KINEMATICS OF MACHINERY

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Course Objectives:

- To acquaint with basic principles of kinetics and kinematics of machine elements.
- To familiarise with basics of Mechanisms and their inversions.
- To study functioning of motion and power transmission machine elements

Course Outcomes:

You will be able to…

- Define various components of mechanisms.
- Develop mechanisms to provide specific motion.
- Draw velocity and acceleration diagrams for various mechanisms.
- Choose a cam profile for the specific follower motion
- Predict condition for maximum power transmission in the case of a belt drive
- Illustrate requirements for an interference-free gear pair

Course contents

Theory :

- **Module-I :** Kinetics of Rigid bodies & Kinematics.
- **Module II:** Special Mechanisms & their Inversions
- **Module III:** Velocity and accelerations in mechanisms
- **Module IV:** Cam and follower mechanisms
- **Module V:** Belt & Chain drives. Brakes
- **Module VI:** Gears & Gear Trains.

Lab :

1. Analysis of velocity of mechanisms by ICR method
2. Analysis of velocity of mechanisms by Relative method
3. Analysis of velocity and acceleration of mechanism by Relative method.
4. Motion analysis and plotting of displacement-time, velocity-time, acceleration-time, jerk-time, and layout of cam profile.
5. Mini Project.

Term Work :

The distribution of marks for term work shall be as follows:

- Laboratory work (Experiments) : 10 marks
- Assignments (Minimum 3) : 5 marks
- Quiz : 5 marks
- Attendance (Theory and Practical) : 05 marks

Overview

- Introduction to subject of study
- Motivation and aim of study
- Examples with motion and force requirements

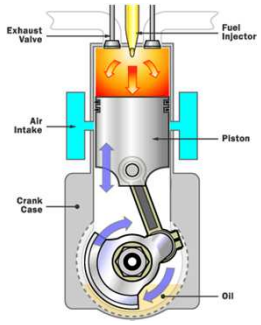
Introduction

Kinematics: study of motion of particles and rigid bodies without
reference to forces

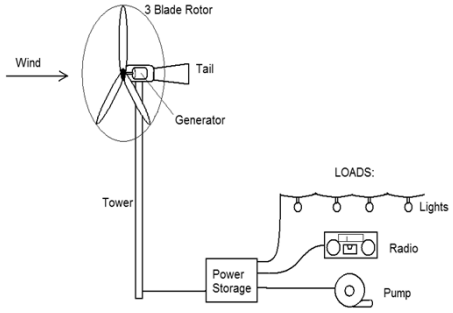
Mechanisms and machines: kinematics of interconnected rigid Bodies

Equilibrating forces: quasi-static analysis

- **What is a machine??**



Engine



Windmill

Lathe

- **Difference between Machine and structure?**

Bridge

Truck chassis

Lathe Bed

Scope of Study

Mechanisms and Machines: Transmission and transformation of motion and force

Motion: displacement, velocity, acceleration, path

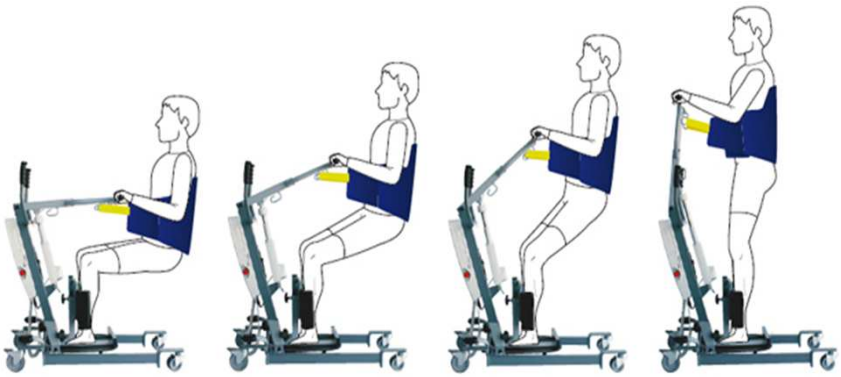
Force transmission: actuator forces

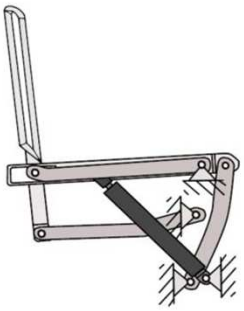
Need to Study Kinematics of Machinery ??

Mechanization and Automation: requirement of specialized mechanical devices (manufacturing, mechanical handling, assembly, painting, packaging)

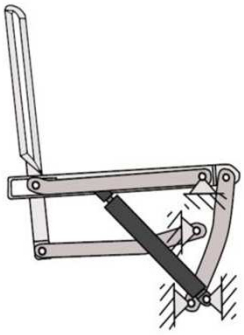
Health-care: transfer aids and devices, physiotherapy, surgery

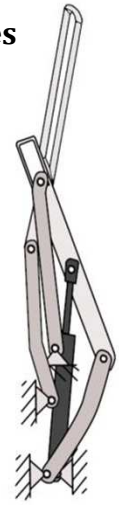
- **Some examples**
- **Transfer Aid/Devices**



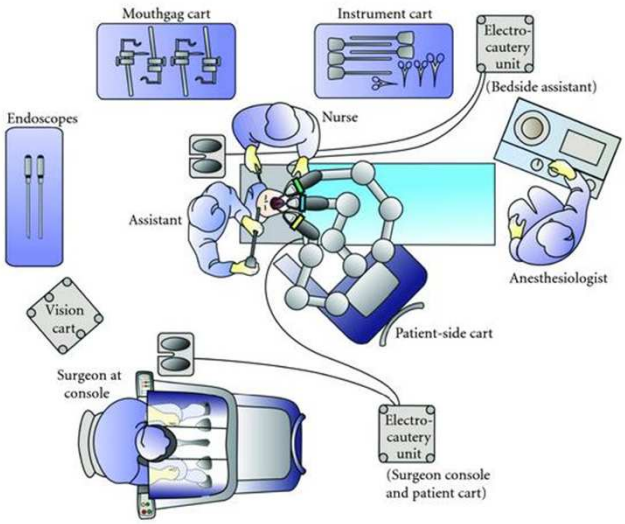


Actuator throw, rates, forces

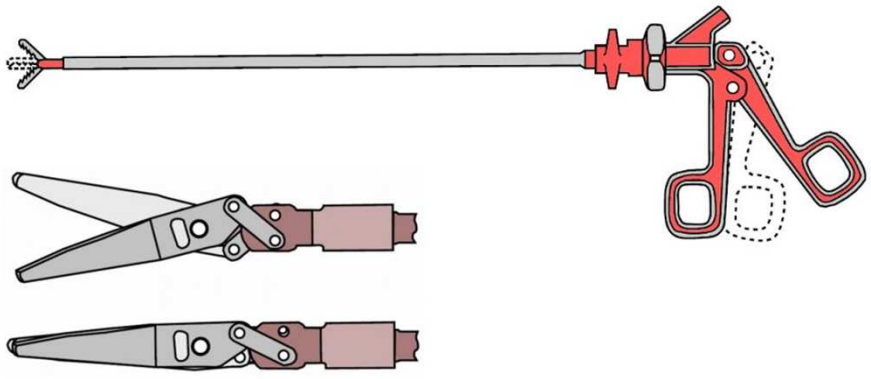




- **Surgical Instruments**



Finger-grip motion range and sensitivity, forces



Landing gear

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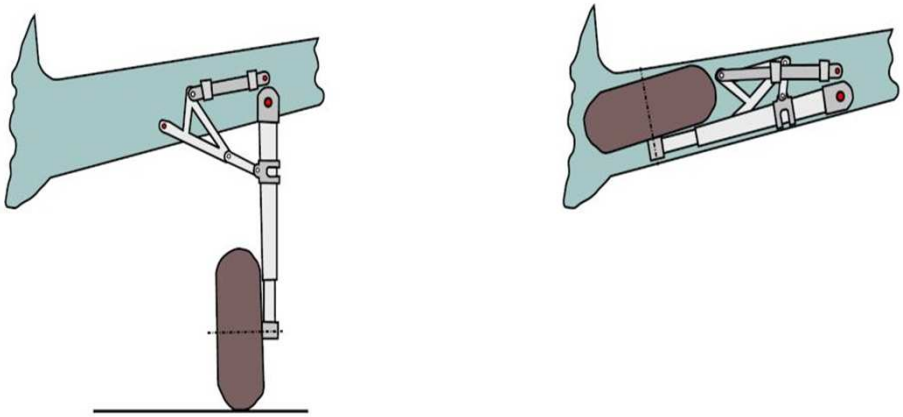
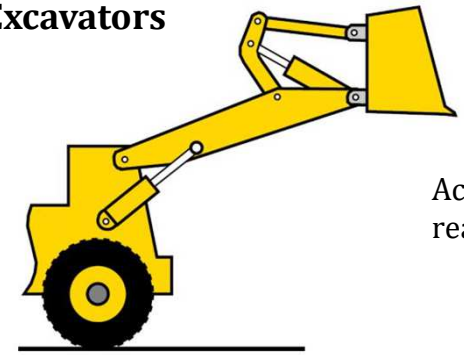
Actuator throw and rate, force



Excavators



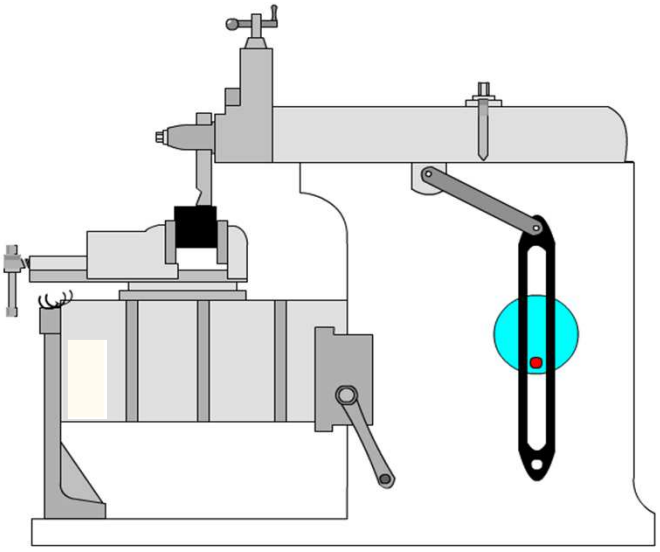
Actuator throw and rate, reach, path, forces

Robots

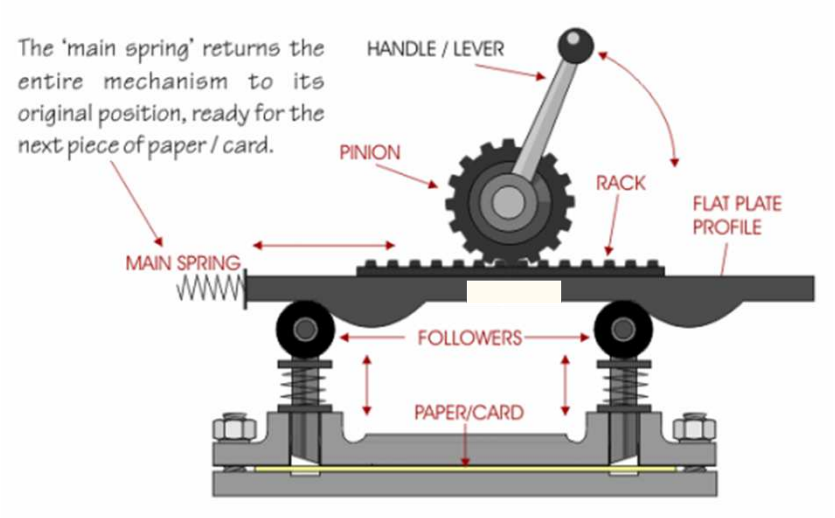
Kinematic geometry (degree of freedom, rigidity), positioning, velocity, acceleration, work-space, motion planning, forces

Fanuc serial manipulator

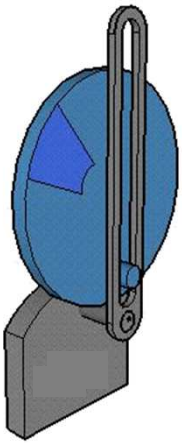
- **Mechanism**



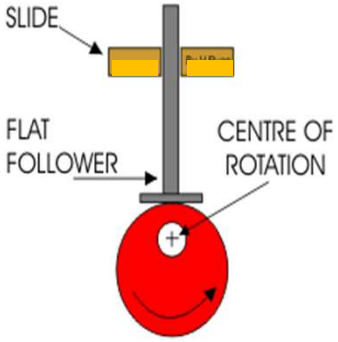
Shaper Machine



Punch Machine

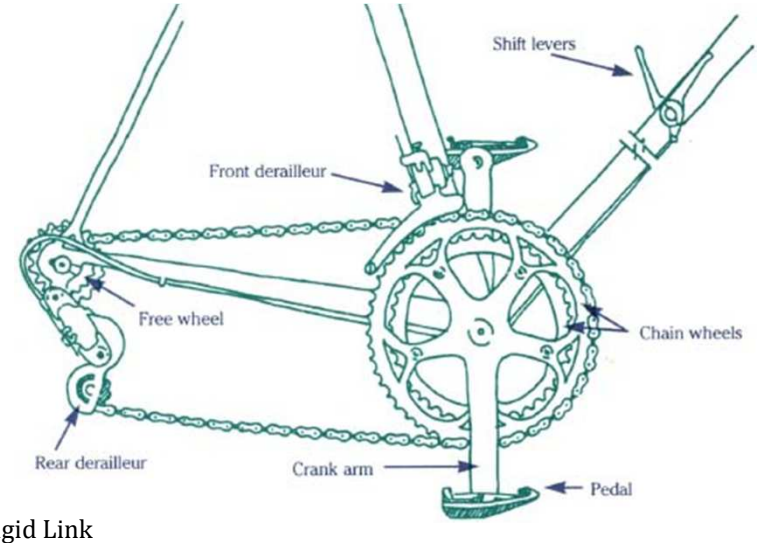


Shaper Mechanism



Cam follower arrangement for valve operation

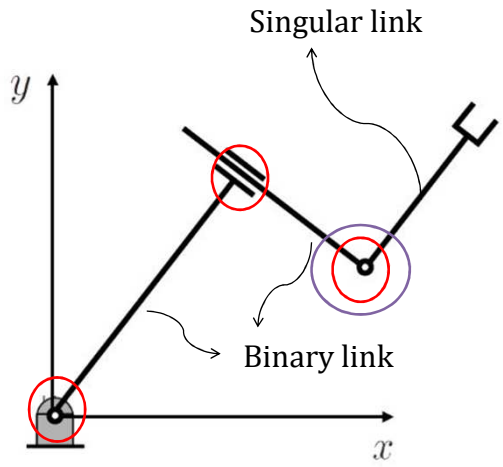
▪**Link**



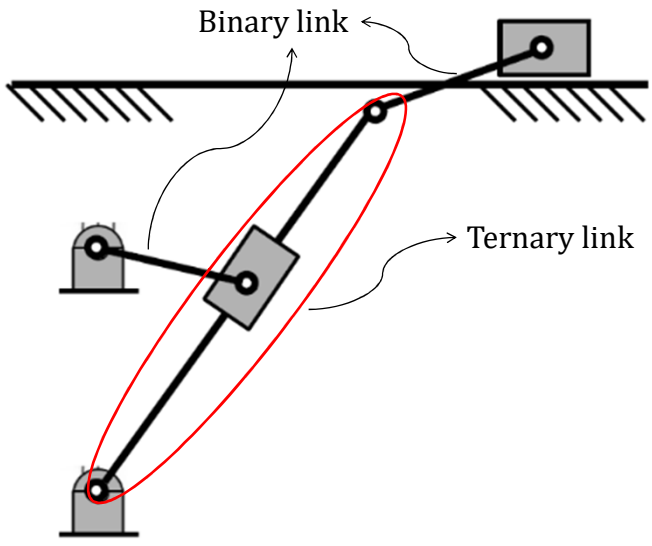
▪Rigid Link

▪Fixed Link

Link classification: singular, binary, ternary, ...



Link classification



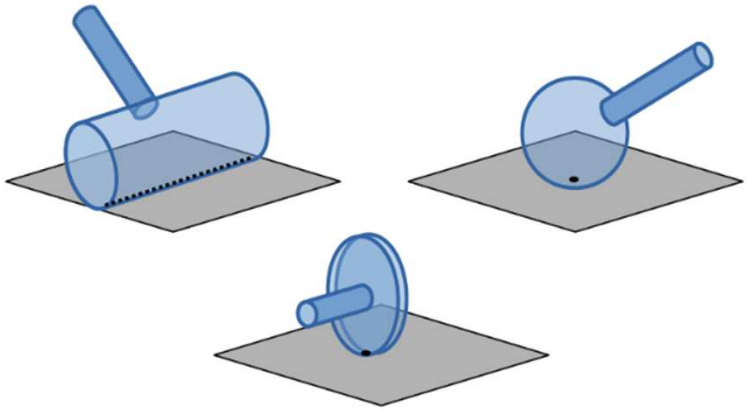
- **Kinematic pair**: Connection between two links

Example: hinge,pin,screw etc

Pair variable: quantifies relative motion

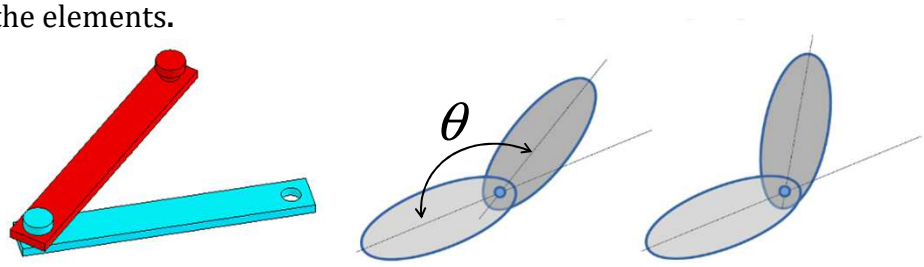
Classification: **Based upon type of contact**
- Lower pair or Higher pair
- **Lower pair**: Area contact
- **Higher pair**: Line contact or Point contact

Higher pair

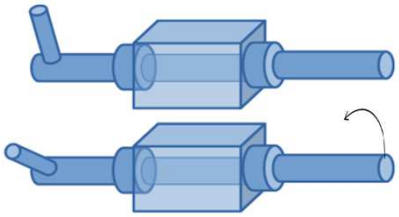


Line/point contact
Pair variables Single/Multi

▪**Kinematic Pairs** According to the type of relative motion between the elements.

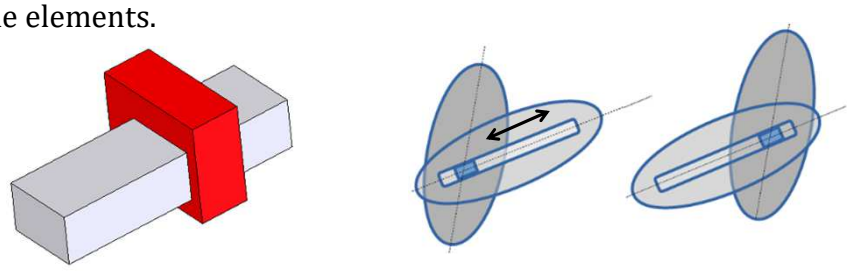


Revolute Pair

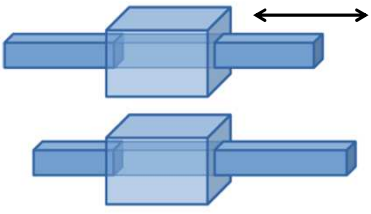


Lower pair
One pair variable: 1 degree of freedom

▪**Kinematic Pairs** According to the type of relative motion between the elements.

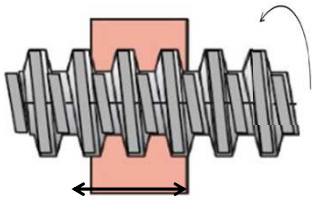


Prismatic Pair



Lower pair
One pair variable: 1 degree of freedom

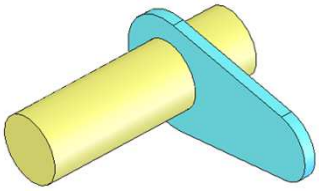
▪**Kinematic Pairs** According to the type of relative motion between the elements.

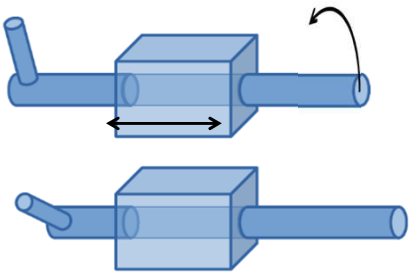


Screw Pair

Lower pair
One pair variable: 1 DOF

▪**Kinematic Pairs** According to the type of relative motion between the elements.

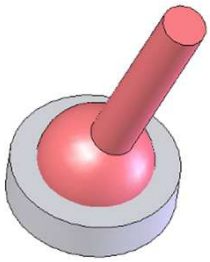




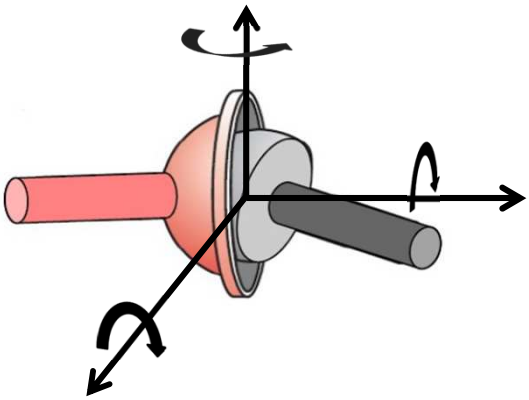
Cylindrical Pair

Lower pair
Two pair variables: 2 degree of freedom

▪**Kinematic Pairs** According to the type of relative motion between the elements.



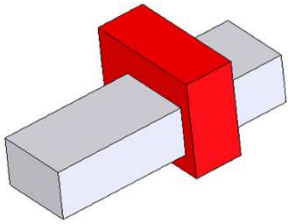
Spherical Pair



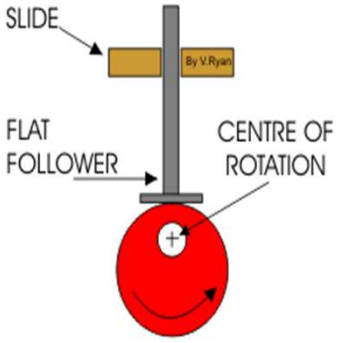
Lower pair
Three pair variables: 3 degree of freedom

Kinematic Pairs According to the type of closure

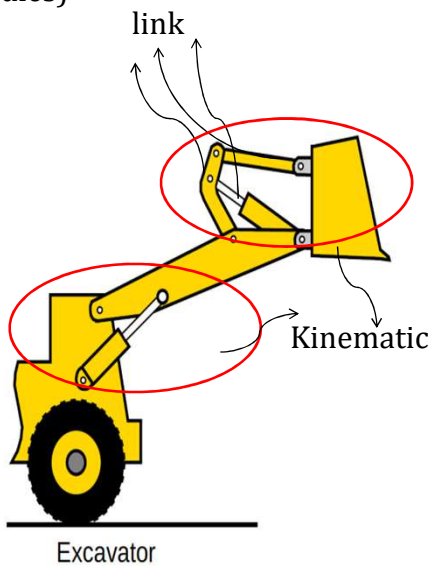
Self closed pair

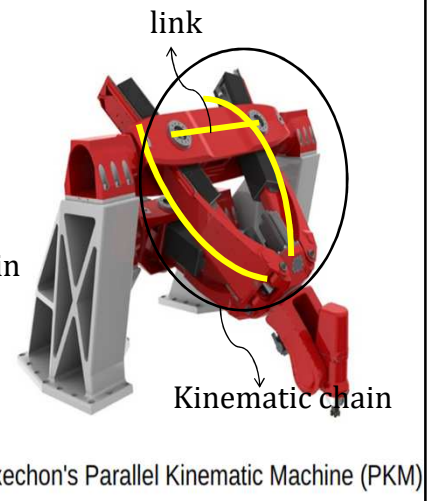


Force closed pair

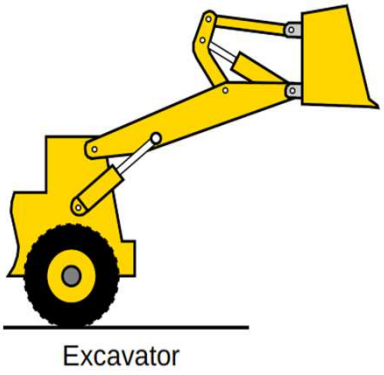


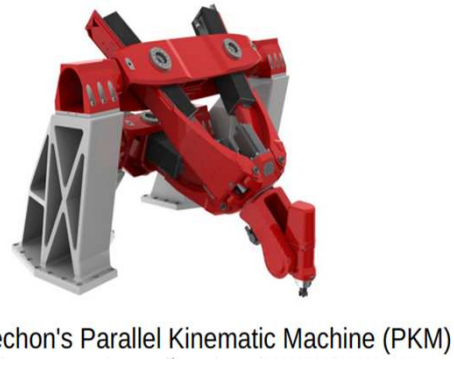
Kinematic chain: a combination of inter-connected links (rigid bodies)





Classification of chains : Planar and spatial chains

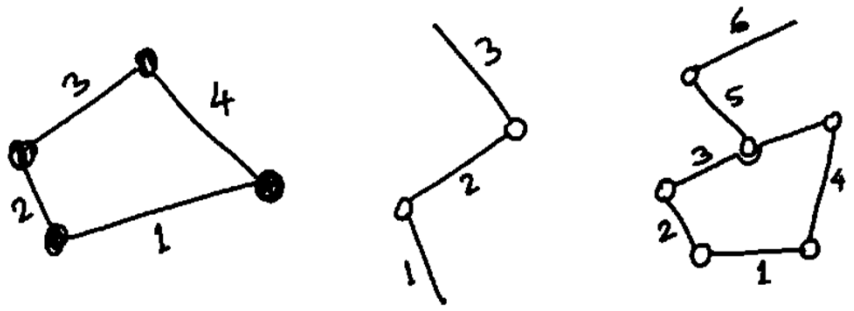




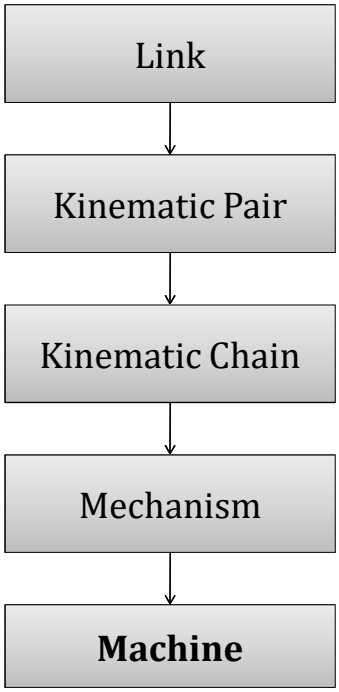
Planar kinematic chain:
all links move in parallel planes

Spatial kinematic chain:
link motion not restricted to a plane

Classification of chains: closed, open and hybrid kinematic chains



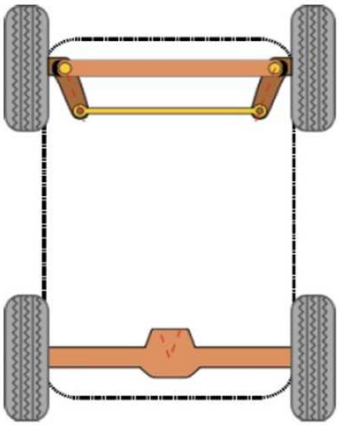
Closed chain: no singular link
Open chain: at least one singular link; no closed chains
Hybrid chain: combination of closed and open chains

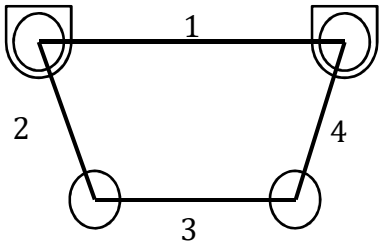


Kinematic diagram

- Schematic line diagram showing the arrangement of links and their inter-connection
- Reveals the kinematic chain(s)
- Dimensions are secondary

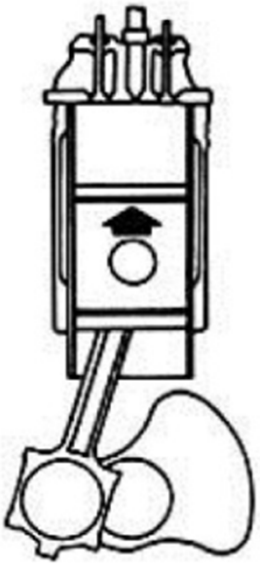
Ackerman steering Mechanism

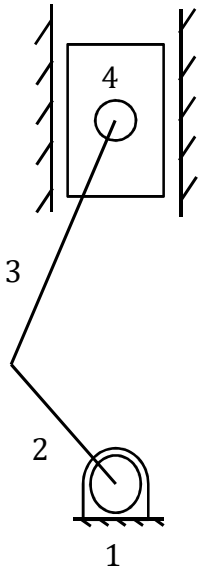




4-Bar kinematic chain
4R kinematic chain

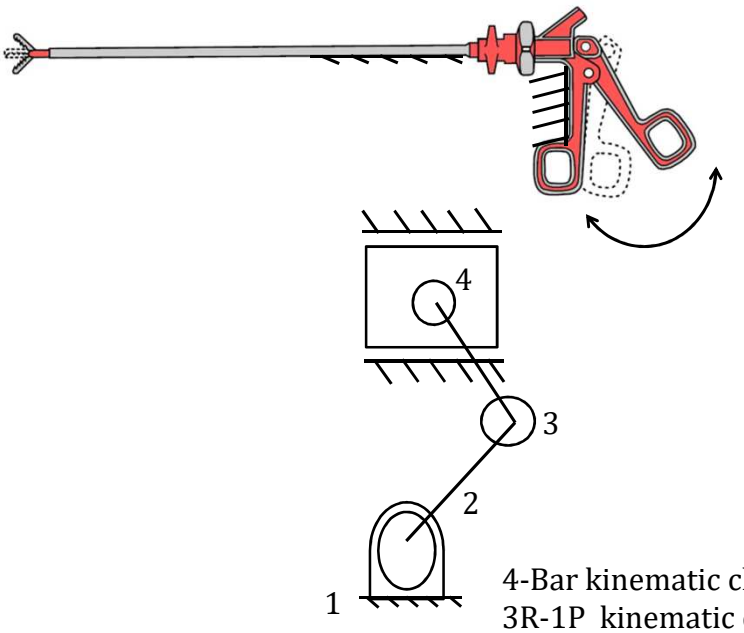
IC Engine





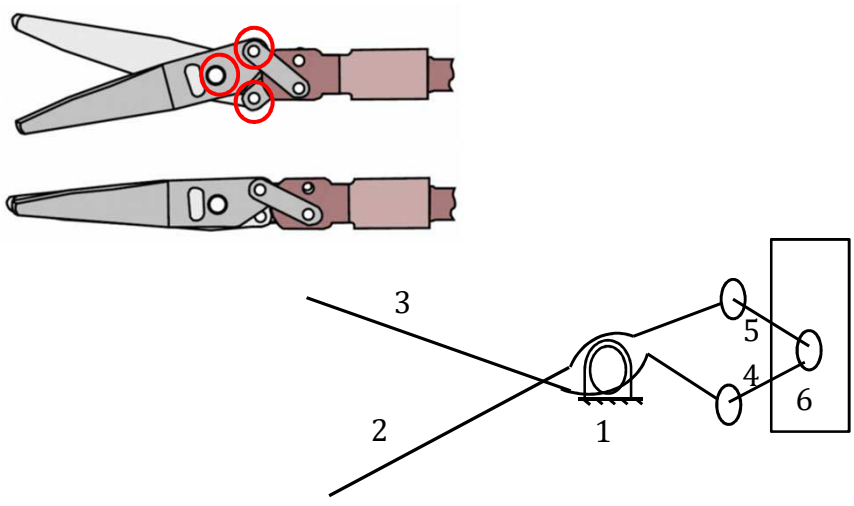
4-Bar kinematic chain
3R-1P kinematic chain

Surgical Instrument



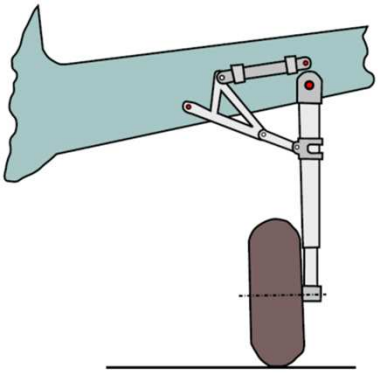
4-Bar kinematic chain
3R-1P kinematic chain

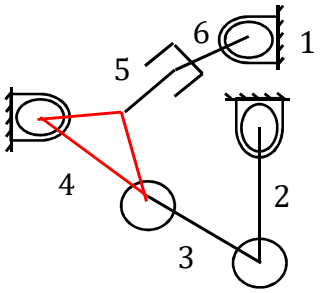
Surgical Scissor



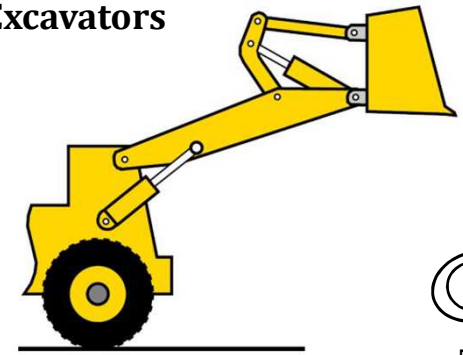
6-Bar kinematic chain
6R-1P kinematic chain

Aircraft Landing gear





Excavators

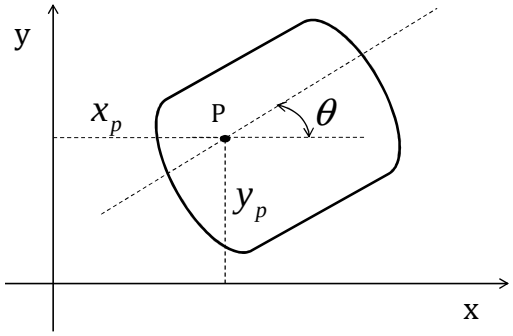


- **Degrees of Freedom DOF**

Minimum number of independent coordinates (variables) that need to be specified to fix the configuration of a mechanism

One link of the chain is grounded

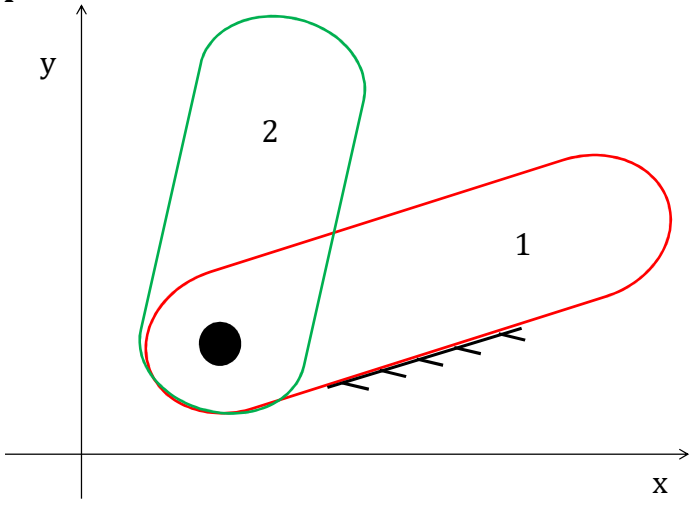
- **DOF Rigid link in a plane**



x_p, y_p, θ

A rigid link in a plane has 3 DOF

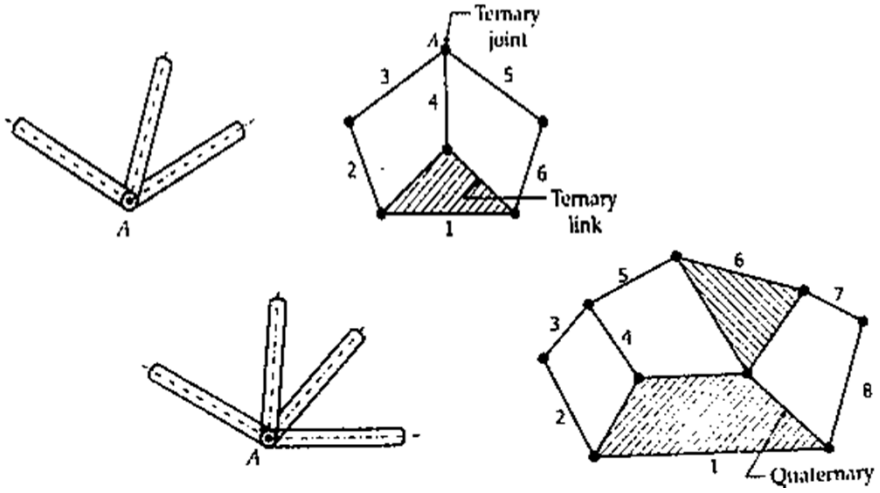
- **DOF**



$DOF = 3(l-1) - 2j - h$ ⟶ Kutzbach criteria

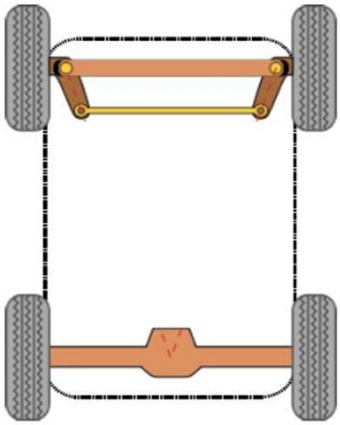
$DOF = 3(l-1) - 2j$ ⟶ Grubler's criteria

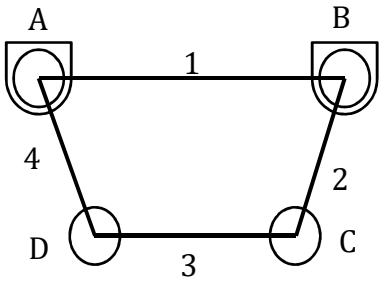
Classification of Joints : Binary, Ternary, Quaternary joint



Equivalent Binary joint =(l-1)Links connected to a joint

▪**Some examples on calculation of DOF**



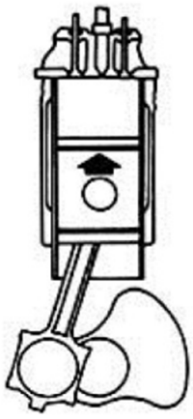


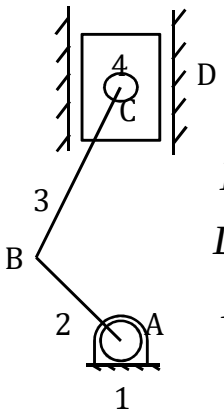
Type of Joint	Points	Equivalent Binary Joint
Binary	A, B,C,D	4
Ternary		
Quaternary		
	Total Binary Joints =4	

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

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

$$DOF = 1$$



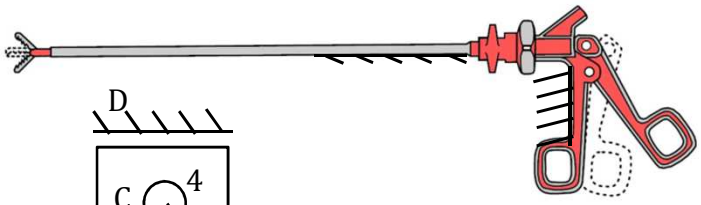


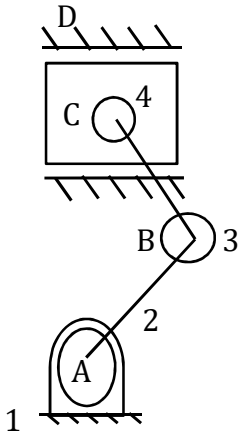
$$DOF = 3(l-1) - 2j - h$$

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

$$DOF = 1$$

Type of Joint	Points	Equivalent Binary Joint
Binary	A, B, C, D	4
Ternary		
Quaternary		
	Total Binary Joints =4	



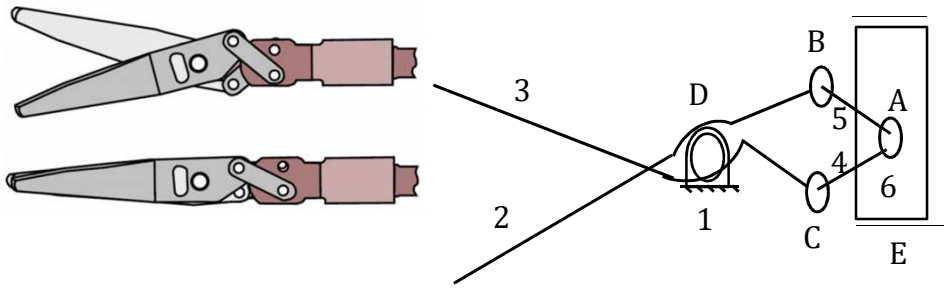


Type of Joint	Points	Equivalent Binary Joint
Binary	A, B, C, D	4
Ternary		
Quaternary		
	Total Binary Joints =4	

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

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

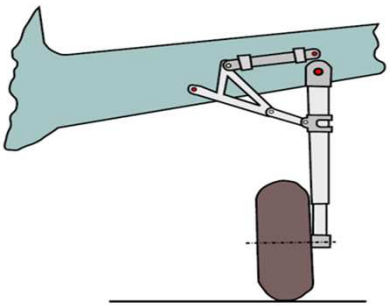
$$DOF = 1$$

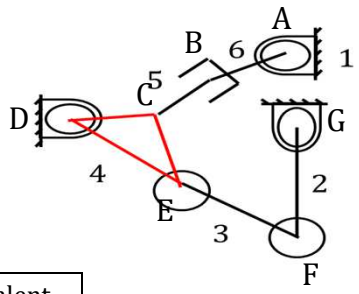


Type of Joint	Points	Equivalent Binary Joint
Binary	B,C,E	3
Ternary	A, D,	2x2=4
Quaternary		
	Total Binary Joints =7	

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

$$DOF = 3(6-1) - 2\times 7 - 0 \qquad DOF = 1$$

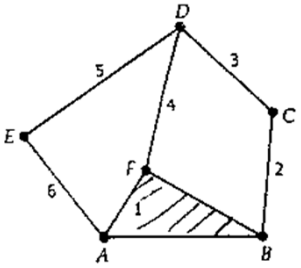




Type of Joint	Points	Equivalent Binary Joint
Binary	A, B,C,D, E, F, G	7
Ternary		
Quaternary		
	Total Binary Joints =7	

$$DOF = 3(l-1) - 2j - h \;\; ; DOF = 3(6-1) - 2\times 7 - 0$$

$$DOF = 1$$

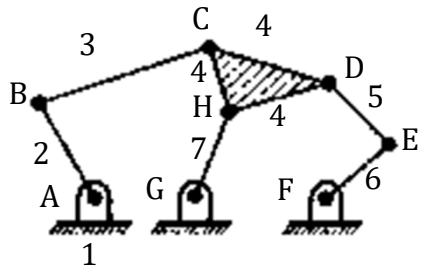


Type of Joint	Points	Equivalent Binary Joint
Binary	A,B,C,E,F	5
Ternary	D,	1x2=2
Quaternary		
	Total Binary Joints =7	

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

$$DOF = 3(6-1) - 2\times 7 - 0$$

$$DOF = 1$$

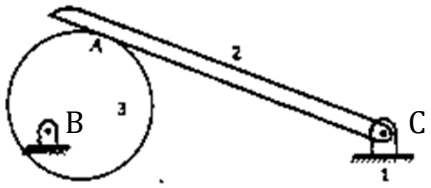


$$DOF = 3(l-1) - 2j - h$$

$$DOF = 3(7-1) - 2\times 8 - 0$$

$$DOF = 2$$

Type of Joint	Points	Equivalent Binary Joint
Binary	A, B,C,D, E, F, G H	8
Ternary		
Quaternary		
	Total Binary Joints =8	

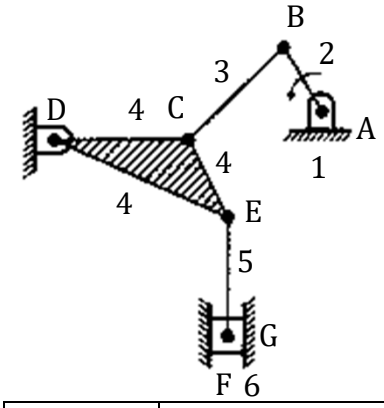


Type of Joint	Points	Equivalent Binary Joint
Binary	B, C	2
Ternary		
Quaternary		
	Total Binary Joints =2	

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

$$DOF = 3(3-1) - 2\times 2 - 1$$

$$DOF = 1$$



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

$$DOF = 3(6-1) - 2\times 7 - 0$$

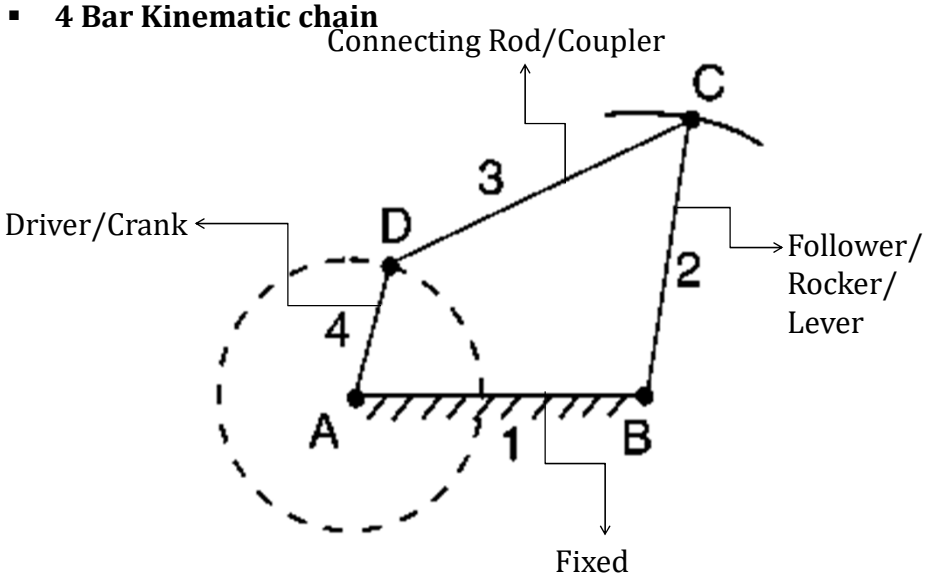
$$DOF = 1$$

Type of Joint	Points	Equivalent Binary Joint
Binary	A, B,C,D, E, F, G	7
Ternary		
Quaternary		
	Total Binary Joints =7	

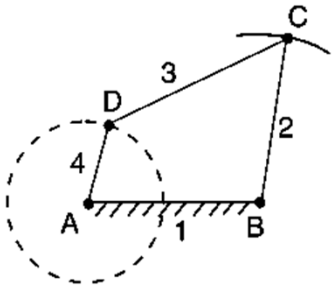
- **Inversions of a Mechanism**

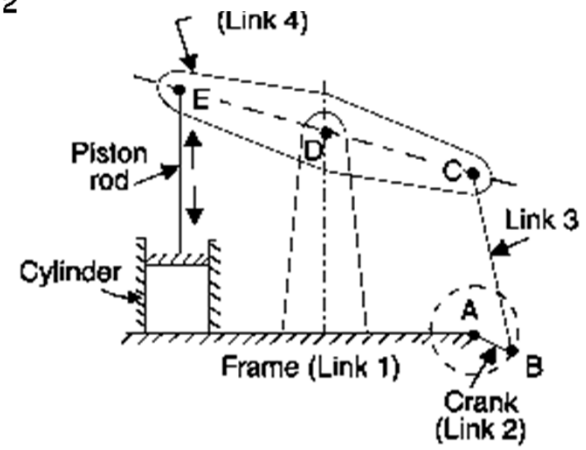
  Method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as inversion of the mechanism.

- **4 Bar Kinematic chain**

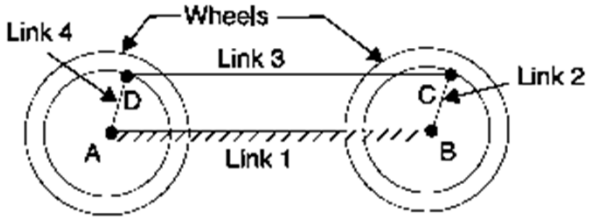


- **Inversions of 4 Bar Kinematic chain**





1.Beam Engine



2.Double crank mechanism