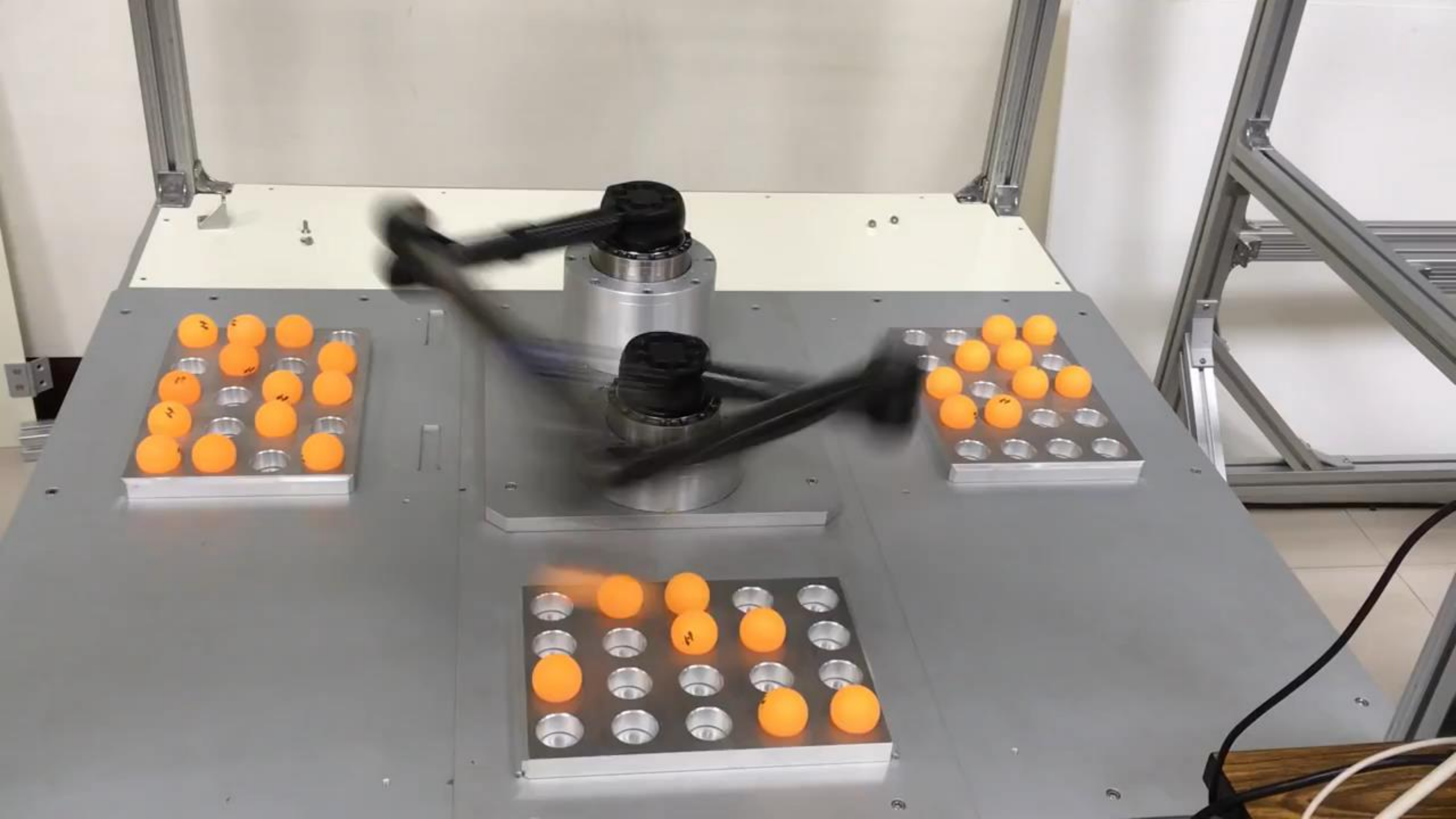


Degrees of Freedom



Reading: Modern Robotics 2.2

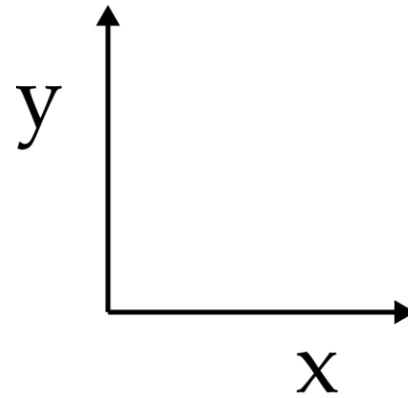


This Lecture

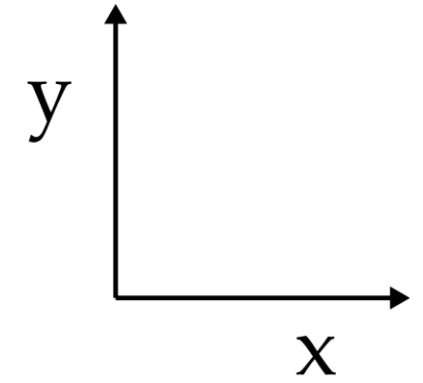
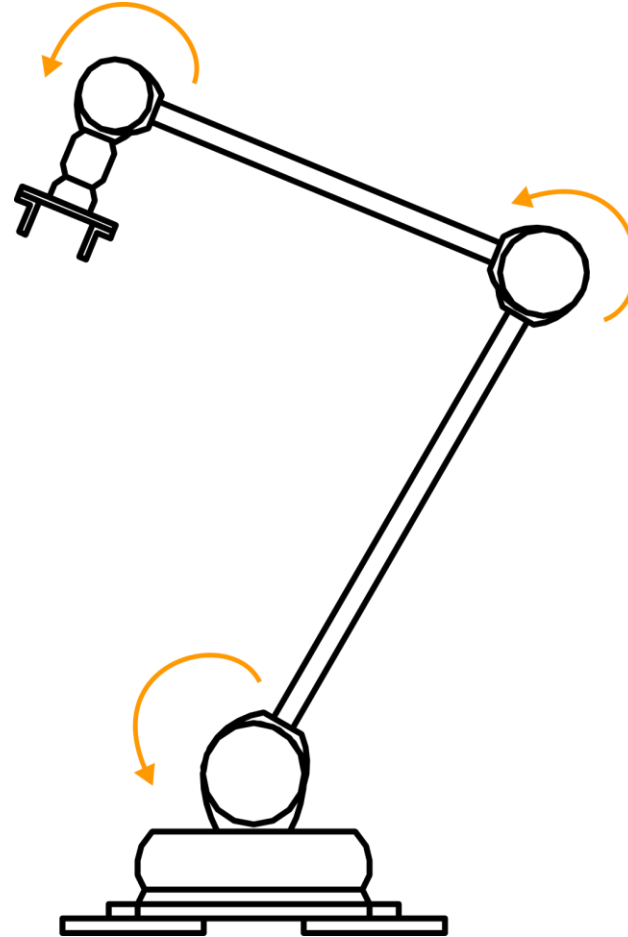


- What are degrees of freedom?
- How many degrees of freedom does a robot have?

How many **coordinates** do we need to specify car's configuration?




How many **coordinates** do we need to specify robot's configuration?



Degrees of Freedom

- Minimum number of **coordinates** needed to capture the robot's configuration
- If we need n coordinates, robot has n degrees of freedom

A blue robotic arm is positioned in the center of a warehouse aisle. The aisle is lined with tall blue metal shelving units filled with yellow cardboard boxes. The floor is grey concrete. In the background, a yellow forklift is visible. The text "How many degrees of freedom does a robot have?" is overlaid in white, with "many" in orange. A white wavy line is positioned below the text.

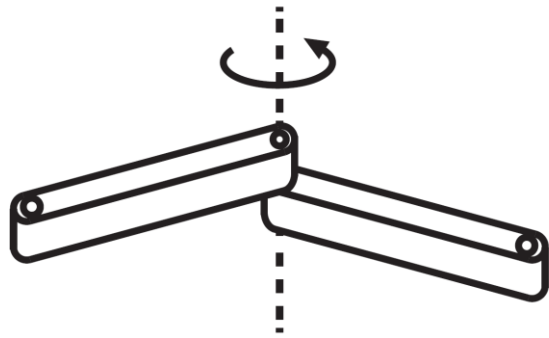
How **many** degrees of
freedom does a
robot have?

Grubler's Formula

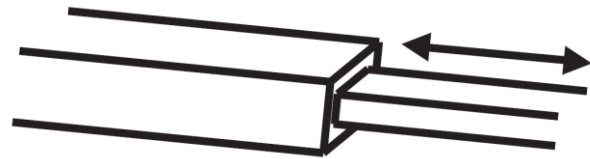
$$m(N - 1 - K) + \sum_{i=1}^K f_i$$

- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint

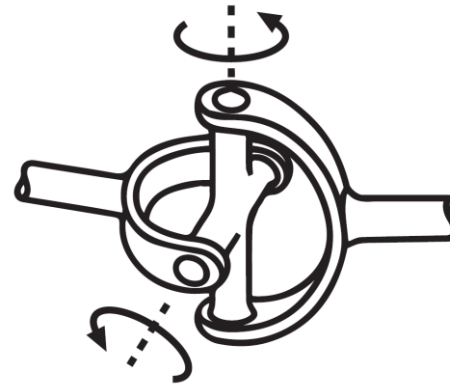
Grubler's Formula



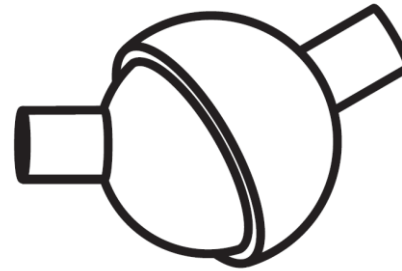
Revolute.
1 DoF



Prismatic.
1 DoF



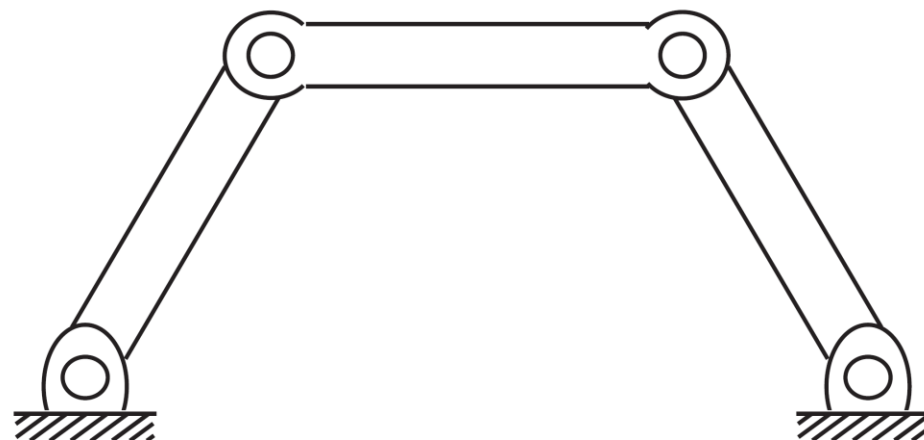
Universal.
2 DoF



Spherical.
3 DoF

Practice

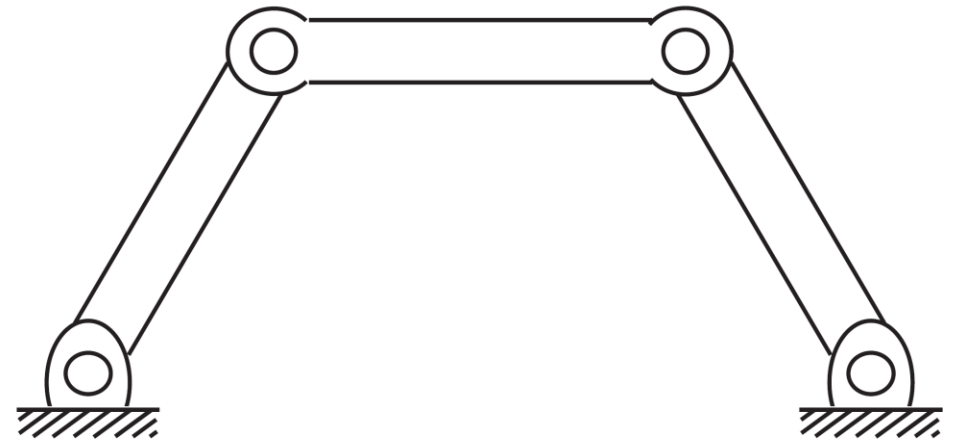
- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint



$$m(N - 1 - K) + \sum_{i=1}^K f_i$$

Practice

- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint



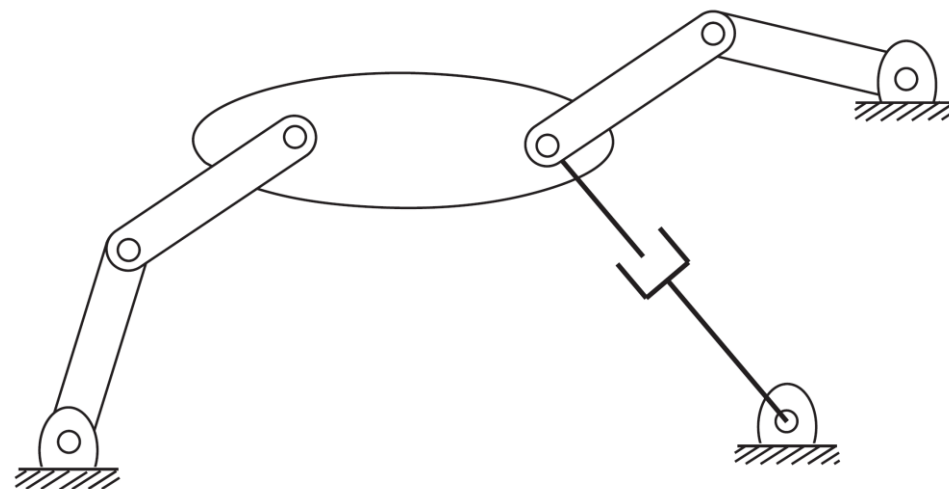
$$\underline{3(4 - 1 - 4) + 4 = 1}$$

Remember to count the ground as a link

$$m(N - 1 - K) + \sum_{i=1}^K f_i$$

Practice

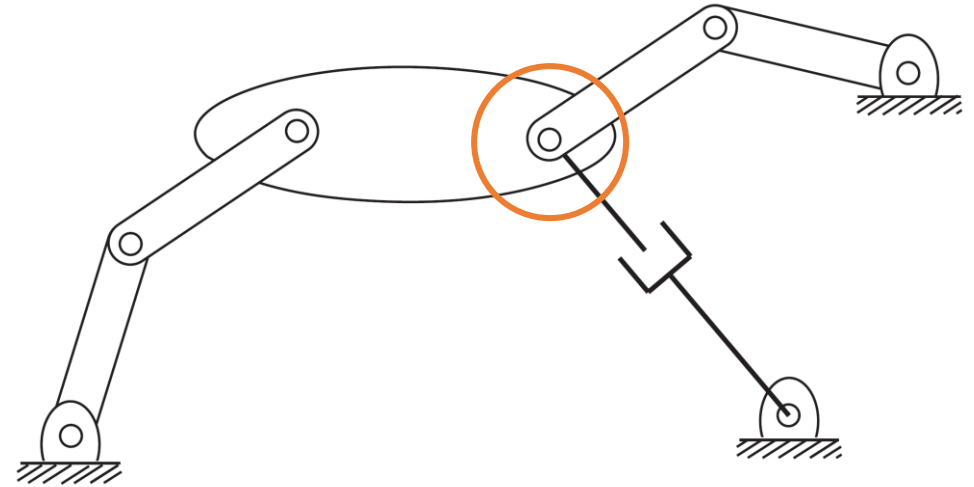
- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint



$$m(N - 1 - K) + \sum_{i=1}^K f_i$$

Practice

- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint

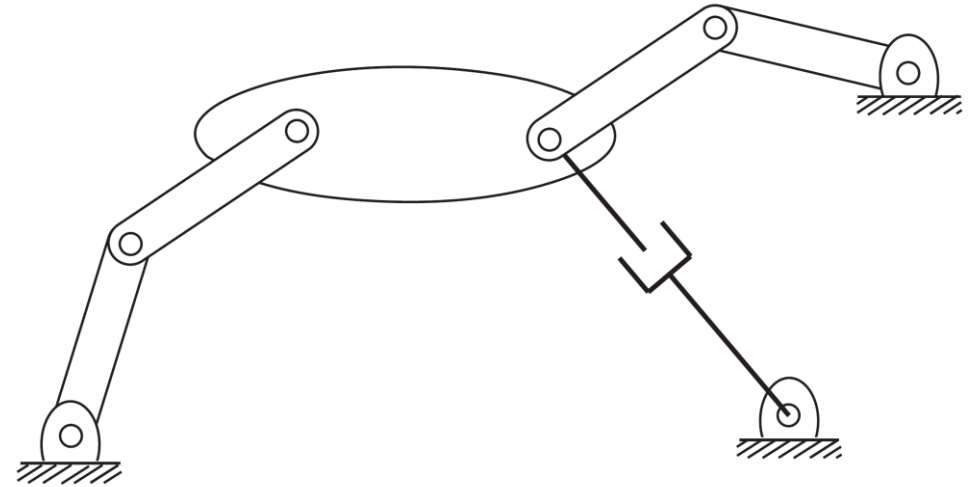


Hint: joints connect two links, so this is **two** overlapping revolute joints

Practice

- N is the number of links
- K is the number of joints
- $m = 3$ for robot on 2D plane
- $m = 6$ for robot in 3D space
- f_i is DoFs for the i -th joint

$$3(8 - 1 - 9) + 9 = 3$$



$$m(N - 1 - K) + \sum_{i=1}^K f_i$$

This Lecture



- What are degrees of freedom?
- How many degrees of freedom does a robot have?

Next Lecture



- How do we capture position and rotation?