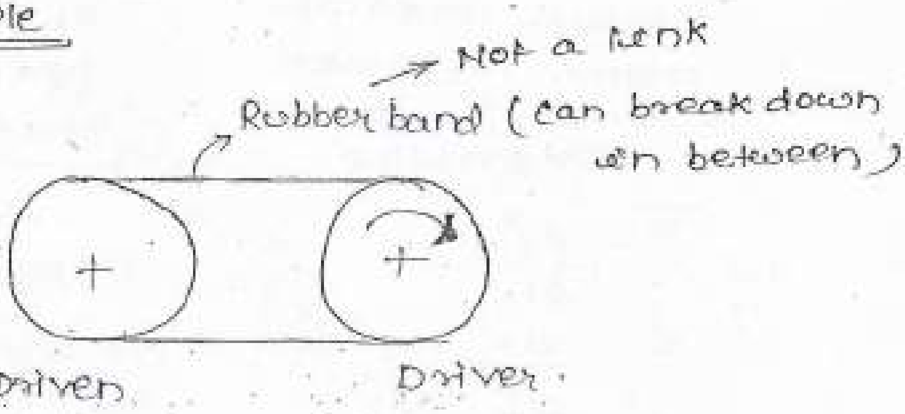
SIMPLE MECHANISMS

Kinematic link or element

"Every part of a machine which is having some relative motion w.r.t some other parts is known as kinematic link or element"

It is necessary for the link to be a resistant body so that it is capable of transmitting power and motion from one element to the other element.

For example



Types of links

(1) Rigid link

Deformations are negligable.
For example :- crank, connecting Rod, piston cylinder.

(2) Flexible link

Deformations are there but are in permissible limit.

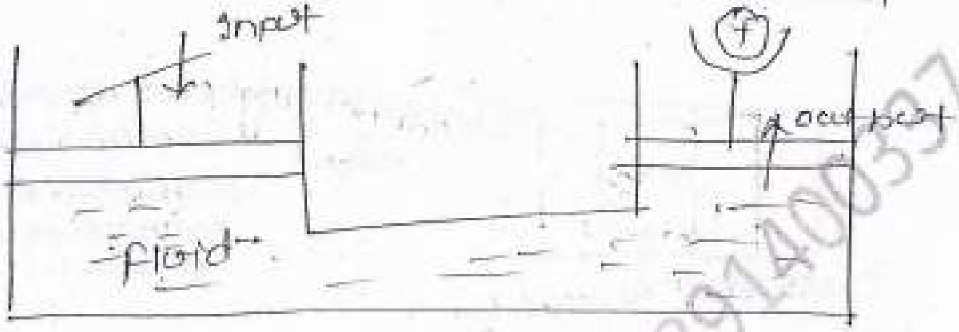
For example

Belt Drives, chain drives, Rope Driver.

Fluid links

when the power is transmitted because of fluid pressure.

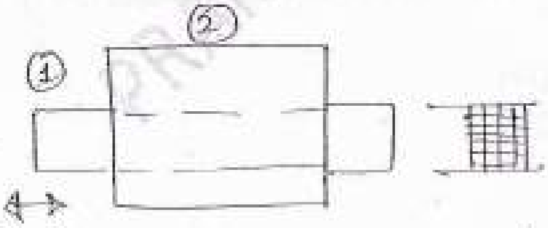
Eg:- Hydraulic crane
" lift
" Jack
" Ram
" pressure

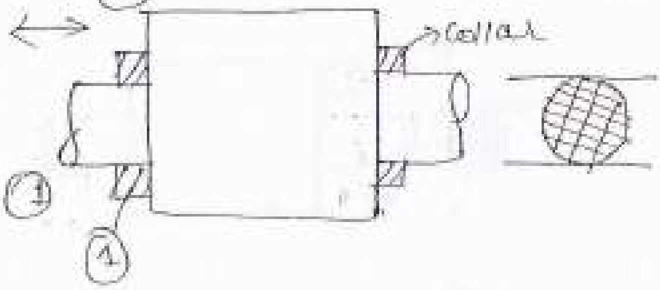


Different types of Relative motions

To analyze the relative motion
↓
(system) is having two links (link 1, link 2).

(1) completely constraint motion → constraint motion (only one relative motion)

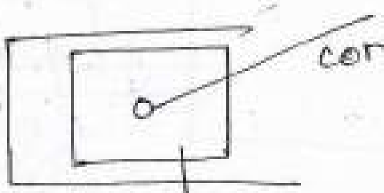


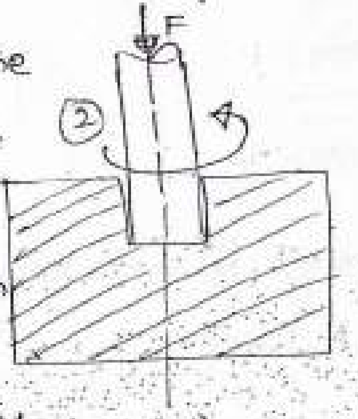


Successfully constraint motion

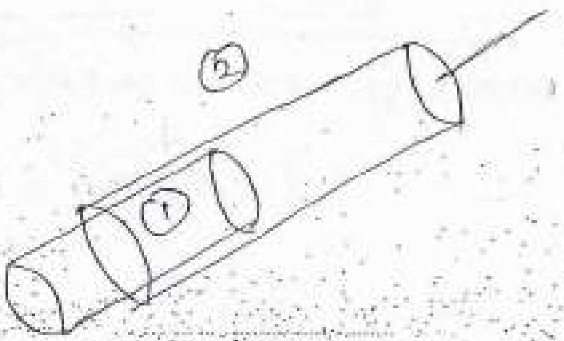
Also, Constraint motion
↓ mean
Desired motion
↓
for unique one input there must be unique output.

Eg:-



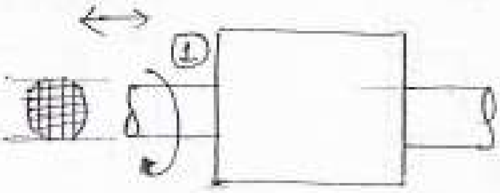


Shaft in foot step bearing



Syringe (Here the person using syringe make the motion constraint).

Incompletely constraint motion



Both reciprocating & rotating motion

kinematic pair

" The connection between the two links is always a joint or a pair but this pair will also be a kinematic pair if the relative motion b/w the links is a constraint motion".

(A) on the basis of the type of Relative motion

- Turning pair : (Revolute Pair) (Pin joint)

  Relative motion is pure turning.

  Eg:- knee joint in our body.

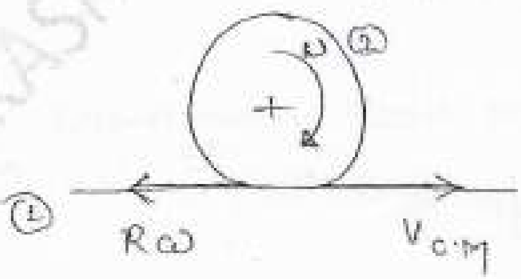
- Sliding pair : (Prizmatic Pair)

  Relative motion is pure sliding.

  Eg:- piston in cylinder.

- Rolling pair

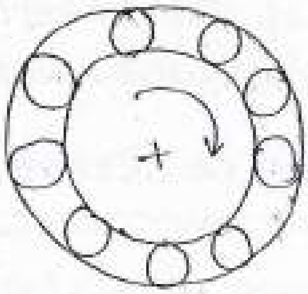
  Relative motion is pure rolling.
  means
  Rolling without slipping.



Condition for pure Rolling

$$V_{C.M} = R\omega$$

Ball Bearing



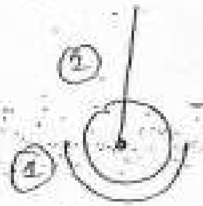
Between inner/outer wall & ball → Rolling pair.
But b/w outer & inner wall → Turning pair.

Screw pair

when the relative motion is over the threads.

Eg :- Nut & bolt.

Spherical pair



Ball & socket

→ 3D rotation
↓
Spherical motion.

Another eg :- our neck movement.

(B) According to type of contact

Lower pair :- Surface contact.

Higher pair :- line/point "

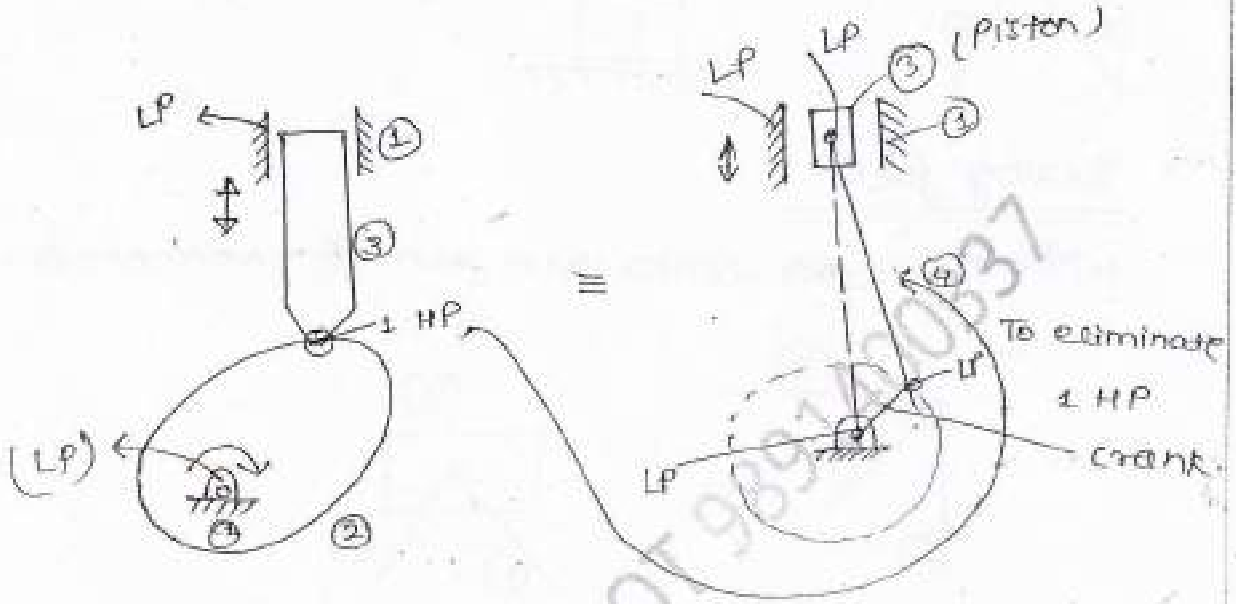
Wrapping pair :- when one link is wrapped over other link.
↓
close to Higher pair

Eg :- Belt & pulley , Rope & pulley .

1 Higher pair ≡ 2 Lower pair

1 HP ≡ 2 LP

For example



c) According to the type of closure

- Self closed pair (closed pair)
  ↳ permanent contact
  eg :- Piston in cylinder
- Force closed pair (open pair)
  ↳ Forceful contact

For eg :-

Higher pair in cam & follower.
Automatic clutch opening system.
Door closer.

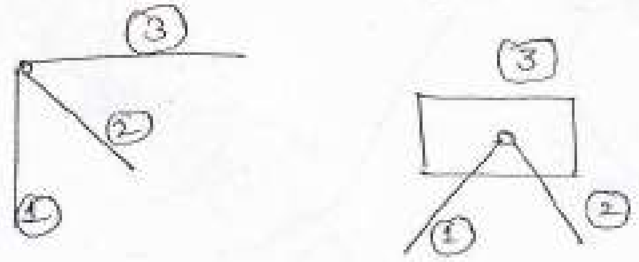
Different types of pairs & joints

- **Binary joint**

where two links are connected.

- **Ternary joint**

where three links are ~~joined~~ connected.



Independent { (1, 2), (2, 3) } three Binary joints.

Dependent ← (1, 3)

Taking any of two we can make Ternary joint.

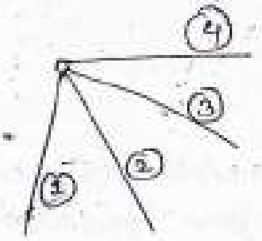
Thus,

$$1T = 2B$$

1 Ternary = 2 Binary.

Quaternary joint

where four links are connected.



(1, 2) (1, 3) (1, 4)

(2, 3) (2, 4)

(3, 4)

1P = 3B

- J. S Rattan } problems
  P. L Balani }
  Vishal conventional

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Kinematic chain

If all the links are connected in such a way such that the 1st link is connected to the last link in order to have close chain and if all the relative motions in this closed chain are constrained then such a chain is known as kinematic chain.

Kinematic chain (constrained chain).

↓ to use this chain one link must be fixed

→ Mechanism :- which can give desired o/p w.r.t i/p.

↓ utilize it

→ Machine :- Desired o/p is obtained.

Degrees of freedom

Also known as **Mobility**.

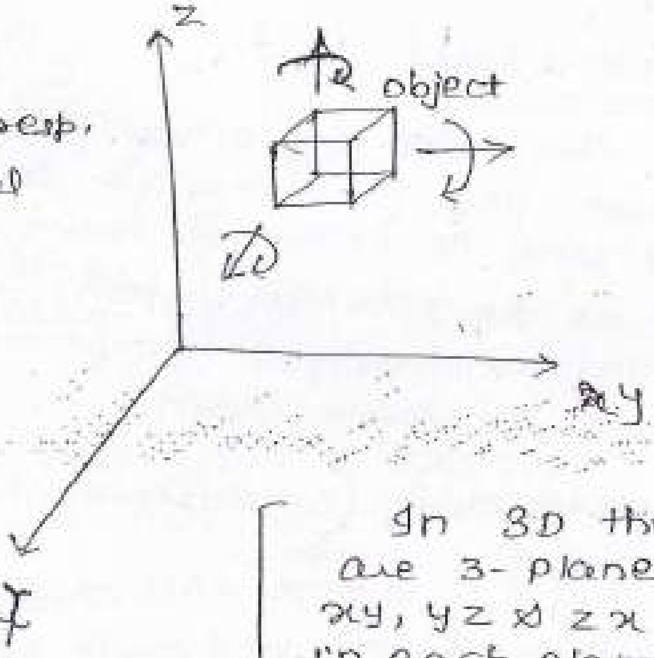
"The minimum no. of independent variables required to define the position or motion of the system is known as degrees of freedom of the system"

Position | Motion

Both are same in general.

In general in 3-D (space)

Translational motion is in x, y & z dirn resp. ∴ 3-Translational motion.



In 3D there are 3- planes xy, yz & zx & in each plane there is one rotation. Thus, there is 3- "

No. of Motions

= 3 Translational + 3 Rotational.

= 3T + 3R.

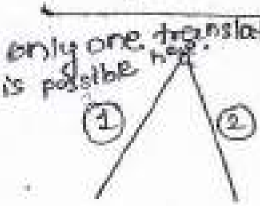
= 6 (Maxm no. of motions).

Degree of freedom,

$D.O.F = 6 - Restraints$

<u>Restraints :-</u>

No. of those motions which are not possible.
Restraints (also known as constraints) are seen in two systems in form of pairs.

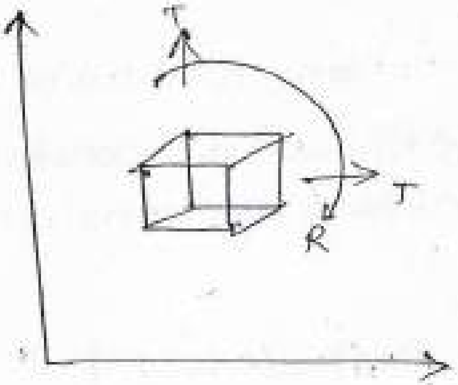
Pair	Restraints	D.O.F
	$3T + 2R = 5$	$6 - 5 = 1$
	$1T = 1$	$6 - 1 = 5$

* 1 Lower pair = 1 Degree of freedom pair.
* 1 HP → 2 L.P → 2 D.O.F.
* Spherical pair (only to Rotational motion in all the 3-D)

$\therefore$ 1 SP = D.O.F = 6-3 = 3.

Any object

To find out the Degree of freedom of 2-D planer mechanism.



Max^m no. of motion

= 2T + 1R = 3.

No. of links = L.

" " Binary joints = j.

" " Higher pairs = h.

when one link is fixed

$$F = 3(L-1) - 2j - h$$

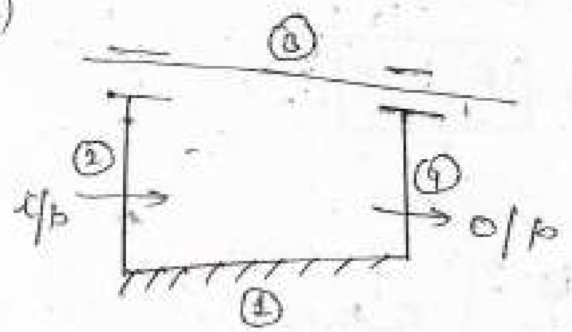
No. of max^m motion in 2D planer Mechanism.

This is known as Kutzback's eq^n.

$$F = [3(L-1) - 2j - h] - F_r$$

No. of those motions which are not the part of mechanism.

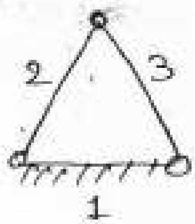
1)



$l = 4$
$j = 4$
$h = 0$
$f_r = 1$

$$F = [3(4-1) - 2\times4 - 0] - 1$$

$$\boxed{F = 0}$$

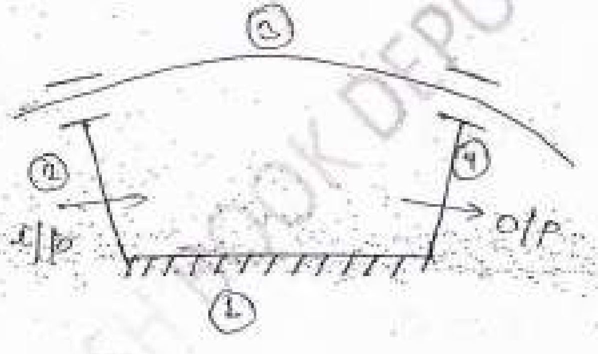


$l = 3$
$j = 3$
$h = 0$

$$F = 3(3-1) - 2\times3 - 0$$

$$\Rightarrow F = 0$$

(2)



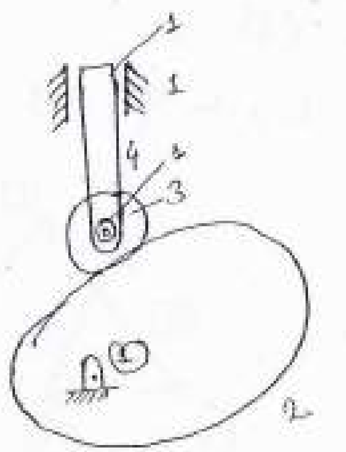
$l = 4$
$j = 4$
$h = 0$
$f_r = 0$

$$\boxed{F = 1}$$

(3) $L = 4$

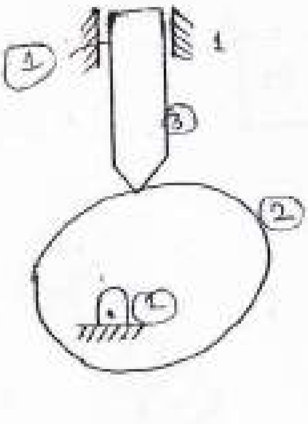
$j = 3$, $h = 1$

$f_r = 1$



$F = [3(4-1) - 2\times3 - 1] - 1$

$= (9 - 6 - 1) - 1 \Rightarrow \boxed{F = 1}$



$l = 3$
$j = 2$
$h = 1$] $F_r = 0$.

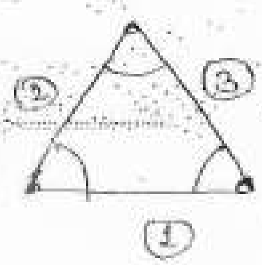
$F = [3(3-1) - 2\times2 - 1]$

$= 6 - 4 - 1$

$\boxed{F = 1}$

* If $\boxed{F = 0}$ No relative motion i.e, frame/ structure.

For examp:-

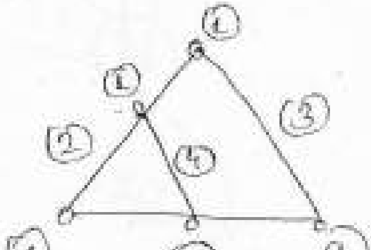


$l = 3$
$j = 3$
$h = 3$

$F = 0$.

If $F < 0$

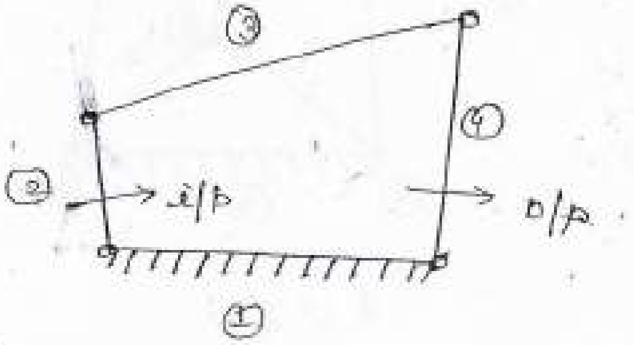
$\Rightarrow -1, -2, -3$] Super structure [Intermediate structure].



$F = -1$.

* If $\boxed{F = 1}$
↓
kinematic chain (constrained).

For example

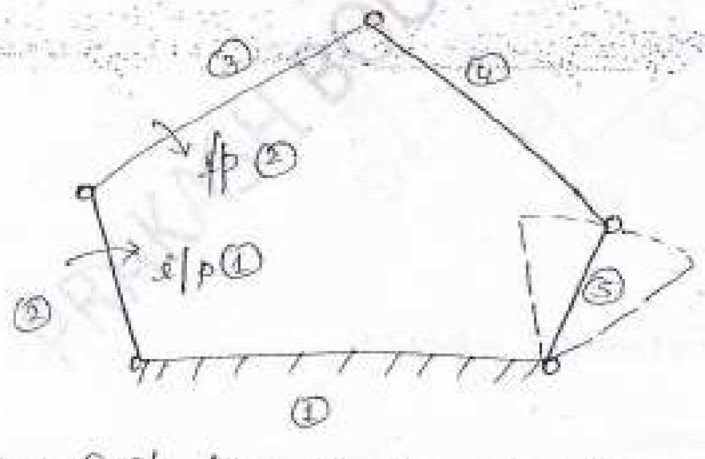


$l = 4$, $j = 4$, $h = 0$.

$F = 1$.

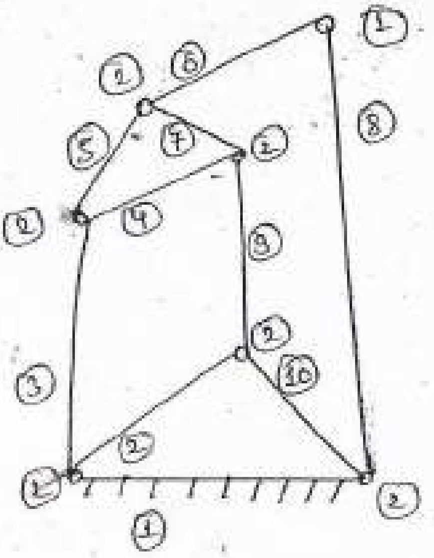
* If $F > 1 = 2, 3, 4, 5$ ——
↓
unconstraint chain

Eg:-

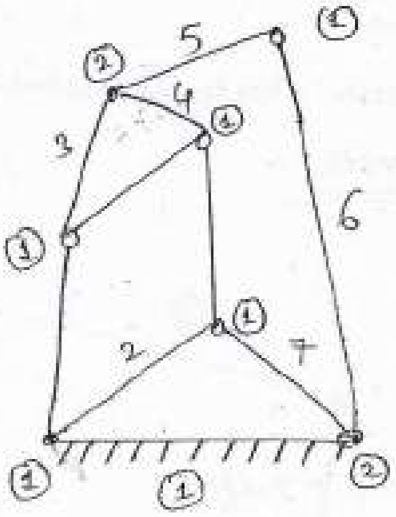


$l = 5$
$j = 5$
$h = 0$
$F = 2$.

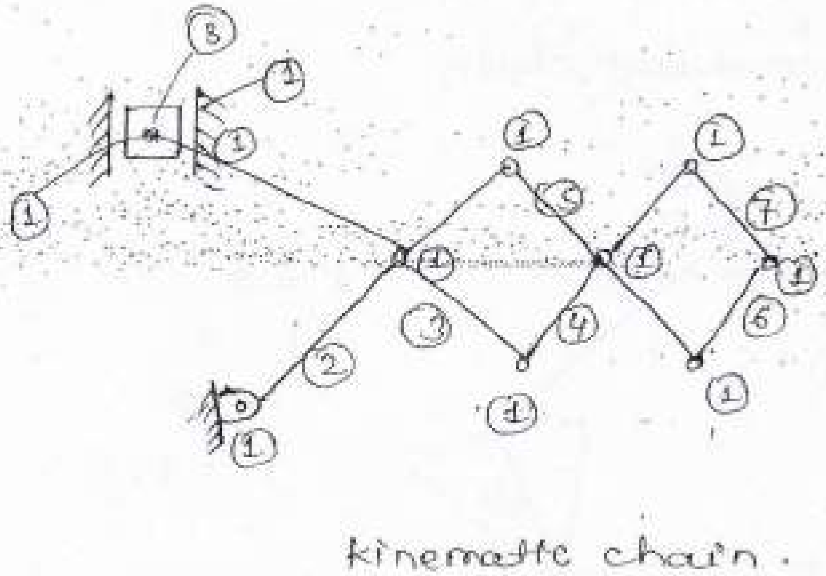
D.O.F of the chain is the no. of input required to get the desired o/p.
(constraint)



$l = 10$
$j = 13$
$h = 0$
$F = 1$



$l = 7$
$j = 9$
$h = 0$
$F =$

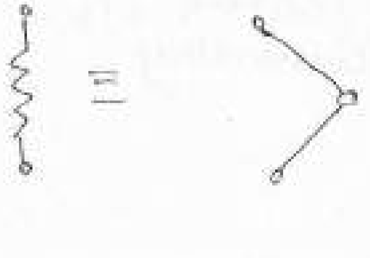


$l = 8$
$j = 10$
$h = 0$
$F =$

kinematic chain.

Spring as a link

link of flexible length.



Grubler's equation

For those mechanisms in which $F = 1$ and $h = 0$.

Apply kutzback eqn :-

$$F = 3(L-1) - 2j - h$$

$$1 = 3l - 3 - 2j - 0$$

$$\Rightarrow \boxed{3l - 2j - 4 = 0}$$

$3l \rightarrow$ even.

$[l]_{always} \rightarrow$ even.

$[l]_{min.} = 4.$

First mechanism with lower pair called simple mechanism.

↳ 4 - Bar mechanism.

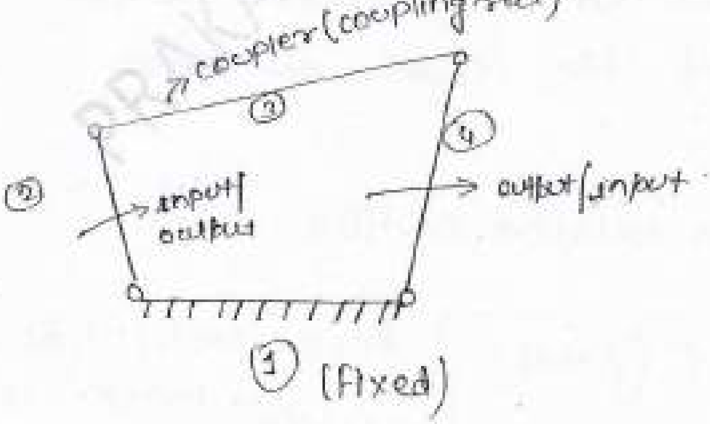
Single - slider crank mechanism.

Double - slider crank "

four bar Mechanism (Quadric cycle mechanism)

four bar Mechanism

= 4 link + 4 T.P.



Best position → Fixed.

Fixed position is best because it governs both input and output.

Input/output links

→ complete Rotation → CRANK.

→ Partial Rotation → Rocker/Lever.
(oscillation)

Inversion

Mechanisms which are obtained by fixing one by one different links.

(1) Double link mechanism.

(2) crank ⟷ Rocker Mechanism.

(3) Double Rocker

If no. of links = l " " Inversions ≤ l

Grashoff's law.

"For the continuous relative motion b/w the no. of links in the 4-bar mechanism the summation of the lengths of shortest & longest link should not be greater than the summation of the lengths of other two links".

For the continuous relative motion

$$(s+l) \leq (p+q)$$

Best position of 4-bar mechanism
FIXED
Input output.

(as occupy less space & easily rotate)
Best link for rotation → shortest (s)

$(s+l) < (p+q)$ → law satisfied.

(1) When s → fixed < input / output ⇒ Double crank Mechanism

(2) s → Adjacent to fixed ⇒ crank rocker mechanism.

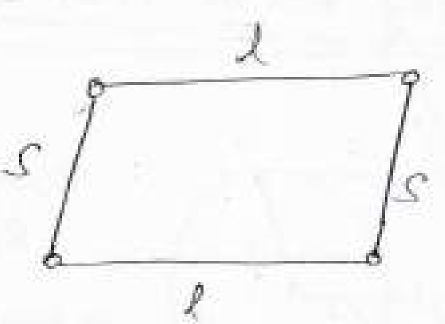
(3) s → couple → Double rocker mechanism.

* $(s+l) = (p+q)$ ⇒ law satisfied
(Not having pairs of equal links)
2, 5, 4, 3 (same as previous)
2 → shortest (s)
5 → longest (L).
∴ $2+5 = 4+3$

~~Paralle~~lo

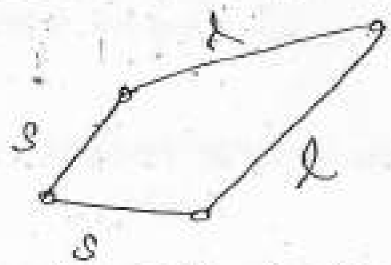
$(s+l) = (p+q)$ ⇒ law satisfied
Having the pair of equal links
2, 2, 5, 5
s s l l

Parallelogram linkage



s → fixed → Double crank.
l → fixed → Double crank

(2) Deltoid linkage



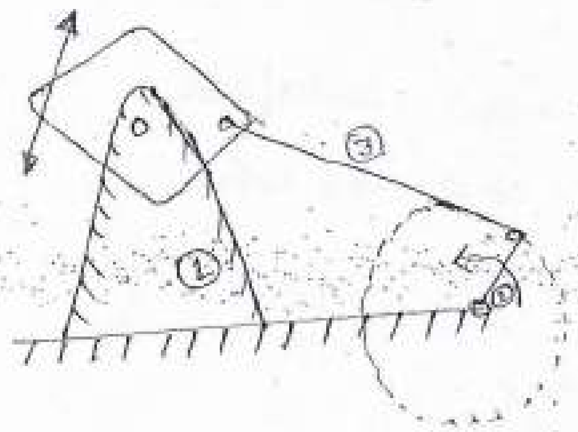
s-fixed ⇒ Double crank.

l-fixed ⇒ crank - Rocker.

If $(s+l) > p+q$] ⇒ law not satisfied.
⇓
Double crank mechanism.

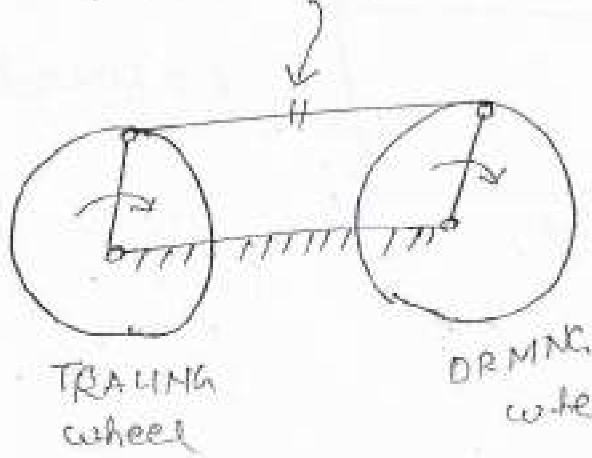
Some practical applications of four bar mechanism

(1) Beam engine mechanism



Rotation ⟷ oscillation.
crank ⟷ Rocker.

(2) completely coupling rod of locomotive



Rotation ⟷ Rotation

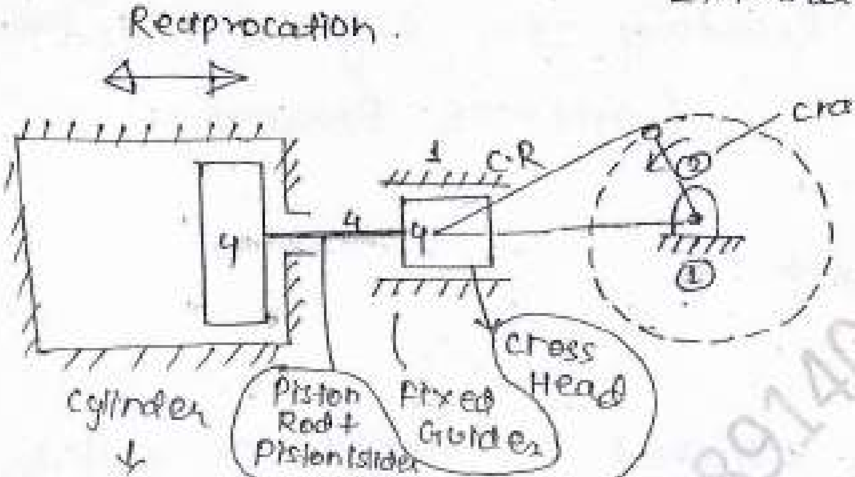
⇒ Double crank

Single Slider ~~Mech~~ Crank Mechanism

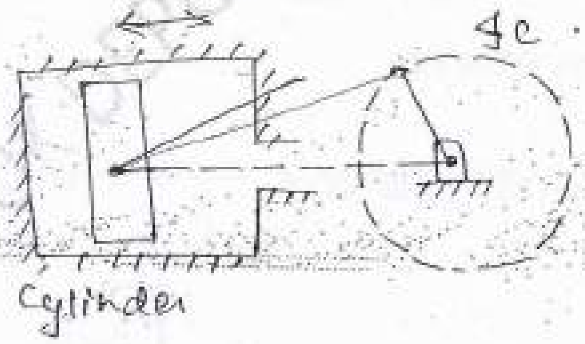
4 links + 3 Turing pair + 1 sliding pair.

Basic Single slider crank Mechanism

External combustion.



Cylinder ↓ Cylinder → Fixed



I Inversion

cylinder fixed

Rot ⟷ Rec
crank piston

o ← i → Reci. Engine

i → o → Reci. Comp.

II Inversion

Crank fixed

- Whitworth Quick Return Motion Mechanism (QRMM)
- Rotatory I.C Engine Mechanism (GNOME ENGINE)

III Inversion

C.R fixed

- Crank & Slotted Lever QRMM (Fixed Best)
- Oscillation cylinder Engine Mech.

IV Inversion

Slider fixed ⟶ Hand pump (Pendulum pump) (Bull Engine).

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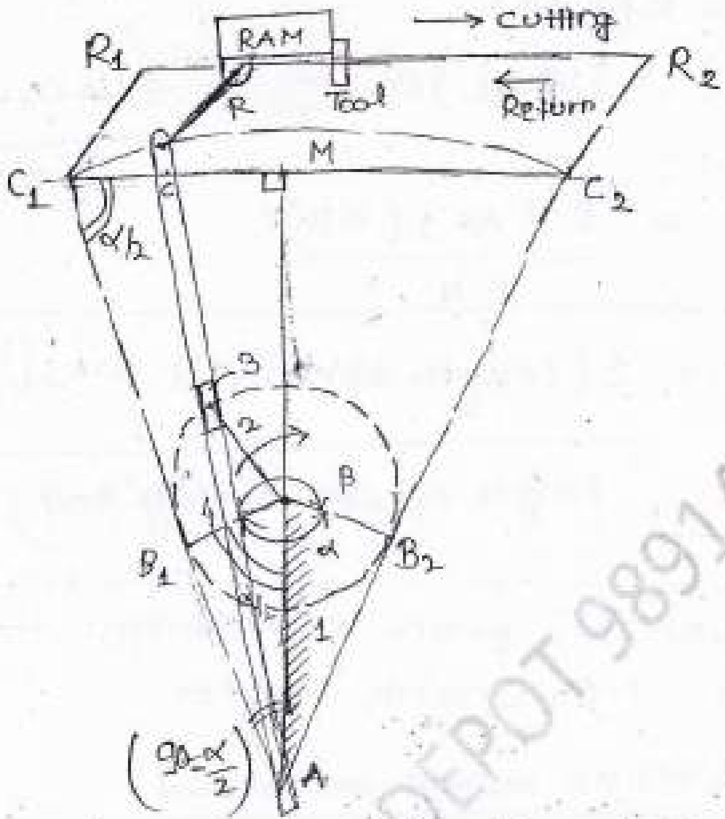
crank and slotted lever quick return motion mechanism
(connecting rod is fixed)



β = cutting stroke angle

α = Return stroke "

$$\alpha + \beta = 360^\circ$$

$$\alpha < \beta \text{ (QRMM)}$$

$$\frac{(\text{time})_{\text{cutting}}}{(\text{time})_{\text{Return}}} = \frac{\beta}{\alpha} \Rightarrow \text{Quick Return Ratio}$$

(Always > 1).

Stroke length :- $R_1 R_2$ Length covered in forward or return stroke.

$$R_1 R_2 = C_1 C_2$$
$$= 2(C_1 M)$$
$$= 2(AC_1)\cos\frac{\alpha}{2} = \frac{2(AC_1)(OB_1)}{OA}$$
$$= \frac{2(AC)(OB)}{OA}$$

$$\text{Stroke} = \frac{2(\text{length of slotted Bar})(\text{Length of crank})}{(\text{Length of connecting Rod})}$$

Here, motion is from rotation to oscillation i.e, crank Rocker.

Whitworth quick return motion mechanism

Rotation → Rotation (Motion)

Double crank.

β → cutting stroke Angle.

α → Return " "

$$\alpha + \beta = 360^\circ$$

$$\alpha < \beta \text{ (QRMM)}$$

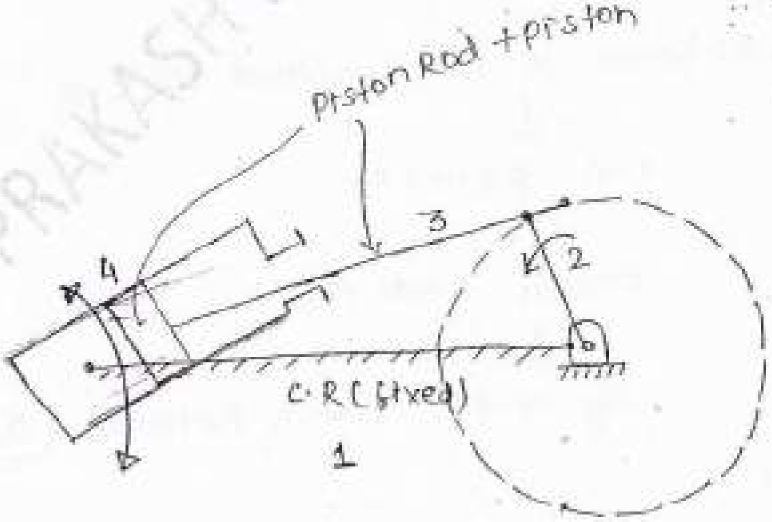
$$\frac{t_{cutting}}{t_{return}} = \frac{\beta}{\alpha}$$ (quick return ratio > 1).

Stroke ⇒ $R_1 R_2$
$= C_1 C_2$
$= 2(OC)$.

Oscillating cylinder Engine Mechanism

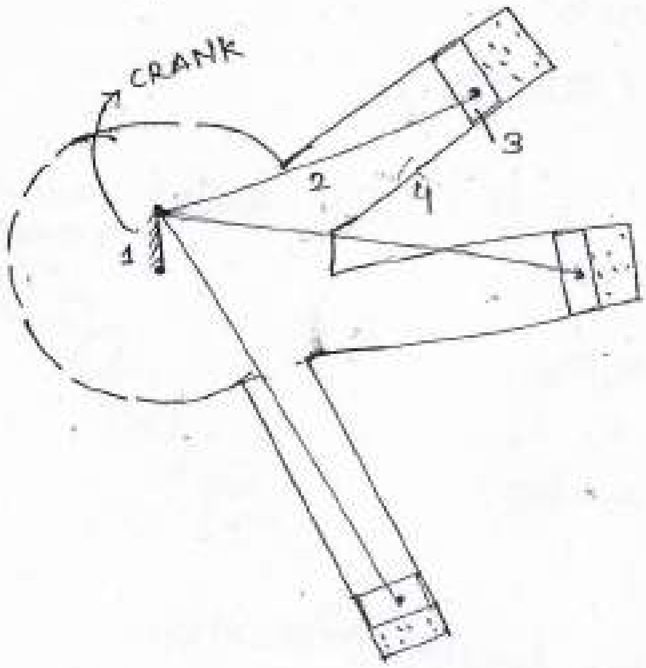
connecting rod (C·R) fixed

Rotation → oscillation
Crank – Rocker



Rotary I.C Engine Mechanism (GNOME Engine)

* crank fixed.



when combustion takes place inside the cylinder (Input)

↓

Input force comes on piston

↓

This force is transmitted to C.R.

↓

C.R Rotates

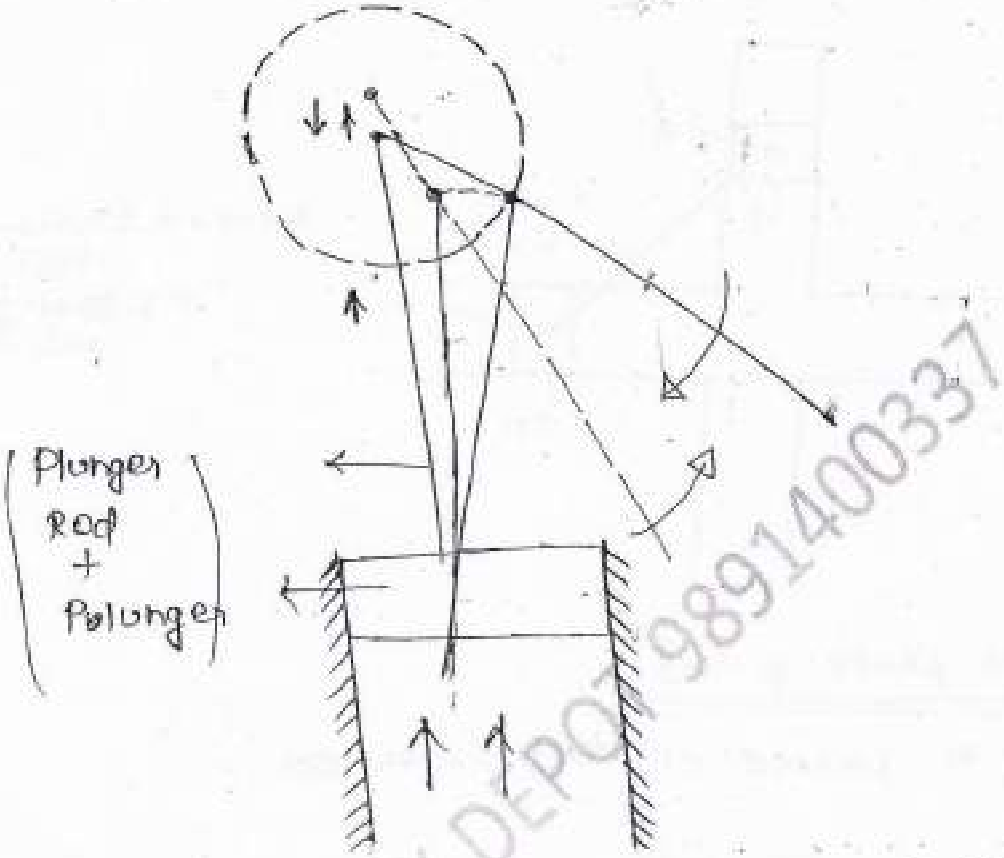
↓

Piston Rotates.

↓

Cylinder Block Rotates (Output)

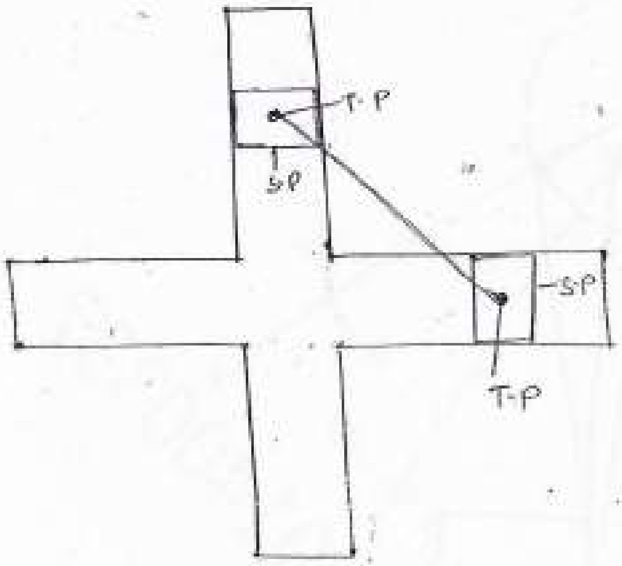
Hand Pump (slider fixed)



Here, plunger rod + plunger comes in place of cylinder. To make a link in place of it.

Double slider crank chain

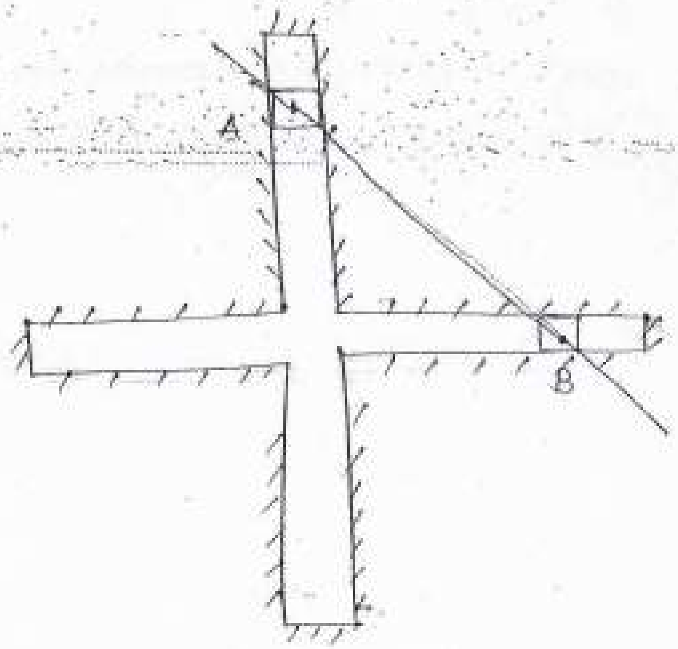
4 links = (one plate + two links □ □ + one link connecting the two pin)



4 links + 2 Turning pair + 2 sliding pair.

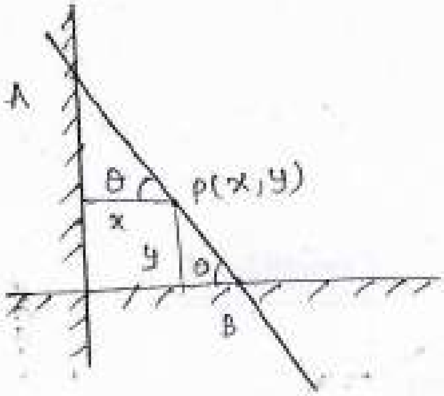
(1) Slotted plate fixed

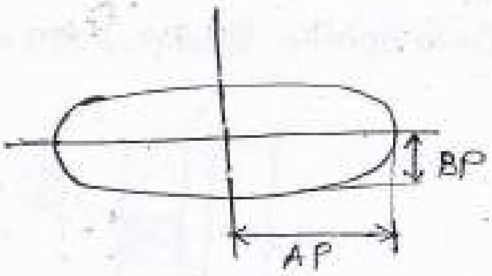
This is called elliptical Trammels :-



used for drawing ellipse by taking any pt. other than central pt. of line.

Eg:-

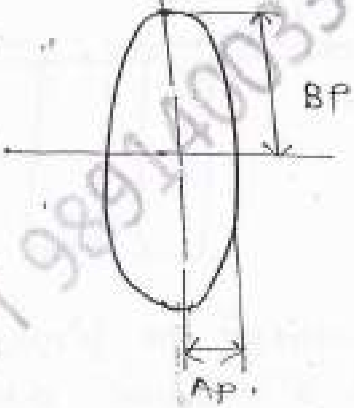




$\cos\theta = \frac{x}{AP}$

$\sin\theta = \frac{y}{BP}$

$$\frac{x^2}{AP^2} + \frac{y^2}{BP^2} = 1$$



AP → semi-major axis.

BP → " minor "

Eg:-

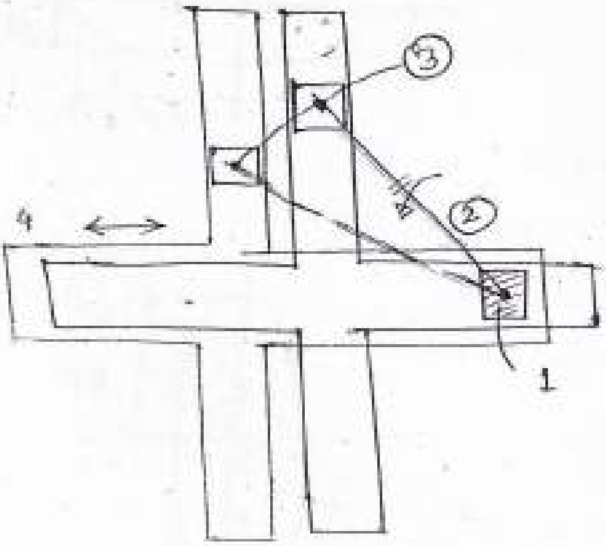
Major axis = 250×2
= 500mm

Minor axis = ~~100~~ 150×2
= 300mm

(2) If any of the slider is fixed :-

Scotch - yoke Mechanism

Rotation -> Reciprocation.

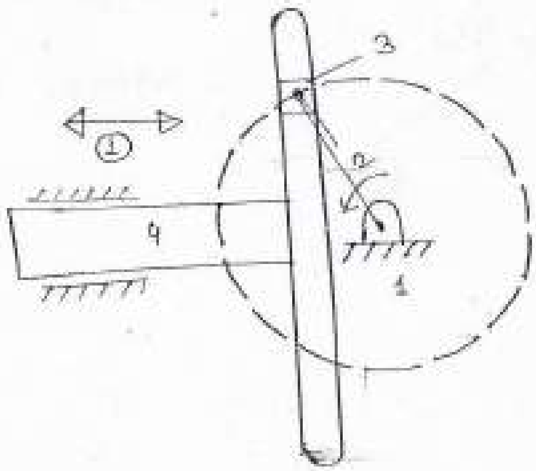


Concept

Here, slider is fixed only plate can slide which is shown above.

Manufacturing

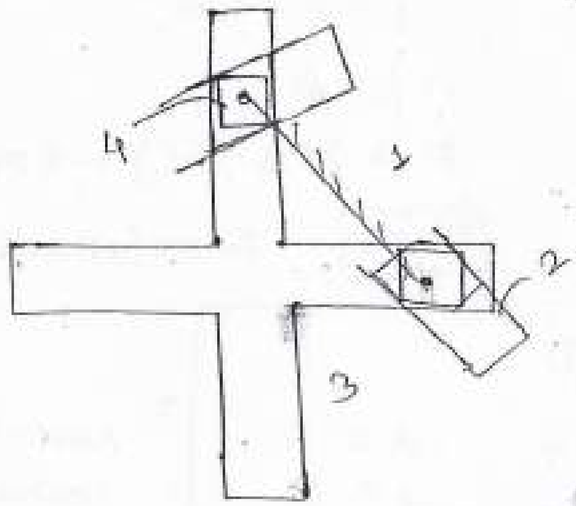
By applying the above concept.



(3) If link connecting slider is fixed

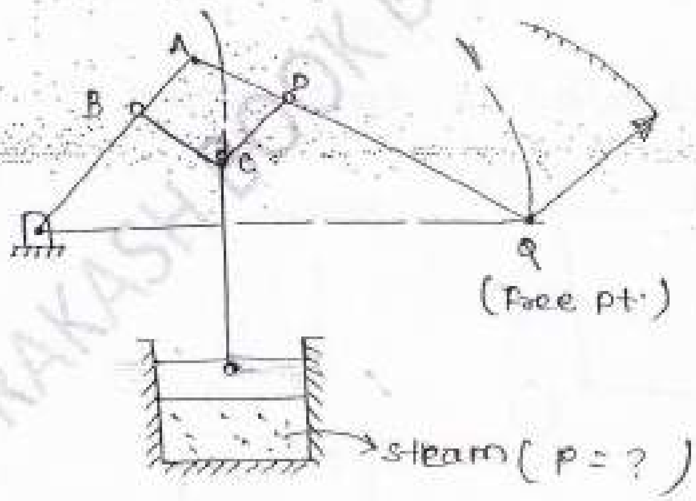
Oldhams coupling

↳ used to connect the shafts which have lateral misalignmen.



Watt's Indicator Mechanism

This mechanism is used for measuring the high pressure of steam

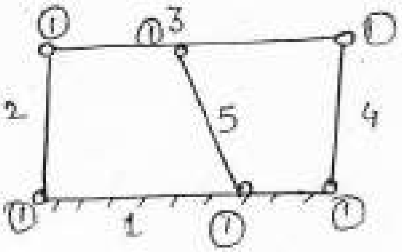


OBSERVATIONS

- pt. C & pt. Q both move in approx. straight line motion → Approx. St. line motion mechanism.
- There is no relative motion b/w links BC & CD
  → BCD → one link.

- Link BCD] → Behaves like lever.
  Link AQ] → Double lever mechanism.

Note.



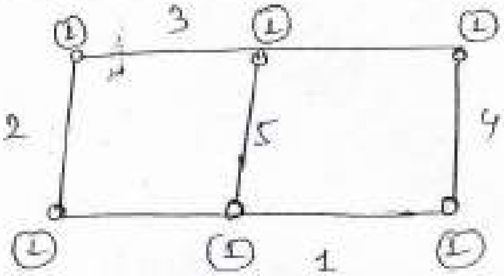
$l = 5$

$j = 6$

$h = 0$

$F = 3(5-1) - 2\times6 - 6$

$\boxed{F = 0}$ Frame/structure.



$l = 5$

$j = 6$

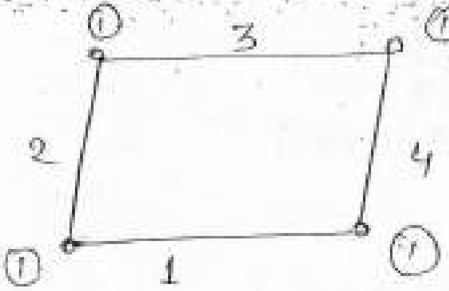
$h = 0$

$F = 0$

× Not correct
the link parallel to the side play as Redundant link. No role in this.

|||

Thus, the above is equivalent to



Now,

$l = 4$

$j = 4$

$h = 0$

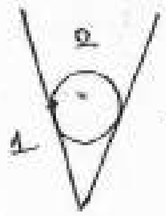
$\boxed{F = 1}$

Note :-

Cylindrical pair

2 Motions are possible one rotation & another reciprocation (when one cylinder is inside other like pen with cap).

4 Restraints



Cylinder in
V-block

2- motions are possible.
4 - Restraints

- lower pairs are more resistant