Mechatronics System Design

EC4.404 - S2023

Lecture 8

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Preliminaries

- **Kinematics**

  - study of motion of system of particles or rigid bodies without regard to forces

    - Motion described by position and its time derivatives, velocity, acceleration, Jerk, etc.

  - ensure the functionality of the mechanism/machine

- **Dynamics**

  - Study of forces on systems in motion

  - verify that the parts can withstand the induced forces

Some _____ Definitions

- **Rigid body**: A body that does not undergo deformation. A distance between any two points is invariable.

- **Mechanism**: A device to transform one motion to another – connection of links and joints – at least one of the link should be grounded.

- **Machine**: is a collection of mechanisms to transmit substantial forces.

TYPES OF MOTION

Pure rotation:

- The body possesses one point that has no motion with respect to the “stationary” frame of reference.

Pure translation:

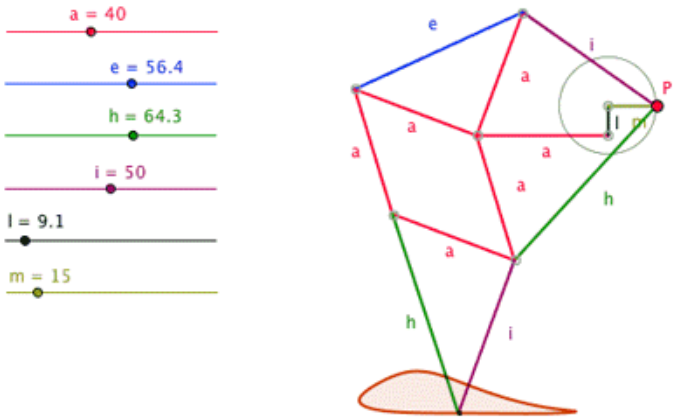
- All points on the body describe parallel (rectilinear) paths.

Complex motion:

- Points on the body will travel nonparallel paths, and there will be, at every instant, a center of rotation, which will continuously change location.

Mechanism design

- Mechanism design involves finding a mechanism which carries out a user specified task.



- The process involves selection of joint types and link dimensions.

- Example – Eight-bar **Theo-Jansen** linkage enables robotic walking.

Definitions

- **Degrees of Freedom or Mobility:** is equal to the number of independent parameters (measurements) that are needed to uniquely define its position in space at any instant of time.

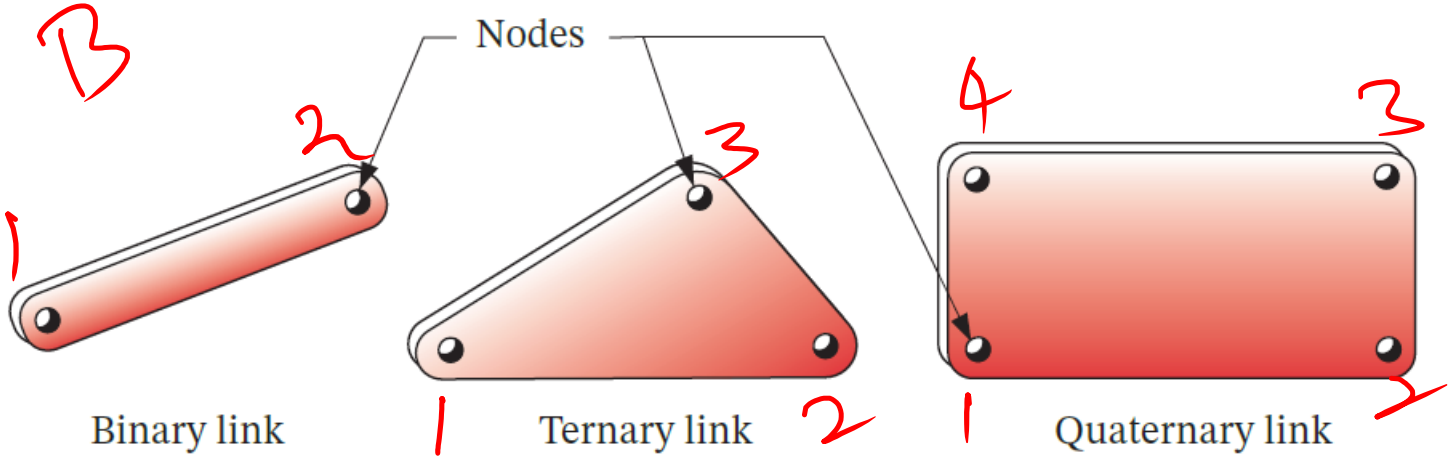
  Object on a plane = 3 parameters are required

  Object in a 3D space = 6 parameters

Links

Link: rigid body that possesses at least two nodes that are points for attachment to other links.

- Binary link - one with two nodes.
- Ternary link - one with three nodes.
- Quaternary link - one with four nodes.

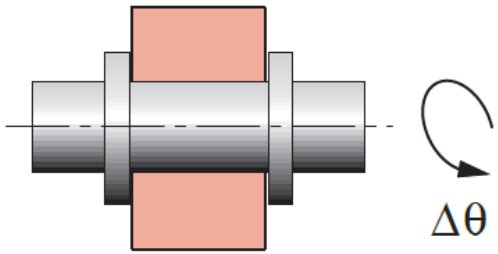


Joints

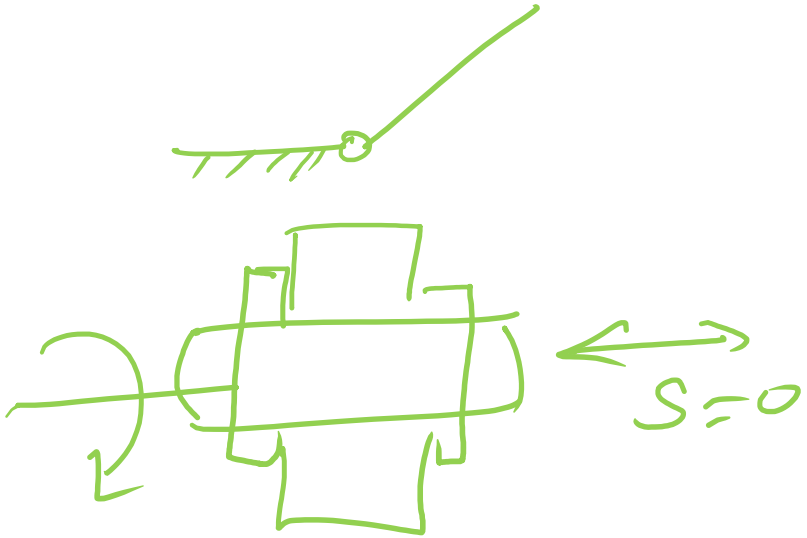
- A joint is a connection between two or more links (at their nodes), which allows some motion between the connected links.
- Joints (also called kinematic pairs)
  - Revolute (R) pair
  - prismatic (P) pair

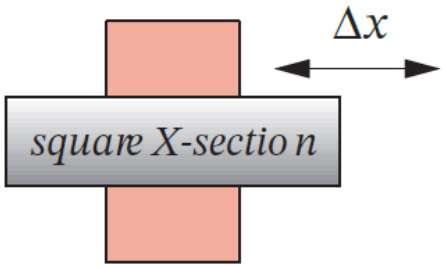
  The R and P pairs are the basic building blocks of all other pairs.
  - Screw (H)
  - Cylindrical (C)
  - Spherical (S)
  - Flat (F) pairs
  - Universal (U)

Joints

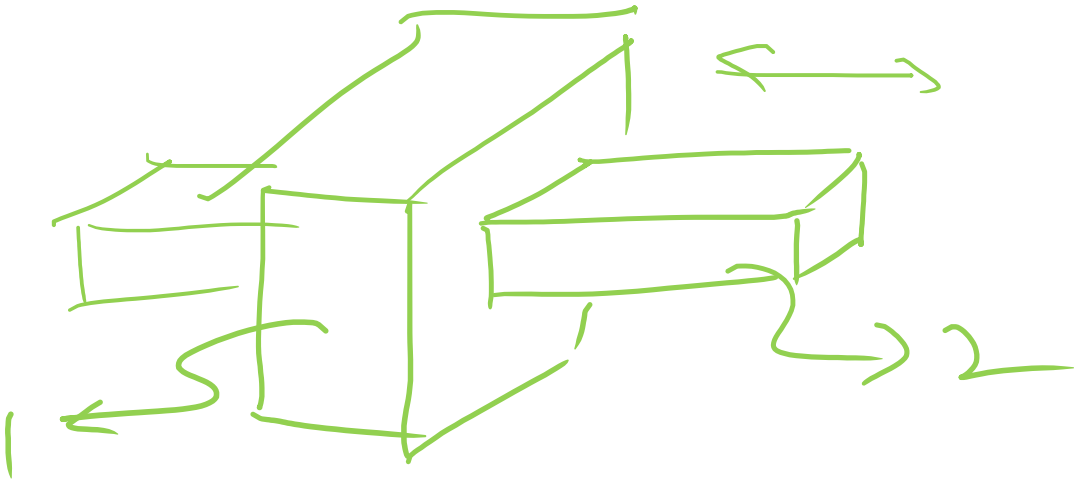


Revolute (R) joint—1 *DOF*



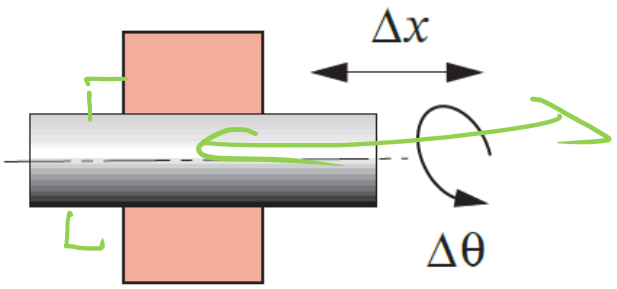


Prismatic (P) joint—1 *DOF*

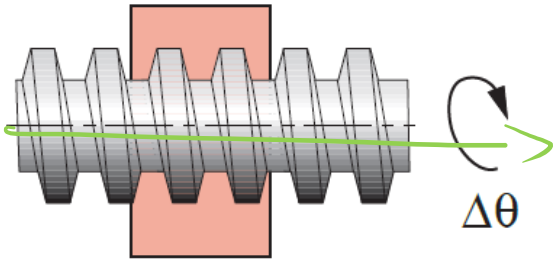


Ref: L. Norton, Design of Machinery "An Introduction to the. Synthesis and Analysis of Mechanisms

Joints



Cylindric (C) joint—2 *DOF*



Helical (H) joint—1 *DOF*

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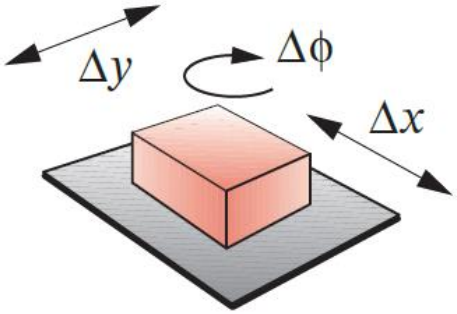
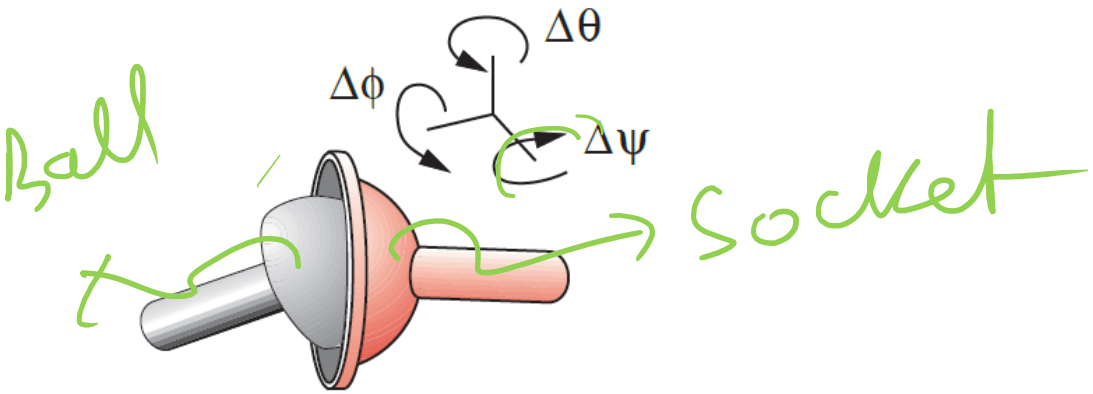
Joints



Planar (F) joint—3 *DOF*

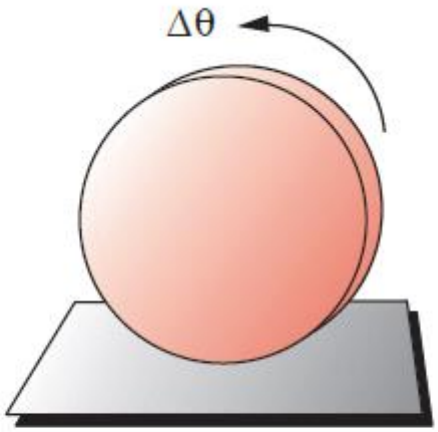


Spherical (S) joint—3 *DOF*

Ref: L. Norton, Design of Machinery "An Introduction to the. Synthesis and Analysis of Mechanisms

Joints

- **Half joint** is also called a **roll-slide joint** because it allows both rolling and sliding.



May roll, slide, or roll-slide, depending on friction

Planar pure-roll (R), pure-slide (P), or roll-slide (RP) joint —1- or 2 *DOF* (higher pair)

- **Friction** determines the actual number of freedoms at this kind of joint. It can be pure roll, pure slide, or roll-slide

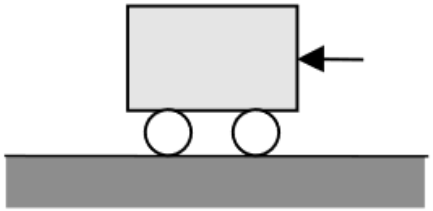
Friction

- Friction is a force **between two surfaces** that are sliding, or trying to slide, across each other.

- The intensity of frictional force varies with the state of contact.

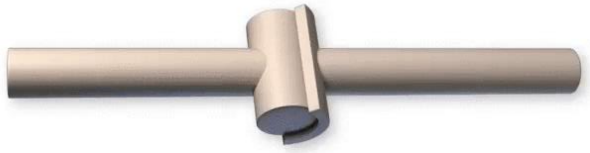
- A friction force of **rolling contact** is usually smaller than that of **sliding contact**

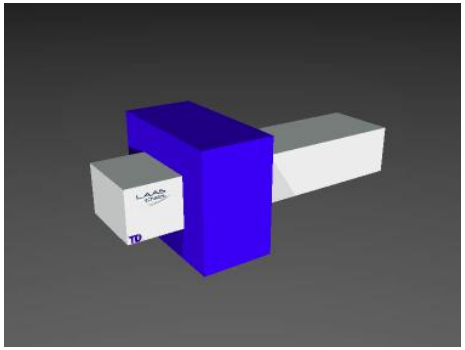
Sliding friction ↔ Sliding guide
(Requires larger force)

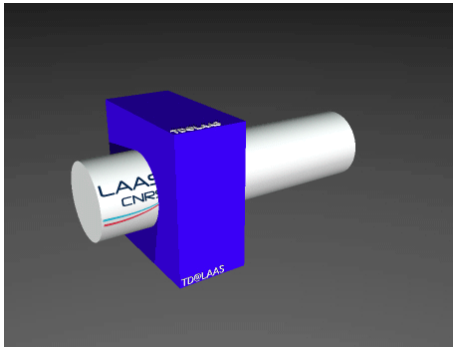


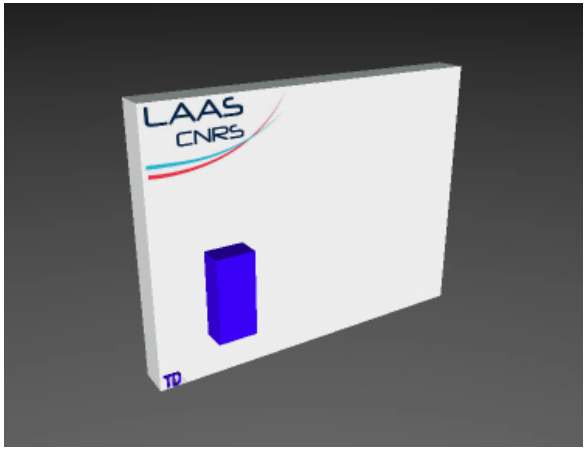
Rolling friction ↔ Rolling element guide
(Requires far less force)

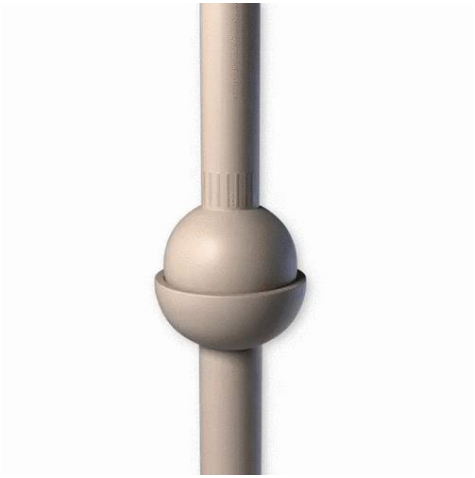
Joints



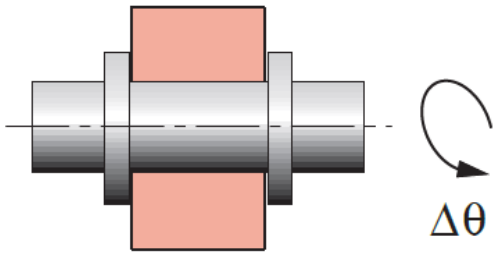




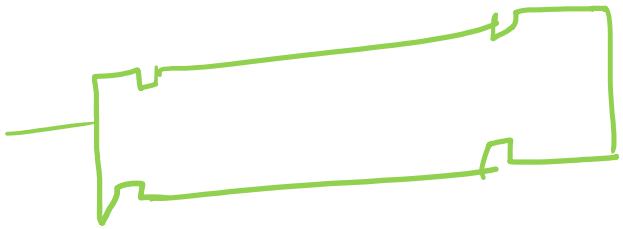


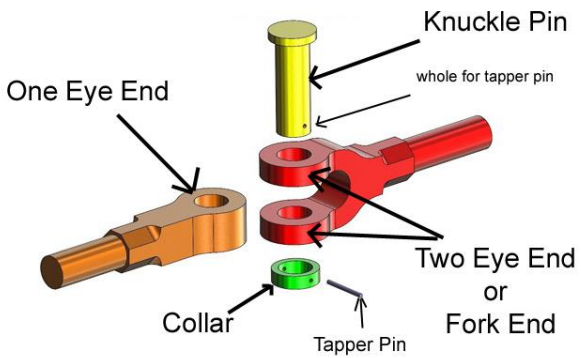


Revolute joint

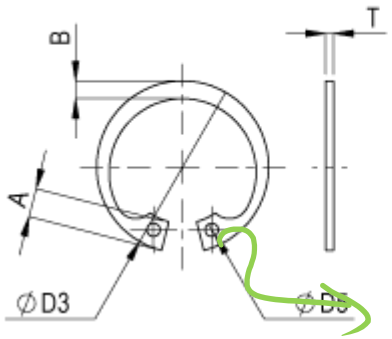


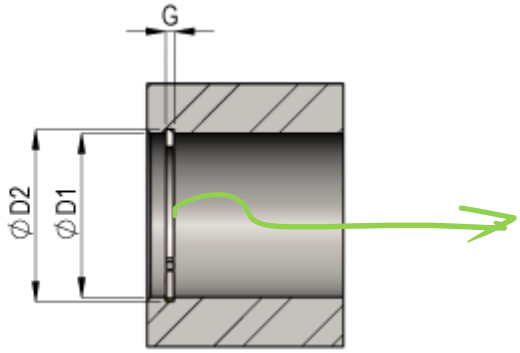
Revolute (R) joint—1 *DOF*





https://en.wikipedia.org/wiki/Knuckle_joint_(mechanical)





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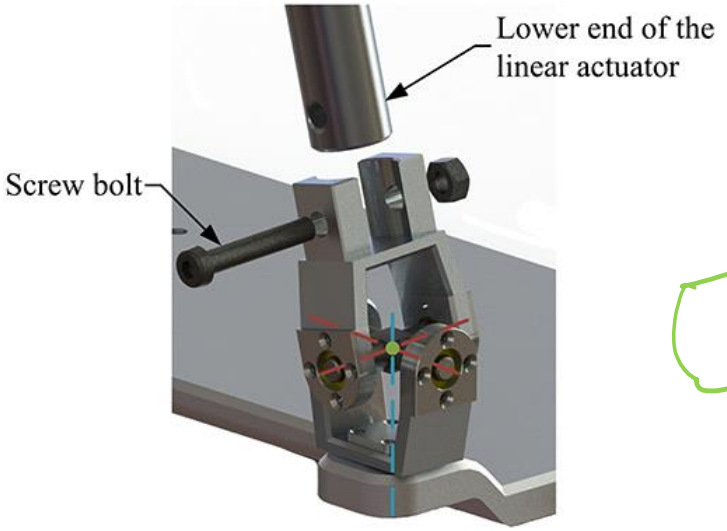
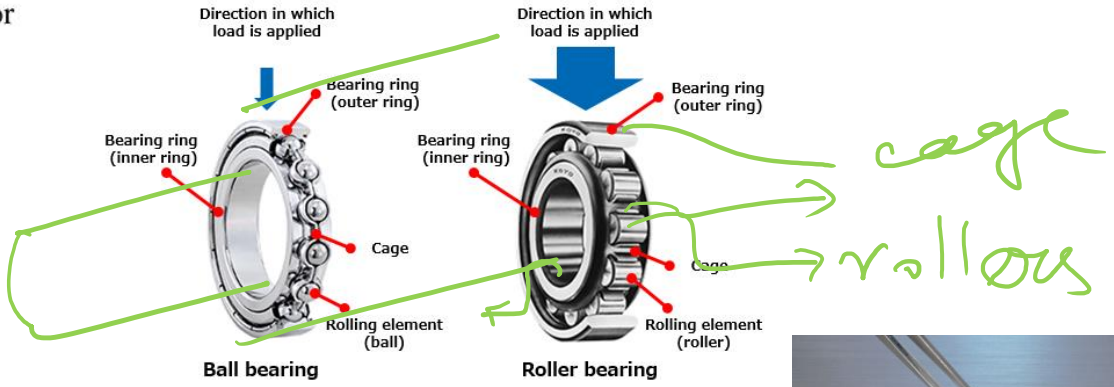
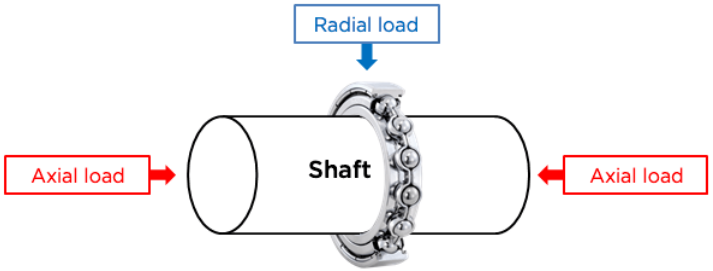
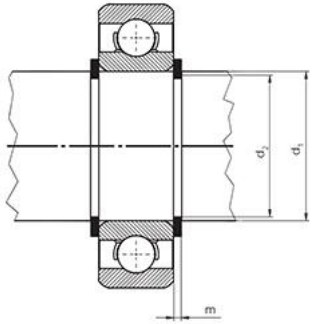
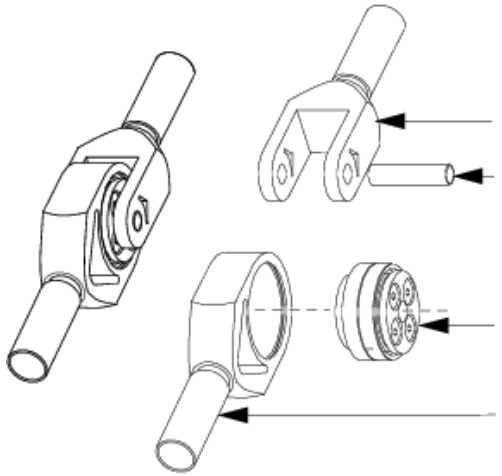
Revolute joint



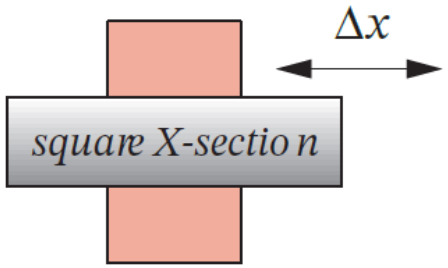








Sliding Joint

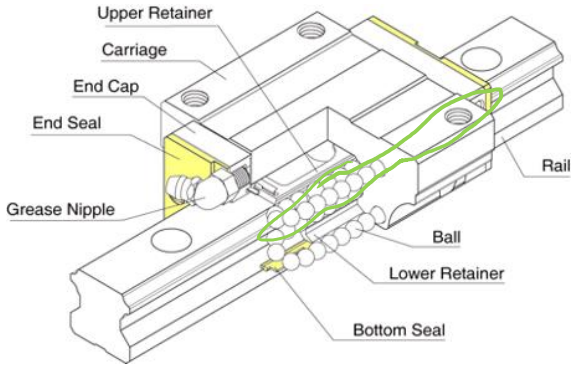


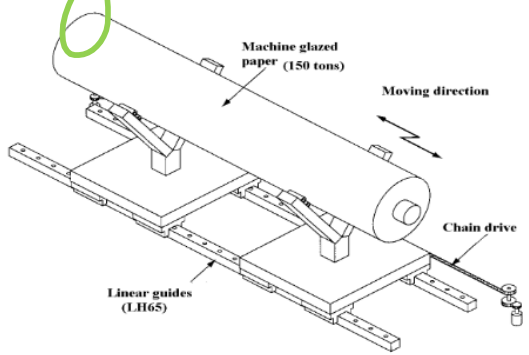
Prismatic (P) joint—1 *DOF*

rail.

roller

guide

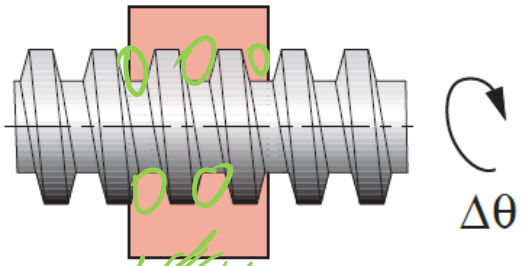




Linear guides are used to lessen the friction force to transfer machine glazed paper (150 tons).

Ref: L. Norton, Design of Machinery "An Introduction to the. Synthesis and Analysis of Mechanisms

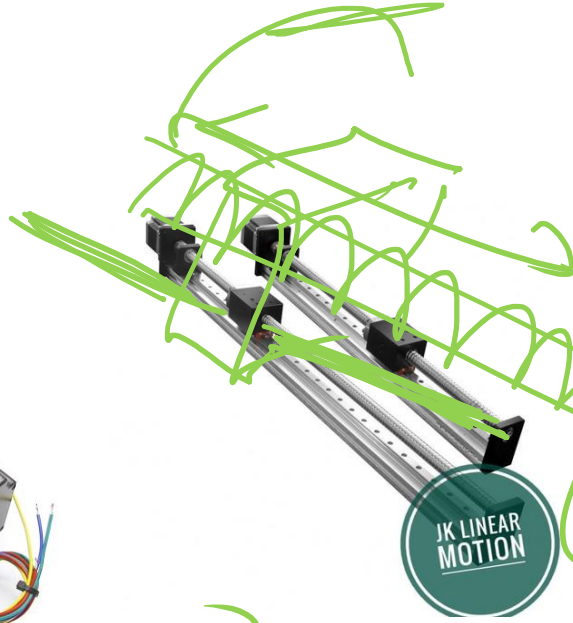
Joints



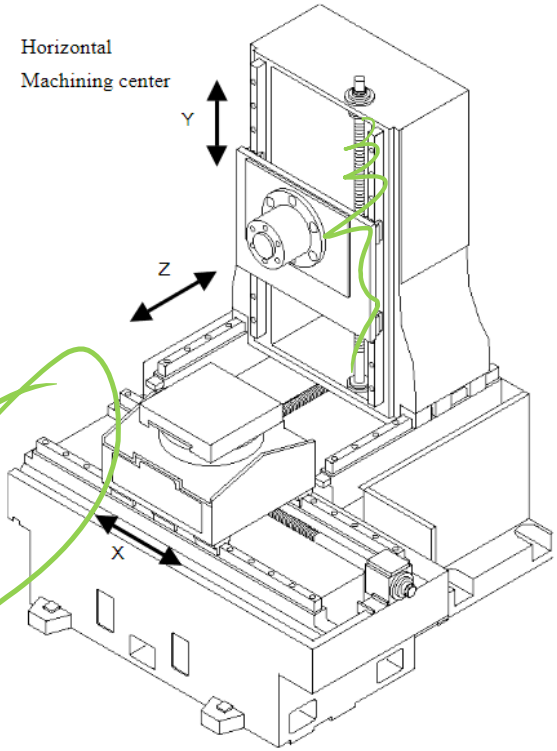
Helical (H) joint—1 *DOF*

Ball nut

Screw shaft / rack



Leadscrew



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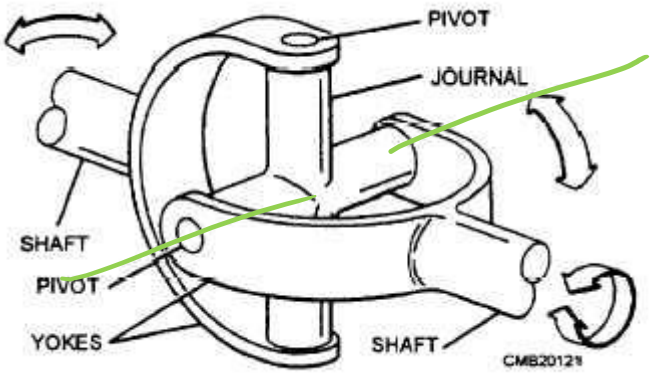
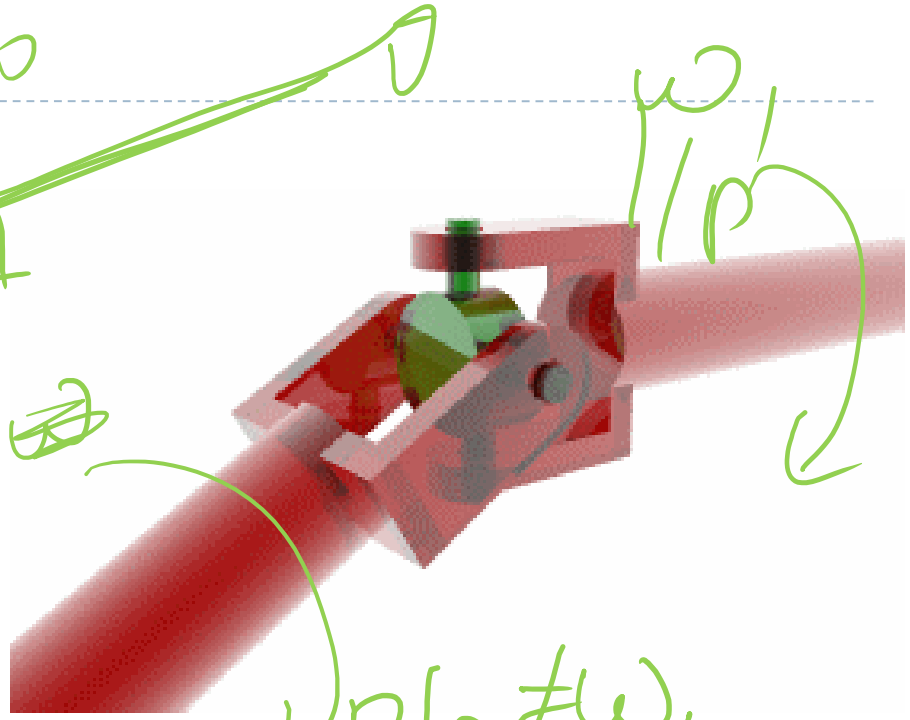
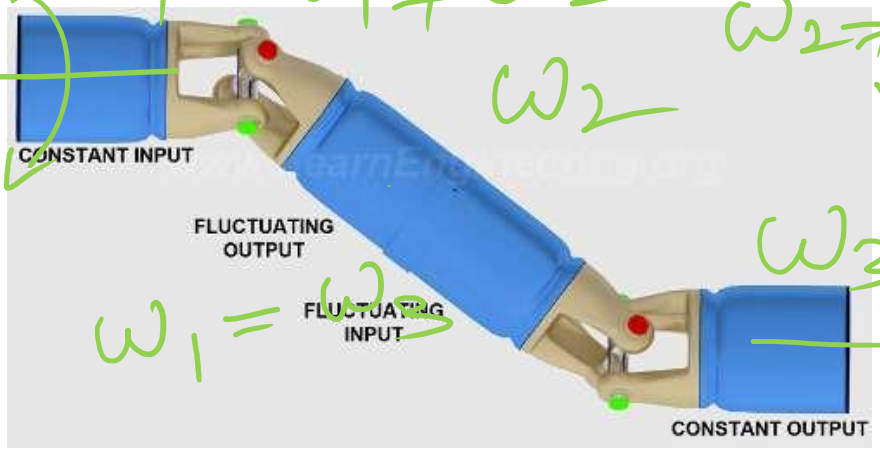
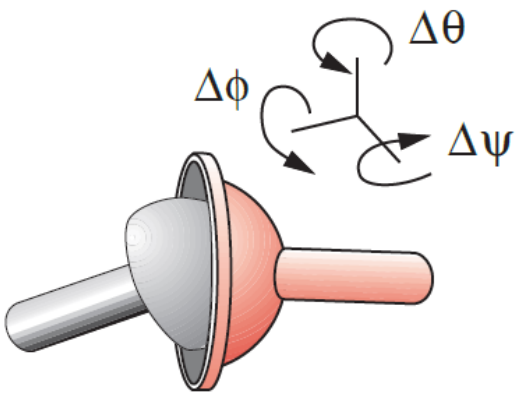
Universal joint



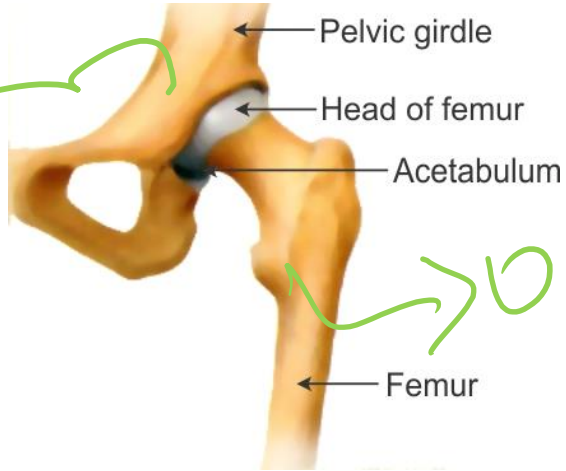




Spherical Joint



Spherical (S) joint—3 *DOF*



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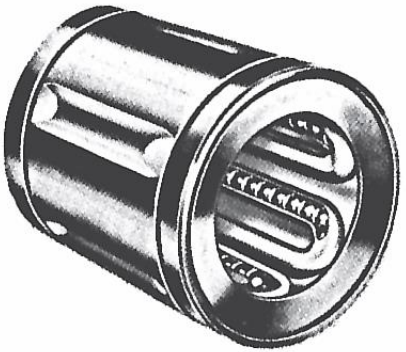
Kinematic Pairs - According to nature of relative motion

Rolling pair

Screw pair



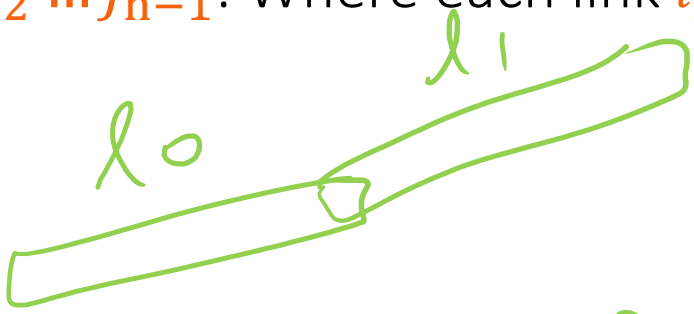
Linear ball bushing

Spherical pair

Roller bearing

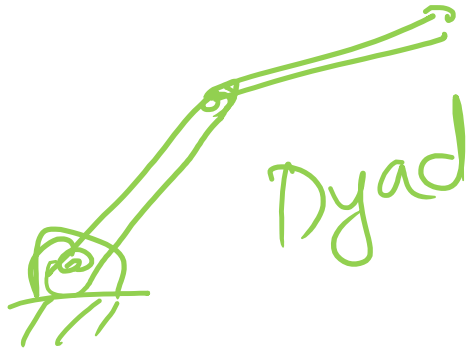
Kinematic chains

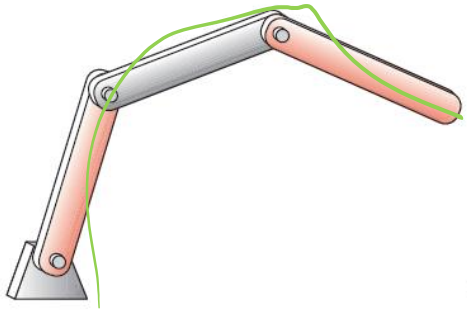
- Kinematic chain: an assemblage of rigid bodies/links, $l_0, l_1, l_2 \dots l_{n-1}$ connected via joints $j_1, j_2 \dots j_{n-1}$. Where each link l_i is attached to link l_{i+1} at joint j_{i+1}



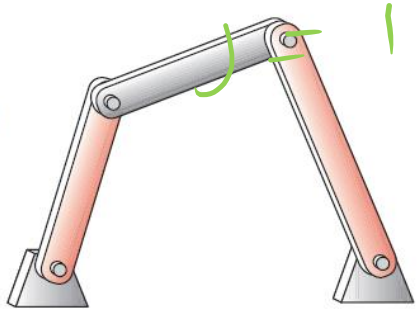
- **Open Chain:**

An open kinematic chain of two binary links and one joint is called a dyad





(a) Open mechanism chain



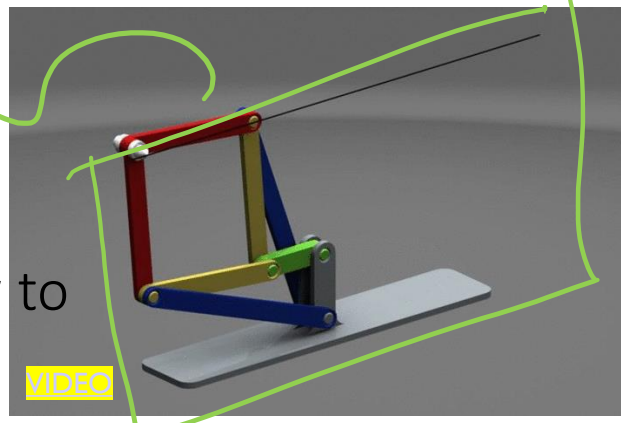
(b) Closed mechanism chain

- **Closed Chain:**

A closed mechanism will have no open attachment points or nodes and may have one or more degrees of freedom

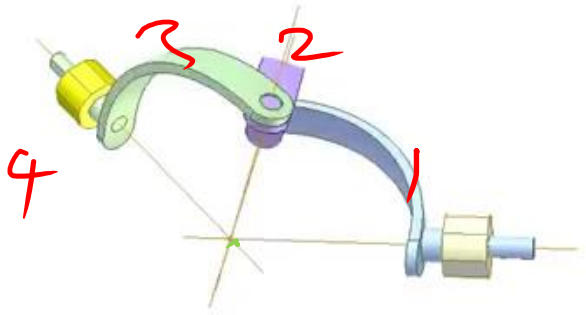
Mechanism Types:

- Planar mechanism:
  - If all the points of a mechanism move in planes $parallel$ to certain plane.
  - If the axes of hinges are $perpendicular$ to the base plane



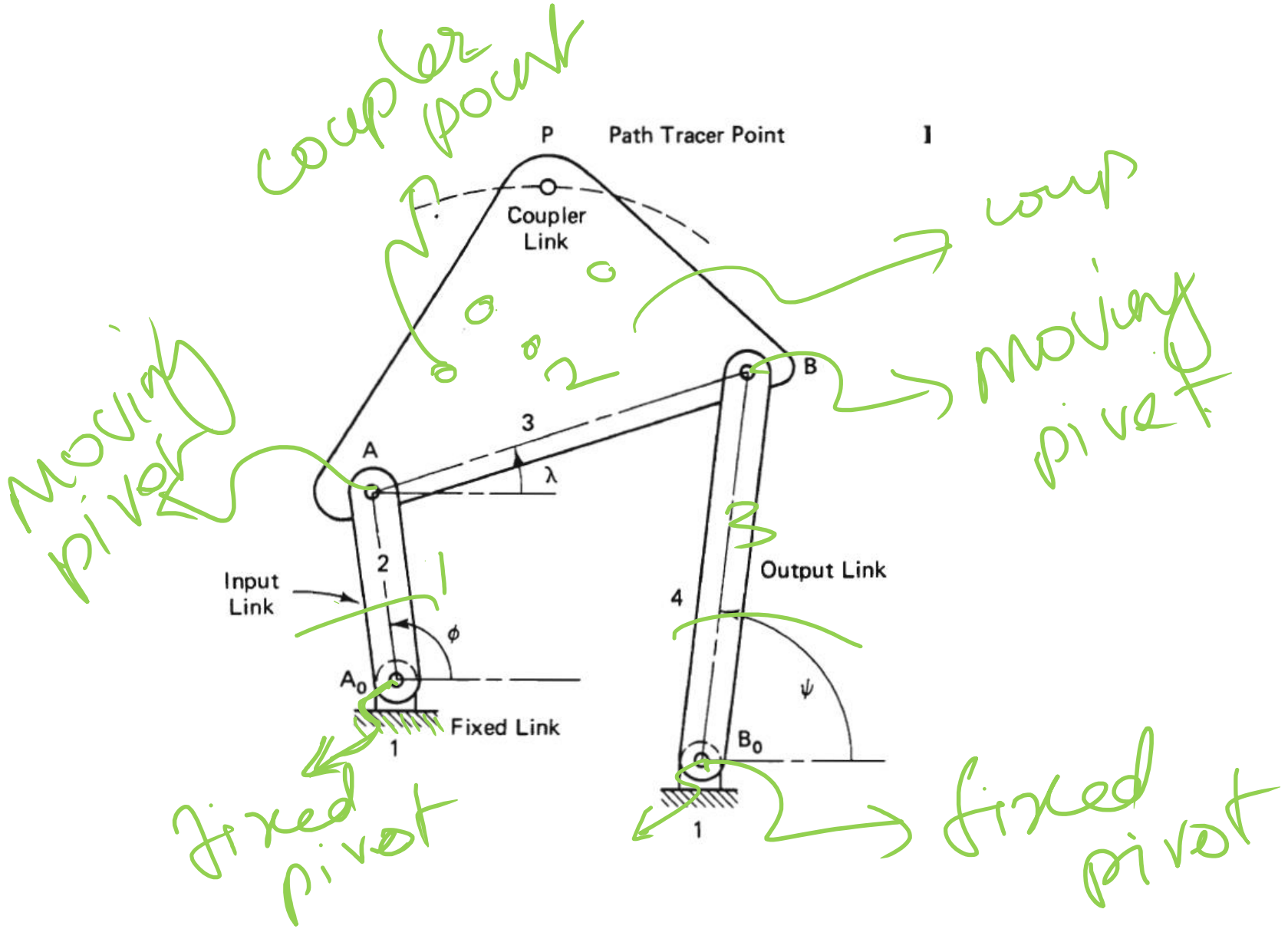
Peaucellier–Lipkin linkage, invented in 1864, was the first true planar straight line mechanism

- Spherical mechanism:
  - The axes of all joints intersect at a point.
  - Example – Gyro.

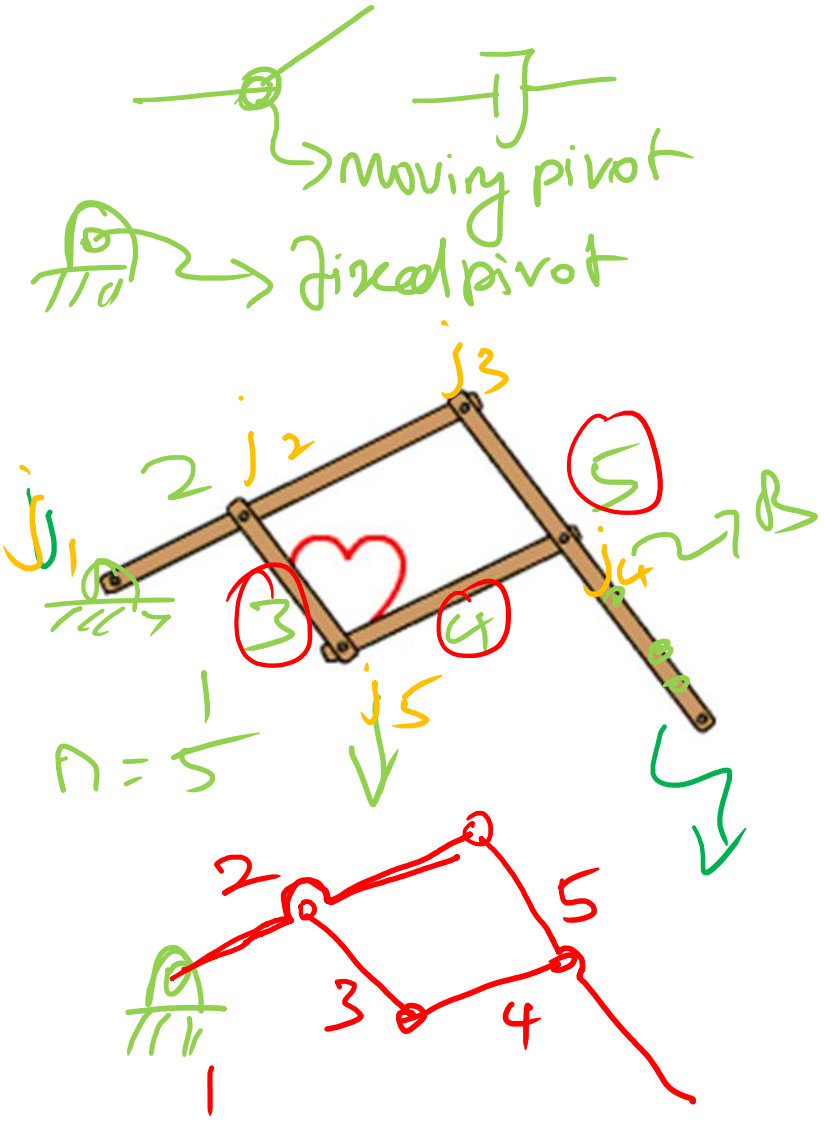


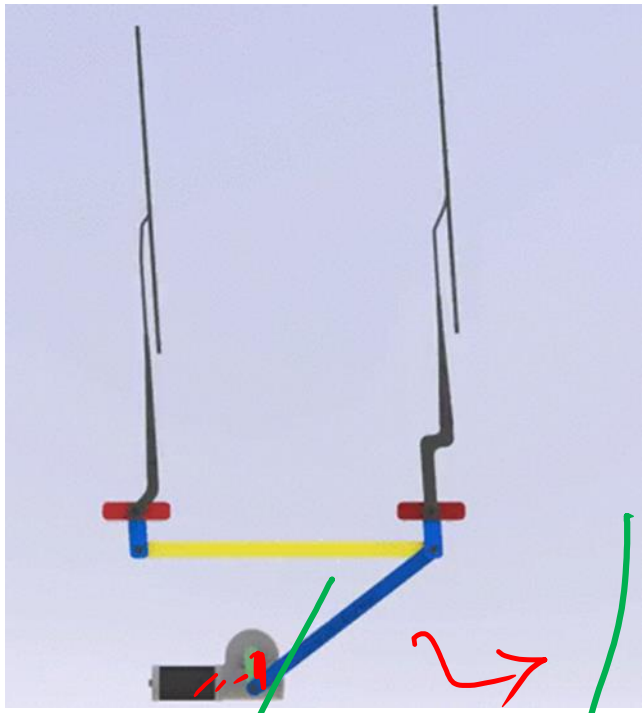
- Spatial mechanism:
  - Do not have special points or special base plane, in general, it means all the joint axes are skew to each other.

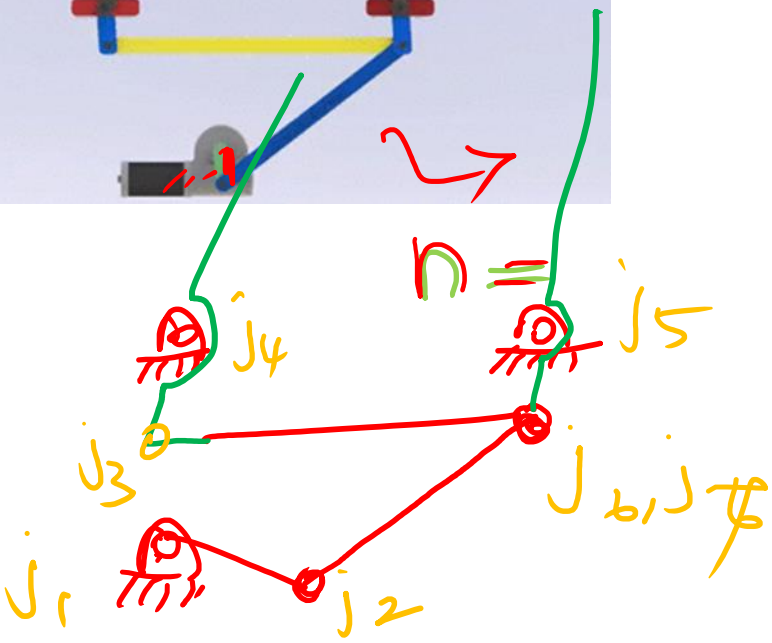
Fourbar Linkage



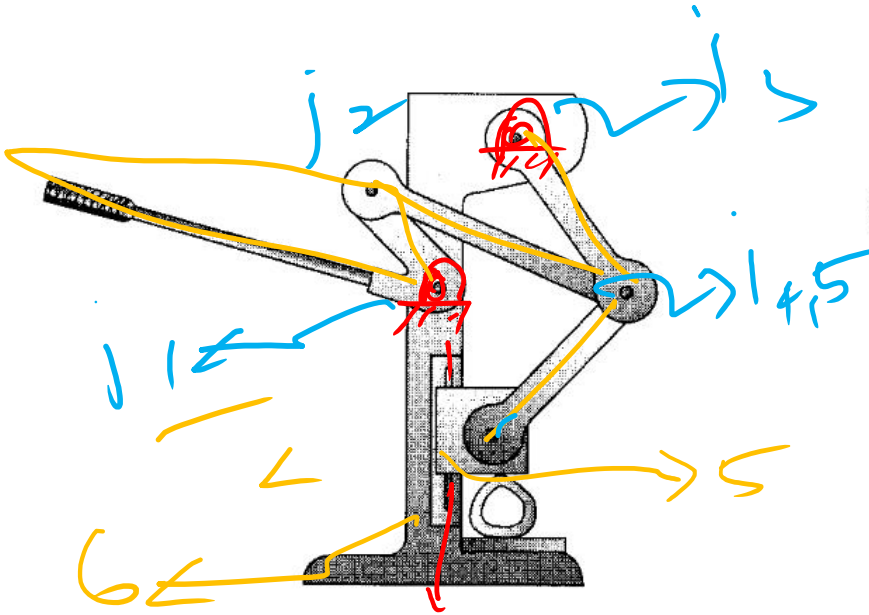
Kinematic Diagram



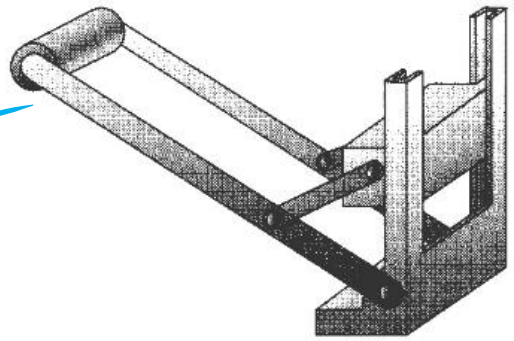




Kinematic Diagram



Simple press



Can crusher

Kinematic Diagram