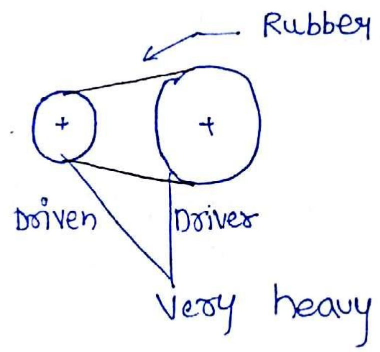
Simple Mechanism

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

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

A link must be rigid Resistant



(Not a link if weigh is more)

If it is case of plastic driven/driver i.e. Very small weight then we can say ~~it is~~ Rubber band a link.

Types of link :

① **Rigid link** :- Deformation are negligible (microscopic)

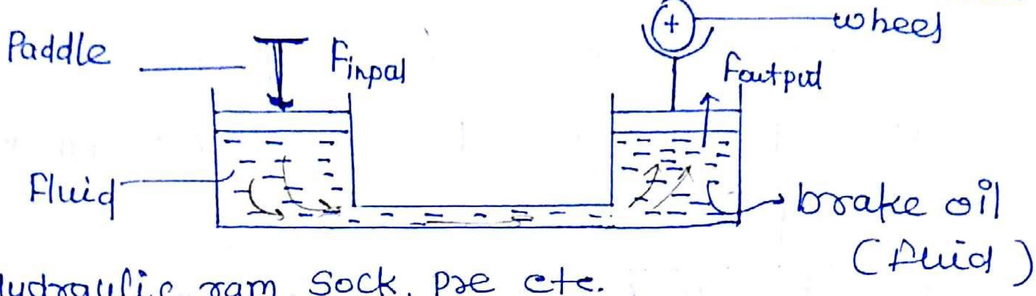
For eg :- Crank, Connecting rod, piston, Cylinder

All rigid links in a mechanism treated as single link.

2. Flexible link :- Deformation are not negligible but are in permissible limit.

eg:- Belt drive, Rope drive, chain drive.

3. Fluid link :- when power is transmitted due to fluid pressure



eg. Hydraulic ram, Sock, Pre etc.

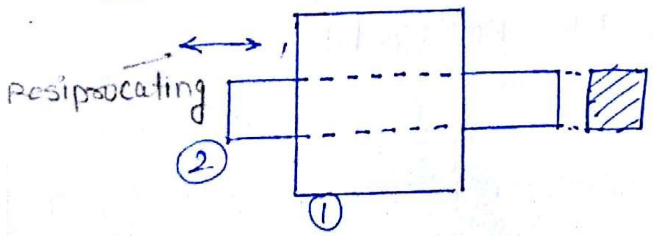
* Hydraulic turbine is not a case of link ~~it~~ as there is conversion of energy not transmition.

Different type of Relative Motion:

For a Relative motion
↳ system is having Two Links

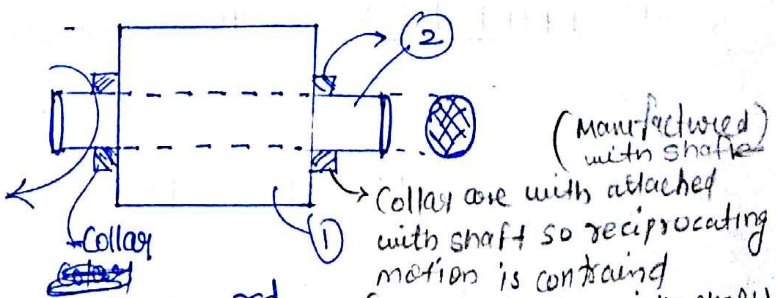
(1) Completely Constrained motion :- (Desired motion)
(Self)
100% Constrained

eg one direction motion



Square rod in sq. hole
only one motion.

eg.

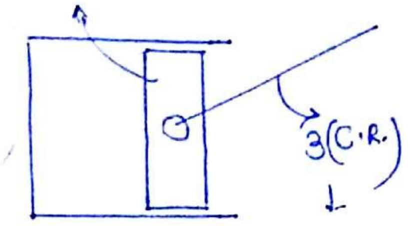


Circular rod in (Collar will rotate with shaft)
Circular hole with Collar.

2) Successfully constrained motion (Desired Motion)
↳ (Forcefully)

eg.

② Pistion

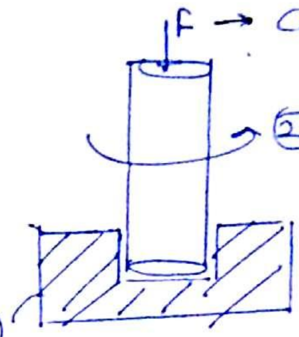


① Cy.

↓
Constraint.
(Force Fully)
since force is passing through the center so net torque is zero

eg. Shaft in foot - step bearing

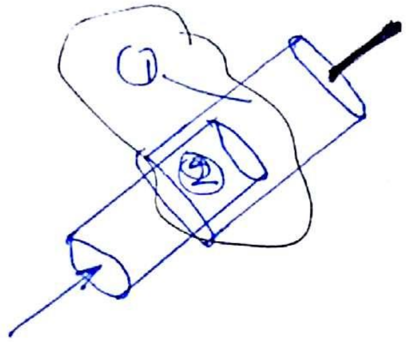
F → Constraint.
(Force fully)



② only shaft rotate because there is load above shaft in foot step bearing.

① & ② are link in every diagram

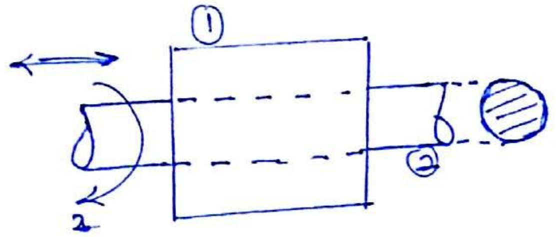
eg. Syrings → Suck and inject.
सिरिंज



Cylindrical pair
→ Doctor's Injection syringe
→ screw driver operating on screw.

(3) Unconstrained motion:-

eg. two motions



completely constrained motion
successfully constrained motion } – Desired motion (both are 100% constrained)
unconstrained motion

Kinematic Pair:- Any connection b/w the two links is always a joint or pair but this pair will only be a kinematic pair if the relative motions b/w link is a constrained motion.

Classification of kinematic pairs:–

(A) According to the type of Relative motion

- **Turning pair (Revelute pair) (Pin- Joint)**

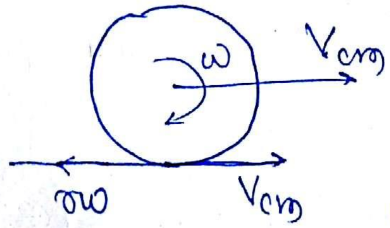
  Relative motion is pure turning

- **Sliding pair (Prizmatic Pair)**

  Relative motion is pure sliding
  eg. key in key way.

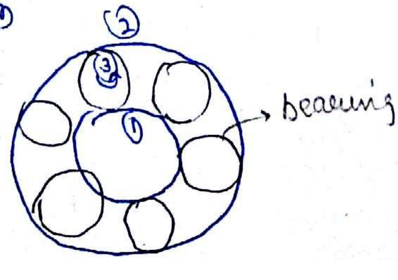
- **Rolling Pair:-**

  Relative motion is pure rolling
  ⇓
  Rolling without sliding



Condition of pure rolling $\boxed{V_{cm} = R\omega}$

eg. Ball Bearing



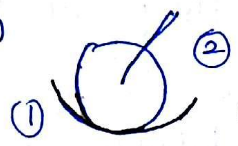
- Screw pair:- when the relative motion over the thread

eg. Nut - bolt {dependant motion}

- Spherical Pair: (Ball in Socket Joint)

Relative motion is 3-D Rotation (Spherical Motion)

{Ball in Socket



at microscopic level it have a point contact

B] According to the type of contact

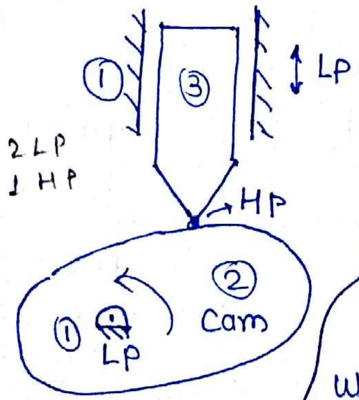
- lower pair: Surface Contact { turning pair, sliding pair }
- Higher pair: Point / line Contact { Rolling Pair }
- Wrapping pair: when one link is wrapper over the other link

eq: Belt - Pulley

In belt and pulley we increase the friction so the belt can rotate the pulley, + we can say ∞ No. of HP in case of belt & pulley.

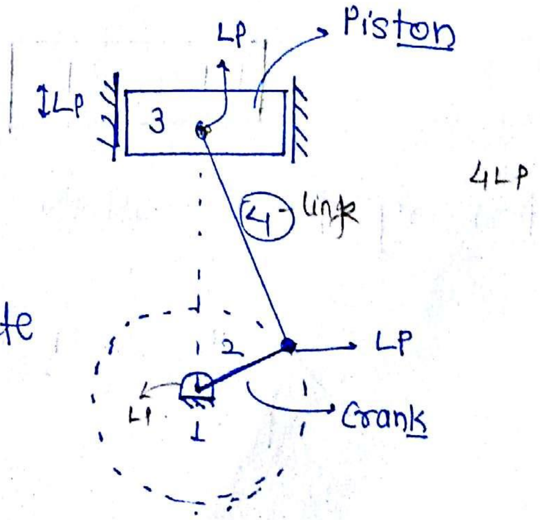
* 1 HP = 2 LP

eg



≡

To eliminate HP we have to add 2LP



C] According to type of Closure:-

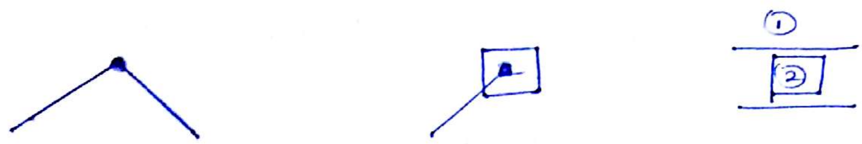
- Self closed Pair (Closed pair):- permanent Contact
- Force closed pair (open pair): Force Full Contact

eg:- - Higher Pair in Cam & Follower
- Door closers
- Automatic clutches Operating System.

18/10/2016

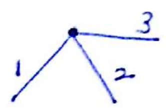
Different Types of Pair/ Joints:

- Binary Joint:- where two links are Connected



1TP

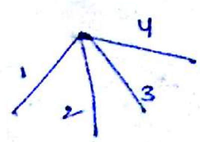
- Ternary Joint: where three links are connected



(1, 2) → B
(2, 3) → B
(1, 3) → B One is independent

1T = 2B 2LP

- Quaternary Joint: where Four link are Connected



(1,2) (1,3) (1,4)
(2,3) (2,4)
(3,4)
} other three are independent

1Q = 3B 3LP

kinematic chain :- " If all the links are connected in such a way such that the first link is connected to last link in order to get close chain and if all the relative motion in this chain are constrain then such a chain called kinematic chain."

kinematic chain also callad
(constrained chain)

↓ To use this chain one link Must be fixed

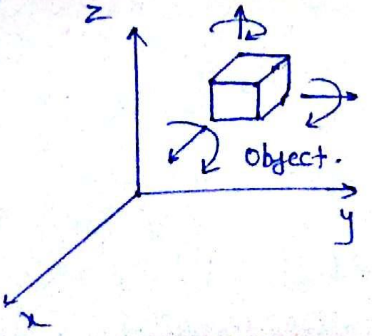
Mechanism → which can gives the desired o/p w.r.t. given I/p
{What??} (science) (concept)

↓ Utilize it

Engg → Machine → Desired ~~op~~ o/p is obtained
{How??}

Degrees of freedom (Mobility) :- " The minimun number of Independent is require to define the position or motion of system is know as DOF of the system."

In General (3-D) system

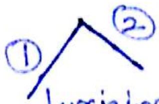
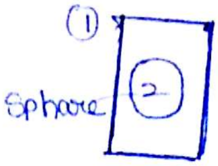


⇒ max. No. of motions = 3 tran. + 3 Rot.
= 6

DoF = 6 − [Restraints]

No. of those motion which are not possible

* Restraints are always due to "PAIRS"

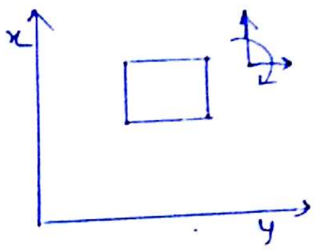
Pair	Restraint	DoF
 turning pair	5 (3T + 2R)	6 − 5 = 1
	1T = 1	6 − 1 = 5

* { 1LP − 1 DOF
  1HP − 2 DOF } Always → 1HP = 2LP

{ Spherical Pair − 3 DOF

Aim:- To find out the D.O.F. of (2-D) planer mechanism

In (2-D) system



max. No. of possible motions = 3

No. of link = l

No. of Binary joint = j

No. of Higher pair = h

one link is fixed

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

- $3(l-1)$ ⇓ No. of max. motion in (2-D) planner mechanism
- $2j$ ⇓ 1 LP ⇒ 1 DOF ↓ block 2 motion (2 Restraint by 1 LP)
- h → 1 HP ⇒ 2 DOF ↓ block 1 motion (1 Restraint by 1 HP)

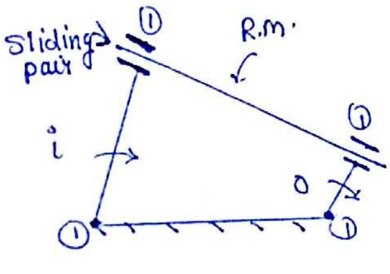
Kutzback's eqn

☆ $$\boxed{F = 3(l-1) - 2j - h}$$

Redundant motion

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

1.

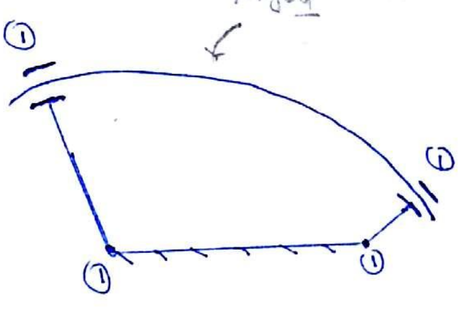


$l = 4$
$j = 4$
$h = 0$
$f_r = 1$

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

$F = 0$

2.

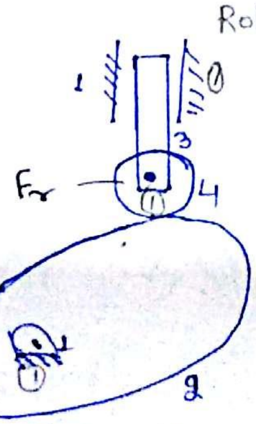


$l = 4$
$j = 4$
$h = 0$
$f_r = 0$

$F = 1$

3.

Rollor follower best

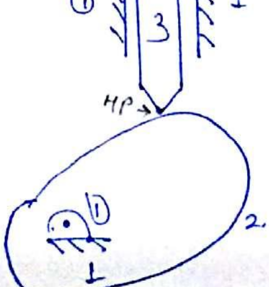


$l = 4$
$j = 3$
$h = 1$
$f_r = 1$

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

4.

(knife edge follower worst)



$l = 3$
$j = 2$
$h = 1$
$f_r = 0$

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

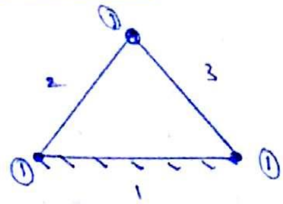
$F = 1$

If F = 0

No Relative motion

Frame/ structure

For exm:



$l = 3$

$j = 3$

$h = 0$

$F = 0$

If F < 0

⇒ −1, −2, −3 . . .

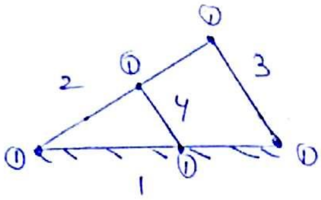
Super structure

(Indeterminate structure)

No Relative motion

used for load bearing

For exm.



$l = 4$

$j = 5$

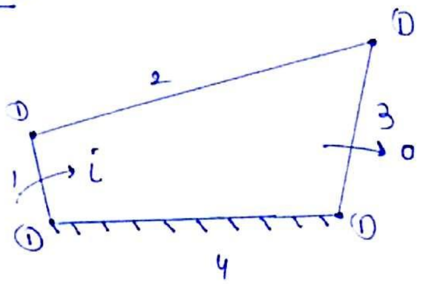
$h = 0$

$F = -1$

If F = 1

kinematic chain

For exm:



$l = 4$

$j = 4$

$h = 0$

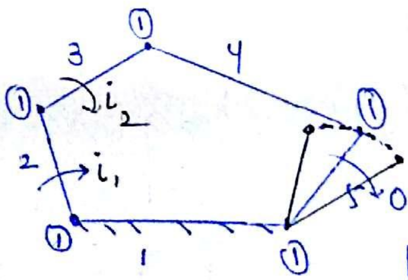
$F = 1$

If F > 1

i.e. 2, 3, 4 - -

Unconstrained chain

For exm.



$l = 5$

$j = 5$

$h = 0$

$F = 2$

* DOF is the no. of input required to get the unstrained output in any chain.

An Alternative way :- (don't apply unless not Given)

If $\left(j + \frac{h}{2}\right) = \left(\frac{3}{2}l - 2\right)$ kinematic chain

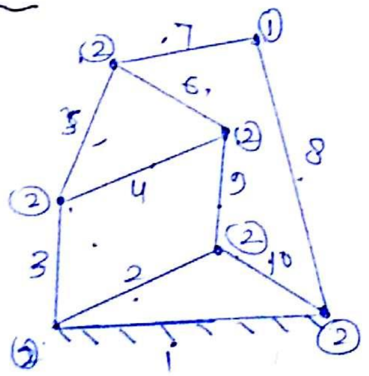
If $\left(j + \frac{h}{2}\right) > \left(\frac{3}{2}l - 2\right)$

$\Rightarrow$ (L.H.S − R.H.S) = 0.5   frame/structure

$\Rightarrow$ (L.H.S − R.H.S) > 0.5   super structure

If $\left(j + \frac{h}{2}\right) < \left(\frac{3}{2}l - 2\right)$ Unconstrained chain

Note:-



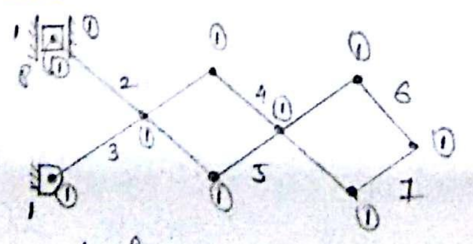
$l = 10$

$j = 13$

$h = 0$

$F = 1$ k.c.

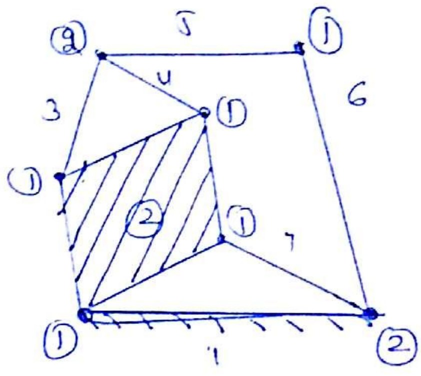
eg



$l = 8$

$j = 10$

$F = 21 - 20 = 0$



$L = 7$

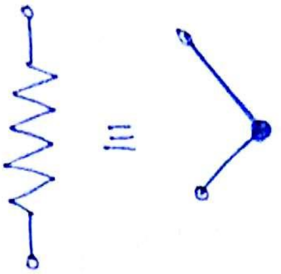
$j = 9$

$h = 0$

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

$\boxed{F = 0}$

Spring as a link :-



link of flexible length
(variable length

Grubler's eq^n

for those mechanism which have $\boxed{F = 1 \;\&\; h = 0}$

applied kutzback's eq^n

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

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

$$\boxed{3l - 2j - 4 = 0}$$ Grubler's equation

* $(3l)_{always} \Rightarrow$ even

$(l)_{always} \Rightarrow$ even

$(l)_{min} = 4 \rightarrow$ First mechanism with LP

⇓

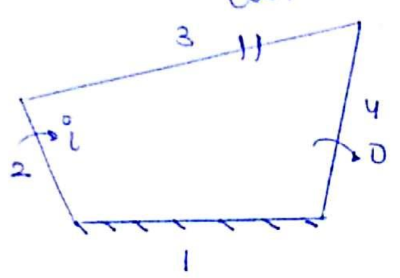
Simple mechanism

All mech have $l = 4$, $f = 1$, $h = 0$ →
- four bar mechanism
- single slider mechanism
- Double slider mechanism

Four Bar Mechanism :-

V. Imp

Quadric Cycle Mechanism ⇒ 4 links + 4 TP



Best position

Fixed (bcoz it governs) both — i/p, o/p

Coupler ⇒ which connect input & output

Worst Position

Coupler (just a transmitting body)

Input/Output link :-

Having only option of rotation

- Complate rotation (360°) ⇒ Crank — it can be input, can be output.
- Partial rotation (< 360°) ⇒ Rocker / lever

Inversion : Mechanism which are obtained by fixing one by one diff-diff link.

In four bar

1. Double - crank mechanism
2. Crank ↔ Rocker mechanism
3. Double Rocker Mechanism

if Input ⟷ output it treated as single (one) inversion

In General If No. of links = l

No. of Inversions $\leq l$

Imp

Grashof's law:– "For a Contineous relative motion between the number of links in the mechanism the sumation of shortest and longest length sould not be greater than the sumation of other two links."

For continous Relative motion

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

Best position → fixed

Best link for Complate Rotation → s

If $(s+l) < (p+q)$ law satisfied

1. s → fixed → Double crank
2. s → Adjecent to fixed → Crank – Rocker
3. s – Coupler → Double Rocker

If $(s+l) = (p+q)$ law satisfied

Not having pair of equal links

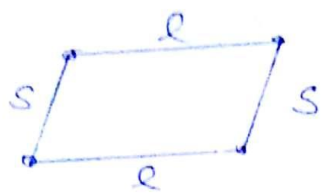
eg. 5, 2, 4, 3

Same as previouse.

If $(s+l) = (p+q)$ law satisfied

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

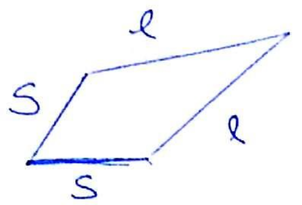
1. Parallelogram linkage



s - fixed → Double crank

l - fixed → Double crank.

2. ~~Det~~ Deltoid linkage



s - fixed → Double crank

l - fixed → crank Rocker

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

law not satisfied

⇓

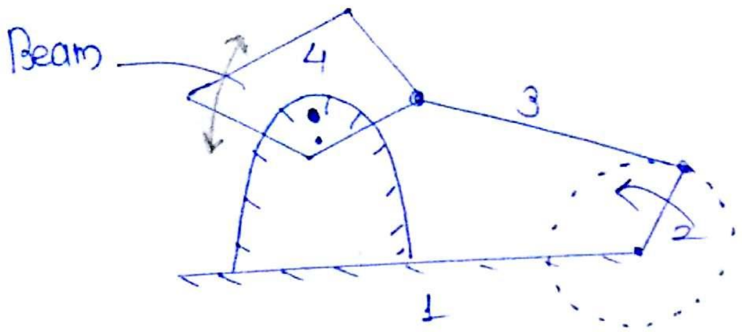
Any link fixed

⇓

Double ~~crank~~ Rocker/lever

Some Practical Application of 4-Bar Mechanism

1. Beam Engine mechanism

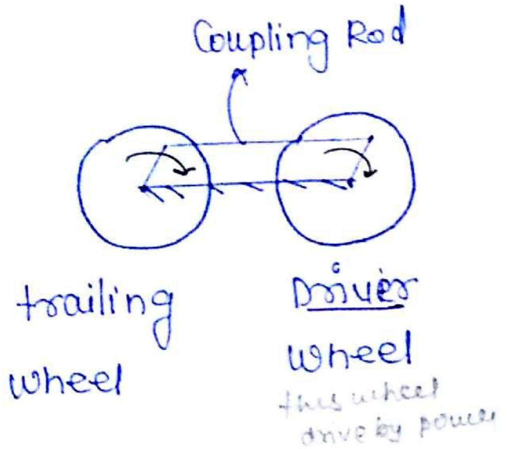


Rotation ↔ oscillation

crank ↔ Rocker

1st steam engine by James watt was based on this but due to less efficient it desolve.

2. Coupling Rod of locomotive:-



Rotation → Rotation

Double crank

Parallelogram linkage

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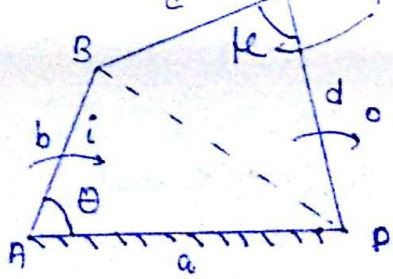
Transmission Angle:- (μ):- "The angle between the coupler link and output link in four bar mechanism is known as transmission angle."



C transmission angle

apply Cosine Rule

$$BD^2 = a^2+b^2-2ab\cos\theta$$

$$= c^2+d^2-2cd\cos\mu$$

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

Diff both side

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

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

for μ to be max. & min

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

$\Rightarrow \sin\theta = 0$

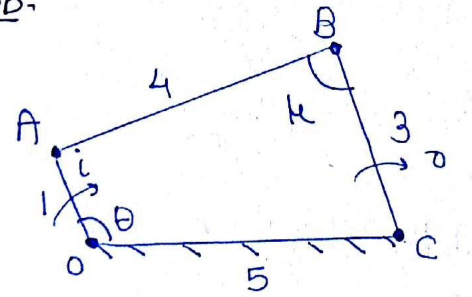
$\theta = 0°, 180°$

$0°$ → min, $180°$ → max.

Befor calculating μ check the triangle identity $a+b>c$

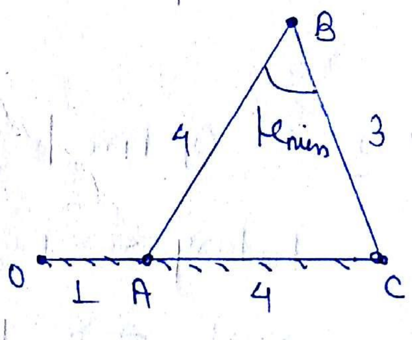
Read transmission angle for single slide in conv. notes

Prob.



Find μ_{max} & μ_{min} = ?

$\mu_{min} = (\theta = 0°)$



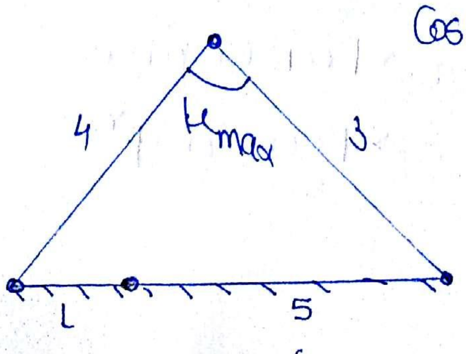
Check Δ law

$4+4>3$

Valid

Cosine Rule $\Rightarrow (4)^2 = (4)^2 + (3)^2 - 2(4)(3)\cos\mu$

$(\mu)_{min} = 67.95°$



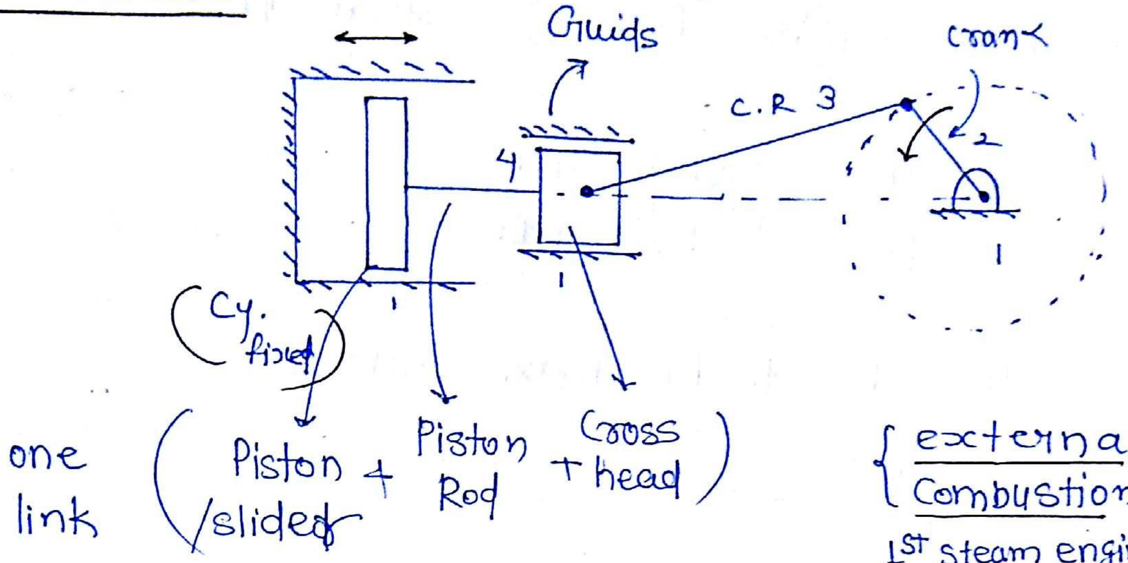
$4+3>6$ (Valid

$(6)^2 = (4)^2 + (3)^2 - 2(4)(3)\cos\mu$

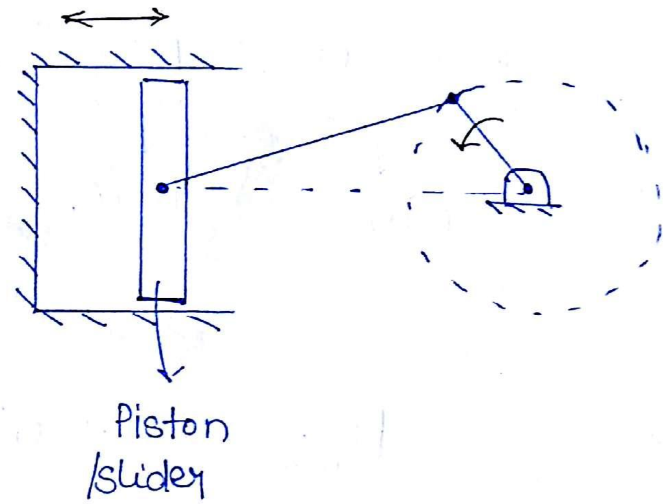
$(\mu)_{max} = 117.27°$

Single - slider - Crank Mechanism :- Drag link mechanism
(4l + 3TP + 1SP)

1st Inversion



{ external / Combustion }
1st steam engine was made on this mechanism.



{ Internal Combustion }

1st Inversion :- Cy. fixed (cylinder is fixed)

Rotary ↔ Reciprocatory

Crank ↔ Piston

output ← input → Reci. engine

input → output → Reci Compr.

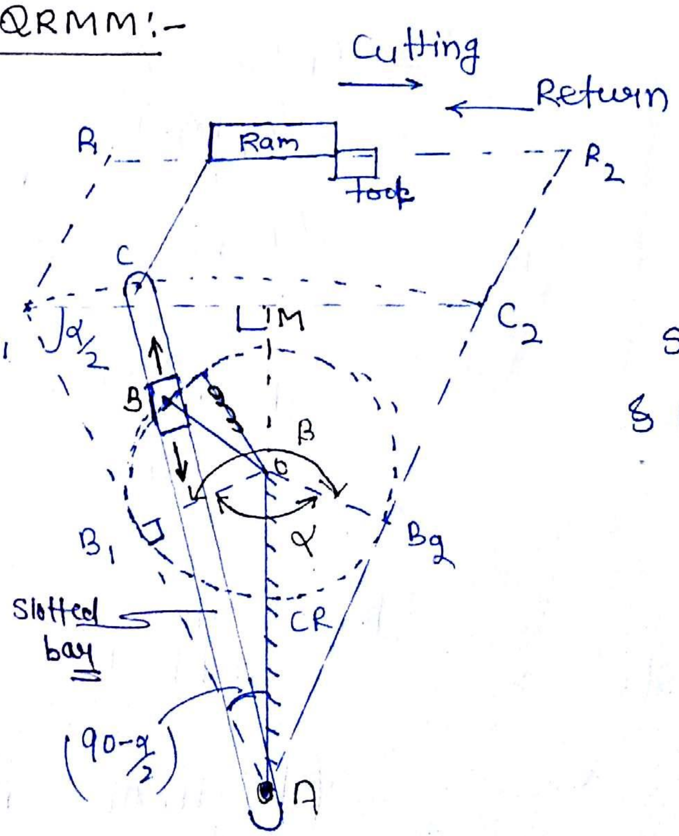
II Inversion: — ~~whitworth~~ whitworth quick return motion mechanism (qrmm)
(Crank fixed) — Rotary Ic engine (Gnome engine)
earlier this was used in Aircraft

III Inversion: — Crank & slotted lever QRMM (Best)
(C.R. fixed) — oscillating Cy. engine mechanism

IV Inversion → Hand pump (pedulum pump)
(Slider fixed) (Bull engine)

Crank & slotted lever QRMM:-

III Inv.
(CR fixed)



used in shaper & planer.

motion
⇓
Rotary → oscillation

Crank → Rocker.

Notations

β - Cutting stroke angle

α - Return stroke angle

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

$$\alpha < \beta \quad (QRMM)$$

Quick Return Ratio (QRR)

$$(QRR) = \frac{(\text{time})_{\text{cutting}}}{(\text{time})_{\text{return}}} = \frac{\beta}{\alpha}$$

{Always > 1}

if it is given less (< 1 than then take α/β = < 1

Stroke ⇒

$$\text{Stroke} = R_1 R_2$$

$$= C_1 C_2$$

$$= 2(C_1 m)$$

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

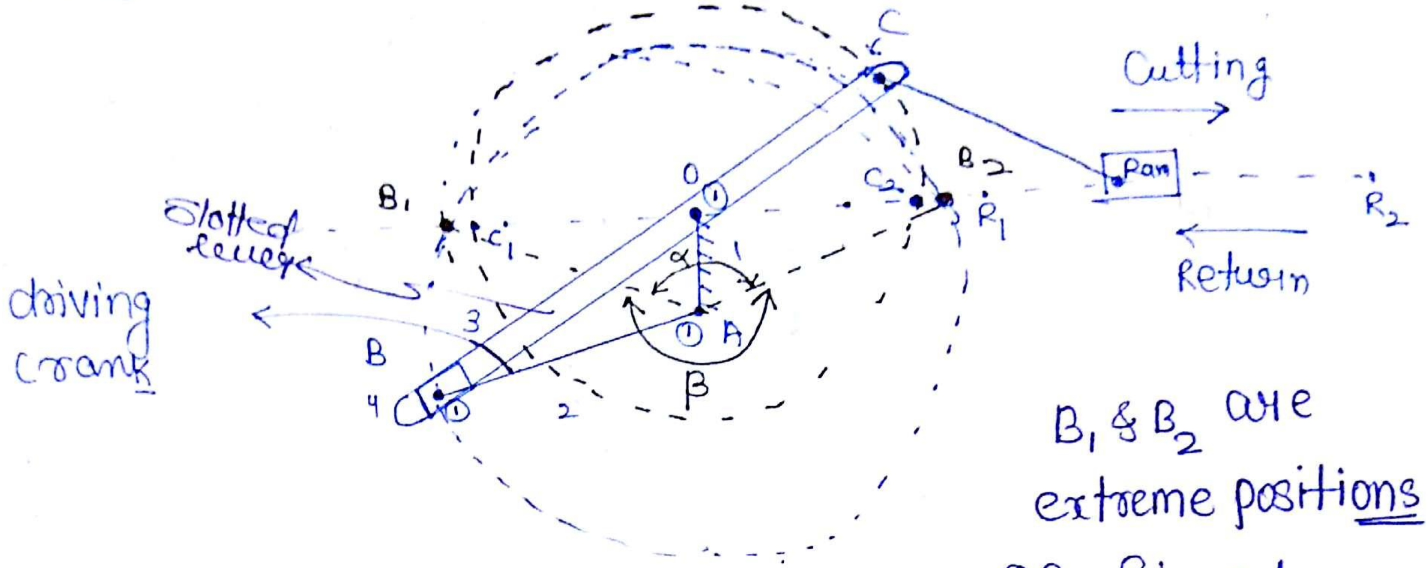
$$= \frac{2(AC)(OB)}{(OA)}$$

$$\text{Stroke} = \frac{2\begin{pmatrix}\text{length of} \\ \text{slotted bar}\end{pmatrix} \times \begin{pmatrix}\text{length of} \\ \text{crank}\end{pmatrix}}{(\text{length of C.R.})}$$

Whitwarth QRMM:-

Crank Fixed

II inv.



B1 & B2 are extreme positions

OA - fixed

Rot. ⟶ Rot. (Double crank)

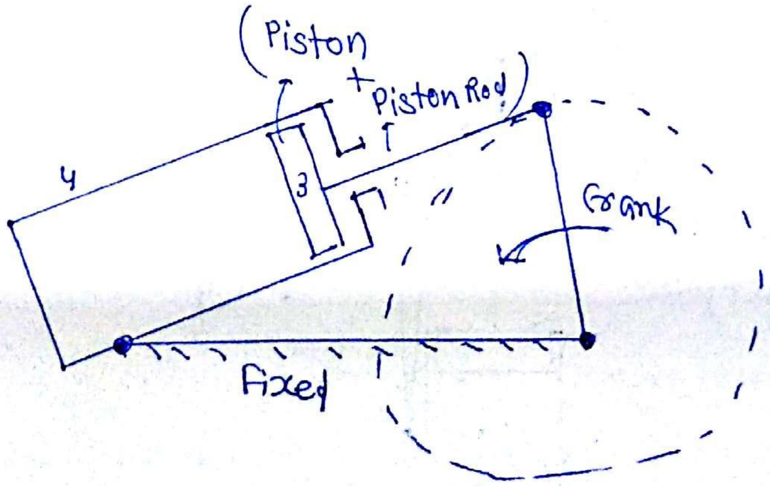
Stroke:- $R_1 R_2$

$= C_1 C_2$

$= 2(OC)$

Oscillating Cylinder Engine Mechanism

III Inv. (C.R. fixed)



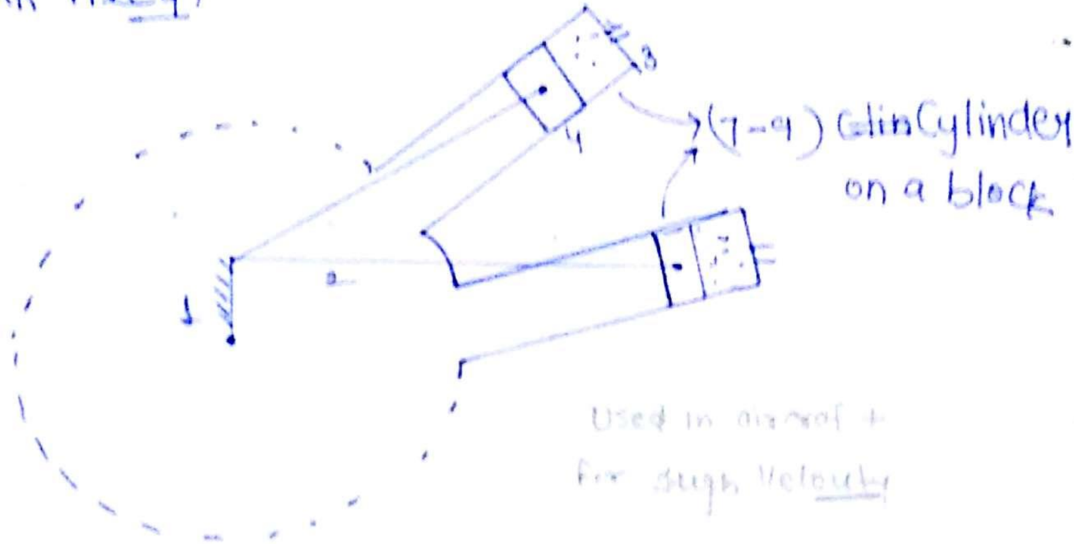
Rot → oscillation

Crank-Rocker

Rotary Ic engine:-

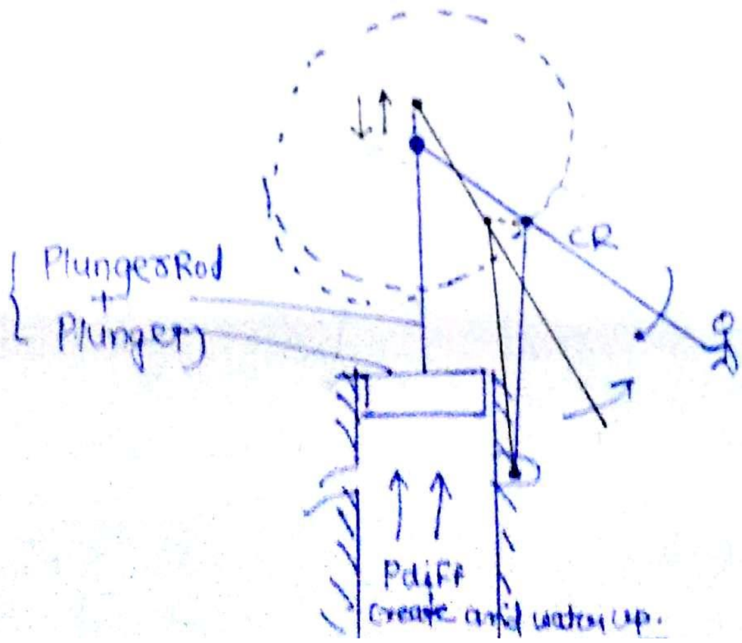
Gnome engine

II inv. (crank fixed)

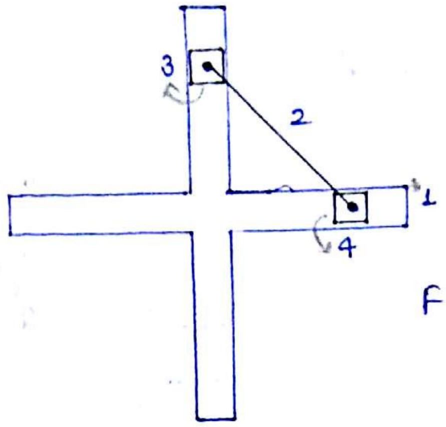


- When combustion takes place Inside the Cylinder input Force comes one the piston this force is transmitted to C.R. C.R. and piston both rotate then Cylinder block rotate Propeller mount on this block.

Hand Pump: (IV) Inversion (Slider Fixed



Double slider - Crank chain :-



4 link

2 TP

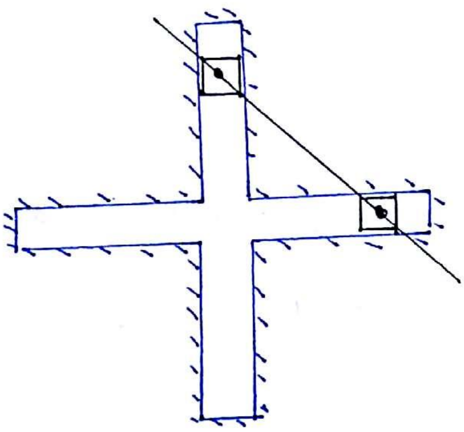
2 SP

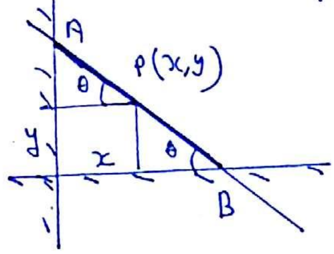
$$F = 3(4-1) - 2\times 4 - 0$$

$$F = 1$$

1. Slotted plate is fixed :- Elliptical trammel → every point on this, give locus of ellips except Mid

Elliptical trammel

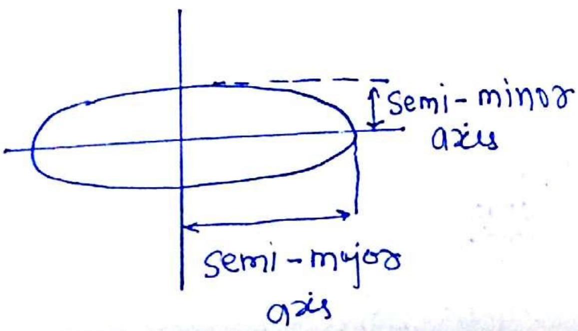




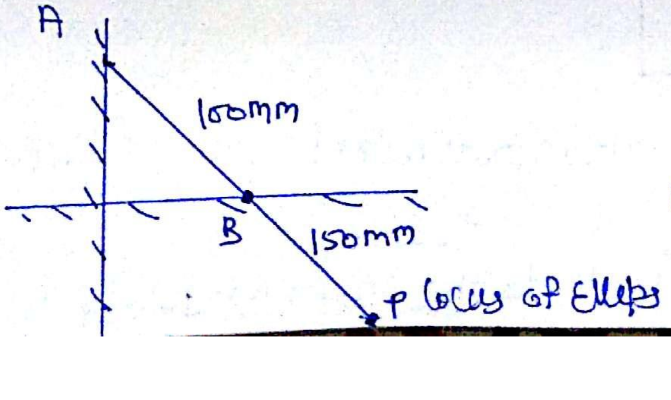
$$\cos\theta = \frac{x}{AP}, \quad \sin\theta = \frac{y}{BP}$$

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

Ellips.



Prob



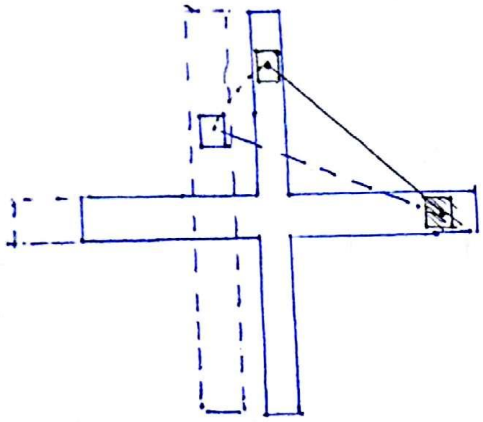
major axis = 2AP = 500 mm

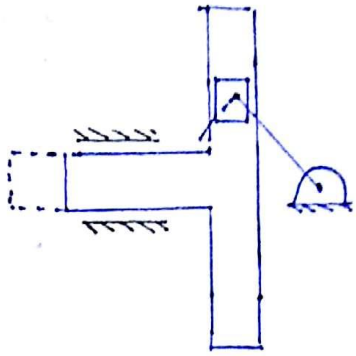
Minor axis = 2BP = 300 mm

2. If any of the slider is fixed.

Scotch - yoke mechanism

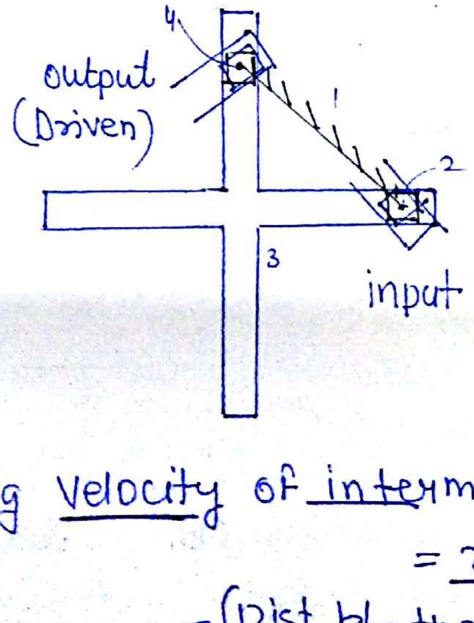
Rotary → Reci





3. Link connecting slider is fixed : (Old ham's coupling)

This is used to connect the shaft having lateral misallignment.



max. sliding velocity of intermidiate plate (link3)

$= r\omega$

$= (\text{Dist. b/w the shaft} \times \omega_{driver})$

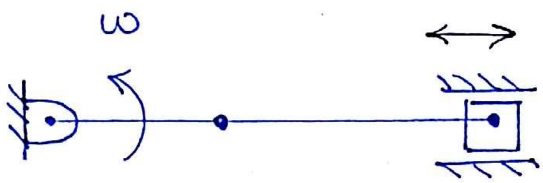
Mechanical Advantage:- (M.A)

$$M.A. = \frac{F_{output}}{F_{input}} \rightarrow M.A. = \frac{V_{input}}{V_{output}} \times \eta_{mechanism}.$$

$$M.A. = \frac{T_{output}}{T_{input}} \rightarrow M.A. = \frac{W_{input}}{W_{output}} \times \eta_{mechanism}$$

$$\eta_{mechanism} = \frac{P_{output}}{P_{input}} = \frac{F_{output} \times V_{output}}{F_{input} \times V_{input}} = \frac{T_{output} \times W_{output}}{T_{input} \times W_{input}}$$

Problem:-



Find M.A.

$W_{input} = W$

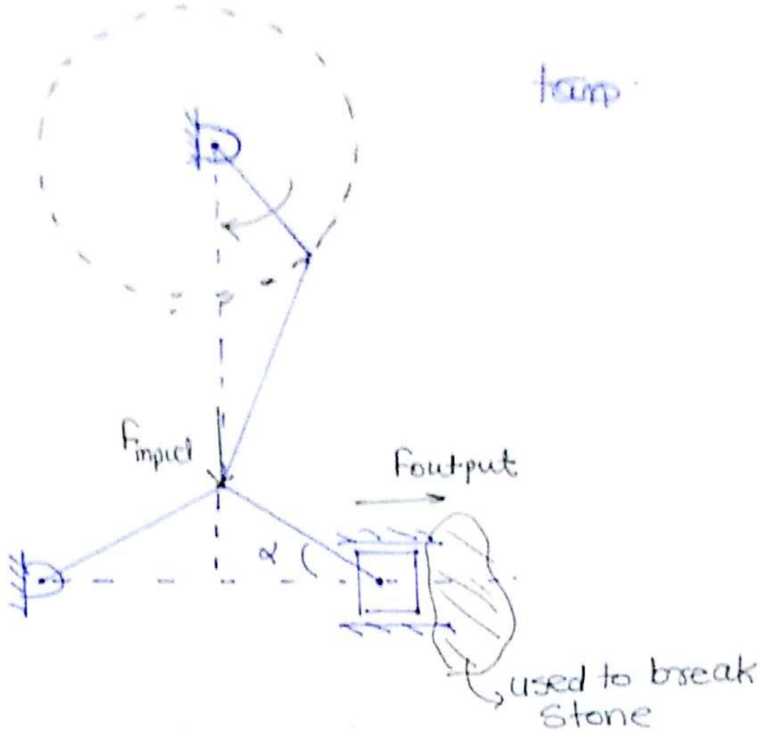
$W_{\text{~~input~~ output}} = 0$

$\Big\}$ $M.A. = \frac{W}{0} = \infty$

Rot. → Reciprocating

↳ Rot. of ∞ Radius.

Toggle Mechanism :-



$$\tan\alpha = \frac{F_{input}}{F_{output}} \Rightarrow F_{output} = \frac{F_{input}}{\tan\alpha}$$

As $\alpha \rightarrow 0$ At that moment

$\tan\alpha \rightarrow 0$

$F_{output} \rightarrow \infty$

$M.A. \rightarrow \infty$

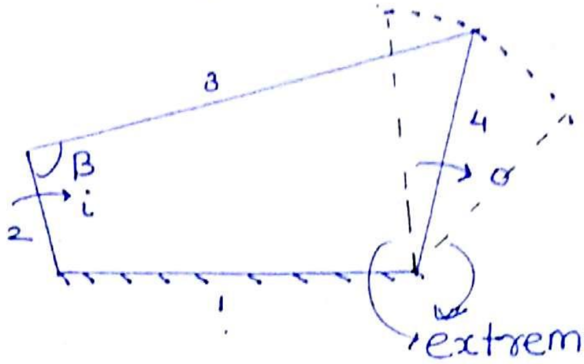
$F_{output} >>>> F_{input}$

Toggle Positions in 4-Bar mechanism:-

extreme positions of output link as Rocker in 4-bar mechanism

input may/may not be act crank
but output must be Rocker

dead position connotes



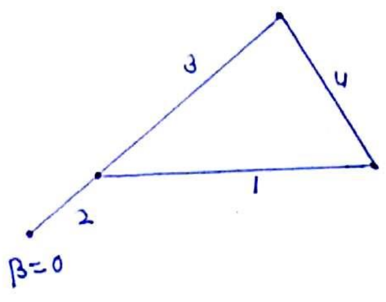
extreme positions

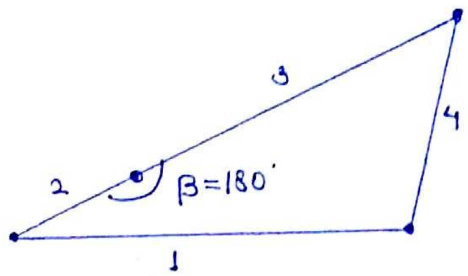
$\omega_{output} = 0$

$M.A \rightarrow \infty$

left extreme position of output link ($\beta = 0$)

Right extreme position of output link ($\beta = 180^\circ$)





रुक-रुक कर

Intermittent Motion Mechanism:- periodic motions with constant breaks at output wrt given continous input

1. Geneva Mechanism :⇒ used in indexing in milling M/c

2. Ratchet Mechanism ⇒ Used in clocks

Steering Gear Mechanism:-

⇓

Changing the direction of motion

1. Ackermann steering Mechanism → used in automobile

↳ Only having TP (less wear and tear thus)

↳ life is very high

↳ Exact at only three positions

Mid + two extreme positions

2. Davis steering Mechanism :-

↳ ~~Hist~~ Having TP & SP (more wear and tear)

↳ life is very less

↳ Exact at all positions

Straight line Motion Mechanism:- These are the extensions of simple mechanism.

- Exact straight line motion mechanism :- (extension of 4-bar.)

  → Hart's mechanism] 6 links
  → Scott - Russell Mechanism ✓
  → Modified scott - Russell mechanism ✓

(SHM)

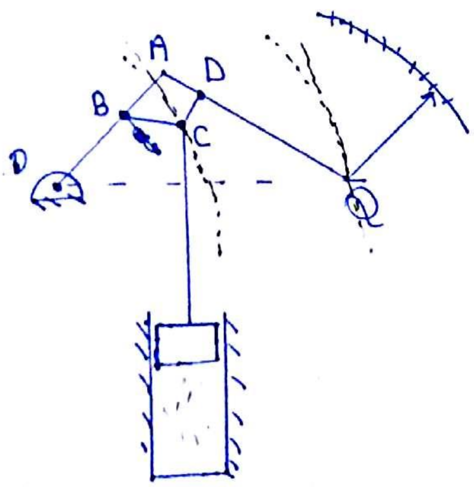
- Approx straigth line Motion mechanism :-→ (4 link)

  → Grasshopper Mechanism
  → Robert's Mechanism
  → Tchebichett Mechanism
  → Pantograph { used in railway to connect electrisity }
  → Watt's Indicator Mechanism ✓

(PGTRW)

(✓ - slider)

Imp
Watt's Indicator Mechanism :- Observation



- Point C & Point Q both move in approx straigh line Motion
- There are no relative motion between link BC & CD

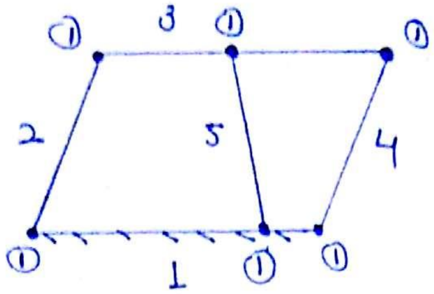
  ⇒ BCD is one link

- link BCD & link AQ } → Rocker/lever

Double lever mechanism

By James watt
used to calibrate pressure inside cumbustion chamber.

Note:-

* 

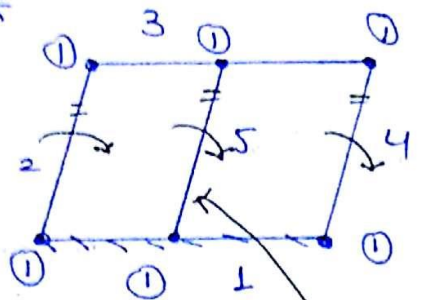
$l = 5$

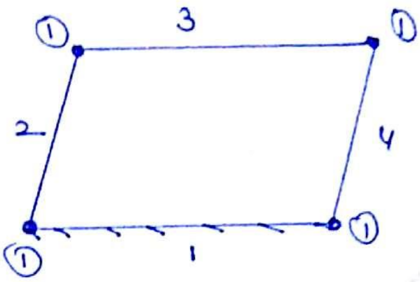
$j = 6$

$h = 0$

$F = 3(5-1) - 2\times 6 - 0$

$\boxed{F = 0}$ ✓ Frame/structure

* 

= 

$l = 5$

$j = 6$

$h = 0$

{dummy link}

$F = (3(5-4) - 2\times 6)$

$\boxed{F = 0}$ ✗

$l = 4$

$j = 4$

$F = 3(4-1) - 2\times 4$

$\boxed{F = 1}$ ✓

Note:-

Binary link :- Connected at two places

Ternary link :- Connected at three places

Quaternary link :- Connected at four places

eg