

SEM0104 - Aula 3

Tipos de Mecanismos: Simples e Complexos

Prof. Assoc. Marcelo Becker

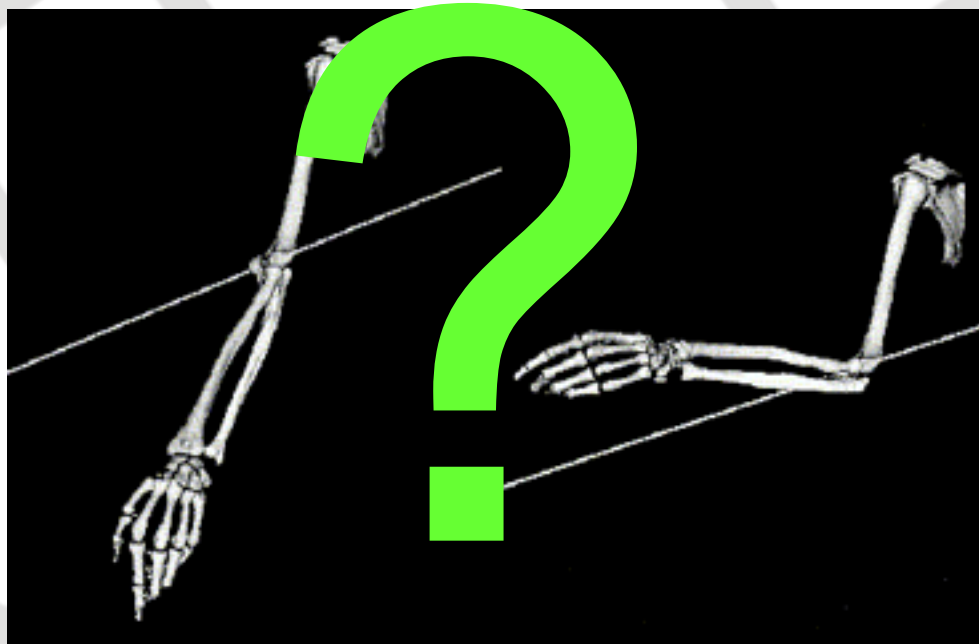
USP - EESC - SEM

LabRoM

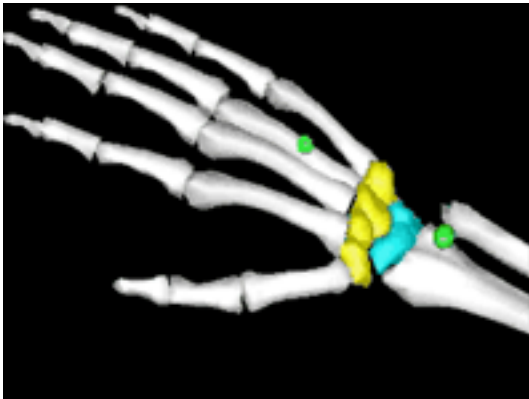
Prof. Dr. Marcelo Becker - SEM - EESC - USP

Pergunta da Aula Passada

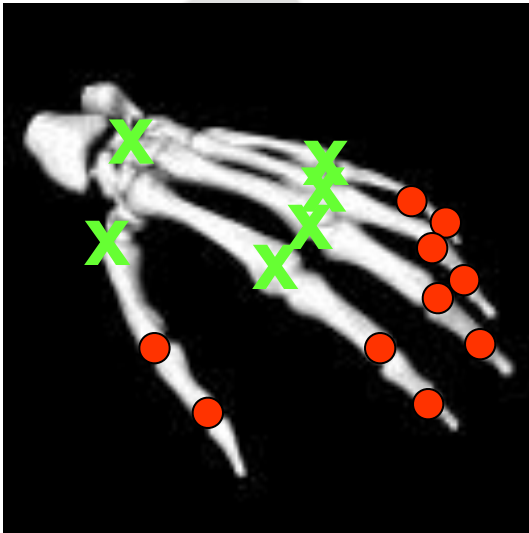
Quantos GDLs possui o conjunto mão, ante-braço e braço?



Pergunta da Aula Passada



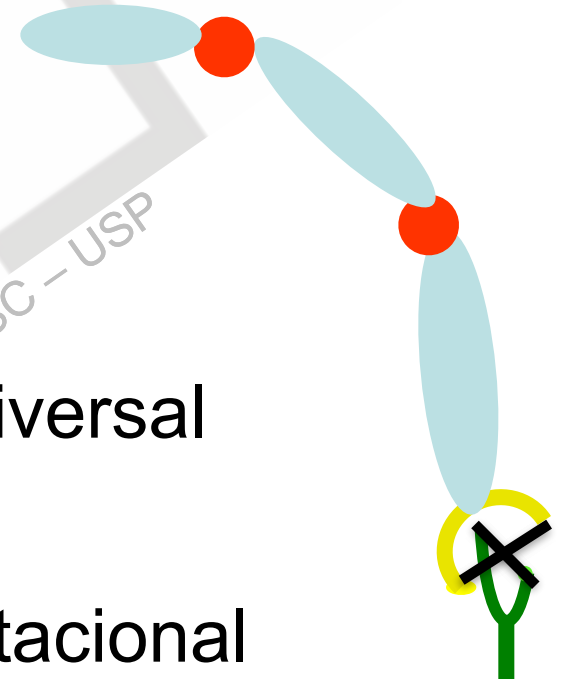
22 DoFs



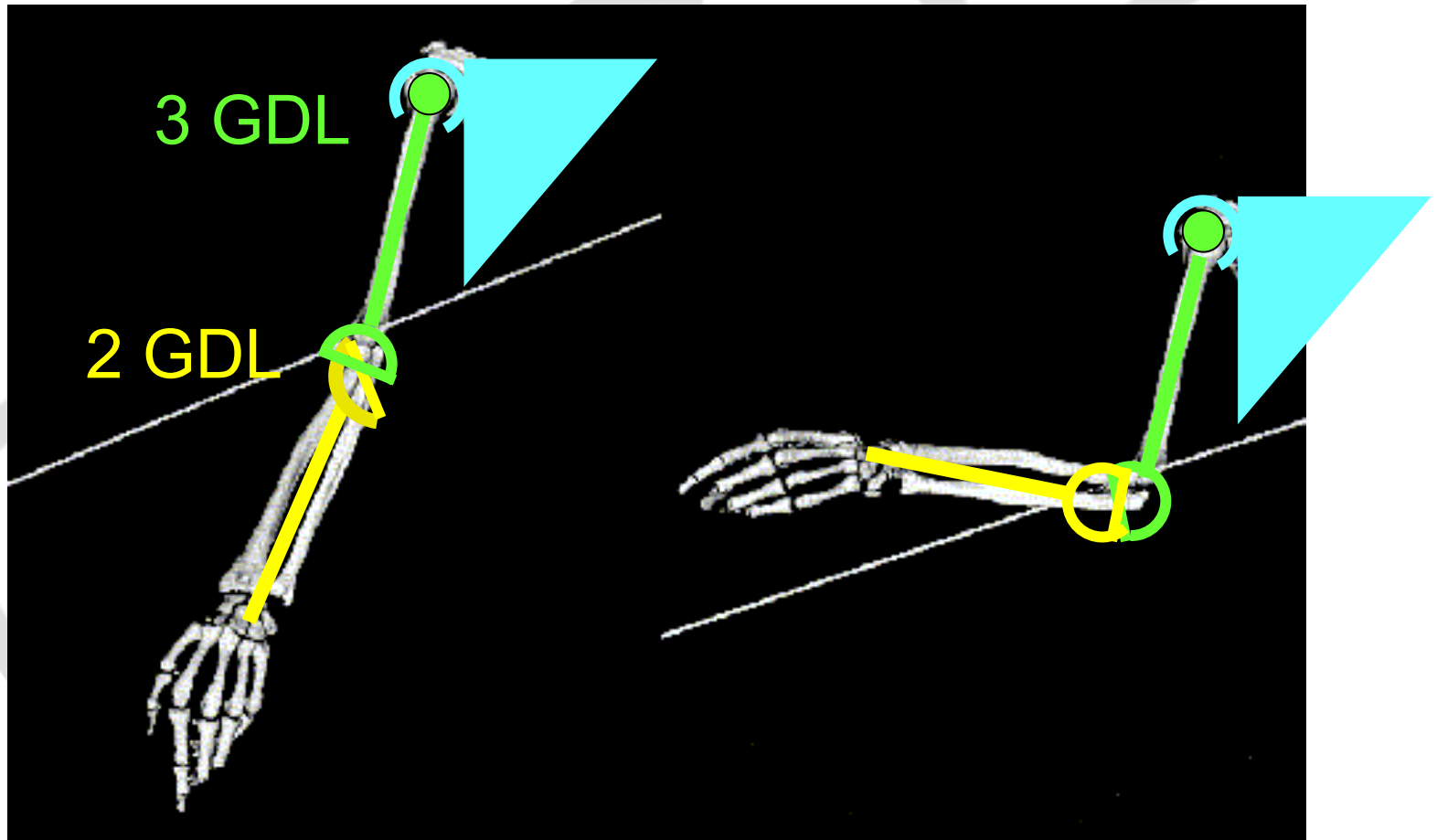
X Junta Universal



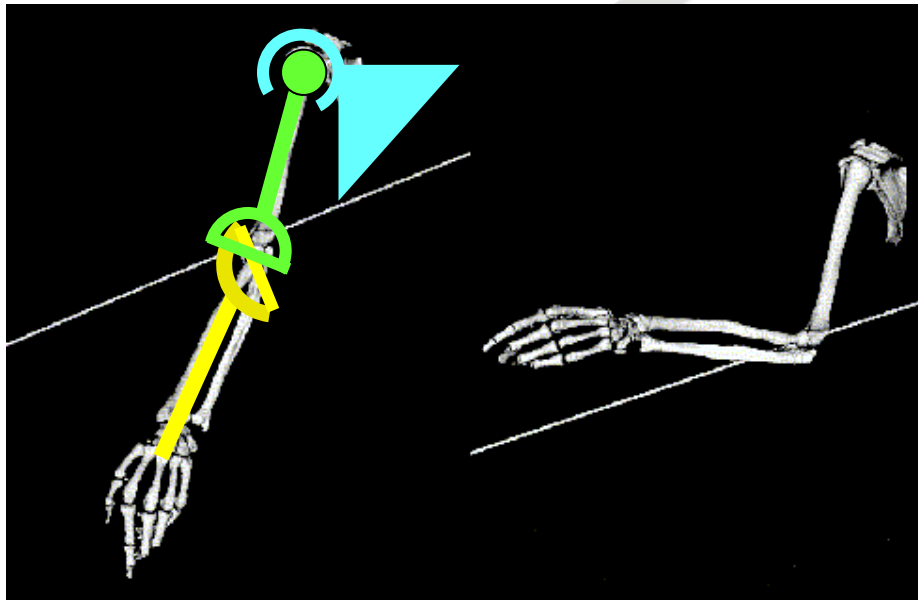
• Junta Rotacional



Pergunta da Aula Passada



Pergunta da Aula Passada



No Total:

22 DoFs da mão

3 DoFs do braço

2 DoFs do ante-braço

27 DoFs

Sumário da Aula

- **Classificação de Mecanismos**
- Mecanismos Simples
 - 4 Barras
 - Lei de Grashof
 - Lei de Reuleaux
 - Biela Manivela
- Mecanismos Complexos
- Bibliografia Recomendada

Classificação de Mecanismos

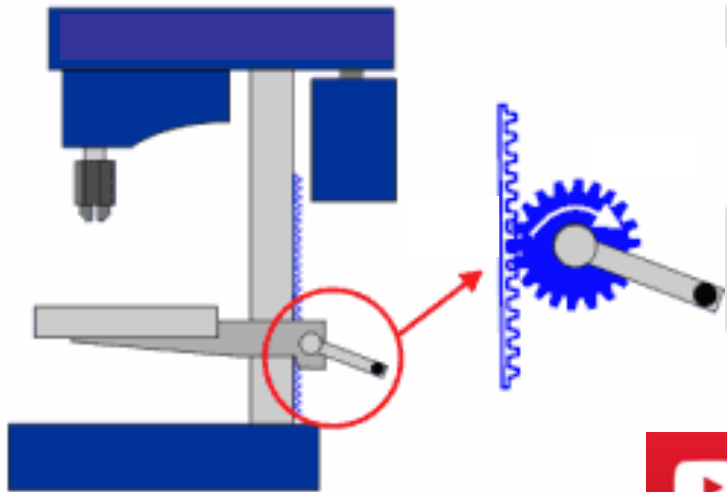
L. E. Torfason

- Feita pelo tipo de transformação de movimento (262 Classes)
- 12 Classes Principais:
 - Atuadores Lineares
 - Ajuste Fino
 - Hesitação, Pausa e Parada
 - Posicionamento
 - Catraca
 - Contadores
 - Osciladores
 - Retorno Rápido
 - Reversíveis
 - Acoplamento
 - Geradores de Curvas
 - Geradores de Retas

Classificação de Mecanismos

L. E. Torfason – Atuadores Lineares

- Parafuso Fixo, Porca Fixa
- Cilindro Pneumático ou Hidráulico
- Pinhão - Cremalheira



<https://www.youtube.com/watch?v=kl6qNn9-nkk>

Classificação de Mecanismos

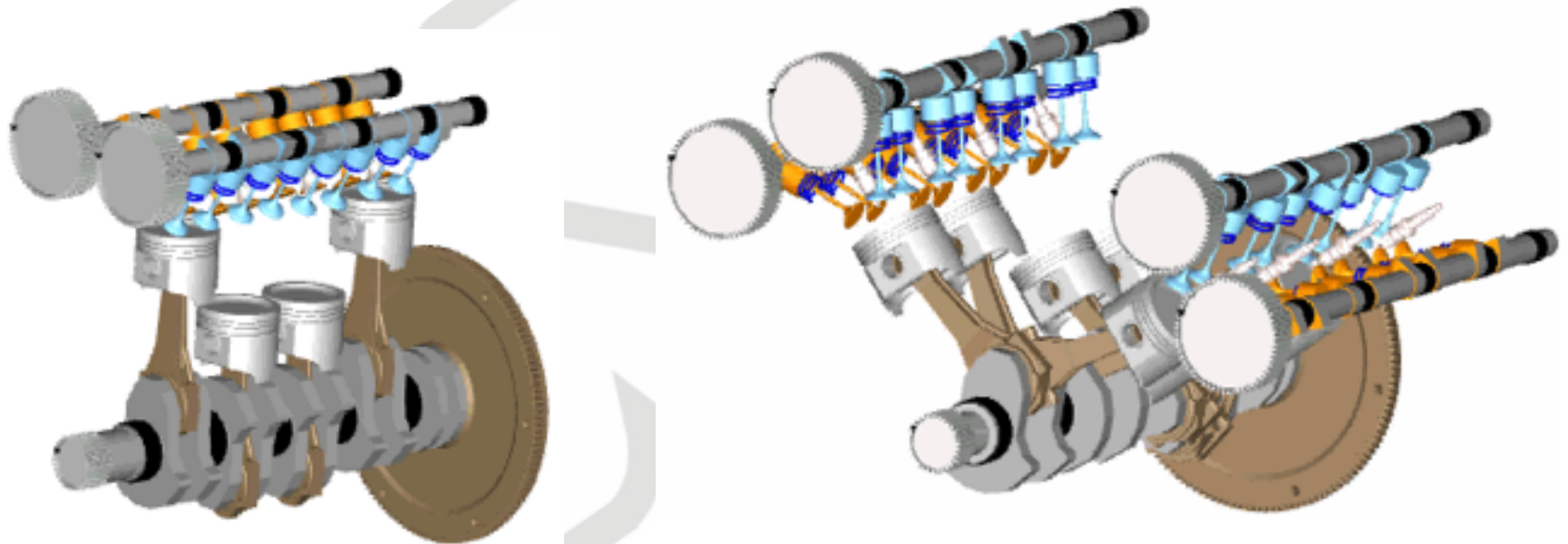
L. E. Torfason – **Ajuste Fino**

- Parafuso e Porca
- Engrenagens

Classificação de Mecanismos

L. E. Torfason – **Hesitação, Pausa e Parada**

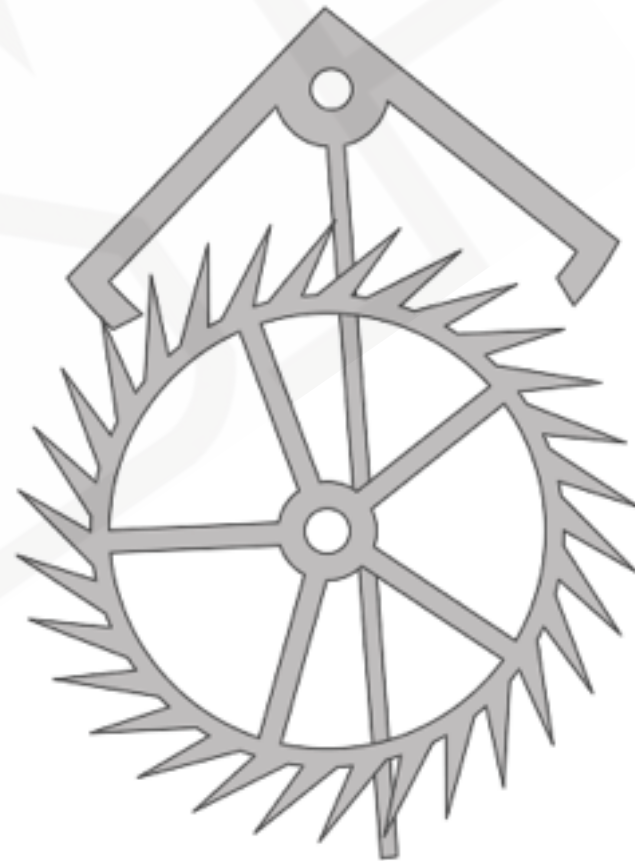
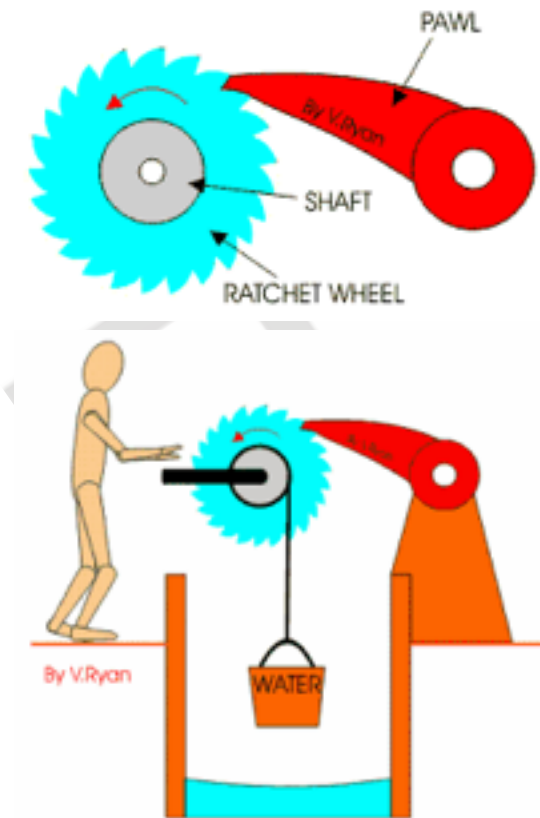
- Came-Seguidor



Classificação de Mecanismos

L. E. Torfason – **Catraca**

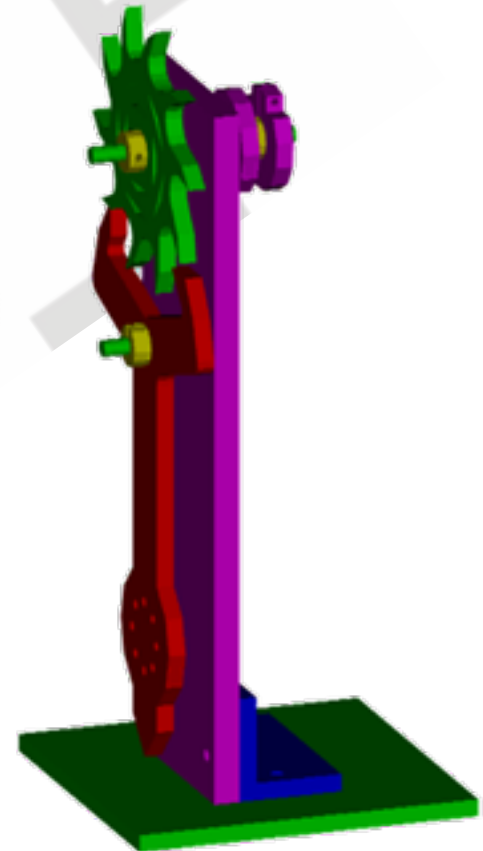
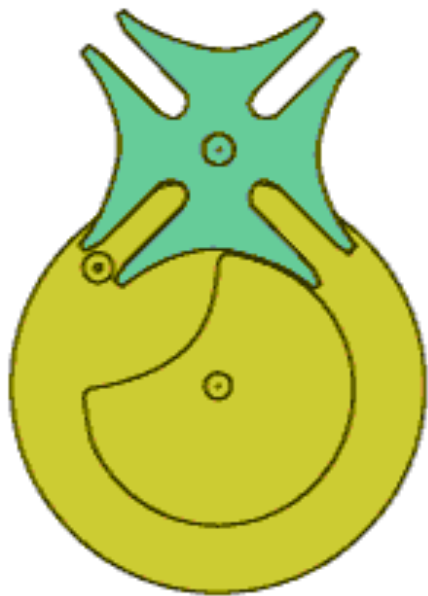
- Ratchet



Classificação de Mecanismos

L. E. Torfason – Contadores

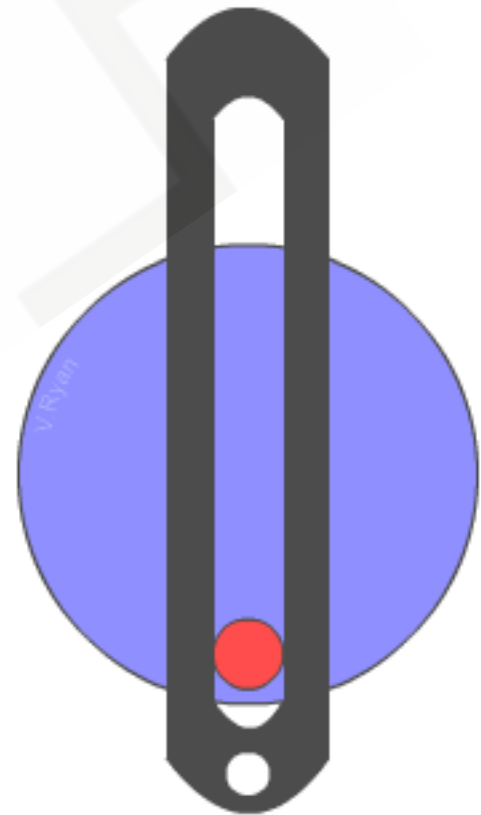
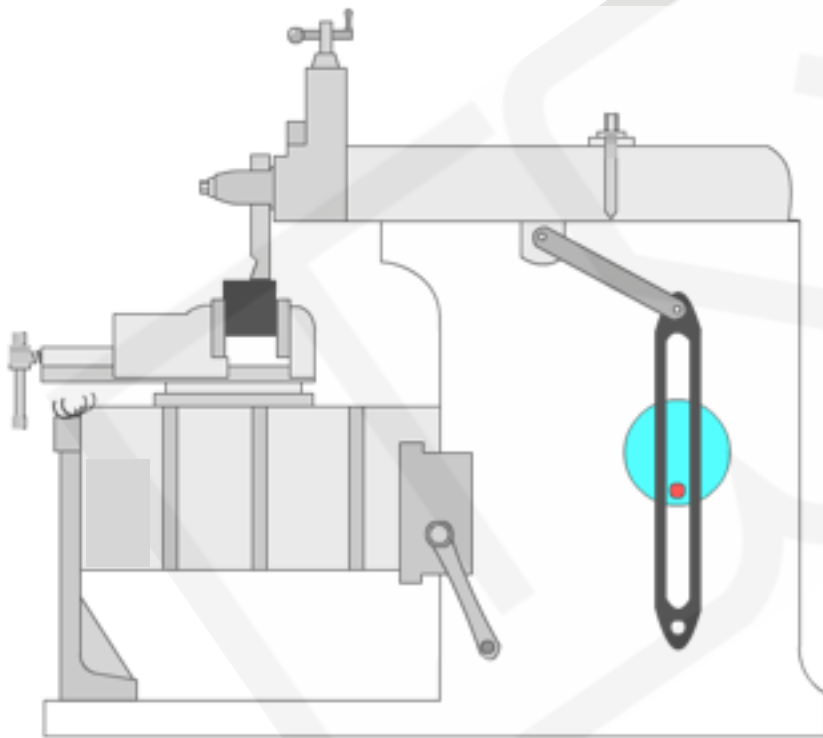
- Roda de Genebra
- Ratchet



Classificação de Mecanismos

L. E. Torfason – Osciladores

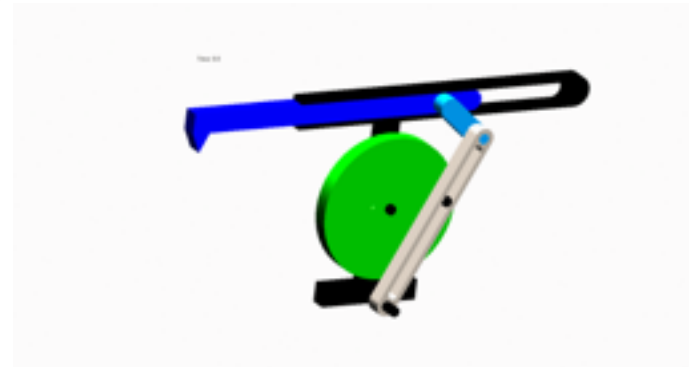
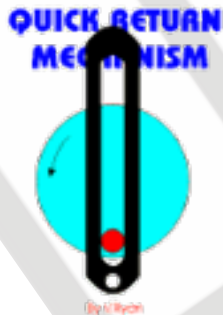
- Bila-Manivela



Classificação de Mecanismos

L. E. Torfason – Retorno Rápido

- Mecanismo de Retorno Rápido
 - Caracterizam-se por possuírem 2 fases de movimento para uma dada velocidade angular constante
 - Relação de tempo “ida-retorno”
 - Podem ser constituídos apenas por uma biela manivela ou por mecanismos mais complexos.



Classificação de Mecanismos

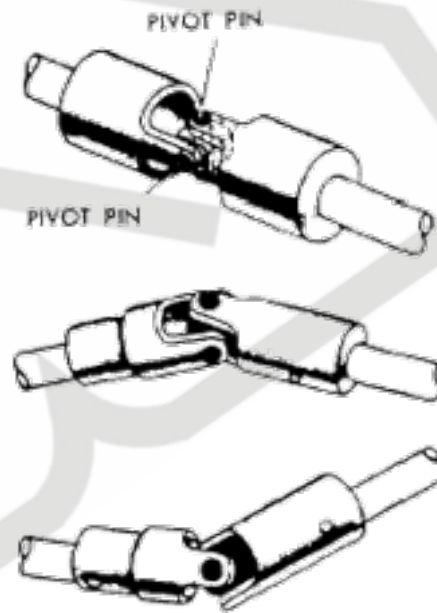
L. E. Torfason – Reversíveis

- Permitem que a direção de rotação possa ser alterada
 - Engrenagens
 - 4 Barras
 - Etc.

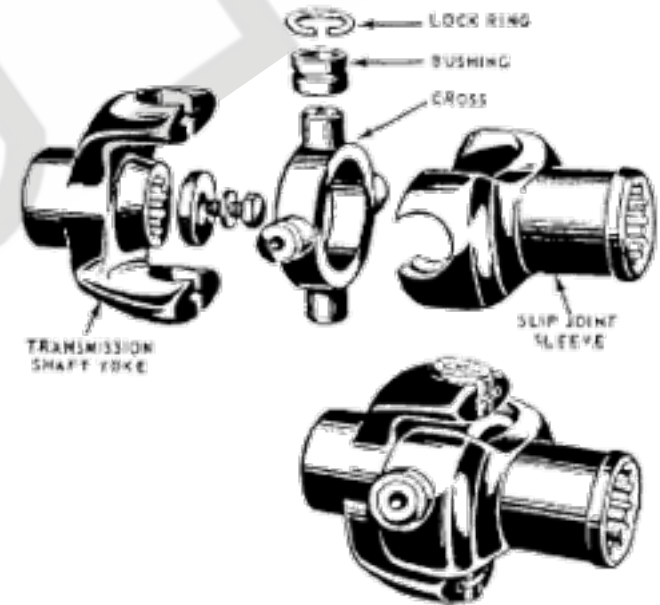
Classificação de Mecanismos

L. E. Torfason – Acoplamento

- Junta Universal
- Correia
- Corrente



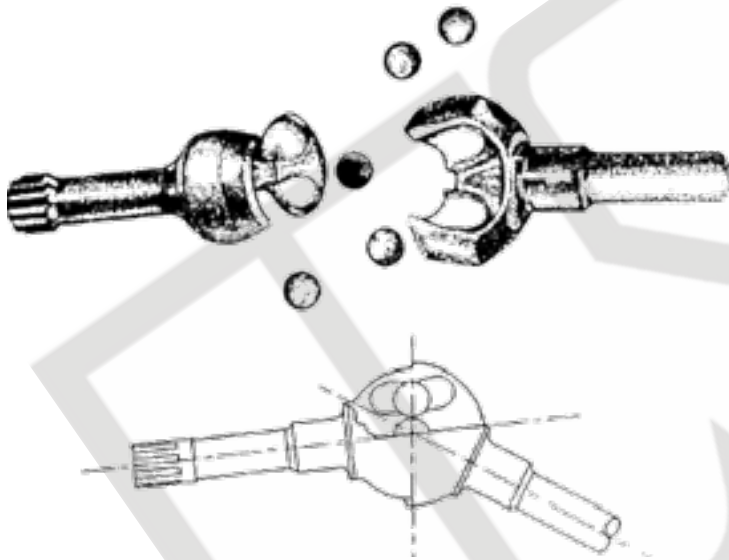
Hooke



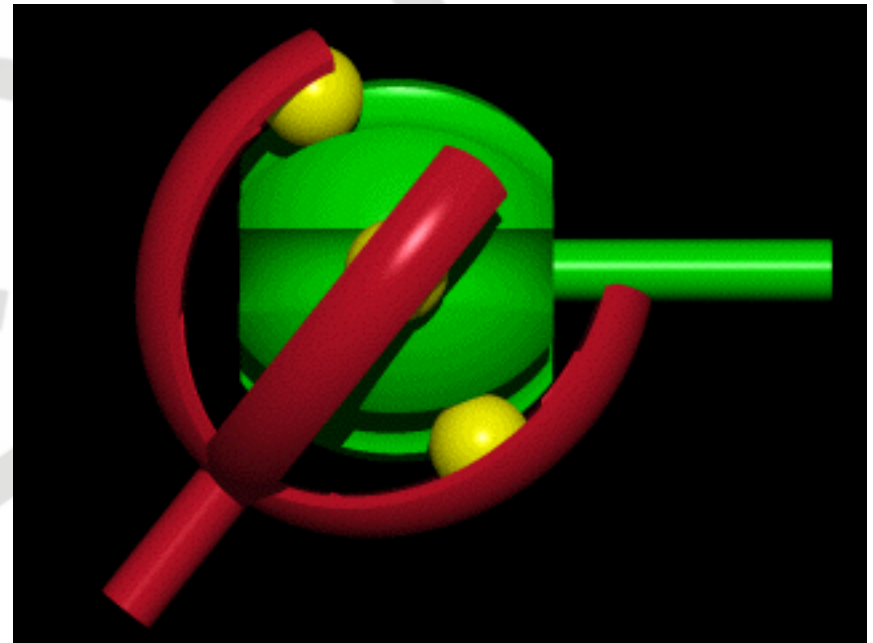
Ring and Trunnion

Classificação de Mecanismos

L. E. Torfason – **Acoplamento**



Bendix-Zeiss



Classificação de Mecanismos

L. E. Torfason – **Acoplamento**

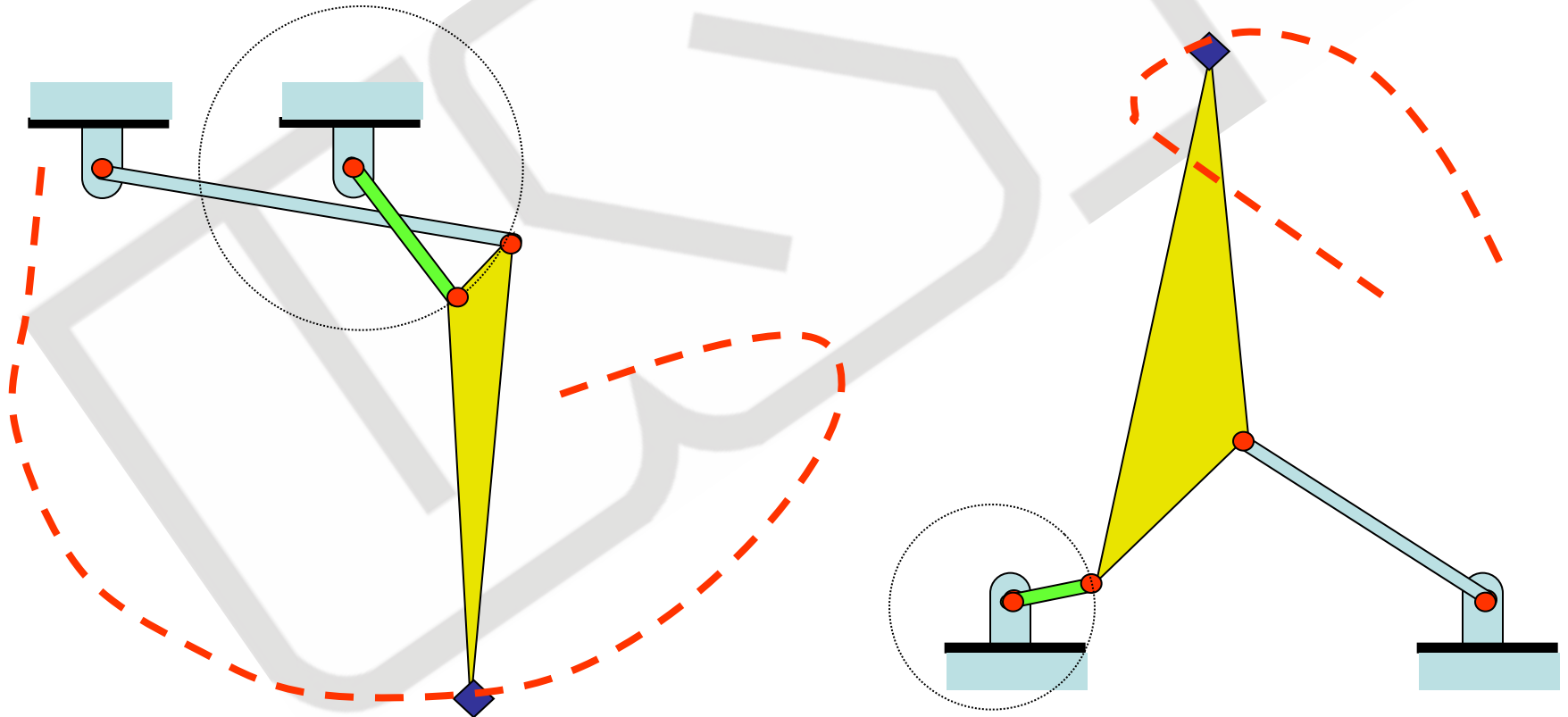


<http://giphy.com/gifs/>

Classificação de Mecanismos

L. E. Torfason – Geradores de Curvas

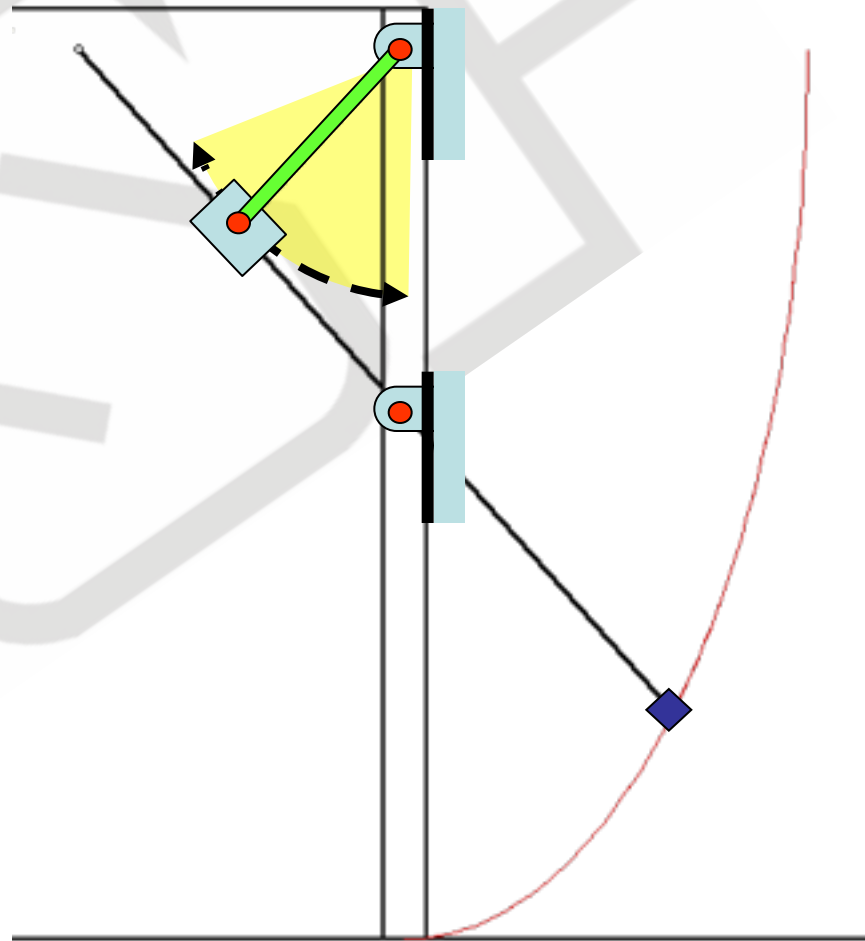
- 4 Barras



Classificação de Mecanismos

L. E. Torfason – Geradores de Curvas

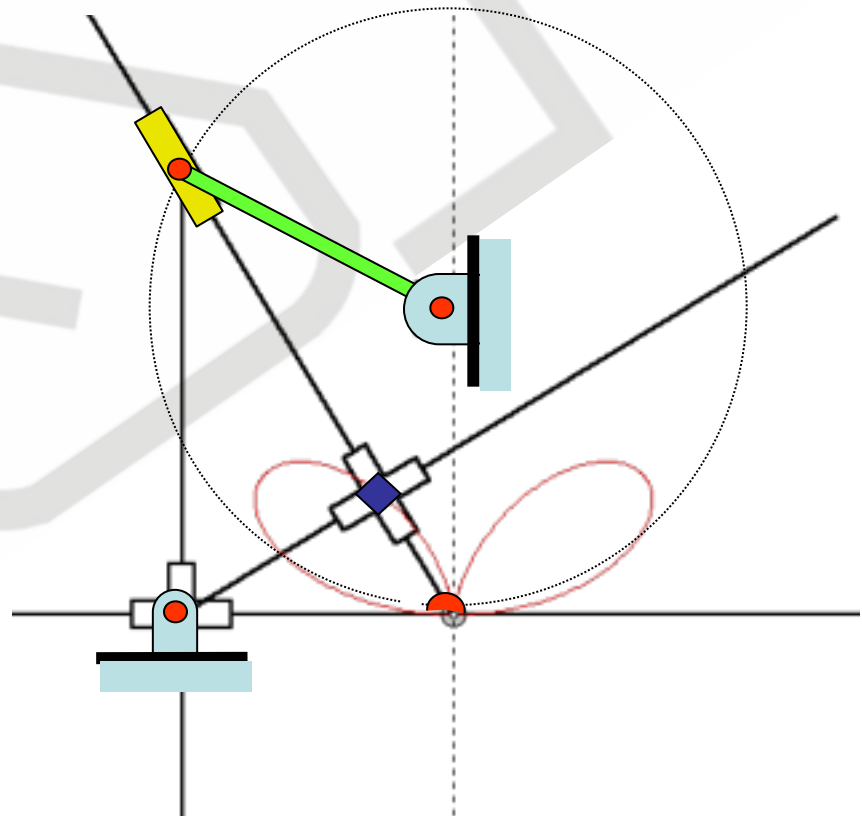
- Biela-Manivela



Classificação de Mecanismos

L. E. Torfason – Geradores de Curvas

- Biela-Manivela



Sumário da Aula

- Classificação de Mecanismos

- **Mecanismos Simples**

- **4 Barras**

- Lei de Grashof
 - Lei de Reuleaux

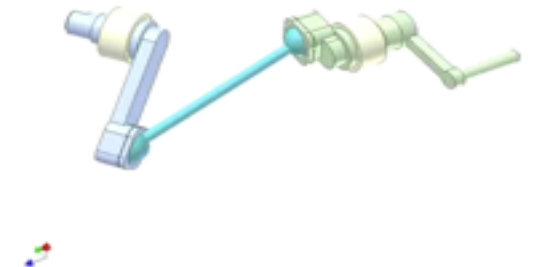
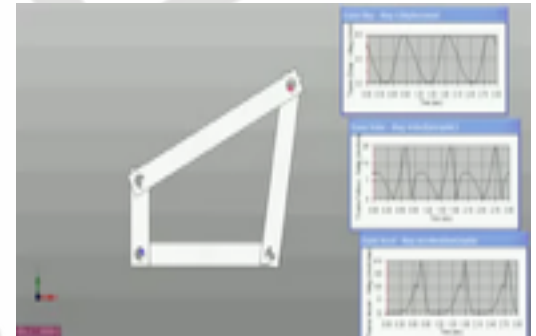
- Biela Manivela

- Mecanismos Complexos
- Bibliografia Recomendada

Mecanismos Simples

4 Barras

- Mecanismo Simples
 - Movimento oscilatório do link seguidor
 - Movimento do link acoplador
- 4 Barras Plano
- 4 Barras Espacial



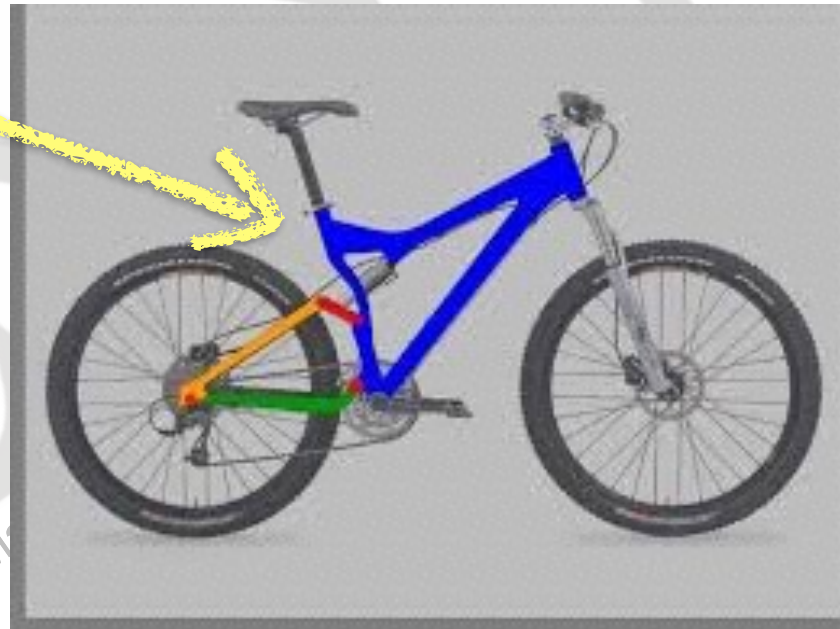
<http://www.youtube.com/watch?v=-KYomnT8xSc>

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

Mecanismos Simples

4 Barras

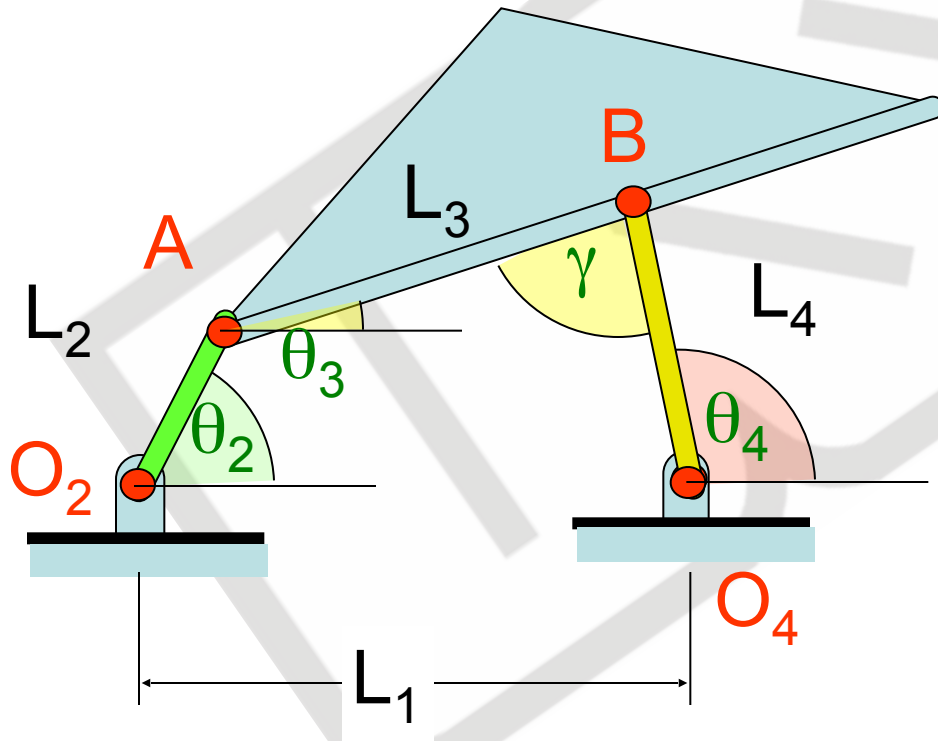
- Mecanismo Simples
 - Movimento oscilatório do link seguidor
 - Movimento do link acoplador
- 4 Barras Plano



https://en.wikipedia.org/wiki/Four-bar_linkage

Mecanismos Simples

4 Barras



L_2 : link motor

L_1 : solo

L_3 : link acoplador

L_4 : link seguidor

θ_2 : âng. da barra motriz

θ_4 : âng. da barra seguidora

θ_3 : âng. da barra acopladora

γ : âng. de transmissão

Lei de Grashof

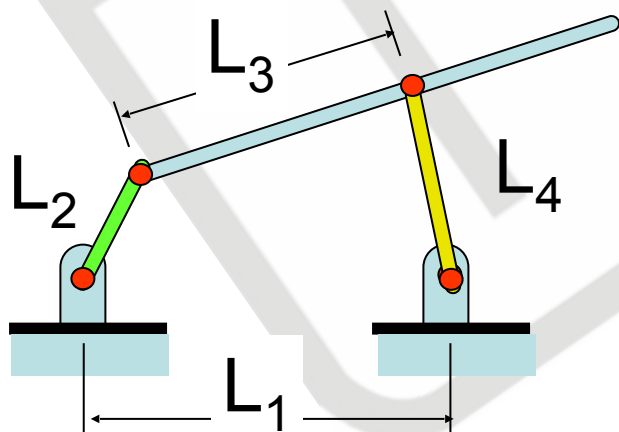
- **Franz Grashof** - Prof. na Univ. de Karlsruhe



*1826 +1893

Condição para rotação completa
barra motriz de mecanismo 4-barras

“A soma da menor e da maior barra de um mecanismo 4-barras não pode ser maior que a soma das 2 outras barras”



$$Me = L_2$$

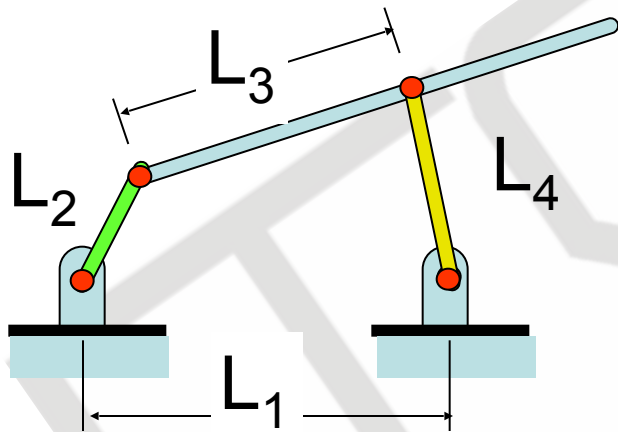
$$Ma = L_1$$

$$b_1 = L_3$$

$$b_2 = L_4$$

Lei de Grashof

Equação



$$Me + Ma \leq b_1 + b_2$$

$$Me = L_2$$

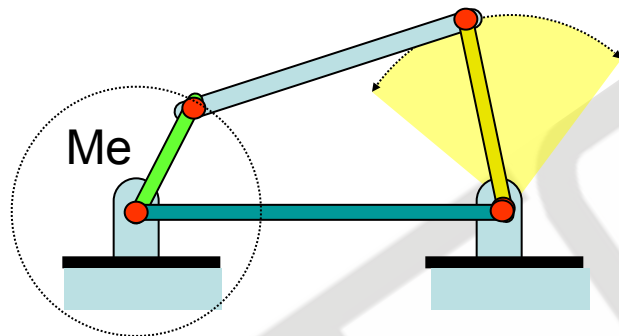
$$Ma = L_1$$

$$b_1 = L_3$$

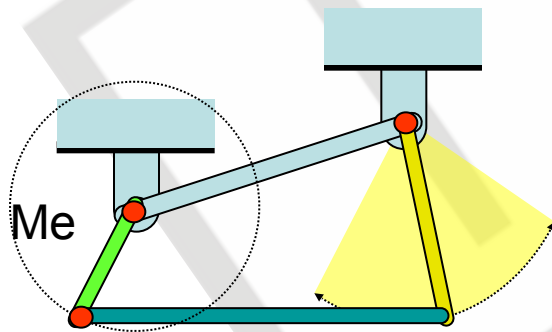
$$b_2 = L_4$$

Lei de Grashof

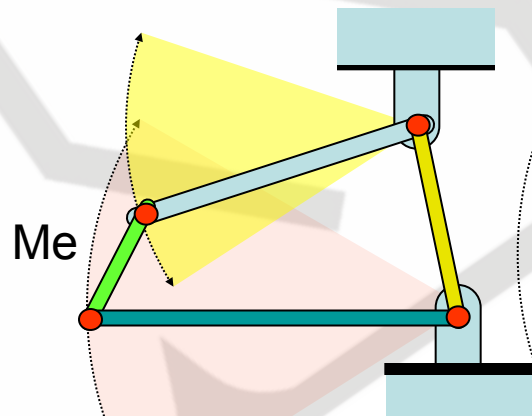
Inversões do Mecanismo 4-Barras



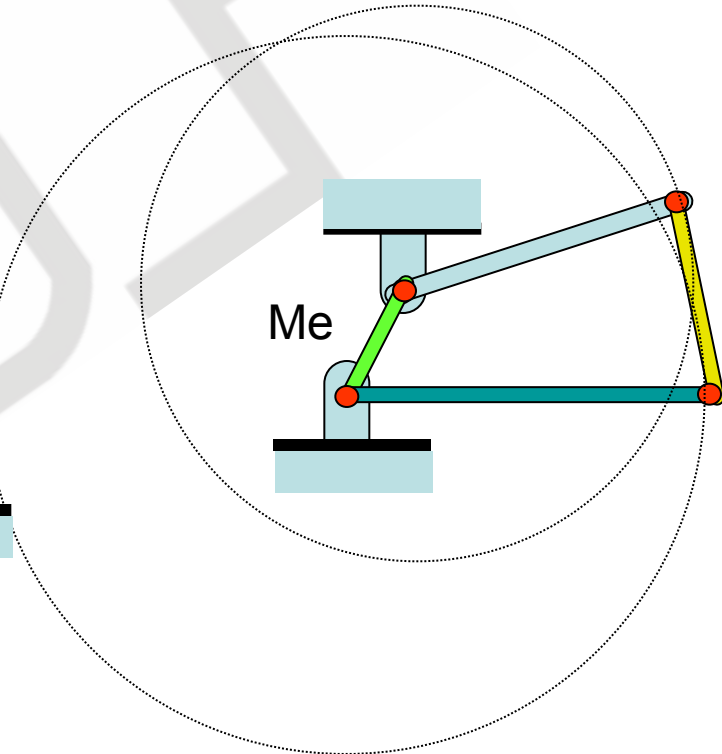
Crank-rocker



Crank-rocker



Double-rocker

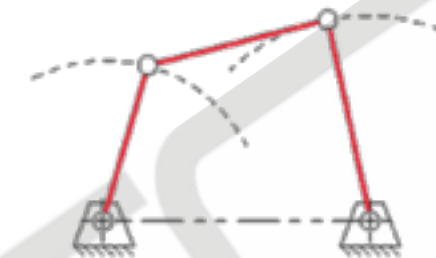


Double-crank

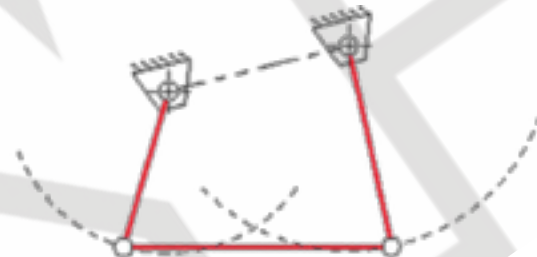
Me adjacente a Ma

Lei de Grashof

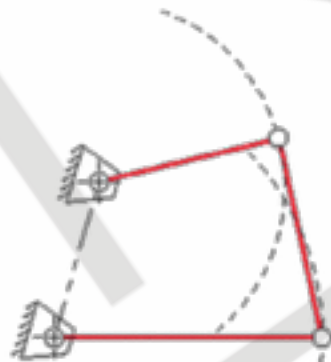
- Inversões do mecanismo 4-barras



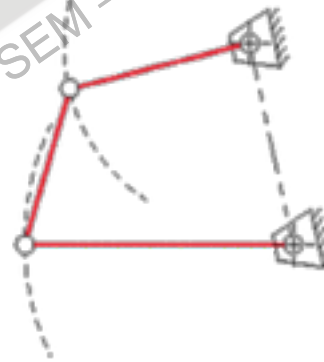
(a) Triple-rocker #1 (RRR1)



(b) Triple-rocker #2 (RRR2)



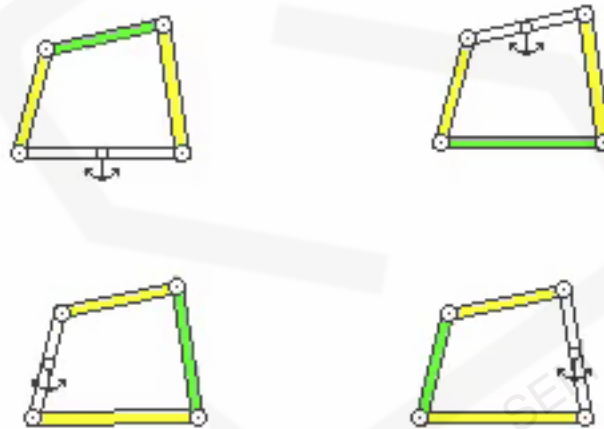
(c) Triple-rocker #3 (RRR3)



(d) Triple-rocker #4 (RRR4)

Lei de Grashof

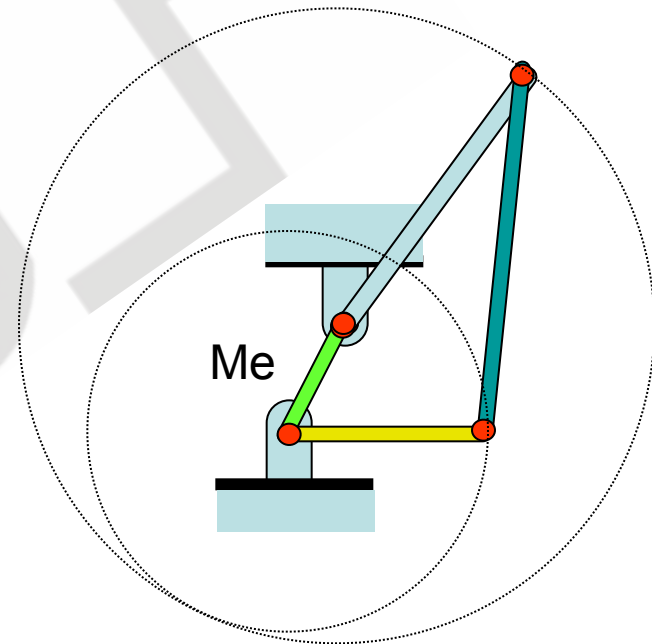
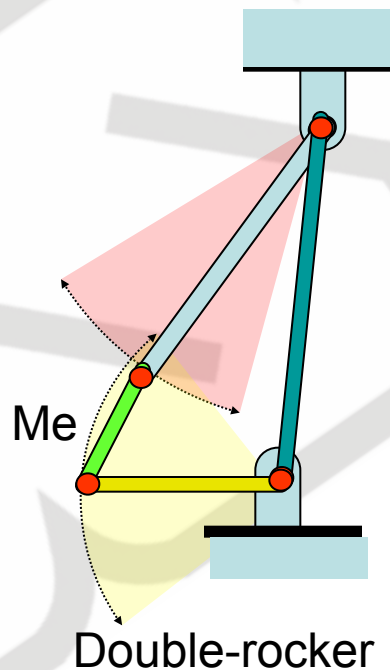
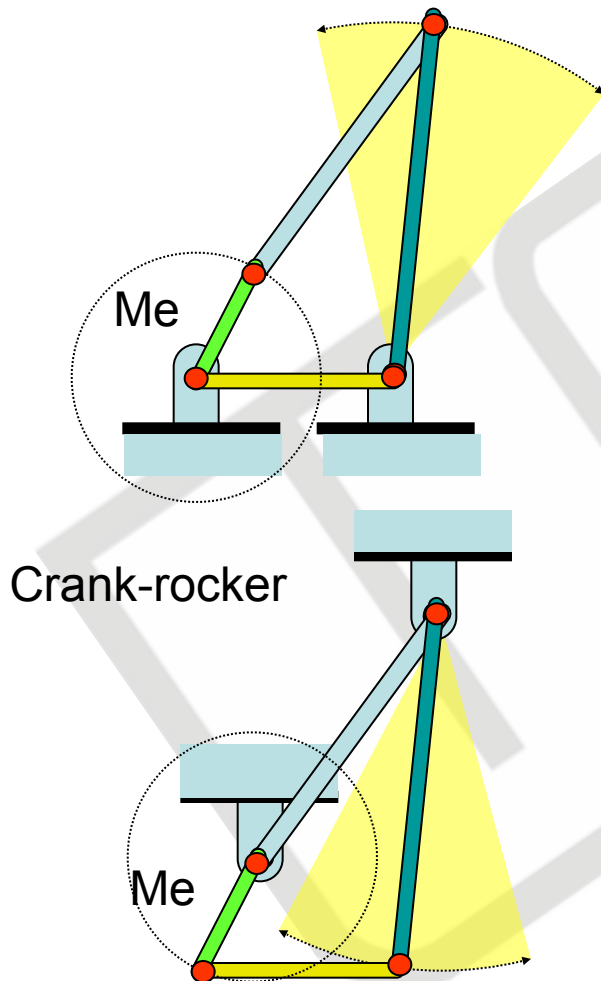
- Inversões do mecanismo 4-barras



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Lei de Grashof

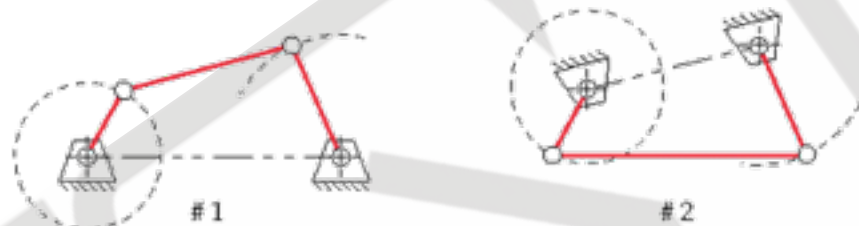
Inversões do Mecanismo 4-Barras



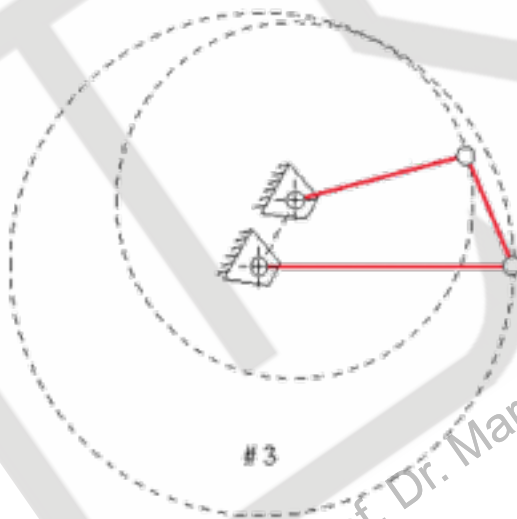
Me oposto a Ma

Lei de Grashof

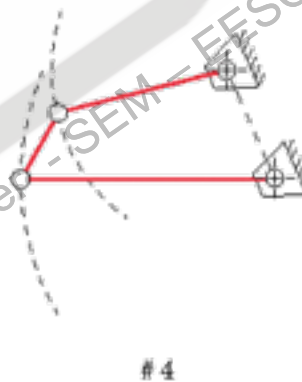
- Inversões do mecanismo 4-barras



(a) Two non-distinct crank-rocker inversions (GCR)



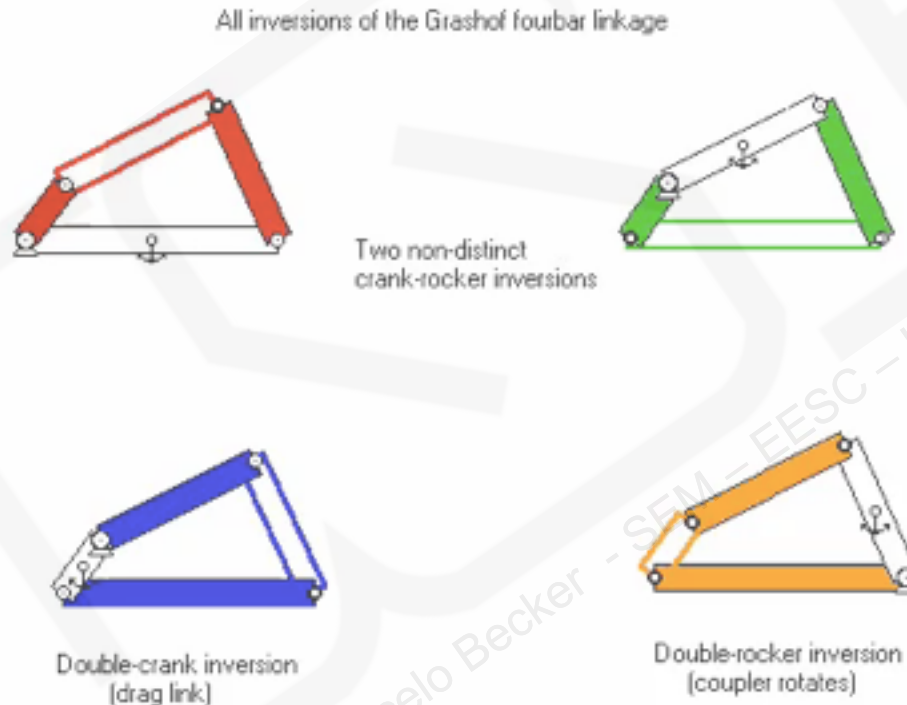
(b) Double-crank inversion (GCC)
(drag link mechanism)



(c) Double-rocker inversion (GRC)
(coupler rotates)

Lei de Grashof

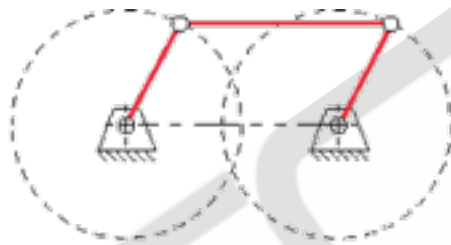
- Inversões do mecanismo 4-barras



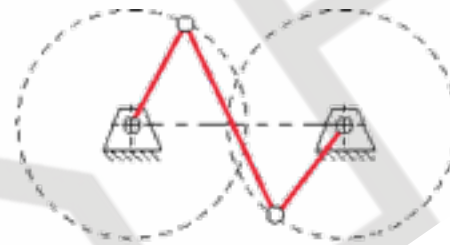
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Lei de Grashof

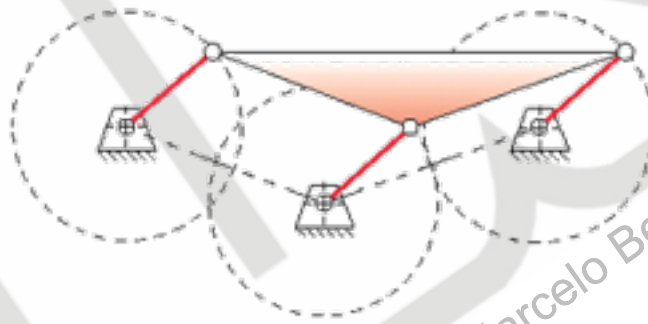
- Classes de Grashof - Configurações Especiais



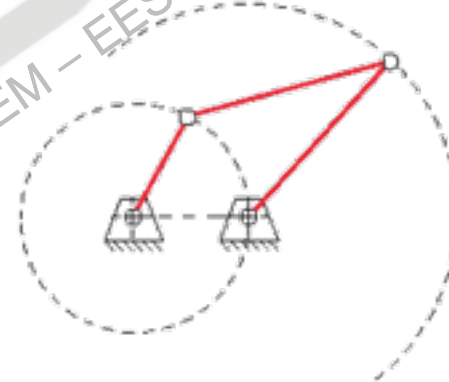
(a) Parallelogram form



(b) Antiparallelogram form



(c) Double-parallelogram linkage gives parallel motion (pure curvilinear translation) to coupler and also carries through the change points



(d) Deltoid or kite form

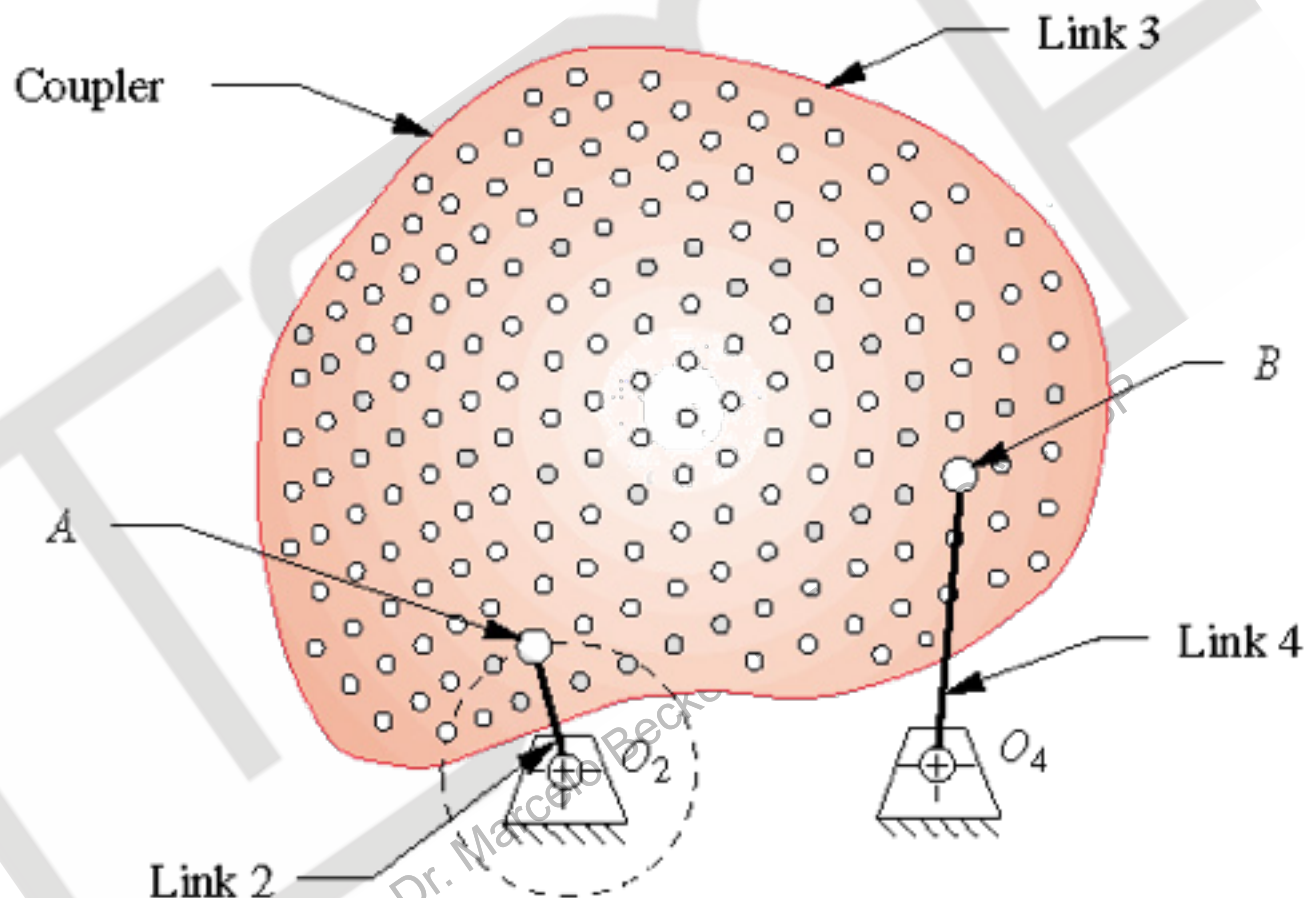
TABLE 2-4 Barker's Complete Classification of Planar Fourbar MechanismsAdapted from ref. (10). s = shortest link, l = longest link, Gxxx = Grashof, RRRx = non-Grashof, Sxx = Special case

Type	$s + l$ vs. $p + q$	Inversion	Class	Barker's Designation	Code	Also Known As
1	<	$L_1 = s = \text{ground}$	I-1	Grashof crank-crank-crank	GCCC	double-crank
2	<	$L_2 = s = \text{input}$	I-2	Grashof crank-rocker-rocker	GCRR	crank-rocker
3	<	$L_3 = s = \text{coupler}$	I-3	Grashof rocker-crank-rocker	GRCR	double-rocker
4	<	$L_4 = s = \text{output}$	I-4	Grashof rocker-rocker-crank	GRRC	rocker-crank
5	>	$L_1 = l = \text{ground}$	II-1	Class 1 rocker-rocker-rocker	RRR1	triple-rocker
6	>	$L_2 = l = \text{input}$	II-2	Class 2 rocker-rocker-rocker	RRR2	triple-rocker
7	>	$L_3 = l = \text{coupler}$	II-3	Class 3 rocker-rocker-rocker	RRR3	triple-rocker
8	>	$L_4 = l = \text{output}$	II-4	Class 4 rocker-rocker-rocker	RRR4	triple-rocker
9	=	$L_1 = s = \text{ground}$	III-1	change point crank-crank-crank	SCCC	SC* double -crank
10	=	$L_2 = s = \text{input}$	III-2	change point crank-rocker-rocker	SCRR	SC crank-rocker
11	=	$L_3 = s = \text{coupler}$	III-3	change point rocker-crank-rocker	SRCR	SC double-rocker
12	=	$L_4 = s = \text{output}$	III-4	change point rocker-rocker-crank	SRRC	SC rocker-crank
13	=	two equal pairs	III-5	double change point	S2X	parallelogram or deltoid
14	=	$L_1 = L_2 = L_3 = L_4$	III-6	triple change point	S3X	square

* SC = special case.

Mecanismos Simples

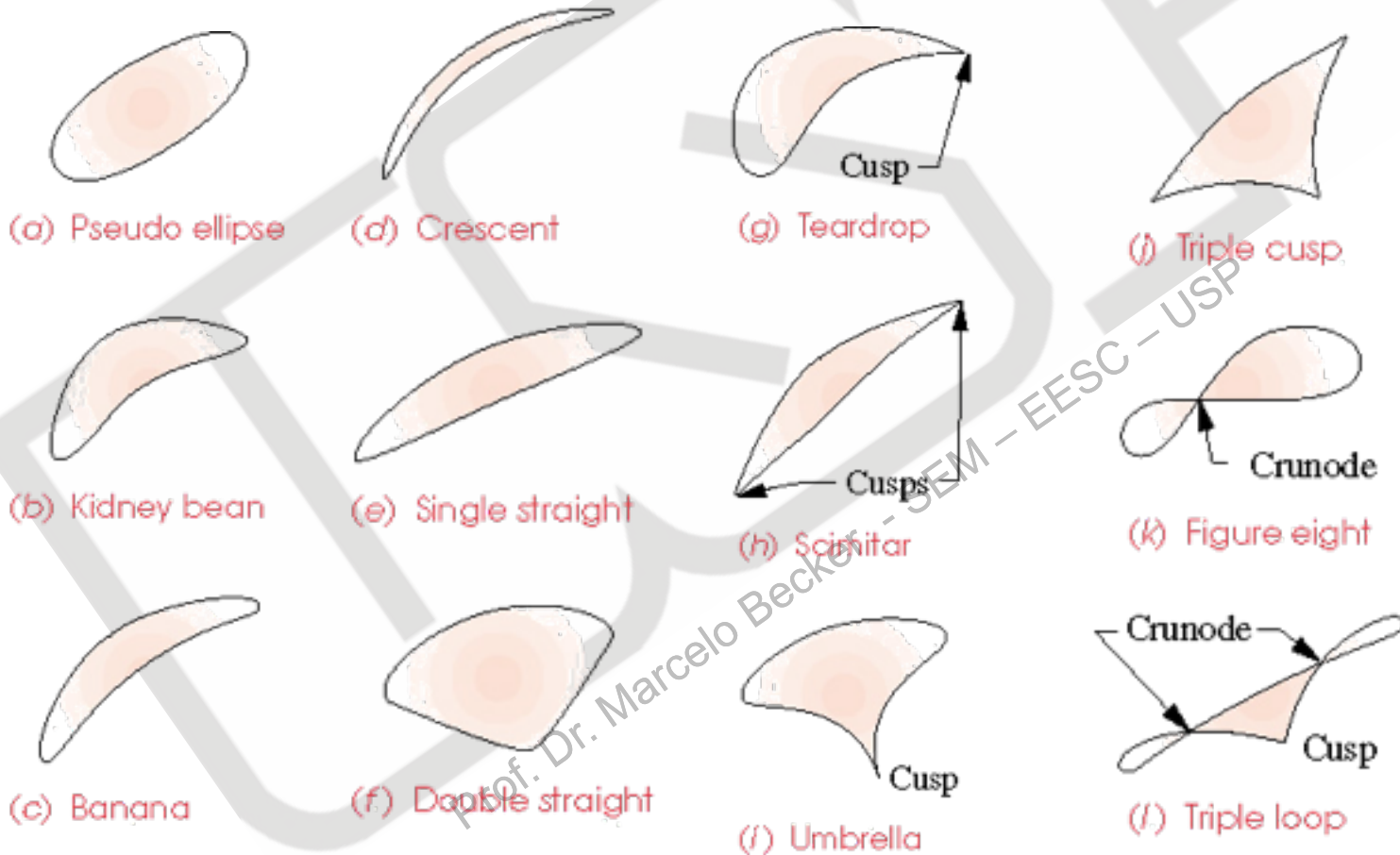
4 Barras



Mecanismos Simples

4 Barras

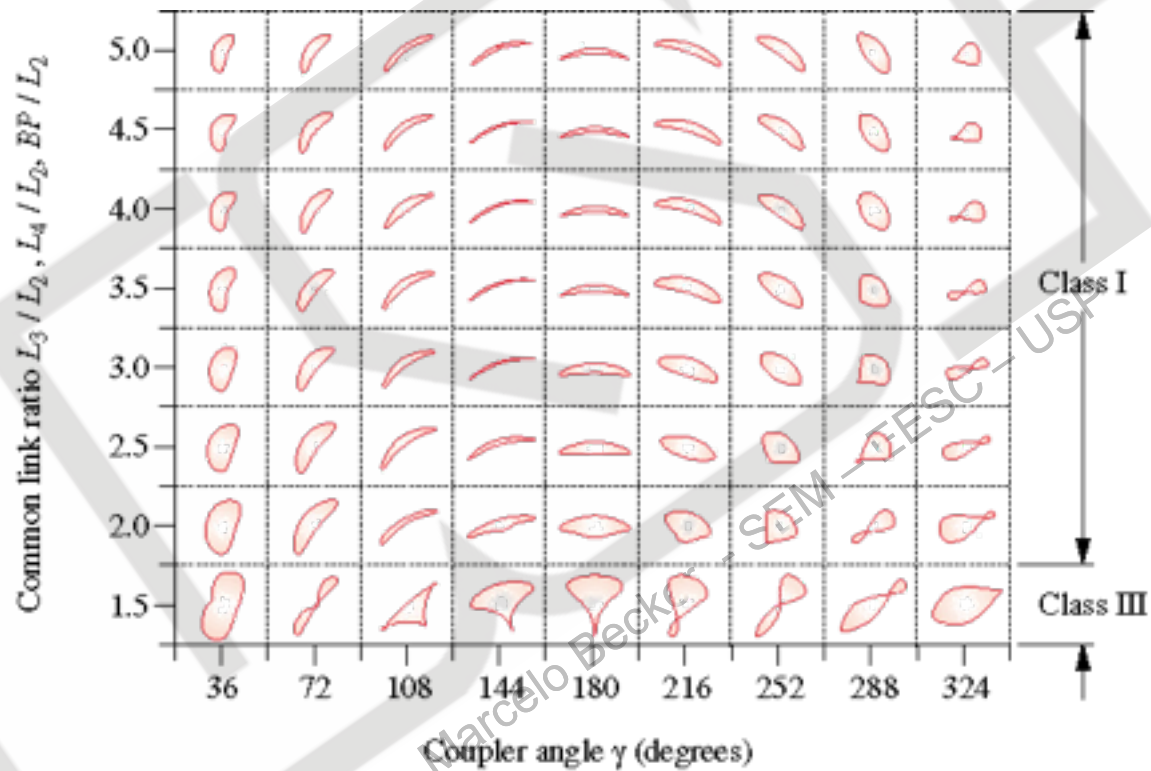
- Possíveis curvas geradas pelo link acoplador



Mecanismos Simples

4 Barras

- Informações de Atlas

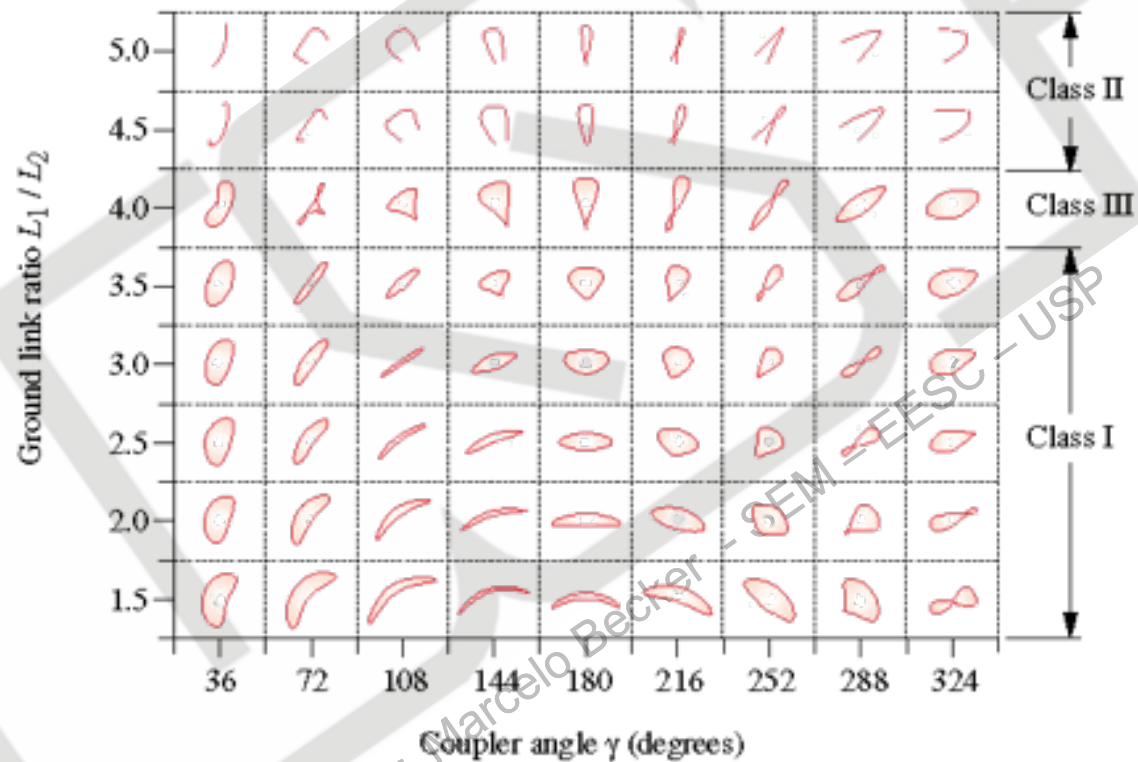


(a) Variation of coupler curve shape with common link ratio and coupler angle for a ground link ratio $L_1 / L_2 = 2.0$

Mecanismos Simples

4 Barras

- Informações de Atlas

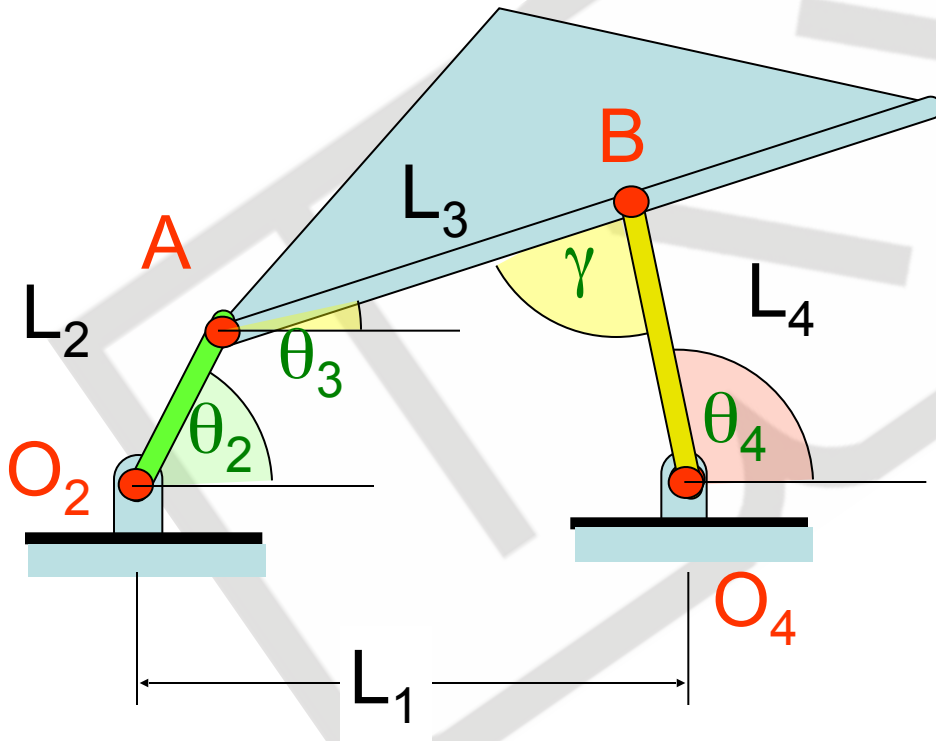


(b) Variation of coupler curve shape with ground link ratio and coupler angle for a common link ratio $L_3 / L_2 = L_4 / L_2 = BP / L_2 = 2.5$

Mecanismos Simples

4 Barras - Equacionamento

- Na Lousa



L_2 : link motor

L_1 : solo

L_3 : link acoplador

L_4 : link seguidor

θ_2 : âng. da barra motriz

θ_4 : âng. da barra seguidora

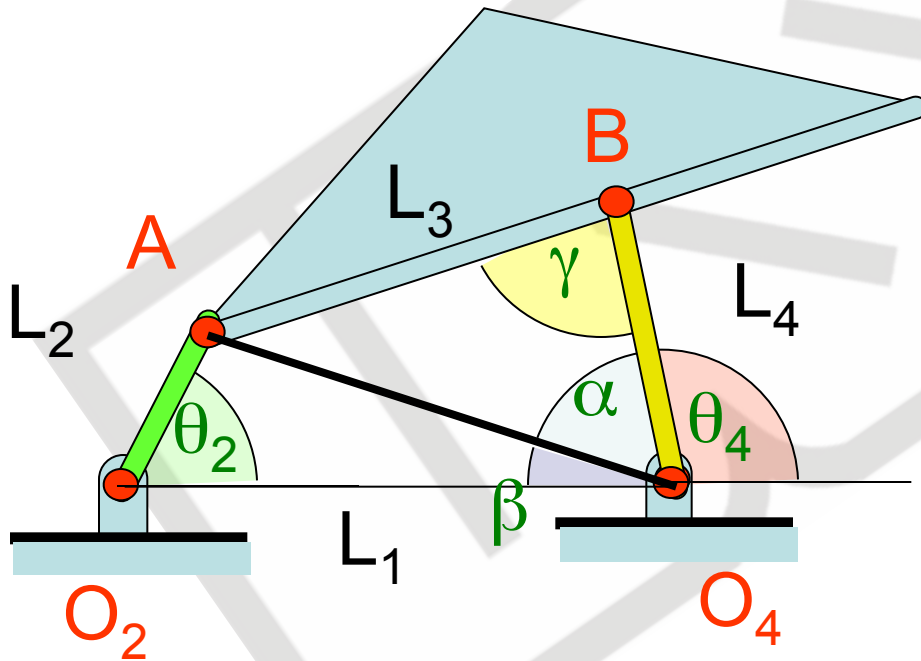
θ_3 : âng. da barra acopladora

γ : âng. de transmissão

Mecanismos Simples

4 Barras - Equacionamento

- Na Lousa



Na Lousa...

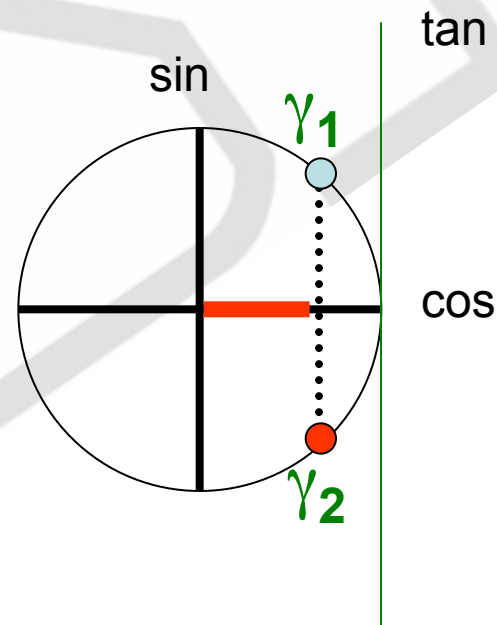
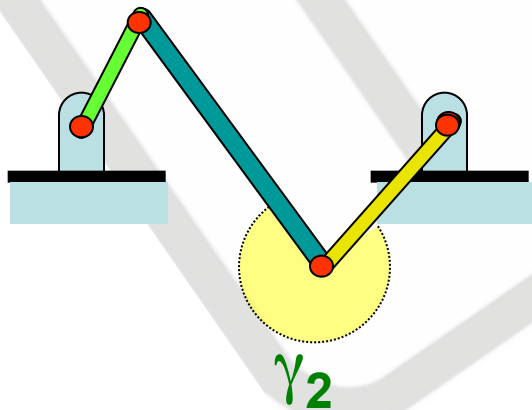
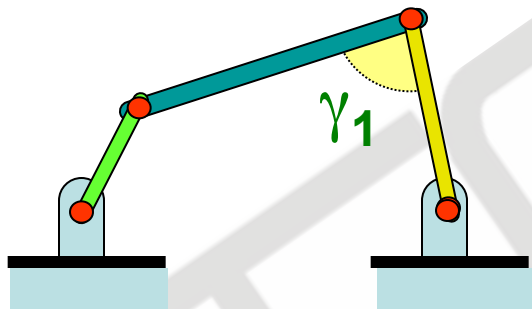
$$\Delta ABO_4$$

$$\Delta AO_2O_4$$

Mecanismos Simples

4 Barras

- Significado físico dos 2 valores de γ



Sumário da Aula

- Classificação de Mecanismos
- Mecanismos Simples
 - 4 Barras
 - Lei de Grashof
 - **Lei de Reuleaux**
 - Biela Manivela
- Mecanismos Complexos
- Bibliografia Recomendada

Lei de Reuleaux

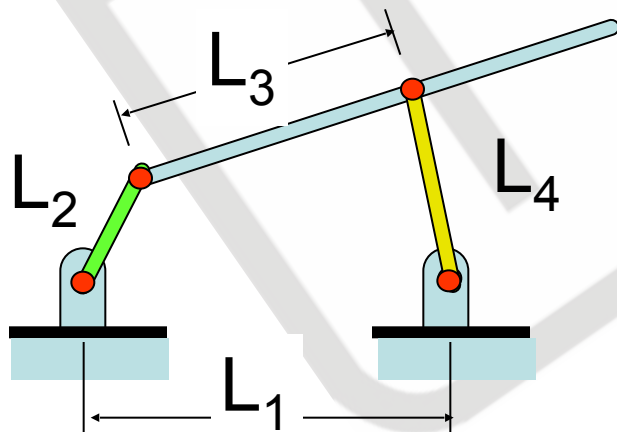
Montagem do Mecanismo 4-Barras

- **Franz Reuleaux** - “Pai da Cinemática”



*1829 +1905

Condição para a montagem
mecanismos 4-barras



L_2 : link motor

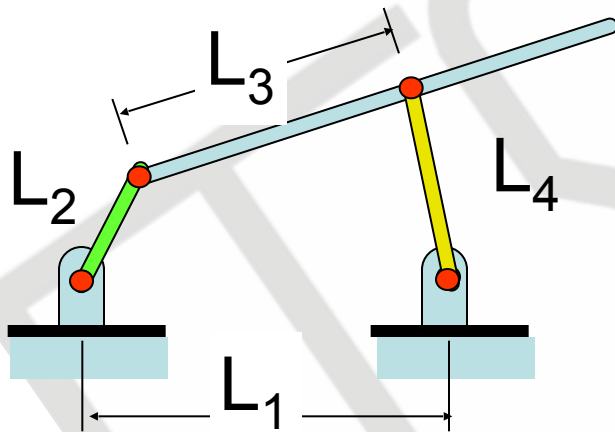
L_1 : solo

L_3 : link acoplador

L_4 : link seguidor

Lei de Reuleaux

Montagem do Mecanismo 4-Barras



$$L_2 + L_3 + L_4 \geq L_1$$

$$L_2 + L_3 - L_4 \leq L_1$$

$$L_2 + L_1 + L_4 \geq L_3$$

$$L_2 + L_1 - L_4 \leq L_3$$

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Mecanismos Simples

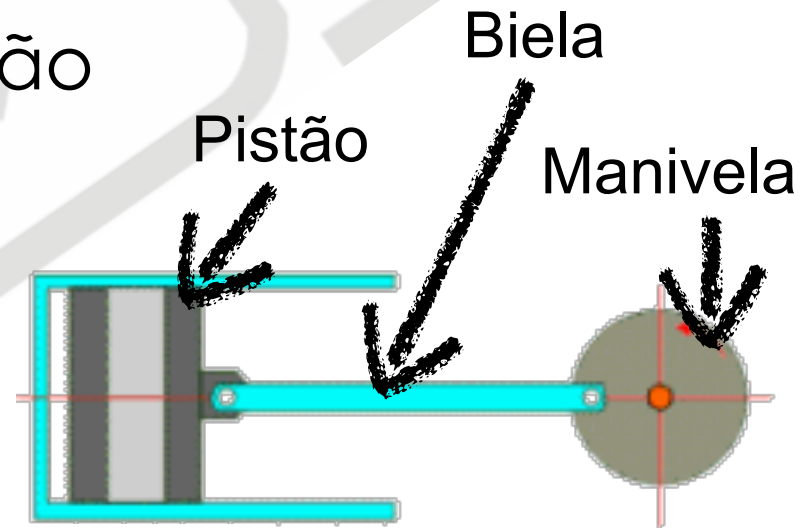
Biela-Manivela

- Exemplos de Aplicação: Motores de Combustão Interna, Máquinas Ferramenta, Compressores, etc.

- Deslocamento do Pistão

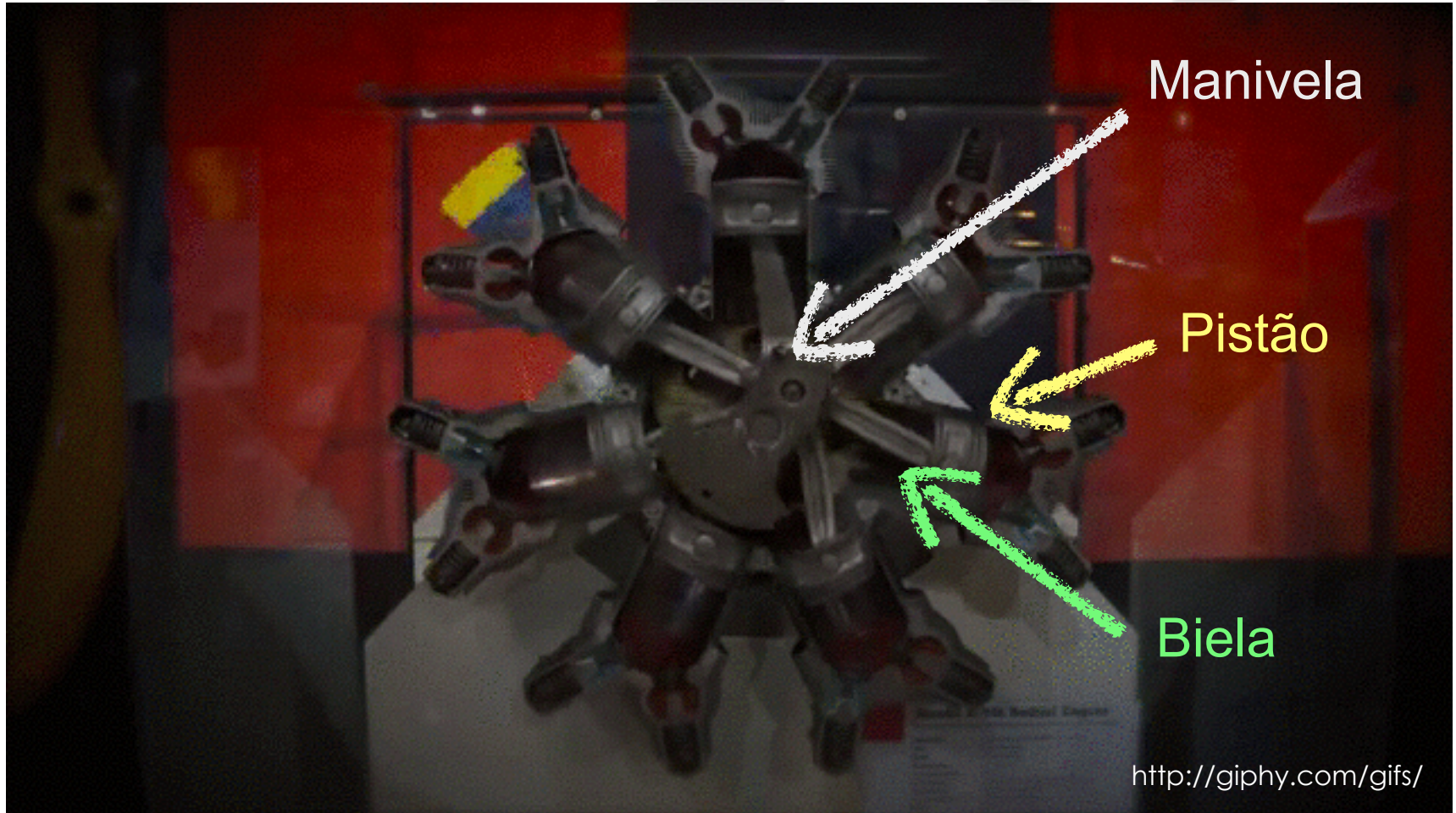
- Velocidades

- Aceleração



Mecanismos Simples

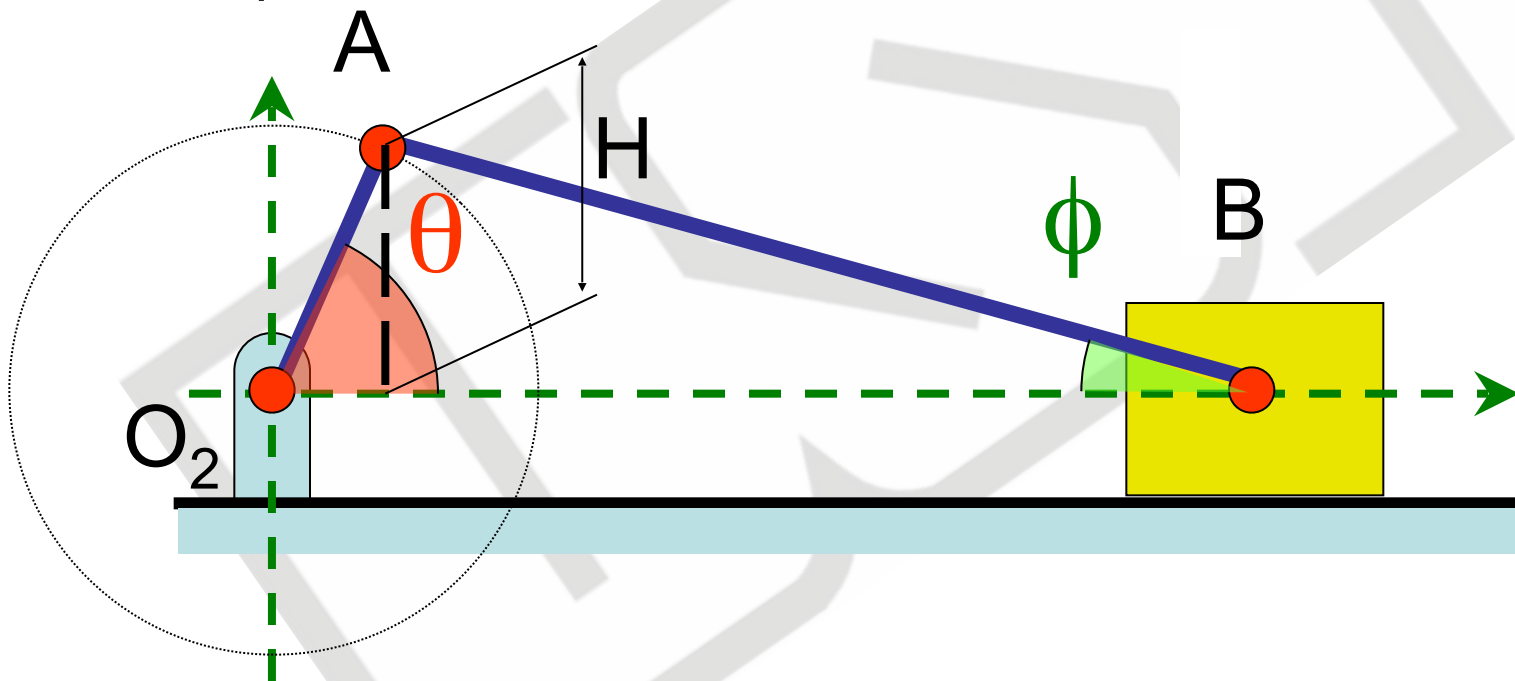
Biela-Manivela



Mecanismos Simples

Biela-Manivela

- Diagrama de Corpo Livre e Equacionamento

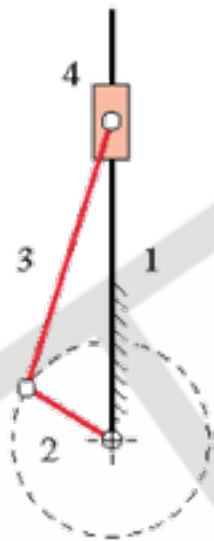


Na Lousa...

Mecanismos Simples

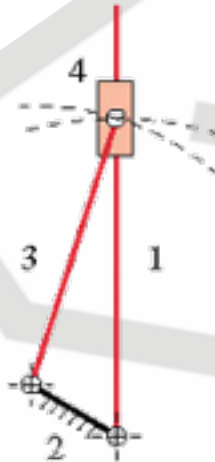
Biela-Manivela

- Outras Configurações para o Biela-Manivela



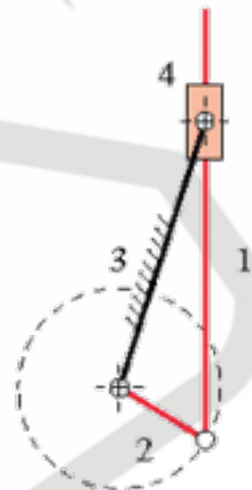
(a) Inversion # 1
slider block
translates

Compressores
Motores

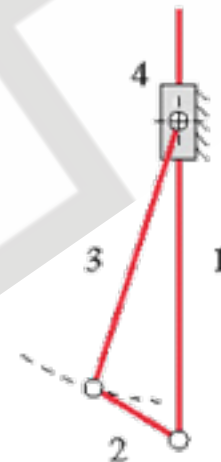


(b) Inversion # 2
slider block has
complex motion

Mecanismo de
Whitworth



(c) Inversion # 3
slider block
rotates

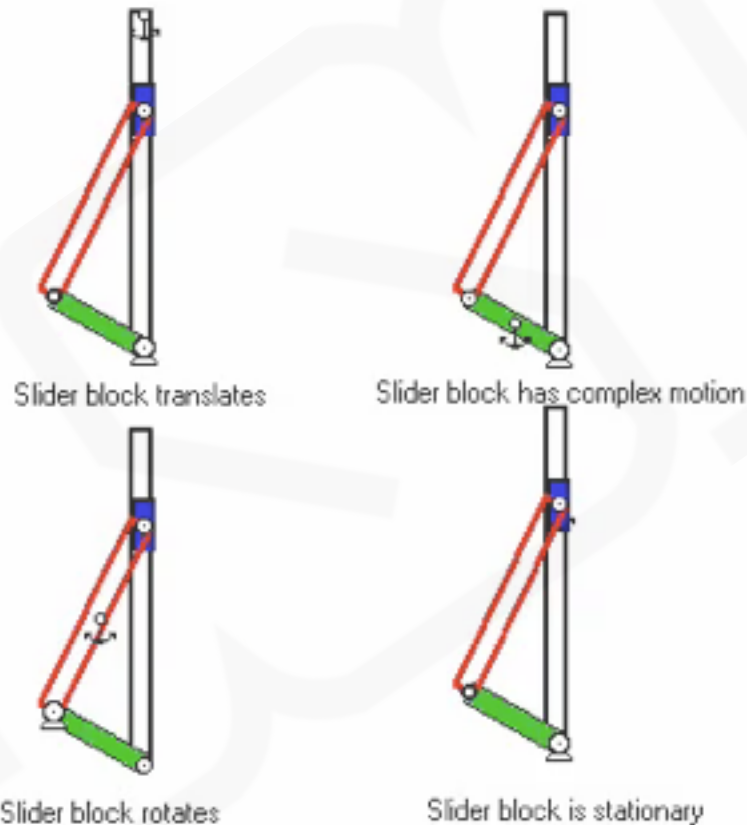


(d) Inversion # 4
slider block
is stationary

Bomba de água
Manual

Mecanismos Simples

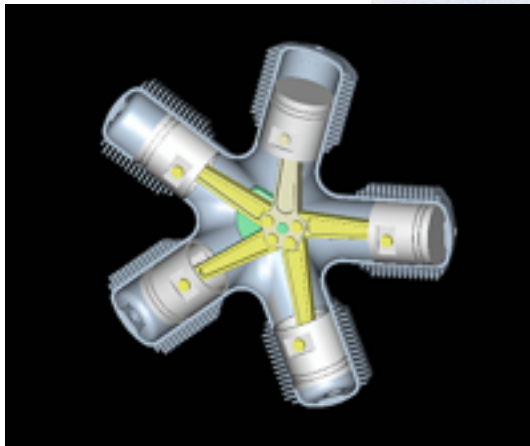
Biela-Manivela



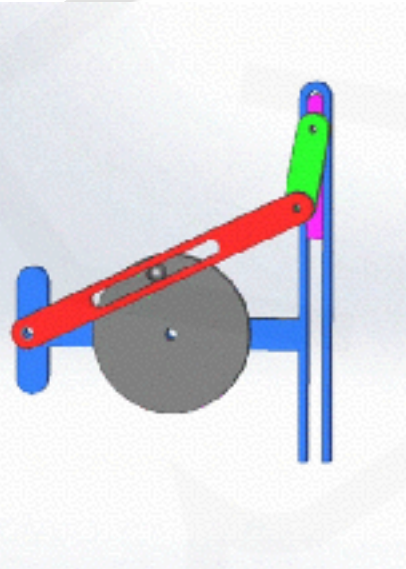
Created for "Design of Machinery, 3rd ed." by R. L. Norton and
"The Multimedia Handbook of Mechanical Devices" by S. Wang
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Mecanismos Simples

Biela-Manivela



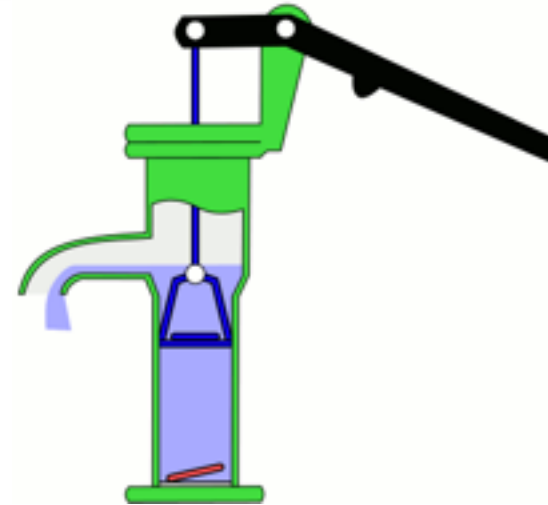
Compressores
Motores



Mecanismo de
Whitworth



Portão de Garagem



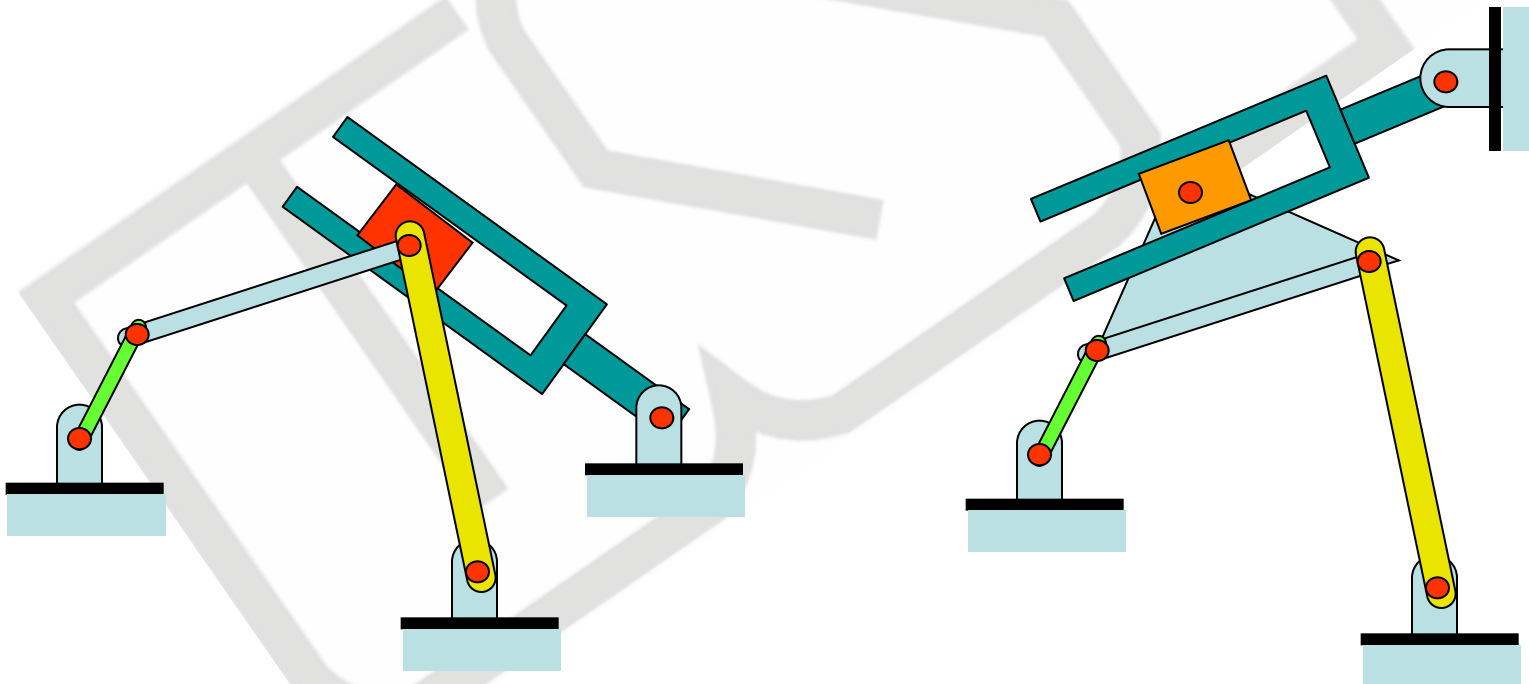
Bomba de água
Manual

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Mecanismos Complexos

- União de 2 ou mais mecanismos simples
4 Barras + Biela-Manivela



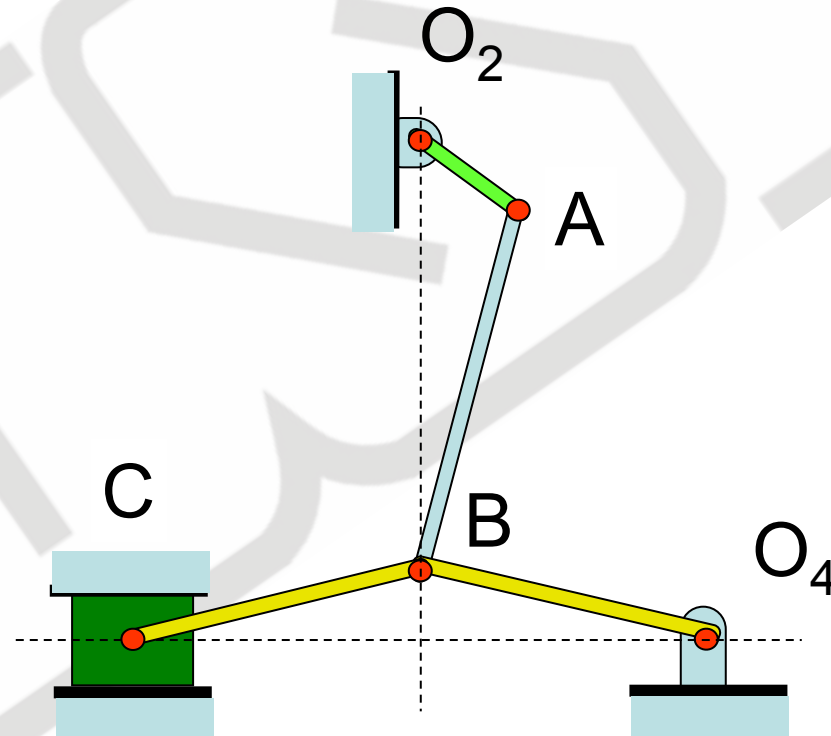
Mecanismos Complexos

Mecanismo Toggle

- Barras CB e BO_4 com mesmo comprimento

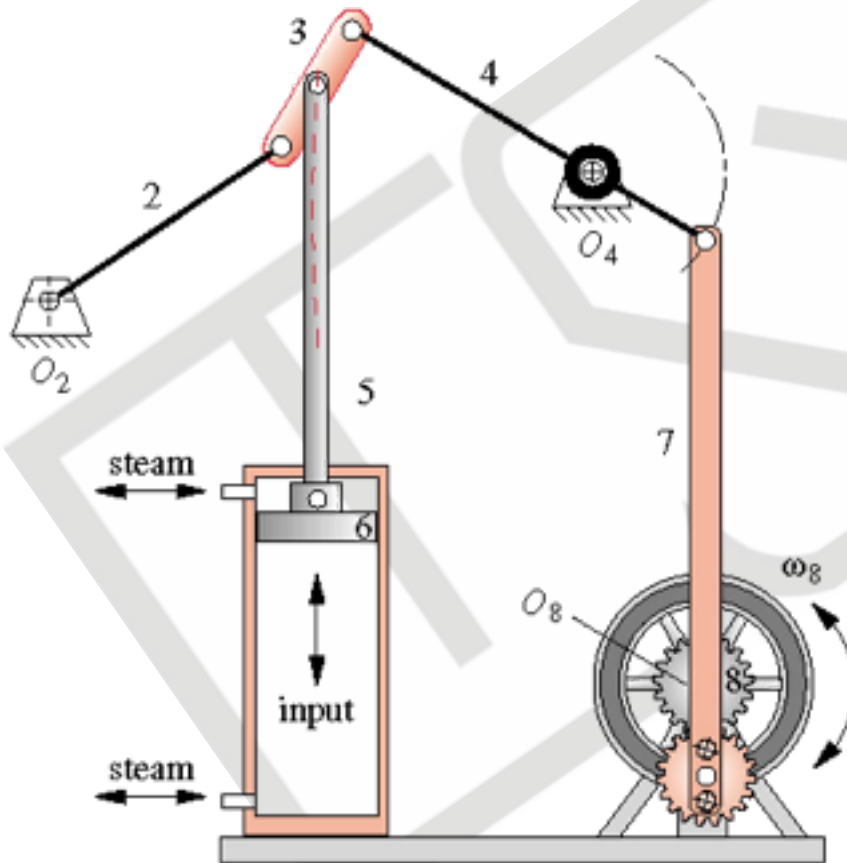


<https://www.youtube.com/watch?v=dCfYlvcfS0k>

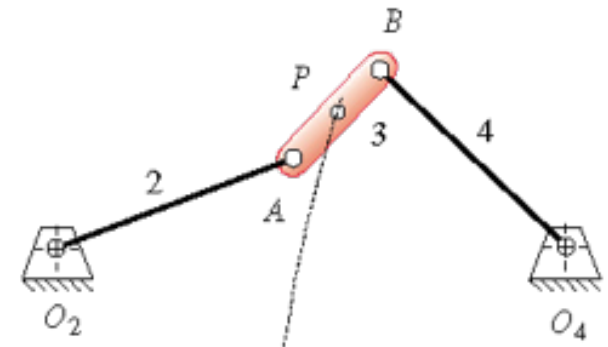


Mecanismos Complexos

- Máquina a vapor de James Watt



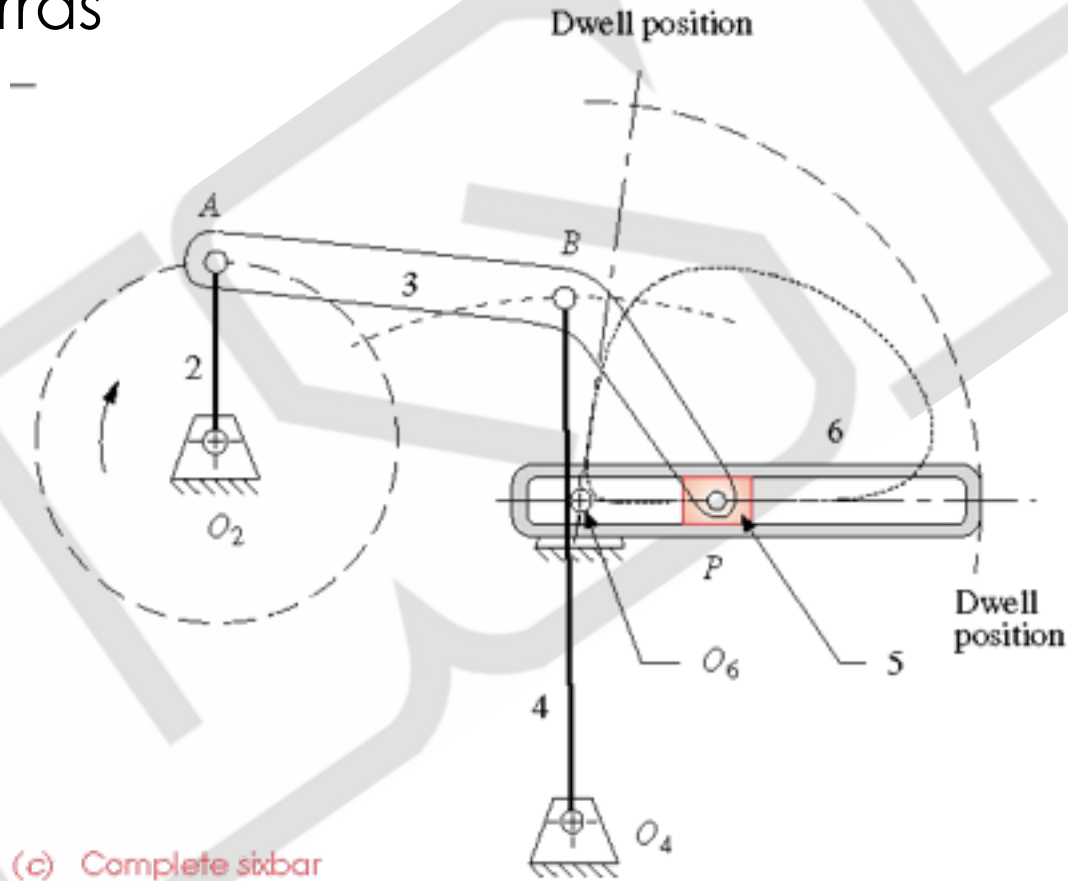
$$\begin{aligned} L_1 &= 4 \\ L_2 &= 2 \\ L_3 &= 1 \\ L_4 &= 2 \\ AP &= 0.5 \end{aligned}$$



(a) A Watt straight-line linkage

Mecanismos Complexos

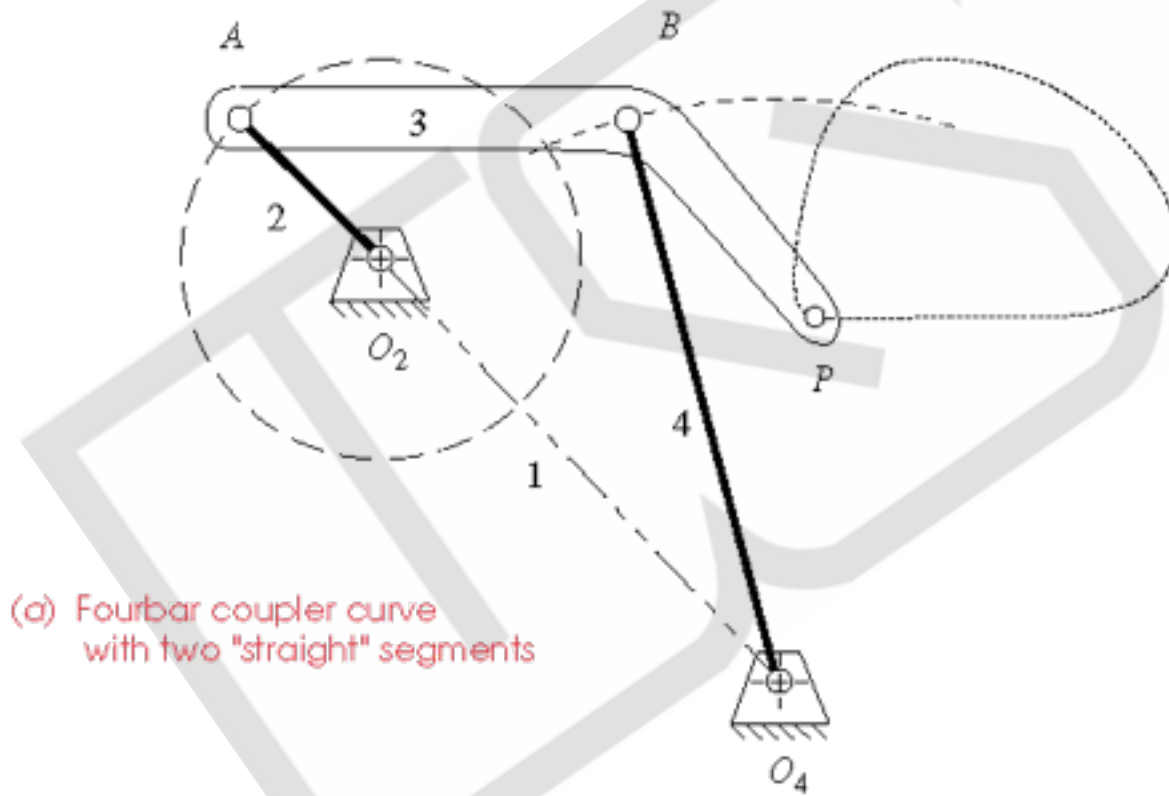
– 6 barras



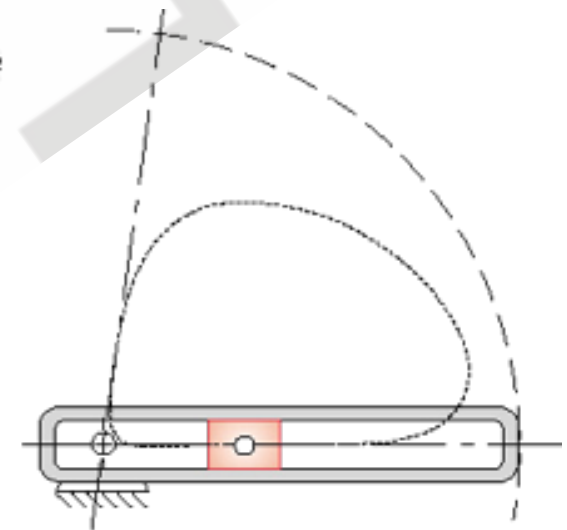
(c) Complete sixbar double-dwell linkage

Mecanismos Complexos

– 6 barras



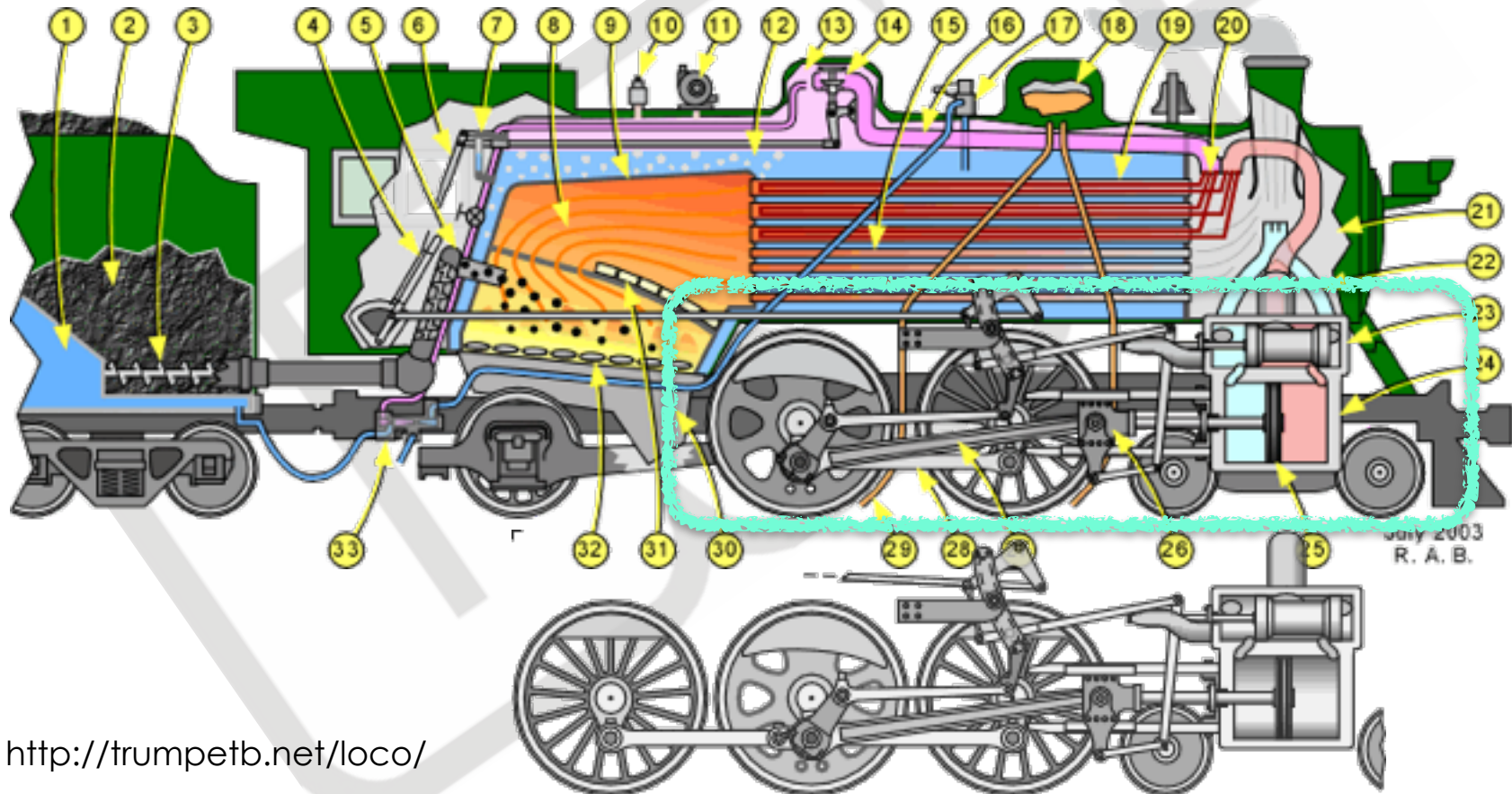
(a) Fourbar coupler curve with two "straight" segments



(b) Slider dyad for double-dwell

Mecanismos Complexos

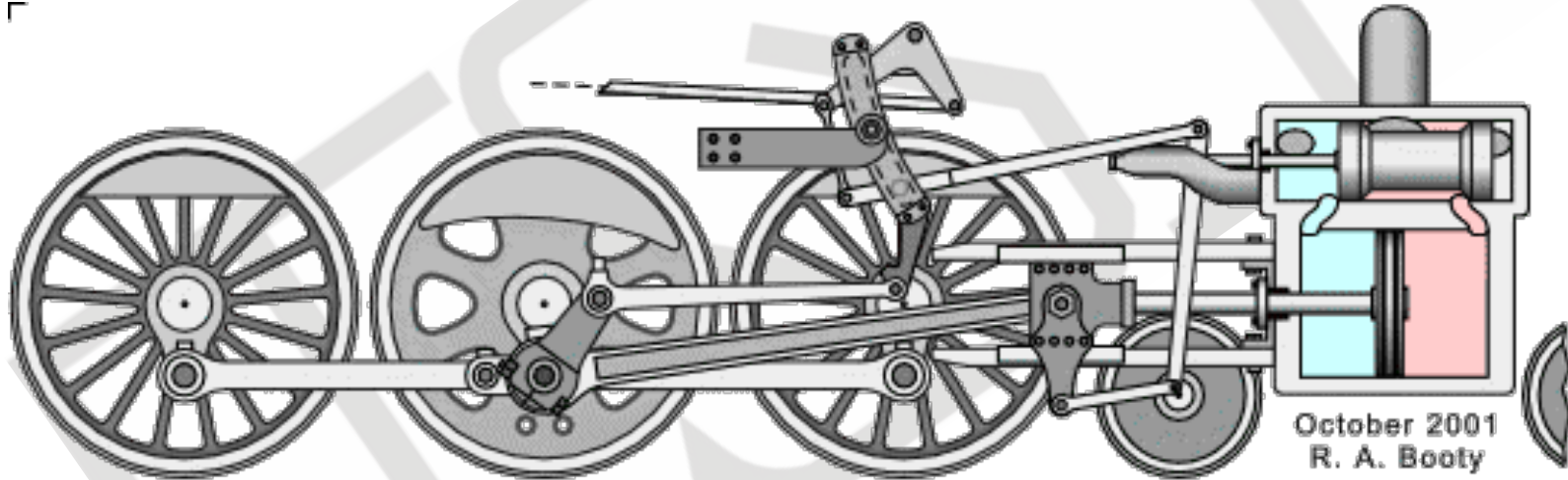
– Locomotiva a Vapor



<http://trumpetb.net/loco/>

Mecanismos Complexos

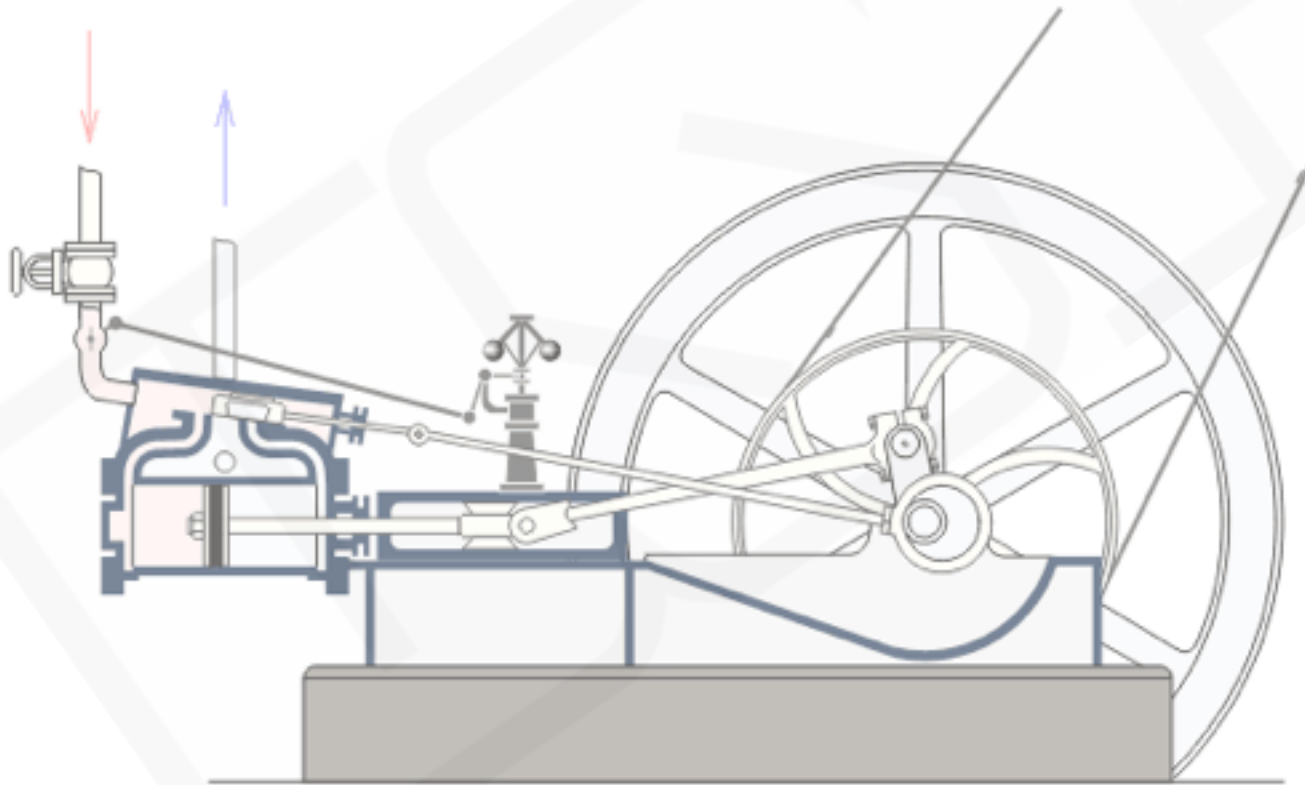
- Locomotiva a Vapor



<http://trumpetb.net/loco/>

Mecanismos Complexos

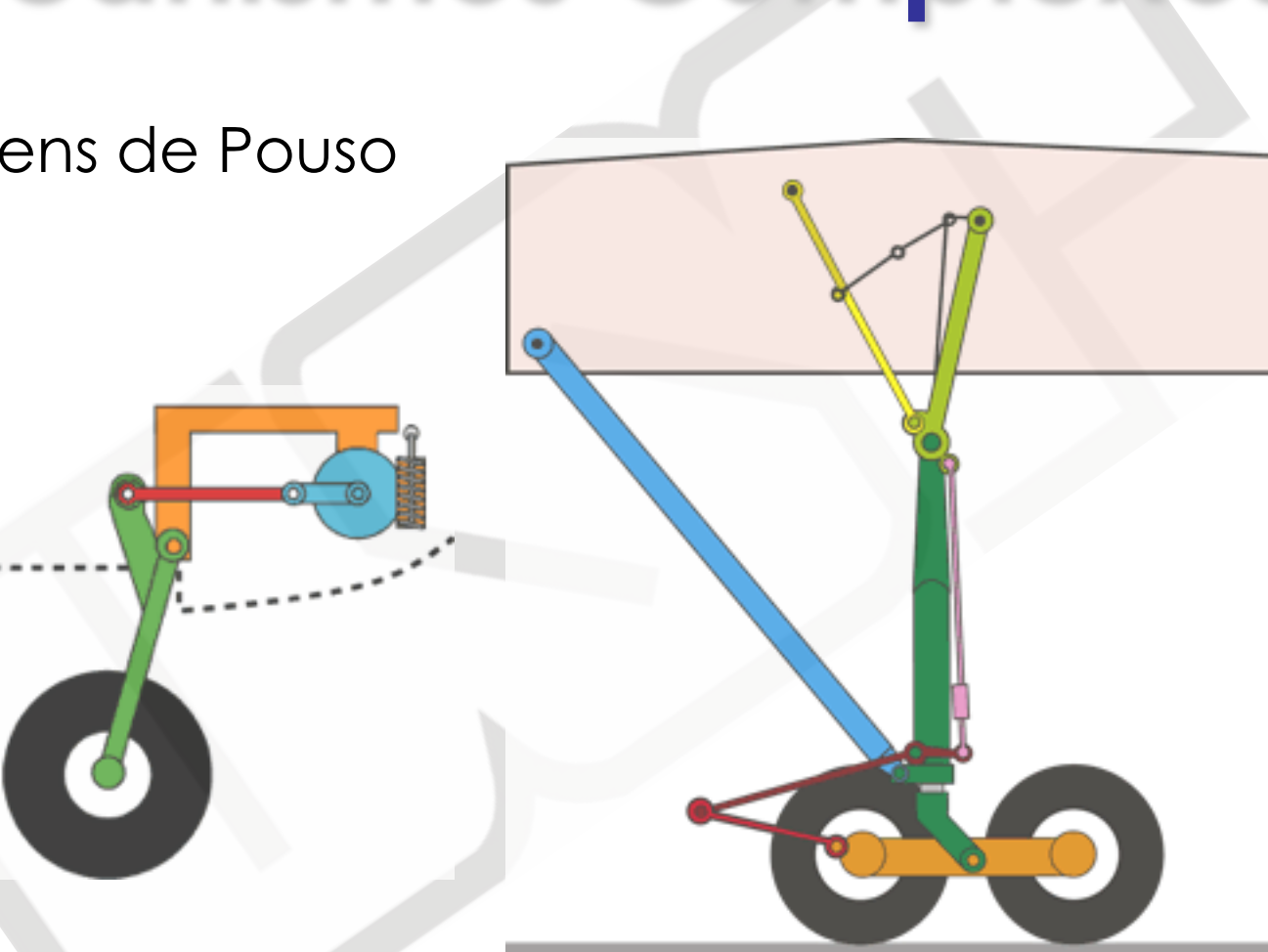
- Motor a Vapor



<http://giphy.com/gifs/>

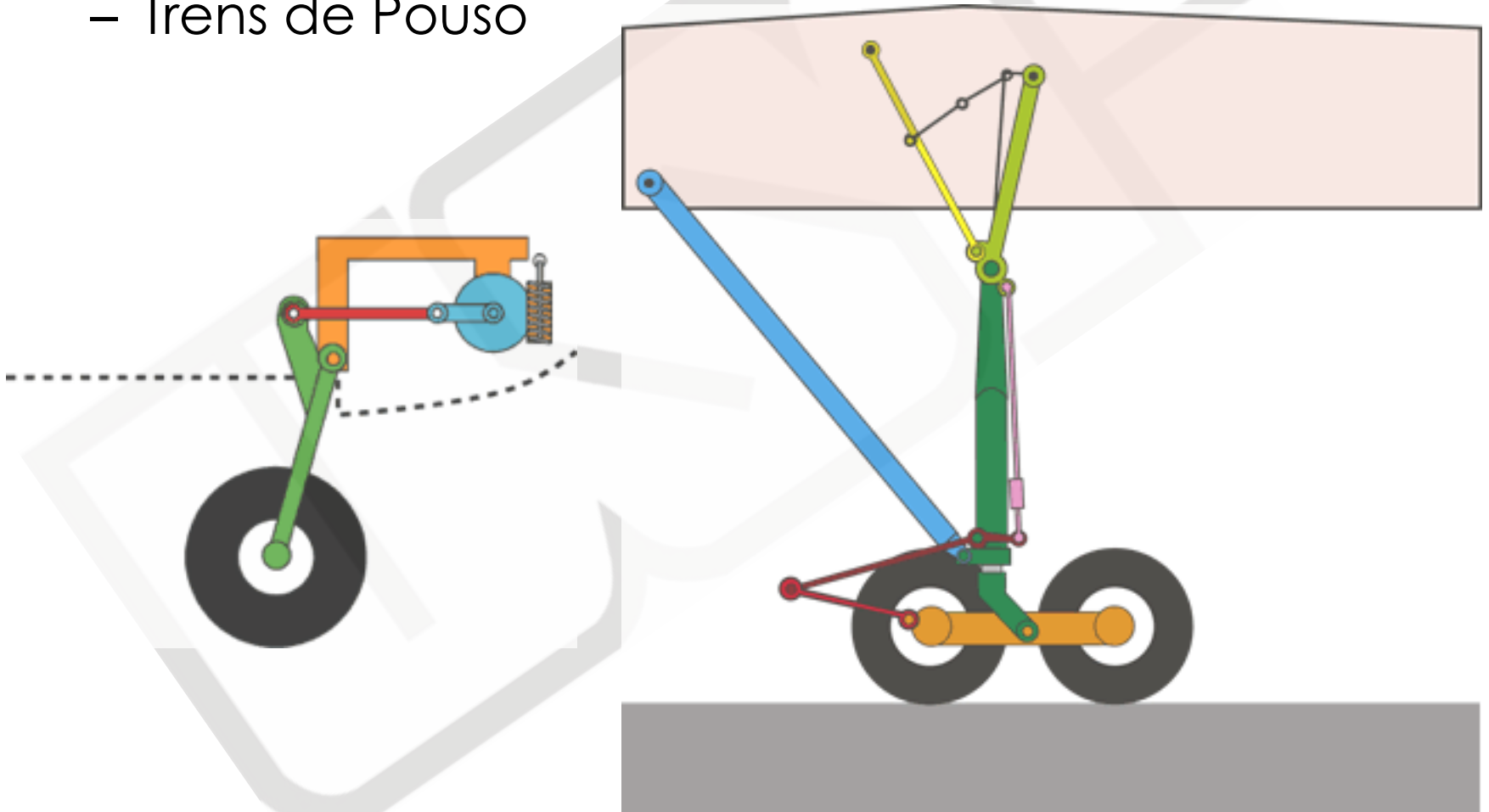
Mecanismos Complexos

- Trens de Pouso



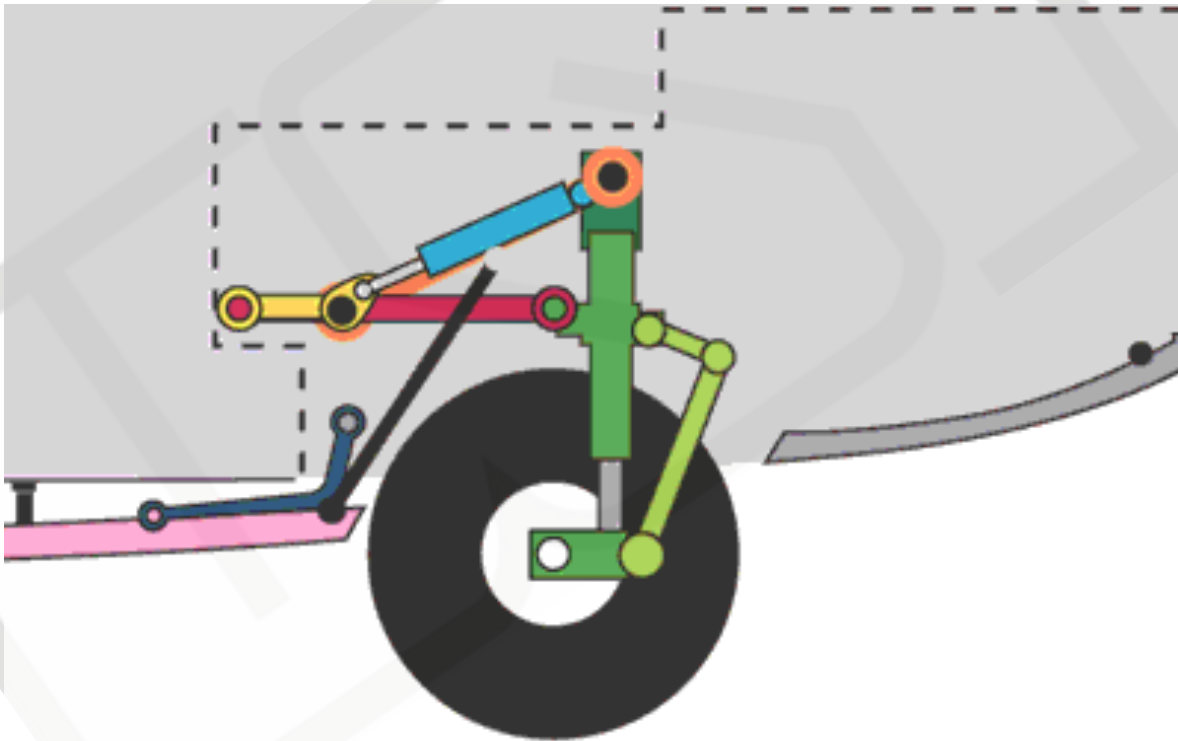
The diagram illustrates a complex landing gear mechanism, likely for an aircraft. It features a main fuselage (light blue) and a landing gear assembly (orange and green). The landing gear assembly includes a main strut (orange), a shock absorber (green), and a landing gear door (light blue). The mechanism is shown in a retracted position, with the landing gear door closed. A dashed line indicates the path of the landing gear door as it moves. The landing gear is mounted on a landing gear door (light blue) which is part of the fuselage. The landing gear itself consists of a main strut (orange) and a shock absorber (green). The landing gear is shown in a retracted position, with the landing gear door closed. A dashed line indicates the path of the landing gear door as it moves. The landing gear is mounted on a landing gear door (light blue) which is part of the fuselage. The landing gear itself consists of a main strut (orange) and a shock absorber (green). The landing gear is shown in a retracted position, with the landing gear door closed. A dashed line indicates the path of the landing gear door as it moves.

– Trens de Pouso



Mecanismos Complexos

– Trens de Pouso

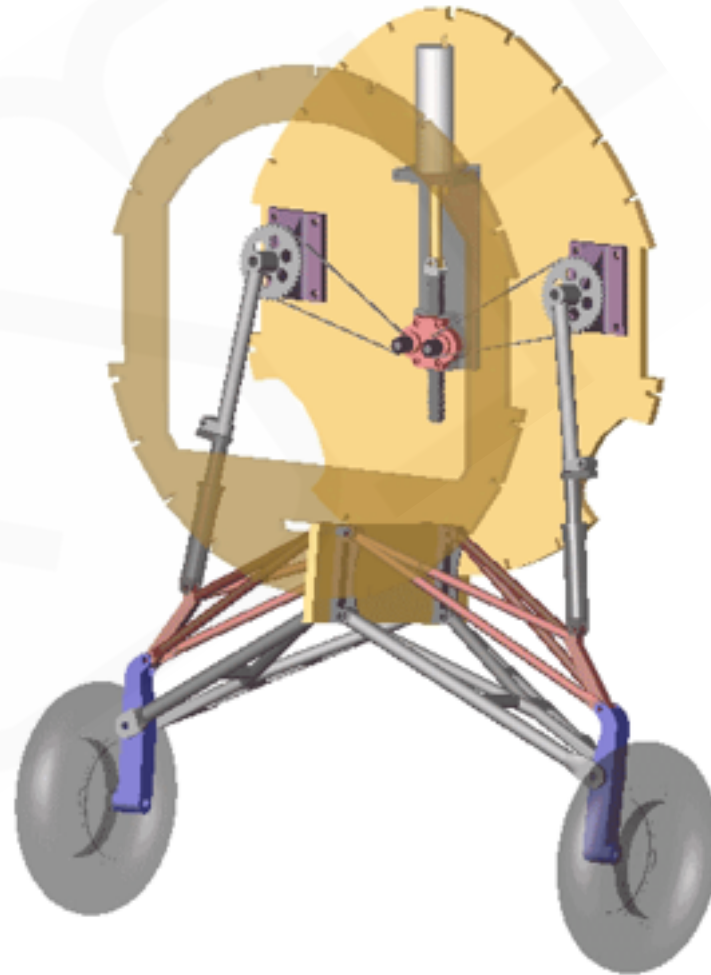


Mecanismos Complexos

– Trens de Pouso

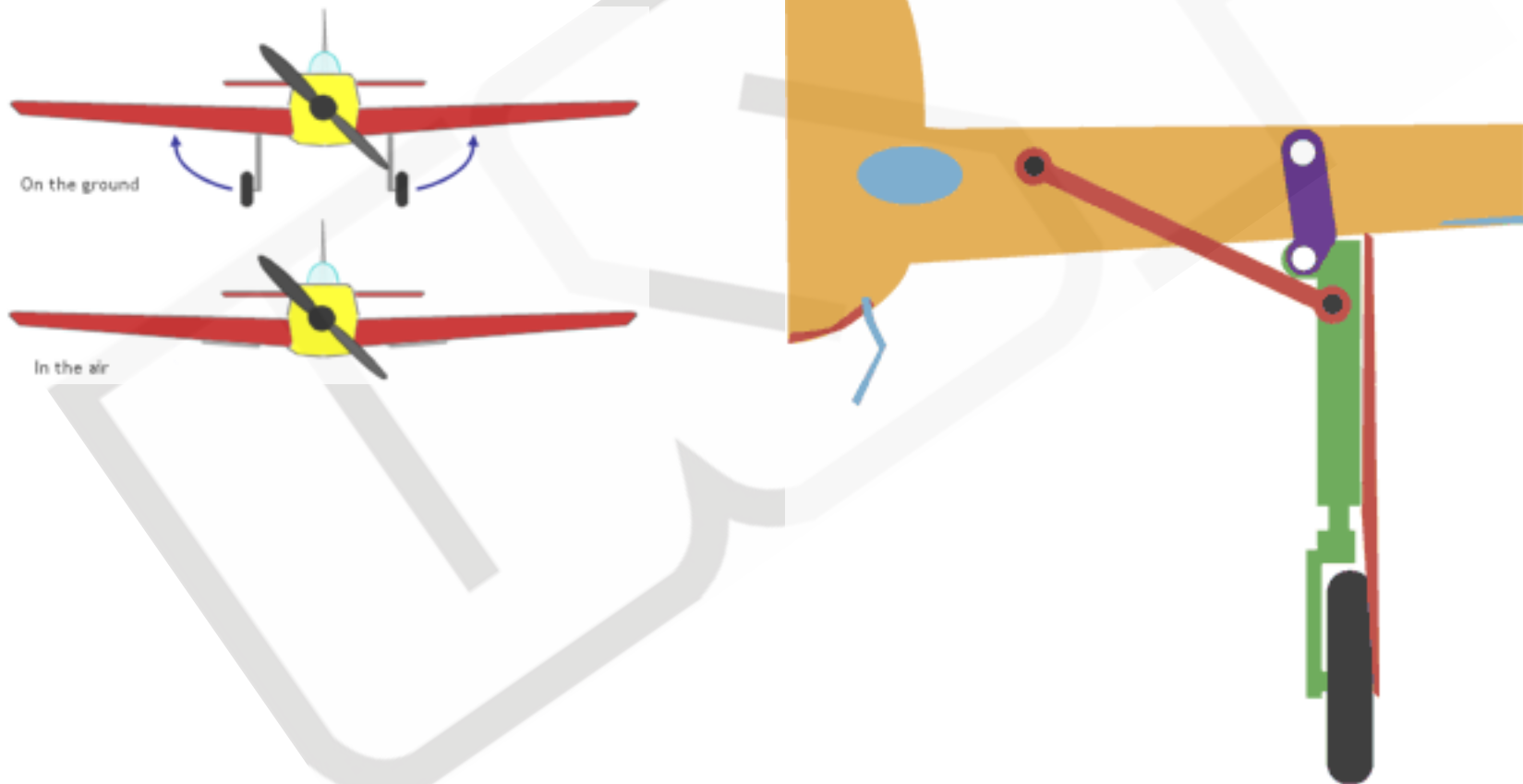


Grumman F4F Wildcat
WWII, 1940



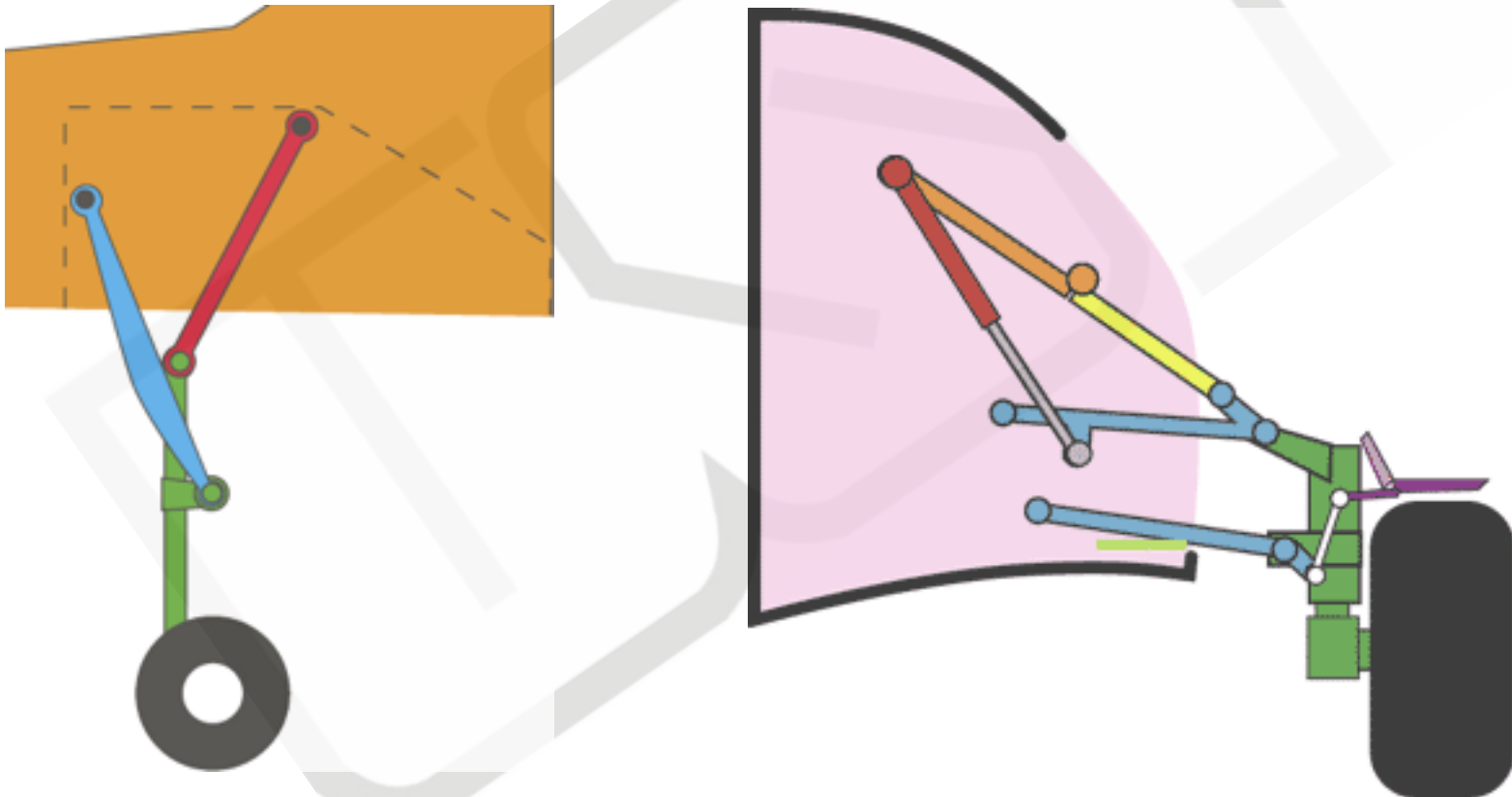
Mecanismos Complexos

– Trens de Pouso



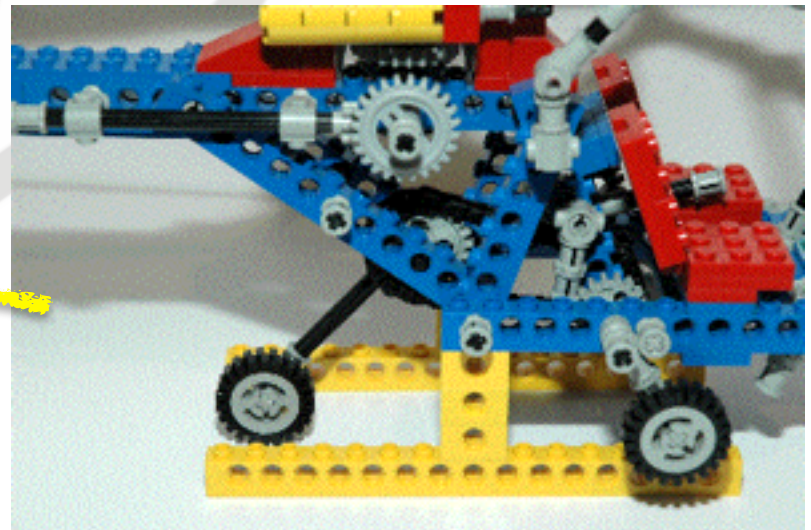
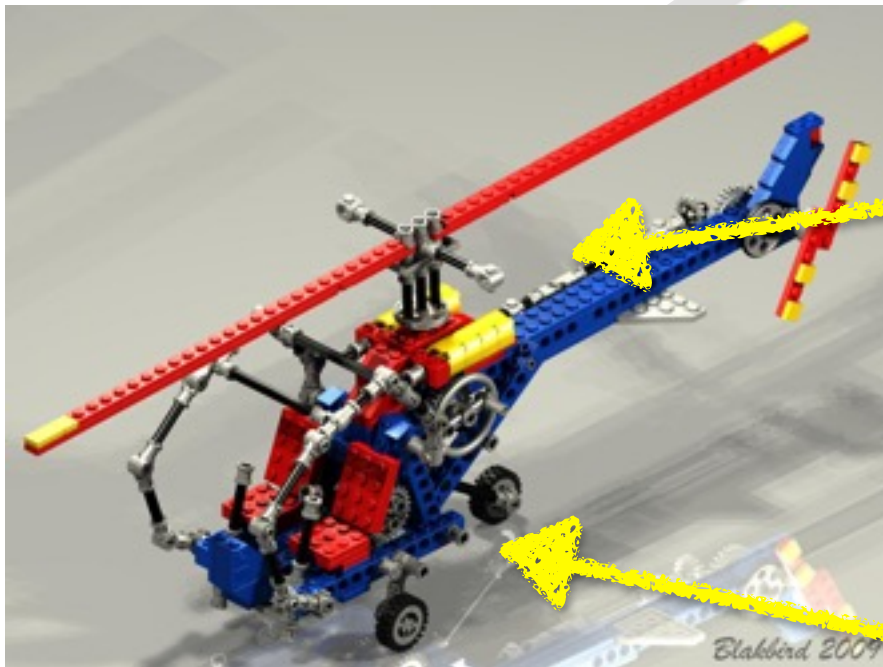
Mecanismos Complexos

– Trens de Pouso



Mecanismos Complexos

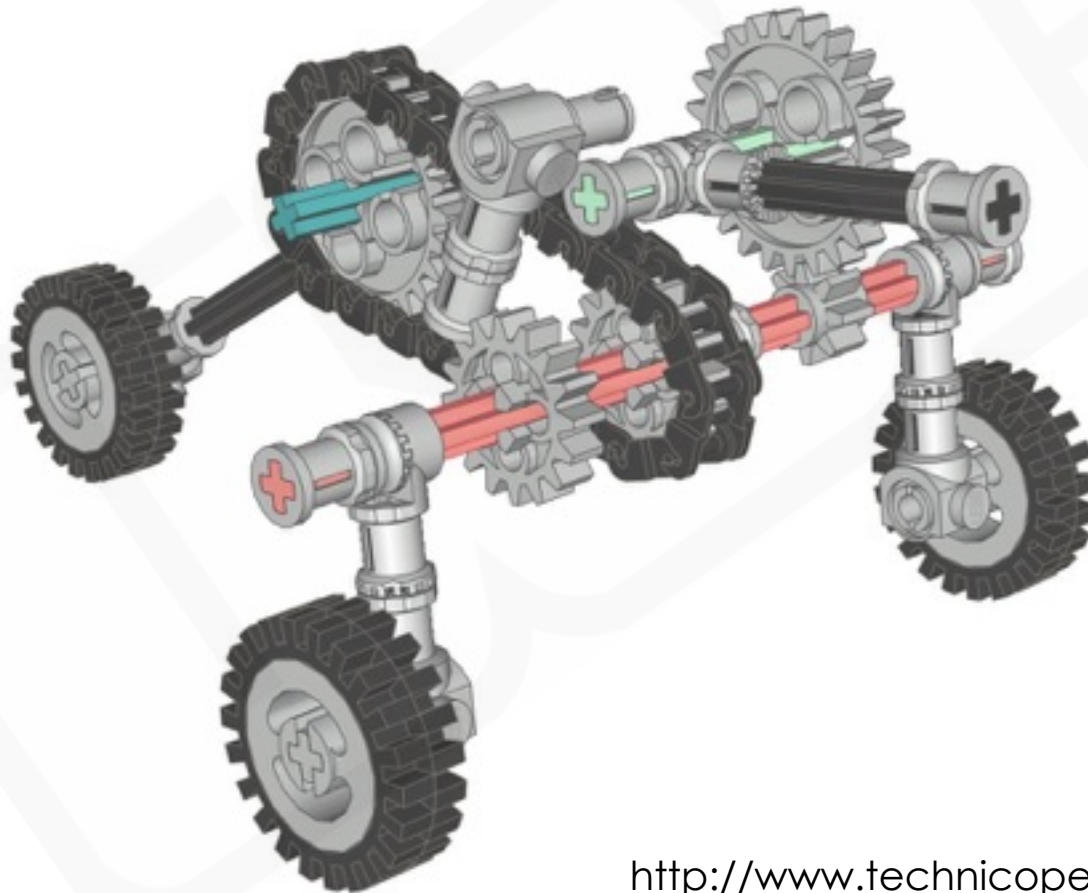
– Trens de Pouso



<http://www.technicopedia.com/8844.html>

Mecanismos Complexos

– Trens de Pouso



<http://www.technicopedia.com/8844.html>

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- MABIE, H.H., OCVIRK, F.W. "Mecanismos e dinâmica das máquinas".
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