MIET2510

Mechanical Design

Week 1 – Analysis of Mechanisms – Part 1

School of Science and Technology, RMIT Vietnam

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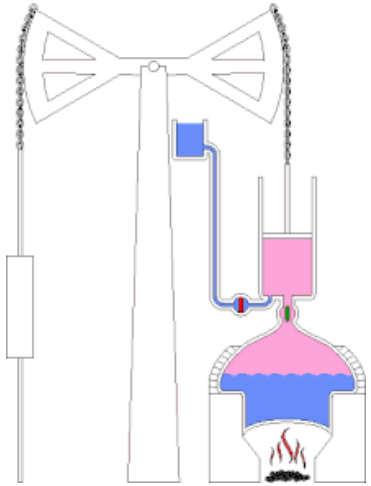
Why study mechanical design?

- Machines and mechanisms are a part of our everyday life.



Newcomen Engine 1712
Used for pumping water out of mines

Power: 7.5 kW
Speed: About 12 strokes/minute
Dimensions: 9 metres high!

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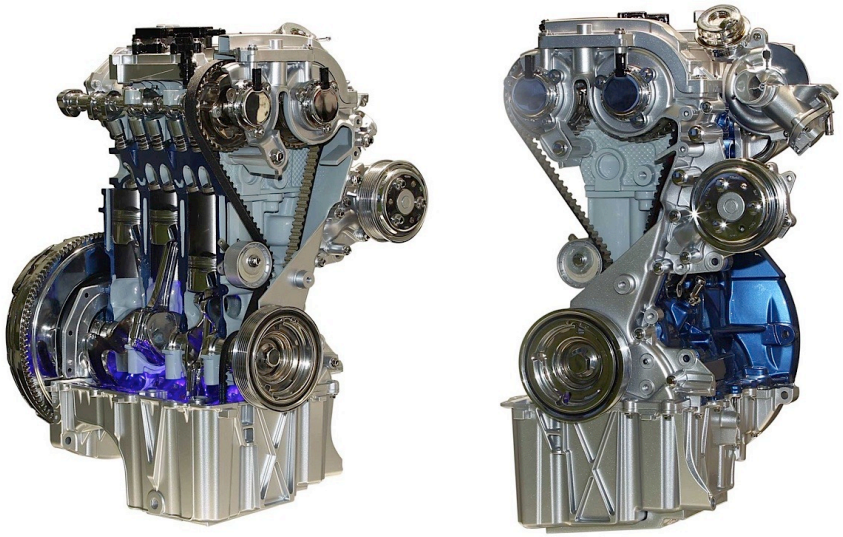
Why study mechanical design?



Ford 1l ecoboost

Power = 116 kW
Rotational speed: Up to 6750 rpm
Piston speed at 6000rpm: 16.28 m/s
Acceleration force on piston: 655g
Max exhaust temp: 1200C
Width x length – about the size of an A4 page

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Why study mechanical design

Formula 1 engine typical values

Power = 750 kW + MGU
Rotational speed: Up to 15000 rpm
Piston speed at 6000rpm: 20+ m/s
Acceleration force on piston: 1200g

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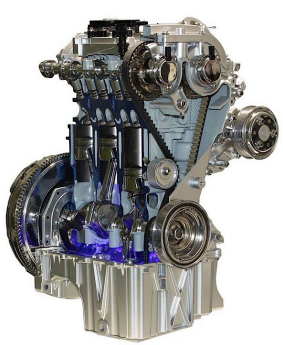
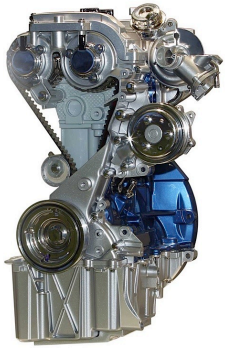
Why study mechanical design





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Outlines

1. Degree of Freedom
2. Types of Motion
3. Links and Joints
4. Kinematics Diagrams
5. Determining Degree of Freedom or Mobility

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1. Degree of Freedom

- **Mobility** is also known as **Degree of Freedom (DoF)**, is the number of independent parameters that are needed to uniquely define position in space at any instant in time.
- The concept of DoF is fundamental to both **synthesis and analysis** of mechanisms.
- **Rigid body** is an object with negligible deformation under any applied loads.

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Degrees of Freedom

- Working in pairs find a mechanism / object with;
  - 1 DOF
  - 2 DOF
  - 3 DOF

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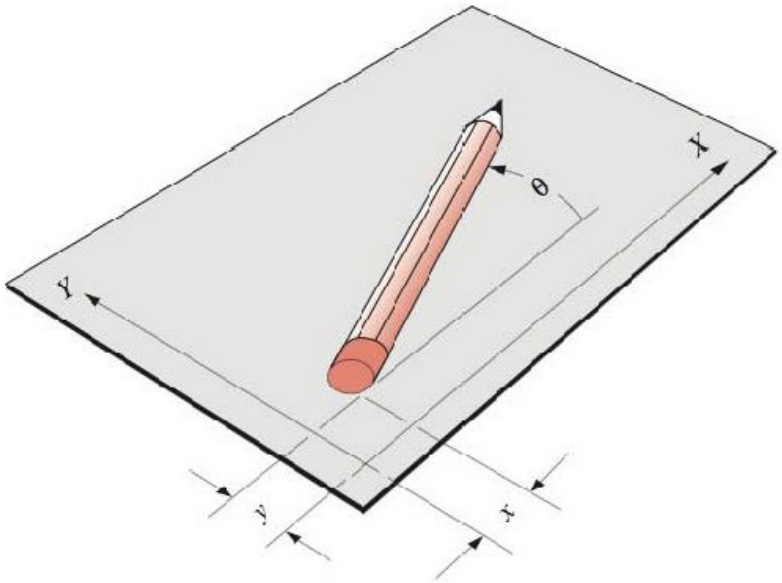
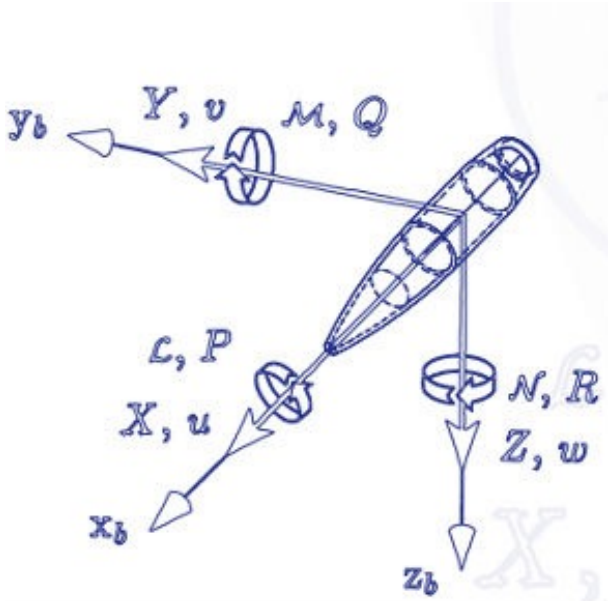
1. Degree of Freedom



A rigid body in a plane has 3 DOF



A rigid body in a space has 6 DOF

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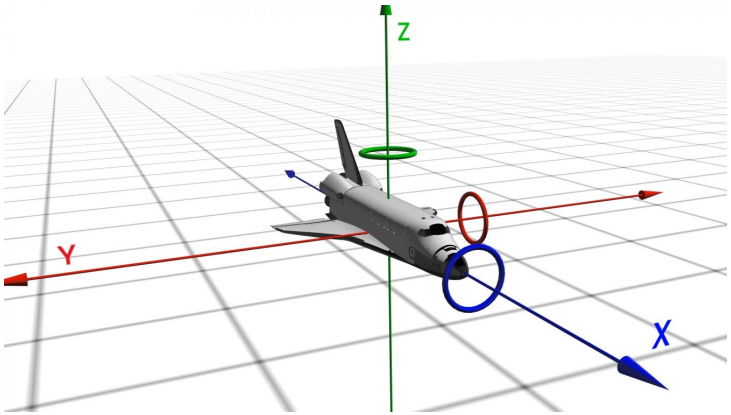
1. Degree of Freedom



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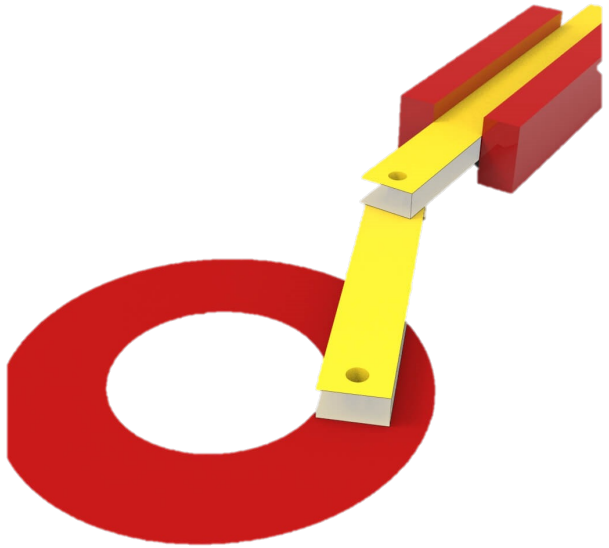
2. Types of Motion

- **Pure rotation**: the body possesses one point that has no motion with respect to the “stationary” frame of reference. All other points on the body describe arcs about that centre.
- **Translation**: all points of the body describe parallel paths.
- **Complex motion** can be defined by instantaneous change of both linear and angular orientation of the reference drawn line.



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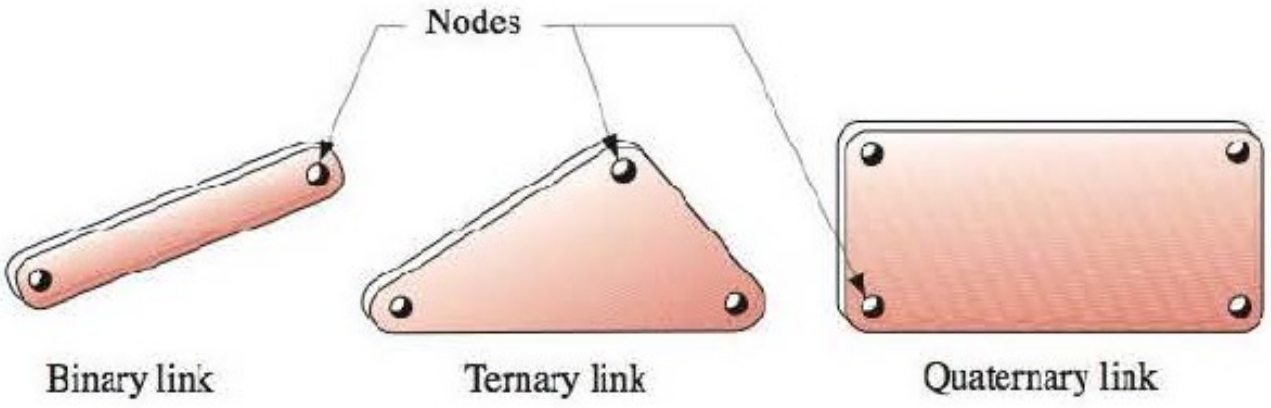
3. Links and Joints

A **link** is an (assumed) rigid body that possesses at least two nodes that are points for attachment to other links.



Ref: *Design of Machinery by Robert L. Norton*

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3. Links and Joints

- **A joint** is a connection between two or more links (at their nodes), which allows some motion, or potential motion, between connected links.
- Joints are also called **kinematic pairs**.

Lower pair - two links having a surface contact between them.

Higher pair – two links having line or point contact between them.

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3. Links and Joints

- Use ChatGTP/Google to find the most interesting example of;
  - Lower pair joint
  - Higher pair joint

- In your example explain why it is lower or higher pair joint?
- Be prepared to draw it!

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3. Links and Joints

- The joints could be classified by the ***number of degrees of freedom*** that they allow between two elements joined.
- **One-Freedom** joint is referred as a **"full joint"** and **Two-Freedom** joint is sometimes referred as a **"half joint".** There are also **Three-Freedom** joints and more *(Applied to spatial mechanism).*

Ref: *Design of Machinery by Robert L. Norton*

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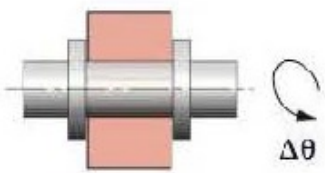
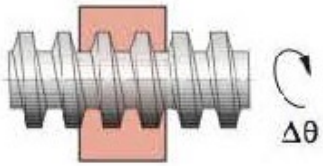
3. Links and Joints

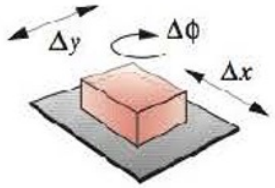
Have a look at https://bamason2.github.io/miet2510-module/notes/links_and_joints.html and decide what type of links these are and the DOF.



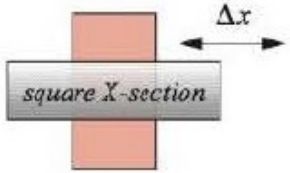
Revolute (R) joint—1 *DOF*



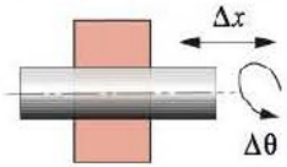
Helical (H) joint—1 *DOF*



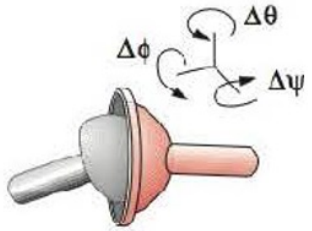
Planar (F) joint—3 *DOF*



Prismatic (P) joint—1 *DOF*



Cylindric (C) joint—2 *DOF*



Spherical (S) joint—3 *DOF*

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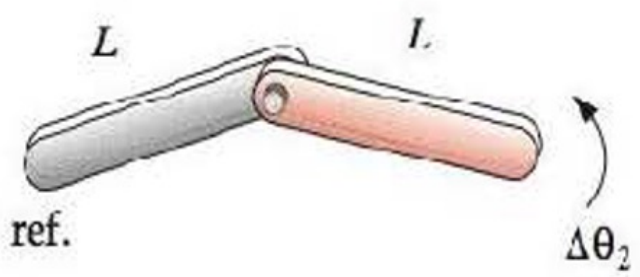
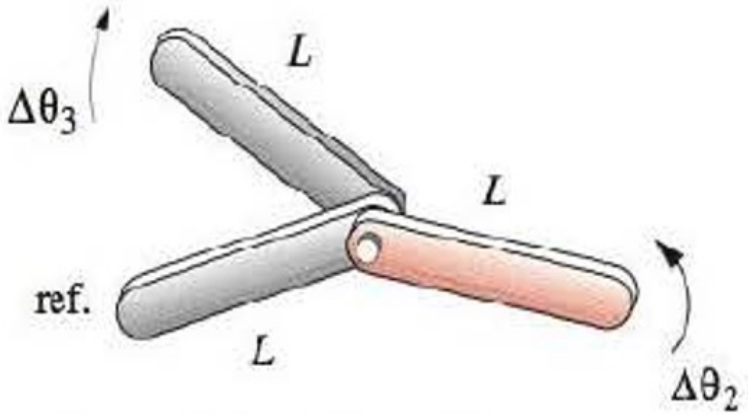
3. Links and Joints

The joints could be classified by ***the number of links joined*** (or of the joint).

The ***joint order*** is defined as the number of links joined minus one.



First order pin joint - 1 *DOF*
(two links joined)



Second order pin joint - 2 *DOF*
(three links joined)

Ref: *Design of Machinery by Robert L. Norton*

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4. Kinematic Diagram - Definitions

- **Kinematic chain** is an assembly of links and joints, interconnected in a way to provide a controlled output motion in response to a supplied input motion.
- **Mechanism** is a kinematic chain in which at least one link has been attached to the frame of reference (which can be in motion).
- **Machine** is a combination of resistant bodies arranged to compel the mechanical forces of nature to do work accompanied by determinate motions.

What is work?

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4. Kinematic Diagram - Definitions

A mechanism

A machine

Why is one of these a machine and the other a mechanism since work is being done in both cases?

Ref: *Design of Machinery by Robert L. Norton*

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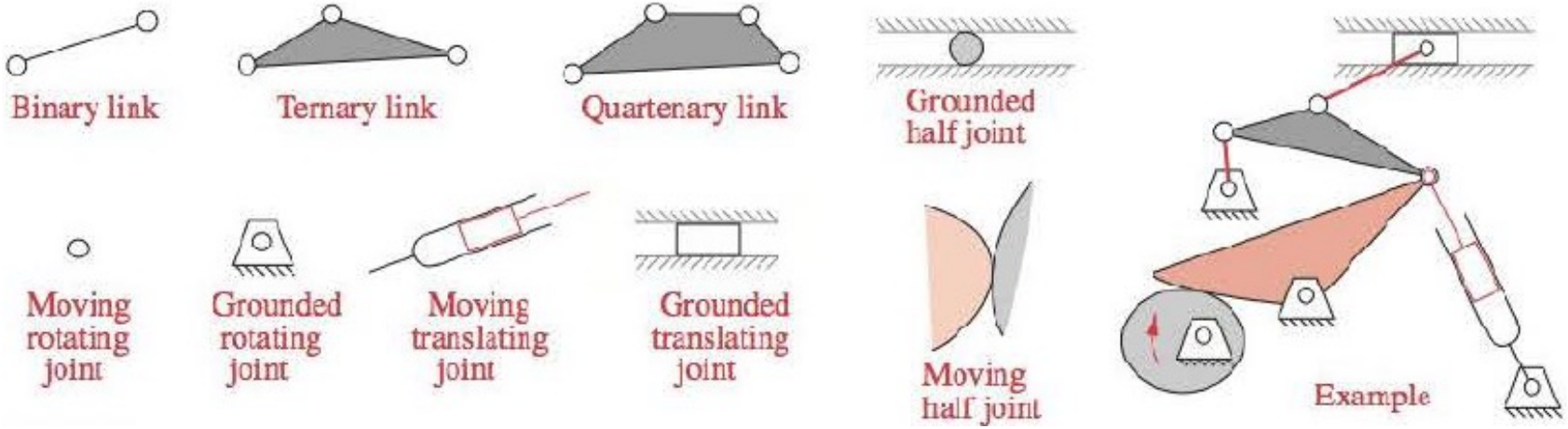
4. Kinematic Diagram

Kinematics of mechanism requires that we draw clear, simple, schematic kinematic diagrams of the links and joints of which they are made.



Ref: *Design of Machinery by Robert L. Norton*

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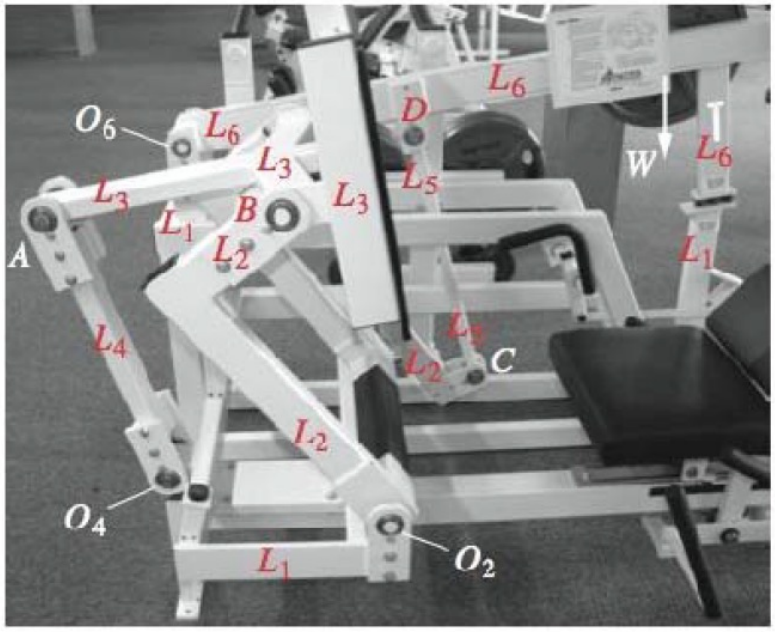
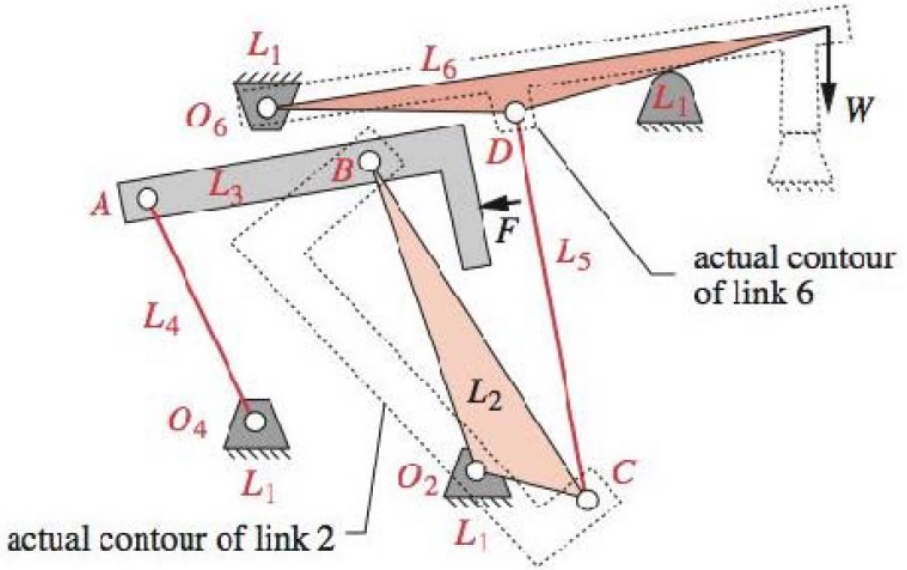
4. Kinematic Diagram



(a) Weight-training mechanism



(b) Kinematic diagram

Ref: *Design of Machinery by Robert L. Norton*

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4. Kinematic Diagram

Draw a kinematic diagram.

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5. Determining DoF or Mobility

To calculate mobility of the mechanism, the **Gruebler's equation** is used and presented as:

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

where

- M is number of DoF
- L is number of links
- J_1 are number of one DoF joints
- J_2 are number of two DoF joints

Note: the ground is counted as 1 link.

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5. Determining DoF or Mobility

Using Mobility calculations, there are several possible mechanisms:

- DoF>0: **Mechanism,** motion is possible and can be controlled;
- DoF=0: **Structure,** no motion is possible;
- DoF<0: **Preloaded structure,** no motion is possible, and stresses are added during assembly.

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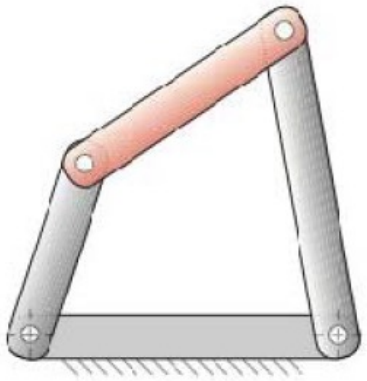
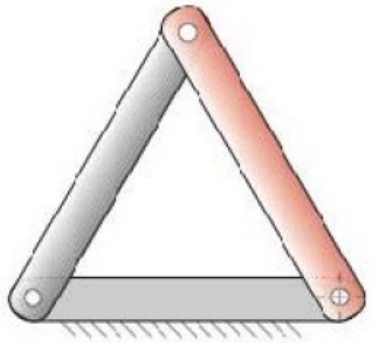
5. Determining DoF or Mobility

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

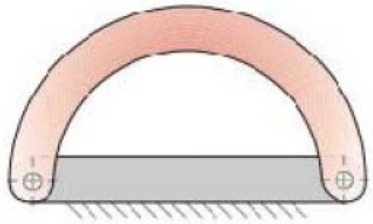
Find L, J1, J2 and M



$M = 3(4-1) - 2 \cdot 4 - 0$



$M = 3(3-1) - 2 \cdot 3 - 0$



$M = 3(2-1) - 2 \cdot 2 - 0$

Ref: *Design of Machinery by Robert L. Norton*

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5. Determining DoF or Mobility

Example 1

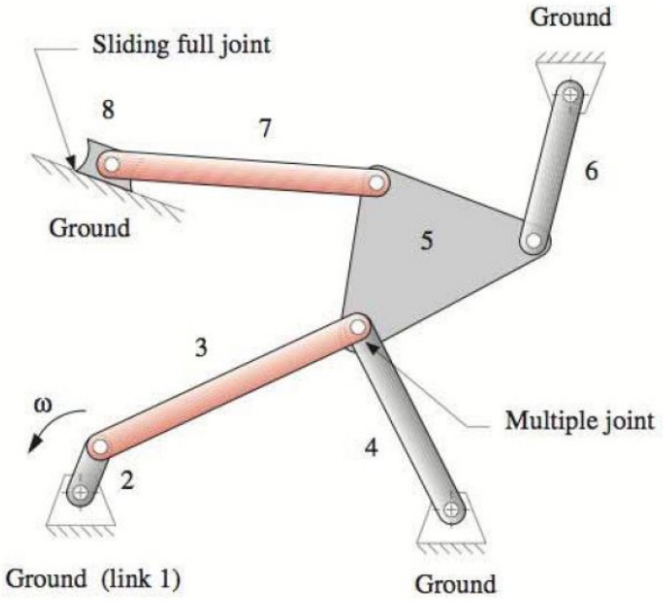
The total number of links (including ground), $L = 8$

The total number of joints, $J = 10$

The total number of 1DOF (full) joints, $J_1 = 10$

The total number of 2DOF (half) joints, $J_2 = 0$

$$M = 3(L-1) - 2J_1 - J_2$$
$$M = 3(8-1) - 2 \cdot 10 - 0$$
$$M = 1$$



Ref: *Design of Machinery by Robert L. Norton*

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5. Determining DoF or Mobility

Example 2

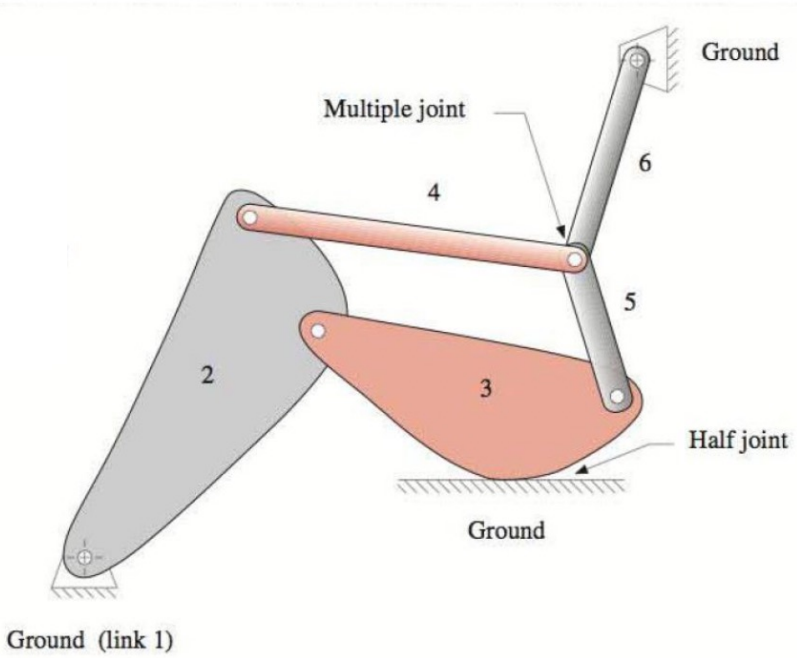
The total number of links (including ground), $L = 6$

The total number of joints, $J = 7.5$

The total number of 1DOF (full) joints, $J_1 = 7$

The total number of 2DOF (half) joints, $J_2 = 1$

$$M = 3(L-1) - 2J_1 - J_2$$
$$M = 3(6-1) - 2 \cdot 7 - 1$$
$$M = 0$$



Ref: *Design of Machinery by Robert L. Norton*

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Review

1. Degree of Freedom
2. Types of Motion
3. Links and Joints
4. Kinematics Diagrams
5. Determining Degree of Freedom or Mobility

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Review

- Read the relevant sections in the reading material provided
- Read through notes in Part 2 and make sure you understand the calculations

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Final thought

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Thank you for your attendance :D

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Reference

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