Theory of machinery

Chapter One

Introduction to theory of machinery

By

Laith Batarseh

Introduction to theory of machinery

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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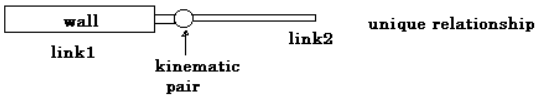
Simple example

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



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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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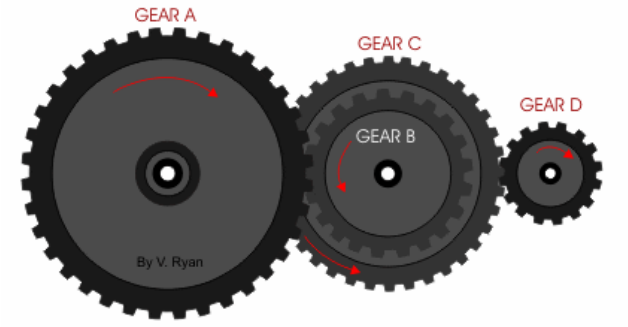
Examples of mechanisms

Gears



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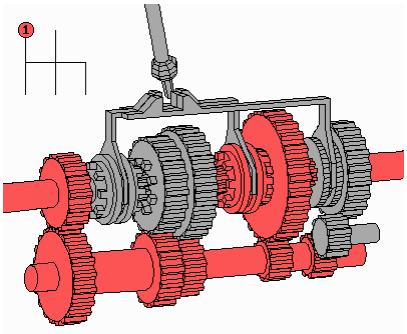
Examples of mechanisms

Gears



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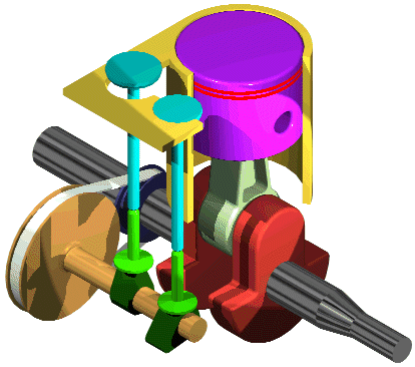
Examples of mechanisms

Cams



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Examples of mechanisms

Slider crank mechanism

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Examples of mechanisms

4-bar mechanism

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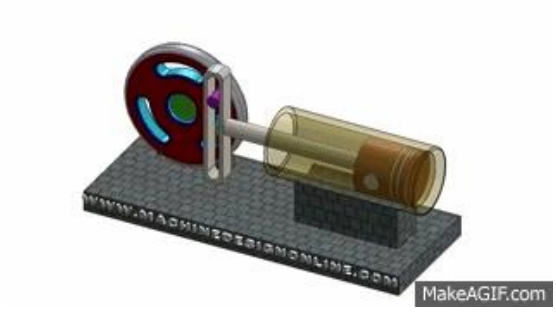
Examples of mechanisms

Scotch Yoke mechanism



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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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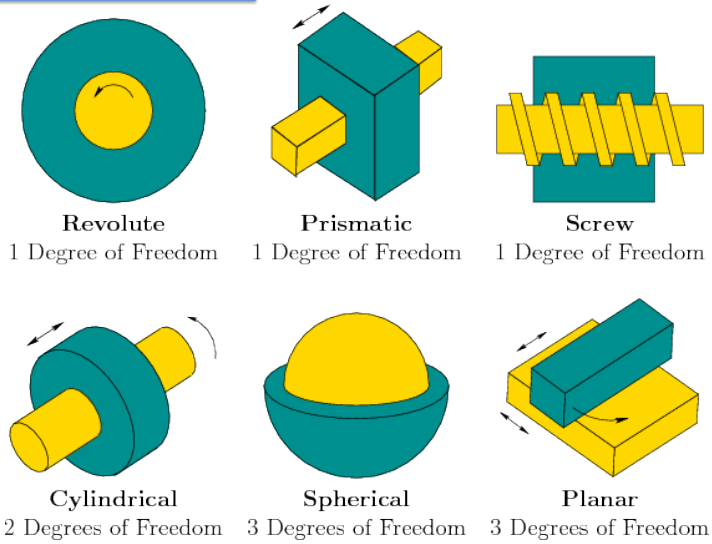
DEGREE OF FREEDOM (DOF):



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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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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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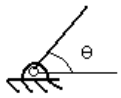
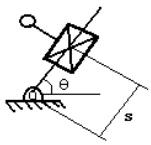
MOBILITY EXAMPLES



N = 2
P_1 = 1(Rev).
P_2 =0

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

Which is Θ



N = 3
P_1 = 2(Rev+Tran).
P_2 =0

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

Which are Θ and s

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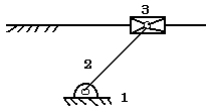
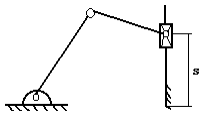
MOBILITY EXAMPLES



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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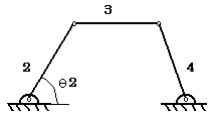
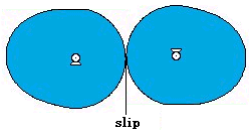
MOBILITY EXAMPLES



N = 4
P_1 = 4.
P_2 =0

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

Which is Θ_2



N = 3
P_1 = 2.
P_2 =1

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

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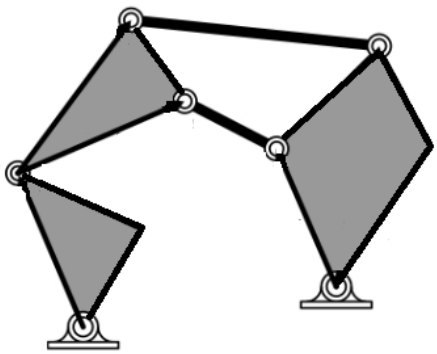
MOBILITY EXAMPLES

N=6

P_1=7

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



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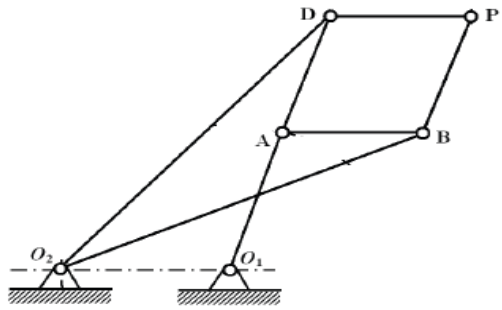
MOBILITY EXAMPLES

N=8

P_1=10

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



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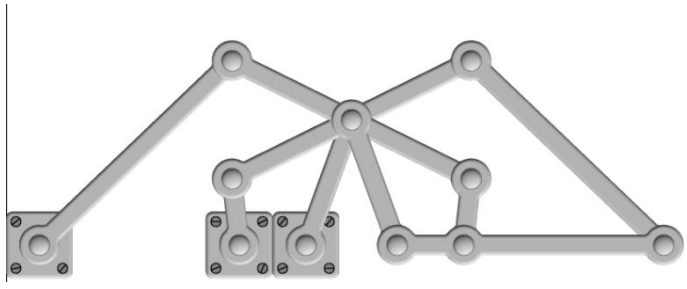
MOBILITY EXERCISES



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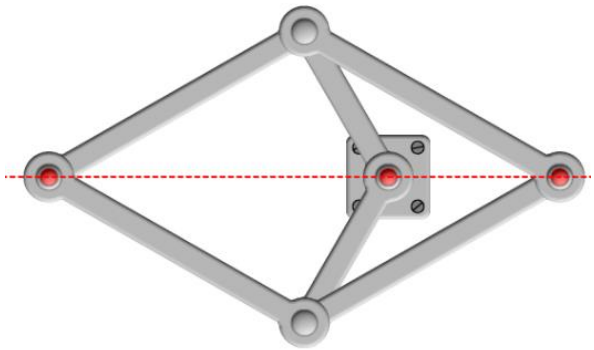
MOBILITY EXERCISES



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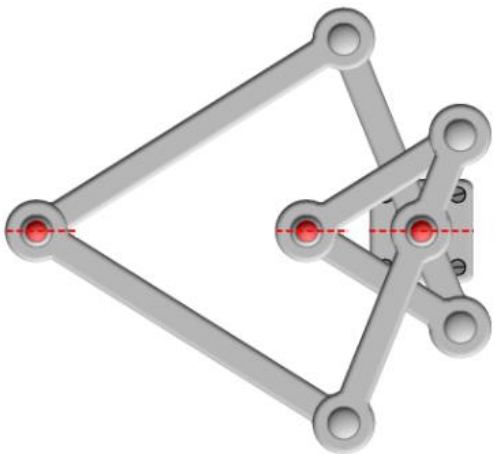
MOBILITY EXERCISES



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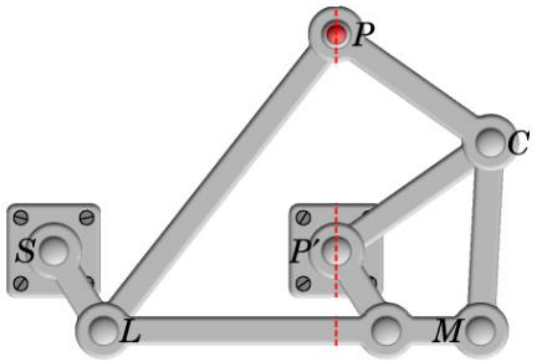
MOBILITY EXERCISES



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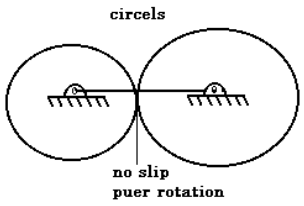
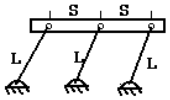
MOBILITY SPECIAL CASES

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.



(a)



(b)

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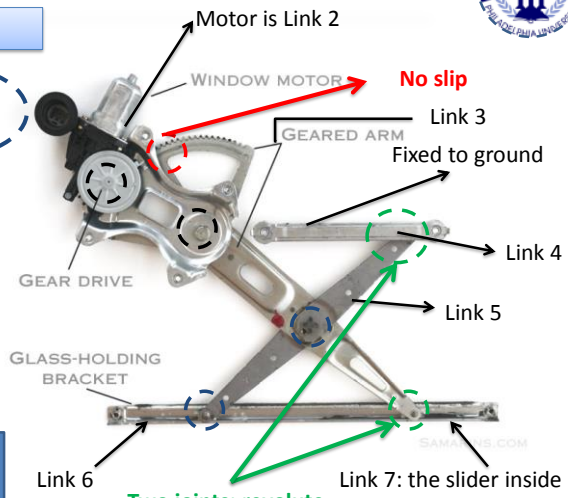
MOBILITY SPECIAL CASES

Joint to ground

Revolute joint



$N=7$

$P_1=9$

$M = 3(7-1) - 2(9) = 0$

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