Degrees of Freedom:

An unconstrained rigid body moving in space can describe the following independent motions.

1. Translational Motions along any three mutually perpendicular axes x, y andz,
2. Rotational motions along theseaxes.

Thus a rigid body possesses six degrees of freedom. The connection of a link with another imposes certain constraints on their relative motion. The number of restraints can never be zero (joint is disconnected) or six (joint becomes solid).

Degrees of freedom of a pair is defined as the number of independent relative motions, both translational and rotational, a pair can have.

Degrees of freedom = 6 – no. of restraints.

To find the number of degrees of freedom for a plane mechanism we have an equation known as Grubler's equation and is given by

$$F = 3(n-1) - 2j_1 - j_2$$

F = Mobility or number of degrees of freedom
n = Number of links including frame.
j_1 =Joints with single (one) degree of freedom.
j_1 = Joints with two degrees of freedom.

If $F > 0$, results a mechanism with 'F' degrees offreedom.
$F = 0$, results in a statically determinate structure.
$F < 0$, results in a statically indeterminate structure.

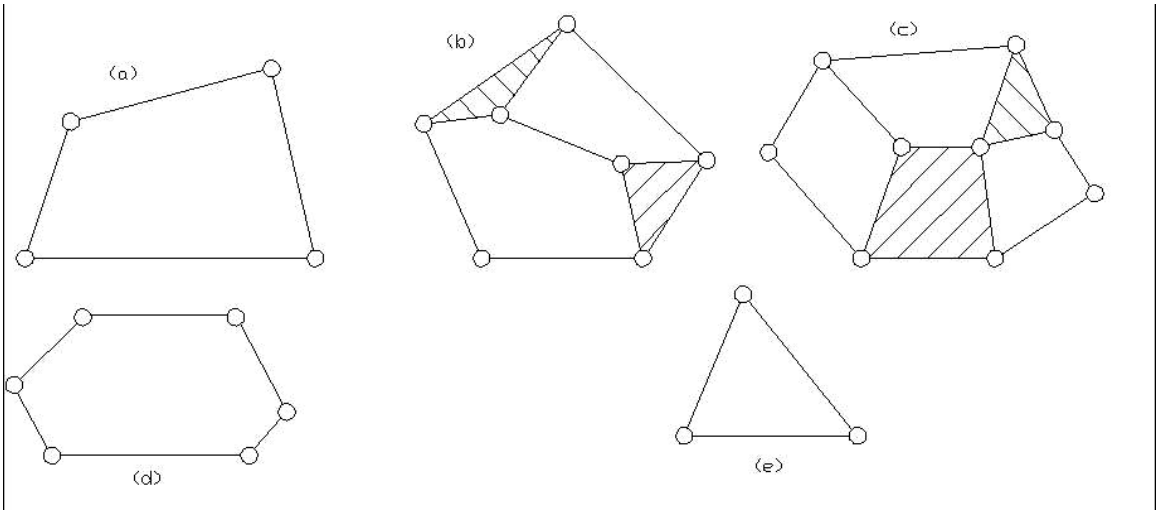
The degrees of freedom for various joints are given by:

Type of joint	Nature of Motion.	Degrees of freedom.
Hinges (Revolute)	Pure rolling	1
Slider (prismatic)	Pure Sliding	1
Cylindrical, Cam, Gear, Ball Bearings	Rolling and Sliding	2
Rolling Contact	Pure Rolling	1
Spherical		3

Note: A revolute joint connecting m links at the same point must be considered as (m-1) joints.

Kinematic Chain:

A Kinematic chain is an assembly of links in which the relative motions of the links is possible and the motion of each relative to the others is definite (fig. a, b, and c.)



In case, the motion of a link results in indefinite motions of other links, it is a non-kinematic chain. However, some authors prefer to call all chains having relative motions of the links as kinematic chains.

Linkage, Mechanism and structure:

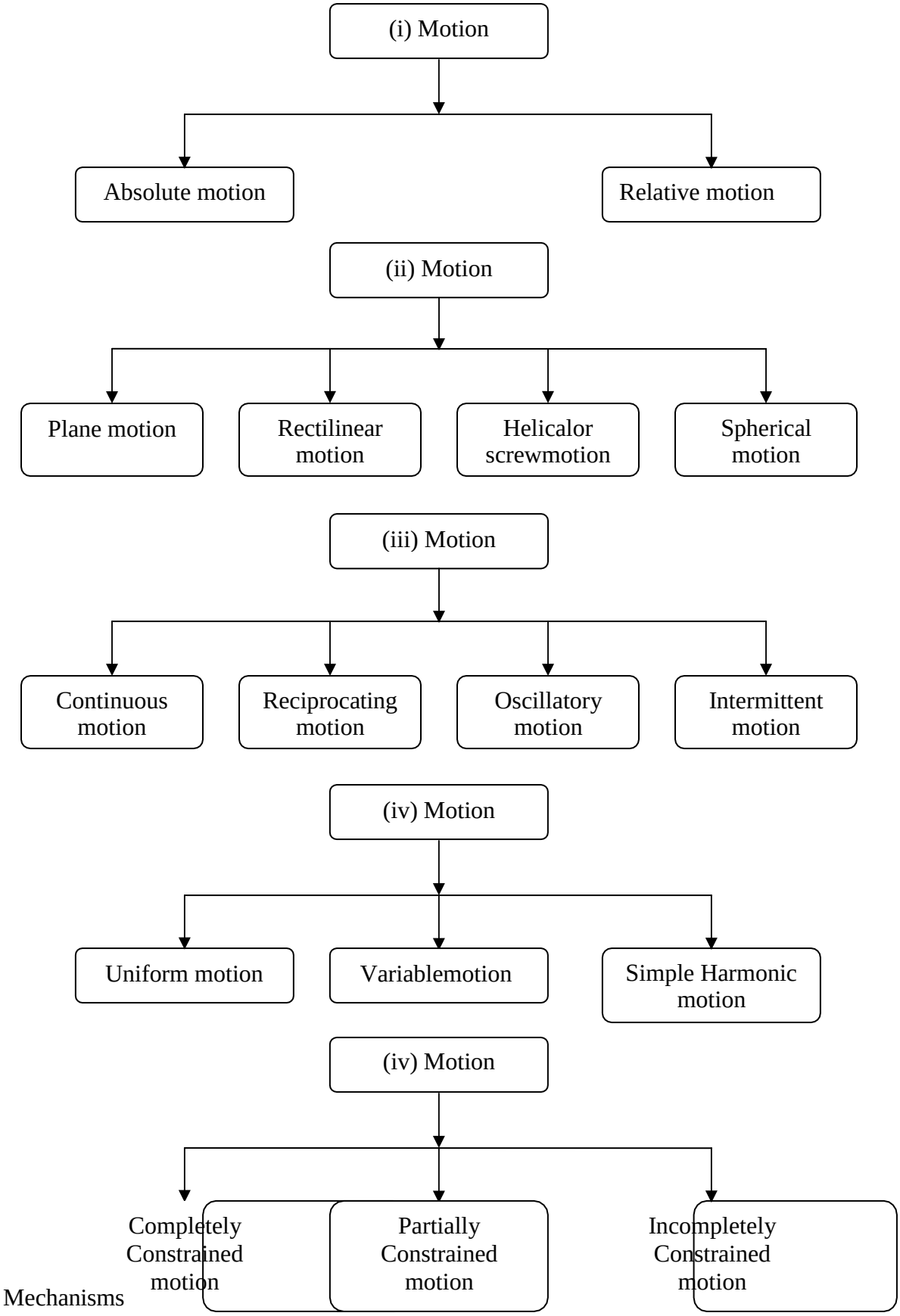
A linkage is obtained if one of the links of kinematic chain is fixed to the ground. If motion of each link results in definite motion of the others, the linkage is known as *mechanism*.

If one of the links of a redundant chain is fixed, it is known as a *structure*.

To obtain constrained or definite motions of some of the links of a linkage, it is necessary to know how many inputs are needed. In some mechanisms, only one input is necessary that determines the motion of other links and are said to have one degree of freedom. In other mechanisms, two inputs may be necessary to get a constrained motion of the other links and are said to have two degrees of freedom and so on.

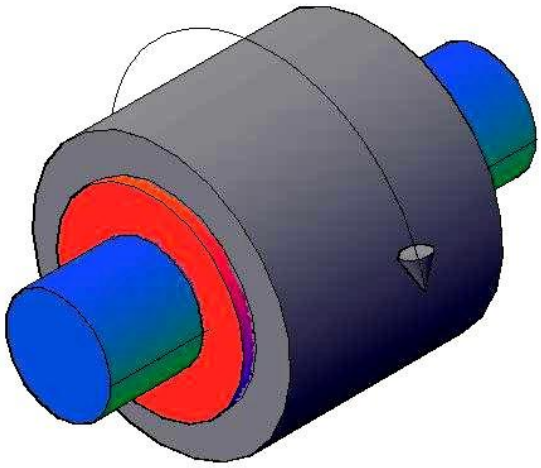
The degree of freedom of a *structure* is zero or less. A structure with negative degrees of freedom is known as a *Superstructure.*

<u>Motion and its types</u>:

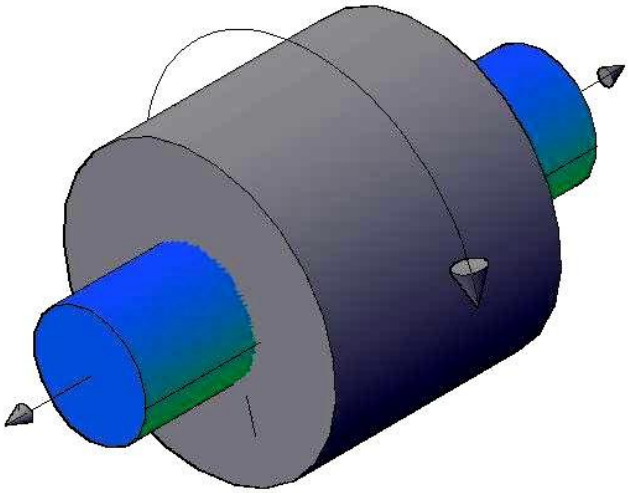


The tree main types of constrained motion in kinematic pair are,

(i) **Completely constrained motion**:
If the motion between a pair of links is limited to a definite direction, then it is completely constrained motion.
E.g.: Motion of a shaft or rod with collars at each end in a hole as shown in fig.



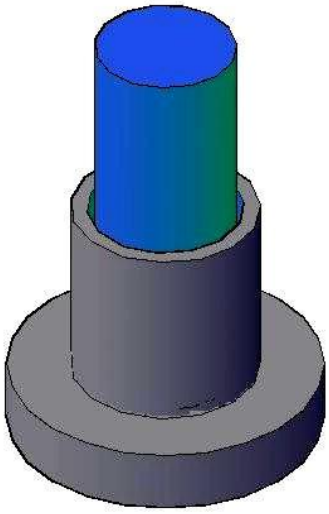
(ii) Incompletely Constrained motion:
If the motion between a pair of links is not confined to a definite direction, then it is incompletely constrained motion.
E.g.: A spherical ball or circular shaft in a circular hole may either rotate or slide in the hole as shown in fig.



(iii) Successfully constrained motion or Partially constrained motion.

If the motion in a definite direction is not brought about by itself but by some other means, then it is known as successfully constrainedmotion.

E.g.: Foot step Bearing.



Inversions:

By fixing each link at a time we get as many mechanisms as the number of links, then each mechanism is called 'Inversion' of the original KinematicChain.

Machine:

It is a combination of resistant bodies with successfully constrained motion which is used to transmit or transform motion to do some useful work.

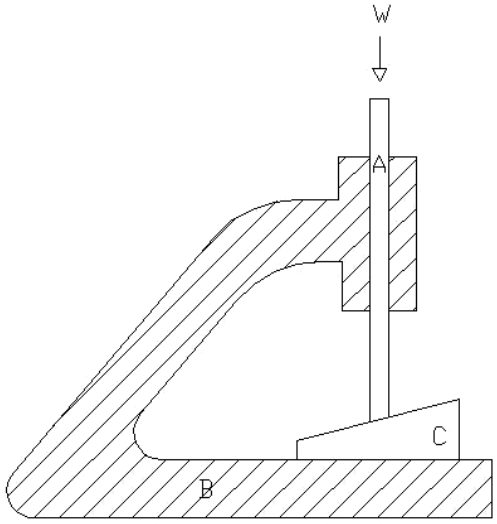
E.g.: Lathe, Shaper, Steam Engine, etc.

Kinematic chains andInversions:

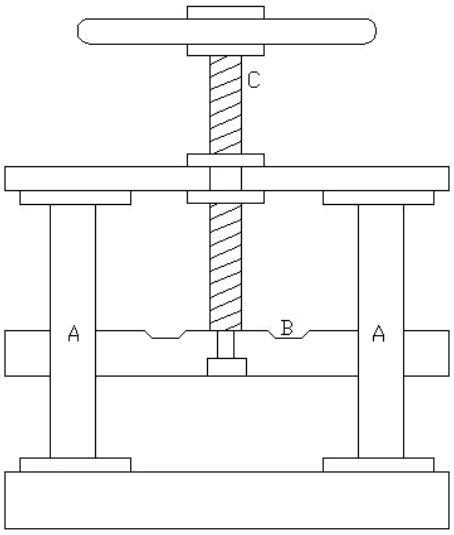
Kinematic chain with three lower pairs

It is impossible to have a kinematic chain consisting of three turning pairs only. But it is possible to have a chain which consists of three sliding pairs or which consists of a turning, sliding and a screwpair.

The figure shows a kinematic chain with three sliding pairs. It consists of a frame B, wedge C and a sliding rod A. Hence the three sliding pairs are, one between the wedge C and the frame B, second between wedge C and sliding rod A and the frame B.



This figure shows the mechanism of a fly press. The element B forms a sliding with A and turning pair with screw rod C which in turn forms a screw pair with A. When link A is fixed, the required fly press mechanism is obtained.



Types of Kinematic Chain:

1) Four barchain
2) Single sliderchain
3) Double Sliderchain

1) Four barChain:

The chain has four links and it looks like a cycle frame and hence it is also called *quadric cycle chain*. It is shown in the figure. In this type of chain all four pairs will be turning pairs.