Kinematic (stick or skeleton) Diagrams

A striped-down (simplified) drawing showing the essentials needed for kinematics analysis. All links are numbered while the joints are lettered.

Mechanism to open and close a window

Kinematic diagram
Kinematic (stick or skeleton) Diagrams
Kinematic (stick or skeleton) Diagrams

- Indicating a fixed angle
- Indicating a rigid link
- Hydraulic actuator

Plate
Type of Joints – Kinematic Pairs

Lower Pairs – motion is transmitted through an area contact, pin and slider joints.

Higher Pairs – motion is transmitted through a line or a point contact; gears, rollers, and spherical joints.
Joints

The Revolute joint (pin or hinge joint) - one degree of freedom

It allows pure rotation between the two links that it connects (R joints)
The *Sliding* joint (prism or piston joint) - one degree of freedom

It allows linear sliding between the two links that it connects (P joint)
Joints

The *Helical* joint (helix or screw joint) - one degree of freedom

The sliding and rotational motions are related by the helix angle of the thread (H joint)
Joints

The *Cylindrical* (cylindric) joint - two degrees of freedom

It permits both angular rotation and an independent sliding motion (C joint)
Joints

The Spherical (spheric) - Three degree of freedom

It permits rotational motion about all three axes, a ball-and-socket joint (S joint)
Joints

The Planar *(flat)* - Three degree of freedom

It permits rotational motion about the Z axes axis and sliding motion in x and y axes (F joint), used seldom in design

![Planar (F) joint—3 DOF](image)
A cam joint allows both rotation and sliding between two links.

A gear connection also allows both rotation and sliding as the gear teeth mesh.
Degrees of Freedom (DOF) – Type of Joints, Higher Pairs

Roll-slide contact, 2 DOF
Rolling contact (no sliding), 1 DOF

Gears – sliding and rotation motion between two teeth, 2 DOF
Degrees of Freedom (DOF) – Type of Joints, Higher Pairs

Belt and pulley (no sliding) or chain and sprocket – 1 DOF

Spring – no effect on mechanism DOF
Degrees of Freedom (DOF) – Type of Joints, Lower Pairs

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<th>Geometric Form</th>
<th>Schematic Representations</th>
<th>Degrees of Freedom</th>
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<tr>
<td>1. Revolute (R)</td>
<td>![Image of a revolute joint]</td>
<td>![Schematic of a revolute joint]</td>
<td>1</td>
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<tr>
<td>2. Cylinder (C)</td>
<td>![Image of a cylinder joint]</td>
<td>![Schematic of a cylinder joint]</td>
<td>2</td>
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<tr>
<td>3. Prism (P)</td>
<td>![Image of a prism joint]</td>
<td>![Schematic of a prism joint]</td>
<td>1</td>
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<tr>
<td>4. Sphere (S)</td>
<td>![Image of a sphere joint]</td>
<td>![Schematic of a sphere joint]</td>
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<td>5. Helix (H)</td>
<td>![Image of a helix joint]</td>
<td>![Schematic of a helix joint]</td>
<td>1</td>
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<tr>
<td>6. Plane (P_L)</td>
<td>![Image of a plane joint]</td>
<td>![Schematic of a plane joint]</td>
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Each pin connection removes two degrees of freedom of relative motion between two successive links.

Two degrees of freedom joints are sometimes called a half a joint (Norton).

A slider is constrained against moving in the vertical direction as well as being constrained from rotating in the plane.

A spheric pair is a ball and socket joint, 3 DOF.

The helical pair has the sliding and rotational motion related by the helix angle of the screw.

Planar pair is seldom used.
Degrees of Freedom

An object in space has **six degrees** of freedom.

- **Translation** – movement along X, Y, and Z axis (three degrees of freedom)
- **Rotation** – rotate about X, Y, and Z axis (three degrees of freedom)
Degrees of Freedom (DOF)

Planar (2D) mechanisms

*Degrees of Freedom* – number of independent coordinates required to completely specify the position of the link

*Three independent* coordinates needed to specify the location of the link AB, \( x_A, y_A, \) and angle \( \theta \)

An unconstrained link in a plane has three degrees of freedom, a mechanism with \( L \) links has \( 3L \) degrees of freedom
**Degrees of Freedom (DOF)**

Kutzbach’s (modified Groubler) equation

$$\text{DOF} = 3(L - 1) - 2J_1 - J_2$$

DOF = degree of freedom or mobility

$L = \text{number of links, including ground link}$

$J_1 = \text{number of 1 DOF joints (full joints)}$

$J_2 = \text{number of 2 DOF joints (half joints)}$

$\text{DOF} \leq 0 \quad \Rightarrow \quad \text{structure}$

$\text{DOF} > 0 \quad \Rightarrow \quad \text{mechanism}$
**Degree of Freedom (DOF) – example**

**Four Bar mechanism**

\[ L = 4, J_1 = 4 \text{ pin connections, } J_2 = 0 \]

\[ \text{DOF} = 3(L - 1) - 2J_1 - J_2 \]

\[ \text{DOF} = 3(4 - 1) - 2(4) - (0) = 1 \]

**Slider crank mechanism**

\[ L = 4, J_1 = 3 \text{ pin connections + 1 slider = 4} \]

\[ J_2 = 0 \]

\[ \text{DOF} = 3(4 - 1) - 2(4) - (0) = 1 \]

1 DOF means only one input (power source) is needed to control the mechanism
Degrees of Freedom (DOF) – trench hoe

Number of links, $L = 12$, Number of one DOF joints, $J_1 = 12$ (pins) + 3 (slider) = 15, Number of two DOF joints, $J_2 = 0$

$$DOF = 3(L - 1) - 2J_1 - J_2 = 3(12-1) -2(15) = 3$$

3 hydraulics are used to control the position of the bucket.
Degree of Freedom (DOF) - example

Number of links, $L = 7$,

Number of one DOF joints, $J_1 = 6$ (pins) + 1 (slider) = 7,

Number of two DOF joints, $J_2 = 1$ (fork joint)

\[
\text{DOF} = 3(L - 1) - 2J_1 - J_2 = 3(7-1) - 2(7) - 1 = 3
\]

Three input sources are needed to control the mechanism
**Paradoxes**

**Two rollers in contact, no slipping**

- \( L = 3, \ J_1 = 3, \ J_2 = 0 \)
- \( \text{DOF} = 3(3-1) - 2(3) = 0 \)

**Two gears in contact**

- \( L = 3, \ J_1 = 2, \ J_2 = 1 \)
- \( \text{DOF} = 3(3-1) - 2(2) - 1 = 1 \)

**Redundant support**

- \( L = 5, \ J_1 = 6, \ J_2 = 0 \)
- \( \text{DOF} = 3(5-1) - 2(6) = 0 \)

Eliminate the redundancy before determining DOF.