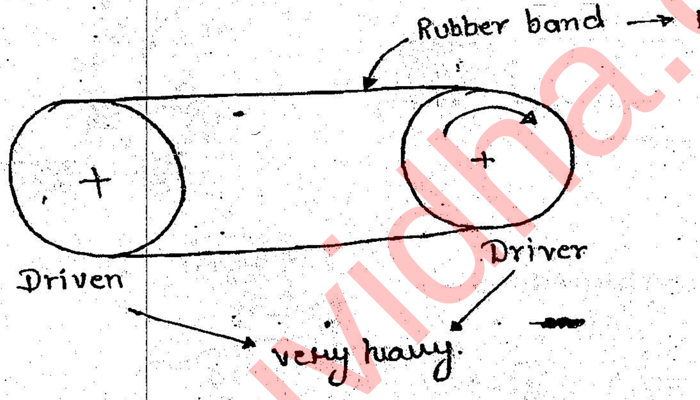
SIMPLE MECHANISM

Kinematic Link or Elements :-

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

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

for ex :-



Type of Links :-

i) **Rigid Link** : Deformations are negligible (microscopic)

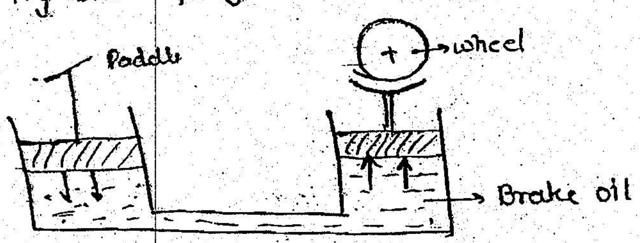
for eg :- crank, CR, piston, cylinder.

ii) **Flexible Link** : Deformations are there but are in permissible limits.

for eg :- Belt, Rope, Chain drives.

iii) **Fluid Link** : when power is transmitted due to fluid pressure.

for eg :- Hy brake, Hy Ram, Hy Press, Hy crane, Hy lift



Hy. Turbine ✗

Different type of relative motions :-

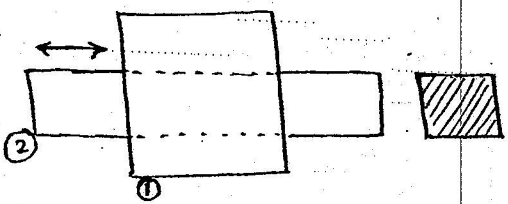
For a relative motion → system is having two links.

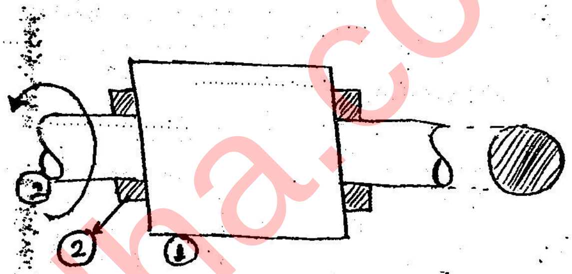
i) completely constrained motion

ii) successfully constrained motion

iii) Incompletely constrained motion.

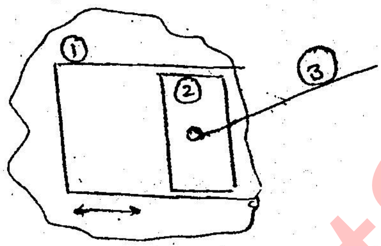
① Completely constrained →

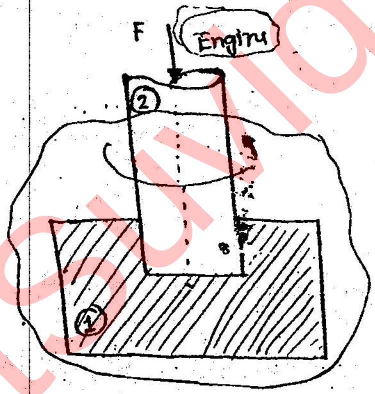


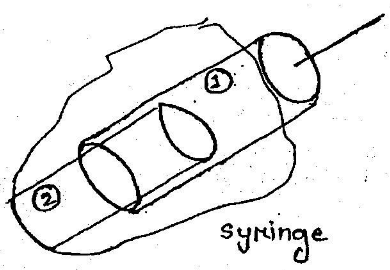


② Successfully constrained →

piston - cylinder

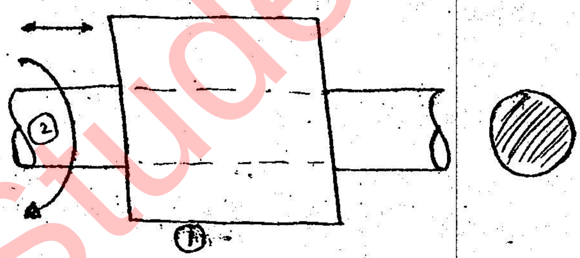






motion controlled by the surrounding

③ Incompletely const →

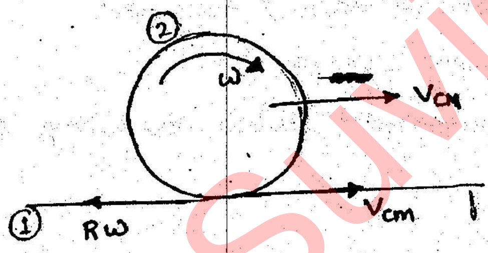


Kinematic Pair :- Any connection b/w the two link is always known as joint or pair. But this pair only be the kinematic pair if relative motion b/w the link is a constrained motion.

Classification of Kinematic Pairs :-

A) According to the type of Relative Motion :

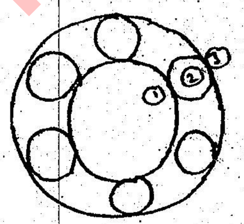
- Turning Pair (Revolute Pair) (pin-joint) -
  → when relative motion is pure turning.
- Sliding Pair (Prizmatic Pair)
  → when relative motion is pure sliding.
- Rolling Pair
  → when relative motion is pure rolling.
  Rolling without slipping.



condition of pure rolling -

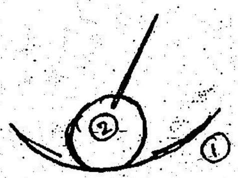
$$\boxed{V_{cm} = R\omega}$$

for ex :- Ball Bearing -



Turning b/w 1 & 3
Rolling b/w 1 & 2
2 & 3

- Screw Pair
  → when the relative motion is over the threads.
  for ex :- Nut bolt
- Spherical Pair
  → when the relative motion is 3-D rotation (spherical motion)



B) According to the type of contact →

- Lower Pair : surface contact
- higher pair : point / line contact
- wrapping pair :

  when one link is wrapped over other link.

  for ex :- Belt - pulley .

  one of the link should be flexible

C) According to the type of closure →

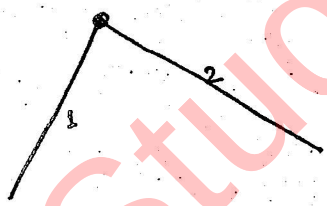
- self closed Pair → permanent contact
  (closed pair)
- Forced closed Pair → Forceful contact
  (open pair)

for eg :- • H.P in cam & follower
• Door Closers
• Automatic clutch operating system .

Different type of joint :-

i) Binary Joint

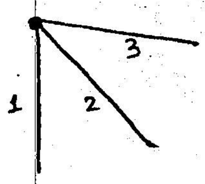
when two links are connected



(1,2)

ii) Ternary Joint

when three links are connected



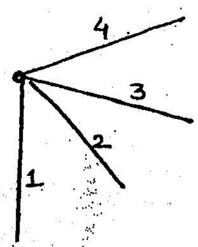
(1,2)
(1,3)
(2,3)

$\boxed{1T = 2B}$

1 is independent
2 dependent link

iii) Quaternary Joint

when four links are connected.



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

$\boxed{1Q = 3B}$

3 independent

Kinematic Chain : If all the links are connected in such a way such that the first link is connected to the last link in order to have closed chain and if all the relative motion 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 is fixed.

Science or concept — $\boxed{\text{Mechanism}}$ → can give desired o/p wrt given i/p.

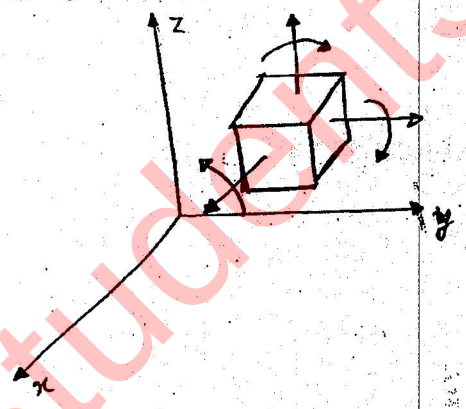
↓ utilise it.

Engg. — $\boxed{\text{Machine}}$ Desired o/p is obtained.

$\boxed{\text{Degree of Freedom}}$ (mobility)

"The minimum number of independent variables required to define the ~~position~~ position or motion of the system is known as Degree of Freedom of the system".

In general 3-D →



• Positional motion

Max. no. of motions $= 3T + 3R$

$= \underline{\underline{6}}$

DOF $= 6 - \underline{\text{Restraints}}$

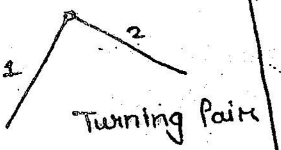
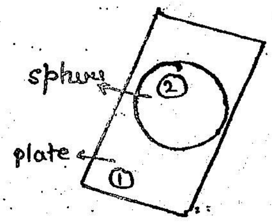
No. of those motions which are not possible.

* Restraints are always due to PAIR.

* LP → 1 DOF

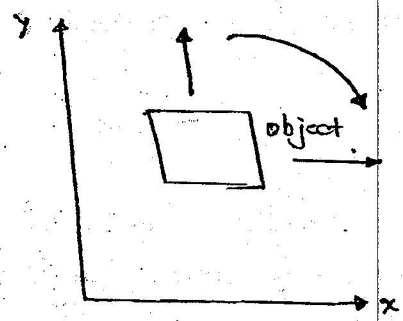
HP → 2 DOF

Spherical PAIR → $\underline{\text{DOF} = 3}$ **

Pair	Restraint	DOF
	$3T + 2R = \underline{5}$	$6 - 5 = 1$
	$1T$	$6 - 1 = 5$

* No a kinematic pair
∵ It is H.P
and HP = 2 DOF

Aim → To find the DOF of 2-D Planar mechanism.



max. no. of motions = 3

- No. of links = l
- No. of Binary joints = j
- No. of Higher pairs = h

* one link fixed

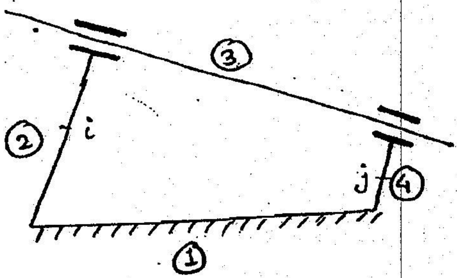
$$\boxed{F = \underbrace{3(l-1)}_{\text{No. of max. motions in 2D Planar Mechanism}} - 2j - h}$$

\# Kutzback's Eq^n

$$\boxed{F = [3(l-1) - 2j - h] - F_R}$$

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

motion which we can do or move by us by fixing all other link.



$l = 4$

$j = 4$

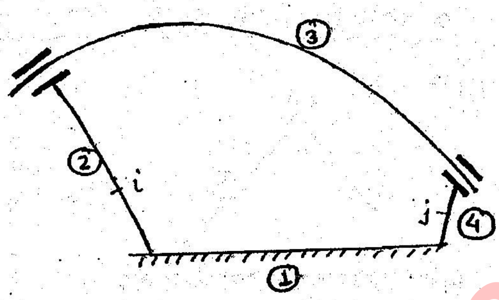
$h = 0$

$F_r = 1$

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

$= 9 - 8 - 1$

DOF $= \underline{0}$



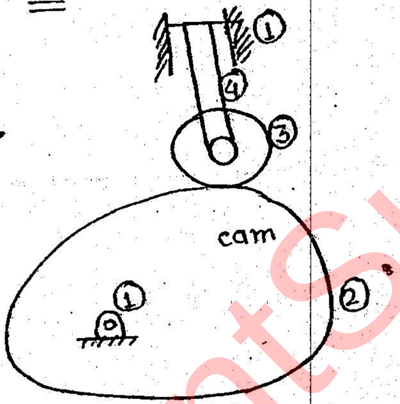
$l = 4$

$j = 4$

$h = 0$

$F_r = 0$

DOF $= \underline{1}$



$l = 4$

$j = 3$

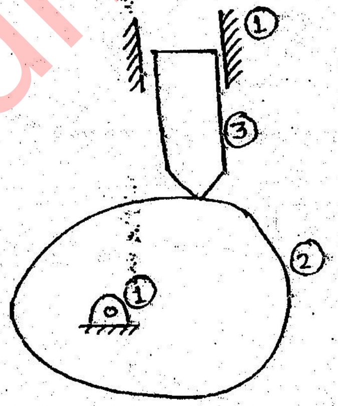
$h = 1$

$F_r = 1$

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

$= [9 - 6 - 1] - 1$

DOF $= \underline{1}$



$l = 3$

$j = 2$

$h = 1$

$F_r = 0$

$F = [3(3-1) - 2\times2 - 1] - 0$

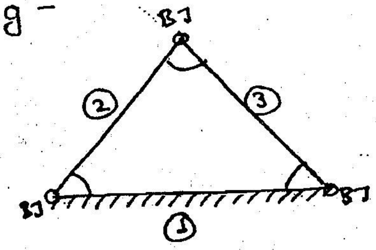
$= 6 - 4 - 1$

DOF $= \underline{1}$

$\boxed{\text{if } F = 0}$ →

No relative motion ⇒ Frame / structure

for eg –



$l = 3$

$j = 3$

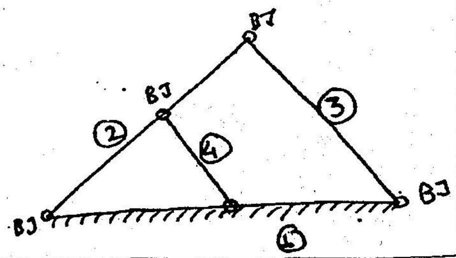
$h = 0$

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

$F = \underline{\underline{0}}$

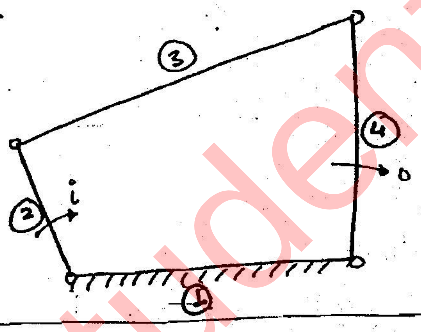
$\boxed{\text{if } F < 0}$ → $-1, -2, -3, \ldots$

Super structure ⇒ Indeterminate structure (No relative motion)



$l = 4$; $j = 5$; $h = 0$; $\boxed{F = -1}$

$\boxed{\text{if } F = 1}$ → Kinematic Chain

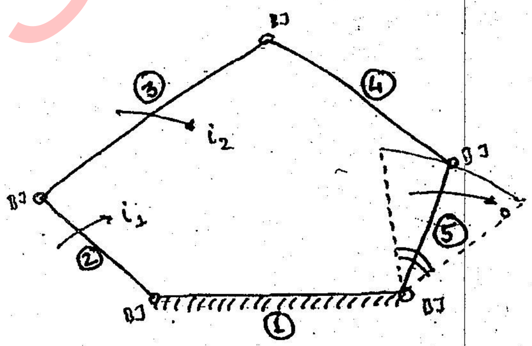


$l = 4$; $j = 4$; $h = 0$,

$F = \underline{\underline{1}}$

$\boxed{\text{if } F > 1}$ → $2, 3, 4, 5, \ldots$

Unconstrained chain



$l = 5$

$j = 5$

$h = 0$

$F = \underline{\underline{2}}$

NOTE →

"DOF is the number of Inputs required to get the constrained output in any chain".

An alternative way →

if $\left(j + \frac{h}{2}\right) = \left(\frac{3}{2}L - 2\right)$ → K.C

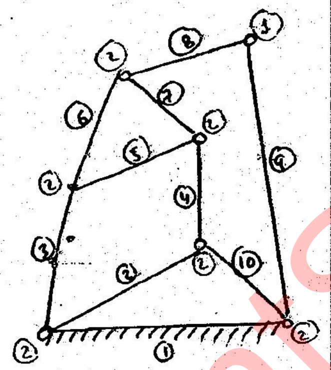
if $\left(j + \frac{h}{2}\right) > \left(\frac{3}{2}L - 2\right)$ → Frame / structure / Super structure.

if $(LHS - RHS) = 0.5$ → Frame / structure.

if $(LHS - RHS) > 0.5$ → Super structure.

if $\left(j + \frac{h}{2}\right) < \left(\frac{3}{2}L - 2\right)$ → Unconstraint chain.

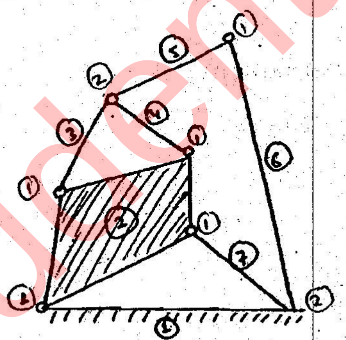
Note →



$L = 10$; $j = 13$; $h = 0$

$F = 3(10-1) - 2 \times 13 - 0$

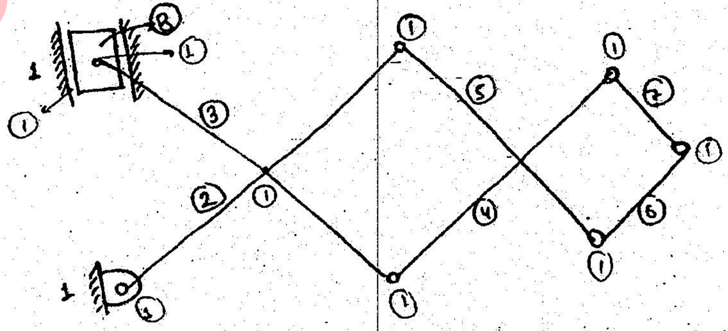
$F = 1$ K.C



$L = 7$; $j = 9$, $h = 0$

$F = 3(7-1) - 2 \times 9 - 0$

$F = 0$ Frame / structure

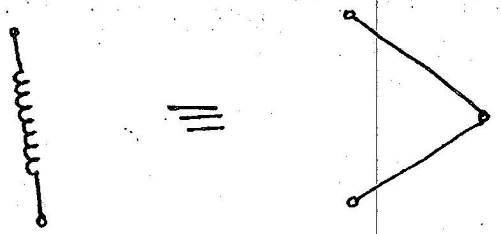


$L = 8$; $j = 10$; $h = 0$

$F = 1$

K.C

Spring as a Link :-



Grabler's Eq^n :-

For those mechanisms in which.

$F = 1$ & $h = 0$

Applied Kutzback's eq^n –

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

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

$(3l - 2j - 4) = 0$ # Grabler's Eq^n.

$(3l)_{always}$ = even

$(l)_{always}$ = even.

$\boxed{(l)_{min} = 4}$

→ First Mechanism in L.P.

→ Simple Mechanism

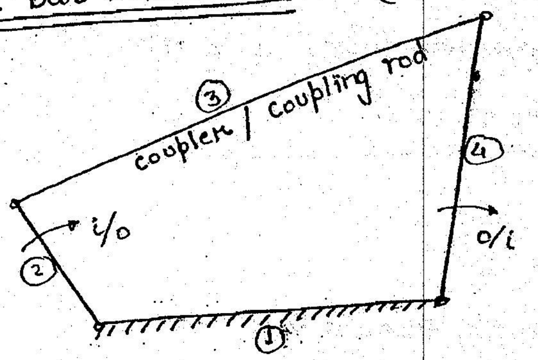
→ Four - bar mechanism

→ Single - Slider crank "

→ Double " " " –

Four Bar Mechanism (Quadric cycle Mechanism)

(4 Links + 4 T.P)



Best Position = Fixed position
(because it governs both $<^{i}_{o}$)

worst Position = coupler
(just a transmitting body)

Input / output links :
Having only one option of motion i.e. Rotation
→ complete Rotation (360°) = Crank
→ Partial Rotation (<360°) = Rocker / Lever
(oscillation)

Inversions : Mechanism which are obtained by fixing one by one different - different links.

if no. of link = l
no. of inversion ≤ l

1) Double crank Mechanism
2) Crank ↔ Rocker Mechanism
3) double rocker Mechanism

** Grashof's Law :-

" For the continuous relative motion b/w the number of links in a mechanism, the sumation of length of shortest and longest link should not be greater than the sumation of length of other two link "

For the continuous relative motion :

** $\boxed{s + l \leq p + q}$

Best position = Fixed
(because it governs both i & o)

Best link for complete rotation = s

if $(s + l < p + q)$ -
(law is satisfied)

1) s - Fixed ⟶ Double crank Mechanism
2) s - Adjacent to fixed ⟶ Crank - Rocker Mechanism
3) s - coupler ⟶ Double Rocker Mechanism.

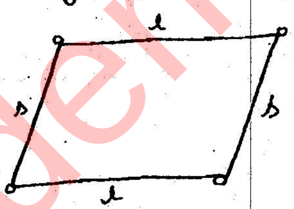
if $(s + l = p + q)$ -
(law is satisfied)

- Not having pair of equal links.
  2, 5, 4, 3

1)
2) same as previous.
3)

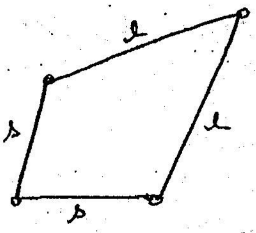
- Having the pair of equal links -
  2, 2, 5, 5

(1) Parallelogram Linkage



s - Fixed → Double - Crank
l - Fixed → Double - crank

(2) Deltoid Linkage :



s - Fixed → Double - crank
l - Fixed → Crank - Rocker.

if $(s+l) > (p+q)$

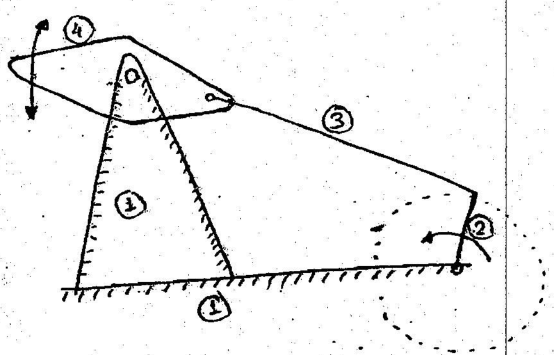
law is not satisfied -

- Any link fixed → Double Rocker Mechanism.

Some practical applications of 4-Bar Mechanism :-

1) Beam Engine Mechanism

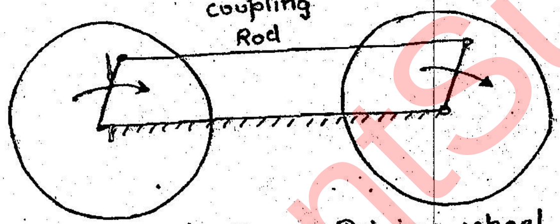
(Sir James watt)



Rotation ⟷ oscillation

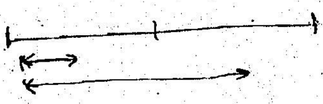
crank ⟷ Rocker Mechanism

2) Coupling Rod of Locomotive -



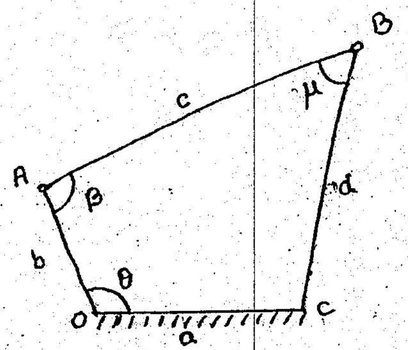
Parallelogram linkage
⇓
Double crank.

$\left[(B \cdot b \omega^2)\right] \leq$ Per wheel static load
↳ limited   to prevent hammer blow.



Transmission Angle (μ) in 4 Bar Mech :-

" An angle b/w the coupler link and output link in 4-Bar mechanism is known as transmission angle



Cop rule -

$$AC^2 = (a^2 + b^2 - 2ab\cos\theta) = (c^2 + d^2 - 2cd\cos\mu)$$

Diff. both side -

$$-2ab(-\sin\theta)\,d\theta = -2cd(-\sin\mu)\,d\mu$$

$$\boxed{\frac{d\mu}{d\theta} = \left(\frac{ab}{cd}\right)\frac{\sin\theta}{\sin\mu}}$$

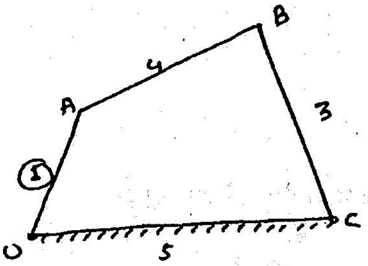
for μ to be max or min -

$$\frac{d\mu}{d\theta} = 0$$

$$\sin\theta = 0$$

$$\underbrace{\theta = 0^\circ}_{\mu_{min}},\ \underbrace{180^\circ}_{\mu_{max}}$$

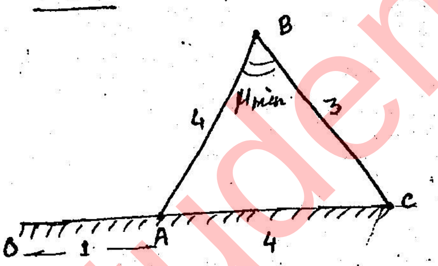
Q→



Find, $\mu_{min} = ?$

$\mu_{max} = ?$

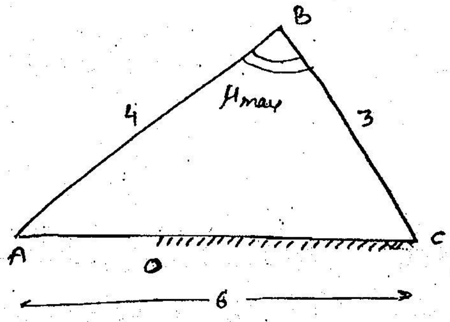
μ_{min} : $\theta = 0^\circ$



$$(4)^2 = 4^2 + 3^2 - 2(4,3)\cos\mu_{min}$$

$$\mu_{min} = \text{—}$$

μ_{max} : $\theta = 180^\circ$



$$(6)^2 = 4^2 + 3^2 - 2(4\times3)\cos\mu_{max}$$

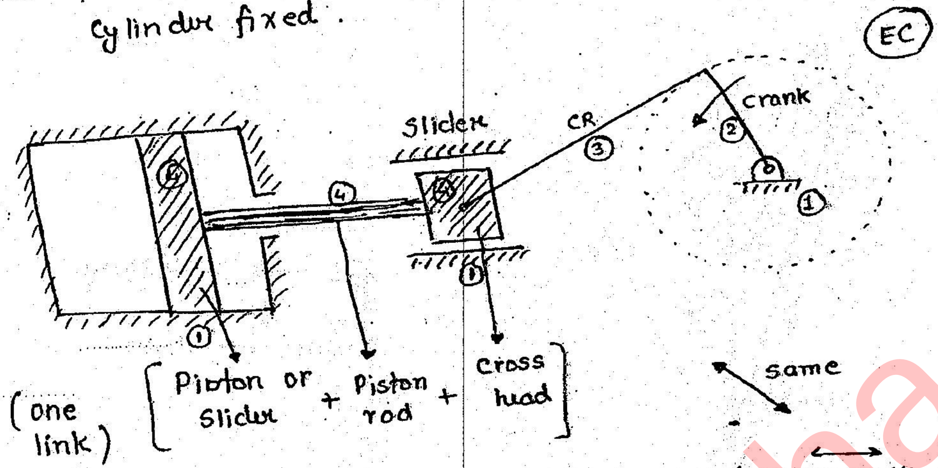
$$\mu_{max} = \text{—}$$

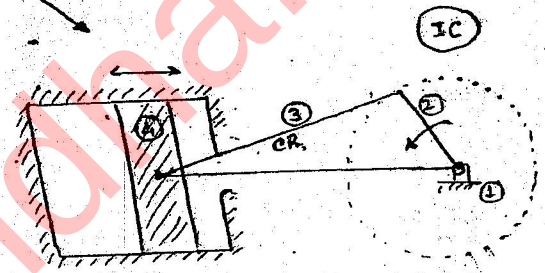
Single Slider - Crank Mechanism :-

(4 links + 3 T.P + 1 S.P)

I-Inversion (Basic)

Cylinder fixed .





1) 1st Inversion -

Cylinder fixed -

Rot ⟷ Reciprocating .

(crank) ⟷ piston

(o) ⟵ (i) = Reciprocating Engine

(i) ⟶ (o) = Reciprocating combustion .

2) II Inversion -

crank fixed - a) whitworth Quick Return motion mechanism

b) Rotary IC engine mechanism (GNOME Engine)

3) III Inversion - * Best :

CR fixed - a) CRANK and slotted Lever QRMM

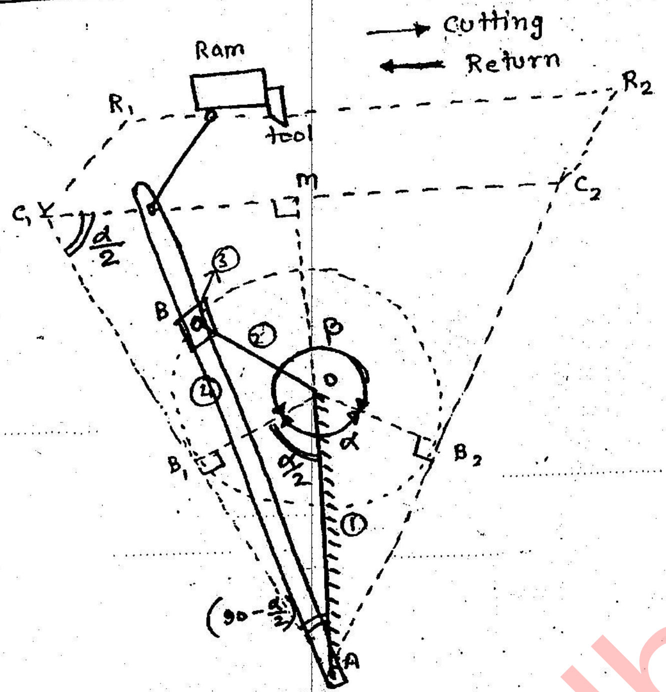
b) oscillating cy engine mechanism .

4) IV Inversion -

Slider fixed - Hand Pump (Pendulum pump)

(Bull Engine)

Crank and slotted lever QRMM :- III Inversion ; CR fixed.



Motion

Rot → oscillatory

Crank → Rocker.

stroke -

$= R_1 R_2$

$= (C_1 C_2)$

$= 2\,(C_1 m)$

$= 2\,(AC_1)\cos\frac{\alpha}{2}$

$= 2\,(AC_1)\frac{(OB_1)}{(OA)}$

$= \frac{2\,(AC_1)\,OB}{(OA)}$

$$\boxed{\text{stroke} = \frac{2\,(\text{length of sloted bar}) \times (\text{length of crank})}{(\text{length of CR})}}$$

β → cutting stroke angle

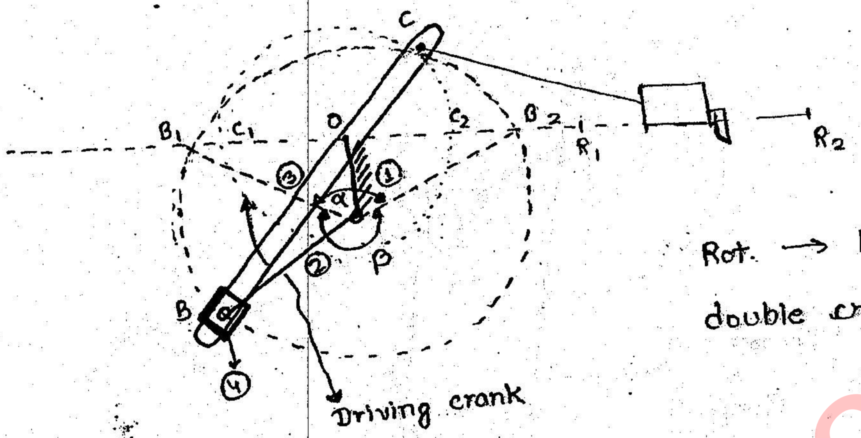
α → Return stroke angle

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

$\alpha < \beta$ = QRMM

Quick return ratio (QRR) $= \frac{(\text{time})_{\text{cutting}}}{(\text{time})_{\text{return}}} = \left(\frac{\beta}{\alpha}\right)$ (always > 1)

Whitworth QRMM : II^{nd} Inversion → (crank fixed)



Rot → Rot

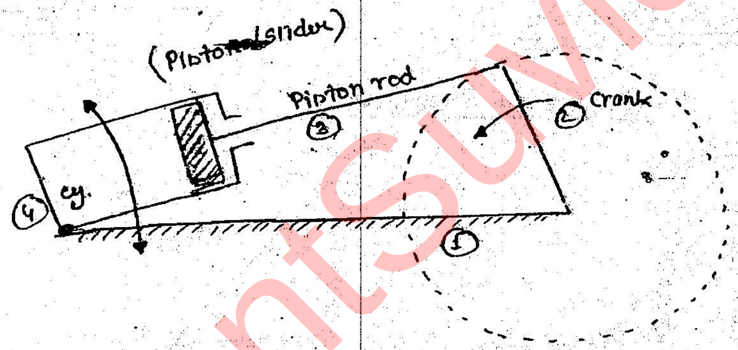
double crank

Stroke →

$R_1 R_2$

$= C_1C_2 = 2(OC)$

Oscillating cy. Engine Mechanism : III inversion (CR Fixed).



Rot ⟷ oscillatory

crank ⟷ Rocker.

Rotary IC Engine - G.NOME Engine → II inversion → crank fixed

when combustion takes place inside the cylinder

⇓

Input force comes on piston

⇓

This force is transmitted to CR

⇓

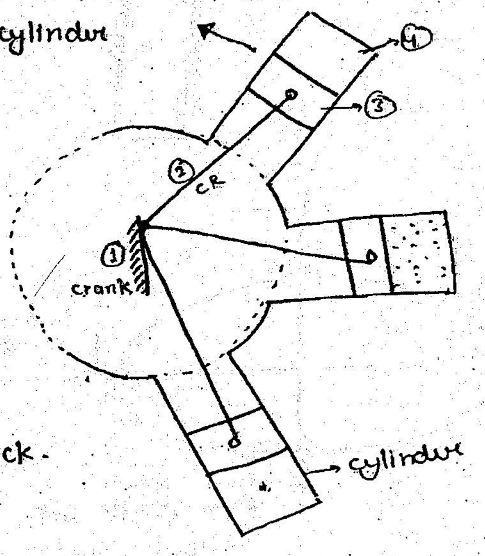
CR and piston both rotates

⇓

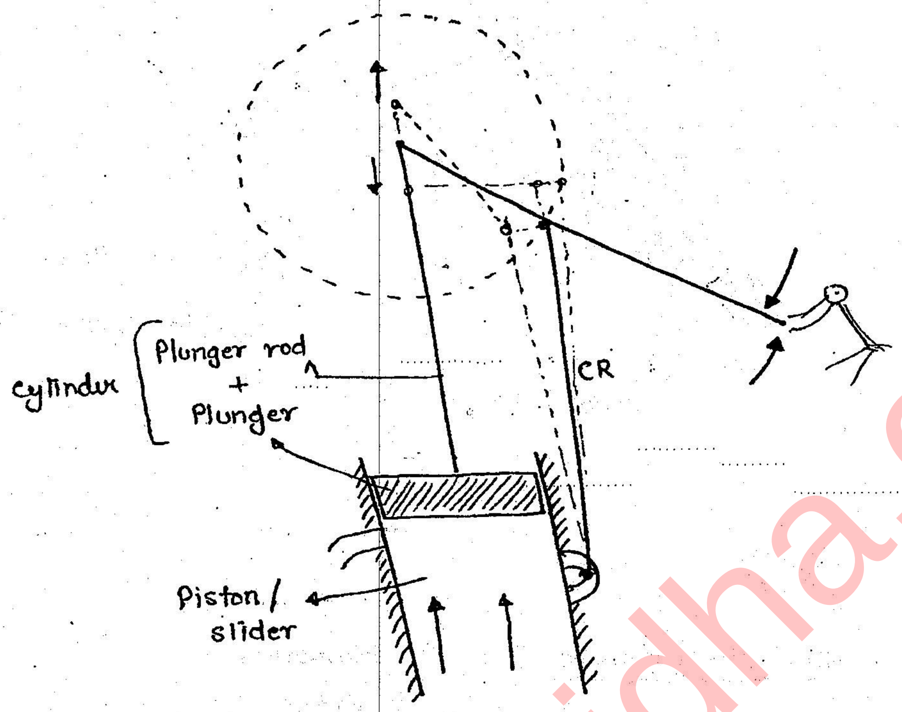
cy. block rotates (output)

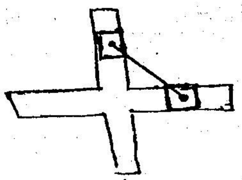
⇓

propeller is mounted on cy. block.



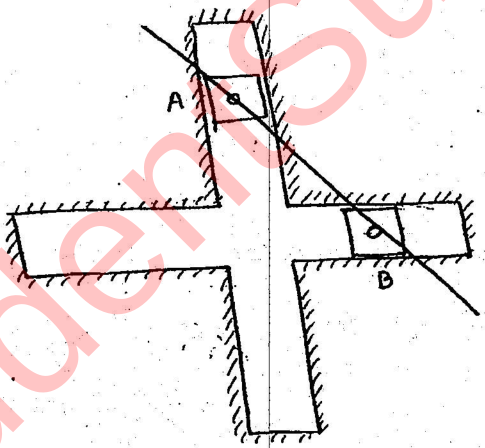
Hand Pump : Pendulum pump or Bull Engine → IV Inversion → slider fixed.

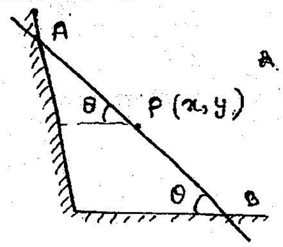




Double Slider Crank Mechanism :-

(1) Slotted Plate is fixed → Elliptical Trammels



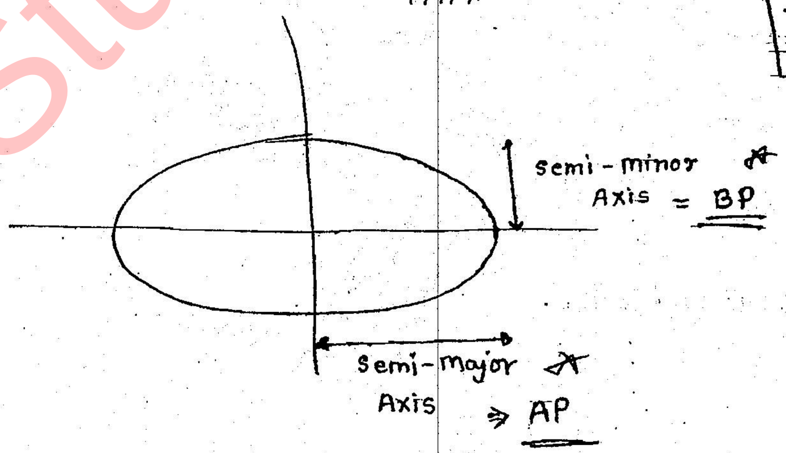


$\cos\theta = \frac{x}{AP}$

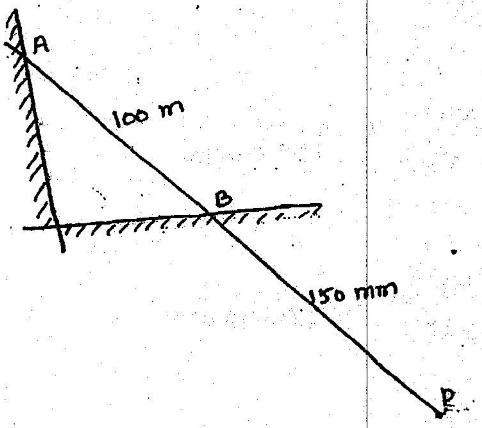
$\sin\theta = \frac{y}{BP}$

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

Ellipse



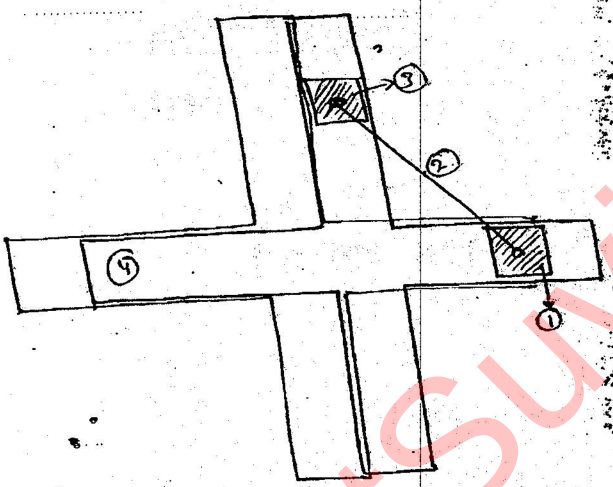
Q →



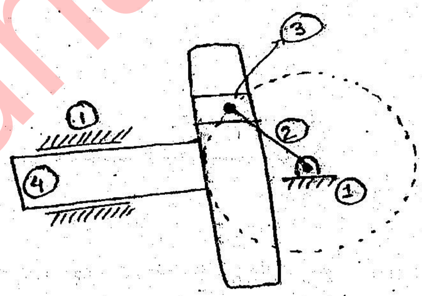
Major Axis = 2 AP
= 2×250 = 500 mm

Minor Axis = 2 BP
= 300 mm

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



Rotary → Reciprocatory .



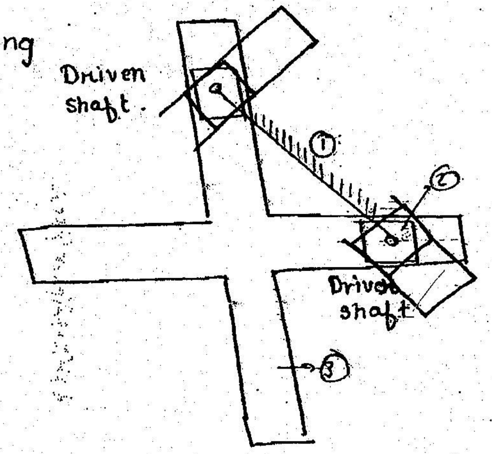
3) If link connecting slider is fixed :-
(oldham's Coupling)

It is used to connect the shaft having lateral mis alignment .

Max . sliding velocity - of the intermediate plate (link-3)

$= (r\omega)$

$= (\text{Distance b/w the shaft}) \times \omega_{\text{DRIVER}}$



Mechanical Advantage (MA) :-

$$MA = \frac{F_{output}}{F_{input}} \longrightarrow MA = \frac{V_{input}}{V_{output}} \times \eta_{mechanism}$$

or

$$MA = \frac{T_{output}}{T_{input}} \longrightarrow MA = \frac{\omega_{input}}{\omega_{output}} \times \eta_{mechanism}$$

Efficiency :-

$$\eta_{mechanism} = \frac{P_{output}}{P_{input}}$$

$$= \frac{F_{output} \times V_{output}}{F_{input} \times V_{input}} = \frac{T_{output} \times \omega_{output}}{T_{input} \times \omega_{input}}.$$

Q →

Find MA = ?

In the sense of rotation -

$\omega_{input} = \omega$

$\omega_{output} = 0$

$$M.A = \frac{\omega}{0} = \infty \qquad \text{(No rotation, only reciprocation)}$$

Rot ⟶ Reciprocation

(Rotation of ∞ radius)