Preloaded Structure

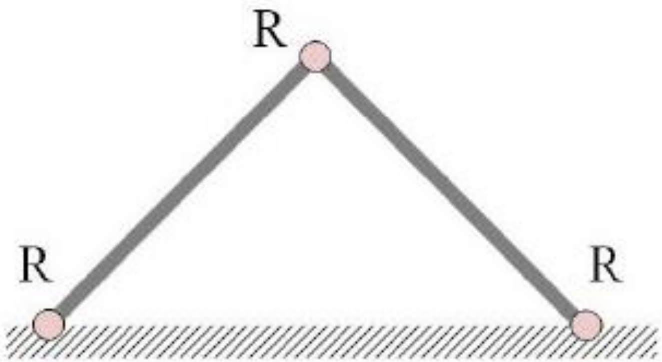
- Preloaded Structure – DOF<0, may require force to assemble

- In order to *insert the two pins without straining the links*, the center distances of the holes in both links must be exactly the same, which is practically impossible, therefore require force to assemble causing stress in links

Calculate mobility of various configurations of connected links

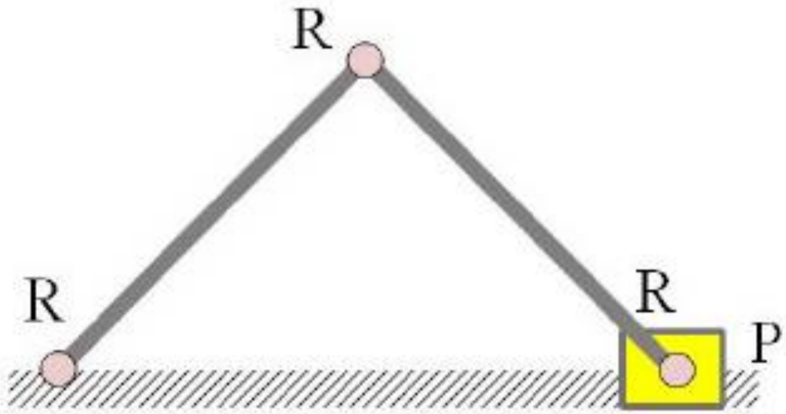
Kutzbach's criterion of mobility

$$M = 3(L - 1) - 2J_1 - J_2$$



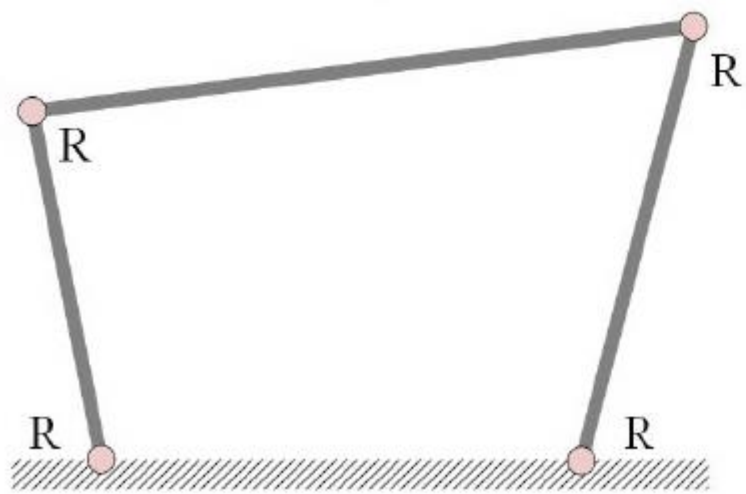
$L = 3$, $J_1 = 3$, $j_2 = 0$ ➔ **$M = 0$**; implying that this system of links is not a mechanism, but a structure.

$L = 4$, $J_1 = 4$, $j_2 = 0$ ➔ **$M = 1$**; implying system of interconnected links in has mobility 1, which means that any link can be used as input link (driver) in this mechanism.

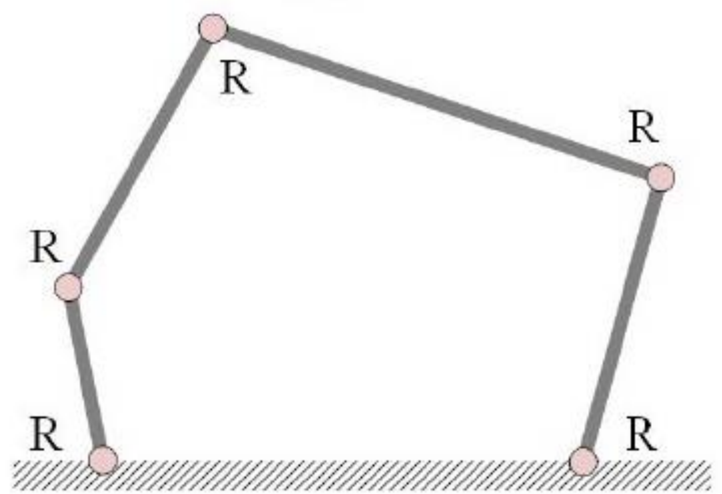


Calculate mobility of various configurations of connected links

$L = 4, J_1 = 4, j_2 = 0$ ➔ **M= 1**; implying system of interconnected links in has mobility 1, which means that any link can be used as input link (driver) in this mechanism.

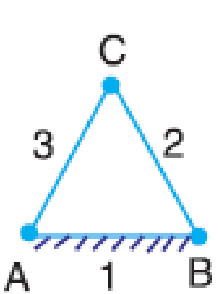


$L = 5, J_1 = 5, j_2 = 0$ ➔ **M= 2**; implying system of interconnected links in has mobility 2, which means that any two links can be used as input links (drivers) in this mechanism.

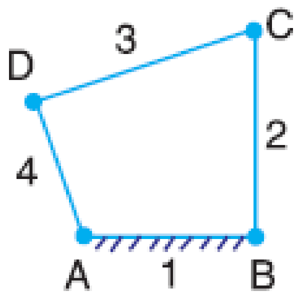


Example: 1

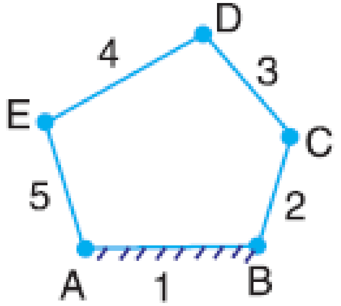
- Determine the degrees of freedom or movability of mechanisms having no higher pair (i.e. h = 0)



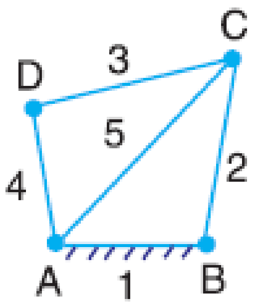
(*a*) Three-bar mechanism.



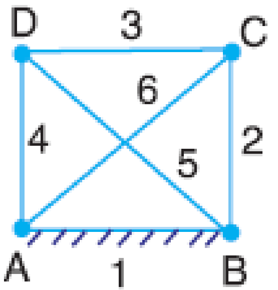
(*b*) Four bar mechanism.



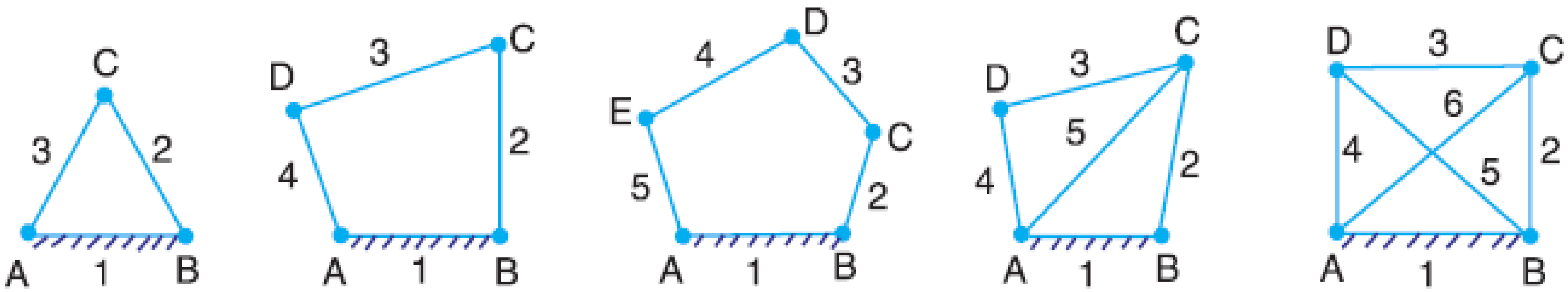
(*c*) Five bar mechanism.



(*d*) Five bar mechanism.



(*e*) Six bar mechanism.



(*a*) Three-bar mechanism. (*b*) Four bar mechanism. (*c*) Five bar mechanism. (*d*) Five bar mechanism. (*e*) Six bar mechanism.

1. The mechanism, as shown in Fig. 5.16 (*a*), has three links and three binary joints, *i.e.* $l = 3$ and $j = 3$.

$$\therefore \quad n = 3\,(3 - 1) - 2 \times 3 = 0$$

2. The mechanism, as shown in Fig. 5.16 (*b*), has four links and four binary joints, *i.e.* $l = 4$ and $j = 4$.

$$\therefore \quad n = 3\,(4 - 1) - 2 \times 4 = 1$$

3. The mechanism, as shown in Fig. 5.16 (*c*), has five links and five binary joints, *i.e.* $l = 5$, and $j = 5$.

$$\therefore \quad n = 3\,(5 - 1) - 2 \times 5 = 2$$

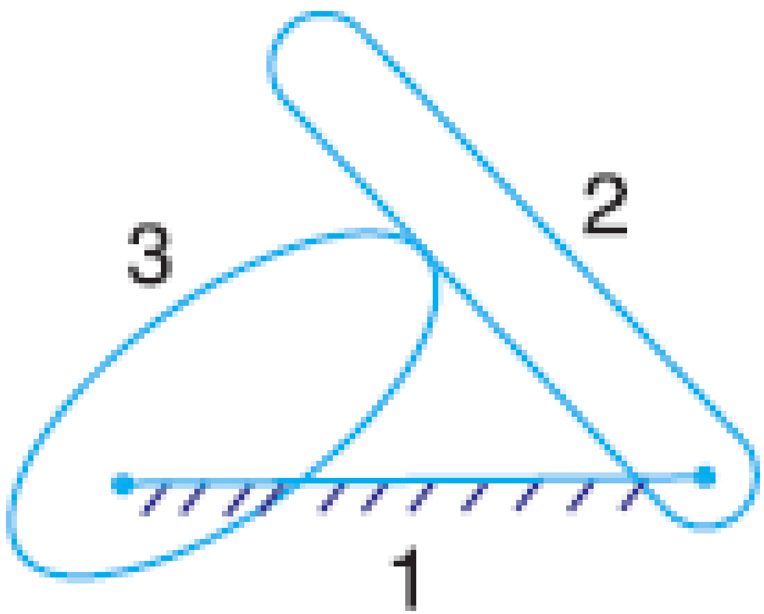
4. The mechanism, as shown in Fig. 5.16 (*d*), has five links and six equivalent binary joints (because there are two binary joints at *B* and *D*, and two ternary joints at *A* and *C*), *i.e.* $l = 5$ and $j = 6$.

$$\therefore \quad n = 3\,(5 - 1) - 2 \times 6 = 0$$

5. The mechanism, as shown in Fig. 5.16 (*e*), has six links and eight equivalent binary joints (because there are four ternary joints at *A, B, C* and *D*), *i.e.* $l = 6$ and $j = 8$.

$$\therefore \quad n = 3\,(6 - 1) - 2 \times 8 = -1$$

Mechanisms with higher pair



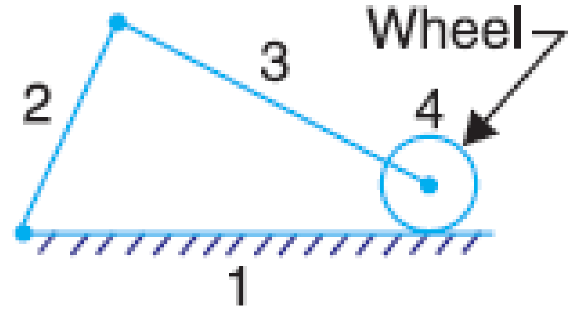
there are three links, two binary joints and one higher pair, *i.e.* $l = 3$, $j = 2$ and $h = 1$.

$$n = 3\ (3 - 1) - 2 \times 2 - 1 = 1$$

Mechanisms with higher pair (contd.)

there are four links, three binary joints and one higher pair, *i.e.* $l = 4$, $j = 3$ and $h = 1$

$$n = 3\ (4 - 1) - 2 \times 3 - 1 = 2$$

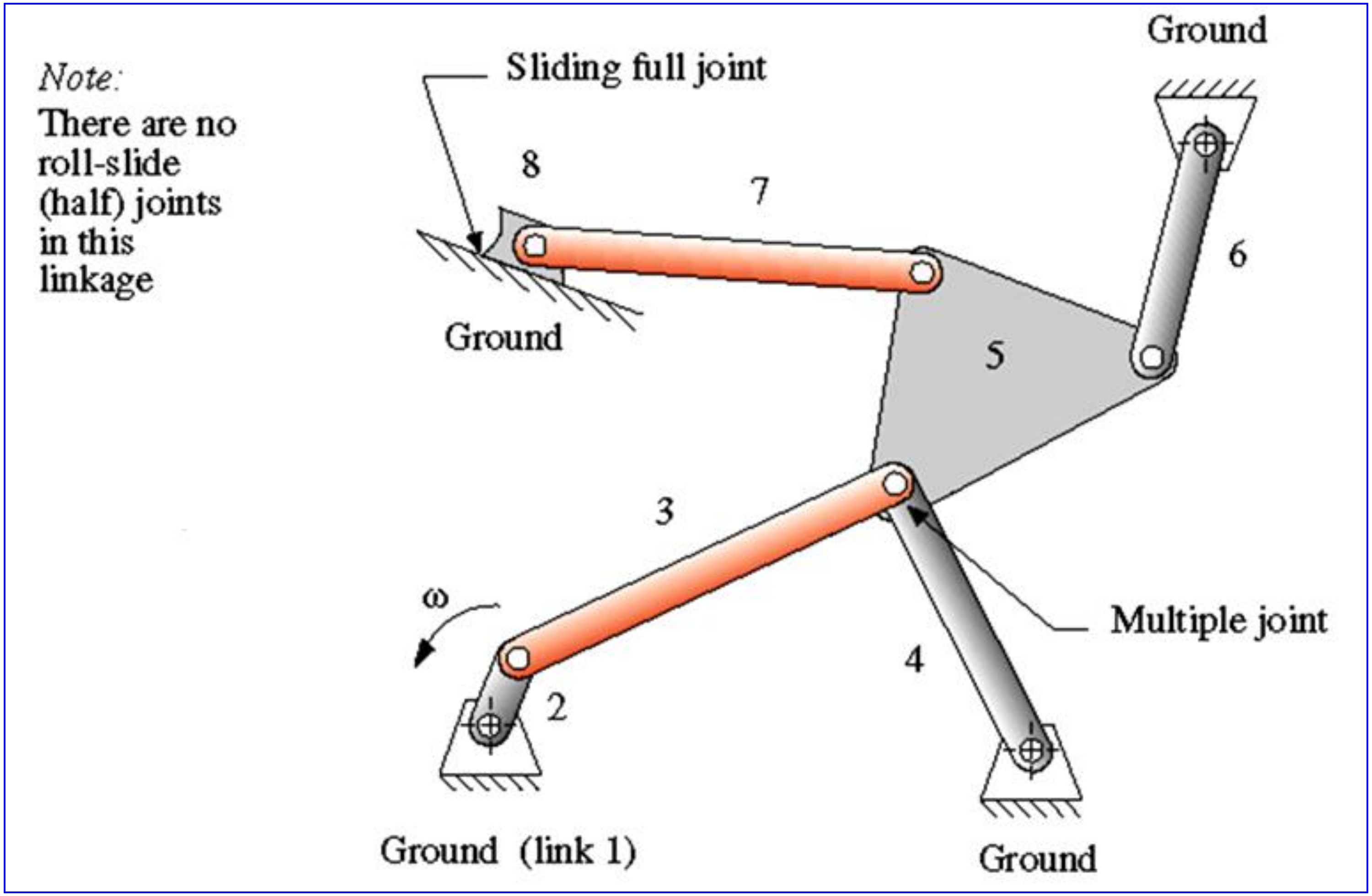


- Here it has been assumed that the **slipping** is possible between the links (i.e. between the wheel and the fixed link).

- However if the friction at the contact is high enough to prevent slipping, the joint will be counted as one degree of freedom pair, because only one relative motion will be possible between the links.

- Ex- driving car on dry & Icy road.

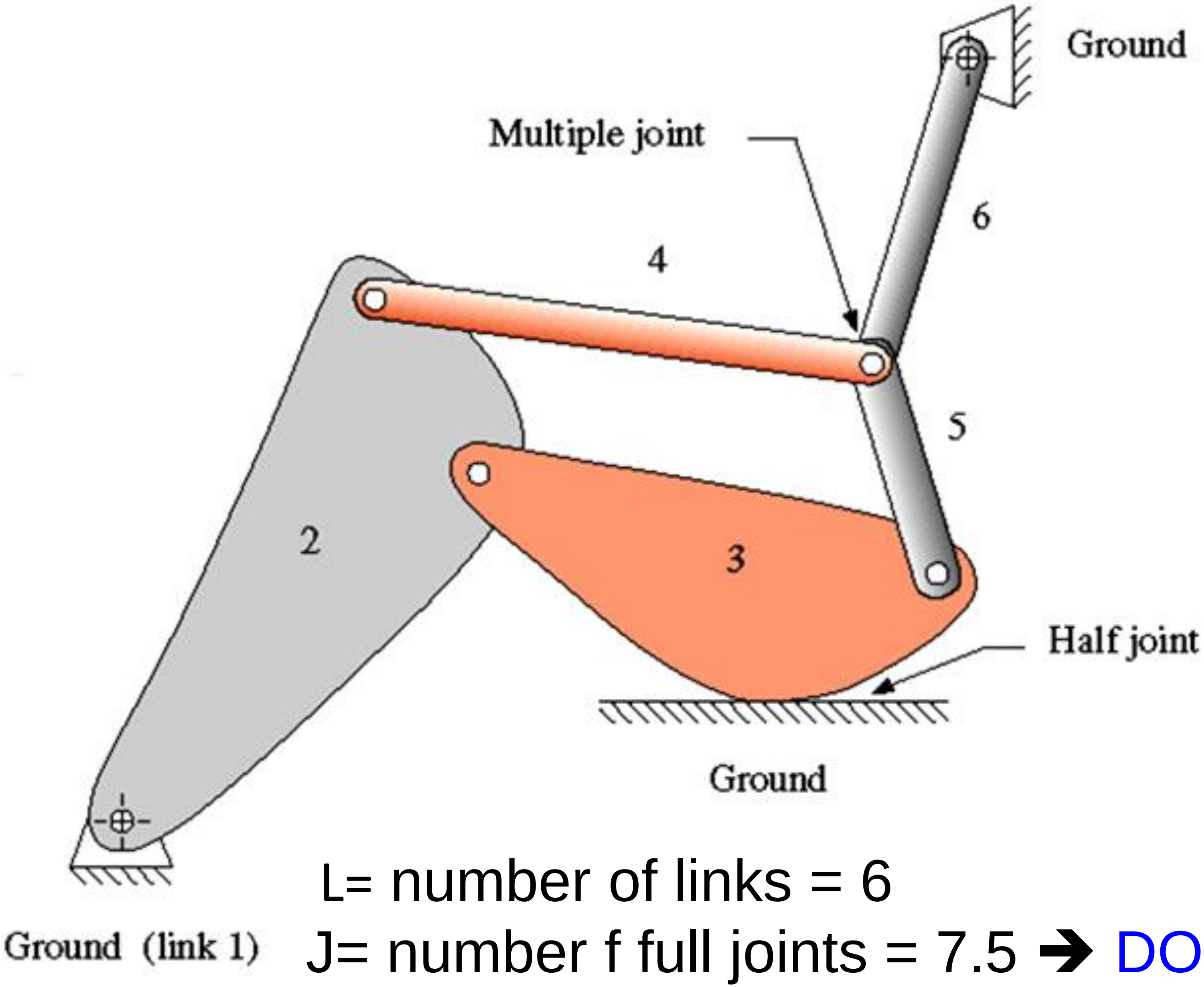
Example: 2



L= number of links = 8; J= number f full joints = 10 ➔ DOF = 1

Note: **Multiple joints** count as one less than the number of links joined at that joint and add to the "full" (J_1) category

Example: 3

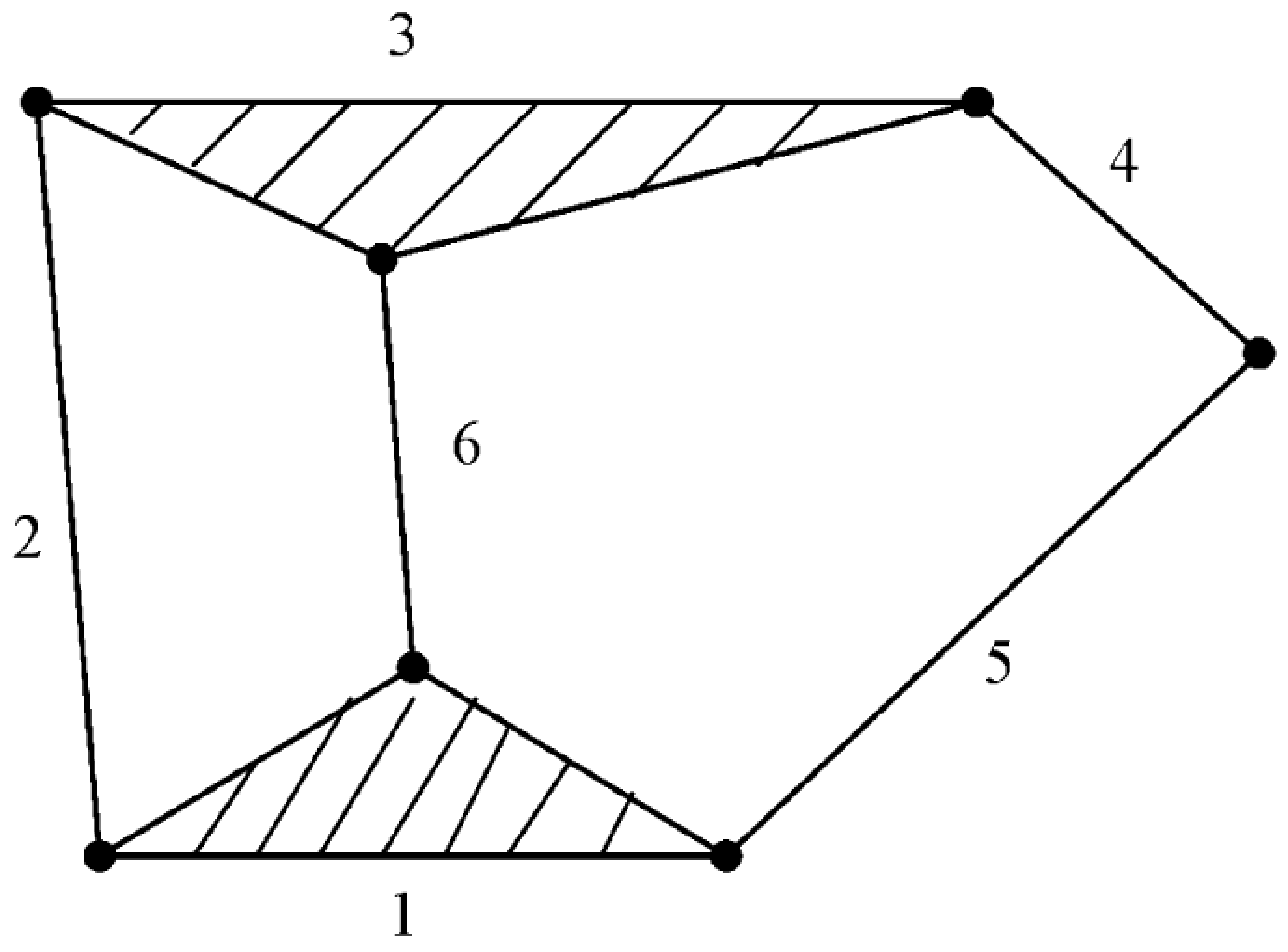


L= number of links = 6

J= number f full joints = 7.5 ➔ DOF = 0

Exercise: 1

- Determine the degrees of freedom of a six bar linkage.



Exercise: 1 (contd.)

- There are four binary links and two ternary links (i.e. link 1 & 3). The number of joints are (you can count them directly or use the following formula)

$$j = \frac{1}{2}(2n_2 + 3n_3)$$

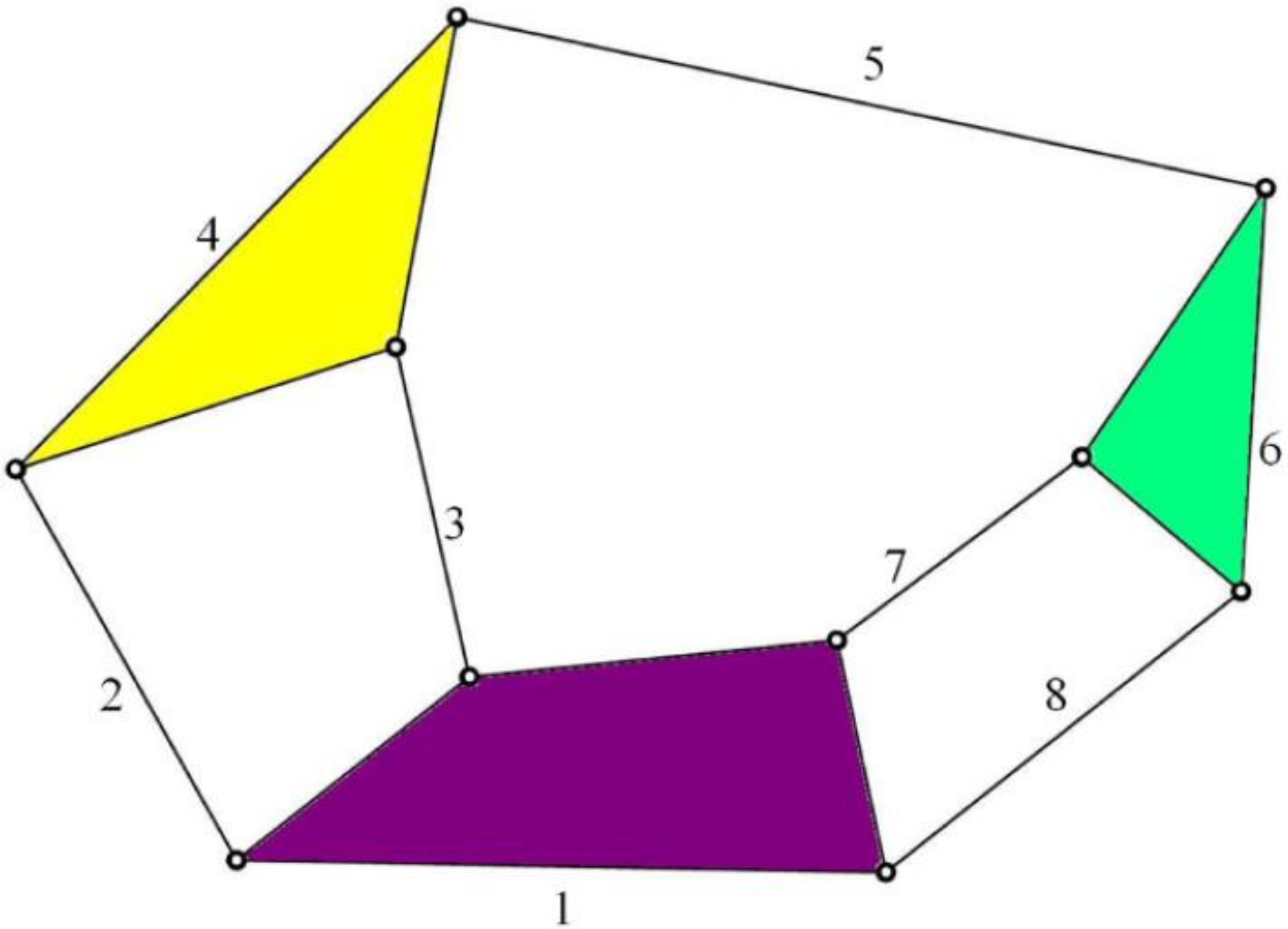
$$= \frac{1}{2}(2 \times 4 + 3 \times 2) = 7$$

- According to Gruebler/Kutzbach equation

M = 3 (6 – 1) – 2 x 7 = 1

Exercise: 2

- Determine the degrees of freedom of a eight bar linkage.



Exercise: 2 (contd.)

- There are five binary links (n_2 = 5), two ternary links (n_3 = 2) and one quaternary link (n_4 = 1). Thus, number of joints are

$$j = \frac{1}{2}(2 \times 5 + 3 \times 2 + 4 \times 1) = 10$$

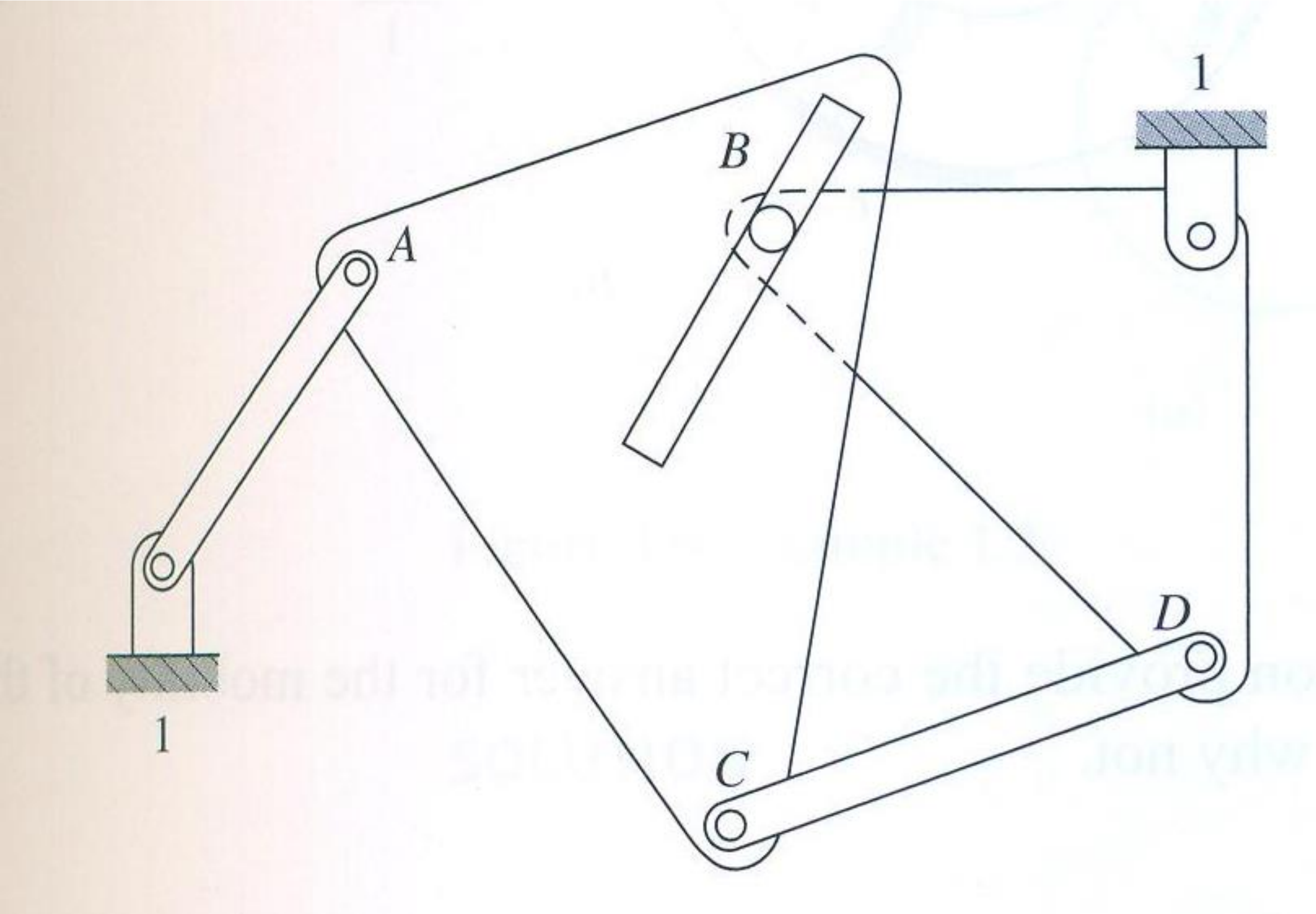
- According to Gruebler/Kutzbach equation

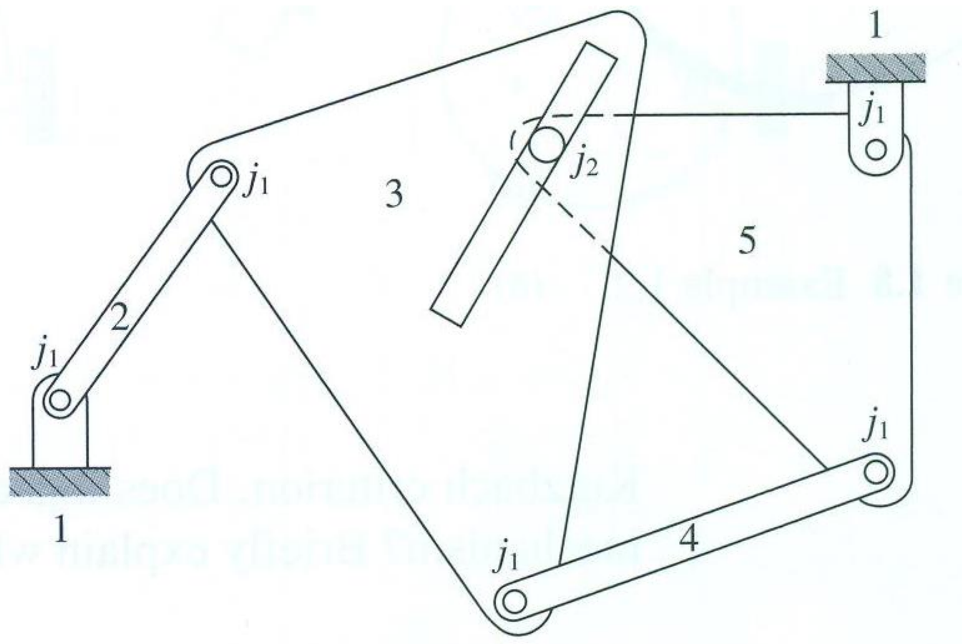
M = 3 (8 – 1) – 2 x 10 = 1

- Thus, this linkage has also one degree of freedom.

Exercise: 3

- Determine the d.o.f or mobility of the planar mechanism illustrated below





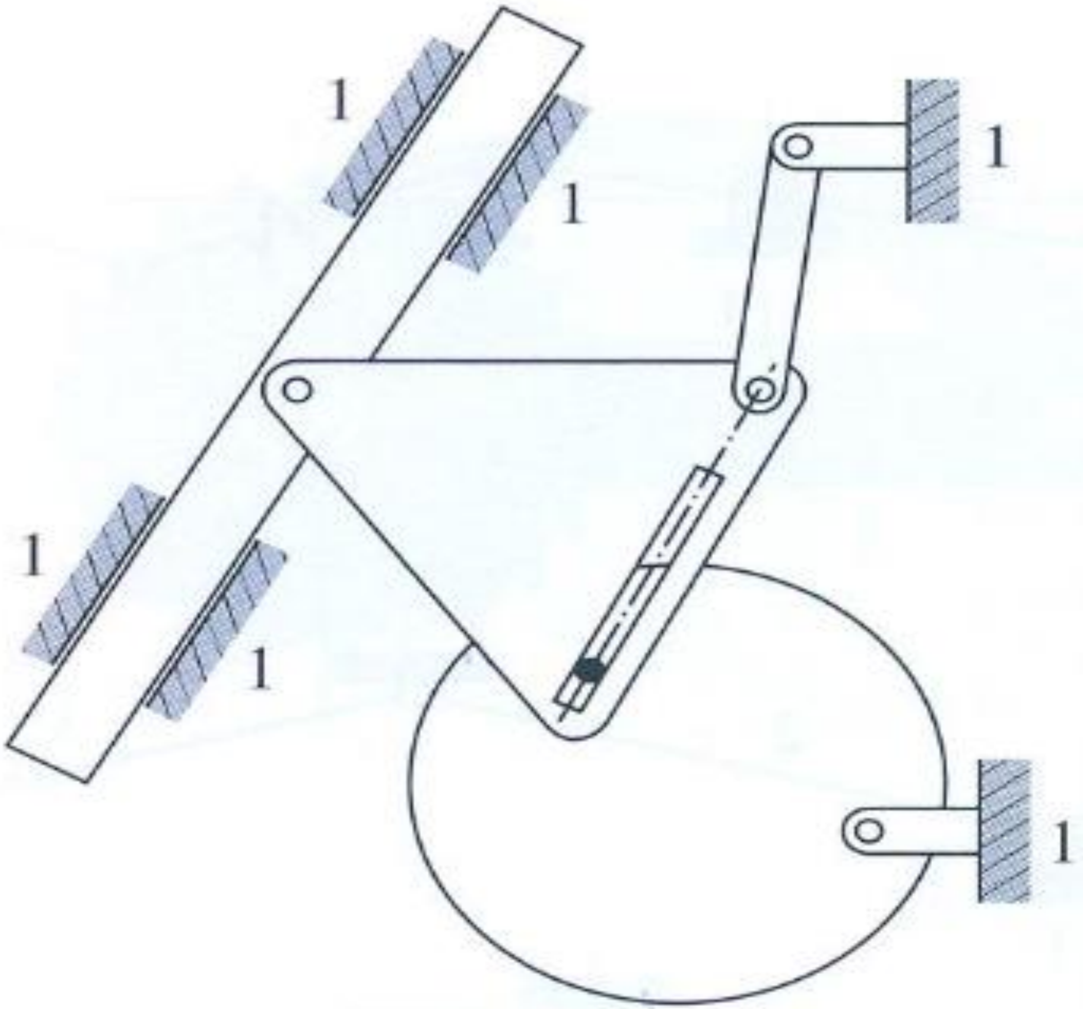
- The link numbers and the joint types for the mechanism are illustrated above. The number of links is n = 5, the number of lower pairs is $j_1 = 5$, and the number of higher pairs is h or $j_2 = 1$. Substituting these values into the Kutzbach criterion, the mobility of the mechanism is

$$\mathbf{M = 3\ (5 - 1) - 2\ \ x\ 5 - 1 = 1}$$

that is, a single input motion is required to gives unique output motion.

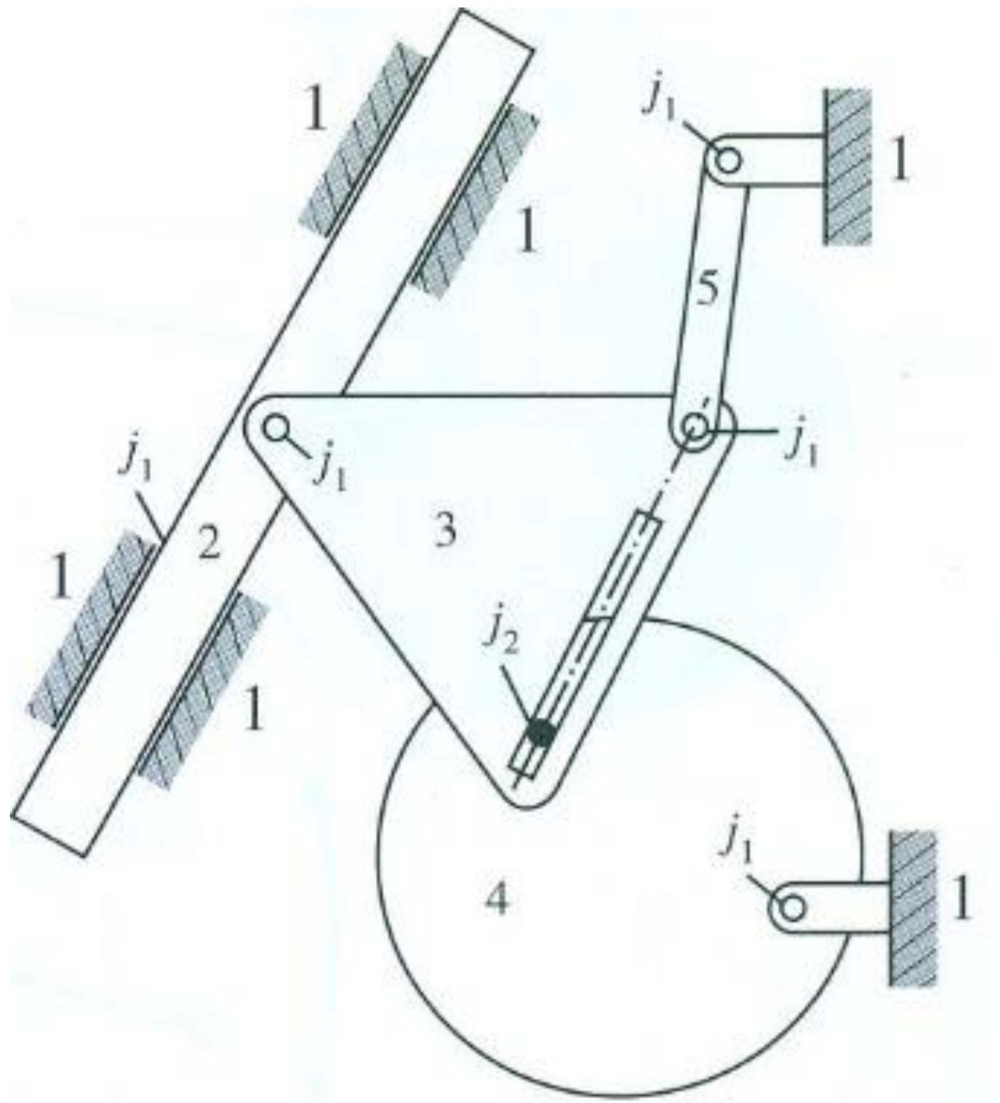
Exercise: 4

- Determine the d.o.f or mobility of the planar mechanism illustrated below



Exercise: 4 (contd.)

- The number of links is $n = 5$, the number of lower pairs is $j_1 = 5$, and the number of higher pairs is h or $j_2 = 1$. Substituting these values into the Kutzbach criterion, the mobility of the mechanism is



$$M = 3\,(5 - 1) - 2 \times 5 - 1 = 1$$