ToppersNotes

IES/GATE

MECHANICAL ENGINEERING

THEORY OF MACHINE,
GAS TURBINE, ENGINE & THERMODYNAMICS

VOLUME-V

Sierra Innovations Pvt. Ltd.

Contents

TOM

THEORY OF MACHINE

THEORY OF M/C

- Simple Mechanism
- Motion analysis
  - → Velocity analysis
  - → Acce^n analysis.
- Gears
- Gear trains.
- Governers
- flywheels
- Balancing
- Mechanical vibrations.

17-22 नंबर Objective.

40-50 नंबर conven. ~~objective~~.

Engg. Mechanics

↓

study of motion.

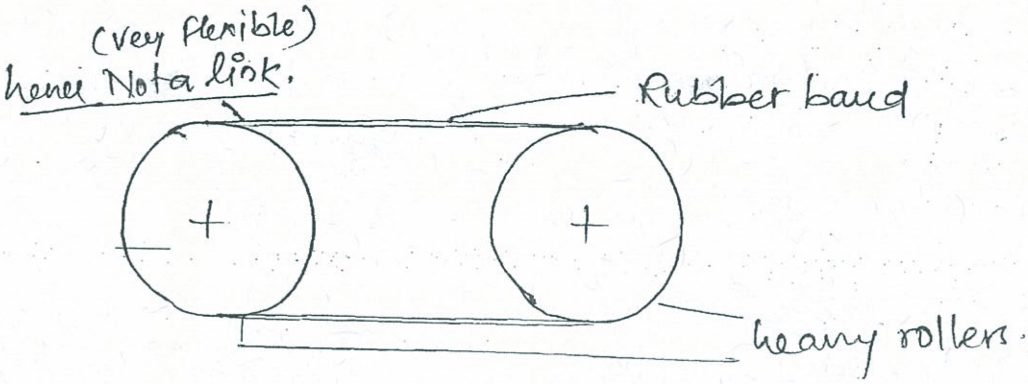
KINEMATICS
Study of motion without consideration of force.

DYNAMICS.
study of Motion with consideration of force.

Kinematic Link or element :-

"Every part of a machine wich is having some relative motion w.r.to some other part will be 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.

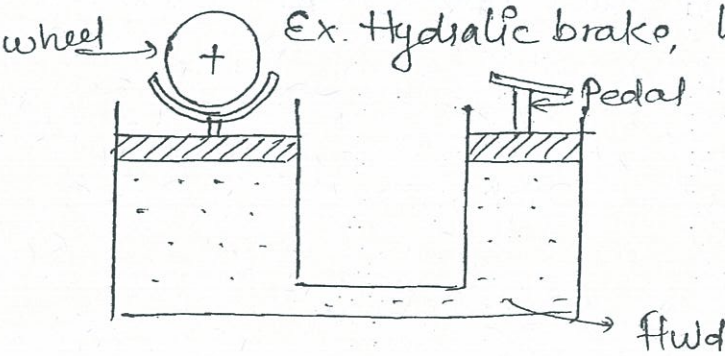


Types of link :-

1. **Rigid Link :-** where deformations are negligible.
   Ex. Crank, connecting rod, piston etc.

2. **Flexible Link :-** Deformations are there but within the permissible limit.
   Ex. Belt drive, Rope drive, chain.

3. **fluid Link :-** when the power is transmitted because of fluid pressure.
   Ex. Hydralic brake, hy. crank, etc.

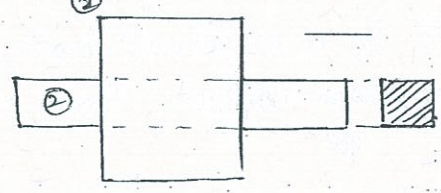


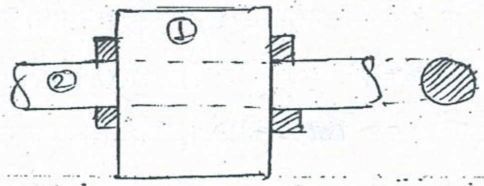
✱ Different types of constrained motion :-

for a relative motion - System is having two link.

1. Completly constrained motion [CONSTRINED] - Desired motion, where system is constrained itself.

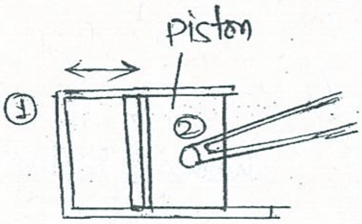
Ex. Usefull.

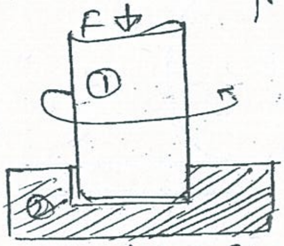


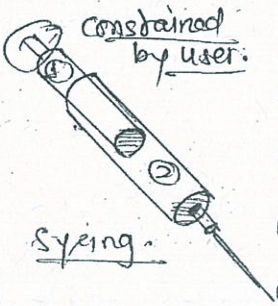


2. Succesfully constrained motion [CONSTRAINED] - Motion is constrained by surrounding.

Ex. usefull

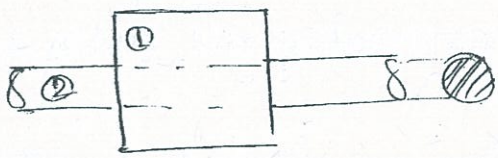






3. Incompletly constrained Motion - unconstrained motion.

Not usefull

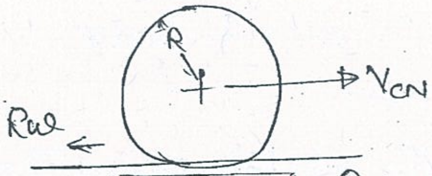


✱ KINEMATIC PAIR :-

"The connection b/w 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 ~~are~~ constrained motion".

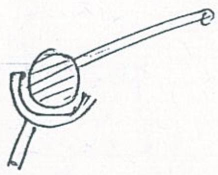
(A) According to the type of relative motion:-

- Turning pair (Revolute pair, Pin joint) → Pure turning
- Sliding pair (Prismatic pair) → Pure sliding.
- Rolling pair. → Pure rolling.



$\boxed{R\omega = V_{cm}}$ fore pure rolling.

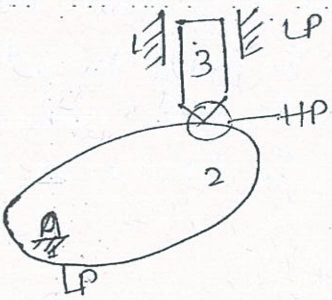
- Screw pair:- Motion over the threads.
  Ex. Nut bolt.
- Spherical pair (Ball in Socket Joint) – Sherical Motion.
  3D - Rotation.

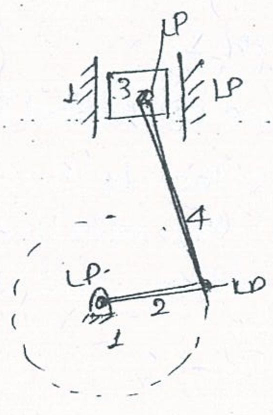


(B) According to the type of contact:-

- Lower pair – Surface contact.
- Higher pair. Point/line contact

$\boxed{1\,HP = 2\,LP}$ *





- Wrapping pair. Beltpully, Chainsprocket, Ropepulley.

(It is close to higher pair)

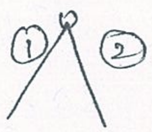
- Self closed pair (Closed pair)
  - → Permanent contact
- forced closed pair
  - → forcefully contacted

Ex: - HP in CAM and follower
- Door closers
- Automatic clutch operating system.

Different types of joints:-

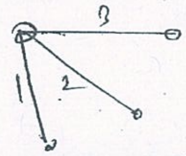
Binary joint

where two links are connected



ternary joint

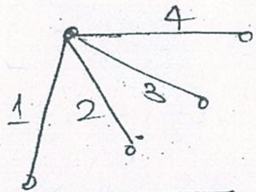
where three links are connected



1 T = 2B

Qualernary joint

where four links are connected



1Q = 3B

★ 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 get the close chain and if all the relative motions in this closed chain are constrained then such a chain is known as kinematic chain."

☆ **Kinamatic chain (constrained chain)**

To use this chain one link should be fixed.

↓

Mechanism → which can give desired o/p w.r.to. given i/p.

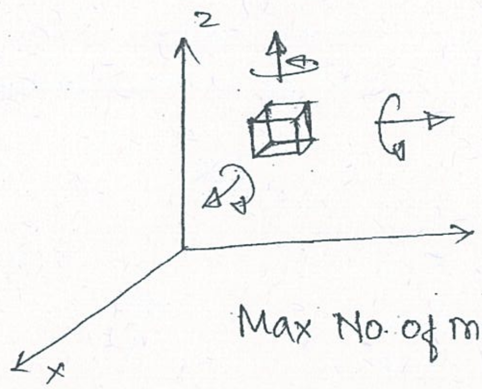
↓ — utilized

Machine - Desired o/p is obtained.

☆ Degree of freedom (DOF) {Mobility}

"Minimum No. of independent variables required to define the position or motion of the system is known as degrees of freedom of a system"

In 3-D Space



Max No. of motion = 3T + 3R
= 6

DOF = (6 − Restrained)

→ No. of those motions which are not possible.

Restrains are alway b'coz of pair.

Pair	Restrains	DOF
	⑤	①
	1T = 1	⑤

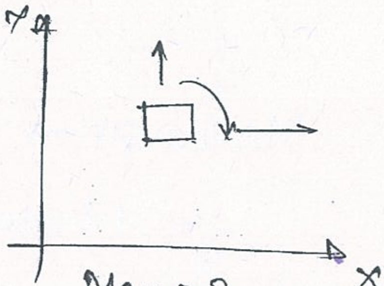
AIM:- To find out DOF of 2-D planner mechanism.

No. of links = l

No. of binary Joints = j

No. of higher pairs = h

one link fixed



Max = 3

2T + 1R

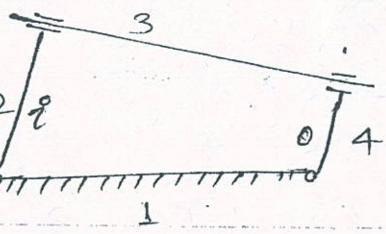
$$F = 3(l-1) - 2j - h$$

Kutzback's eqn

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

f_r: No. of motions which are Not the part of the mechanism.

(1)

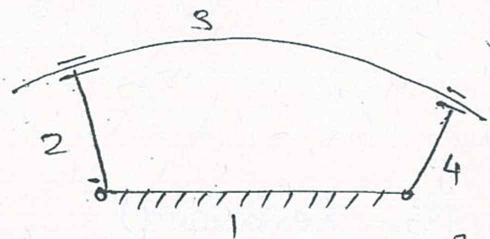


$l = 4$
$j = 4$
$h = 0$
$f_r = 1$

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

$F = 0$

(2)

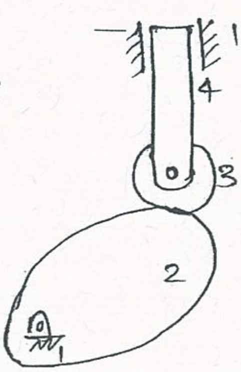


$l = 4$
$j = 4$
$h = 0$
$f_r = 0$

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

$F = 1$

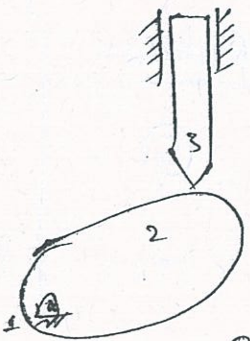
(3)



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

$F = 1$

(4)



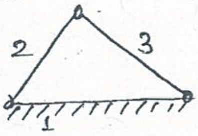
$l = 3$
$j = 2$
$h = 1$

$F = 3(3-1) - 2\times2 - 1.$

$F = 1$

No relative motion → frame/structure

for example :-

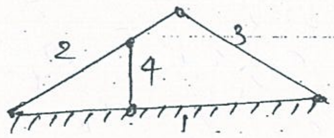


l = 3
j = 3
h = 0

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

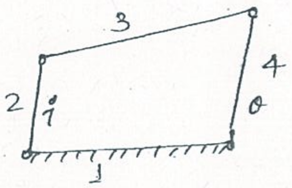
if **f < 0** → superstructure (indeterminate structure)

for example.



l = 4, j = 5, h = 0, **f = -1**

f = 1 → kinematic chain



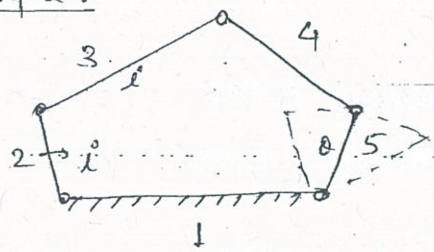
l = 4
j = 4
h = 0

f = 1

if **f > 1**

unconstrained chain.

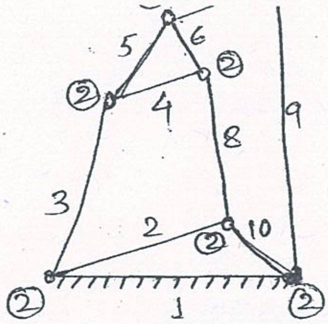
for example :-



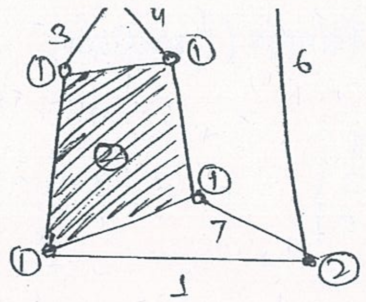
l = 5, j = 5, h = 0

f = 2

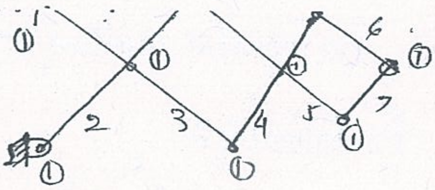
"D.O.F. is the number of inputs required to get the constrained output in a chain."



$l = 10$, $J = 13$, $h = 0$ } $\boxed{F = 1}$

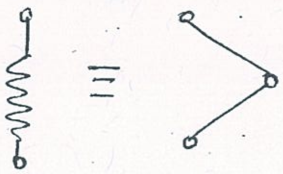


$l = 7$, $j = 9$, $h = 0$ } $\boxed{F = 0}$



$l = 8$, $j = 10$, $h = 0$ } $\boxed{F = 1}$

Spring as a Link. (Flexible Link)



Grubler's Equation :-

for those mechanisms in which $\boxed{F = 1}$ & $\boxed{h = 0}$

Applied Kutzback's equation :-

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

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

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

→ $\boxed{3l - 2j - 4 = 0}$ → $(3l)$ always even
l always - even.

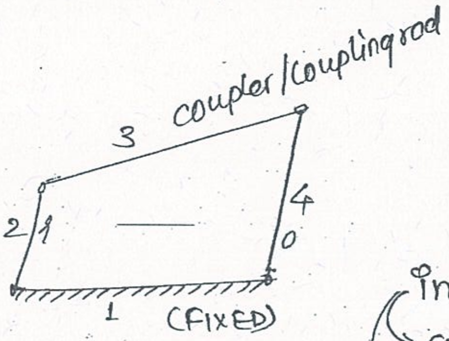
$\boxed{l_{min} = 4}$ → 1st Mechanism with lower pair only
↓
SIMPLE Mechanism.

→ 4-Bar Mechanism.

→ Single slider Mechanism.

→ Double slider Mechanism.

(Quadric cycle Mechanism)



Best position → fixed b'coz it governs < i/p, o/p

input/output
- complete Rotation – CRANK
- Partial Rotation – ROCKER. (Oscillation)

Inversions:-

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

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

Grashof's law:-

"for the contineous relative motion between the number of links in a mechanism the summation of the lenghts of smallest and largest link should not be greater than sum of other two.

for contineous Rotation motion:

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

s - shortes link lenght
l = largest link lenght
p, q = other links lenght.

Best link for rotation = s.
Best position for link = fixed.

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

1 - S - fixed → Double crank.

2 - S - Adjacent to fix — cranck-Rocker

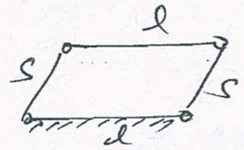
3. S - coupler — double rocker

$(S+l) = (p+q)$ law satisfied

(Having pair of equal lengths)

2, 2, 5, 5

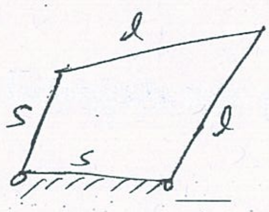
→ **Parallelogram linkage :-**



s - fixed - double crank

l - fixed - double crank.

→ **Deltoid linkage :-**



s - fixed - crank - Rocker

l - fixed - Crank - Rocker

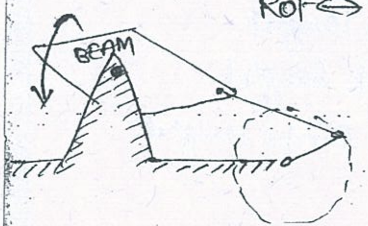
★ If law is not satisfied. $(S+L) > (p+q)$

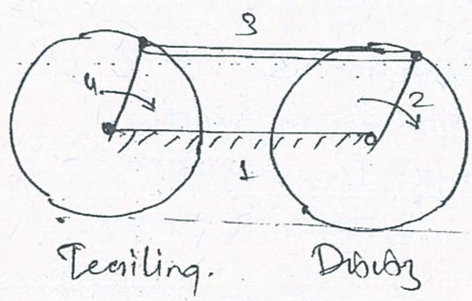
Double Rocker

PRACTICAL APPLICATIONS OF FOUR BAR MECHANISM :-

1. Beam engine Mechanism.
2. coupling rod of locomotive

Rot ⇔ oscillation

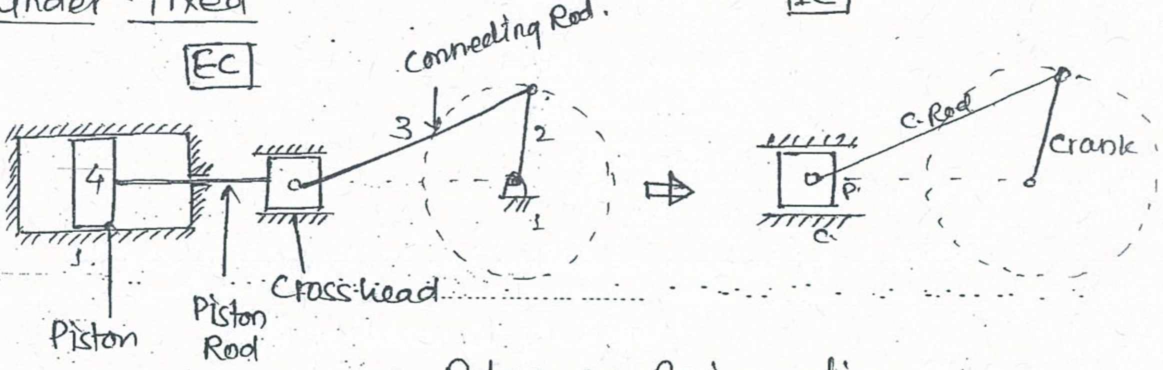




4 Links + 3TP + 1SP

Basic inversion / Ist Inversion :-

If Cylinder fixed



Rotary ↔ Reciprocating.

If crank fixed :-

IInd inversion → Whitworth QRMM
→ Rotary IC engine (GNOME ENGINE)

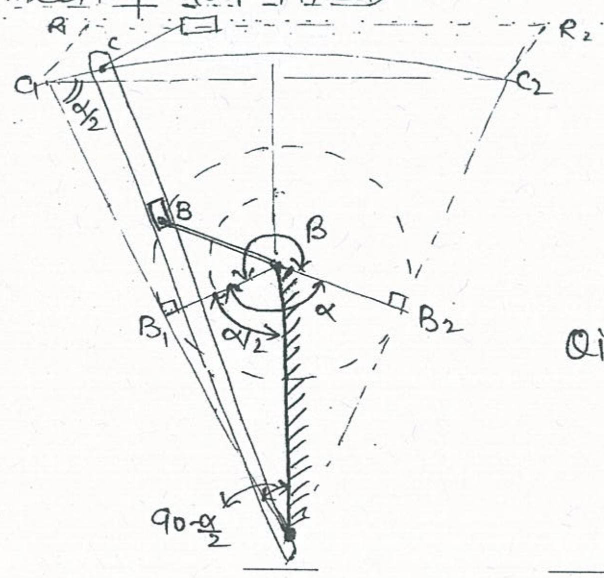
If connecting Rod fixed :-

IIIrd inversion → Crank slotter lever QRMM
→ Oscillating cylinder engine Mechanism.

If slider fixed / Piston fixed.

IVth Inversion → Hand pump, pendulum pump, Bull engine.

☆ CRANK AND SLOTTED LEVER Q.R.MM :-
(Connecting Rod fixed)



β = cutting stroke angle

α = Return stroke angle.

$\alpha + \beta = 360°$

$\boxed{\alpha < \beta}$

Qick return ratio = $\frac{\beta}{\alpha}$ = alway > 1

Stroke = R_1R_2

$= C_1C_2$

$= 2(C_1M)$

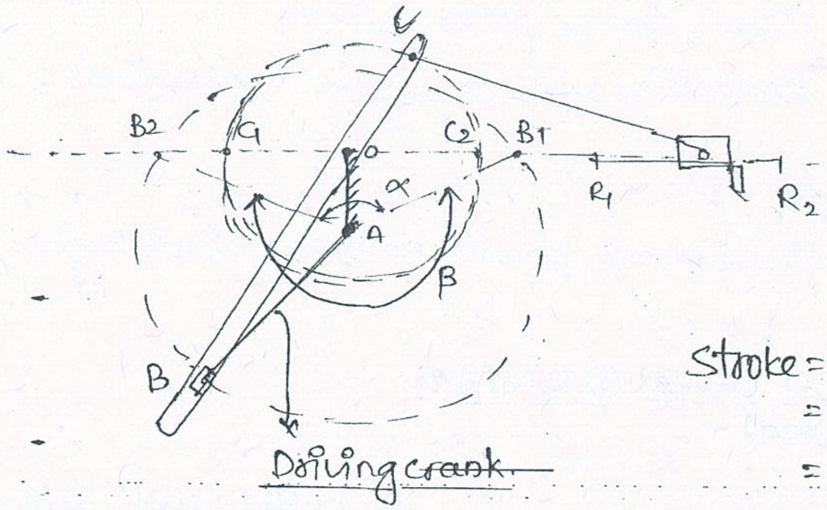
$= 2(AC_1)\cdot \cos\alpha/2$

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

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

Stroke = $\frac{2(\text{lenght of slotted bar}) \times (\text{lenght of crank})}{\text{lenght of connecting Rod.}}$

✱ Whitewath ORMM

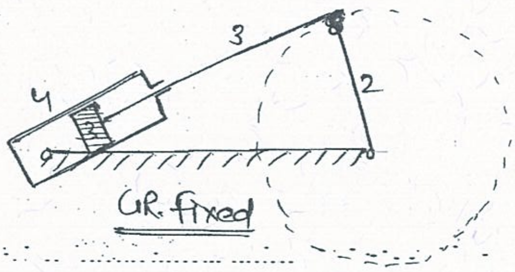


Stroke = R_1R_2

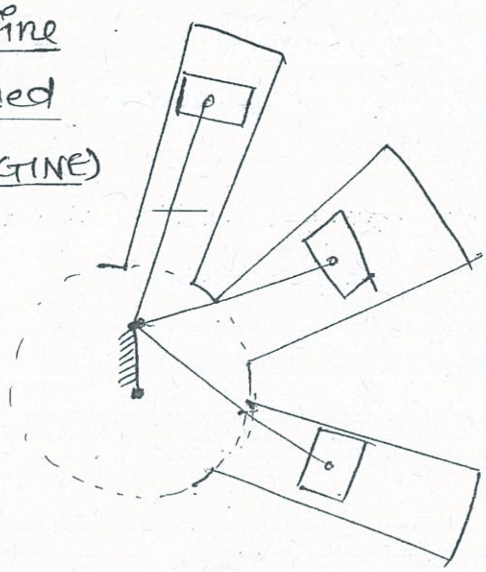
$= C_1C_2$

$= 2(OC)$

Oscillating engine mechanism:
C.R. fixed.

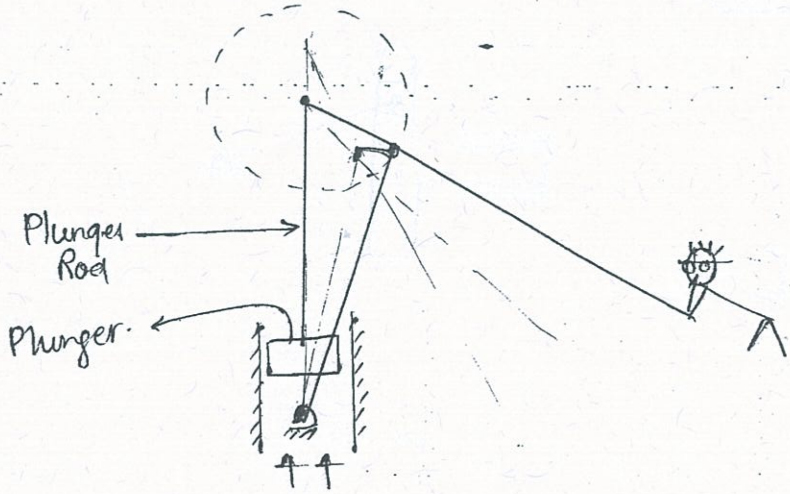


☆ Rotary IC engine
Crank fixed
(GNOME ENGINE)

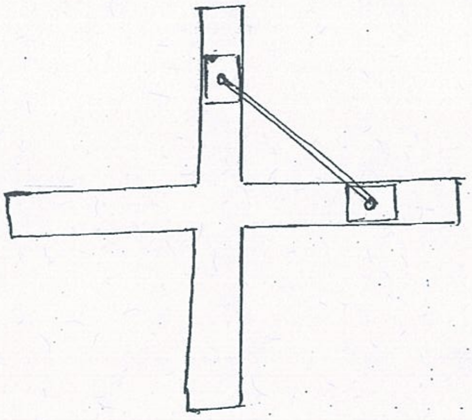


when combustion takes place inside the cy.
↓
Input force comes on piston
↓
This force will be transmitted to C.R.
↓
C.R. & Piston both Rotate
↓
Cy. block Rotates (O/P)

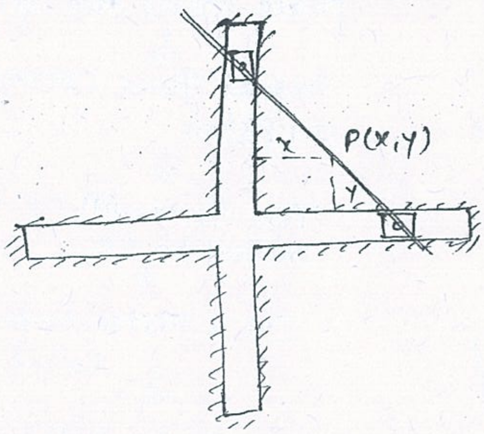
☆ Hand pump:-



Double slider crank Mechanism:



1. Slotted plate fixed (Elliptical Trammels)
(Scotch yoke Mechanism)



$\cos\theta = x/AP$

$\sin\theta = y/BP$

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

Semimajor AP

Semiminor BP

2. Any of slider is fixed: