# NATIONAL INSTITUTE OF TECHNOLOGY

## THEORY OF MACHINES

## Module 1

# UNIT 1

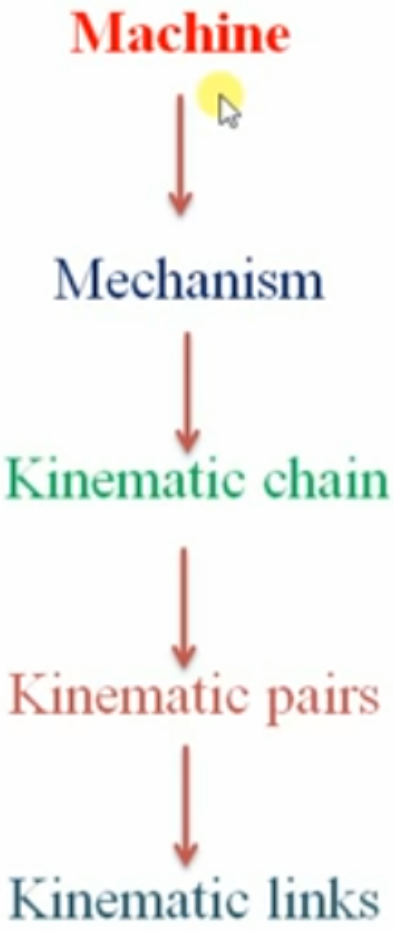
# MACHINES AND MECHANISMS

**SYLLABUS:**

Classification of mechanisms – Definition, Mechanism and Machine, Link, Kinematic Pair, Degrees of Freedom, Kinematic Chain, Various types of joints, Degree of freedom for plain mechanisms, Inversion, Different types of kinematic chain and their inversions.

# INTRODUCTION

**Basic terminology:**



## KINEMATICS

**It is that branch of theory of machine which deals with the relative motion between the various parts of the machine.**

## MACHINE

A machine is a mechanism or a collection of mechanism which transmits power and performs useful mechanical work.

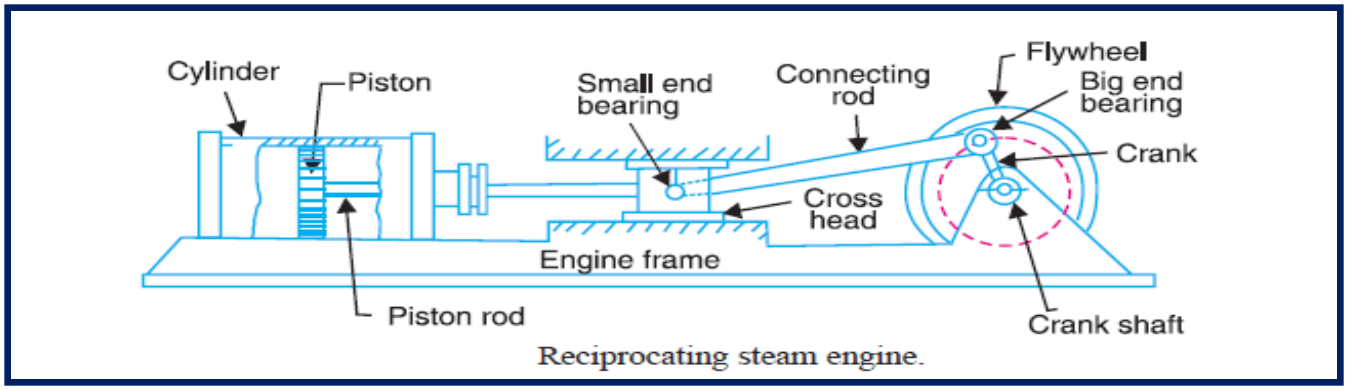
or

A machine in its simplest form may be defined as a device which receives energy and transforms it into some useful work.

Example:-

- Dynamo used in the bi-cycle
- Machine tools in workshop such as lathe, shaper, planer, etc.

# 1. DEFINITIONS




**RECIPROCATING STEAM ENGINE**

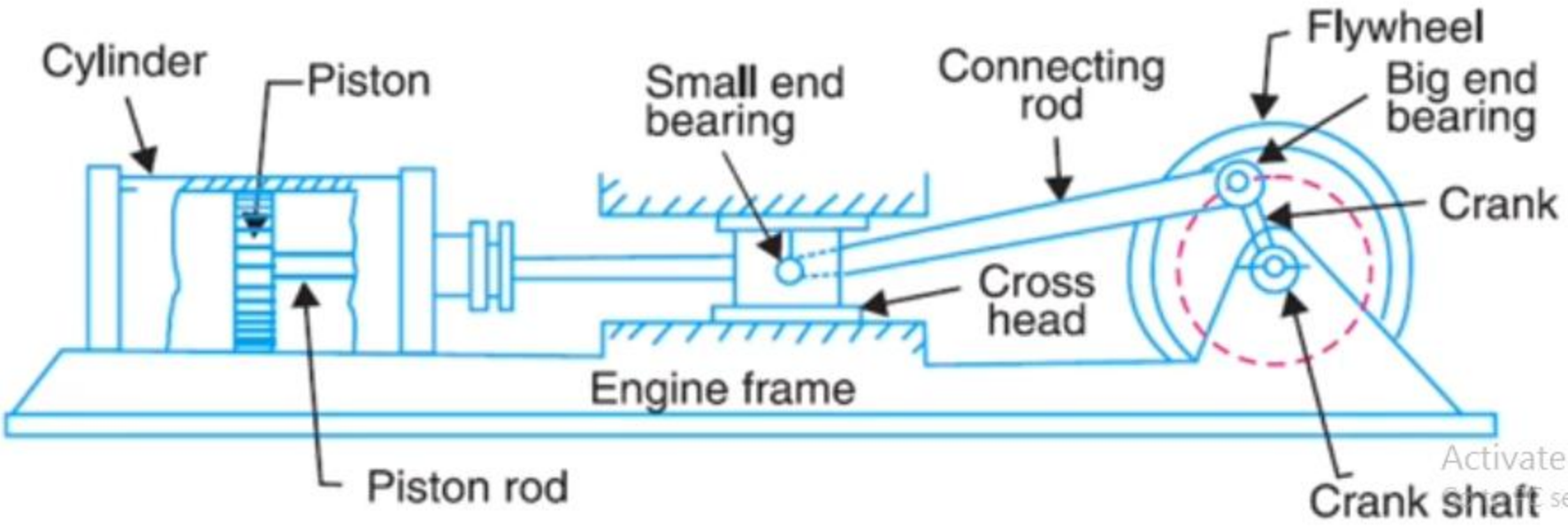
## 1.1. KINEMATIC LINK :

Each part of the machine, which moves relative to some other parts, is known as kinematic link. A link need not to be a single unit, but it may consist of several parts which are manufactured as separate units.

Example: 1. Piston, Piston rod, Cross head.

2. Connecting rod with big end and small end bearing.

For example, in a reciprocating steam engine, as shown, piston, piston rod and crosshead constitute one link ; connecting rod with big and small end bearings constitute a second link ; crank, crank shaft and flywheel a third link and the cylinder, engine frame and main bearings a fourth link.



A link or element need not to be a rigid body, but it must be a ***resistant body.***

***A*** body is said to be a resistant body if it is capable of transmitting the required forces with negligible deformation.

Thus a link should have the following two characteristics:

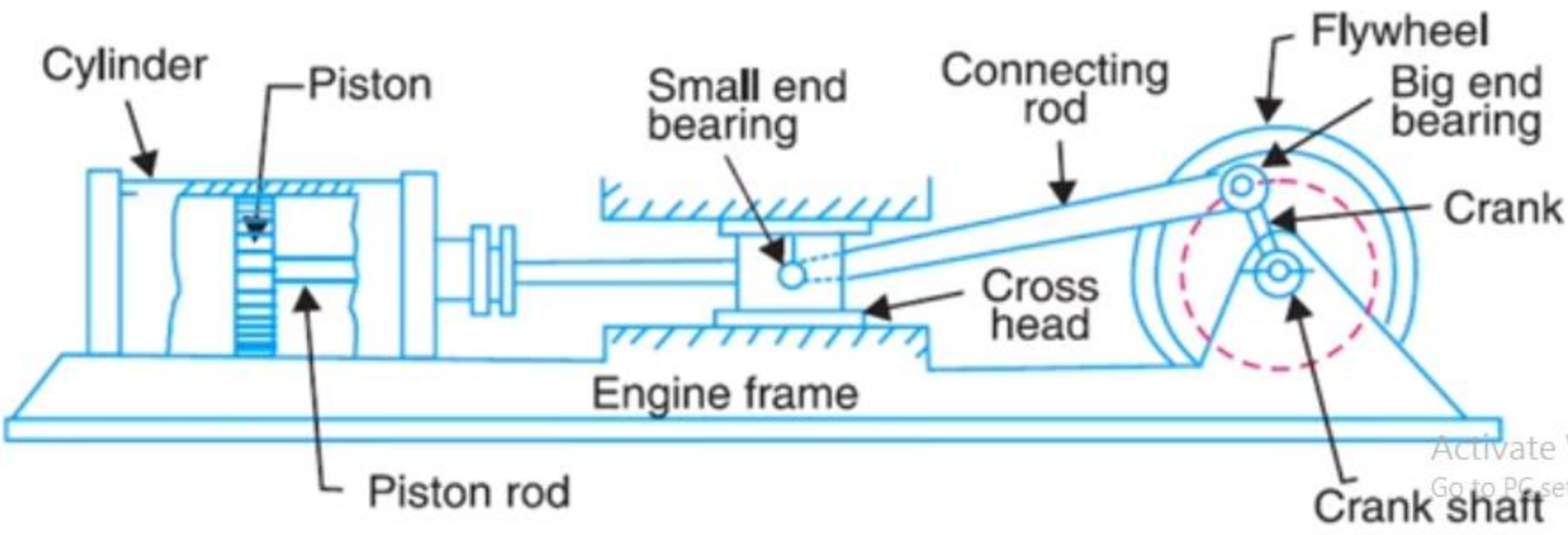
**1. It should have relative motion, and**

**2. It must be a resistant body.**

# Types of Links

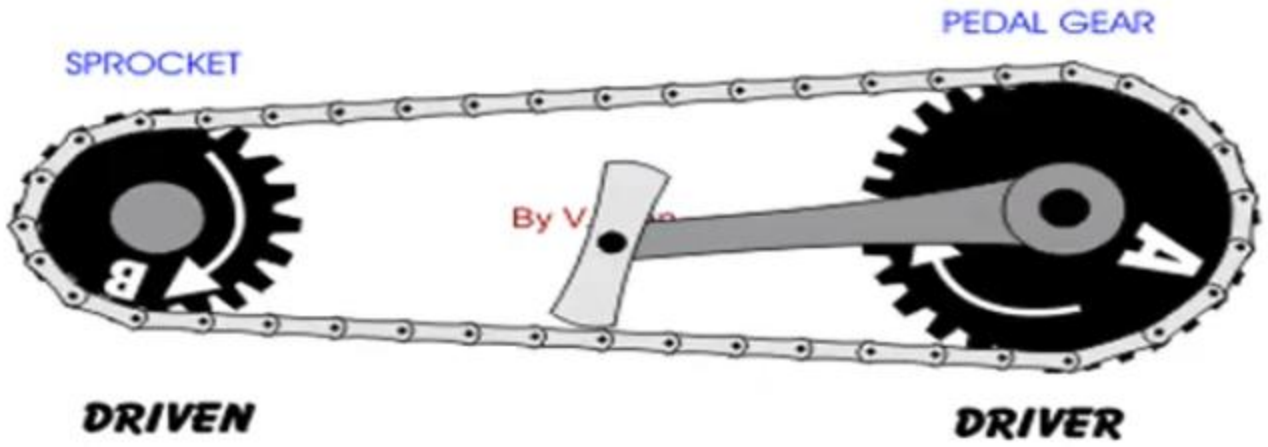
1. ***Rigid link.***

   *A rigid link is one which does not undergo any deformation while transmitting* motion. Strictly speaking, rigid links do not exist. However, as the deformation of a connecting rod, crank etc. of a reciprocating steam engine is not appreciable, they can be considered as rigid links.



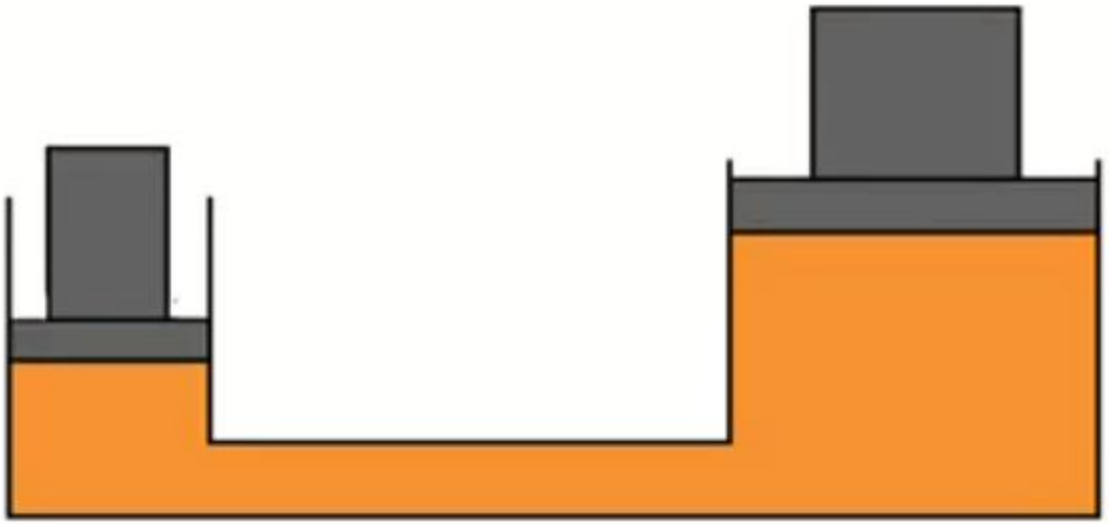
## *2. Flexible link.*

*A flexible link is one which is partly deformed in a manner not to affect the* transmission of motion. For example, belts, ropes, chains and wires are flexible links and transmit tensile forces only.



## 3. *Fluid link.*

*A fluid link is one which is formed by having a fluid in a receptacle and the* motion is transmitted through the fluid by pressure or compression only, as in the case of hydraulic presses, jacks and brakes.



# Difference between machine and structure

| Sr. No. | Particulars | Machine | Structure |
|---|---|---|---|
| 1 | Definition | A machine is a mechanism or group of mechanisms used to perform useful work | It is an assemblage of a number of resistance bodies having no relative motion between them |
| 2 | Work | Modifies or transmit energy to do some kind of work | Modifies & transmit force only |
| 3 | Relative motion | Exists between its members | Not exists between its members |
| 4 | Energy | Transmits useful energy | No energy transmission |
| 5 | Examples | Steam engine, shaper etc | Roof truss, railway bridges, machine frames etc |

# Difference between Machine & Mechanism

| Sr. No. | Particulars | Mechanism | Machine |
|---|---|---|---|
| 1 | Definition | It is a constrained kinematic chain, with one link fixed, which is used to transmit or transform motion | A machine is a mechanism or group of mechanisms used to perform useful work |
| 2 | Purpose | To transmit or transform motion | To transmit energy or to do useful work |
| 3 | Dependency | No mechanism is necessarily a machine | A machine is a series or train of mechanism |
| 4 | Relationship | It is a working model of any machine | It is a practical development of any mechanism |
| 5 | Examples | Clock, mini-drafter etc | Steam engine, shaper etc |

## 1.2. KINEMATIC PAIR :

A pair is a joint of two elements that permits relative motion.

When any two links or elements are connected in such a way that their relative motion is completely constrained they form a kinematic pair.

Example: 1.Connecting rod and Piston
2.Piston and Engine cylinder

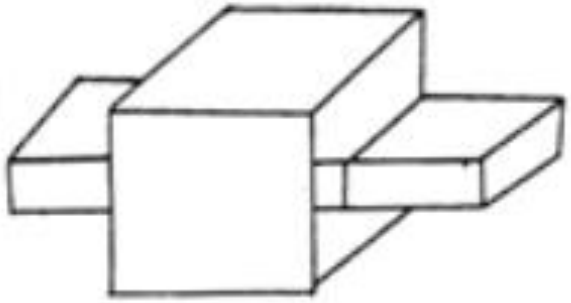
Let us discuss the various types of constrained motions:

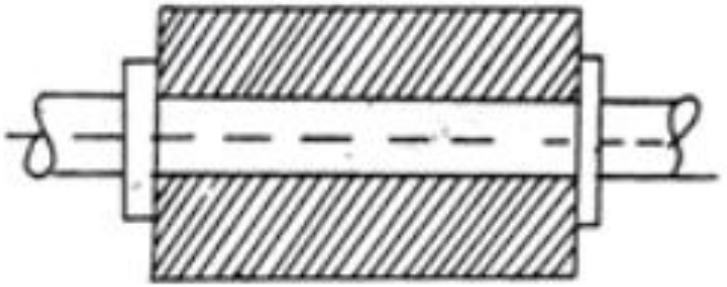
1. Completely constrained motion.
2. In completely constrained motion .
3. Successfully constrained motion .

## Types of Constrained Motions

1. ***Completely constrained motion.***

   *When the motion between a pair is limited to a definite* direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion. For example, the piston and cylinder (in a steam engine) form a pair and the motion of the piston is limited to a definite direction (*i.e. it will only reciprocate) relative to the* cylinder irrespective of the direction of motion of the crank

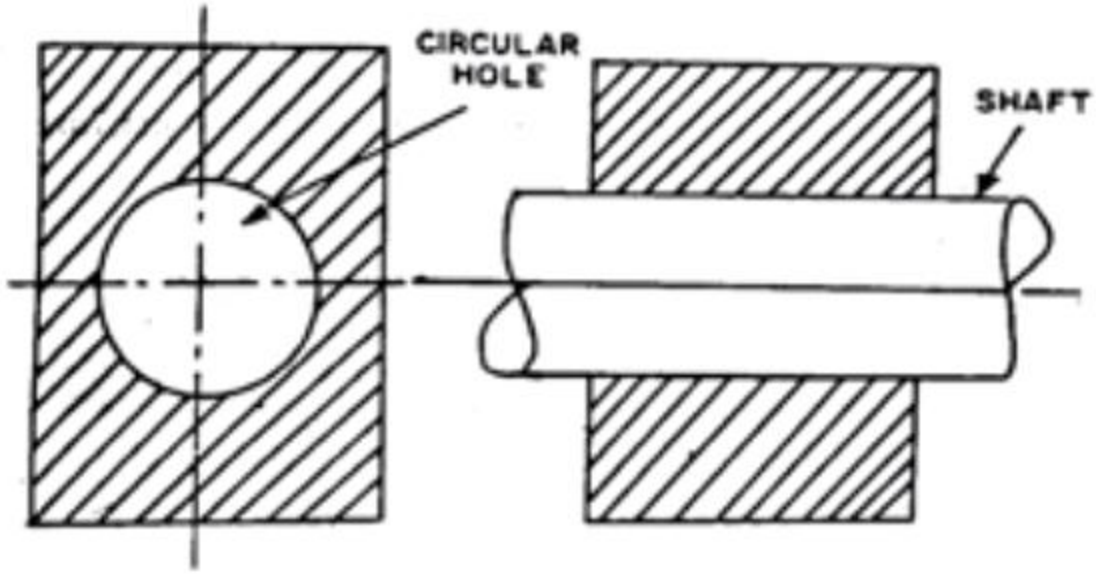




## 2. *Incompletely constrained motion.*

*When the motion between a pair can take place in more* than one direction, then the motion is called an incompletely constrained motion.

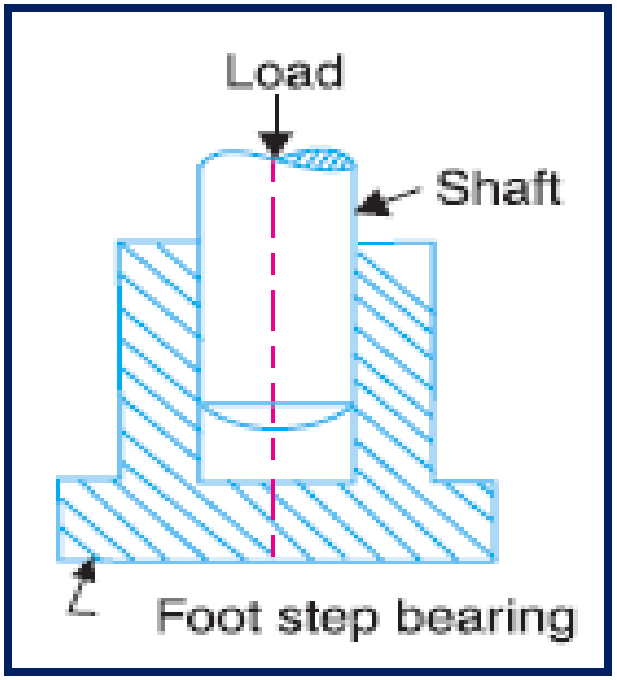
The change in the direction of impressed force may alter the direction of relative motion between the pair. A circular bar or shaft in a circular hole.



### 3. Successfully constrained motion:

When the motion between the elements is not constrained by itself, but some other means, then the motion is said to be Successfully constrained motion.

Example:- The motion of IC Engine valve.



## Classification of kinematic pair:

1.According to the types of relative motion.

- (a) Sliding pair.
- (b) Turning pair.
- (c) Rolling pair.
- (d) Screw pair.
- (e) Spherical pair.

2.According to the types of contact.

- (a) Lower pair.
- (b) Higher pair.

3. According to the types of closure.

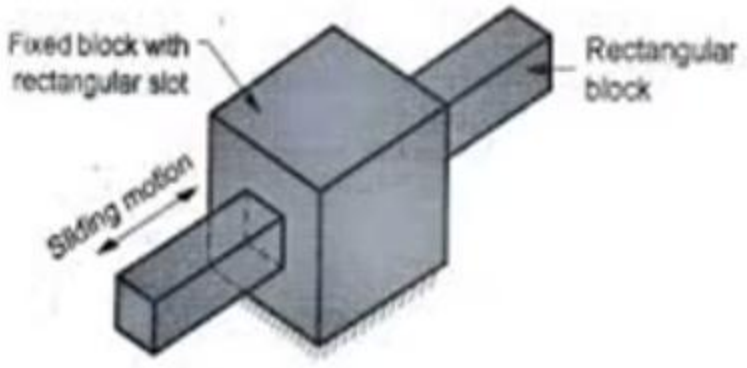
- (a) Self closed pair.
- (b) Force closed pair.

# Classification of Kinematic Pairs

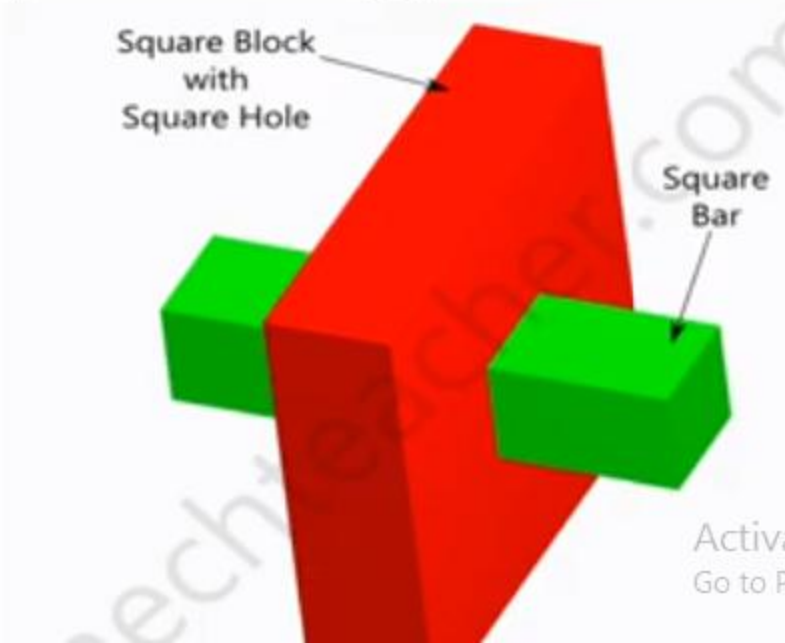
**1. *According to the type of relative motion between the elements.***

## *(a) Sliding pair.*

*When the two elements of a pair are connected in such a way that one can* only slide relative to the other, the pair is known as a sliding pair. The piston and cylinder, cross-head and guides of a reciprocating steam engine, ram and its guides in shaper, tail stock on the lathe bed etc. are the examples of a sliding pair.

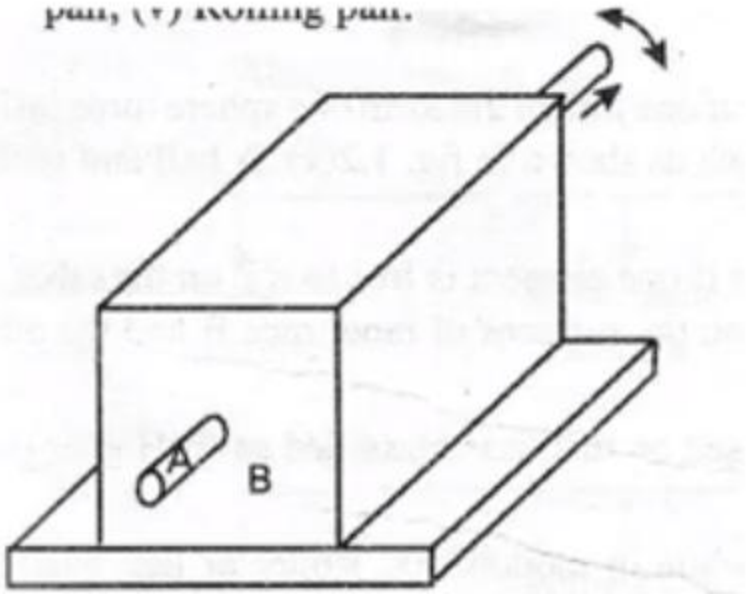


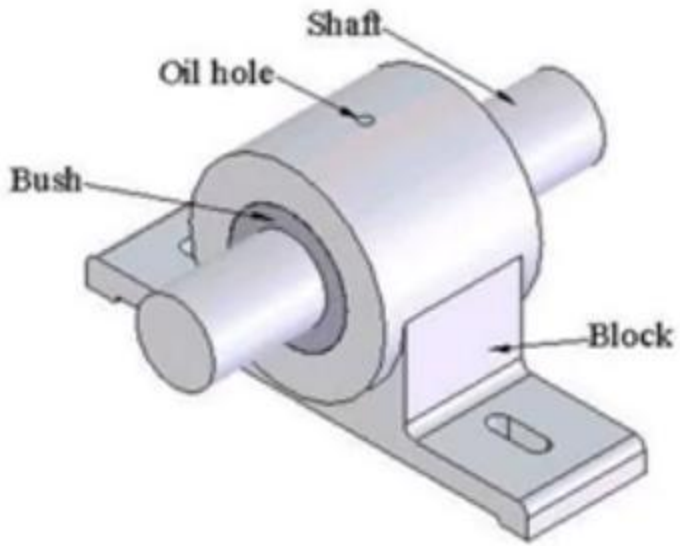

Sliding pair



## (b) Turning pair.

*When the two elements of a pair are connected in such a way that one can* only turn or revolve about a fixed axis of another link, the pair is known as turning pair. A shaft with collars at both ends fitted into a circular hole, the crankshaft in a journal bearing in an engine, lathe spindle supported in head stock, cycle wheels turning over their axles etc. are the examples of a turning pair. A turning pair also has a completely constrained motion.

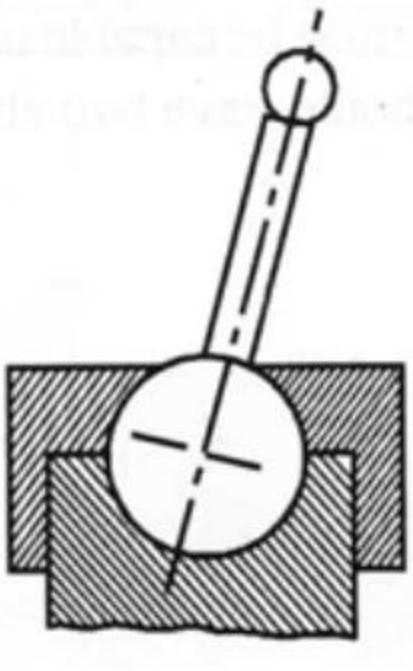


Types of Kinematic Pairs

**(c) Spherical pair.**

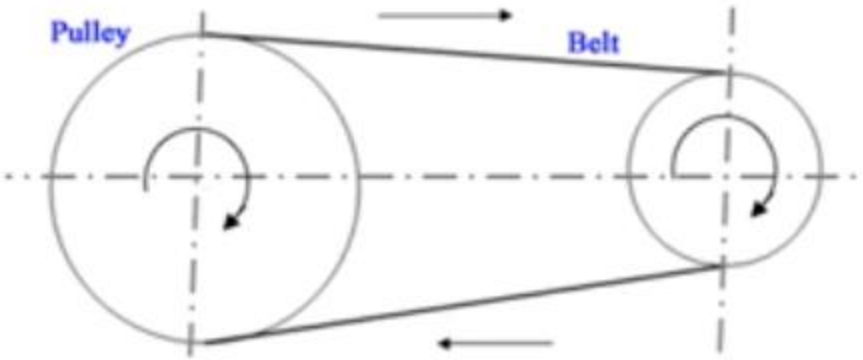
*When the two elements of a pair are connected in such a way that one* element (with spherical shape) turns or swivels about the other fixed element, the pair formed is called a spherical pair. The ball and socket joint, attachment of a car mirror, pen stand etc., are the examples of a spherical pair.



## Types of Kinematic Pairs

### (d) Rolling pair.

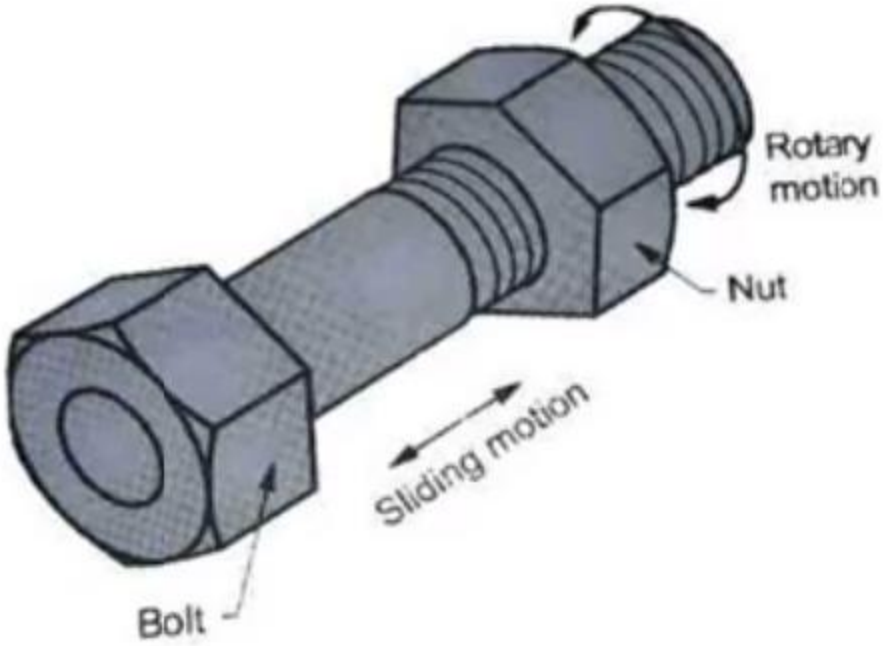
*When the two elements of a pair are connected in such a way that one rolls* over another fixed link, the pair is known as rolling pair. Ball and roller bearings are examples of rolling pair.




Rolling Pair

## (e) Screw pair.

*When the two elements of a pair are connected in such a way that one element* can turn about the other by screw threads, the pair is known as screw pair. The lead screw of a lathe with nut, and bolt with a nut are examples of a screw pair.

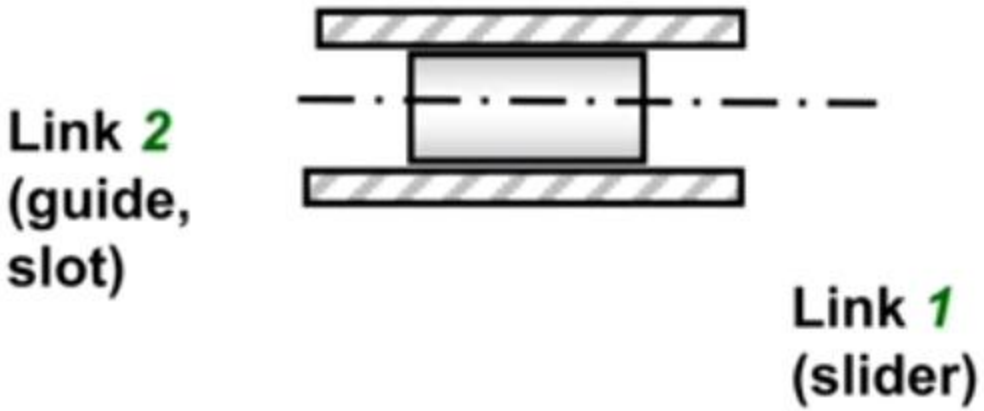



Screw or Helical pair

## 2. According to the type of contact between the elements.

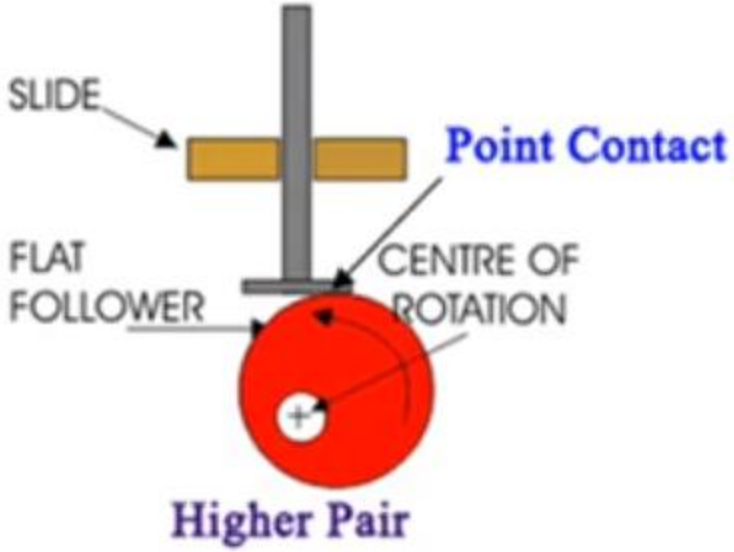
### (a) Lower pair.

*When the two elements of a pair have a surface contact when relative motion* takes place and the surface of one element slides over the surface of the other, the pair formed is known as lower pair. It will be seen that sliding pairs, turning pairs and screw pairs form lower pairs.



## (b) Higher pair.

*When the two elements of a pair have a line or point contact when relative* motion takes place and the motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair. A pair of friction discs, toothed gearing, belt and rope drives, ball and roller bearings and cam and follower are the examples of higher pairs.



### 3. *According to the type of closure.*

#### *(a) Self closed pair.*

*When the two elements of a pair are connected together mechanically in* such a way that only required kind of relative motion occurs, it is then known as self closed pair. The lower pairs are self closed pair.

Types of Kinematic Pairs

**(b) Force - closed pair.**

*When the two elements of a pair are not connected mechanically but* are kept in contact by the action of external forces, the pair is said to be a force-closed pair. The cam and follower is an example of force closed pair, as it is kept in contact by the forces exerted by spring and gravity.