

# Theory of machinery


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**Chapter One**

**Introduction to theory of machinery**

**By**

**Laith Batarseh**



**Introduction to theory of machinery**

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**machine**

Machine is a collection of links connected by kinematic pairs to perform a specific task with unique relationship between inputs and outputs

**link**

A link is usually a rigid body with specific geometry defined by the location of its kinematic pairs and type

**kinematic pairs**

It is the connection between two different links that allows a specific type or form of relative motion between the two links

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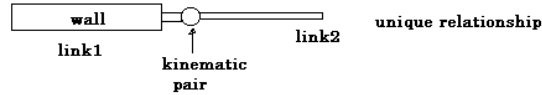


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### Simple example

The simplest example for machine consists of two links is the door as shown in

Figure



## Introduction to theory of machinery



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### Basic definitions

**Machine modeling:** Is to convert the motion relationship between the different links to a set of mathematical equations covering the kinematics and kinetics of aspects motion

**Machine analysis:** the given are the physical parameters of the machine (links, shape and dimensions, kinematic pairs, ..., etc) and you have to find the relationship between the input and the output


**Machine synthesis:** the given is the required relation between the input and output. Find the physical parameters to satisfy the desired relations

**Kinematic chain:** group of links with no links fixed to ground

**The mechanism:** group of links with one link at least is fixed to ground as shown in Figure which is piston mechanism.

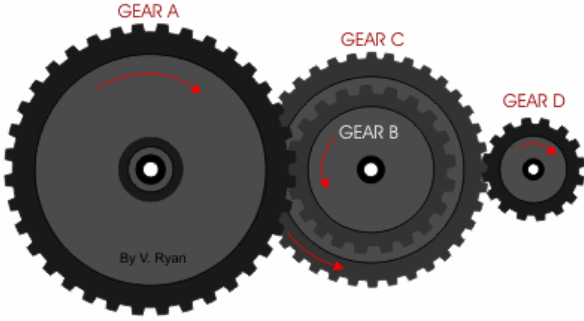
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Examples of mechanisms


Gears



By V. Ryan

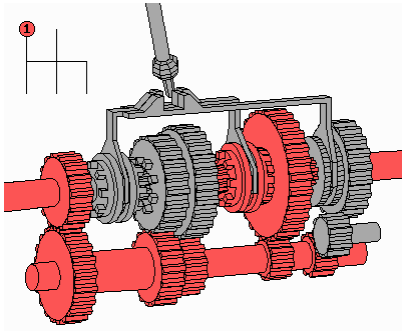
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Examples of mechanisms

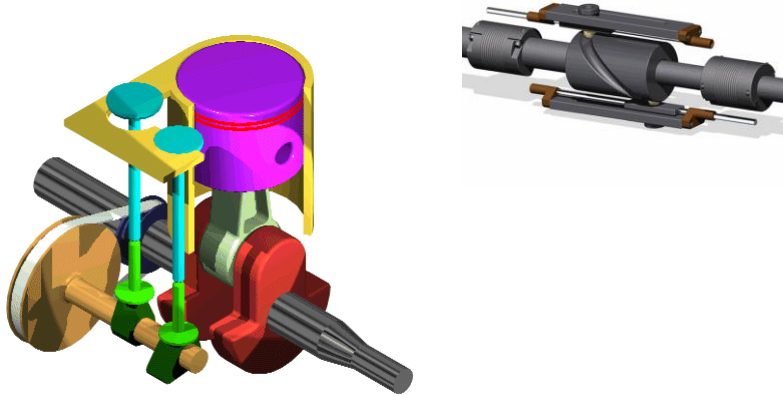
Gears




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**Examples of mechanisms**

**Cams**




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**Examples of mechanisms**

**Slider crank mechanism**



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## Introduction to theory of machinery

Examples of mechanisms

4-bar mechanism



agcoauto.com

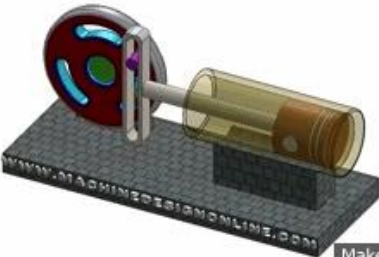
The image shows a 4-bar mechanism used for windshield wipers. It consists of a motor (black handle), a drive shaft, a connecting rod, and a wiper arm. The mechanism is shown in a perspective view, with the wiper arm and connecting rod positioned in front of a windshield. The motor is connected to the drive shaft, which is connected to the connecting rod, which is connected to the wiper arm. The wiper arm is shown in a curved position, indicating its range of motion.

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Examples of mechanisms

Scotch Yoke mechanism



MakeAGIF.com

The image shows a 3D CAD model of a Scotch Yoke mechanism. It consists of a rotating disk with a yoke and a sliding block. The disk is shown in a perspective view, with the yoke and sliding block positioned in front of it. The yoke is connected to the disk, and the sliding block is connected to the yoke. The sliding block is shown in a curved position, indicating its range of motion.

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### DEGREE OF FREEDOM (DOF):

Degree of freedom is the number of independent relative motion allowed by the pair. We can classified to:

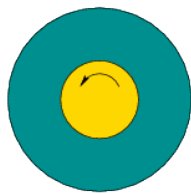
1. Single DOF mechanisms such as: single rotational motion, single translation motion and dependent rotation and translation single motion as shown in Figure
2. Two DOF mechanisms such as: rotation such slotted sphere, two translation motion, one rotation + one translation independently such cam.

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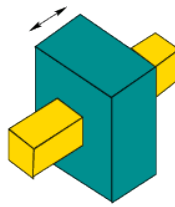
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### DEGREE OF FREEDOM (DOF):



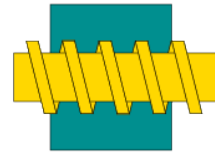
Revolute

1 Degree of Freedom



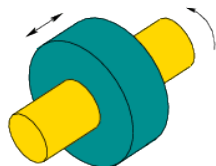
Prismatic

1 Degree of Freedom



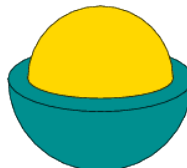
Screw

1 Degree of Freedom



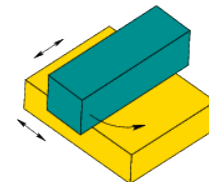
Cylindrical

2 Degrees of Freedom



Spherical

3 Degrees of Freedom




Planar

3 Degrees of Freedom

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MOBILITY ANALYSIS



Mobility means how much degree of freedom the mechanism has


You must follow these steps to find the mobility (M):

1. One link must be grounded
2. For planer mechanism (i.e. all links move in parallel planes) each link has 3-DOF (2- translation + 1-revelution)
3. The kinetic pairs restricts the relative motion between bodies as following :
  - 1DOF pairs restricts two DOF of one body
  - 2DOF pairs restricts one DOF of one body
4. The remaining degrees of freedom equals to the number of input.

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## Introduction to theory of machinery

MOBILITY ANALYSIS




The mobility is now calculated as:

$$M = 3(N - 1) - 2P_1 - P_2$$

Where:

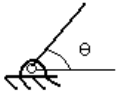
- N is the number of links
- $P_1$  is the number of pairs that has 1 DOF
- $P_2$  is the number of pairs that has 2 DOF

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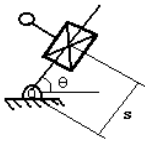
**MOBILITY EXAMPLES**



$N = 2$   
 $P_1 = 1(\text{Rev.})$   
 $P_2 = 0$

$$M = 3(2 - 1) - 2(1) = 1$$

Which is  $\theta$




$N = 3$   
 $P_1 = 2(\text{Rev} + \text{Tran})$   
 $P_2 = 0$

$$M = 3(3 - 1) - 2(2) = 2$$

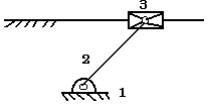
Which are  $\theta$  and  $s$

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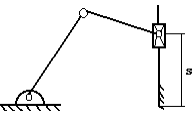
**MOBILITY EXAMPLES**



$N = 3$   
 $P_1 = 3$   
 $P_2 = 0$

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

System will not move



$N = 4$   
 $P_1 = 4$   
 $P_2 = 0$


$$M = 3(4 - 1) - 2(4) = 1$$

Which is  $s$

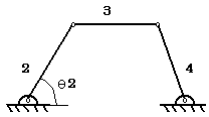


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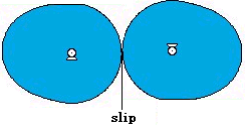
### MOBILITY EXAMPLES



$N = 4$   
 $P_1 = 4.$   
 $P_2 = 0$

$$M = 3(4 - 1) - 2(4) = 1$$

Which is  $\Theta_2$




$N = 3$   
 $P_1 = 2.$   
 $P_2 = 1$

$$M = 3(3 - 1) - 2(2) - 1 = 1$$

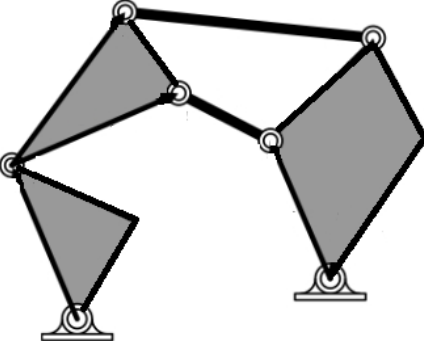
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### MOBILITY EXAMPLES

$N=6$   
 $P_1=7$   
 $M = 3(6-1) - 2(7) = 1$



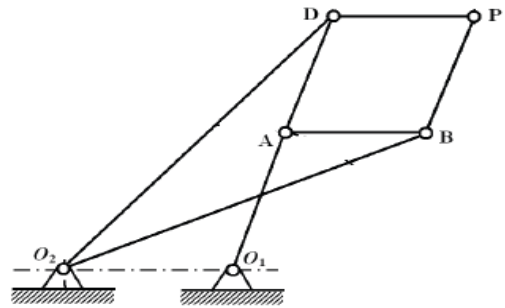
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**MOBILITY EXAMPLES**

$N=8$   
 $P_1=10$   
 $M = 3(8-1) - 2(10) = 1$

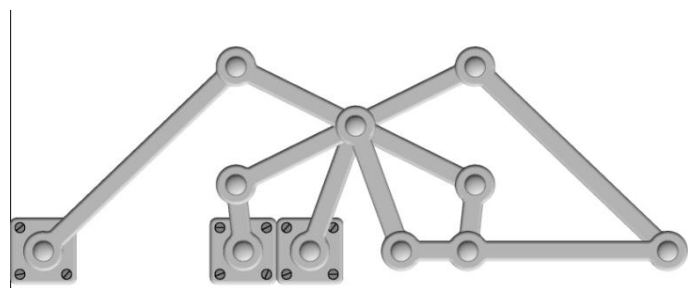


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**MOBILITY EXERCISES**



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**MOBILITY EXERCISES**

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The diagram shows a mechanism with four links. A central rectangular link is connected to two other links that form a diamond shape. A horizontal dashed red line passes through the three pin joints: the left joint of the diamond, the top joint of the central link, and the right joint of the diamond.

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**MOBILITY EXERCISES**

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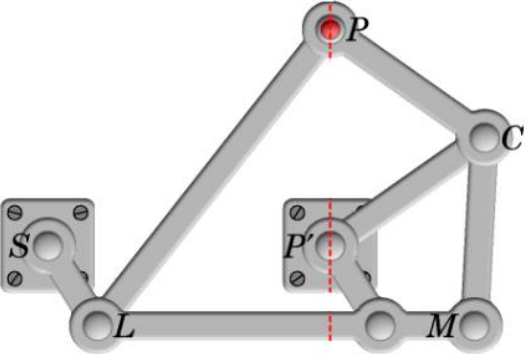
The diagram shows the same mechanism as above, but in a different configuration. The central rectangular link is now rotated and positioned to the right of the diamond. The horizontal dashed red line still passes through the three pin joints: the left joint of the diamond, the top joint of the central link, and the right joint of the diamond.

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MOBILITY EXERCISES



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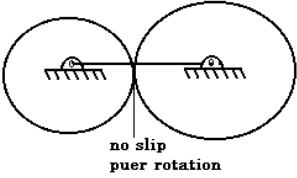
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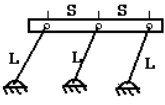
MOBILITY SPECIAL CASES

In some special cases, the mobility calculations results with zero but the system will be able to move. In such cases, we add one to the mobility ( i.e.  $M=1$ ). The figure below illustrates two examples where the system has  $M=0$  and it will move.

circles



(a)



(b)

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MOBILITY SPECIAL CASES

Joint to ground

Revolute joint

N=7  
P<sub>1</sub>=9  
M = 3(7-1) - 2(9) = 0

This mechanism is called gear-drive-type window regulator and it is used to move a car window and so we add 1 to its mobility