ME220 Theory of Machines and Machine Design

Lec 2 – 14 Jan 2020

Some Definitions

Kinematic Chain: An assemblage of links and joints, interconnected in a way to provide controlled output motion in response to a supplied input motion.

Mechanism: (a) A kinematic chain in which at least one link has been "grounded", or attached, to the frame of reference (which itself) may be in motion (typically transmits low forces and little power).

Machine: A combination of resistant bodies arranged to compel the mechanical forces of nature to do work accompanied by determinate motions (provides significant forces and transmits significant power).

Alternatively defined as a collection of Mechanisms arranged to transmit forces and do work.

Boundary between "Machine" and "Mechanism" is fuzzy.

Theory of Machines

The subject **Theory of Machines** may be defined as that branch of Engineering-science, which deals with the study of relative motion between the various parts of a machine, and forces which act on them. The knowledge of this subject is very essential for an engineer in designing the various parts of a machine.

Kinematics: The study of motion without regard to forces

More particularly, kinematics is the study of position, displacement, rotation, speed, velocity, and acceleration.

Kinetics/Dynamics: The study of cause of motion (forces/torques) on systems in motion.

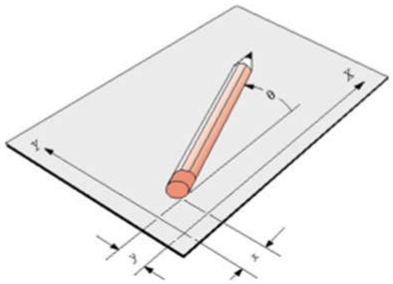
We will focus on kinematics first!!

Degrees of Freedom (DOF) or Mobility

- DOF: Number of **independent** parameters (measurements) needed to uniquely define position of a system in space at any instant of time.
- A mechanical system's **mobility** (*M*) can be classified according to the number of **degrees of freedom** (*DOF*).
- *DOF* is defined with respect to a selected frame of reference (ground).

Degrees of Freedom (DOF) or Mobility

- Rigid body in a plane has 3 DOF: x,y,θ
- Rigid body in 3D-space has 6 DOF, 3 translations & 3 rotations →**three lengths** (*x*, *y*, *z*), plus **three angles** (θ, φ, ρ).
- The pencil in these examples represents a **rigid body**, or **link**.



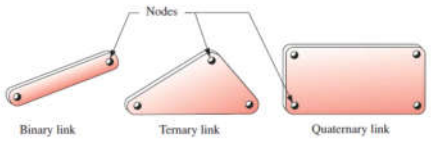
Types of Motion

- Pure rotation: the body possesses one point (center of rotation) that has no motion with respect to the "stationary" frame of reference. All other points move in circular arcs.
- Pure translation: all points on the body describe parallel (curvilinear or rectilinear) paths.
- Complex motion: a simultaneous combination of rotation and translation.

Can you differentiate these different types of motions in terms of movement of a straight line marked on these bodies?

Links

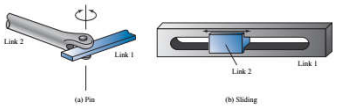
- A link is a rigid body that posses at least two nodes. It is a connection between two or more links (at their nodes), which allows some motion between the connected links.
  - Nodes are points of attachment of other links
  - Binary link: 2 nodes
  - Tertiary link: 3 nodes
  - Quaternary link: 4 nodes

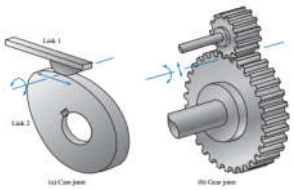


- Another Link classification/types
  - Ground: Link or links that are fixed with respect to the reference frame
  - Crank: Pivoted to ground. Makes complete revolution
  - Rocker: Pivoted to ground, has oscillatory motion
  - Coupler: Not attached to ground, has complex motion

Joints (also called Kinematic Pairs)

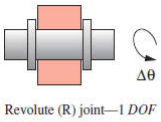
- A joint (or kinematic pair) is a connection between two or more links (at their nodes) that allows motion
- Joints can be classified base upon
  - The type of contact between the links
    - Lower pair – surface contact
    - Higher pair – point or line contact
  - Number of degrees of freedom allowed at the joint
  - By the type of physical closure
    - Form closed – links are kept together by geometry
    - Force closed – require external force to keep links together
  - By number of links joined
    - Order of a joint is one less than the number of links jointed



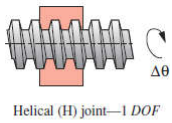


Lower Pairs

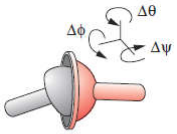
- Kinematic pairs describe the relative motion between two bodies



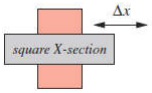
Revolute (R) joint—1 *DOF*



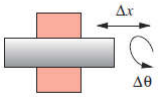
Helical (H) joint—1 *DOF*



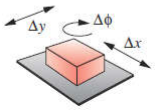
Spherical (S) joint—3 *DOF*



Prismatic (P) joint—1 *DOF*

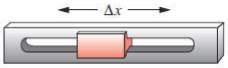


Cylindric (C) joint—2 *DOF*



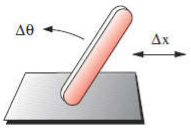
Lower pairs – joints with surface contact

Rotating full pin (R) joint (form closed)

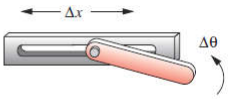


Translating full slider (P) joint (form closed)

Higher Kinematic Pairs

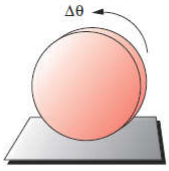


Link against plane (force closed)



Pin in slot (form closed)

This form closed joint can be also thought of as made of a prismatic and revolute joint.

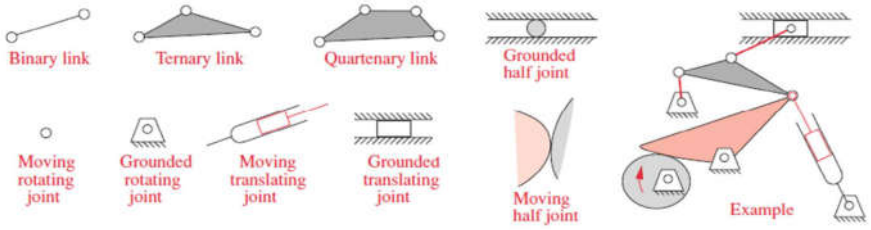


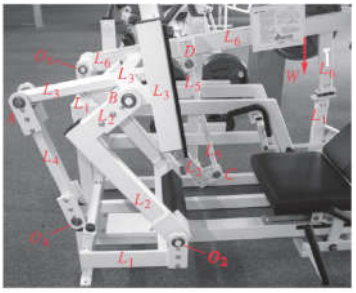
May roll, slide, or roll-slide, depending on friction

Paradoxically, the higher pairs with 2-DOF are also referred to has Half Joints and lower pairs with 1-DOF are referred to as full joints (a potential reason will become clear in coming slides)

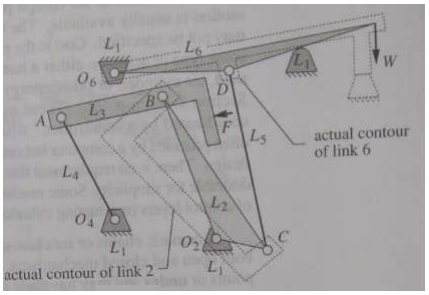
Can you mention any advantage/disadvantage of higher/lower pairs?

Drawing Kinematic Diagrams





Weight-Training Machine



Weight Training Machine (Kinematic Diagram)