MEC2120
Kinematics of Machines

Unit 1

Mechanics

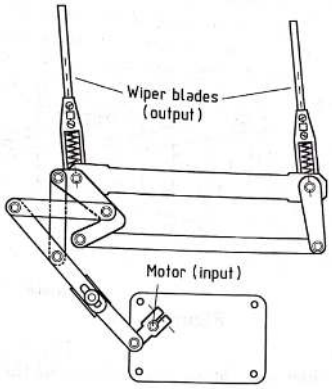
- Science which describes and predicts the condition of rest or motion of bodies under the action of forces
  - ✓ Mechanics of Rigid Bodies
  - ✓ Mechanics of Deformable Bodies
  - ✓ Mechanics of Fluids

Mechanics of Rigid Bodies

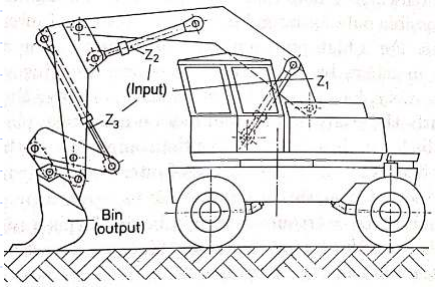
- ✓ Statics: dealing with bodies at rest.
- ✓ Dynamics : dealing with bodies in motion.
  - ❖ Kinematics
    - It describes the motion of objects
    - It is the study of description of motion
  - ❖ Kinetics
    - studies forces that cause changes of motion
    - It is the study of explanation of motion

Mechanisms and Machines

- Mechanisms and Machines refer to devices which transfer mechanical motions and forces from a source to an output member (IFToMM).
- If the idea of transferring motion predominates→ Mechanism
- when substantial forces are also involved → Machine



Wiper Mechanism



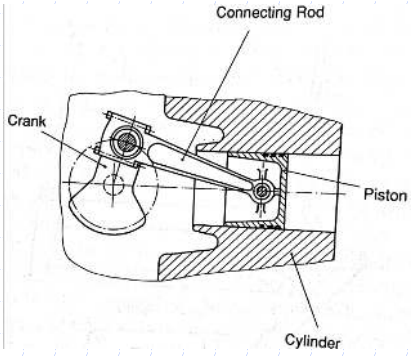
Dumping Machine

Mechanisms and Machines

Study of motion of Connected rigid bodies → Kinematics
Study of motion of Connected rigid bodies → Kinetics

For the same system,

- the word mechanism is used if studying kinematics
- the word machine is used if studying kinetics



Mechanisms and Machines

Kinematics → Kinematic Analysis
Kinematics → Kinematic Synthesis

- In Kinematic analysis, motion characteristics such as displacement, velocity, acceleration are investigated for given geometric parameters.
- Kinematic synthesis deals with the inverse problem.

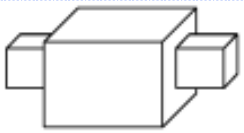
Types of Constrained Motions

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.

e.g.

a) The motion of a square bar in a square hole.
b) The motion of a shaft with collars at each end in a circular hole.



(a)

(b)

Types of Constrained Motions

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.

e.g.

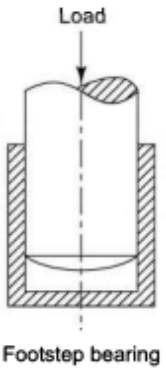
a) A circular bar or shaft in a circular hole, as shown in Fig., is an example of an incompletely constrained motion as it may either rotate or slide in a hole.

Types of Constrained Motions

Successfully constrained motion.

- When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself, but by some other means, then the motion is said to be successfully constrained motion.
- e.g.

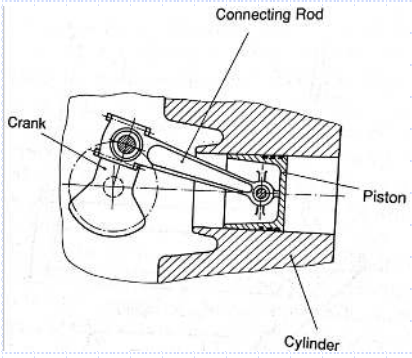
a) A shaft in a foot-step bearing
b) piston reciprocating inside an engine cylinder
c) An I.C. engine valve (these are kept on their seat by a spring)



Footstep bearing

Basic Definitions & Nomenclature

Kinematic Link: A resistant body or a group of resistant bodies with rigid connections preventing their relative movement is called a link or kinematic link.



Slider Crank Mechanism

4 links namely

- Frame and guide
- Crank
- Connecting rod
- Slider (piston)

Singular Link

A link which is connected to only one other link

Binary Link

A link which is connected to two other links.

Ternary Link

A link which is connected to three other links.

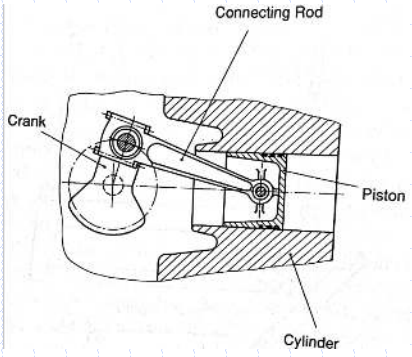
Basic Definitions & Nomenclature

Kinematic Pairs: A kinematic pair or simply a pair is a joint of two links having relative motion between them

Slider Crank Mechanism

4 kinematic pairs

- Crank and Frame
- Crank and Connecting rod
- Connecting rod and Slider (piston)
- Slider (piston) and Frame



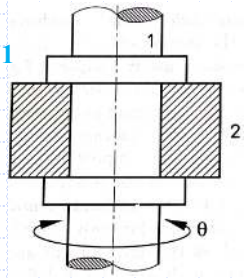
Basic Definitions & Nomenclature

Degrees of Freedom of a kinematic Pair: The number of independent coordinates (pair variables) required to completely specify the relative movement.

Types of Kinematic Pairs
(based on the possible relative movements)

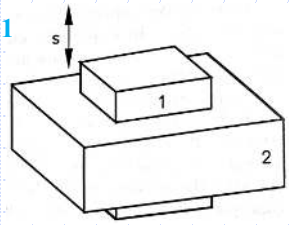
1) Revolute/Turning Pair

D.O.F = 1
P.V: θ



2) Prismatic/Sliding Pair

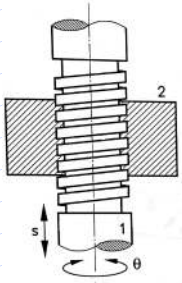
D.O.F = 1
P.V: s



Basic Definitions & Nomenclature

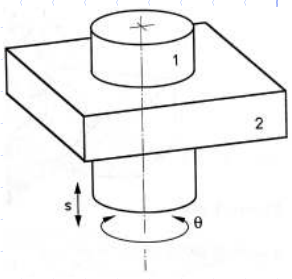
3) Screw/Helical Pair

D.O.F = 1
P.V: θ or s



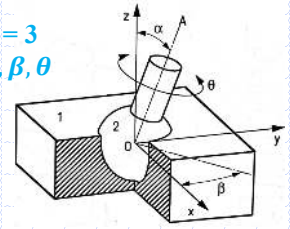
4) Cylindric Pair

D.O.F = 2
P.V: θ & s



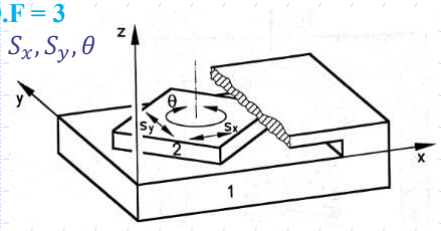
5) Spheric Pair

D.O.F = 3
P.V: α, β, θ



6) Planar Pair

D.O.F = 3
P.V: S_x, S_y, θ

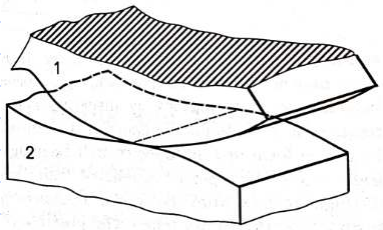


Basic Definitions & Nomenclature

Types of Kinematic Pairs
(based on the nature of contact)

Lower pairs: A pair of links having surface or area contact.
e.g.: Revolute Pair, Prismatic Pair, Screw Pair, Cylindric Pair, Spheric Pair & Planar Pair

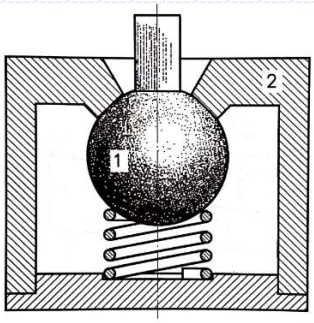
Higher pairs: A pair of links having line or point contact.
e.g.: wheel rolling on a surface, cam and follower pair, toothed gears



Meshing gear tooths

Basic Definitions & Nomenclature

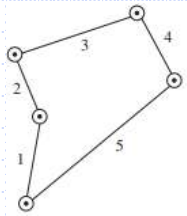
Types of Kinematic Pairs
(based on the nature of constraint)
Form closed pair: when the contact between the elements of a kinematic pair is maintained only by the geometric forms of the contacting surfaces.
e.g.: all the lower pairs
Force closed pair: when the contact between the elements of a kinematic pair is maintained by an external force (e.g. that of spring).
e.g.:

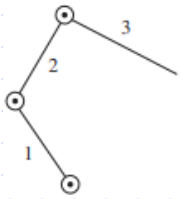


Basic Definitions & Nomenclature

Kinematic Chain : A series of link connected by kinematic pairs.

Kinematic Chain
- **Closed Chain** — The connected links form a closed loop.
- **Open Chain** — The connected links form an open loop.

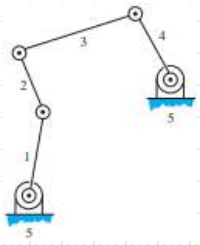




Kinematic Chain
- **Simple Chain**
- **Compound Chain**

Basic Definitions & Nomenclature

- **A mechanism can be defined as a closed kinematic chain with one fixed link.**



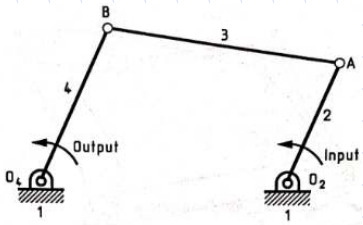
D.O.F. of Mechanism: No. of independent pair variables needed to completely define the relative movements between all its links.
Constrained Mechanism: no. of input motions = D.O.F. of Mechanism

Linkage: A mechanism consisting of only the lower pairs.

Basic Definitions & Nomenclature

Planar Mechanism/linkage: All the points of mechanism move in parallel planes.

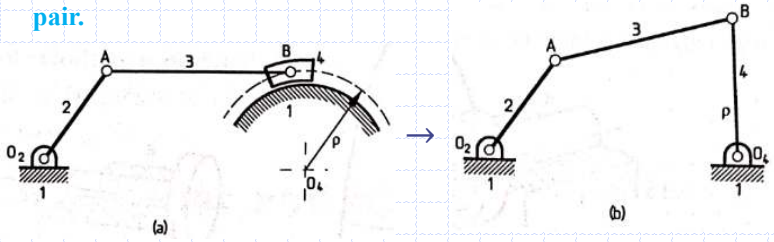
- A planar linkage can have only revolute and prismatic pairs.
- All the revolute axes are normal to the plane of motion.
- All the prismatic pair axes are parallel to the plane.
- A single view perpendicular to the plane of motion reveals the true motions.



Limit and Disguise of Revolute Pair

Revolute and Prismatic pair are the basic building blocks o all lower pairs.

- A prismatic pair can always be thought of as the limit of a revolute pair.



If $\rho \to \infty$, the pair variable transforms from angular movement to linear displacement

If $\rho \to \infty$, $\Rightarrow$ the connection between links 1 and 4 becomes a prismatic pair.