MACHINE THEORY
Bachelor in Mechanical Engineering

INTRODUCTION TO KINEMATICS AND MECHANISMS

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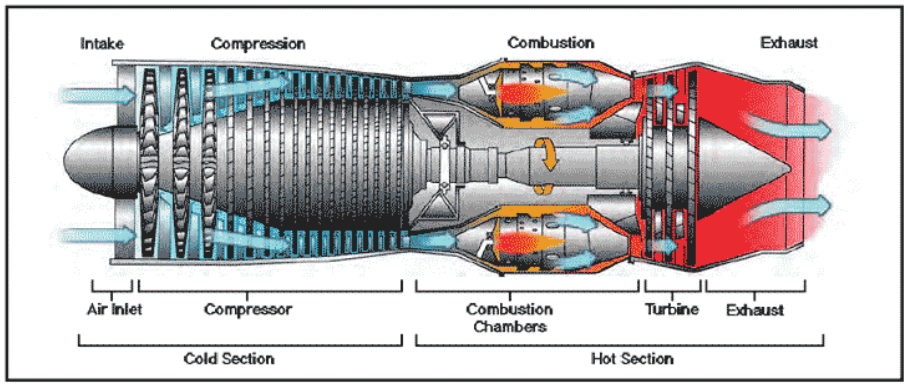
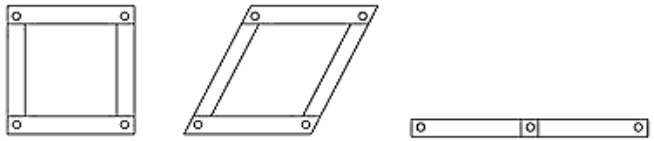
Machine Definition

DEFINITIONS

- **Kinematic chain**: It is a linkage of elements and joints that transmit a controlled output motion related to a given input motion.
- **Mechanism**: It is a kinematic chain where one element (or more) are fixed to the reference framework (which can be in motion)
- **Machine**: Group of resistant elements (which usually contain mechanisms) thought to transmit considerable movement, forces or/and power. **Boundary is not completely clear!!**



Source: Wikipedia



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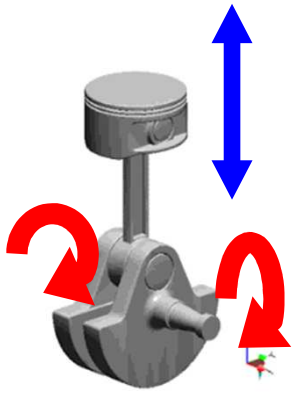
Kinematic Pairs

- **Kinematic pair** – Existing connection between two elements of a mechanism that have a relative motion between them.

  Kinematic pairs was classified by Reuleaux as follow:

  - Lower pair – two links having a surface contact between them.
  - Higher pair – two links having line or point contact between them.

- **Joint** - guarantees the contact between two members and constrains their relative motion



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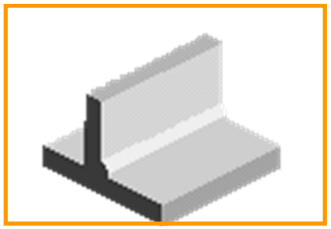
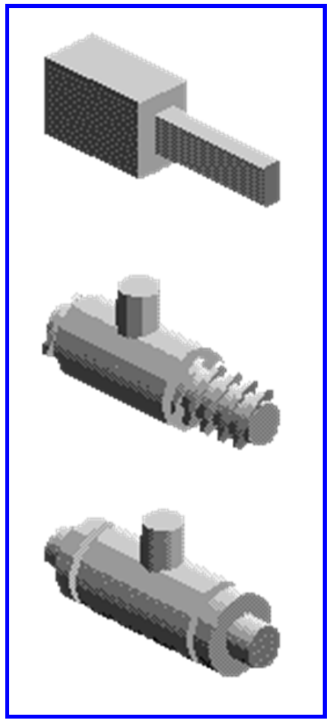
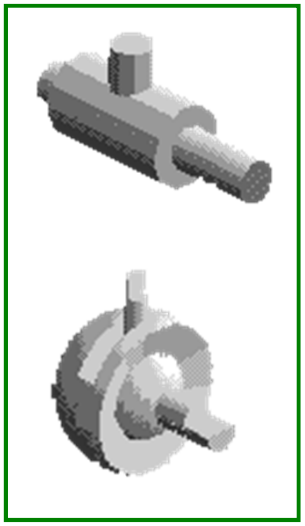
Classification of Kinematic Pairs by Degrees of Freedom



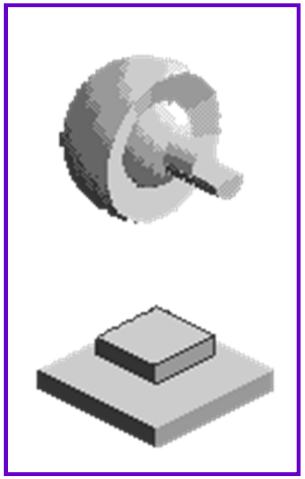
0 DOF



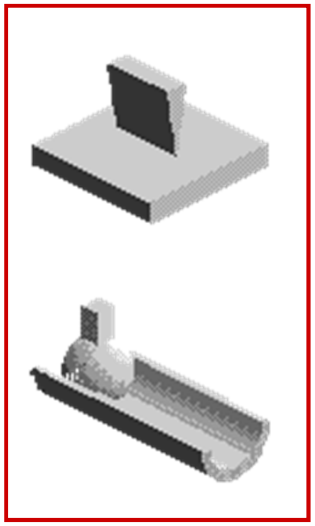
1 DOF



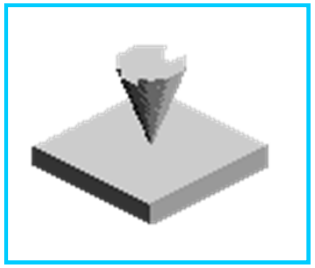
2 DOF



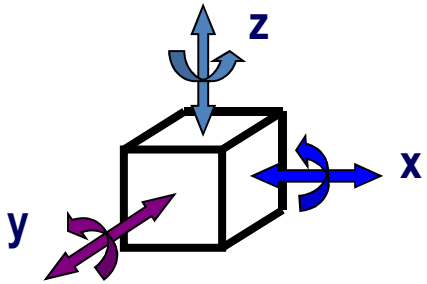
3 DOF



4 DOF

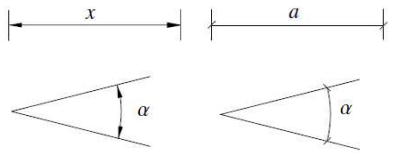


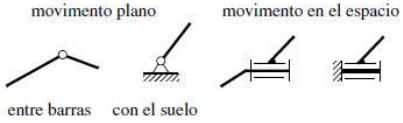
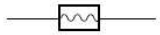
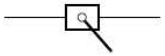
5 DOF



REPRESENTATION

Standard representation UNE-EN ISO 3952:1996.

variables y parámetros	
coordenadas de posición y de orientación	
miembros en general	
elemento barra	
elemento fijo	

par de revolución o articulación	movimento plano / movimento en el espacio  entre barras con el suelo
par prismático o guía-corredera	
par helicoidal	
par cilíndrico	
par plano	
par esférico o rótula esférica	
junta universal	
corredera con articulación	
par guía-botón	
unión rígida entre miembros	
articulaciones enmedio de barras	

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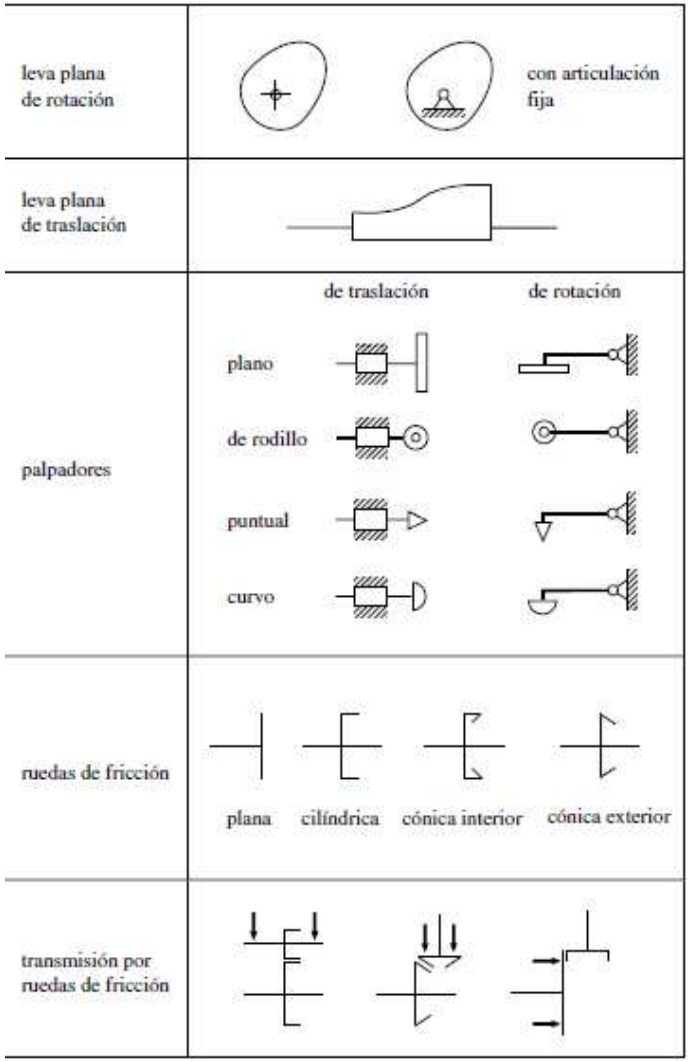
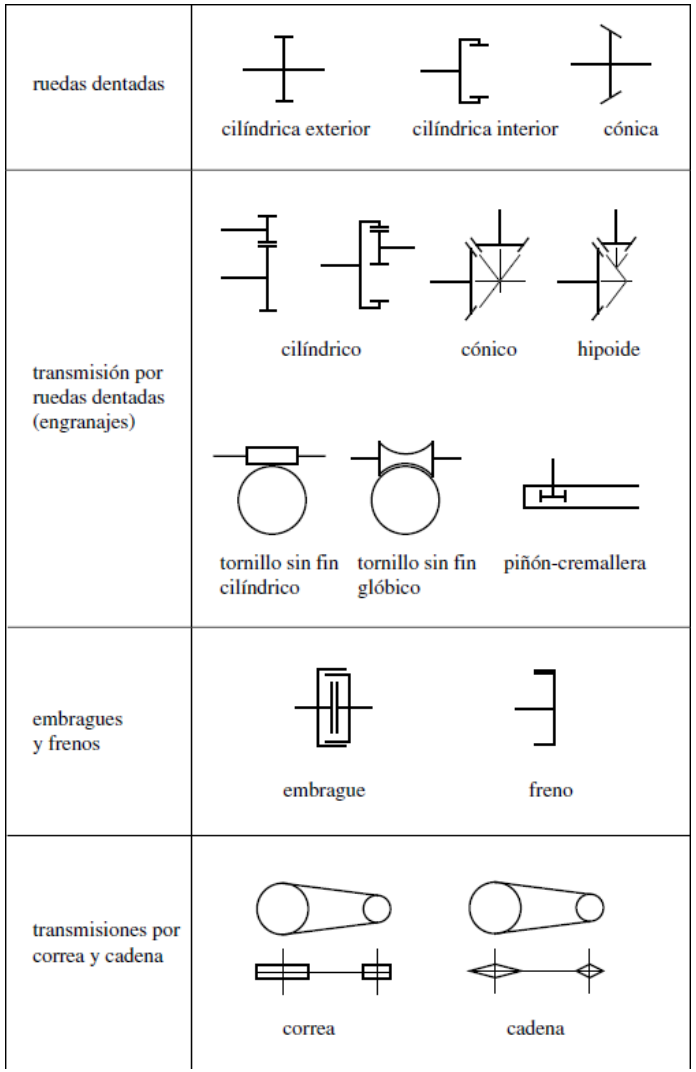
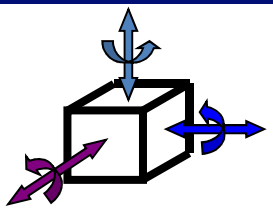
REPRESENTATION





D.O.F

Degrees of freedom:



1. Number of independent coordinates needed to define the position of the element/mechanism...
2. ….. or number of parameters needed to determine unambigously the geometry configuration of a system in space….
3. ….. or the number of **inputs needed to obtain a predictible output of a mechanism**.

GRÜBLER'S EQUATION

$$G = 3 \cdot (N-1) - 2 \cdot f_1 - f_2$$

Kutzbach Criterion for mobility of a planar mechanism

f_1 = nº pairs 1 DOF

f_2 = nº pairs 2 DOF

N = nº of elements

CHEVYCHEF-GRÜBLER-KUTZBACH CRITERION

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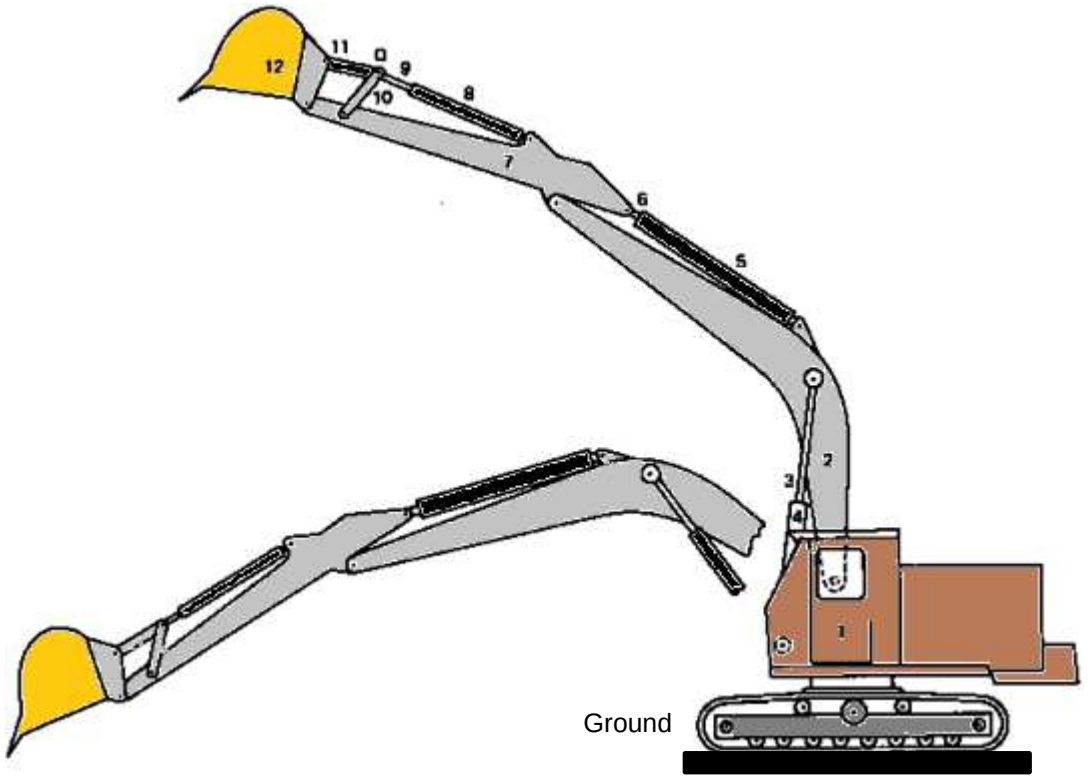
- G=0 Structure. No motion
- G>0 Mechanism. Motion
- G < 0 Hyperestatic Structure. No motion

Example. Obtain the number of DOF of the digger arm.



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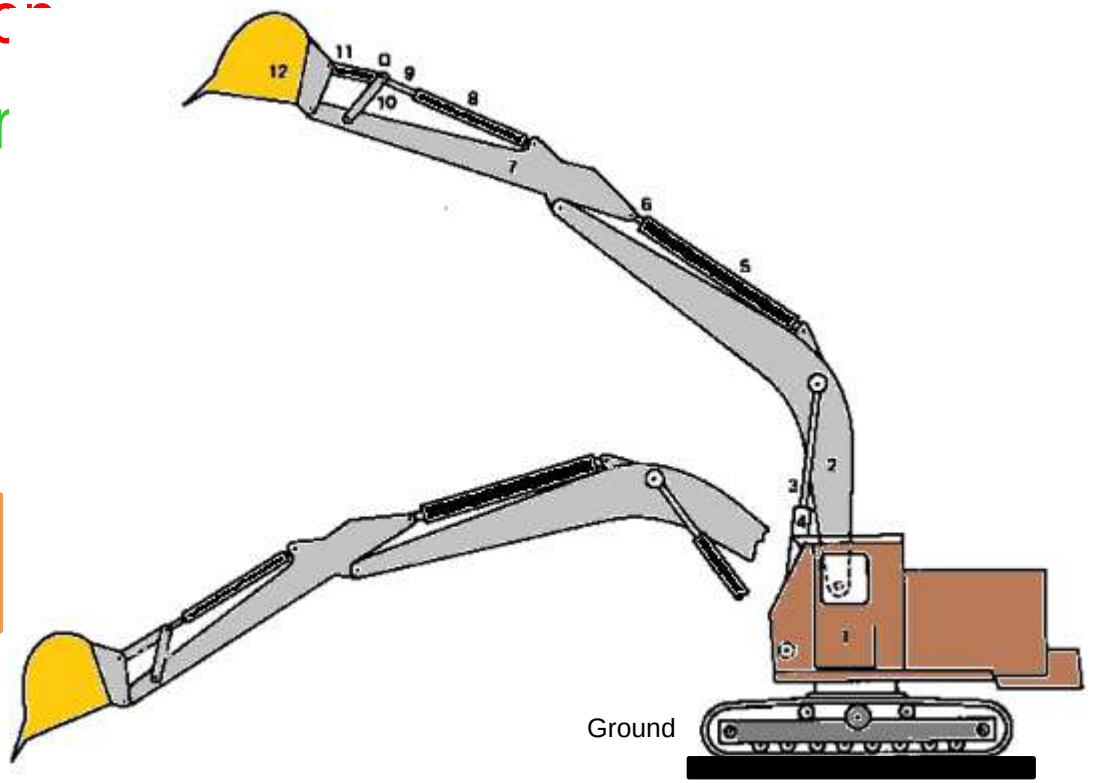
CHEVYCHEF-GRÜBLER-KUTZBACH CRITERION

Example. Obtain the number of DOF of the digger arm.

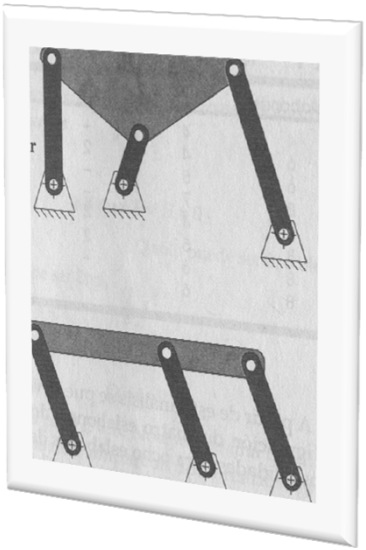
- G=0 Structure. No motic
- G>0 Mechanism. Motior
- G < 0 Hyperestatic Structure. No motion

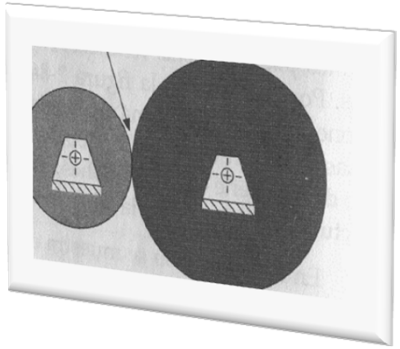
G=3*(12-1)-2*12(pin joints)-2*3(slide joints)=3



D.O.F

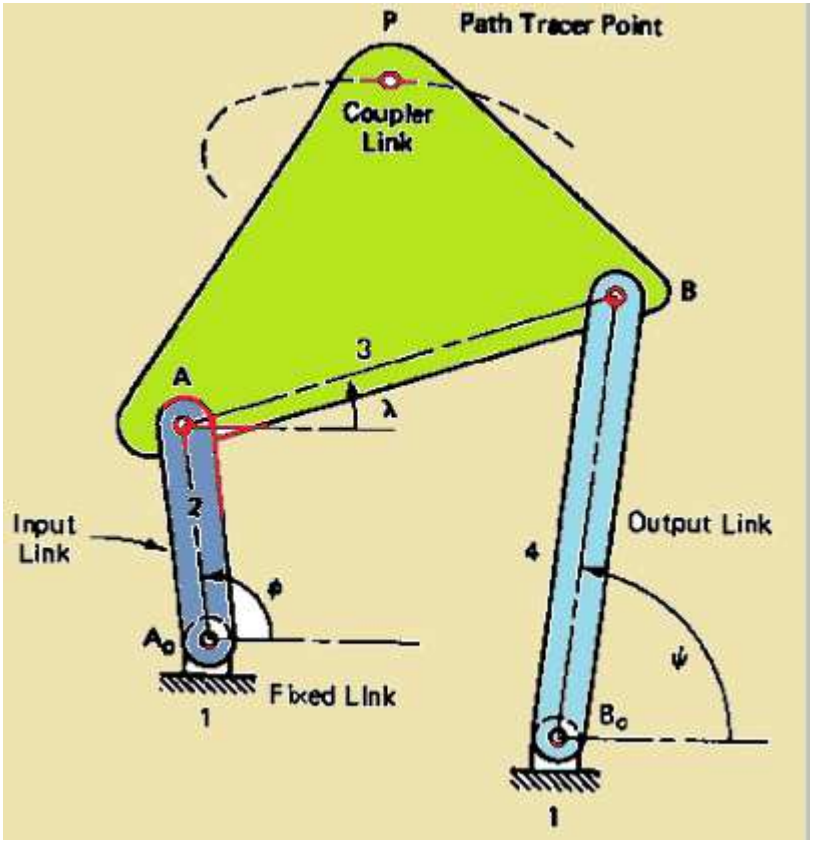
- Be careful!!!! Grübler ecuation not always works. As far as this equation does not consider shape or size of links, there are some exceptions:





FOUR-BAR LINCKAGE

- Very simple but very versatile. First option for design.
- Clasification depending on the task:
  - Function Generator. Output rules
  - Path Generator. Path rules
  - Motion Generator. All important



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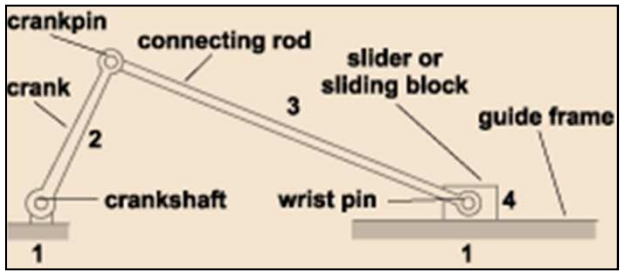
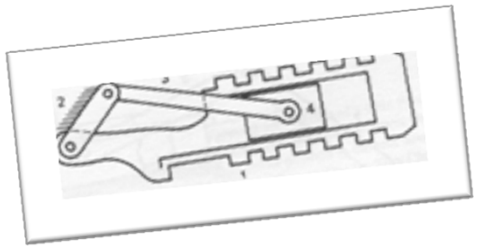
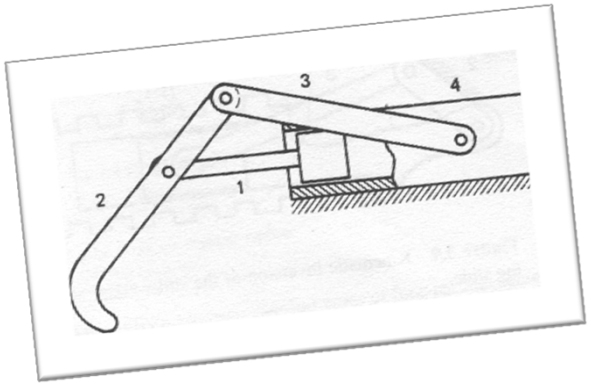
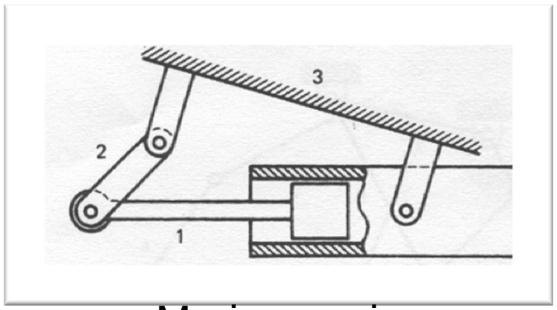
4 BAR KINEMATIC INVERSIONS

- It is the method of obtaining different mechanisms by fixing different links of the same kinematic chain. POWERFUL TOOL. See that with the slider-crank example:









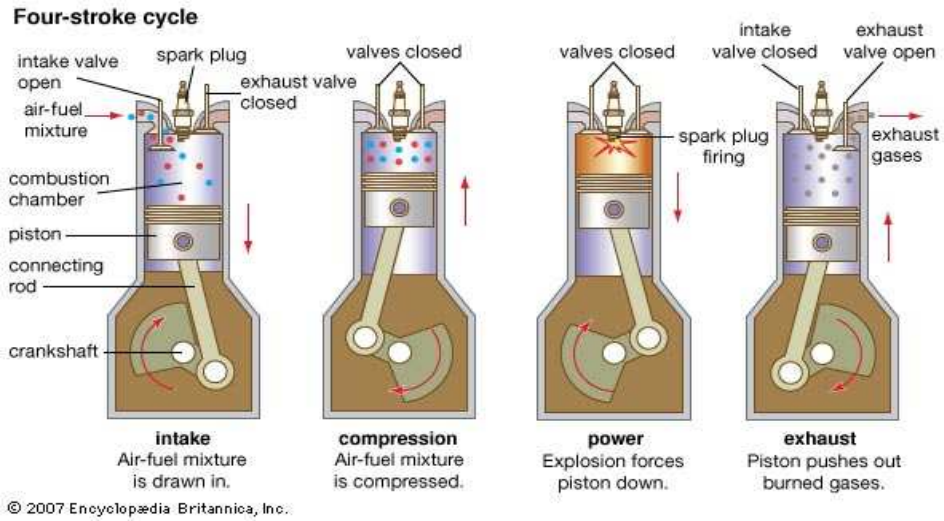
Marine engine

Whitworth mechanism. Gnome engine

Hand pump

GEOMETRIC INVERSION

- In some mechanisms, for a given driver position, there are more than one possible configurations.
- DEAD CENTER POSITION ALWAYS APPEARS in a four bar mechanism.



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GRASHOF CRITERIA

- Simple relation that describes the behavior of the kinematic inversions of a four-bar mechanism.

S= lenght of the shortest link

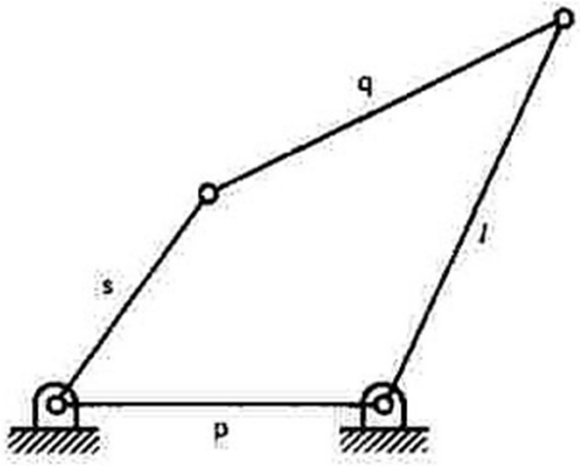
L= lenght of the longest link.

P and Q are the other links.

S+L ≤ P+Q

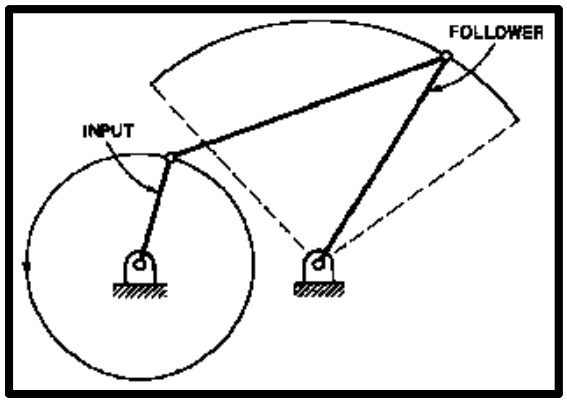
If my condition is satisfied, at least one link would be able to do a full revolution with respect to another link.

CONTINOUS MOTION IS ALLOWED

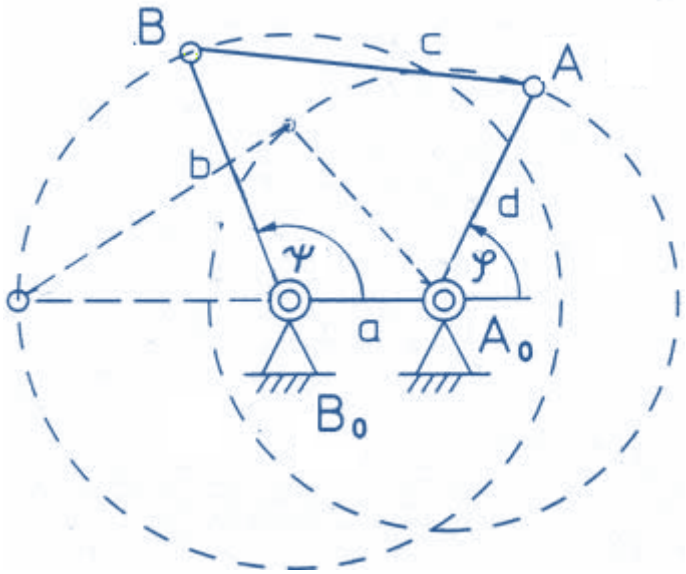


GRASHOF CRITERIA

- **If s + l < p + q: Four possibilities of Grashof mechanism**:
  - **Crank-rocker**: Shortest link is the crank. Frame is adjacent

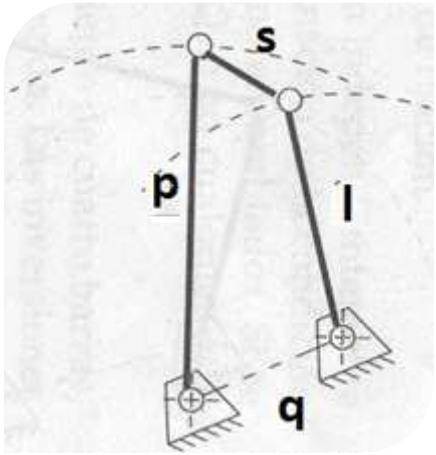


  - **Rocker-Crank**: The shortest link is the follower.
  - **Double Crank** or drag-link: Shortest link is the frame.



GRASHOF CRITERIA

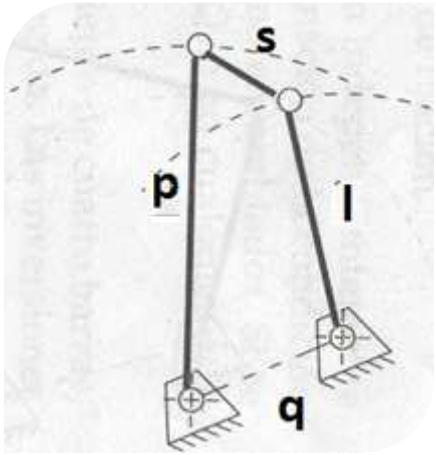
- **Double rocker**: The link opposite the shortest is the frame.



Where is the full rotation of a link?

GRASHOF CRITERIA

- **Double rocker**: link opposite the shortest is the frame



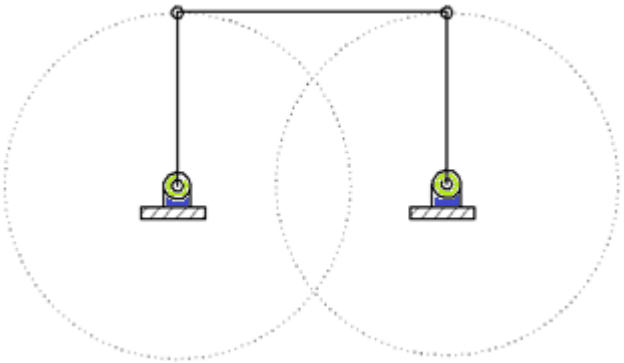
Where is the full rotation of a link? → The Coupler¡¡

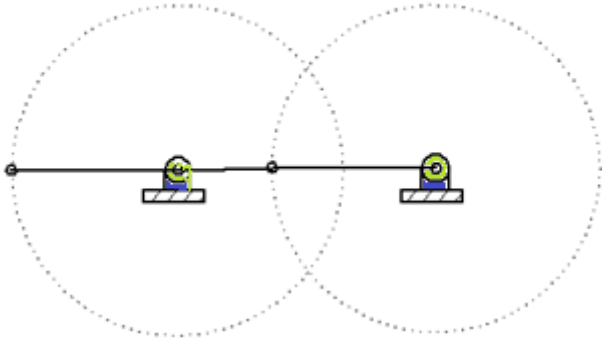
No Grashof mechanisms

- **If s + l > p + q:** All the kinematic inversions will be double rocker. No continous relative motion is posible.

Special Grashof mechanisms.

- **If s + l = p + q. Grashof Special Mechanisms.**
- All inversions are double-crank or crank-rocker.
- These mechanisms suffer from the change-point condition.
  - **All links become collinear creating momentarily a second DOF. OUTPUT RESPONSE IS UNDETERMINED.**





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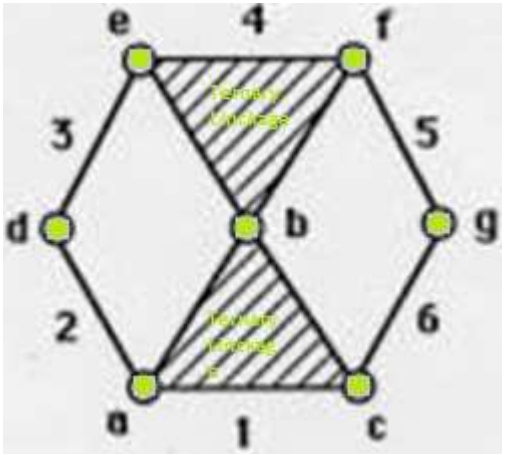
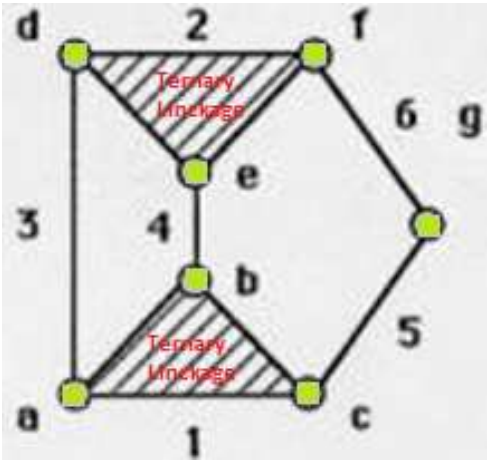
SIX-BAR CHAINS

- Use it when a four-bar lickage does not provide the performance requiered.



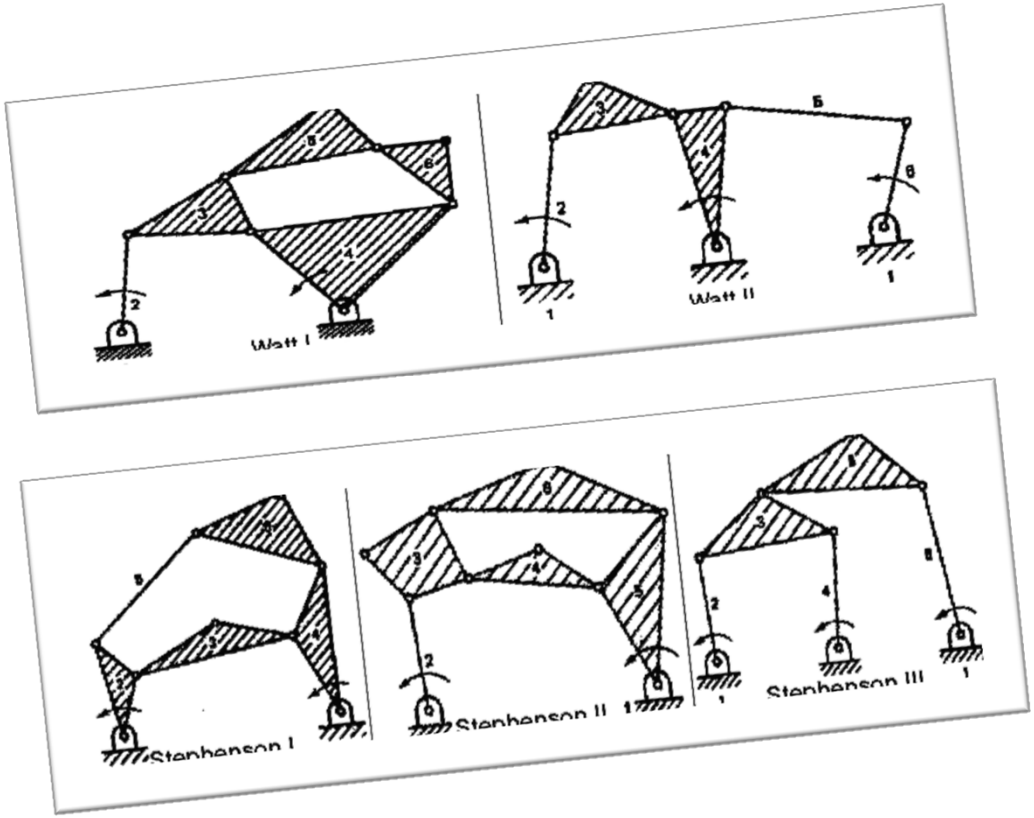
Watt Kinematic Chain



Stephenson Kinematic Chain

6 BAR KINEMATIC INVERSIONS

- Six bar kinematic chains also present kinematic inversions.



Inversions of Watt and Stephenson kinematic chains

REAL MECHANISMS

- See some real examples

http://www.youtube.com/watch?v=ZiAbpscuJdo

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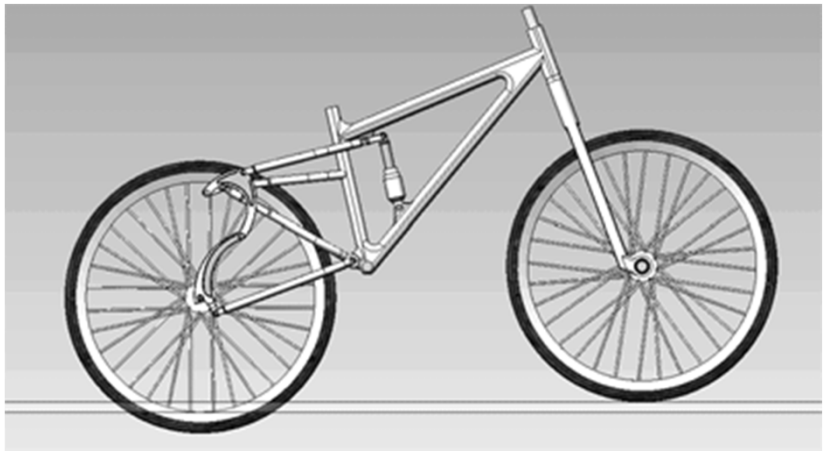
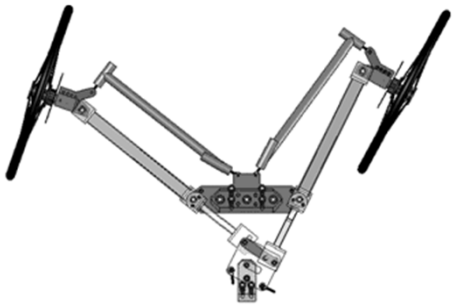
REAL MECHANISMS

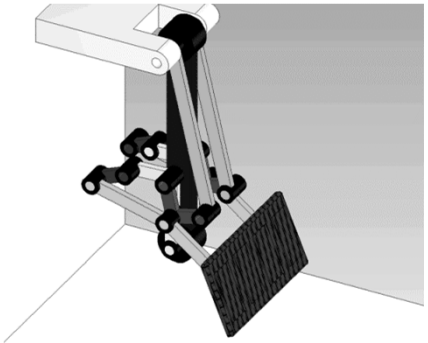
FOUR BAR MECHANISM

SIX BAR MECHANISM: to maintain a constant distance between the axle and bottom bracket. It is a Stephenson III six-bar linkage





UCI XGR gravity racer



Brake pedal

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INTERMITENT MOTION

- Sometimes intermitent motion is needed.

Examples: Geneva mechanism, camshaft, ratchet mechanism.

http://www.youtube.com/watch?v=85BsbncfRqA

http://www.youtube.com/watch?v=eijyLC4ZzQk&feature=related

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LITERATURE

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- MOVIES

http://www.youtube.com/watch?v=ZiAbpscuJdo

http://synthetica.eng.uci.edu:16080/~mccarthy/animations.html

http://synthetica.eng.uci.edu:16080/~mccarthy/Animations/Convertible-2.gif

http://www.youtube.com/watch?v=85BsbncfRqA

http://www.youtube.com/watch?v=eijyLC4ZzQk&feature=related