FACULTY WAHEED UL HAQ
9704968792

1. Mechanisms
2. Gear and Gear Trains
3. Flywheels
4. Cam and followers
5. Gyroscope
6. Balancing of Masses
7. Governors
8. Vibrations

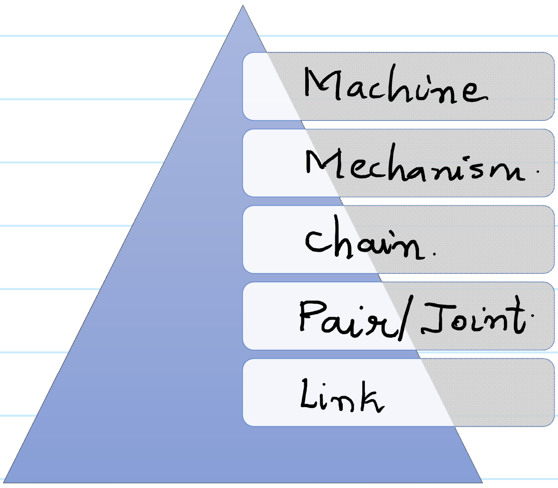
Expected Marks - (7 - 9) marks.

Reference Book

1. Ghosh and Malik (Theory of Mechanisms)
2. SS rattan
3. Sadhu Singh

Mechanism 1. Definition of link, Pair, Chain, Mechanism
2. Mobility Analysis (NAT)
3. Grashof law (NAT)
4. Performance Parameters
5. Inversions of Planer Mechanism
6. Analysis of Quick Return Mechanism
7. Kinematic Analysis of Planer Mechanism (velocity and acceleration analysis) (NAT)
8. Dynamic Analysis of Crank Slider Mechanism (NAT)

FACULTY WAHEED UL HAQ



Link - It is the smallest element in the machine. Link need not be rigid but it is a resistant body which transfers relative motion.

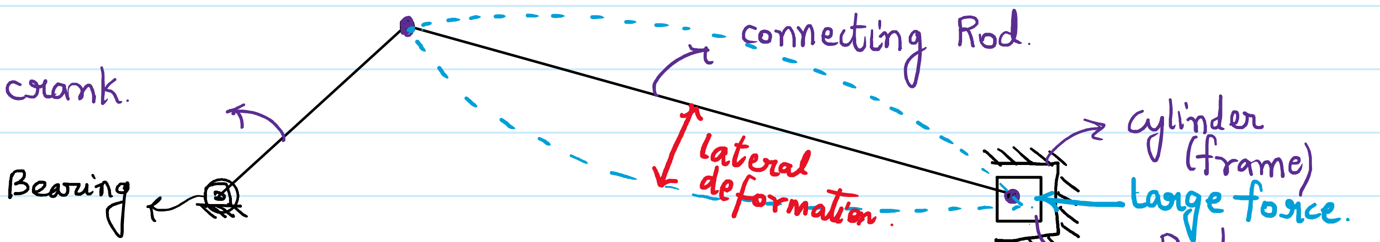
Types of links

↓

Solid

Rigid. | Deformable.

Rigid link doesnot deform while transmitting relative motion.



connecting rod can be assumed as a rigid link.

Deformable link :- A body undergoes small amount of deformation while transmitting relative motion.

Ex :- Belt, chain.

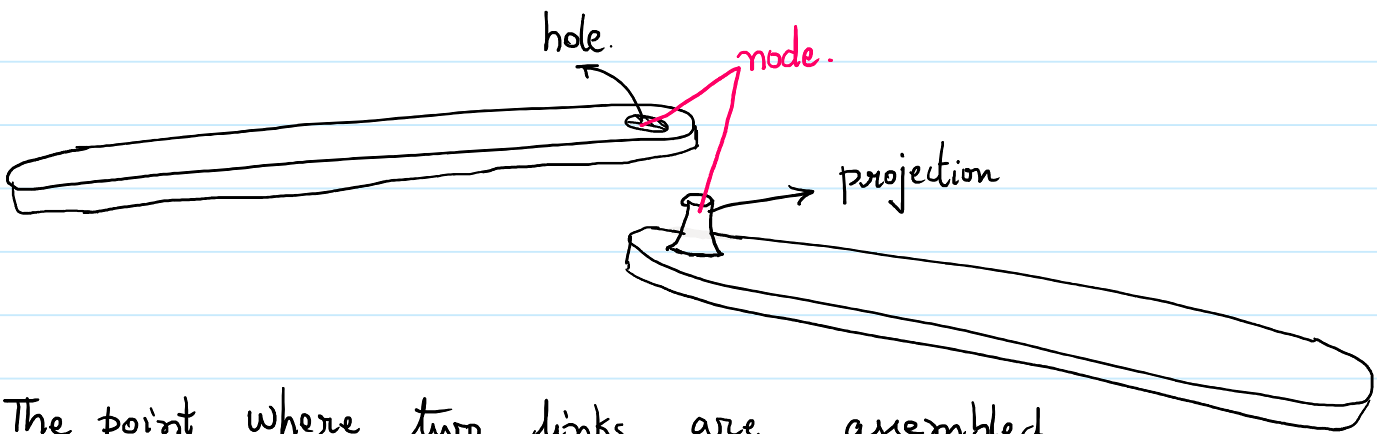
↓

Belt and Pulley arrangement.

Fluid link :- It will undergo very large deformation while transmitting relative motion.

Ex :- Hydraulic / Pneumatic Application.

- A link possess uniaxial rigidity it will be considered as link in a situation when it is able to transfer relative motion. In any other condition when it is not able to transfer relative motion it cannot be treated as link.
- Belt is able to transfer the relative motion under the action of Tensile force.
- Fluid link is able to transfer the relative motion under the action of compressive force.

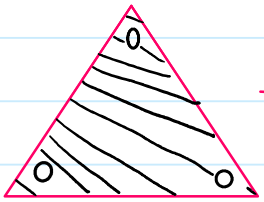


The point where two links are assembled together is called as node.

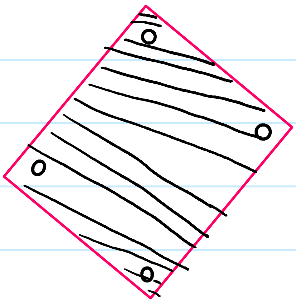
Classification of Links based on nodes

FACULTY **WAHEED UL HAQ**

→ Binary link.

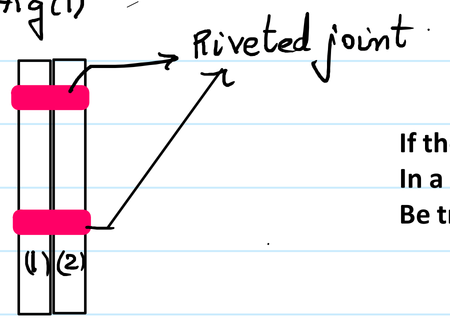


→ Ternary link.

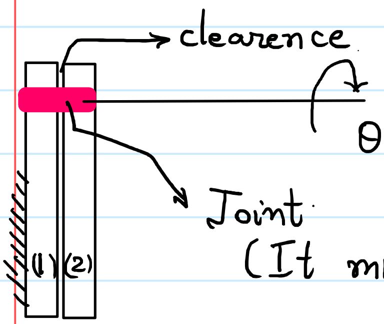


→ Quaternary link.

Fig(1)



If the two bodies are manufactured separately and joined/assembled In a way that there is no relative motion between them then they will Be treated as single link.



θ_x (Relative motion)

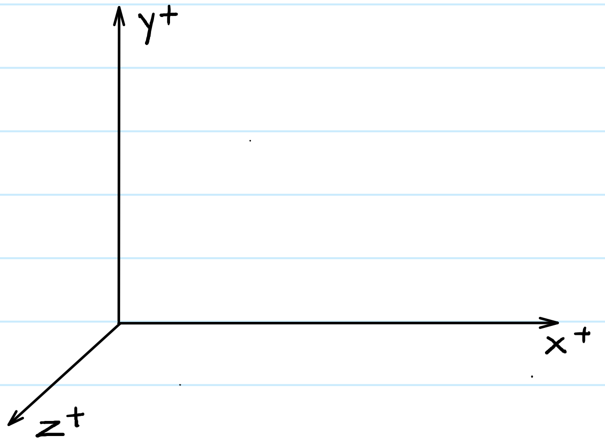
Joint.

(It must permit and transfer the relative motion)

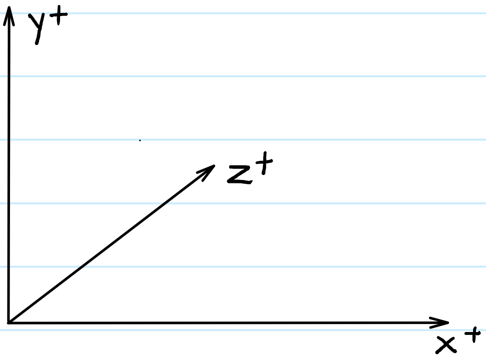
Degree of Freedom - Number of **independent co-ordinates** required to describe the motion of a body in space/plane.

FACULTY **WAHEED UL HAQ**

Right hand co-ordinate System.



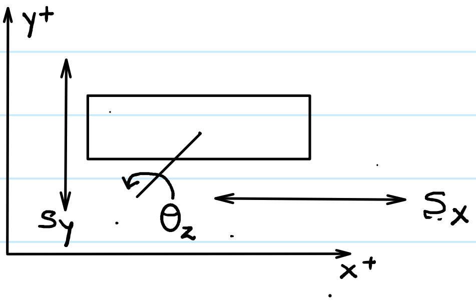
Left hand co-ordinate System.



DOF in space. 6 → 3 (Translation) + 3 (Rotation)

3 (Translation)	3 (Rotation)
S_x	θ_x
S_y	θ_y
S_z	θ_z

DOF in plane →

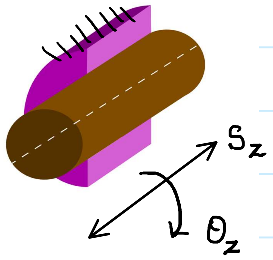


★ **Whenever the pair or contact is formed the degree of freedom are lost.**

Lower Pairs.

FACULTY **WAHEED UL HAQ**

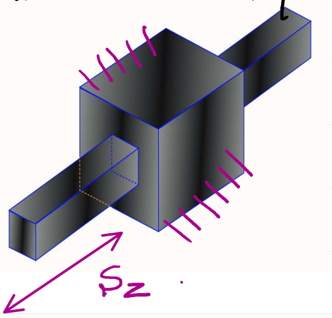
Cylinderical Pair



Permitted DoF = 2

(S_z, θ_z)

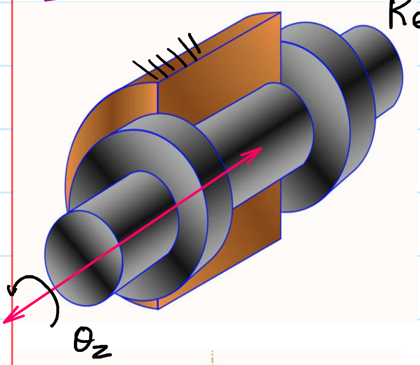
Prismatic Joint / Sliding pair.



Permitted DoF = 1.

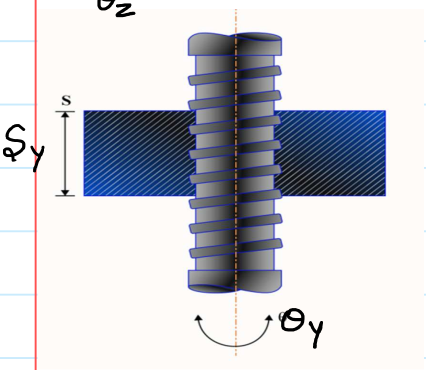
(S_z)

Revolute Joint / Pin joint.



Permitted DOF = 1. (θ_z)

Helical pair / Screw pair.



$S_y = f(\theta_y)$ → independent co-ordinate

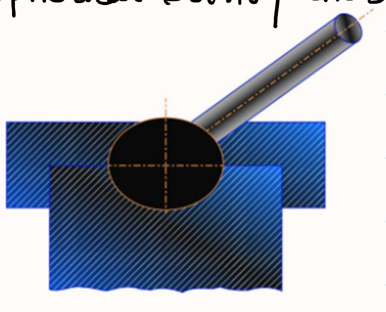
DoF = 1.

Lead = $n \times$ pitch

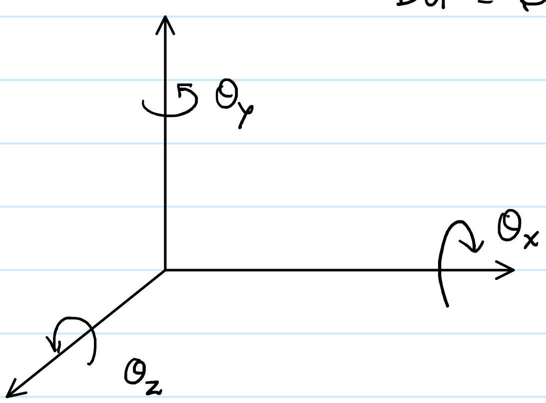
$n = 1$ single start
$n = 2$ double start
$n = 3$ triple start

$$\frac{\text{lead}}{\Delta S_y} = \frac{2\pi}{\Delta \theta_y}$$

Spherical Joint / Globular pair.

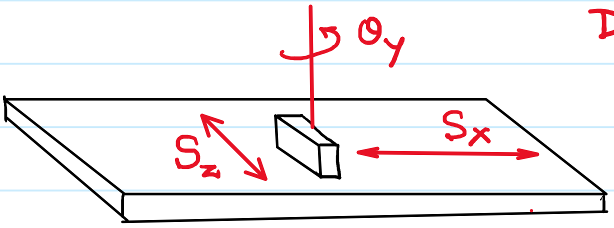


DoF = 3



FACULTY **WAHEED UL HAQ**

6. Evena pair / Planer Pair



DOF = 3.

Lower pairs.

DOF = 1	linear motion pair.	Ex. Prismatic Pair, Revolute Pair, Helical Pair.
DOF > 1	Surface motion Pair (Robotics.)	Ex:- Cylinder Pair, Spherical Pair, Evena pair.

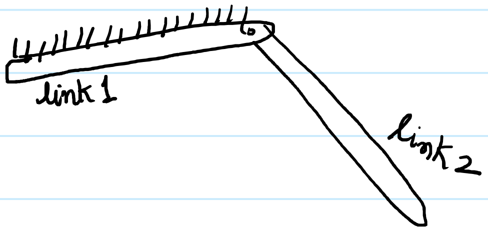
According to hartenberg and Reaulax. if there is a surface contact b/w the mating elements then the pair is called lower pair.

If their is negligible surface contact b/w the mating elements the pair is called higher pair.

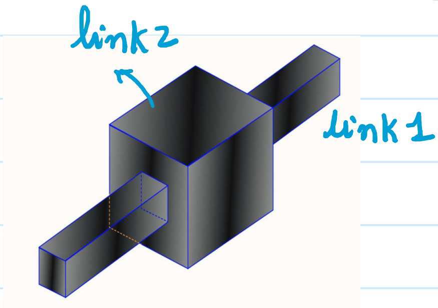
Ex:-
1. Cam and follower
2. Gear and Pinion
3. Wrapping Pair → Belt and Pulley; Chain and Sprocket.

According to hartenberg and Reaulax the inversion is possible only in case of lower pair. Inversion of higher pair is not possible.

Inversion is possible only when the locus of one moving link over another fixed link must be same or viceverse.



Locus of link.2 is circle.

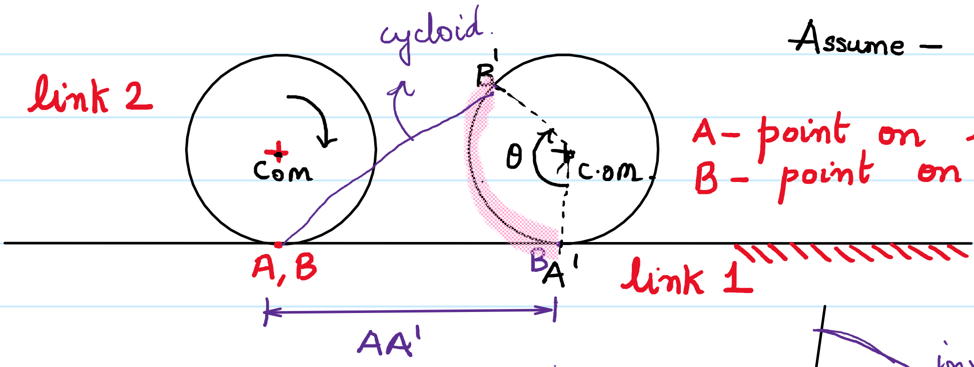


Fixed link — link 1 / link 2
locus of other moving link is straig-ht. line.

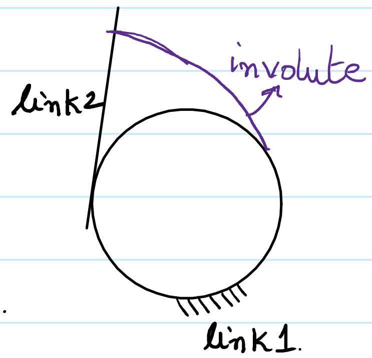
Higher Pair

★ **(In Higher pair Rolling or Rolling + Slipping will only occur)**

Assume – Pure Rolling.



A – point on link 1
B – point on link 2



For Pure Rolling $\overline{AA'} = \widehat{BB'}$

★ Distance covered by the points A and B must be same.

$$\overline{AA'} = S_x / S_{cm}.$$

$$\widehat{BB'} = r\theta_z$$

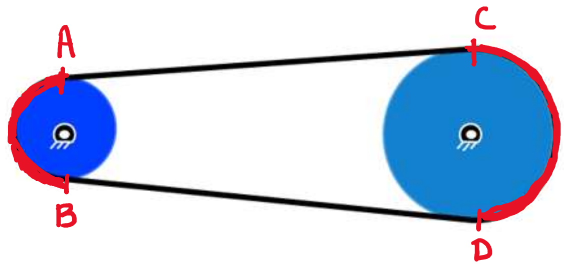
$$S_x = r\theta_z$$

$$S_{cm} = r.\theta_z \Rightarrow V_{cm} = r\omega.$$

If the circular disc moves on a fixed st. line (without slipping) the locus of any point on circumference of disc will be a cycloid.

If the st. line moves on a fixed circle without slipping the locus of any point on a st. line will be a involute.

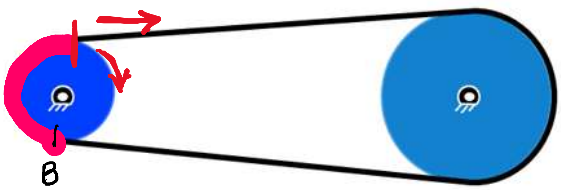
Hence the inversion in the higher is not possible because the locus under different conditions are not same.



case (i) If there is surface contact b/w Belt and pulley in segement $\widehat{AB}$ and $\widehat{CD}$ if the relative motion exists b/w the belt and pulley in segment $\widehat{AB}$ and $\widehat{CD}$ then. the belt tends to slip over the pulley due to which required relat-ive motion is not transmitted.

case (ii) In the segement $\widehat{AB}$ and $\widehat{CD}$ there is no relative motion b/w the belt and pulley they tend to behave as a single link. The relative exists at the points A, B, C & D.

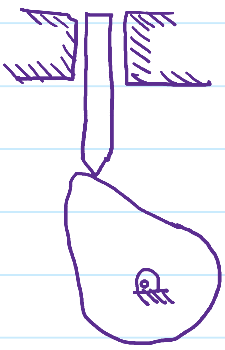
No. of higher pair = 4.



Classification of pair based Mechanical constraint.

1. Open Pair :- If one link is kept over another link and contact b/w them is due to gravity then it is called open pair.

Ex. Cam and follower.



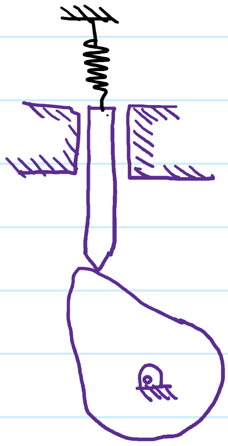
FACULTY **WAHEED UL HAQ**

2. Closed pair :- If one link is kept inside another link and for dissassembly the failure of outer is required then it is called closed pair.

3. Form closed pair :- If the two link are connected by means of geometrical constraint then it is called form closed pair.

Ex:- Spherical joint.

4. Force closed Pair :- If the contact b/w the links is maintained by the application of force then it is called force closed pair



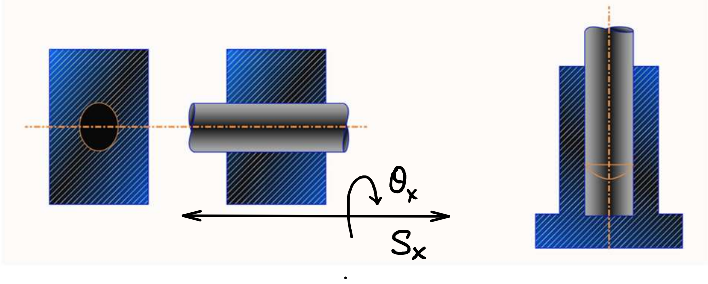
spring is used for exerting force to maintain contact.

Classification pair based on constraint

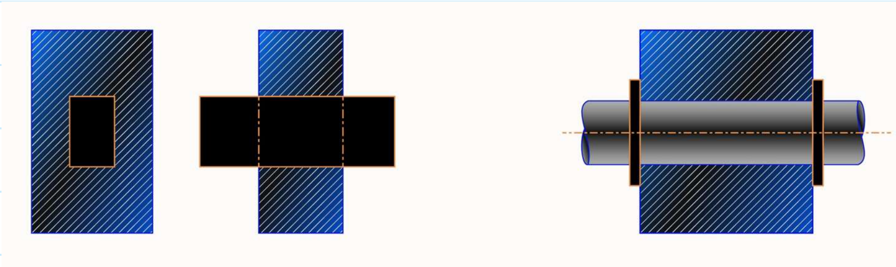
1. Incompletely constrained pair **(DOF > 1)**
2. Completely constrained pair **(DOF = 1)**
3. Successfully constrained pair **(DOF > 1)** $\xrightarrow{\text{link/force}}$ **(DOF = 1)**

Incompletely constrained pair - If the connected links have more than one relative motion between them then the pair is called as incompletely constrained pair.
Ex - (Cylinderical pair , Spherical pair and Evena pair)

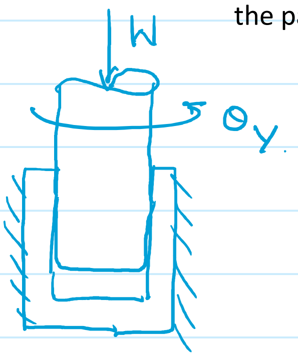
FACULTY **WAHEED UL HAQ**



Completely Constrained Pair - If the connected links have a one definite motion between them then the pair is called as completely constrained pair.
Ex - Prismatic joint , Revolute joint and Helical pair



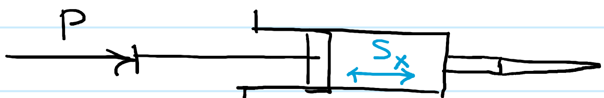
Successfully Constrained Pair - If the connected have more than one relative motion between them then by using some force/link it is converted to one definite motion then the pair is called successfully constrained pair.



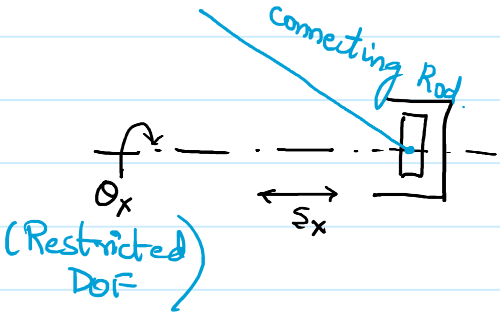
S_y – Restricted.

Foot step bearing

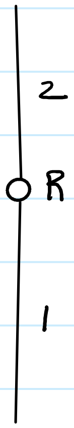
Syringe



Translation S_x – Permitted.
Rotation. θ_x – Restricted.

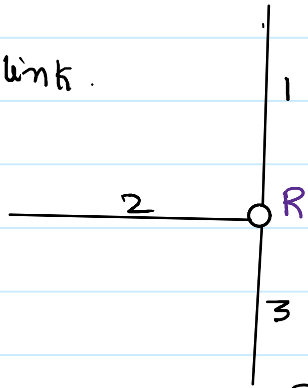


1. Binary pair. (Two link connected @ one node)



$R(1,2)$

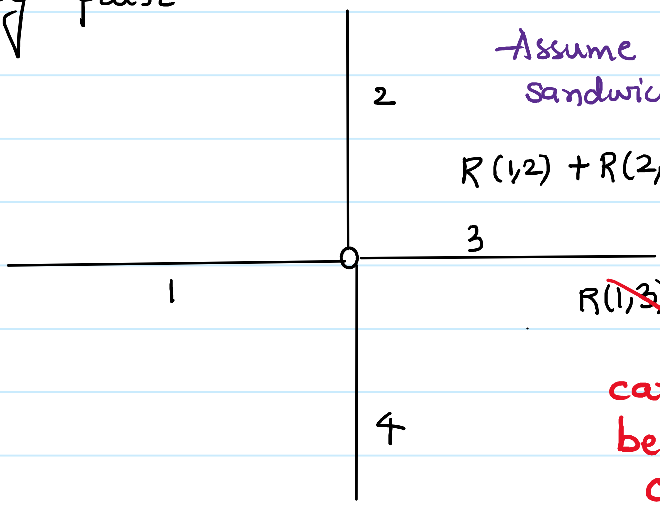
2. Ternary link.



$R(1,2) + R(2,3) + \cancel{R(1,3)}$

1 Ternary pair $\equiv$ 2 Binary pairs.

3. Quaternary pair



Assume link 2 & 3 are sandwiched b/w link 1 & 4.

$R(1,2) + R(2,3) + R(3,4)$

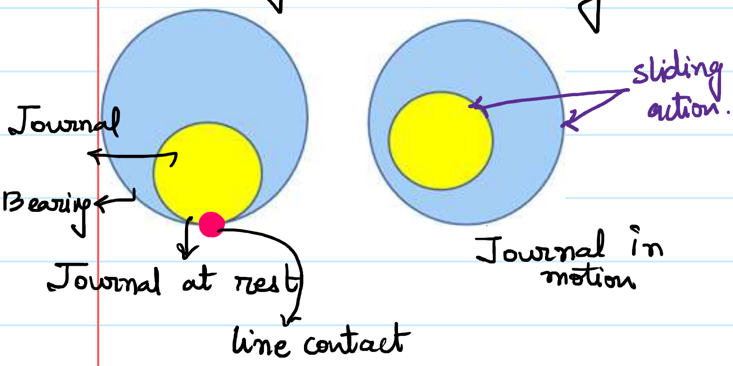
$\cancel{R(1,3)} + \cancel{R(1,4)} + \cancel{R(2,4)}$

cannot be counted because no physical contact.

★ **If there are n number of links connected at a node then the number of pairs formed is equal n-1**

Bearings → sliding contact Bearings.
→ Rolling contact Bearing / Antifriction bearing.

Sliding contact bearing



- Bearing is a mechanical element which is used to support the shaft and bear the various load acting on the shaft or rotor.

Bearing permit the relative motion of the shaft but bearing can't transfer the relative motion and hence bearing are not a kinematic pair.

Chain:

- Assembly of various links and pairs which permit the transfer of relative motion is known as chain.
- If the first link is connected directly or indirectly to the last link then it is knows as closed chain.
- If the first link and last link is not connected then it is known as open chain. It is mainly used in robotics. → Robotic Arm / Manipulator.
- **All the mechanisms are obtained from the closed chain**

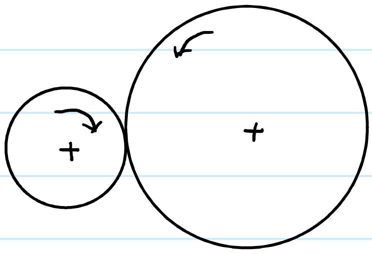
Mechanism/Linkage:

- If any one link of chain is fixed and it can transfer the relative motion with or without transformation it will be known as mechanism.

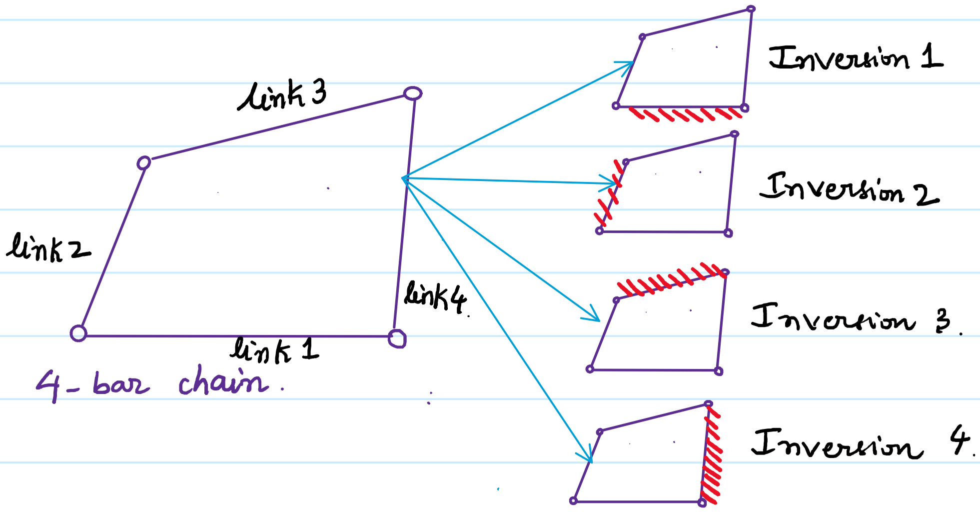
Crank slider Mechanism. → circular motion is transformed to Reciprocating motion.
(Transformation of motion)

Gear and Pinion. / Belt and Pulley. → Relative motion is transferred without transformation.

i/p motion – circular
o/p motion – circular.



Inversion of a Mechanism - Inversion of mechanism is obtained by fixing different links



4-bar chain.

★ **Number of Inversions = Number of Different links**

Inversion of Mechanism:

- The process of fixing different links of a mechanism or chain is known as inversion of mechanism.
- Every inversion results in a unique mechanism
- No of possible inversion is equal to the number of different link.
- Inversion can't effect the ability to transfer the relative motion as it is fundamental property of parent kinematic chain.
- Inversion of higher pair mechanism is not possible.

  → because the locus will be different.

★ **Mechanism is the working model behind the machine.**

Machine:

- Machine is a assembly of various link, pairs and mechanism such that it can transfer relative motion, force or power from source to the load with or without transformation in a **controlled manner**.
- Machine can transfer some form of available energy from source to some other form of available energy at the load.

Mechanism & Machine:

- Every machine is a mechanism in spirit, where as the reverse is not true.
- A machine may consist of one or several mechanism.
    - EX- clock, typewriter, keyboard, are mechanism only not machine.

I.C. Engine.

1. Crank slider mechanism.
2. Cam and follower
3. Governor.
4. Chain and Sprocket | Belt and Pulley | Gears.

Lathe Machine → Head stock (Gear Train)
→ Belt and Pulley.
→ Automatic feed Mechanism. (Lead screw)
→ Tumbler gear Mechanism.

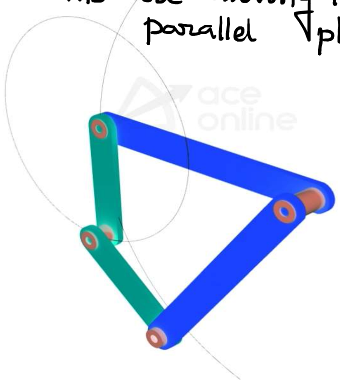
FACULTY WAHEED UL HAQ

Mobility analysis or degree of planar mechanism:

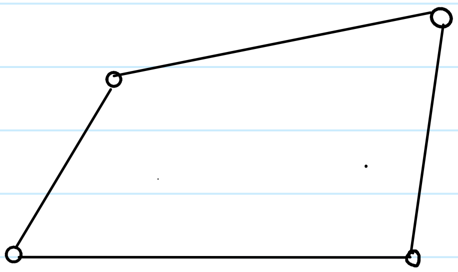
(c) Planar Mechanism: The mechanism in which locus of different points on different links lies on parallel plane is known as planar mechanism.

- The kinematic representation of any planar mechanism can be drawn a single plane.

Links are moving in the parallel planes.



(Representation)



Mobility Analysis of Chain:

Maximum DOF in a plane for a link = 3

Permitted DOF = Maximum DOF in a plane - Restricted DOF

If there are N number of links in a plane then maximum DOF is = 3N

Mechanism is formed by lower pair (Revolute/Prismatic) each of these pair restricts **2 DOF** and permits **1 DOF**

If there are j no. of such pair in the plane then restricted dof = 2j

$$(DOF)_{Permitted} = (DOF)_{Max} - (DOF)_{Restricted}$$

$$(DOF)_{chain} = 3N - 2j$$

In mechanism one link is fixed so DOF lost = 3.

$$(DOF)_{mechanism} = 3N - 2j - 3 = 3(N-1) - 2j$$

$$(DOF)_{chain} = (DOF)_{mechanism} + 3$$

$DOF = 3(N-1) - 2j \longrightarrow$ Grubler's criteria.

Grubler's criteria for completely constrained Mechanism.

$DOF = 1$

$3N - 3 - 2j = 1$

$3N - 2j - 4 = 0$ or $\boxed{3N - 2j - 4 \geq 0}$

$3N-2j-4=0$ Completely constrained Mechanism

FACULTY WAHEED UL HAQ

$3N-2j-4>0$ Incompletely constrained Mechanism or Unconstrained Mechanism.

Higher Pair → Rolling (DOF = 1) $(S_{cm} = r\theta_z)$ → independent variable

→ Rolling + Slipping (DOF = 2) $(S_{cm} \neq r\theta_z)$ → independent variable, → independent variable.

In a plane if a higher pair permits pure rolling motion then it restricts 2 DOF and permits 1 DOF

If there are h no. of higher pairs in plane that permits pure rolling motion then restricted DOF = 2h.

$$\boxed{DOF = 3(N-1) - 2j - 2h}$$ → Pure Rolling motion.

Restricted DOF $= 3(N-1) - 2P_1$ → Permited DOF

In a plane if a higher pair permits Rolling + slipping motion then it restricts 1 DOF and permits 2 DOF

If there are h no of higher pair in plane that permit Rolling + slipping motion then restricted DOF = 1h

★★ $$\boxed{DOF = 3(N-1) - 2j - h}$$ → Rolling + slipping.

→ Kutzbach's equation

$$DOF = 3(N-1) - 2P_1 - 1P_2$$

→ Restricted DOF. → Permitted DOF

N – Number of link.

P_1 – No. of pairs having 1 dof in plane.

P_2 – No. of pairs having 2 DOF in plane.

FACULTY WAHEED UL HAQ