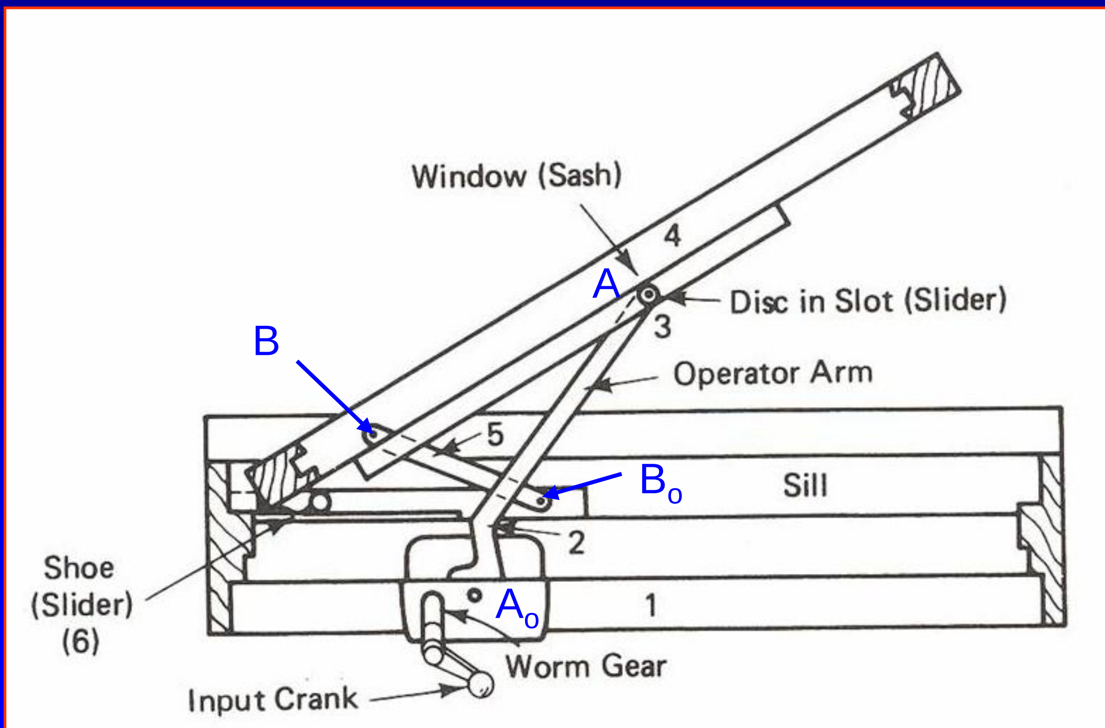
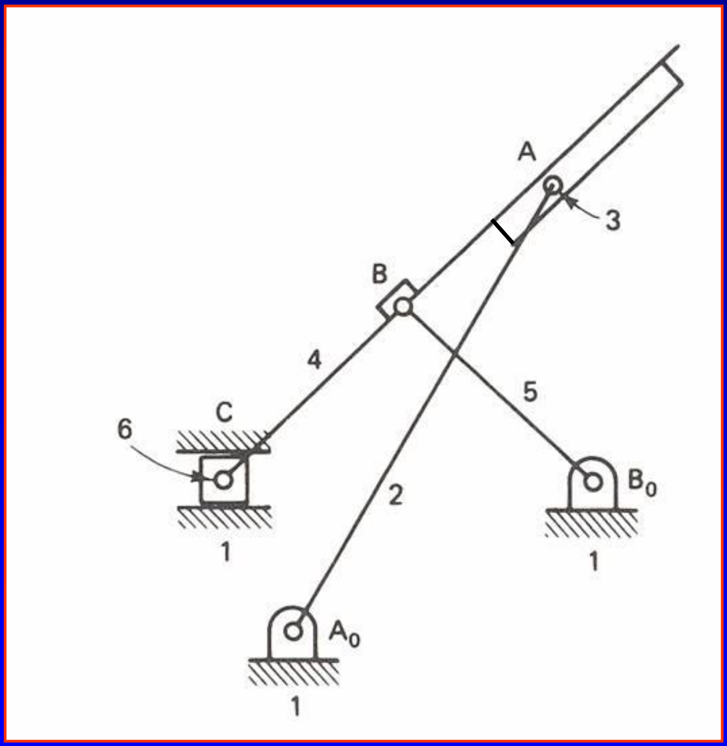
Kinematic (stick or skeleton) Diagrams

A striped-down (simplified) drawing showing the essentials needed for kinematics analysis. All links are numbered while the joints are lettered.

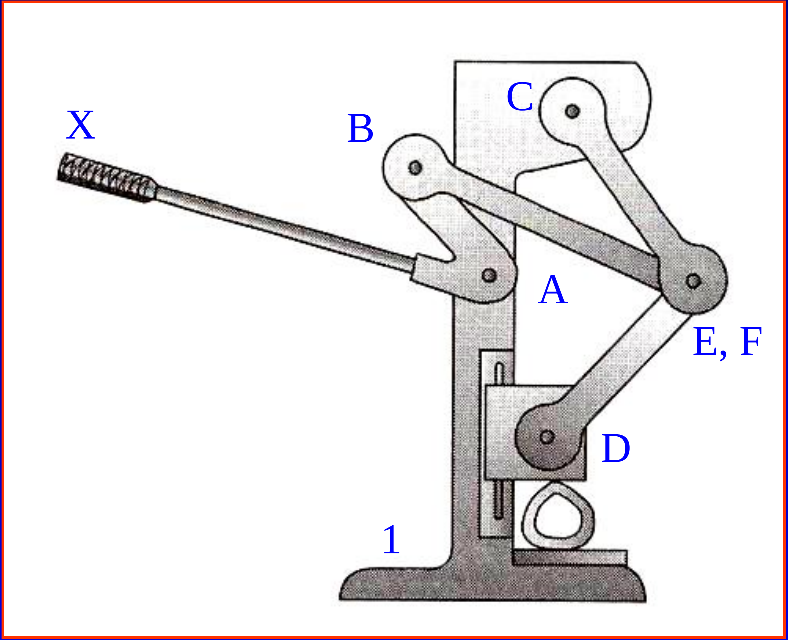


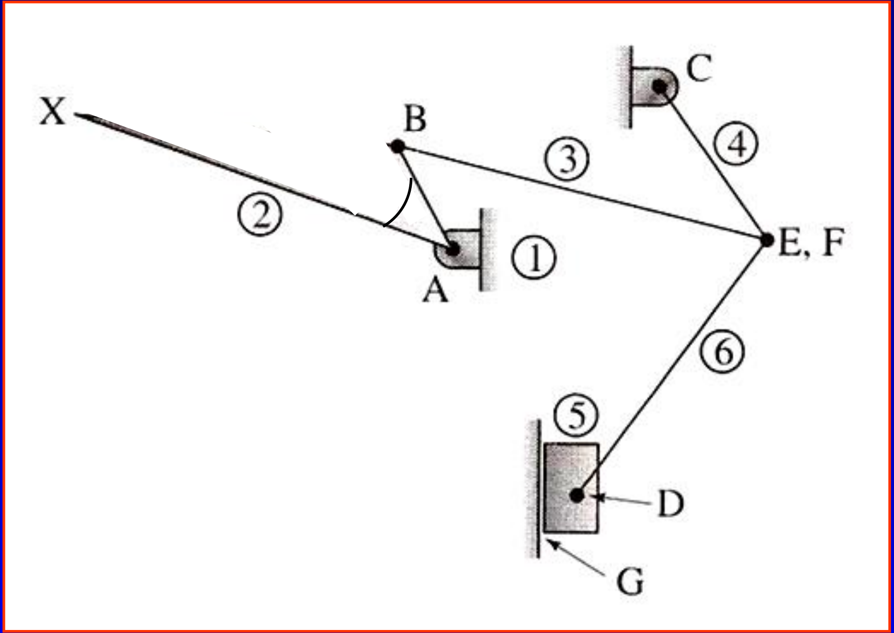
Mechanism to open and close a window

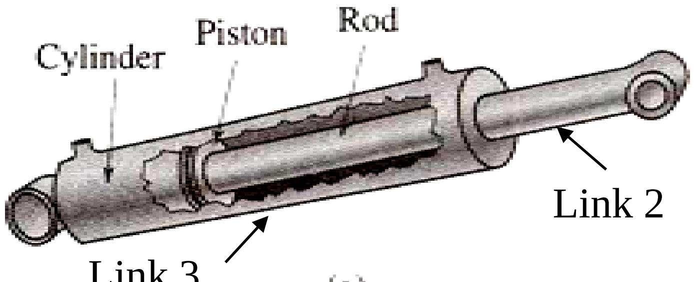


Kinematic diagram

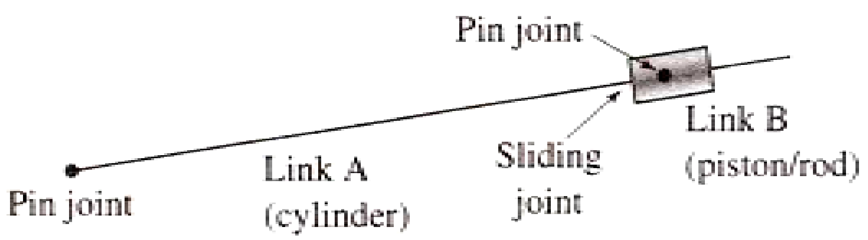
Kinematic (stick or skeleton) Diagrams





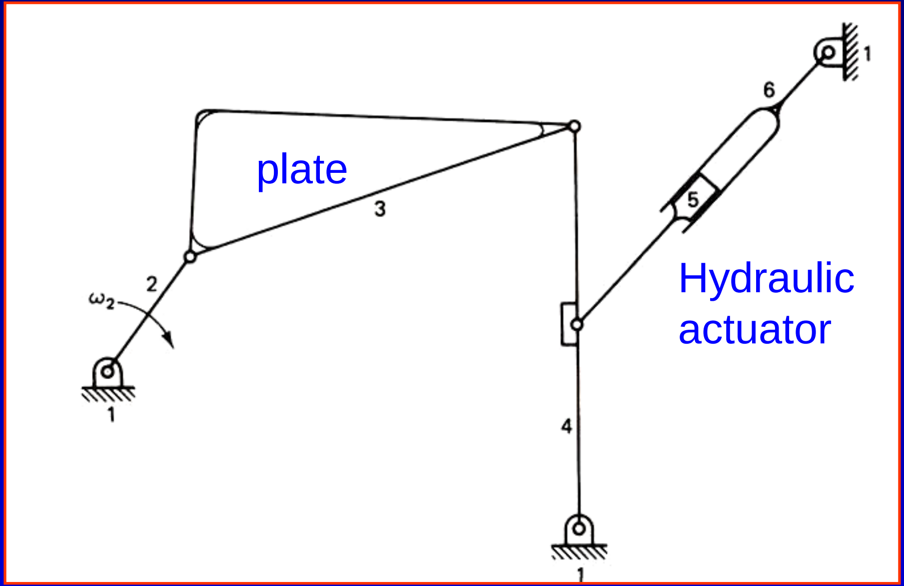


(a)

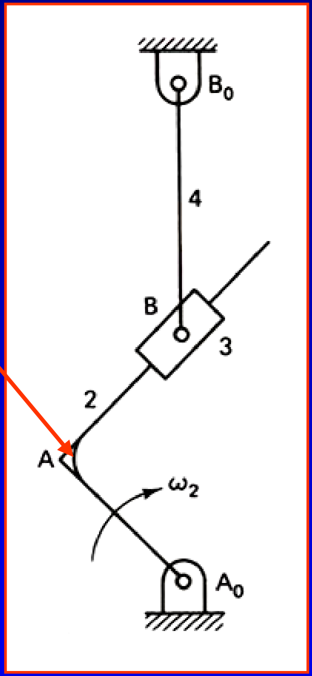


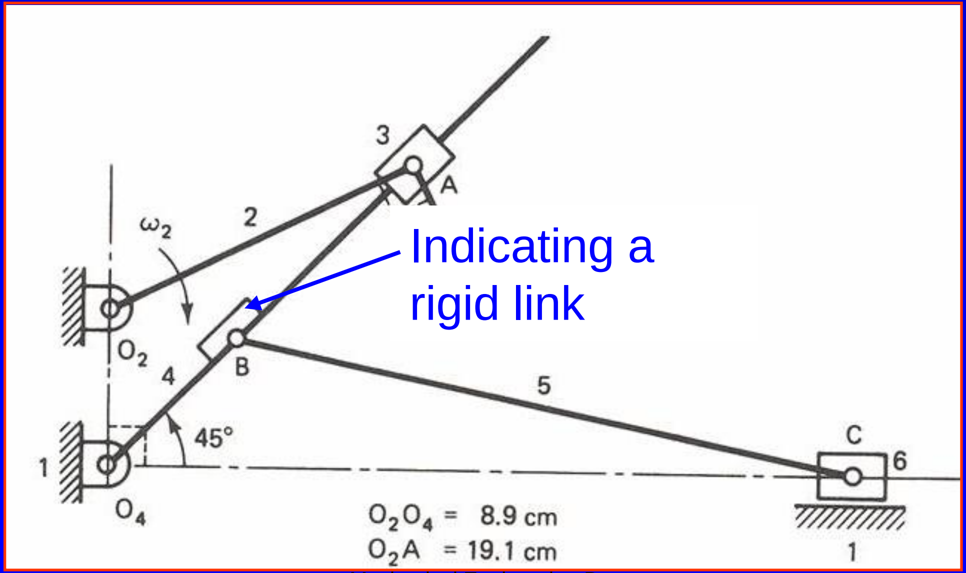
(b)

Kinematic (stick or skeleton) Diagrams



Indicating a fixed angle





Type of Joints – Kinematic Pairs

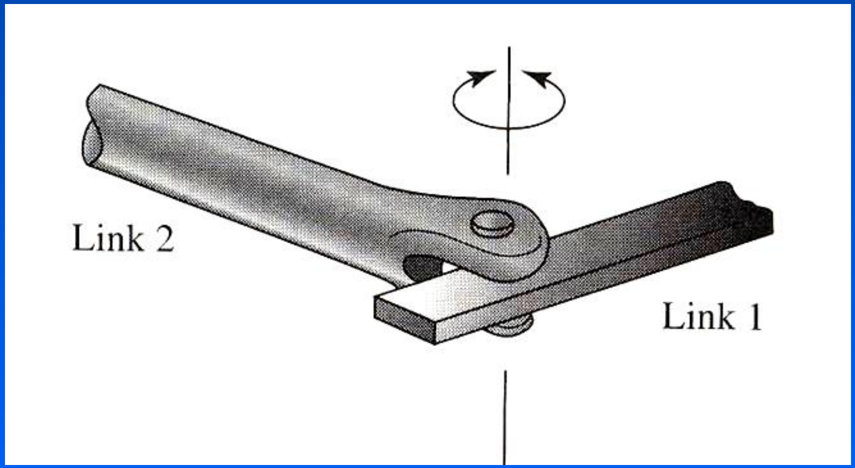
Lower Pairs – motion is transmitted through an area contact, pin and slider joints.

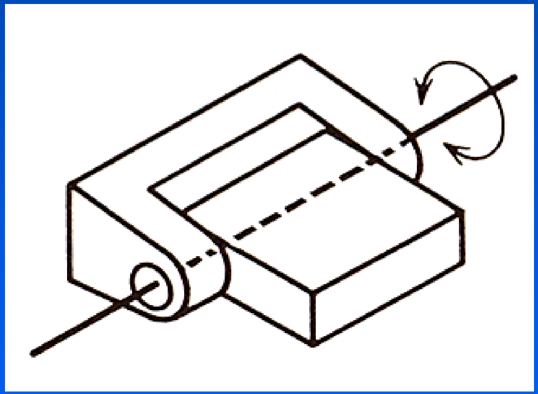
Higher Pairs – motion is transmitted through a line or a point contact; gears, rollers, and spherical joints.

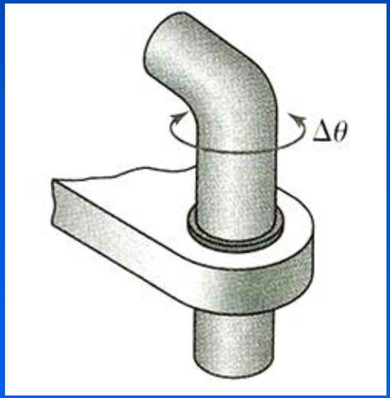
Joints

The *Revolute* joint (pin or hinge joint) - one degree of freedom

It allows pure rotation between the two links that it connects (R joints)



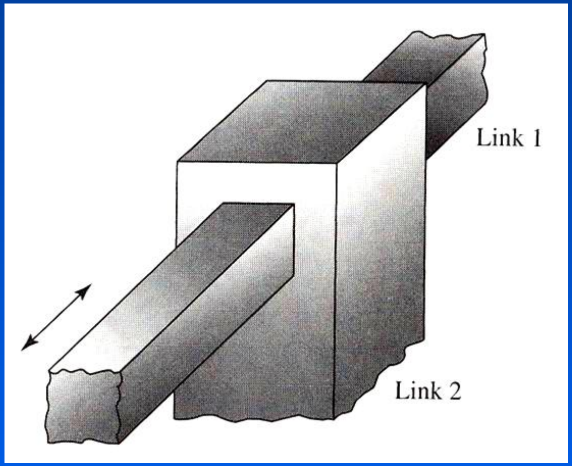


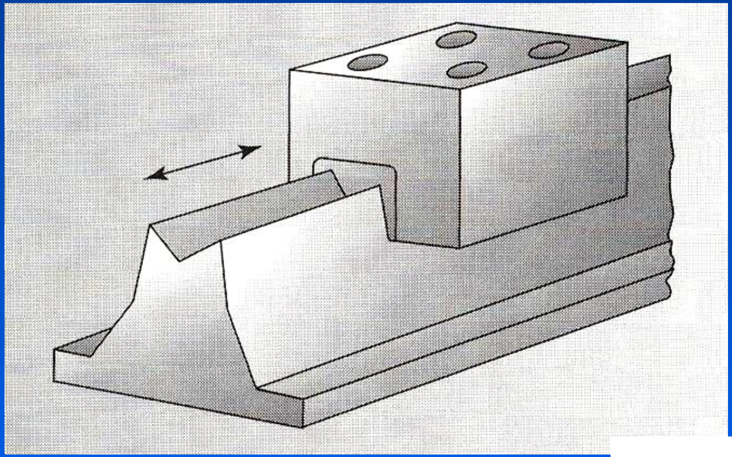


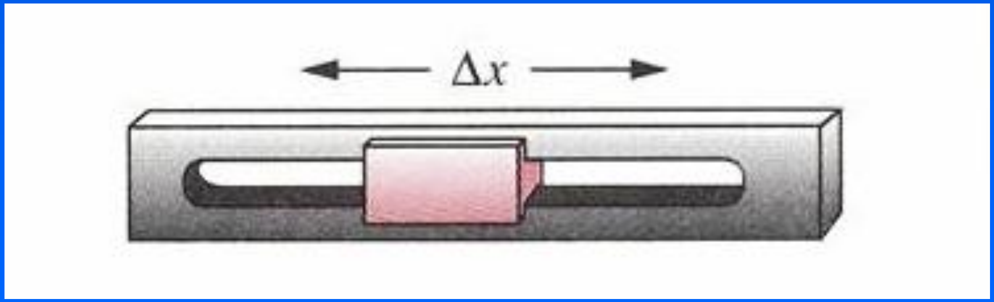
Joints

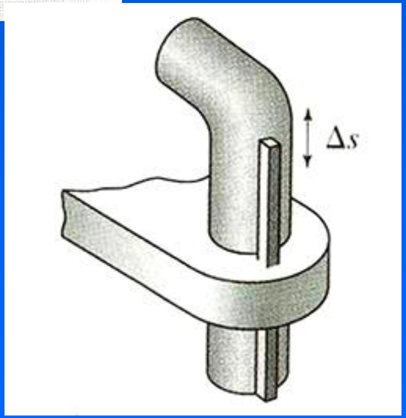
The *Sliding* joint (prism or piston joint) - one degree of freedom

It allows linear sliding between the two links that it connects (P joint)





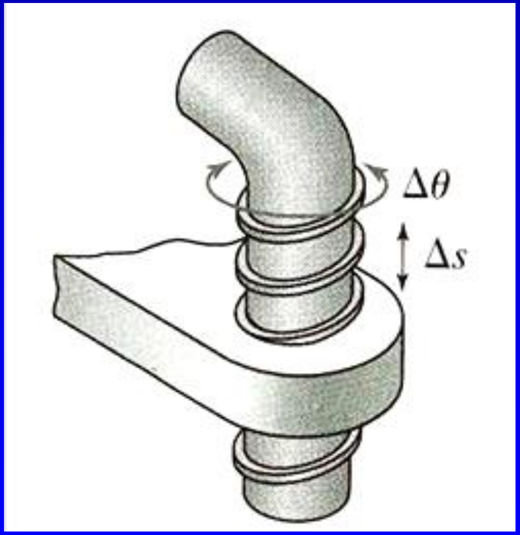


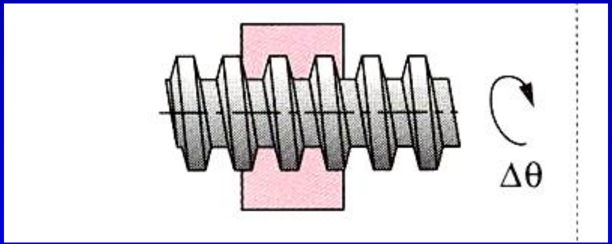


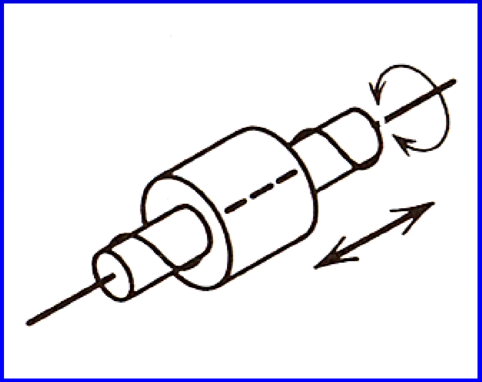
Joints

The *Helical* joint (helix or screw joint) - one degree of freedom

The sliding and rotational motions are related by the helix angle of the thread (H joint)



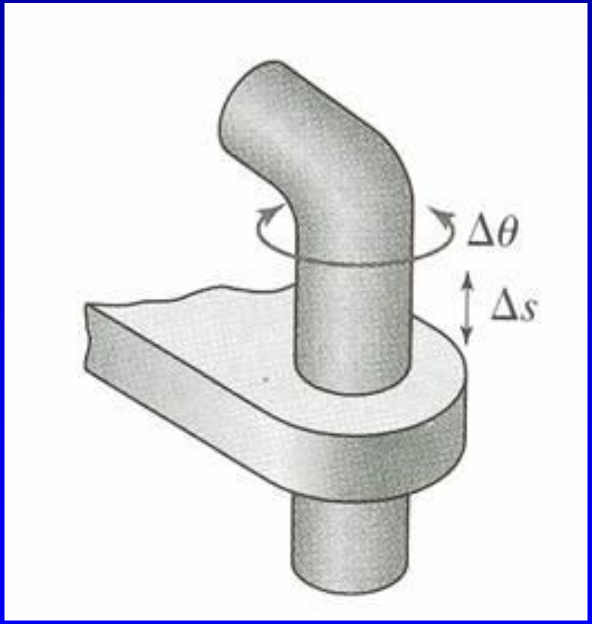


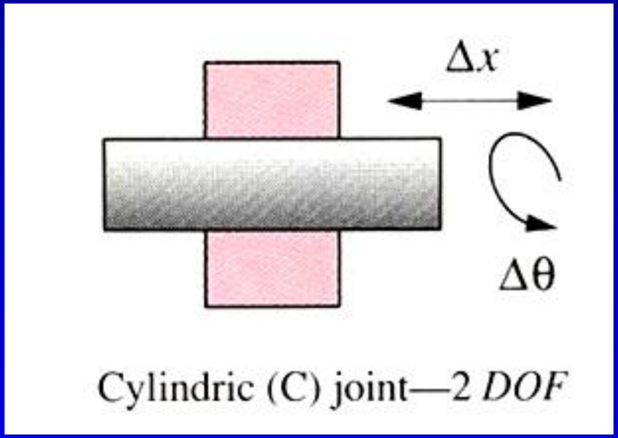


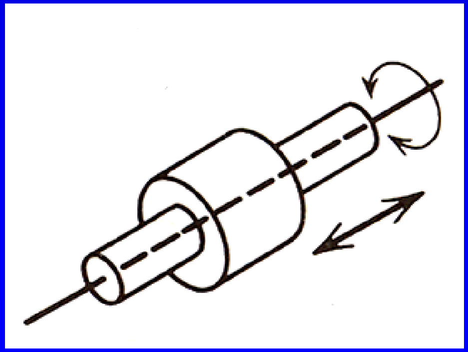
Joints

The *Cylindrical* (cylindric) joint - two degrees of freedom

It permits both angular rotation and an independent sliding motion (C joint)



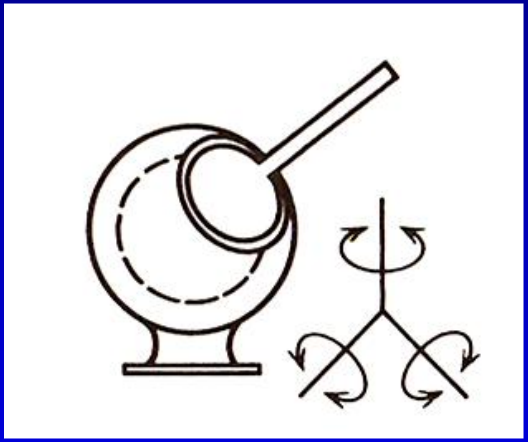


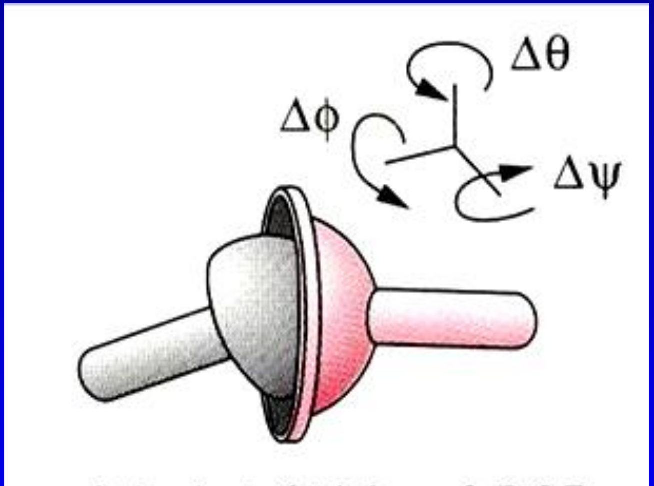


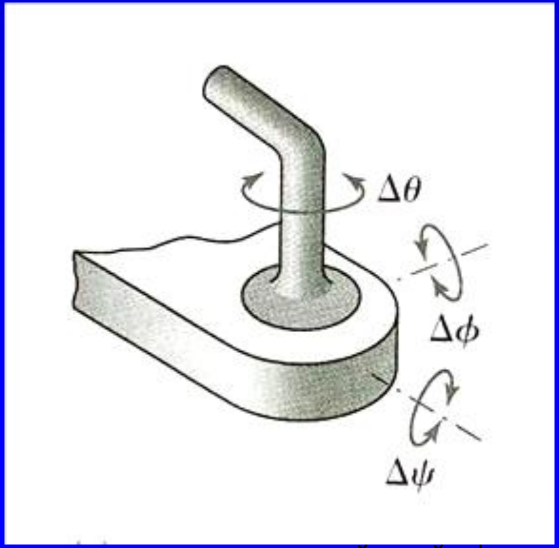
Joints

The *Spherical* (*spheric*) - Three degree of freedom

It permits rotational motion about all three axes, a ball-and-socket joint (S joint)



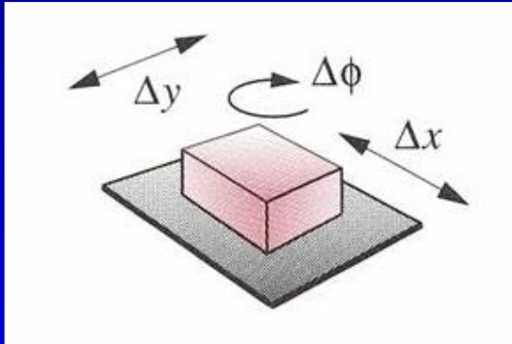




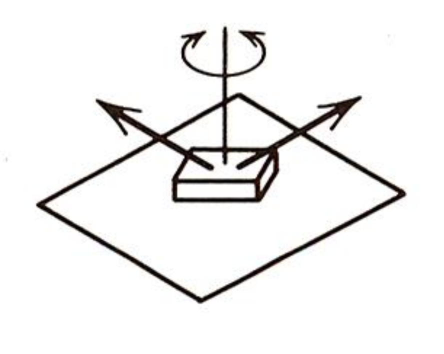
Joints

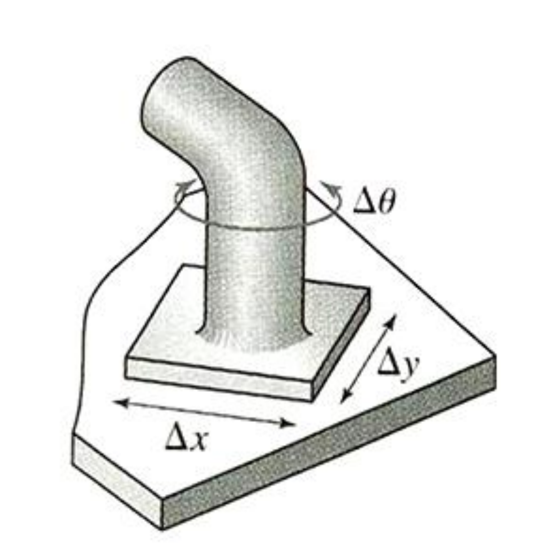
The *Planar* (*flat*) - Three degree of freedom

It permits rotational motion about the *Z* axes axis and sliding motion in x and y axes (F joint), used seldom in design



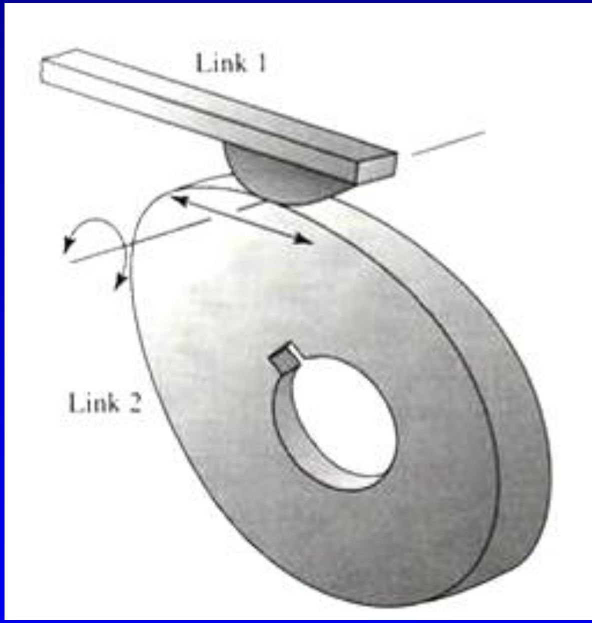
Planar (F) joint—3 *DOF*



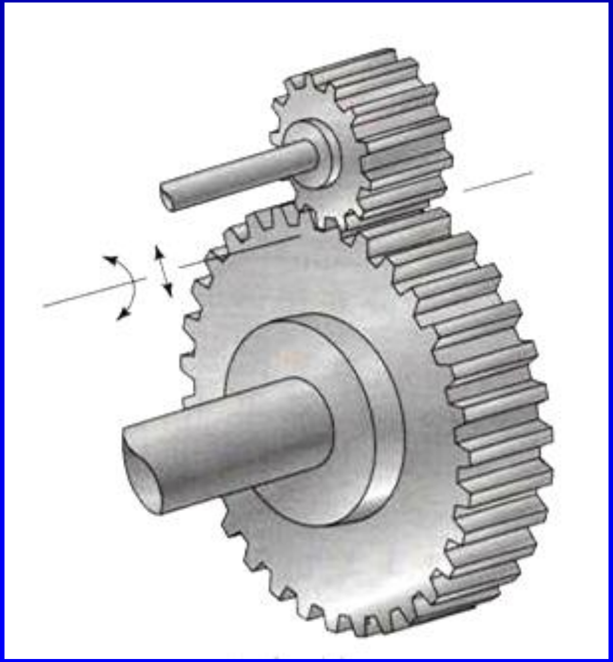


Joints

A cam joint allows both rotation and sliding between two links.

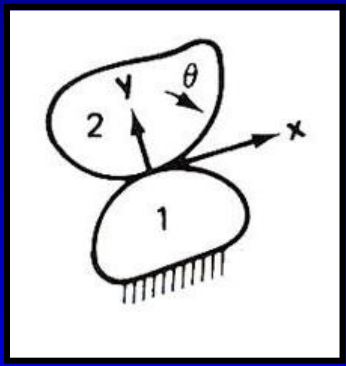


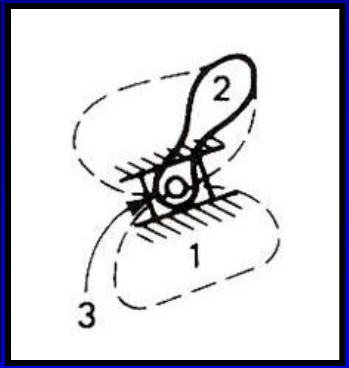
A gear connection also allows both rotation and sliding as the gear teeth mesh



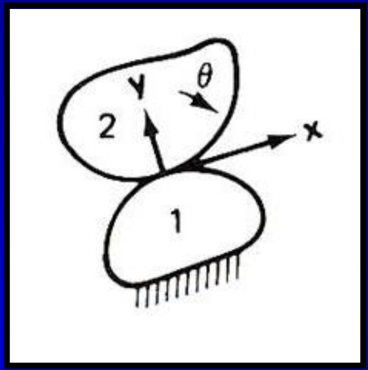
Degrees of Freedom (DOF) – Type of Joints, Higher Pairs

Roll-slide contact, 2 DOF

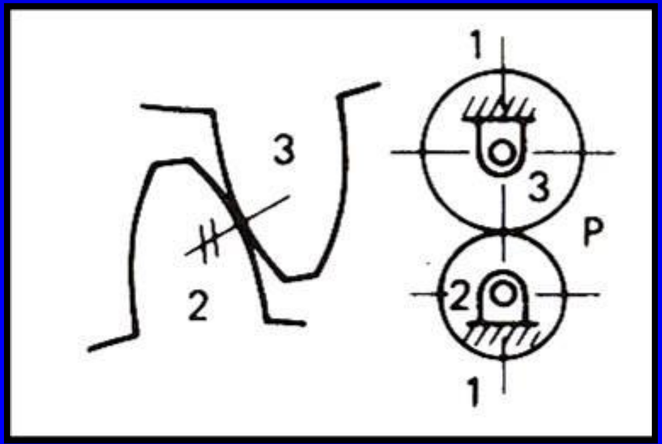


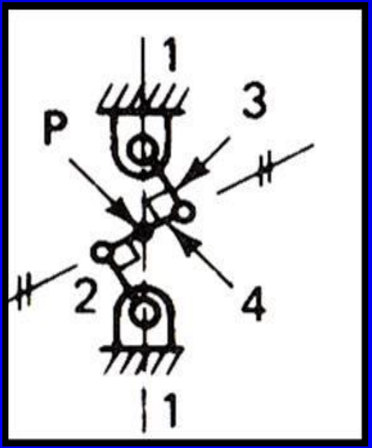


Rolling contact (no sliding), 1 DOF



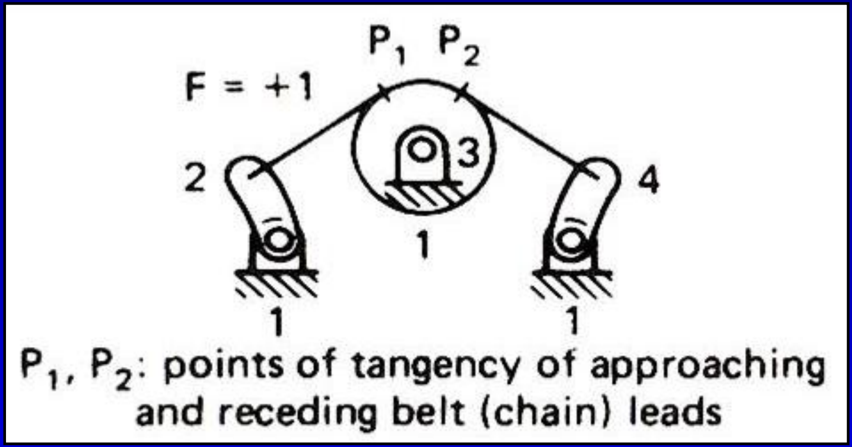
Gears – sliding and rotation motion between two teeth, 2 DOF

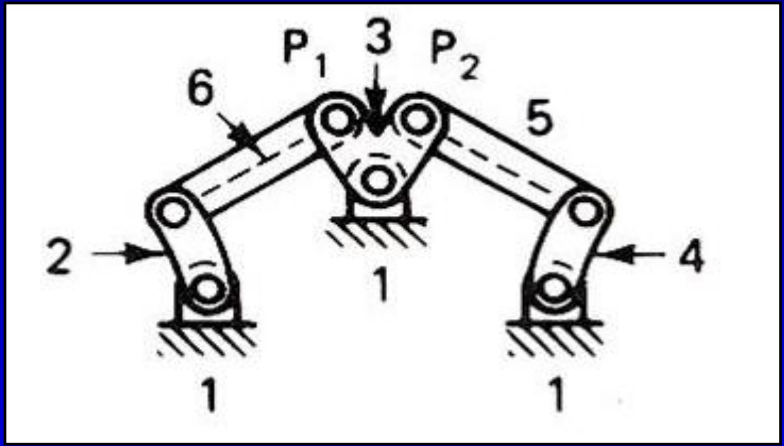




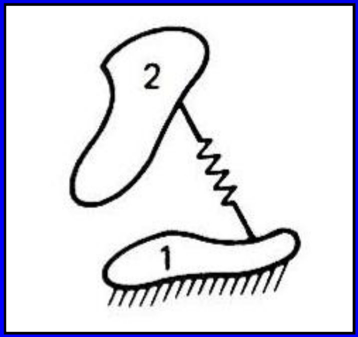
Degrees of Freedom (DOF) – Type of Joints, Higher Pairs

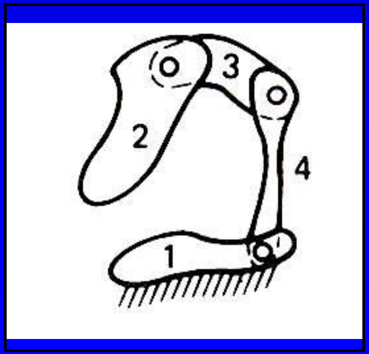
Belt and pulley (no sliding) or chain and sprocket – 1 DOF



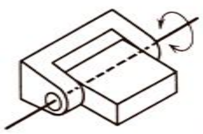
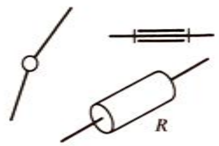
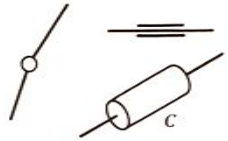
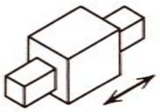
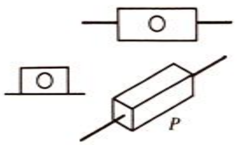
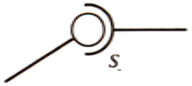
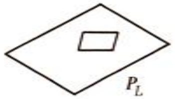


Spring – no effect on mechanism DOF





Degrees of Freedom (DOF) – Type of Joints, Lower Pairs

Name of Pair	Geometric Form	Schematic Representations	Degrees of Freedom
1. Revolute (*R*)			1
2. Cylinder (*C*)			2
3. Prism (*P*)			1
4. Sphere (*S*)			3
5. Helix (*H*)			1
6. Plane (P_L)			3

Each pin connection removes two degrees of freedom of relative motion between two successive links.

Two degrees of freedom joints are sometimes called a half a joint (Norton).

A slider is constrained against moving in the vertical direction as well as being constrained from rotating in the plane.

A spheric pair is a ball and socket joint, 3 DOF.

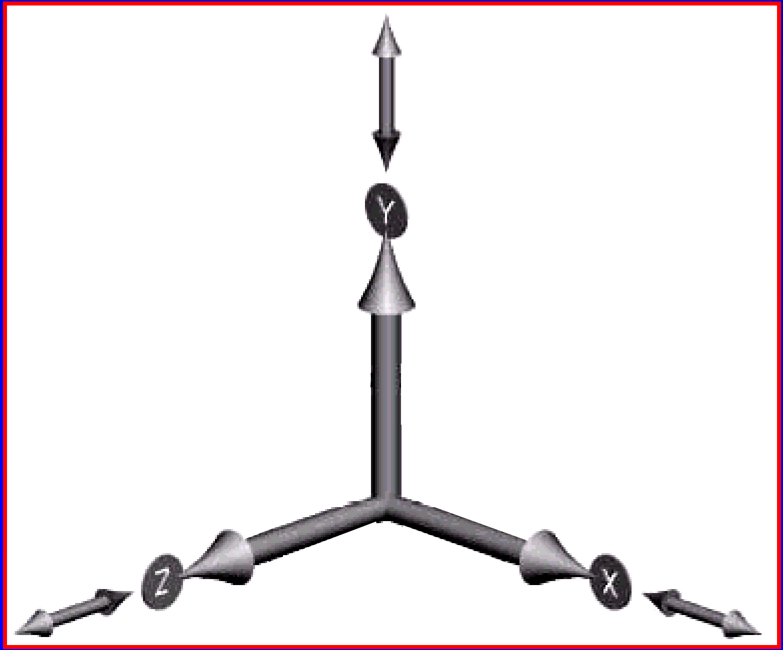
The helical pair has the sliding and rotational motion related by the helix angle of the screw.

Planar pair is seldom used

Degrees of Freedom

An object in space has **six degrees** of freedom.

- **Translation –** movement along X, Y, and Z axis (three degrees of freedom)
- **Rotation** – rotate about X, Y, and Z axis (three degrees of freedom)

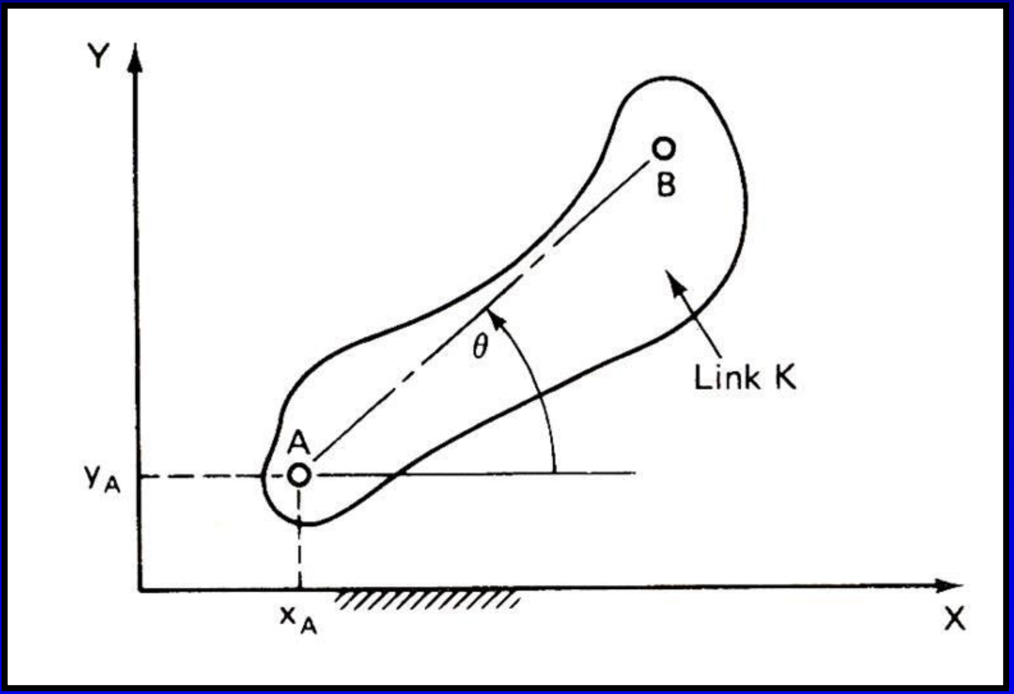


Degrees of Freedom (DOF)

Planar (2D) mechanisms

Degrees of Freedom – number of independent coordinates required to completely specify the position of the link

Three independent coordinates needed to specify the location of the link AB, x_A, y_A, **and angle** θ



An unconstrained link in a plane has three degrees of freedom, a mechanism with L links has $3L$ degrees of freedom

Degrees of Freedom (DOF)

Kutzbach's (modified Groubler) equation

$$DOF = 3(L - 1) - 2J_1 - J_2$$

DOF = degree of freedom or mobility

L = number of links, including ground link

J_1 = number of 1 DOF joints (full joints)

J_2 = number of 2 DOF joints (half joints)

DOF ≤ 0 → structure

DOF > 0 → mechanism

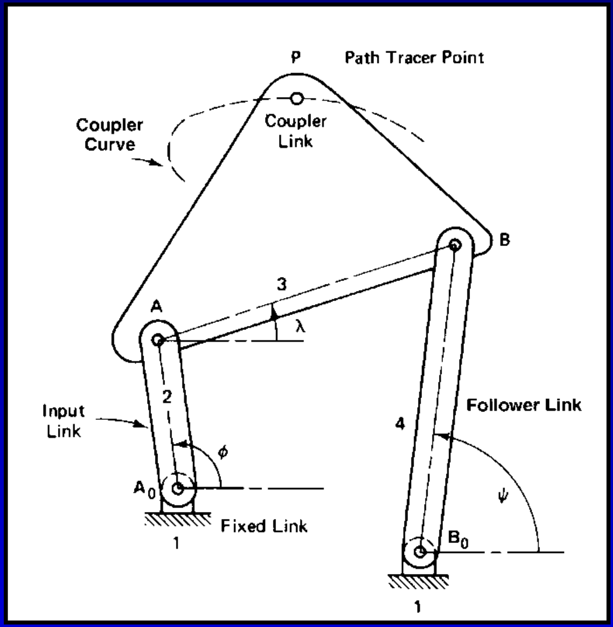
Degree of Freedom (DOF) – example

Four Bar mechanism

$L = 4$, $J_1 = 4$ pin connections, $J_2 = 0$

$DOF = 3(L - 1) - 2J_1 - J_2$

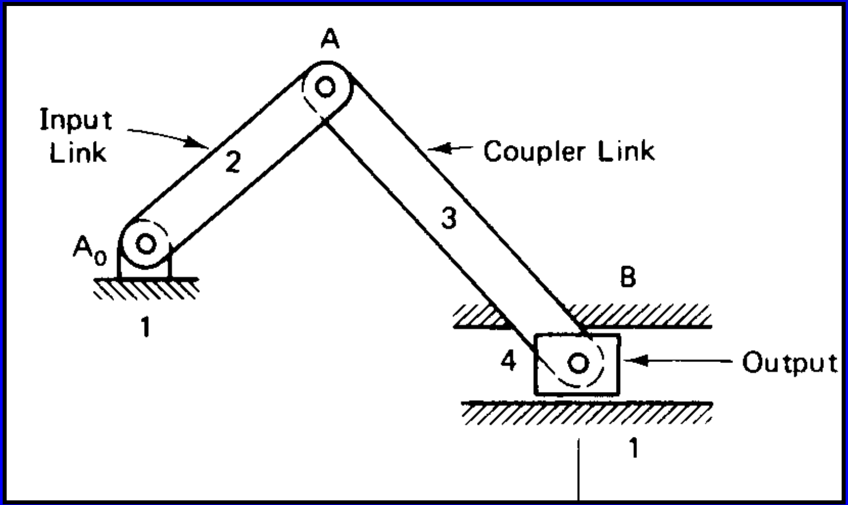
$DOF = 3(4 - 1) - 2(4) - (0) = 1$



Slider crank mechanism

$L = 4$, $J_1 = 3$ pin connections + 1 slider = 4
$J_2 = 0$

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

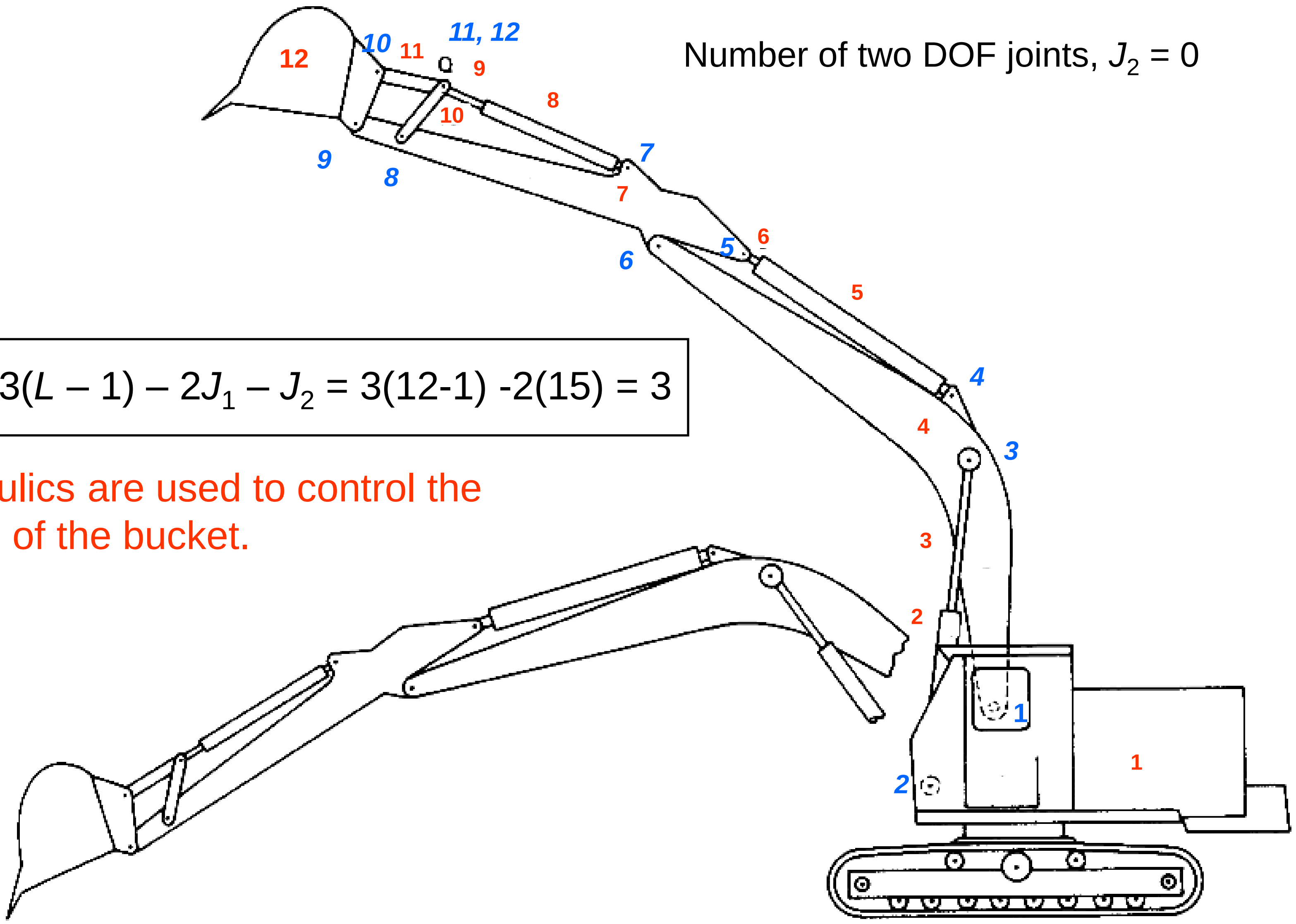


1 DOF means only one input (power source) is needed to control the mechanism

Degrees of Freedom (DOF) – trench hoe

Number of links, L = 12, Number of one DOF joints, J_1 = 12 (pins) + 3 (slider) = 15,

Number of two DOF joints, J_2 = 0



$$DOF = 3(L - 1) - 2J_1 - J_2 = 3(12\text{-}1) \text{ -}2(15) = 3$$

3 hydraulics are used to control the position of the bucket.

Degree of Freedom (DOF) - example

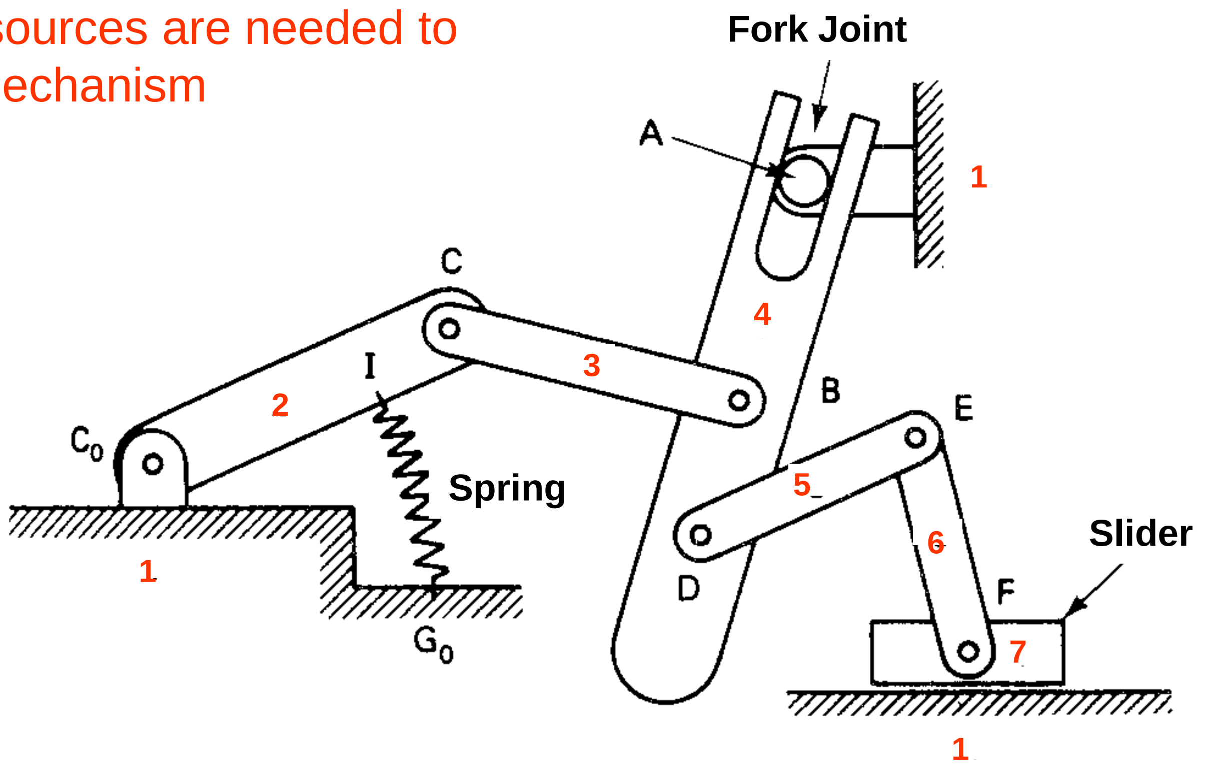
Number of links, $L = 7$,

Number of one DOF joints, $J_1 = 6$ (pins) + 1 (slider) = 7,

Number of two DOF joints, $J_2 = 1$ (fork joint)

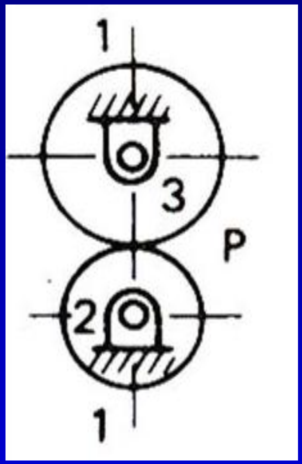
$$\text{DOF} = 3(L-1) - 2J_1 - J_2 = 3(7-1) - 2(7) - 1 = 3$$

Three input sources are needed to control the mechanism



Paradoxes

Two rollers in contact, no slipping



$L = 3, J_1 = 3, J_2 = 0$

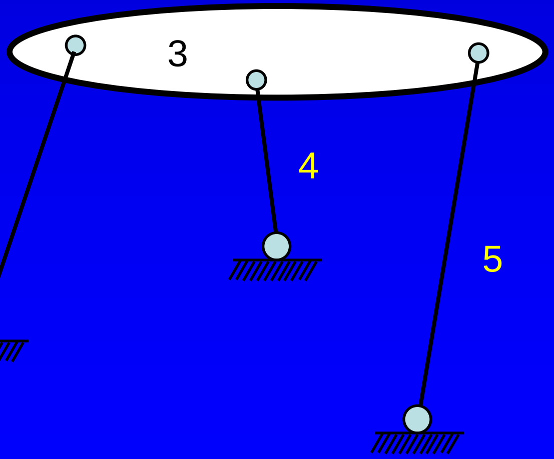
DOF = 3(3-1) - 2(3) = 0

Two gears in contact

$L = 3, J_1 = 2, J_2 = 1$

DOF = 3(3-1) - 2(2) - 1 = 1

Redundant support



$L = 5, J_1 = 6, J_2 = 0$

DOF = 3(5-1) - 2(6) = 0

Eliminate the redundancy
before determining DOF