Tishk International University
Mechatronics Engineering Department
Theory Of Machinery ME 223
Lecture 6:26/10/2021(1hrs)
Lecture 7:28/10/2021(2hrs)

Types of link and kinematic pairs

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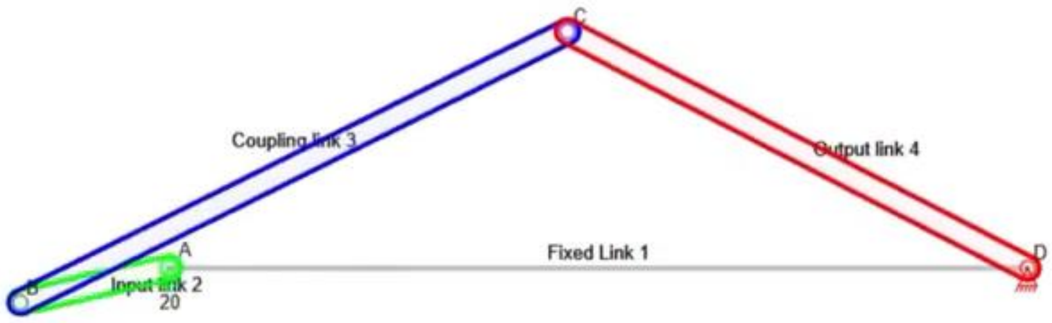
Kinematic Link or Element

- Each part of a machine, which moves relative to some other part, is known as a kinematic link (or simply link) or element.
- **Link may consist of several parts, which are rigidly fastened together, A link or element need not to be a rigid body, but it must be a resistant body**.

Video on describing kinematic link



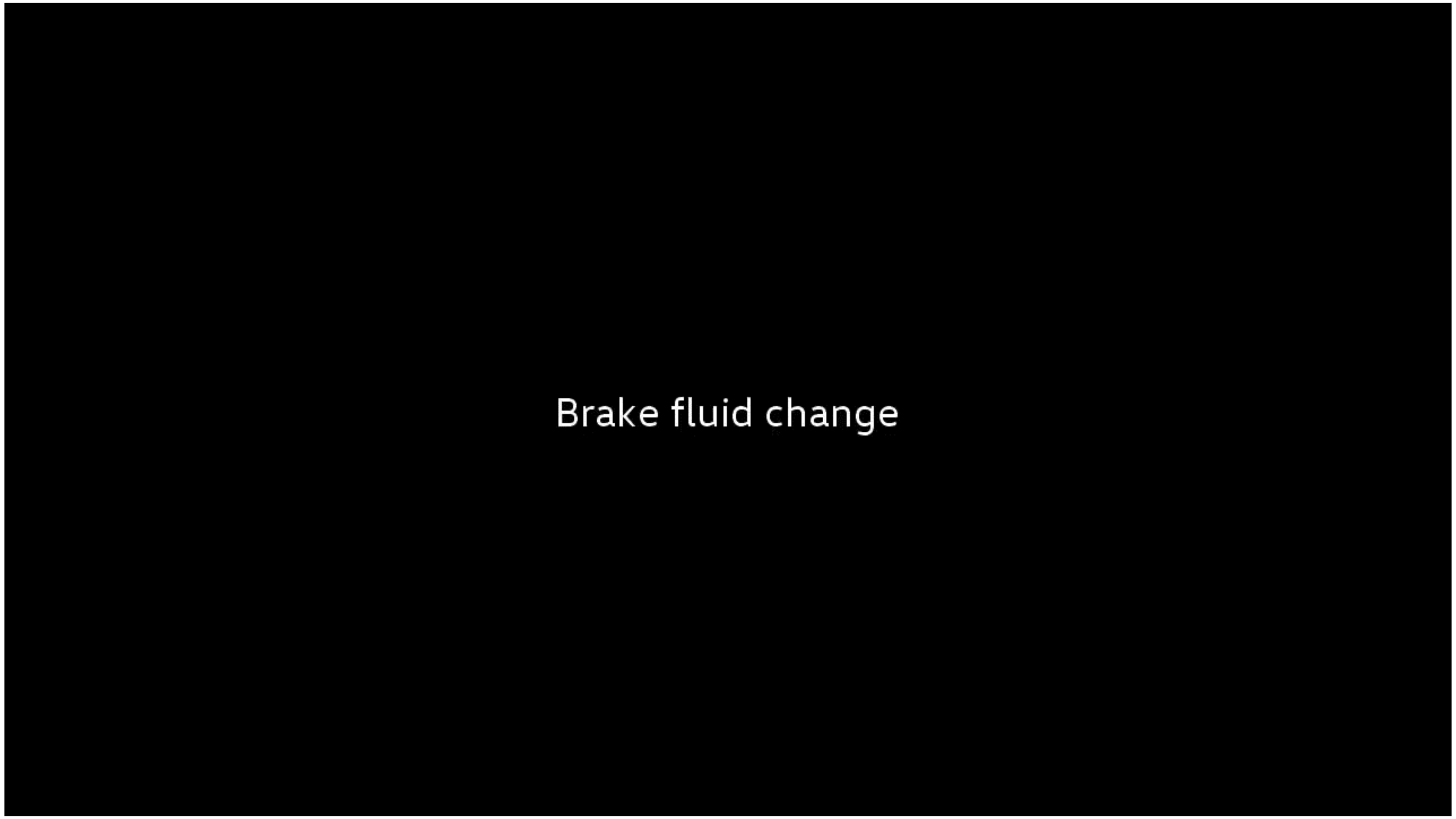
Characteristics of the link

- 1. It should have relative motion, and
- 2. It must be a resistant body.

Types of Links

- **Rigid link**. A rigid link is one which does not undergo any deformation while transmitting motion.
- **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
- **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.

Video on braking system



Structure

- It is an assemblage of a number of resistant bodies (known as members) having no relative motion between them and meant for carrying loads having straining action. A railway bridge, a roof truss, machine frames etc., are the examples of a structure.

Machine	Structure
Machine transform available energy into useful work	Structure dose not transform energy in to the useful work
The link of m/c made transmit both power relative motion and forces.	The members of structure transmit forces only.
M/c can have one or more mechanism.	It does not have mechanism.
e.g. Drilling machine; Lathe machine etc.	e.g. Machine frames, Bridge etc.

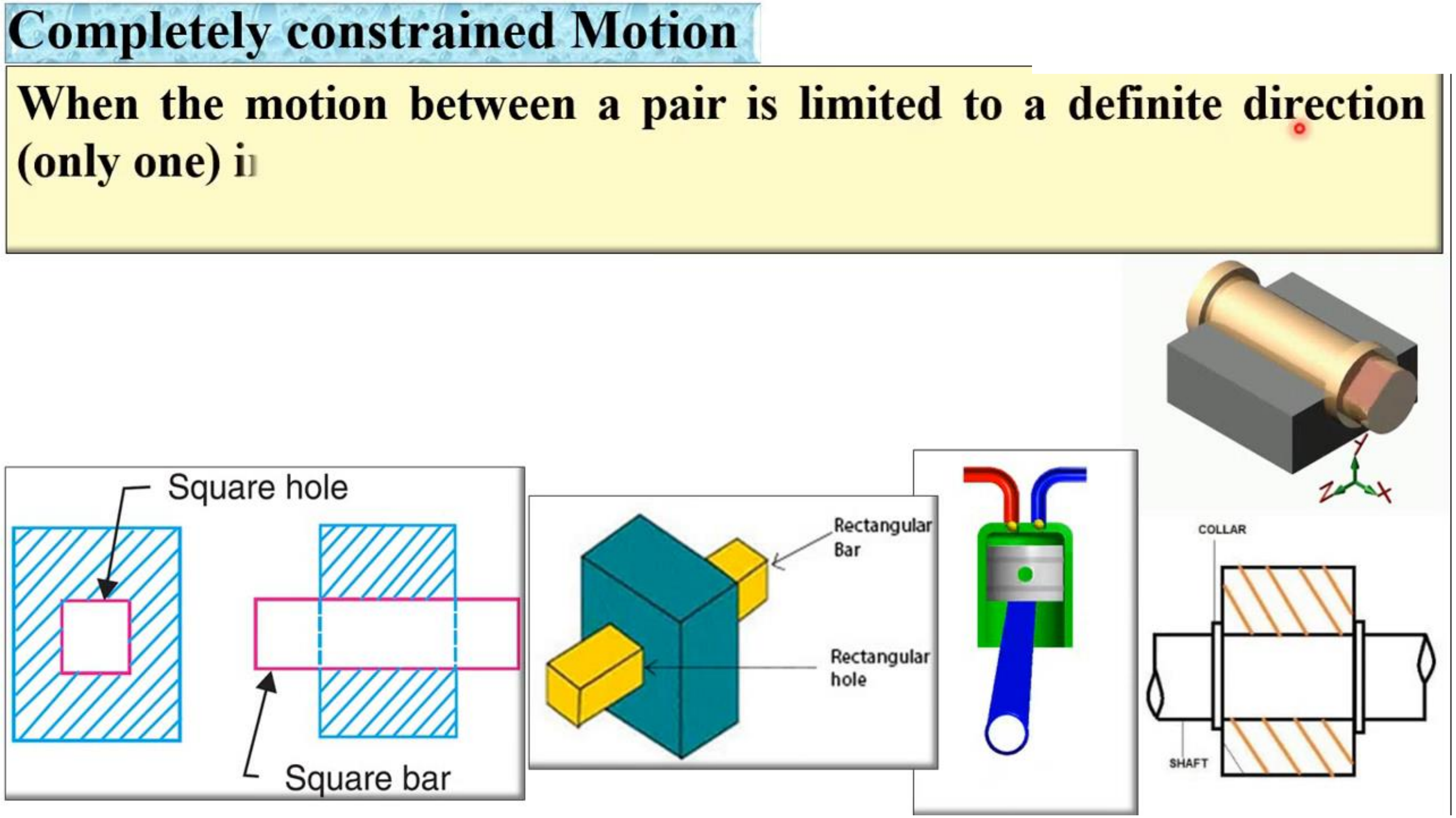
Constrained Motion

- Constrained motion is defined as a motion of mechanical pair which is having definite motion with respect to another element.

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.
- **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.
- **Successfully constrained motion**. The motions which is incompletely constrained type, by some external means it becomes completely constrained.

Video Explaining Constrained motions



Kinematic Pair

Kinematic Pair : The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (i.e. in a definite direction), the pair is known as kinematic 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.**

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.

c. **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

Classification of Kinematic Pairs

d. **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

e. **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

Classification of Kinematic Pairs

- 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.

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

Classification of Kinematic Pairs

- 3. According to the type of closure

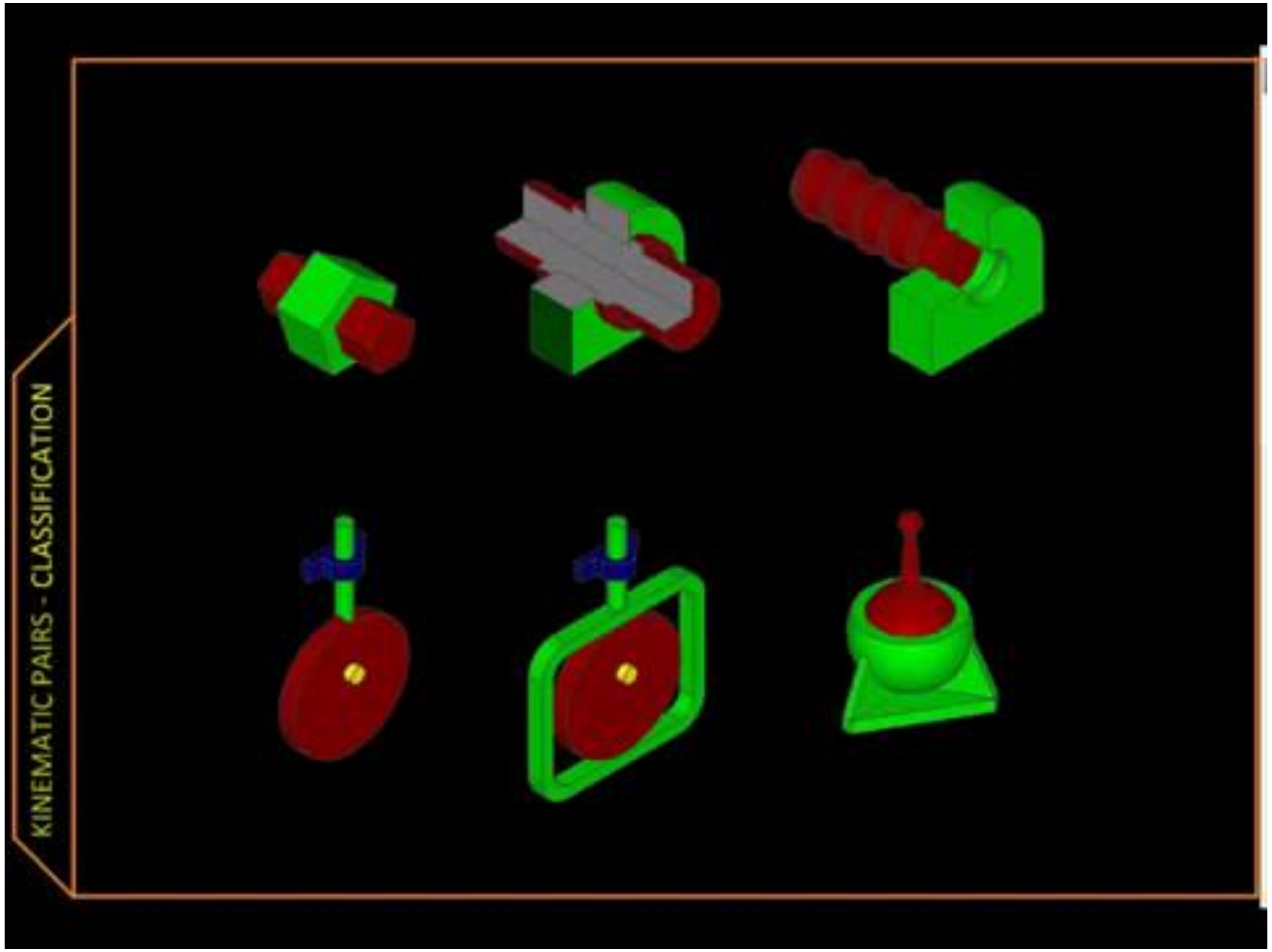
a) **Self closed pair**. When the two elements of a pair are connected together mechanically in such a way that only required kind of relative motion occurs

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

lower pair

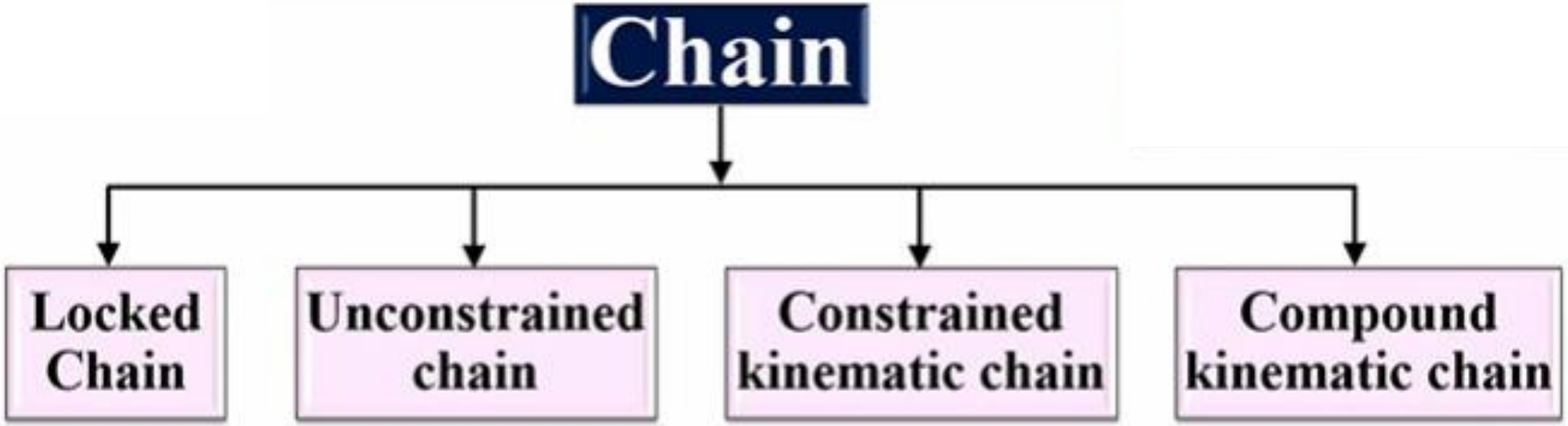
- A lower pair is one in which there occurs a surface or area contact between two members,

Animations for describing of kinematic pairs



Kinematic Chain

- In mechanical engineering, a kinematic chain is an assembly of rigid bodies connected by joints to provide constrained (or desired) motion



$l = 2p - 4$

$j = \frac{3}{2} l - 2$

Klein's formula: $j + \frac{h}{2} = \frac{3}{2} l - 2$

l-Number of links
p-Number of pairs

j-Lower pair joints
h-Higher pair joints

1) When L.H.S > R.H.S, then the **chain is locked**.
2) When L.H.S < R.H.S, then the chain is **unconstrained chain**.
3) When L.H.S = R.H.S, then the chain is a **kinematic chain.**

How to decide chain type ?

Consider the arrangement of three links AB, BC and CA with pin joints at A, B and C as shown in Fig.

- Number of links: $l = 3$
- Number of pairs: $p = 3$
- Number of joints: $j = 3$

$$l = 2p - 4 \quad \text{......(1)}$$

$$j = \frac{3}{2} l - 2 \quad \text{......(2)}$$

From equation (1),

$$l = 2p - 4$$

$$\therefore 3 = 2 \cdot 3 - 4$$

$$\therefore 3 = 2$$

- So L.H.S. > R.H.S.

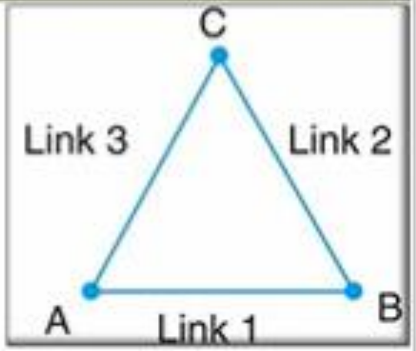
From equation (2),

$$j = \frac{3}{2} l - 2$$

$$\therefore 3 = \frac{3}{2} \cdot 3 - 2$$

$$\therefore 3 = 2.5$$

- So L.H.S. > R.H.S.



- So it is not a kinematic chain.
- And hence no relative motion is possible.
- Such type of chain is called locked chain and forms a rigid frame or structure which is used in bridges and trusses.

Example 2

How to decide chain type ? **Example -2**

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Consider the arrangement of four links AB, BC, CD and DA as shown in Fig.

- Number of links: $l = 4$
- Number of pairs: $p = 4$
- Number of joints: $j = 4$

$$l = 2p - 4 \quad \text{......(1)}$$

$$j = \frac{3}{2}l - 2 \quad \text{......(2)}$$

From equation (1),

$$l = 2p - 4$$

$$\therefore 4 = 2 \cdot 4 - 4$$

$$\therefore 4 = 4$$

- So L.H.S. = R.H.S.

From equation (2),

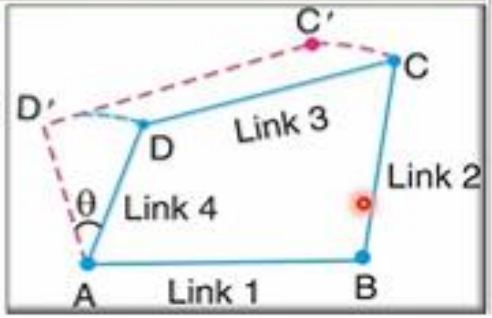
$$j = \frac{3}{2}l - 2$$

$$\therefore 4 = \frac{3}{2} \cdot 4 - 2$$

$$\therefore 4 = 4$$

- So L.H.S. = R.H.S.

- So it is a kinematic chain so relative motion is possible.
- As a single link AD is sufficient to define the position of all other links, it is called a kinematic chain of one degree of freedom.



Types of Joints in a Chain

- 1. **Binary joint**: When two links are joined at the same connection, the joint is known as binary joint. For example, a chain as shown in Fig, has four links and four binary joins at A, B,C and D.

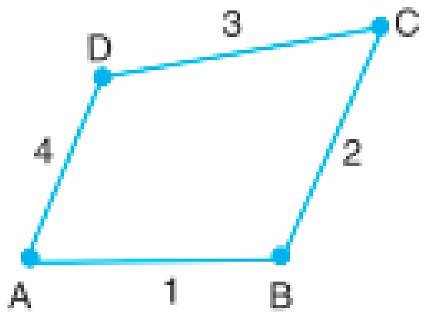


Fig. 5.10. Kinematic chain with all

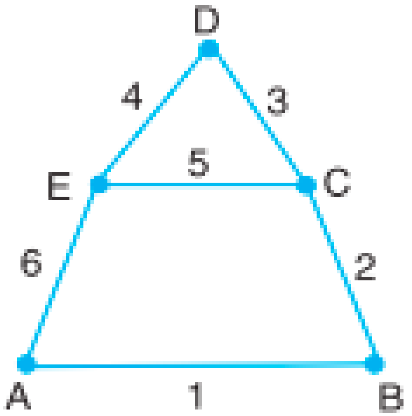
Types of Joints in a Chain

- **Ternary joint**. When three links are joined at the same connection, the joint is known as ternary joint. It is equivalent to two binary joints as one of the three links joined carry the pin for the other two links

$$j = \frac{3}{2} l - 2$$

$$7 = \frac{3}{2} \times 6 - 2 = 7$$

Since left hand side is equal to right hand side, therefore the chain, as shown in Fig., is a kinematic chain or constrained chain.



'ig. 5.11. Kinematic chain having binary and ternary joints.

Types of Joints in a Chain

- 3. **Quaternary joint**: When four links are joined at the same connection, the joint is called a quaternary joint. It is equivalent to three binary joints

Example

How to decide chain type ?

Consider an arrangement of five links, as shown in Fig.

- Number of links: $l = 5$
- Number of pairs: $p = 5$
- Number of joints: $j = 5$

$l = 2p - 4$ ....①

$j = \frac{3}{2} l - 2$ ....②

From equation (1),

$l = 2p - 4$

$\therefore 5 = 2 \cdot 5 - 4$

$\therefore 5 = 6$

- So L.H.S. < R.H.S.

From equation (2),

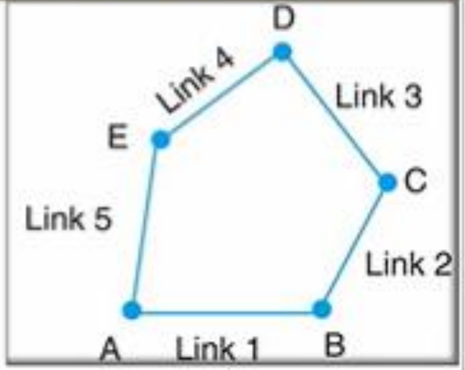
$j = \frac{3}{2} l - 2$

$\therefore 5 = \frac{3}{2} \cdot 5 - 2$

$\therefore 5 = 5.5$

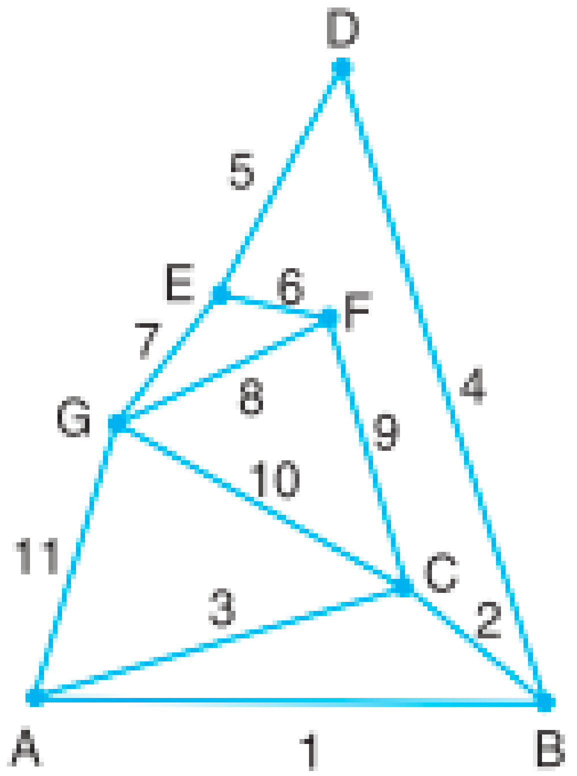
- So L.H.S. < R.H.S.

- So it is not a kinematic chain.
- Such a type of chain is called unconstrained chain i.e. the relative motion is not completely constrained.
- This type of chain has no practical importance.



Homework

- Specify the figure below which type of kinematic chain and why?



Reference

- Khurmi, R. S., & Gupta, J. K. (2005). A textbook of machine design. S. Chand publishing.

- https://www.youtube.com/watch?v=aCm66igL2s4
- https://www.youtube.com/watch?v=cU1PLmkjwIg
- https://www.youtube.com/watch?v=sNLaKPCY-bM