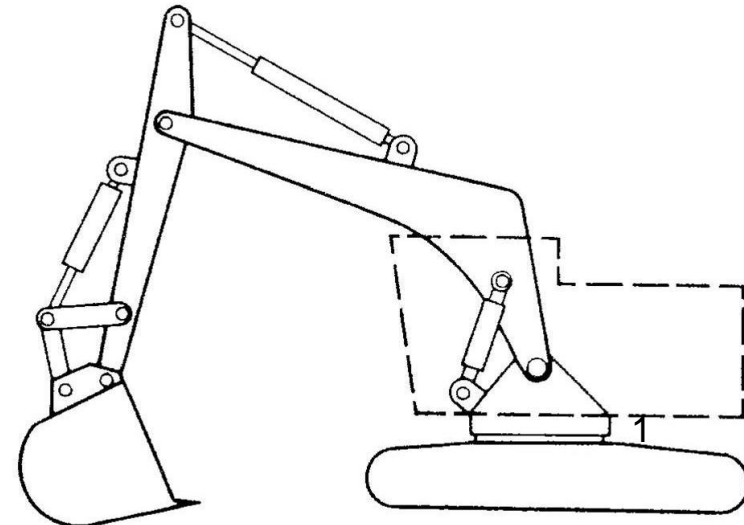


Mecanismos

2-Grau de Liberdade

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04/03/2020



Conteúdo

- Mobilidade de um corpo
- Par cinemático
- Elo
- Cadeia cinemática
- Mecanismo
- Grafo de um mecanismo
- Grau de liberdade de um mecanismo

Definição de Par Cinemático

- Mobilidade
- Par cinemático
- Classificação

Mobilidade

Representa a soma dos movimentos possíveis em cada “direção”.

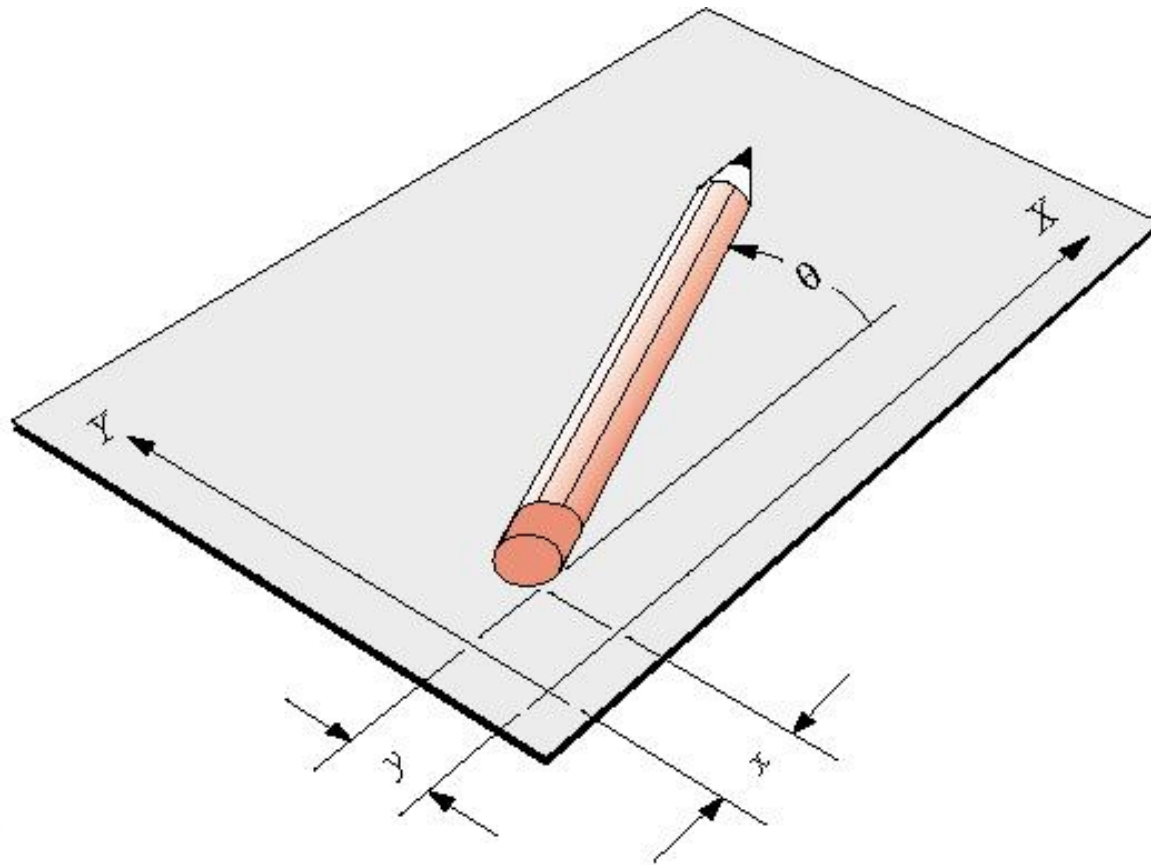


FIGURE 2-1

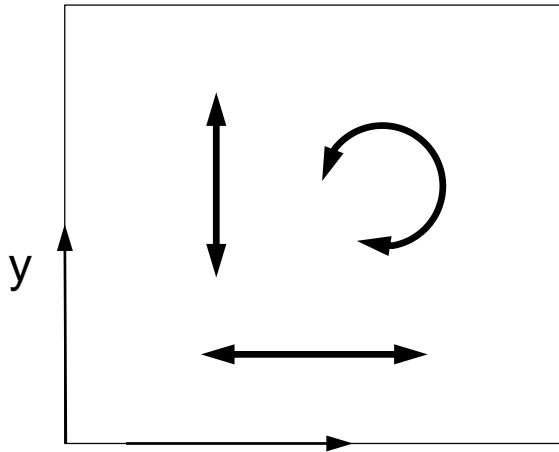
A rigid body in a plane has three *DOF*

Mobilidade

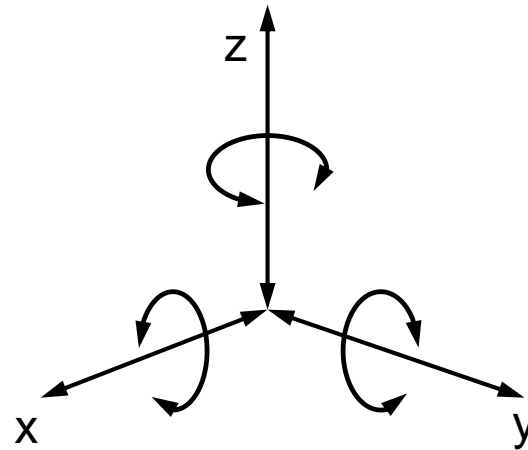
Representa a soma dos movimentos possíveis em cada “direção”.

No plano: $M=3$

No espaço tridimensional: $M=6$



1 rotação
2 translações

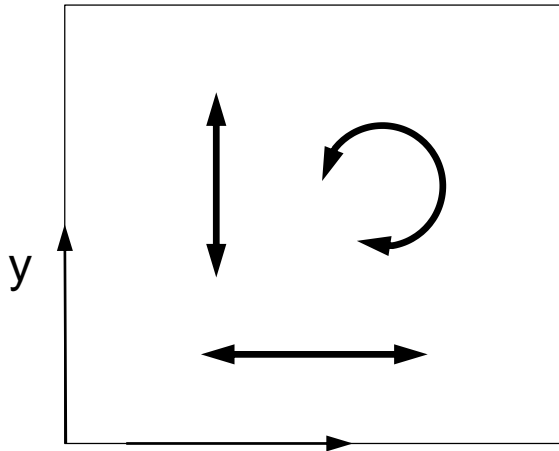


3 rotações
3 translações

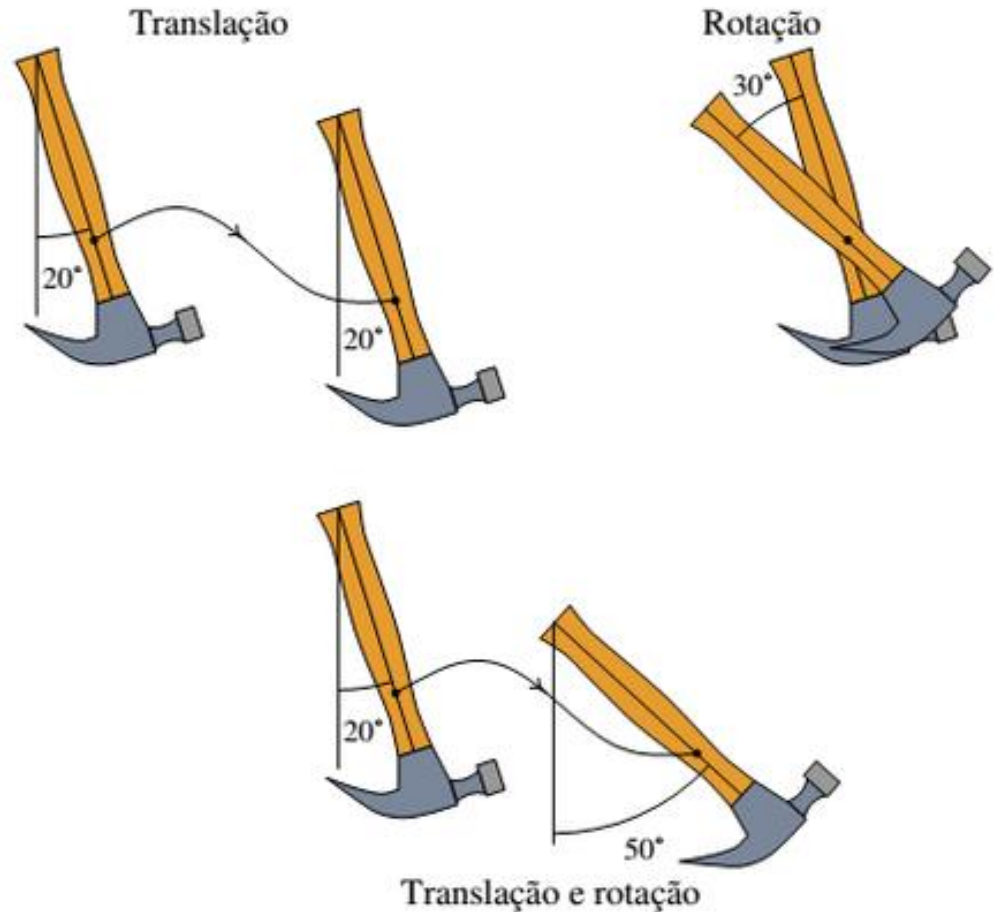
Mobilidade

Representa a soma dos movimentos possíveis em cada “direção”.

No plano: $M=3$



x
1 rotação
2 translações



Junta ou Par cinemático

Par de superfícies mantidas permanentemente em contato de tal forma a produzir um movimento relativo bem definido entre elas.

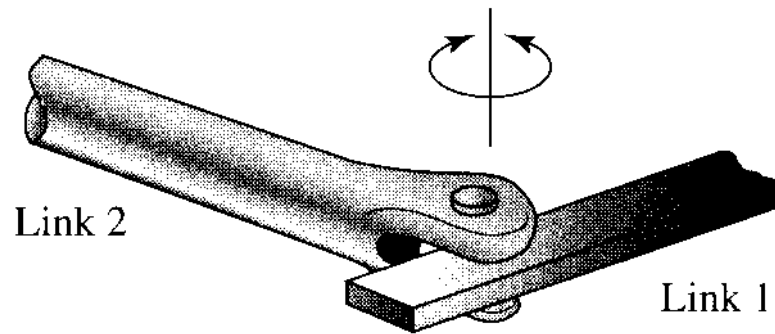
Pode ser:

- **inferior**: o contato é uma superfície
- **superior**: o contato é uma reta ou um ponto

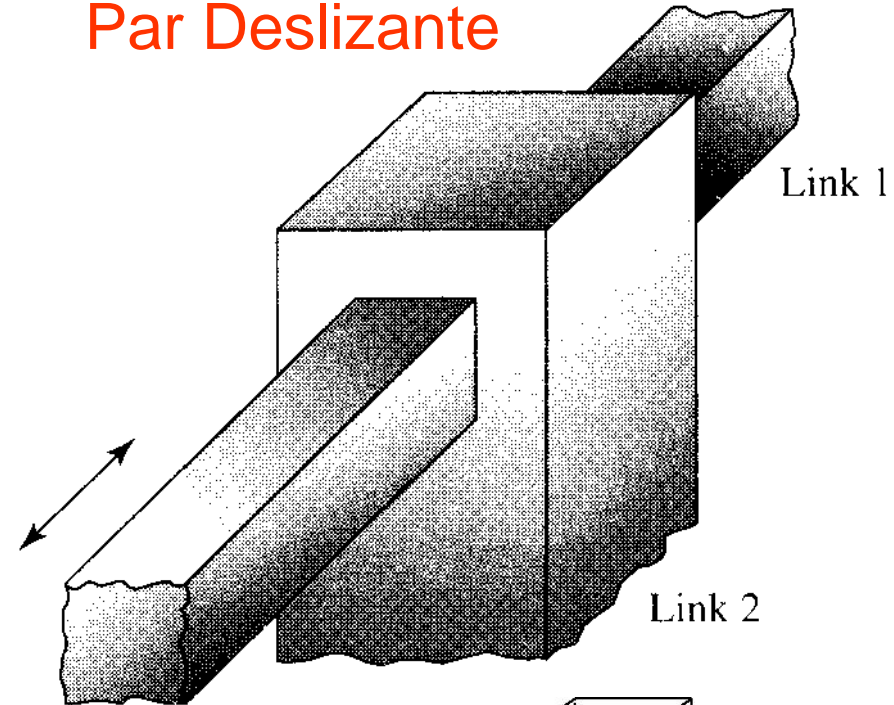
Junta ou Par cinemático Inferior

O contato é uma **superfície**

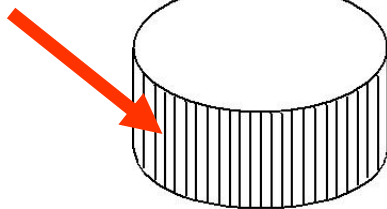
Par Rotativo



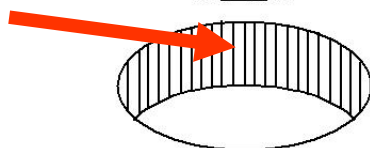
Par Deslizante



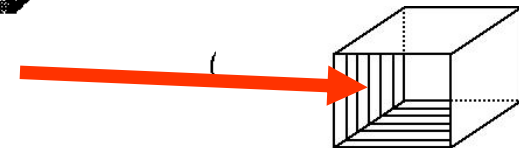
Nó 1 (pino)



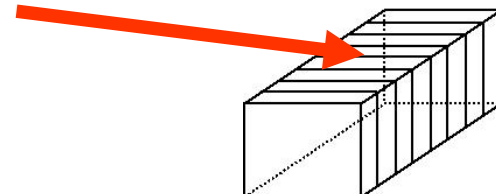
Nó 2 (furo)



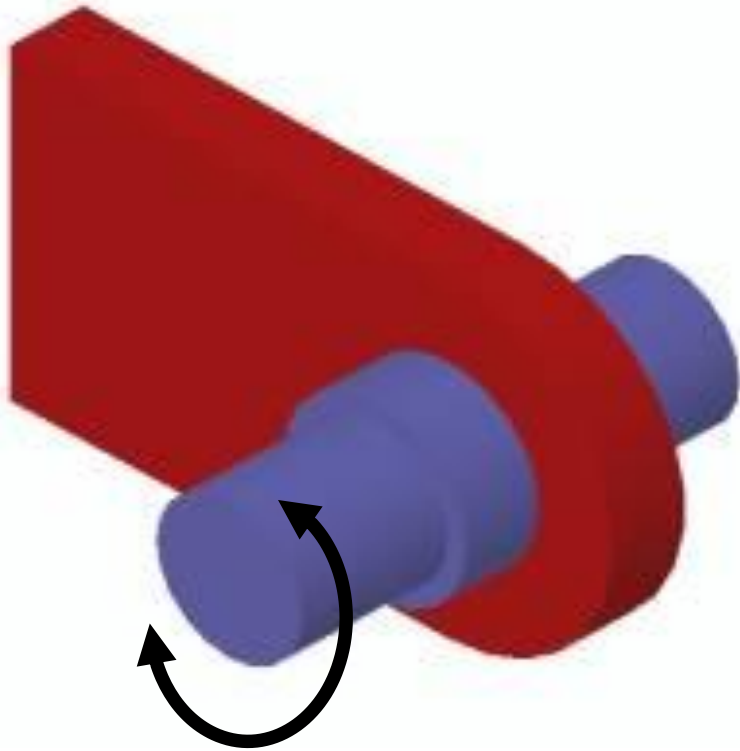
Nó 1 (furo)



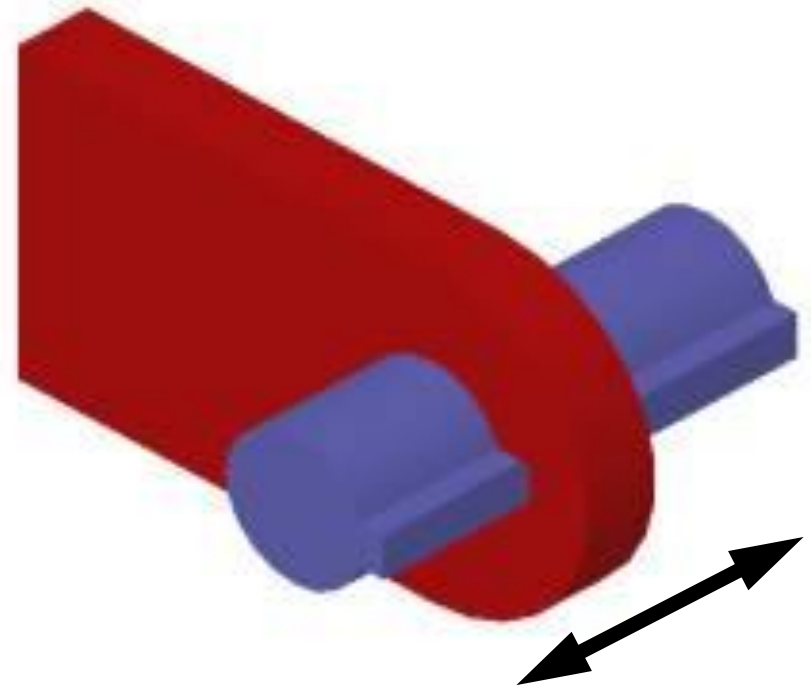
Nó 2 (prisma)



Junta ou Par cinemático Inferior

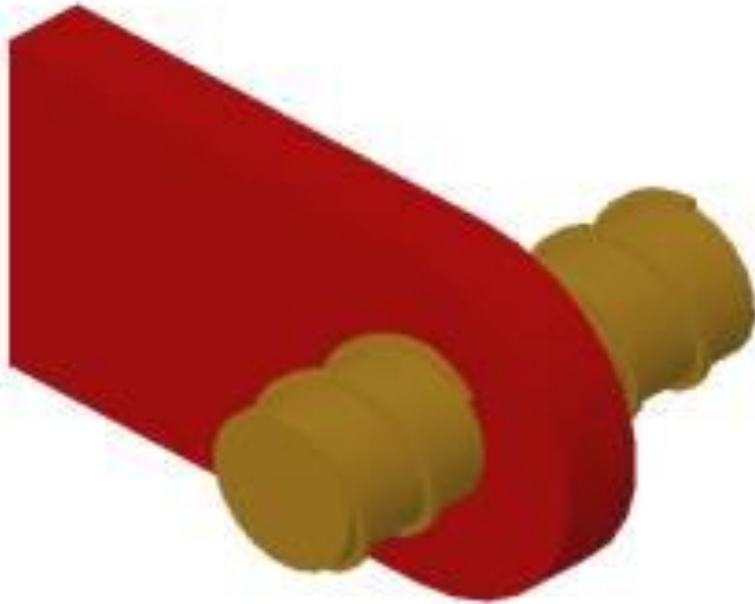


Par Rotativo
1 rotação



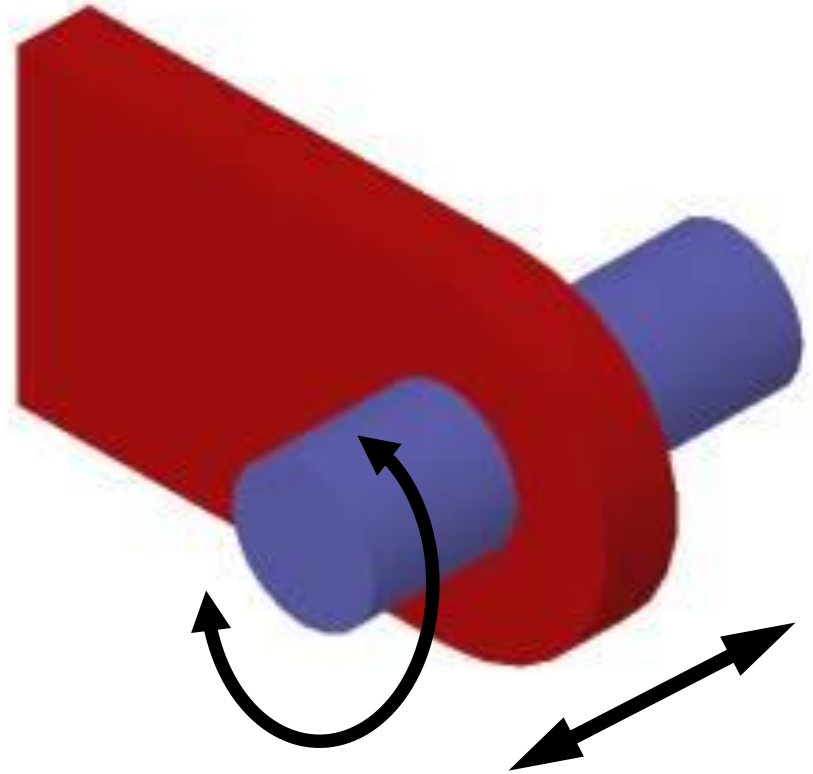
Par Deslizante (prismático)
1 translação

Junta ou Par cinemático Inferior



Par Helicoidal

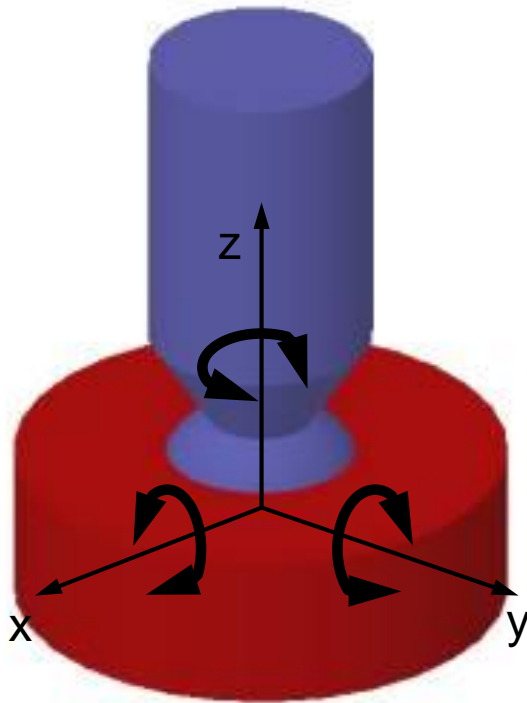
1 rotação **acoplada** a 1 translação



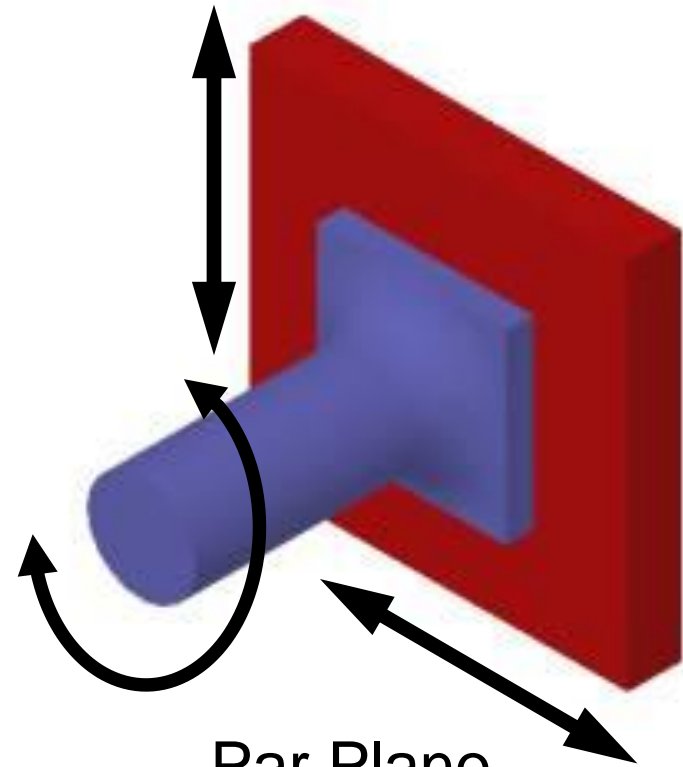
Par Cilíndrico

1 rotação
1 translação

Junta ou Par cinemático inferior



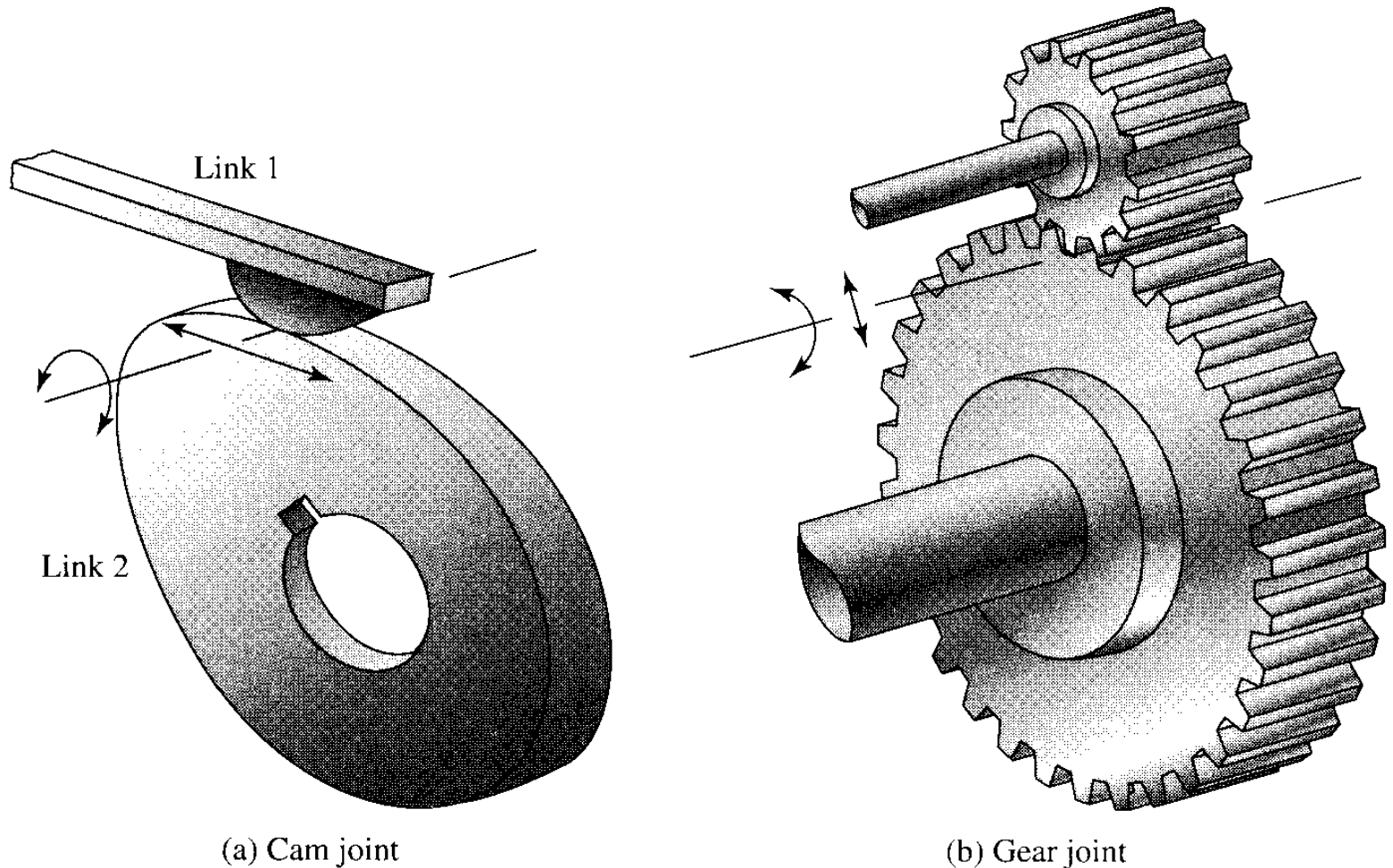
Par Esférico
3 rotações



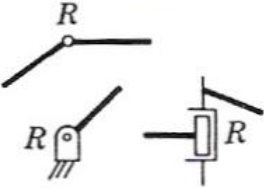
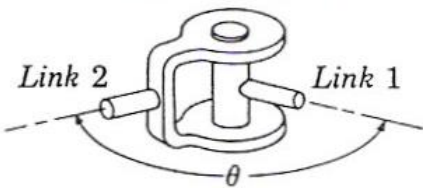
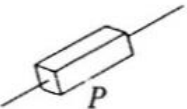
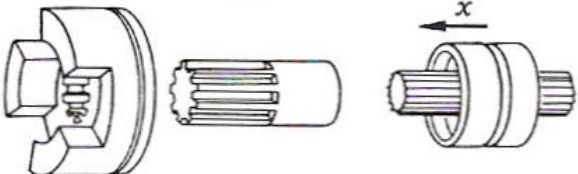
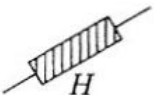
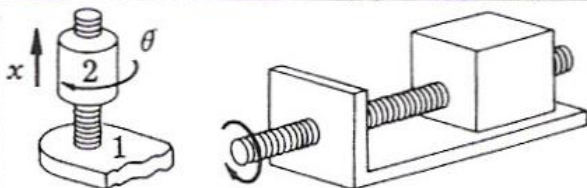
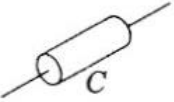

Par Plano
1 rotação
2 translações

Junta ou Par cinemático

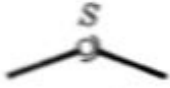
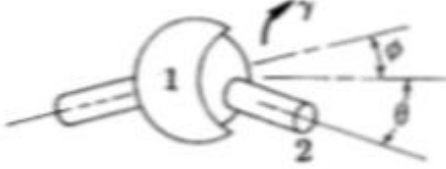
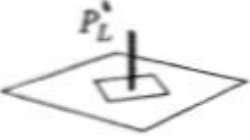
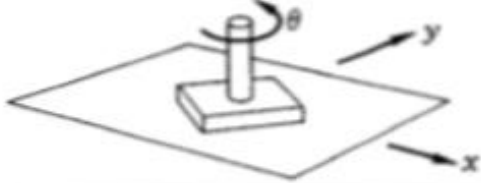
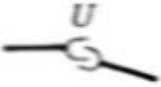
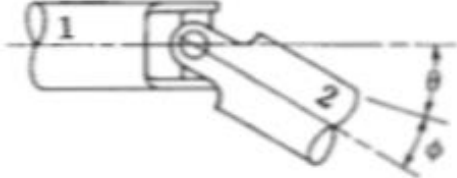
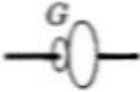


Par cinemático **superior**: o contato é um **ponto** ou uma **linha**



Classificação dos pares cinemáticos

Type of joint (pair)	Lower pair (L) or higher pair (H)	Symbol	Degrees-of-freedom (connectivity) of the joint in a spatial linkage	Schematic representation	Possible configuration	Descriptive example
Revolute	L	R	1 θ			A pin joint that permits rotation only
Prism	L	P	1 x			A straight spline that permits sliding only
Helix	L	H	1 x or θ			Power screw or helical spline
Cylinder	L	C	2 x, θ			A sleeve that permits both rotation and sliding

Classificação dos pares cinemáticos

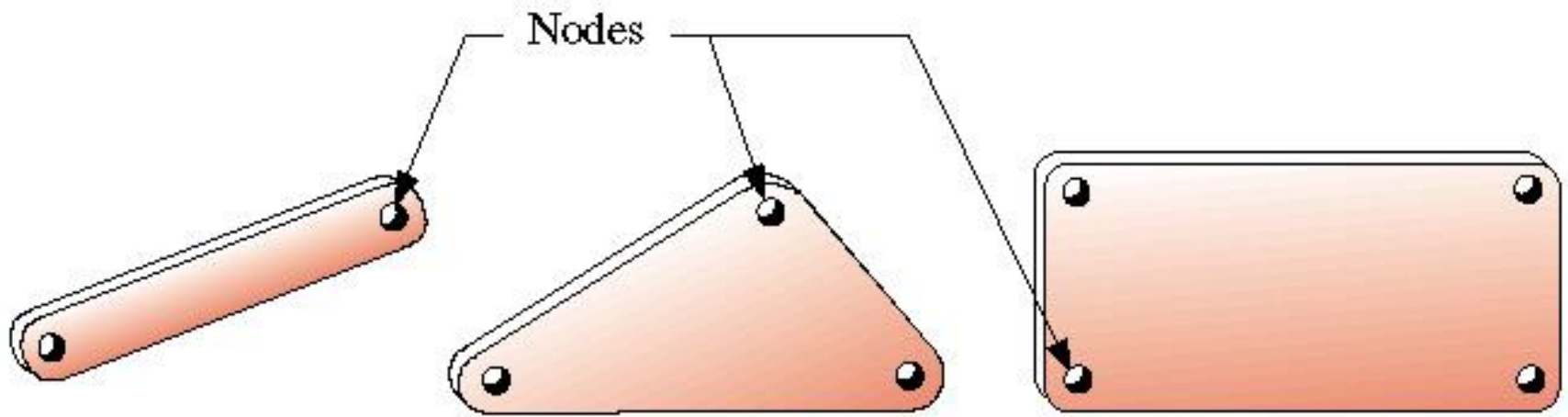
Sphere	L	S	3 θ, ϕ, γ			A ball (and socket) joint permitting rotation in three angular directions
Plane	L	P_L	3 x, y, θ			A surface restraint permitting rotation and motion parallel to the plane of the surface
Universal joint	L	U	2 θ, ϕ			The Hooke-type universal joint that combines two revolute pairs
Spur gear pair	H	G	2 (rolling and sliding)			Spur gears, helical gears, and other gears
Cam pair	H	*	2 (rolling and sliding)	*		Disk cam and follower

Definição de Mecanismo

- Elo
- Cadeia cinemática
- Mecanismo

Elo (*link*)

Corpo rígido composto por dois ou mais nós



Elo Binário

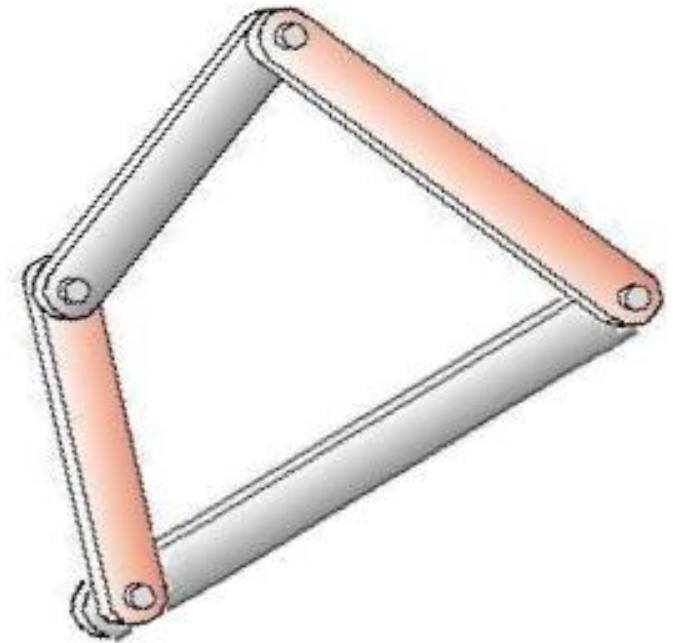
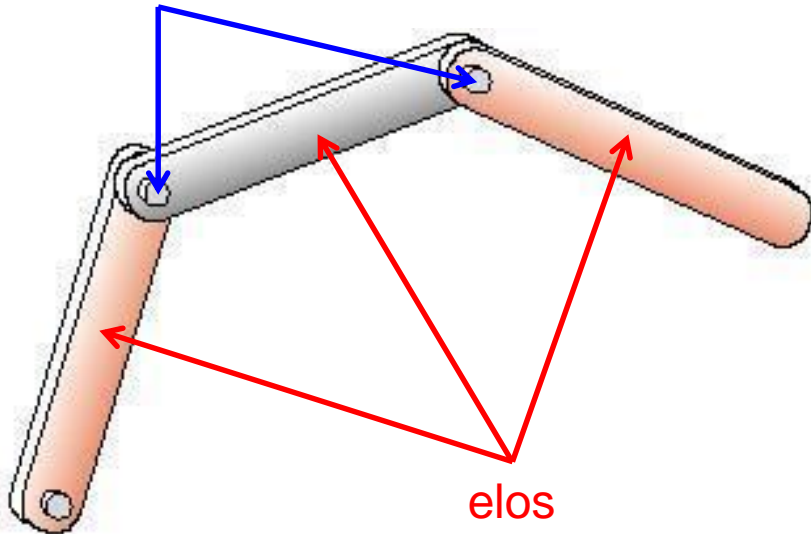
Elo Ternário

Elo Quaternário

Cadeia cinemática

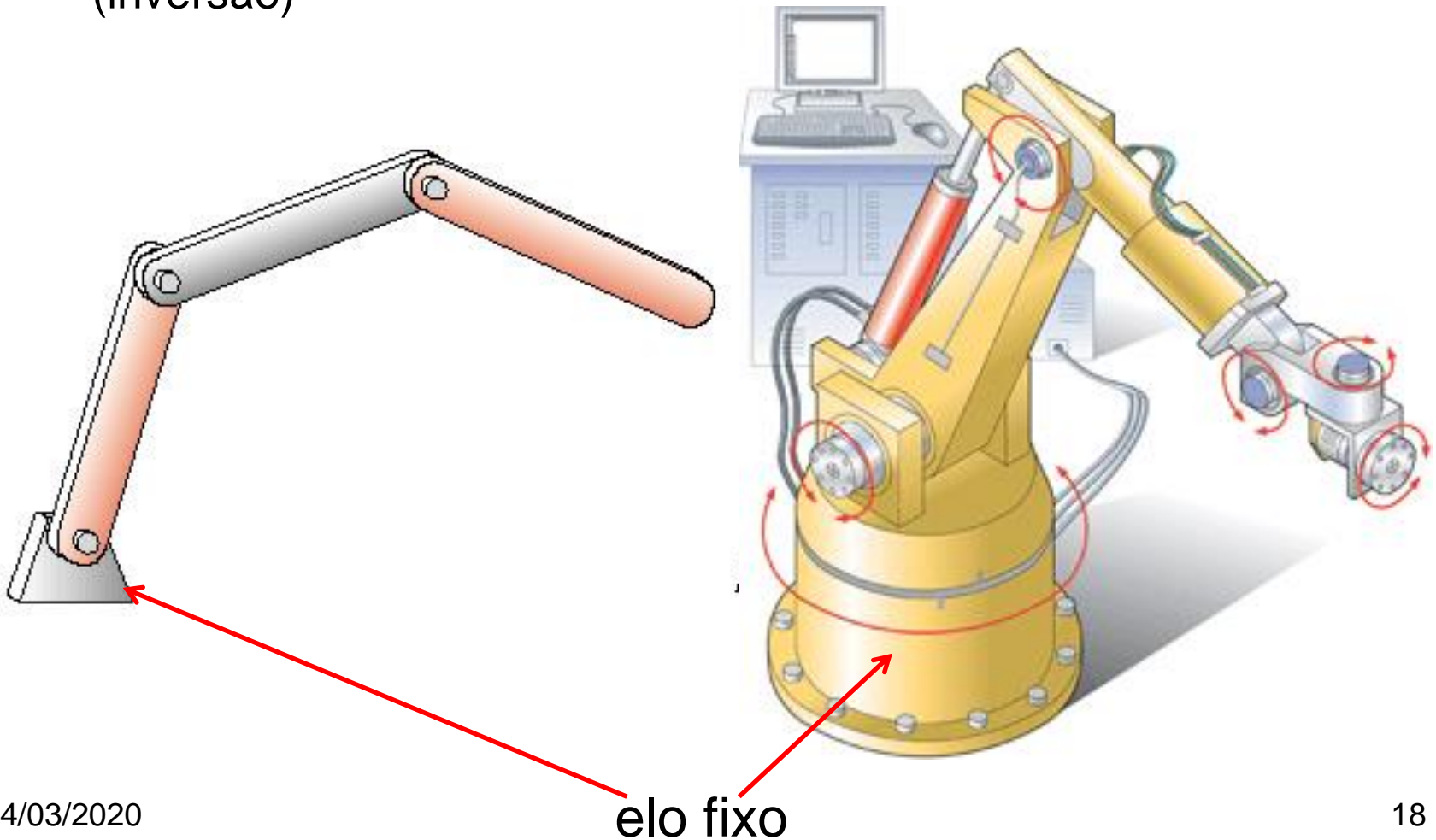
Sistema resultante da conexão de vários **elos** formando um conjunto que ainda pode produzir movimento relativo.

pares cinemáticos



Mecanismo

Def.: Cadeia cinemática onde um dos elos permanece **fixo**.
Fixando-se cada um dos elos tem-se um mecanismo diferente
(inversão)

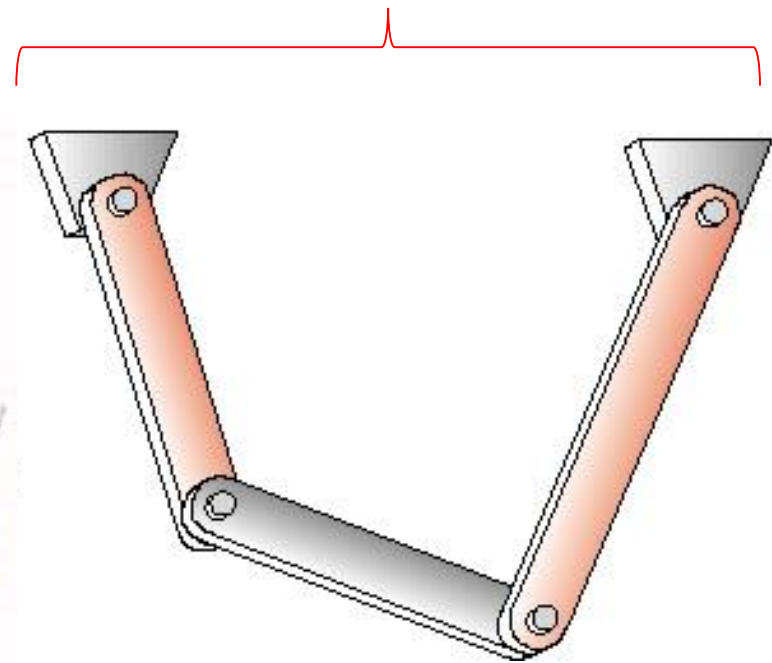
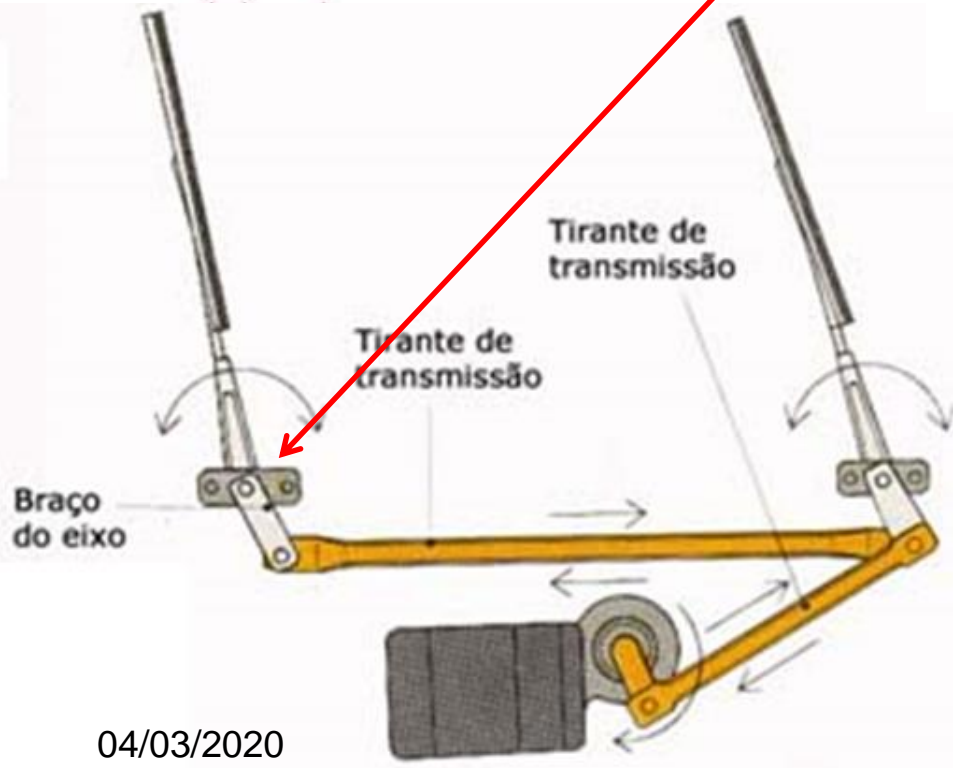


Mecanismo

Def.: Cadeia cinemática onde um dos elos permanece **fixo**.

Fixando-se cada um dos elos tem-se um mecanismo diferente (inversão)

elo fixo

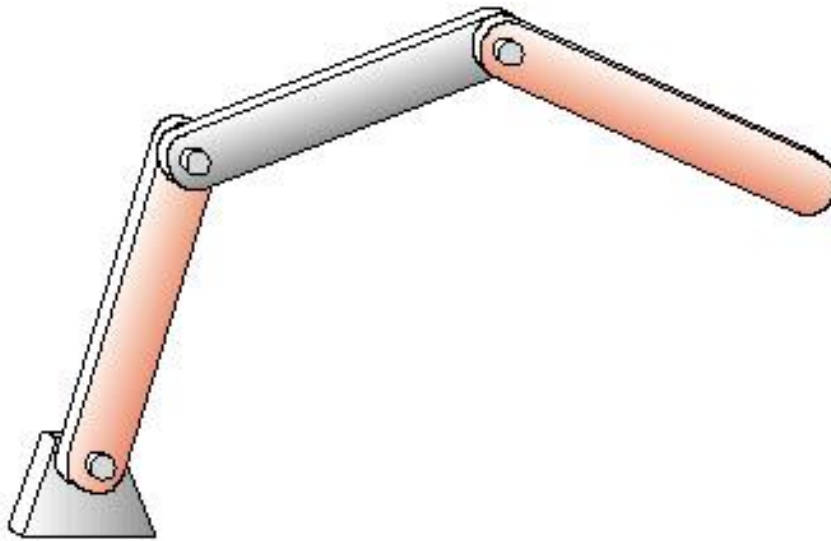


Classificação

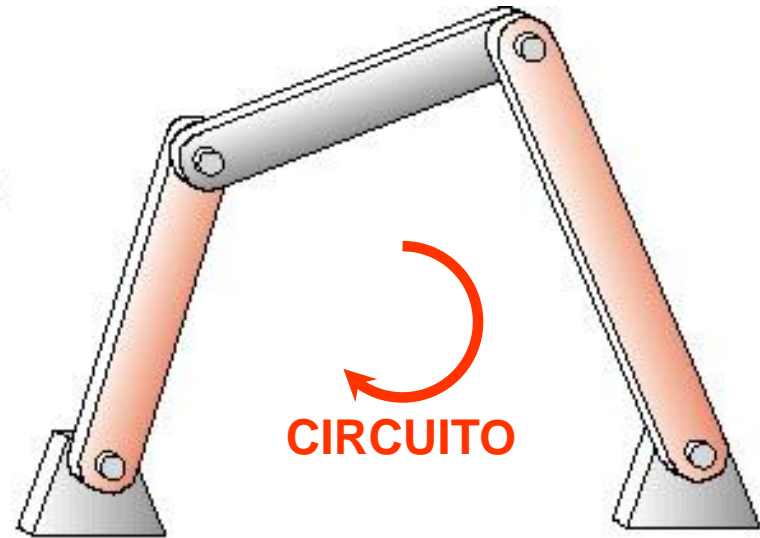
- Quanto ao fechamento da cadeia cinemática
- Quanto ao número de circuitos

Classificação

Quanto ao fechamento da cadeia cinemática



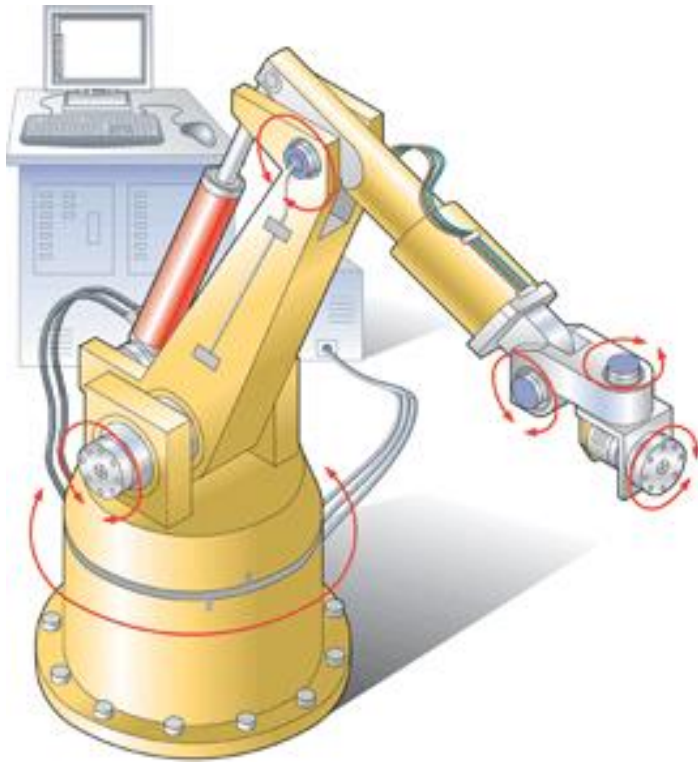
mecanismo de
cadeia cinemática **aberta**



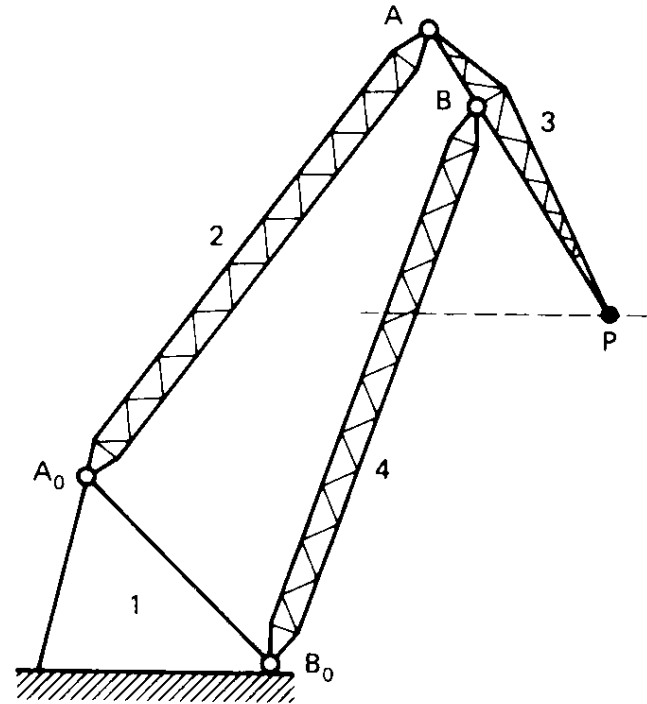
mecanismo de
cadeia cinemática **fechada**

Exemplos

Quanto ao fechamento da cadeia cinemática



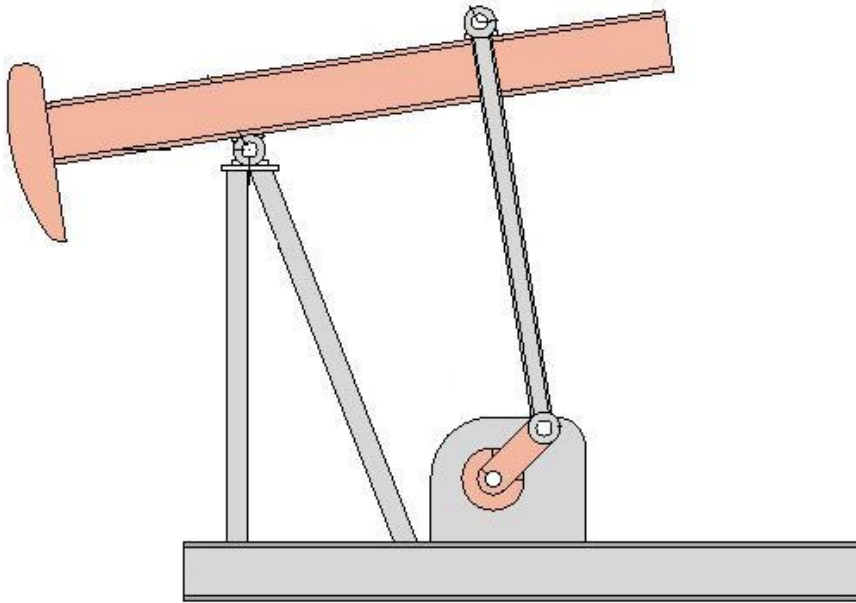
mecanismo de
cadeia cinemática **aberta**



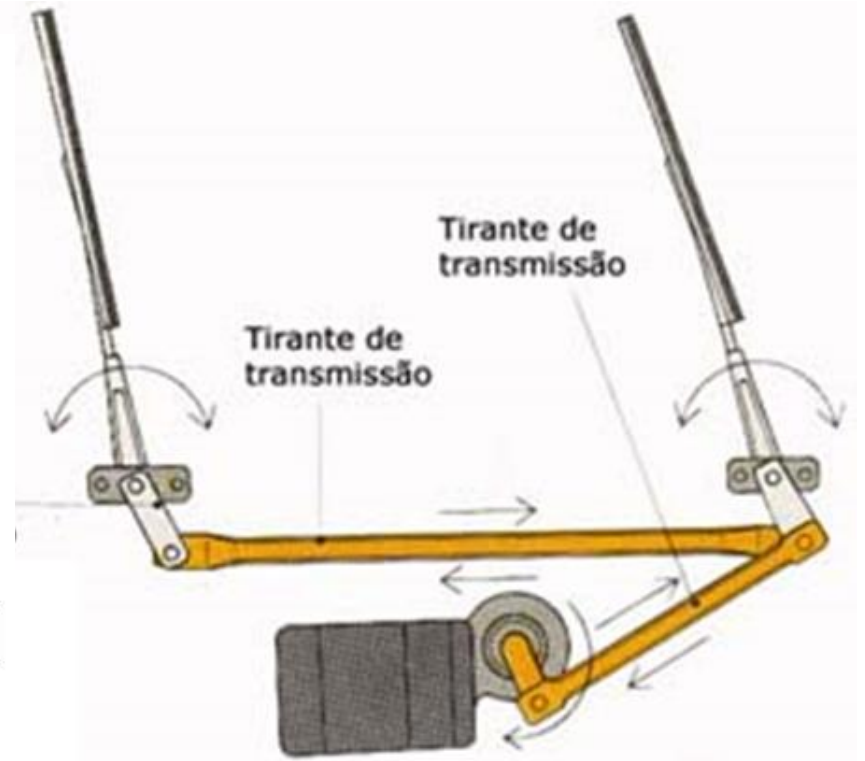
mecanismo de
cadeia cinemática **fechada**

Classificação

Quanto ao número de circuitos

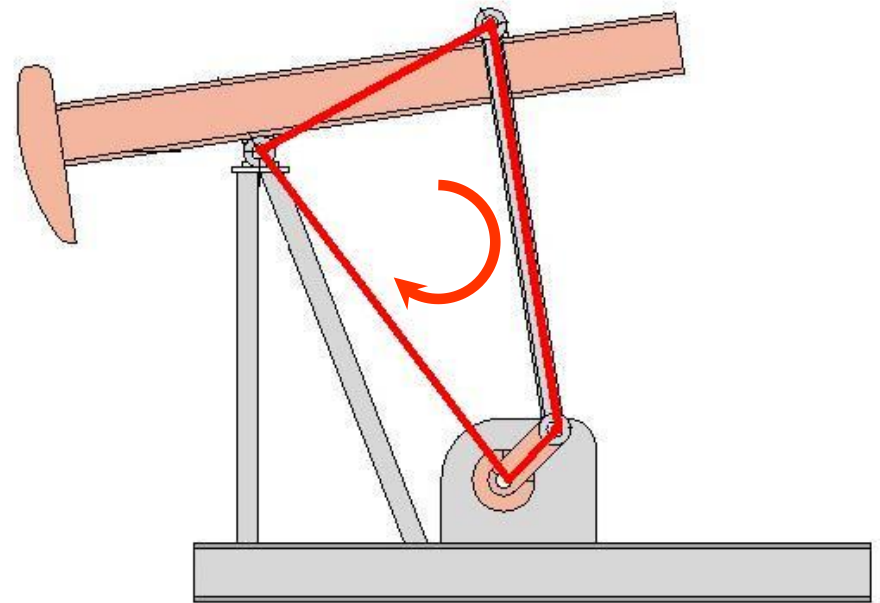
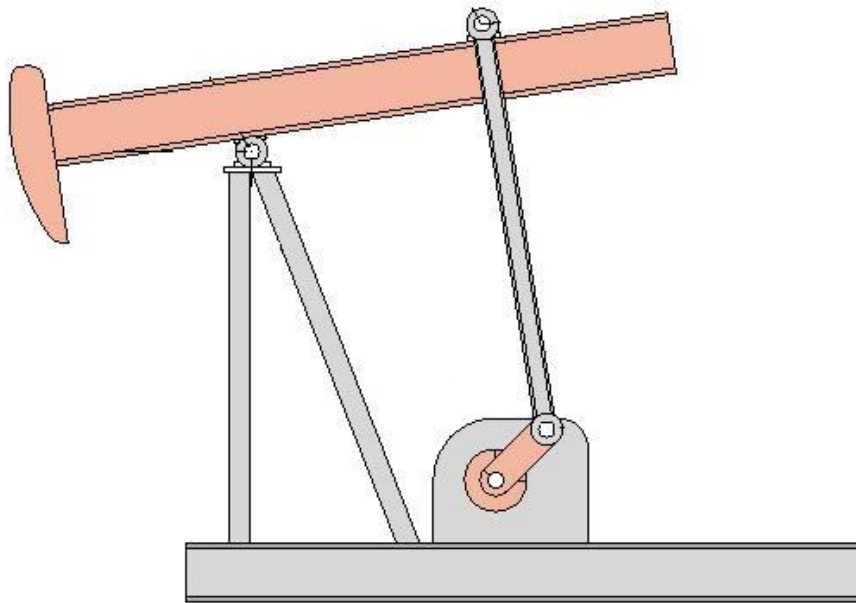


Cadeia SIMPLES
1 circuito

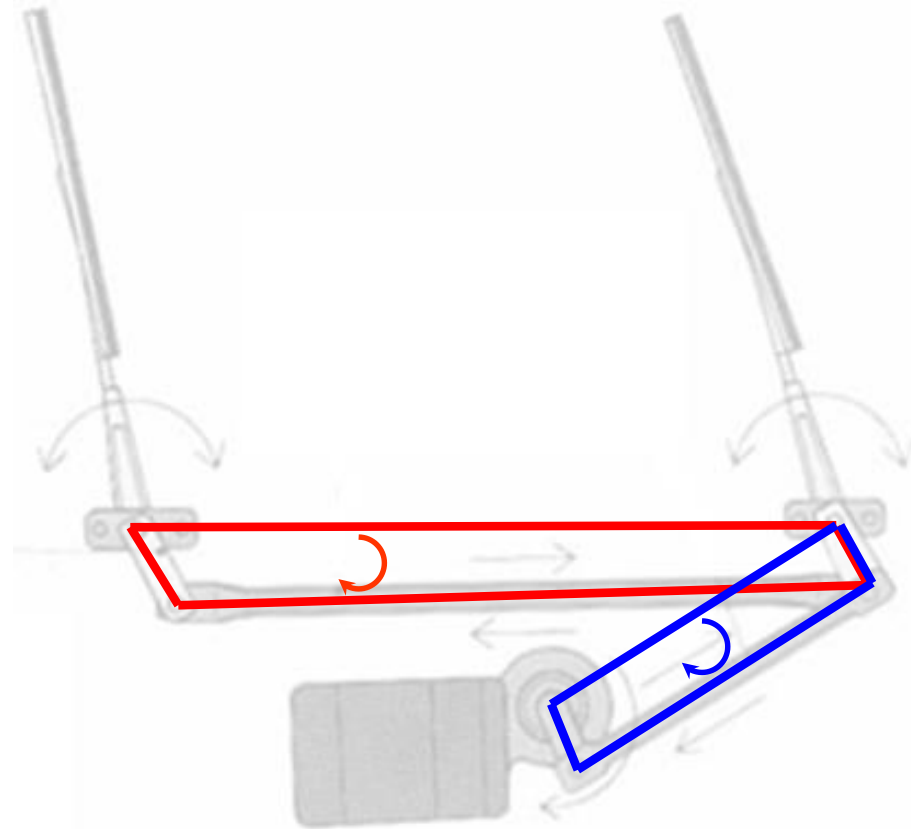
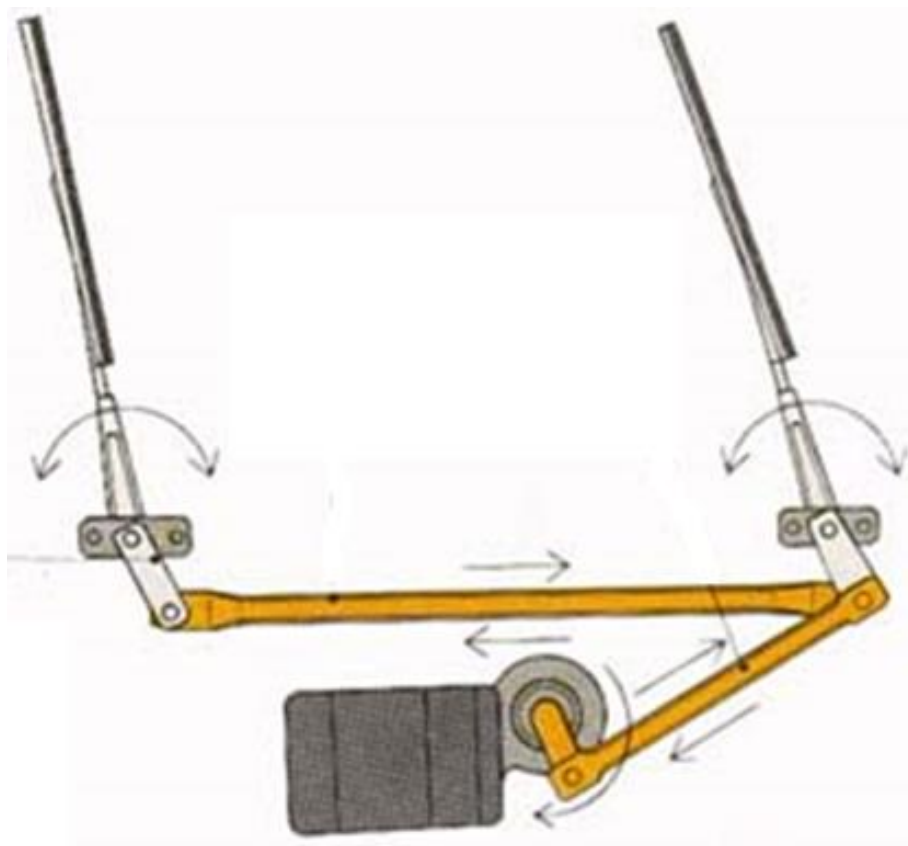


Cadeia COMPOSTA
mais de 1 circuito

Mecanismo de cadeia cinemática simples



Mecanismo de cadeia cinemática composta

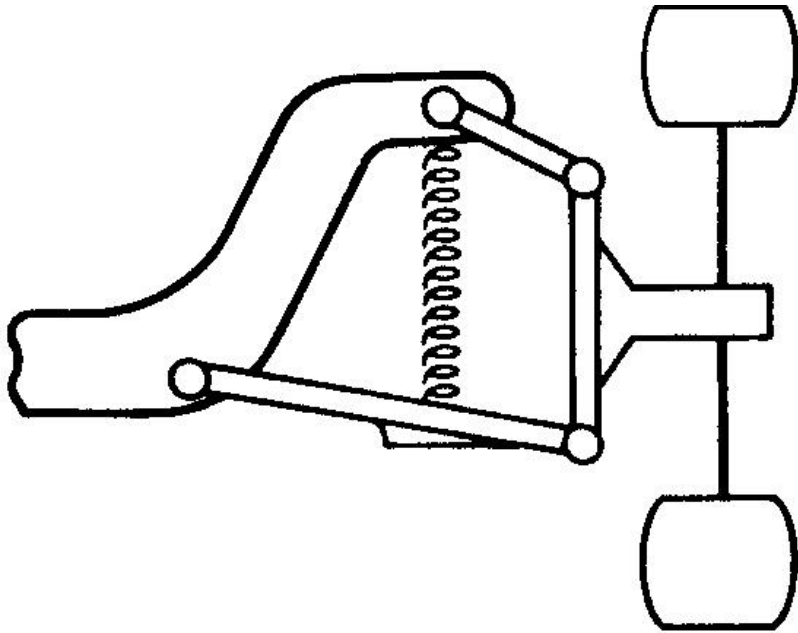


Representação de um Mecanismo

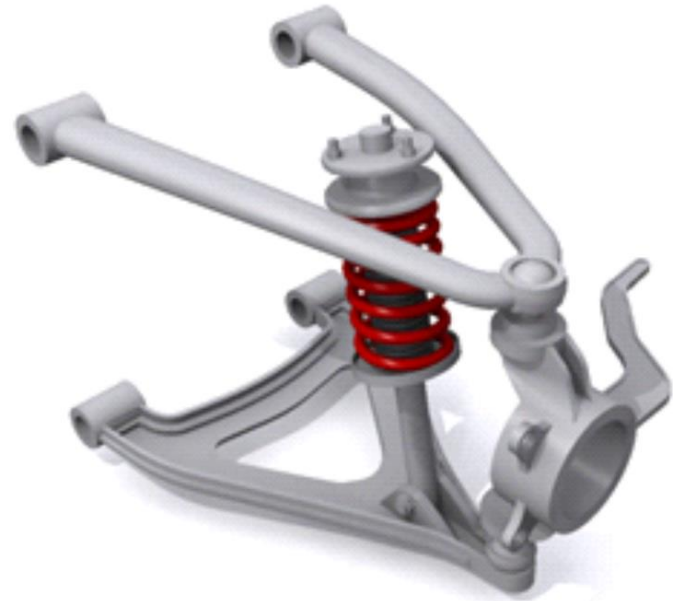
- Grau de detalhamento
- Cadeia cinemática
- Grafo

Representação

Quanto ao grau de detalhamento



mecanismo plano



mecanismo espacial

Representação

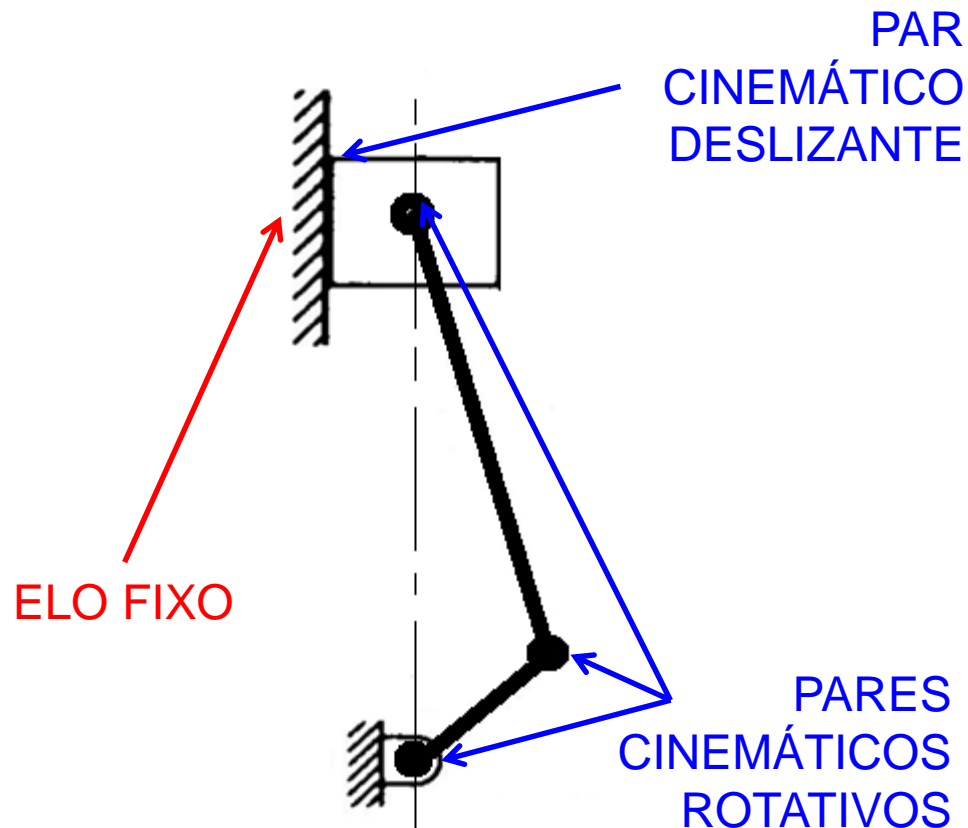
Quanto ao grau de detalhamento



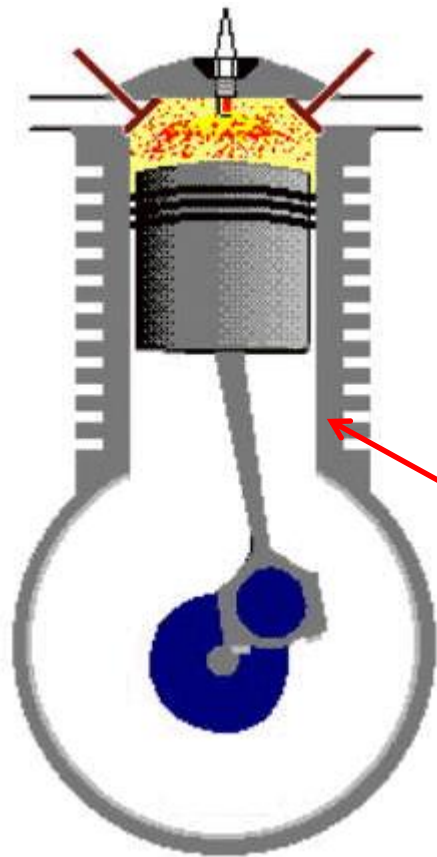
mecanismo espacial

Representação da cadeia cinemática

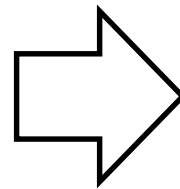
- Elos:
 - móveis: linhas ou polígonos
 - fixo: apenas os pares cinemáticos



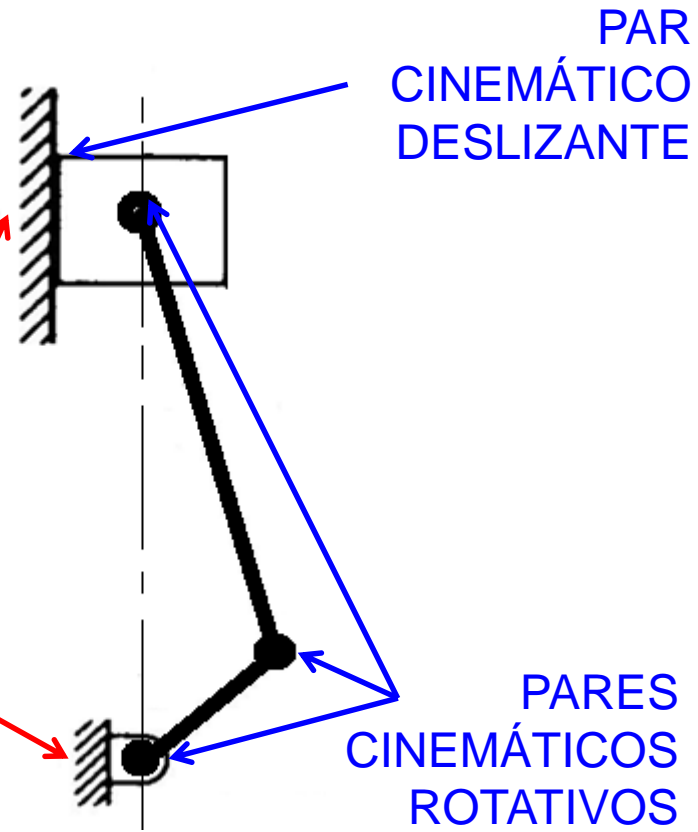
Representação do mecanismo



Representação real



ELO FIXO



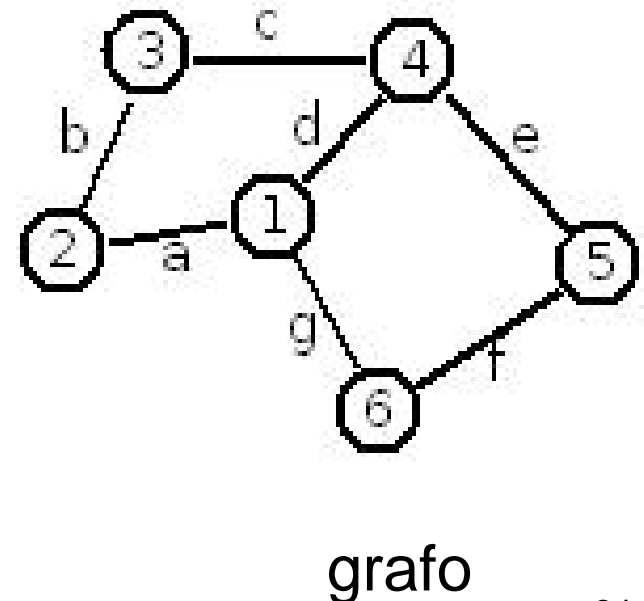
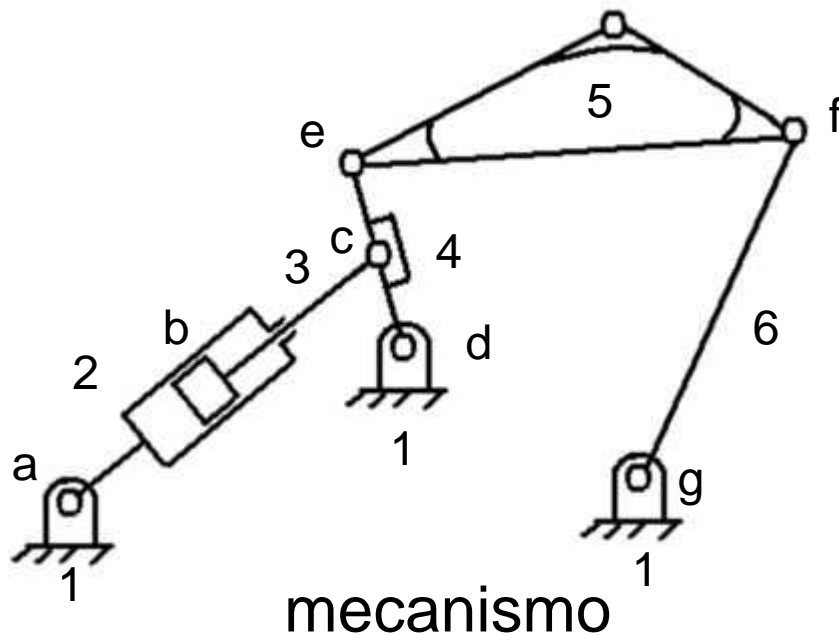
Representação simplificada

Representação por meio de um Grafo

Def.: **Grafo de Conectividade** é um polígono que representa as conexões (ligações) da cadeia cinemática.

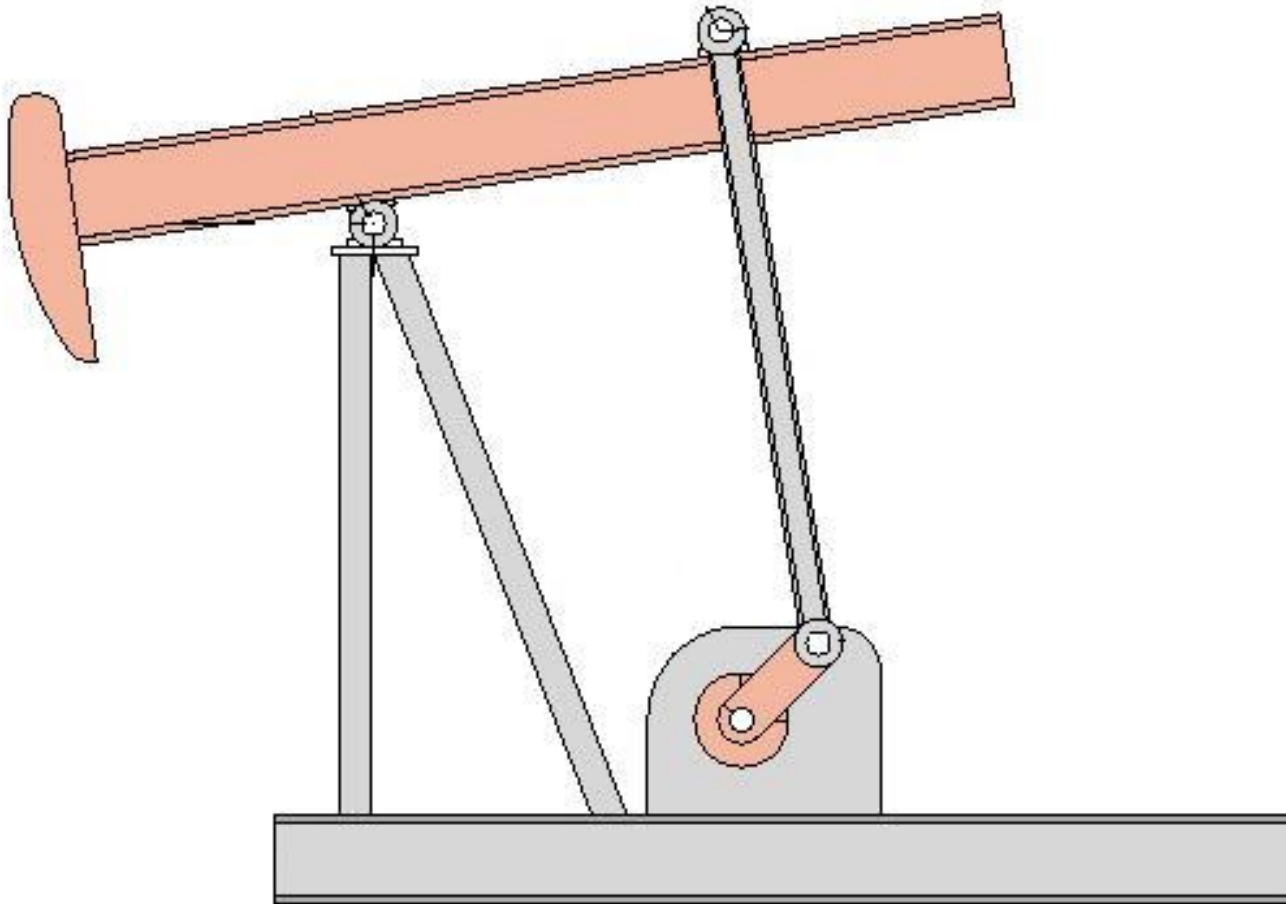
Vértices  Elos

Arestas  Pares cinemáticos (conectividade)



Exemplo 1

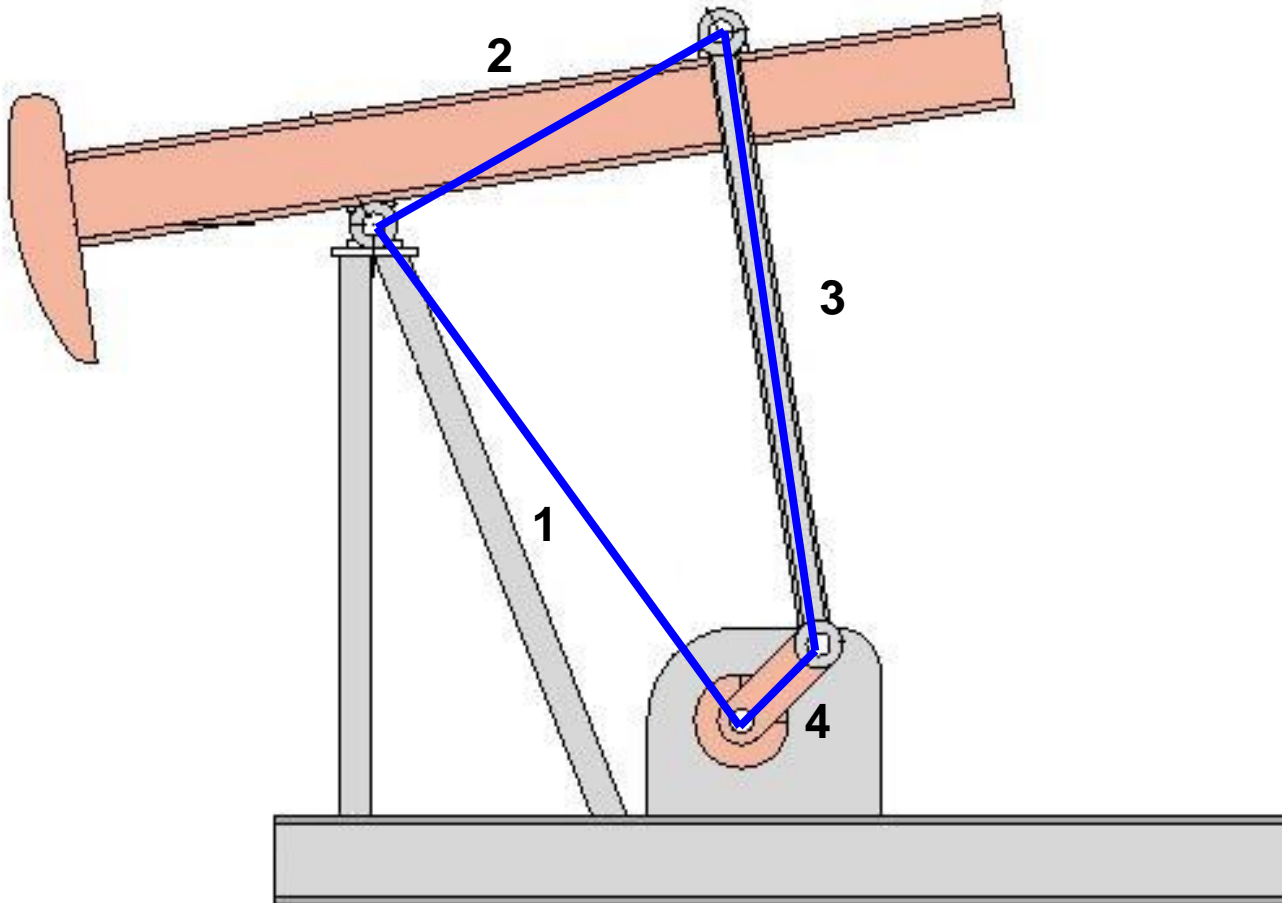
Bomba de petróleo



Exemplo 1

1-Identificação dos elos

números

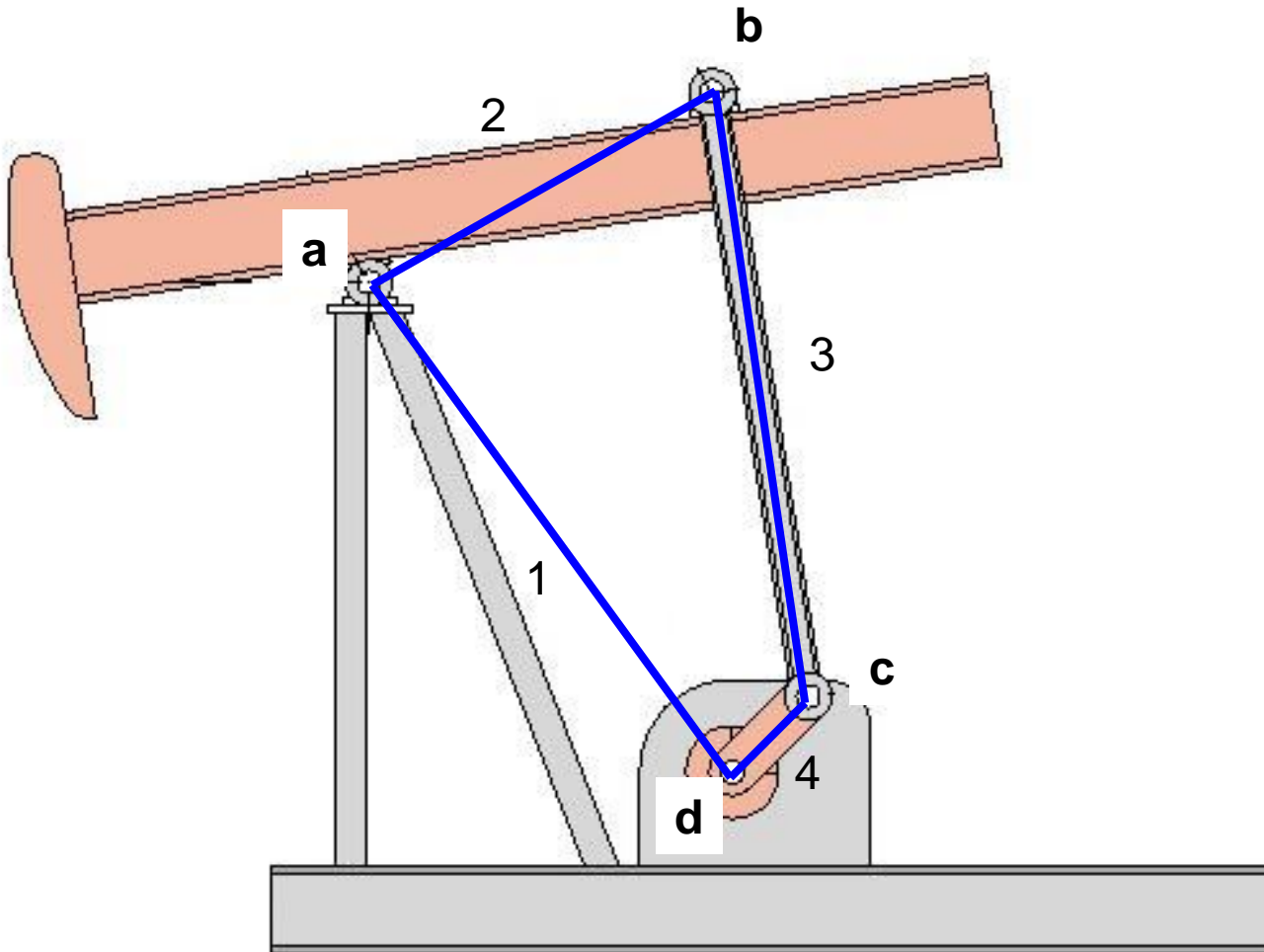


Exemplo 1

1-Identificação dos elos

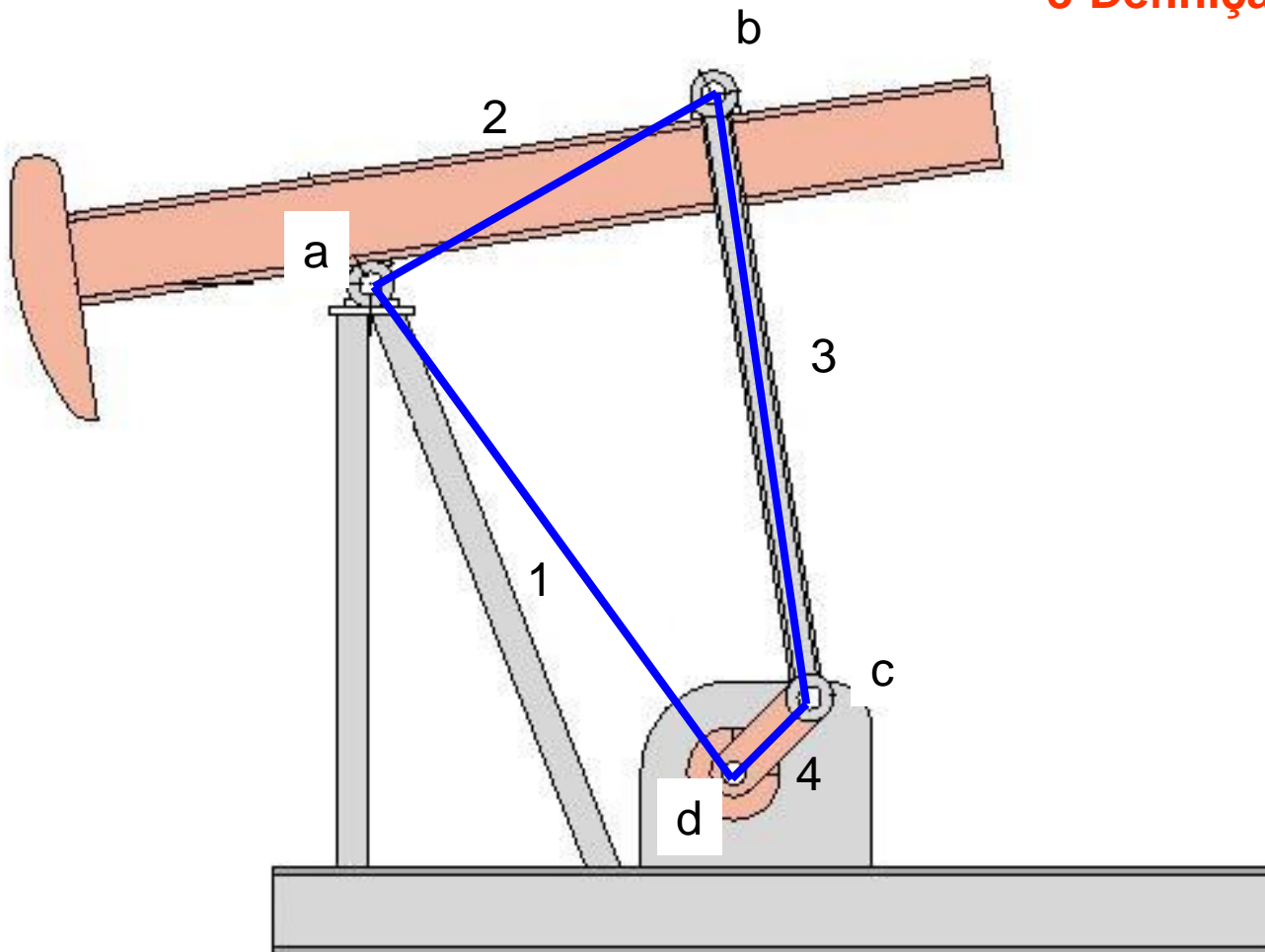
2-Identificação dos pares cinemáticos

letras



Exemplo 1

- 1-Identificação dos elos
- 2-Identificação dos pares cinemáticos
- 3-Definição dos vértices**



elos

2

3

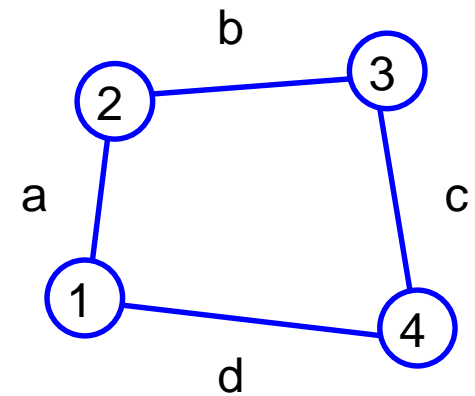
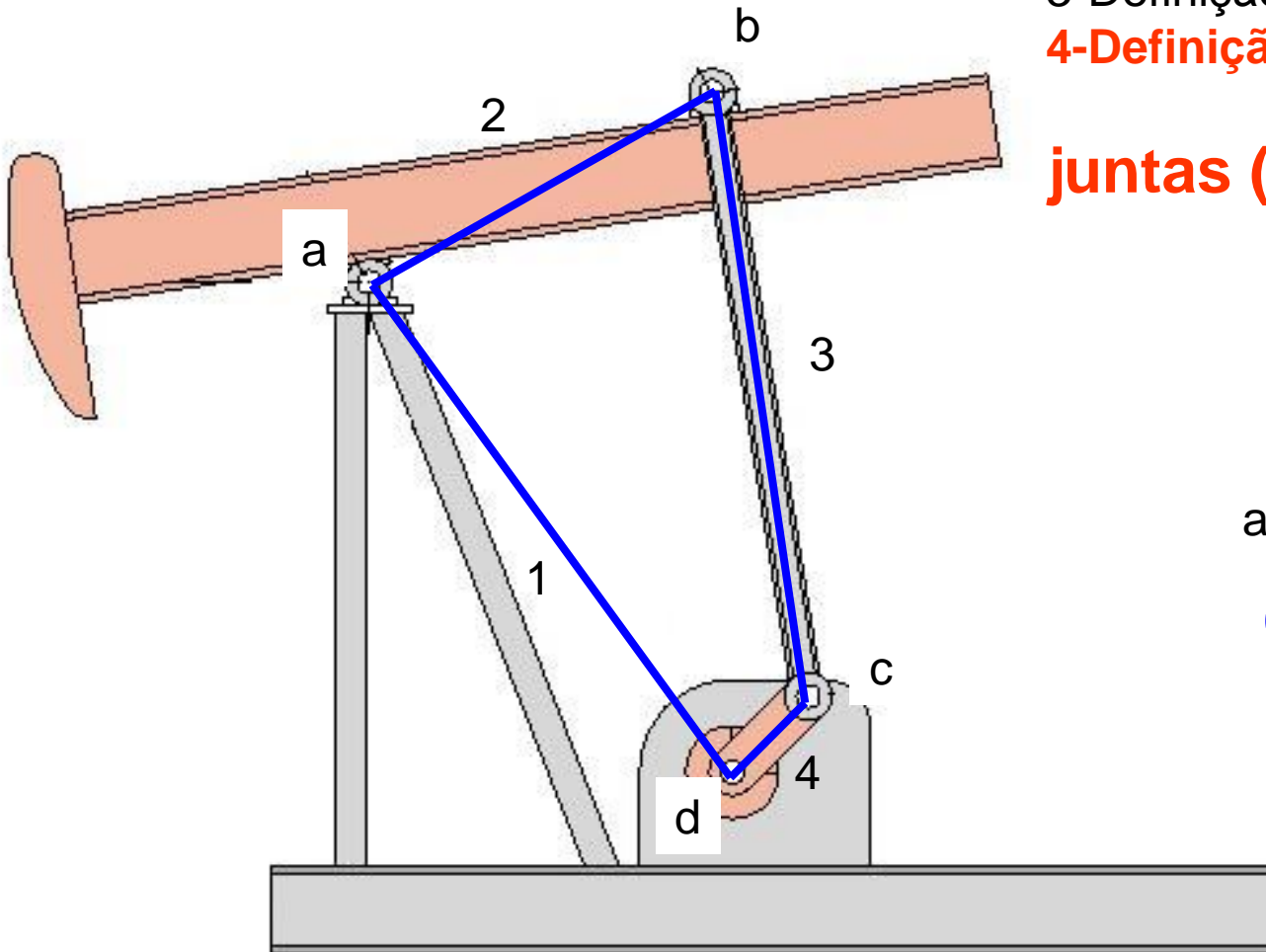
1

4

Exemplo 1

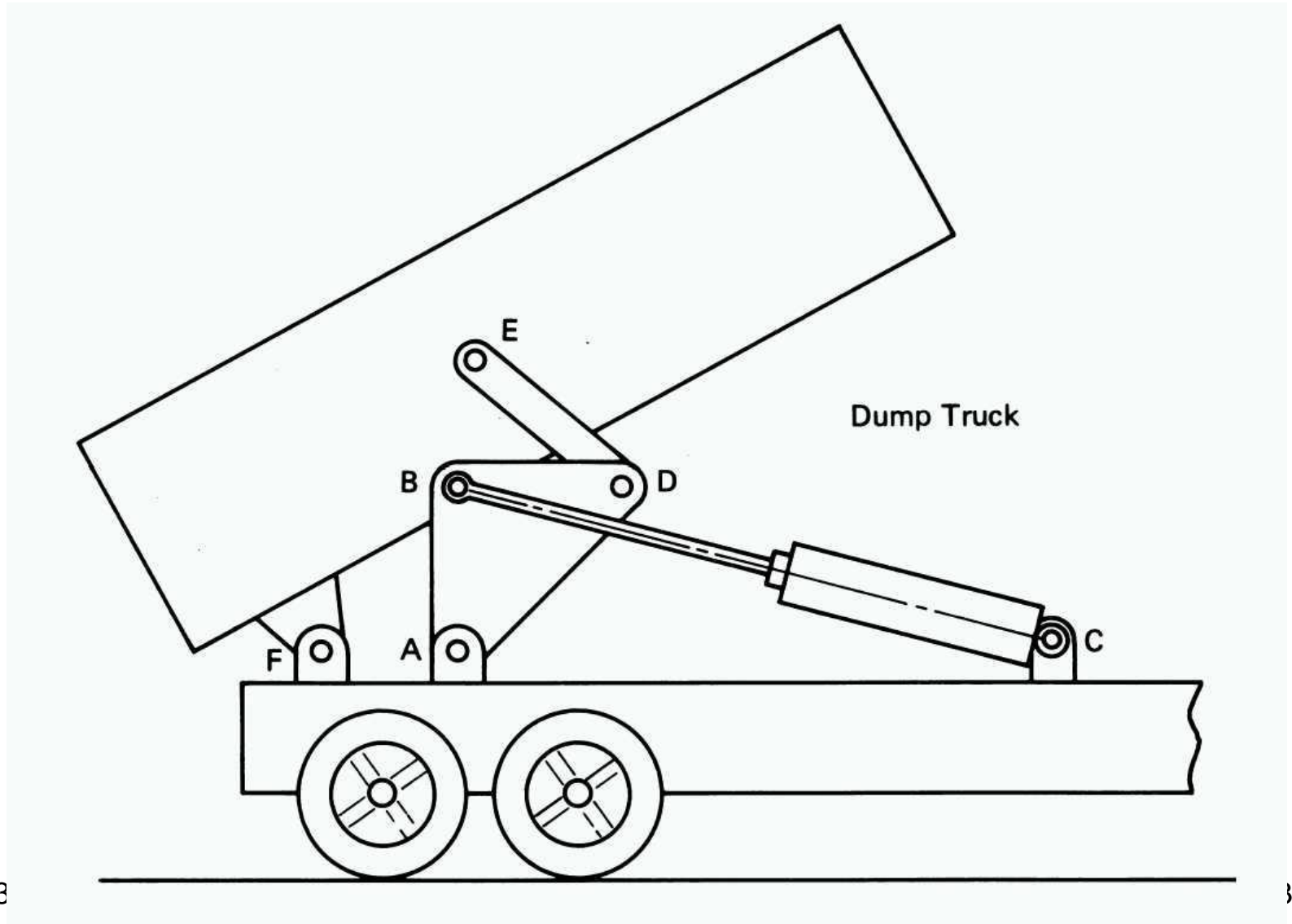
- 1-Identificação dos elos
- 2-Identificação dos pares cinemáticos
- 3-Definição dos vértices
- 4-Definição das arestas**

juntas (pares cinemáticos)



Exemplo 2

Caçamba



Grau de liberdade de um Mecanismo

- Critério de Gruebler

Graus de liberdade (F) de um mecanismo

- Número de acionamentos necessários para movimentar o mecanismo.
- Quantidade de parâmetros independentes necessária para especificar a posição de cada elo.

Critério de Gruebler: $F = 3.(N - 1) - 2.P1 - P2$

F – número de graus de liberdade do mecanismo

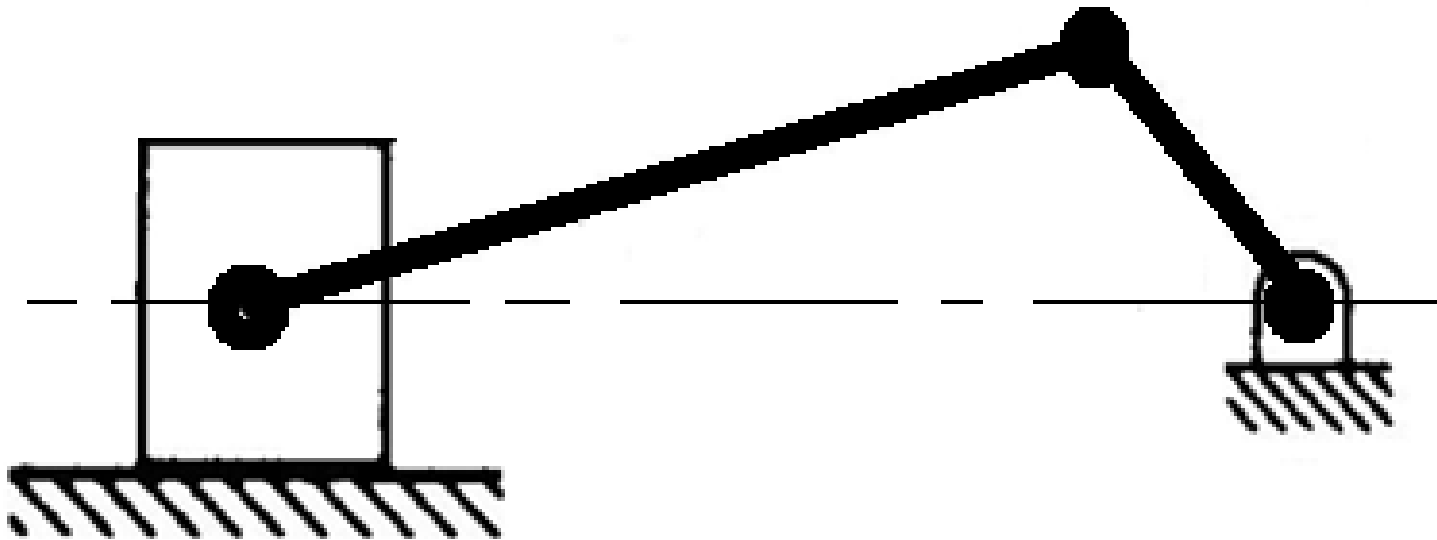
N – número total de elos do mecanismo

P1 – número de pares cinemáticos com 1 g.l.

P2 – número de pares cinemáticos com 2 g.l.

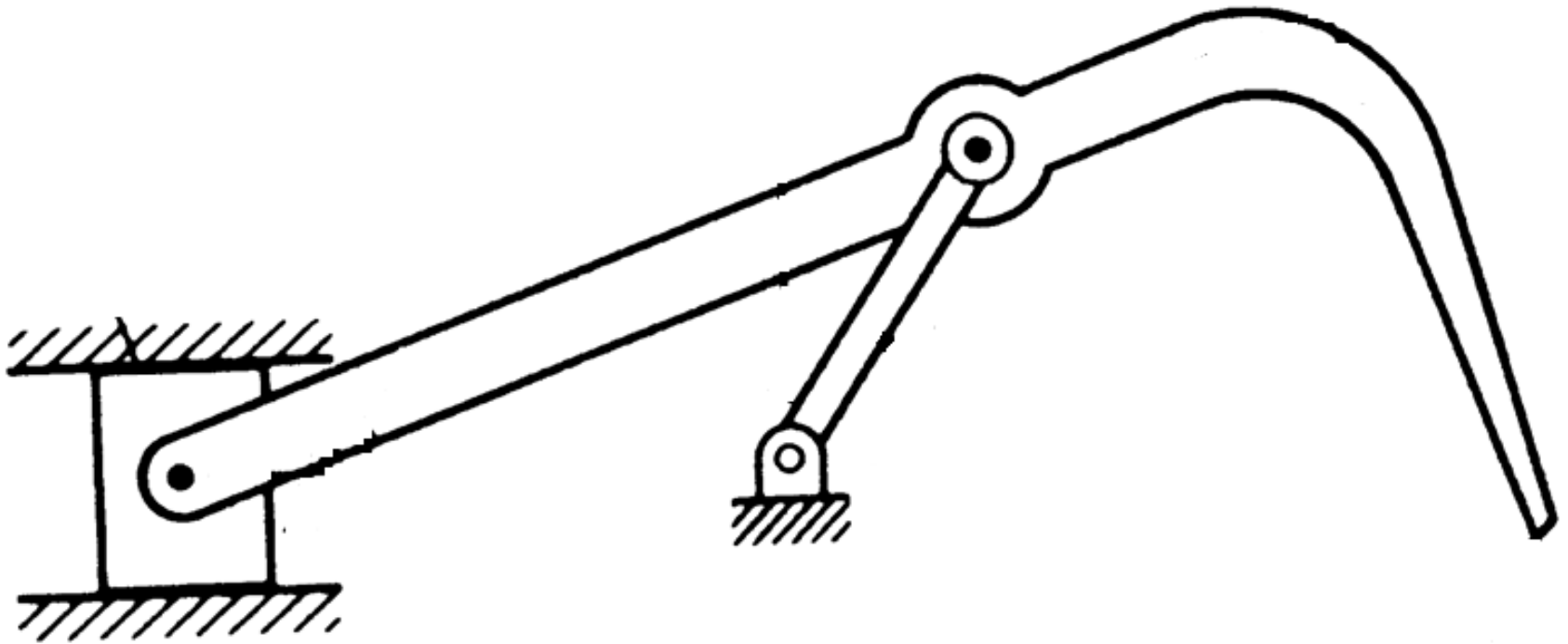
Graus de liberdade (F) de um mecanismo

Exemplo 1:



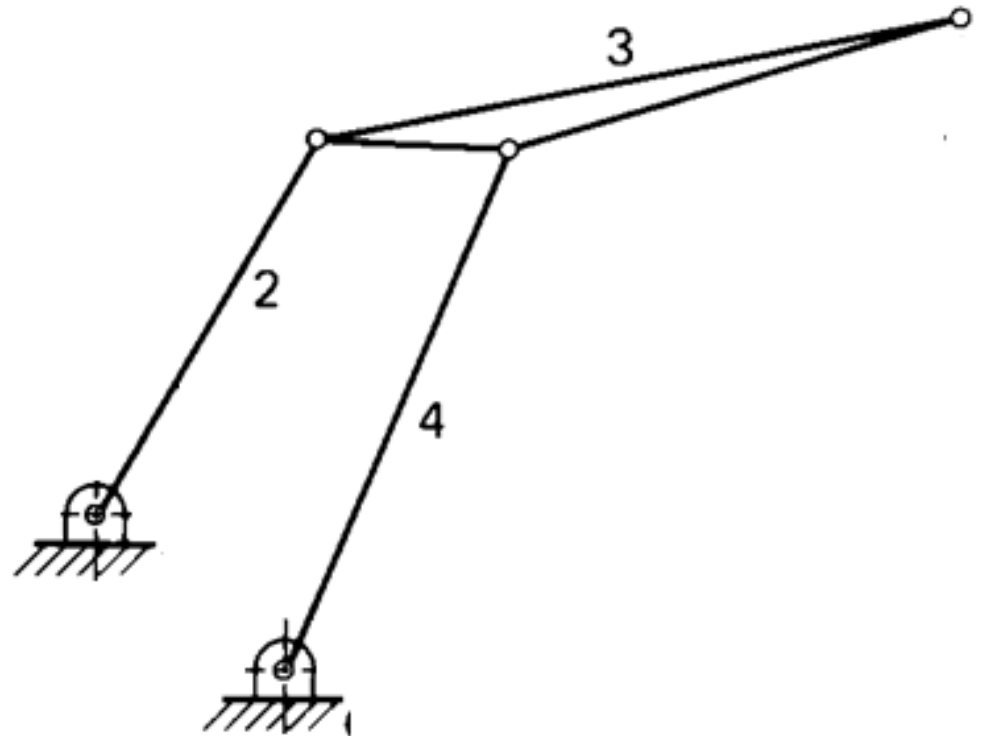
Graus de liberdade (F) de um mecanismo

Exemplo 2:



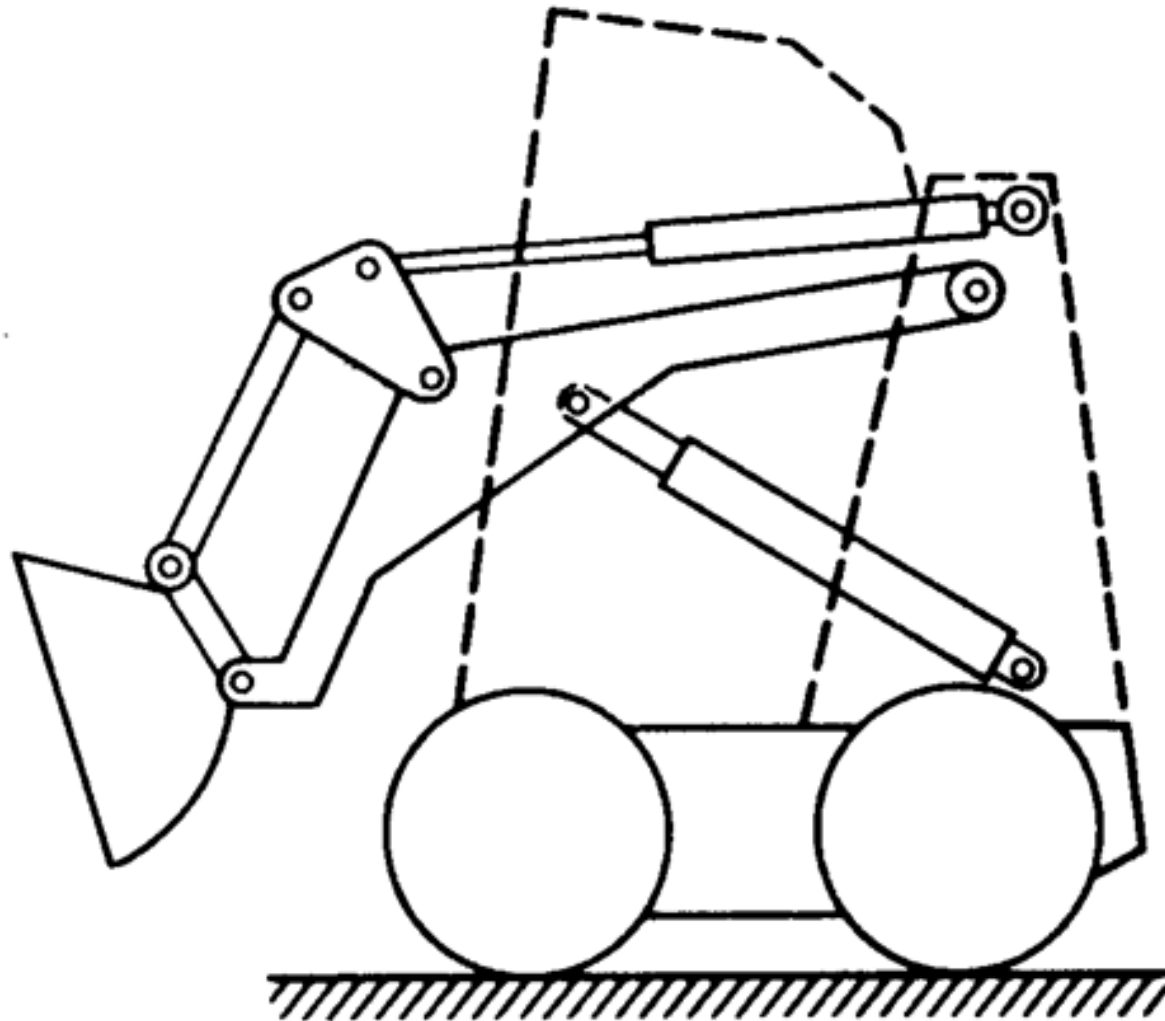
Graus de liberdade (F) de um mecanismo

Exemplo 3:



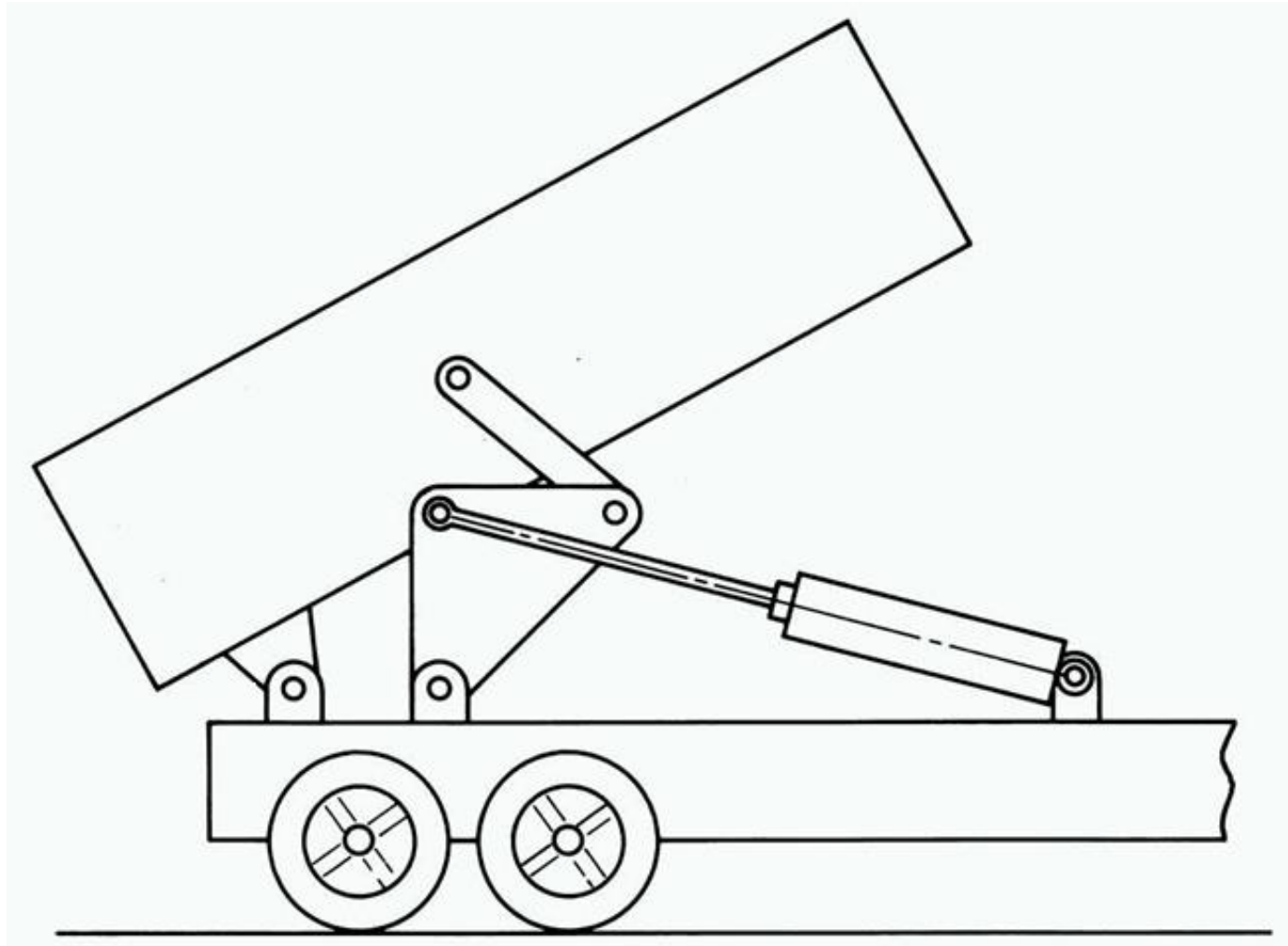
Graus de liberdade (F) de um mecanismo

Exemplo 4:



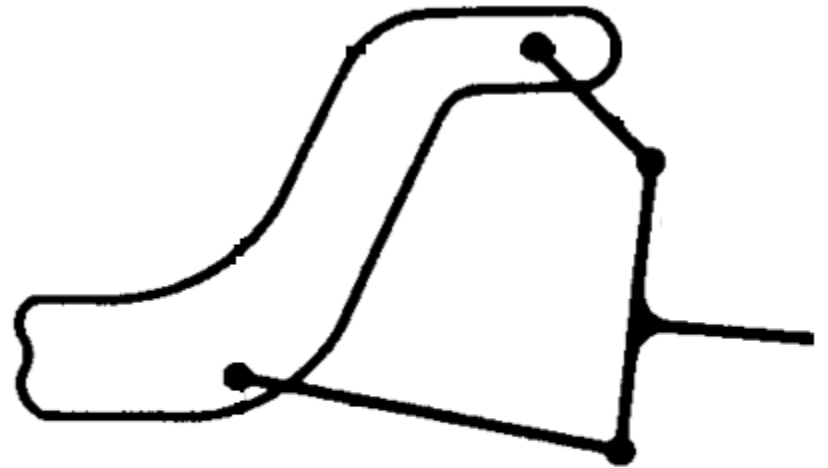
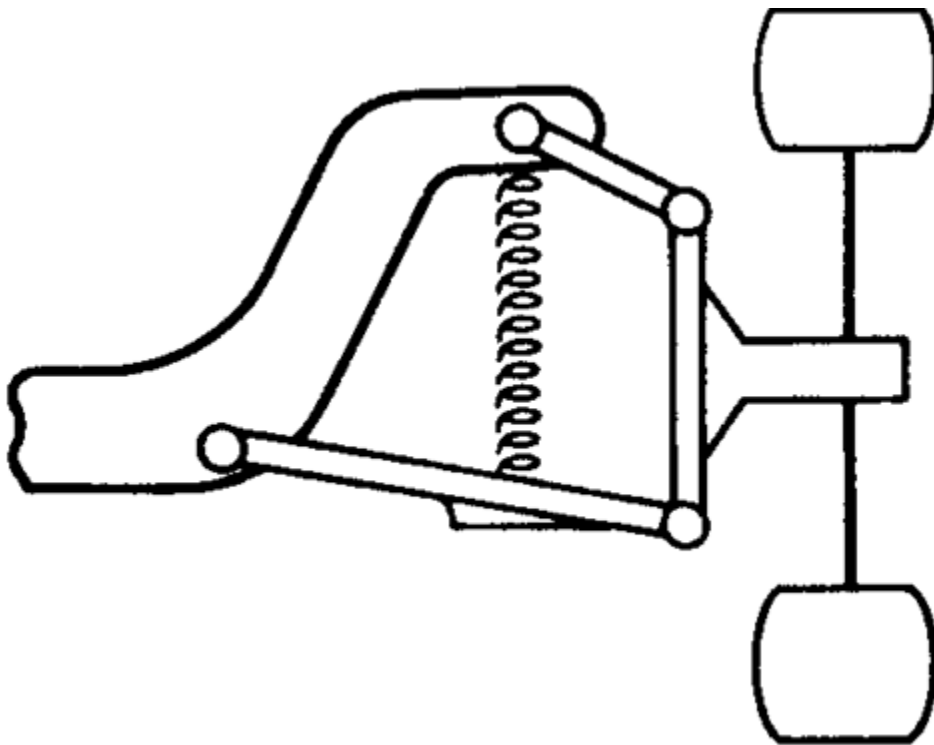
Graus de liberdade (F) de um mecanismo

Exemplo 5:



Graus de liberdade (F) de um mecanismo

Exemplo 6:



Exercícios

Para os mecanismos representados a seguir:

- a) Construir o grafo correspondente
- b) Calcular o número de graus de liberdade

Exercício 1

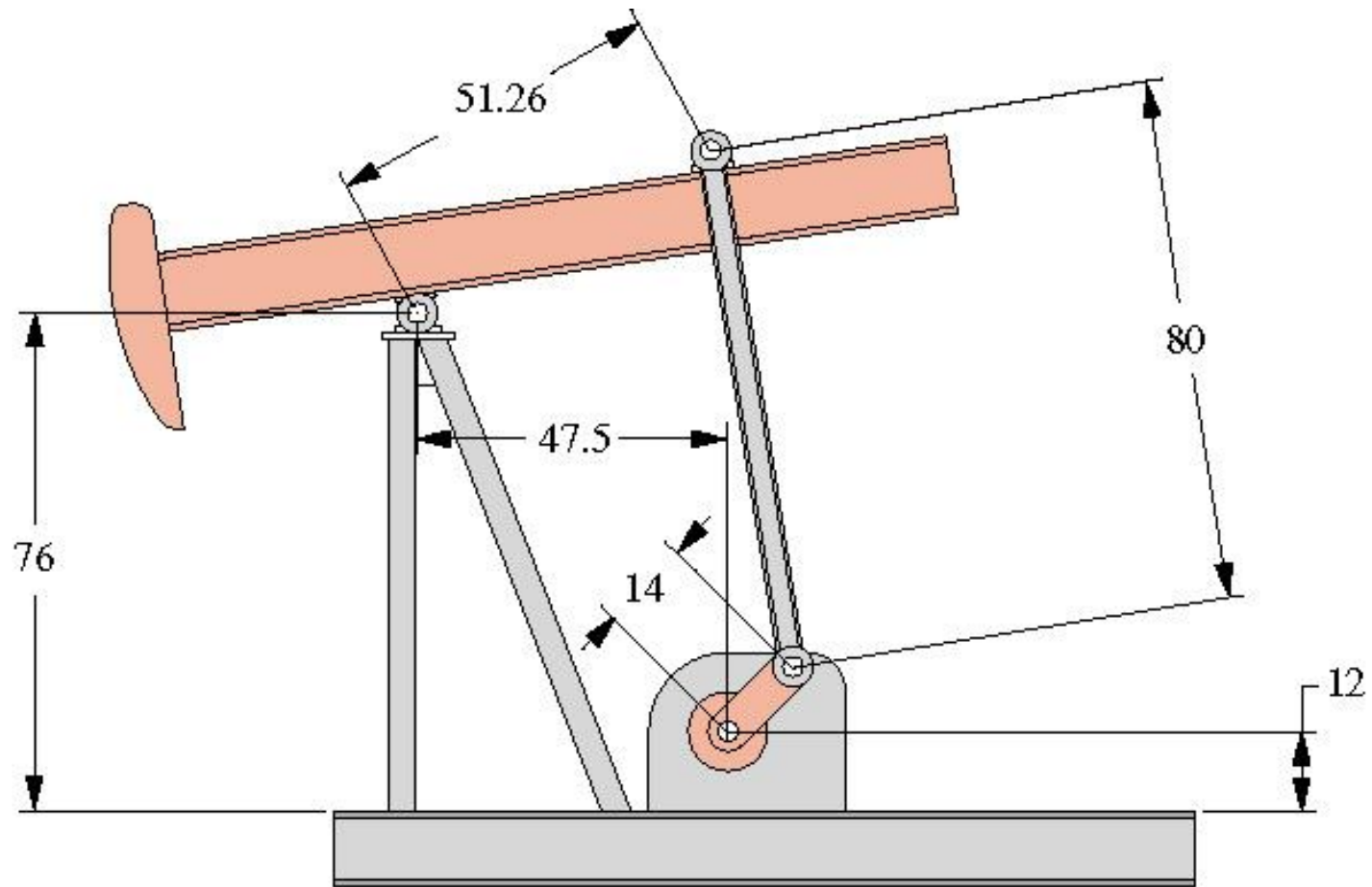
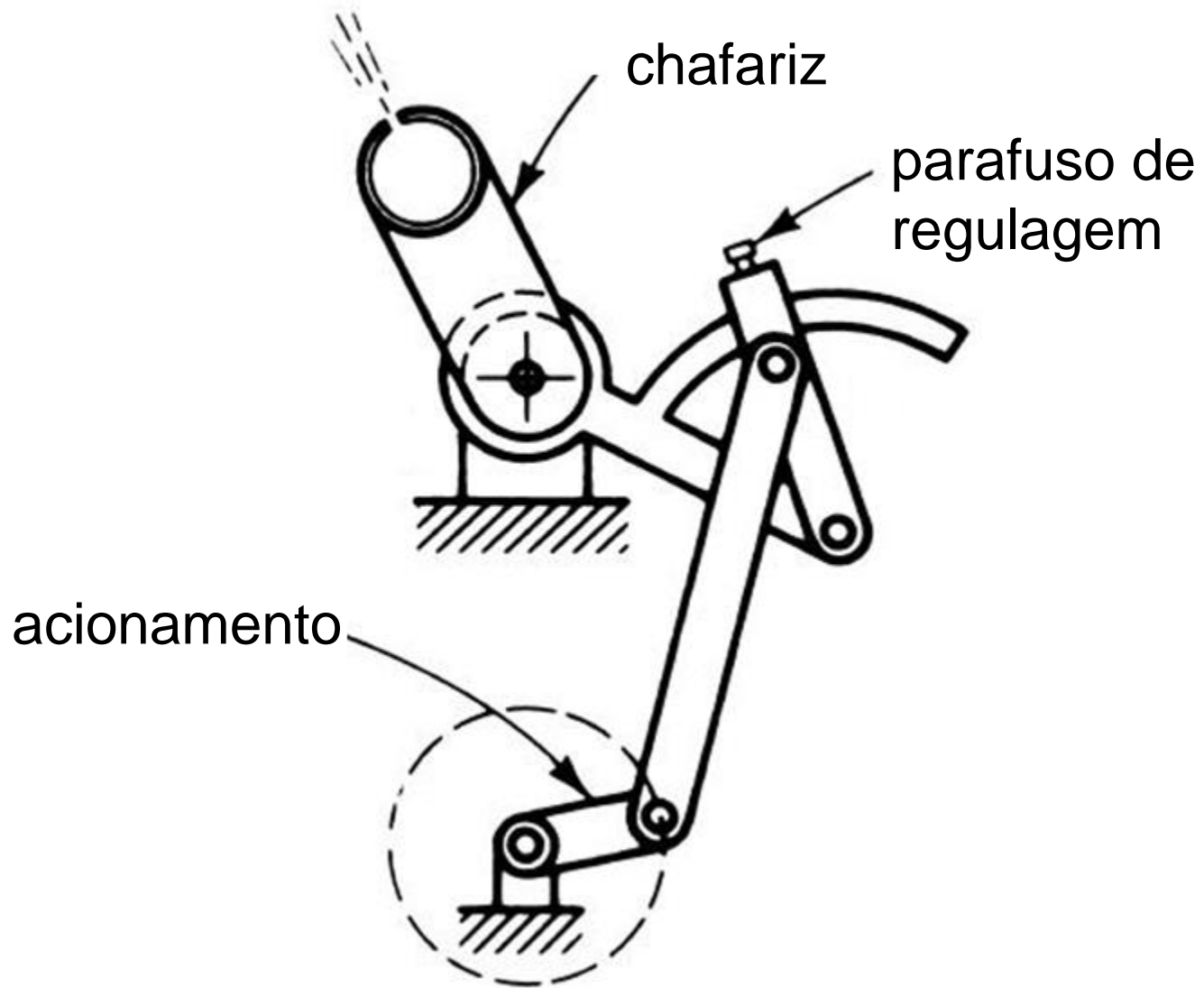


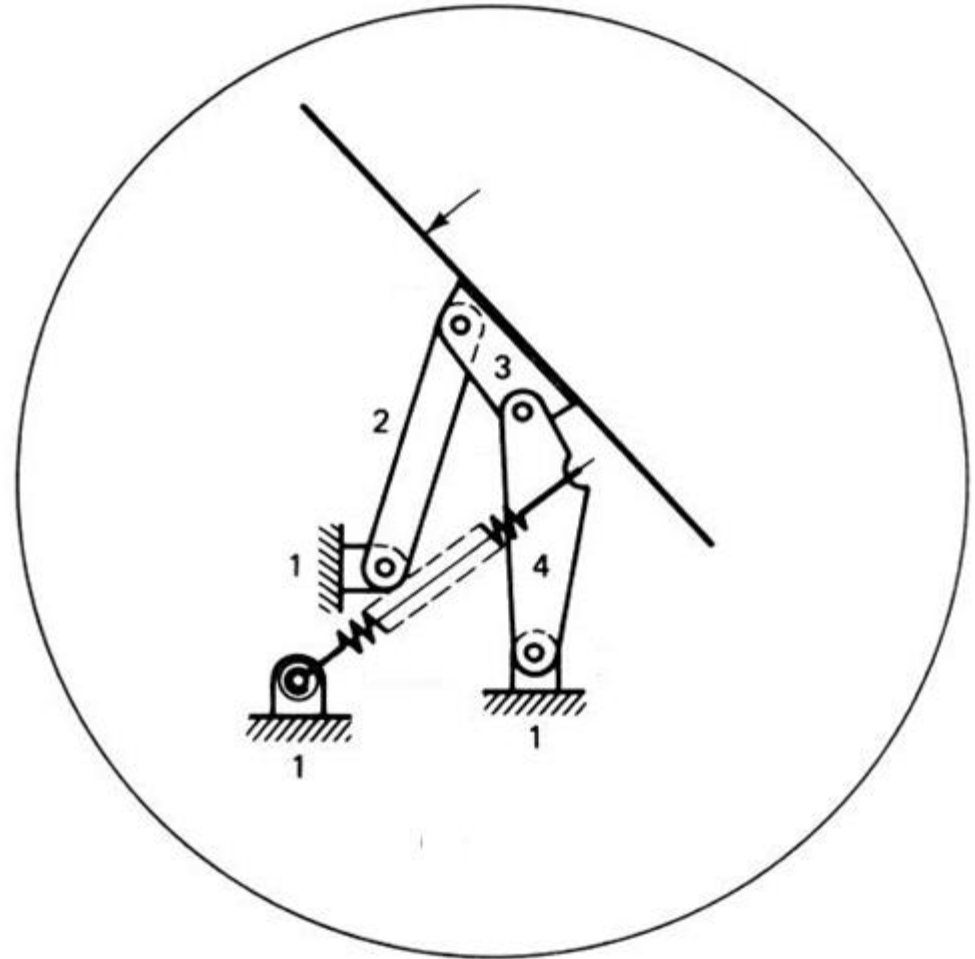
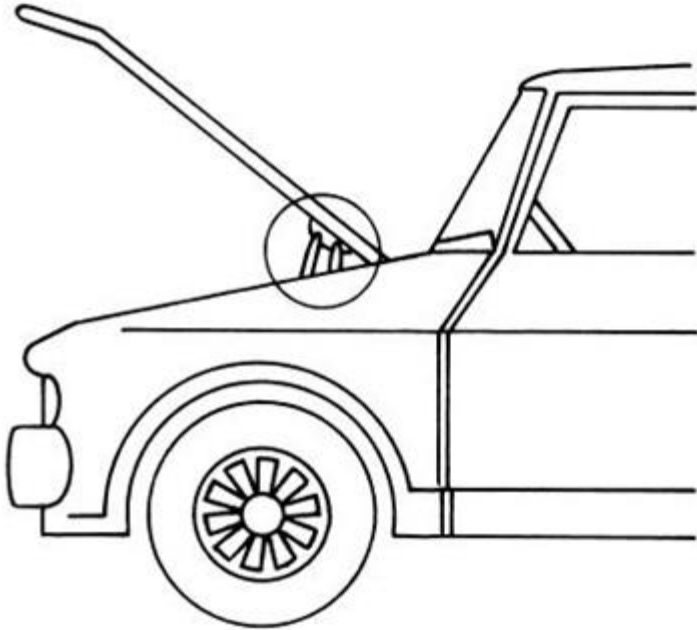
FIGURE P2-18

Problem 2-42 An oil field pump - dimensions in inches

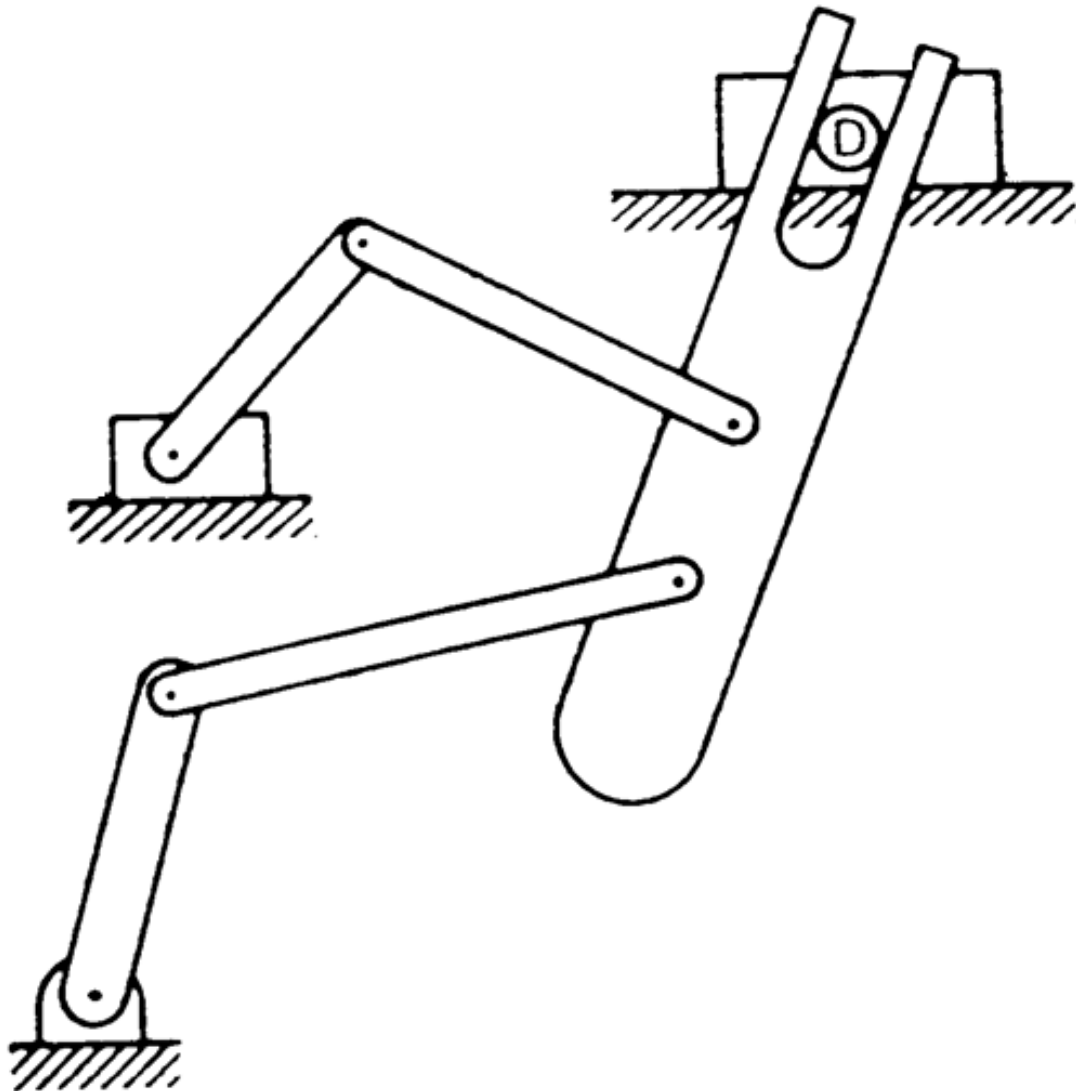
Exercício 2 - Hidrante



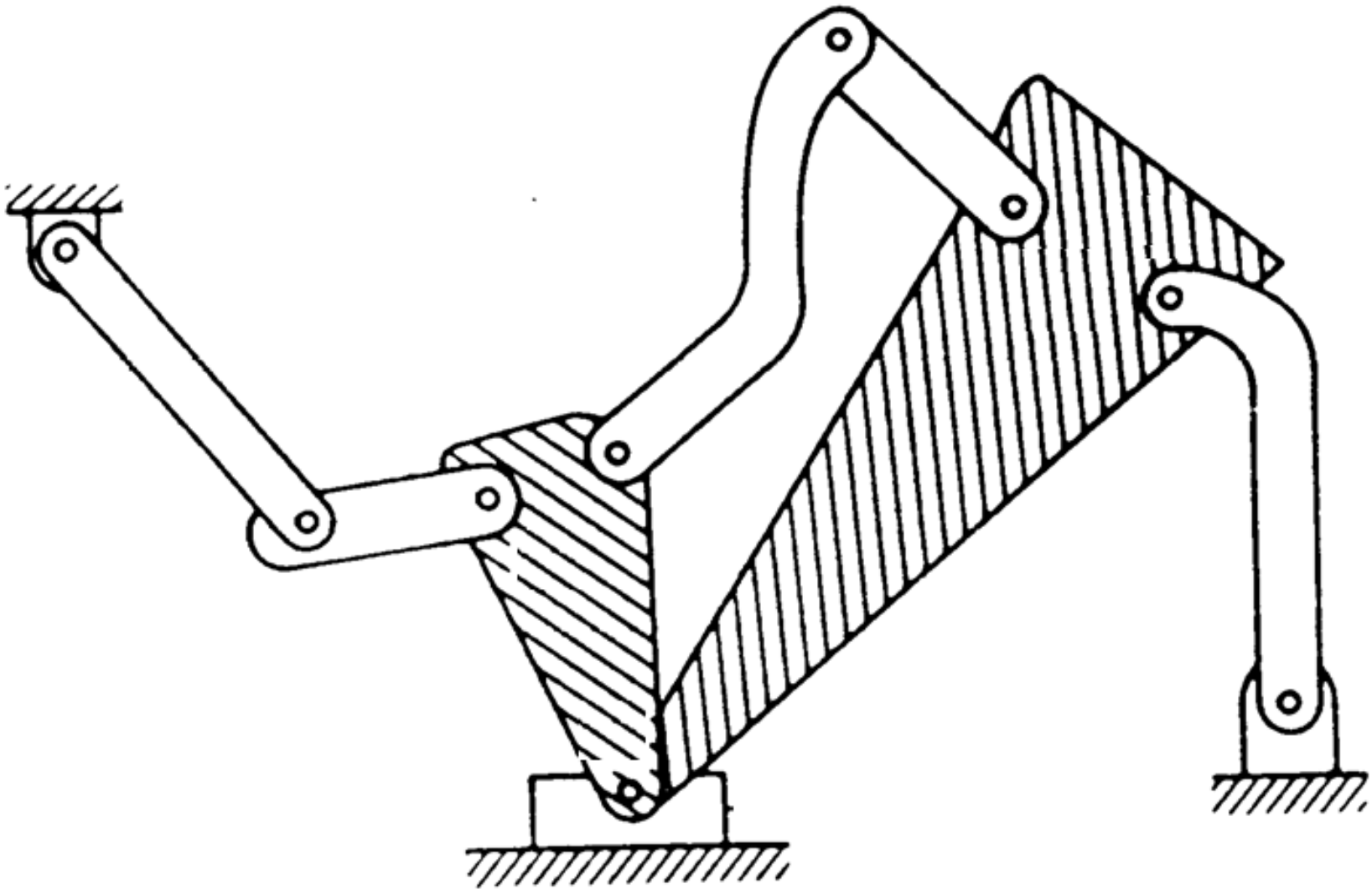
Exercício 3



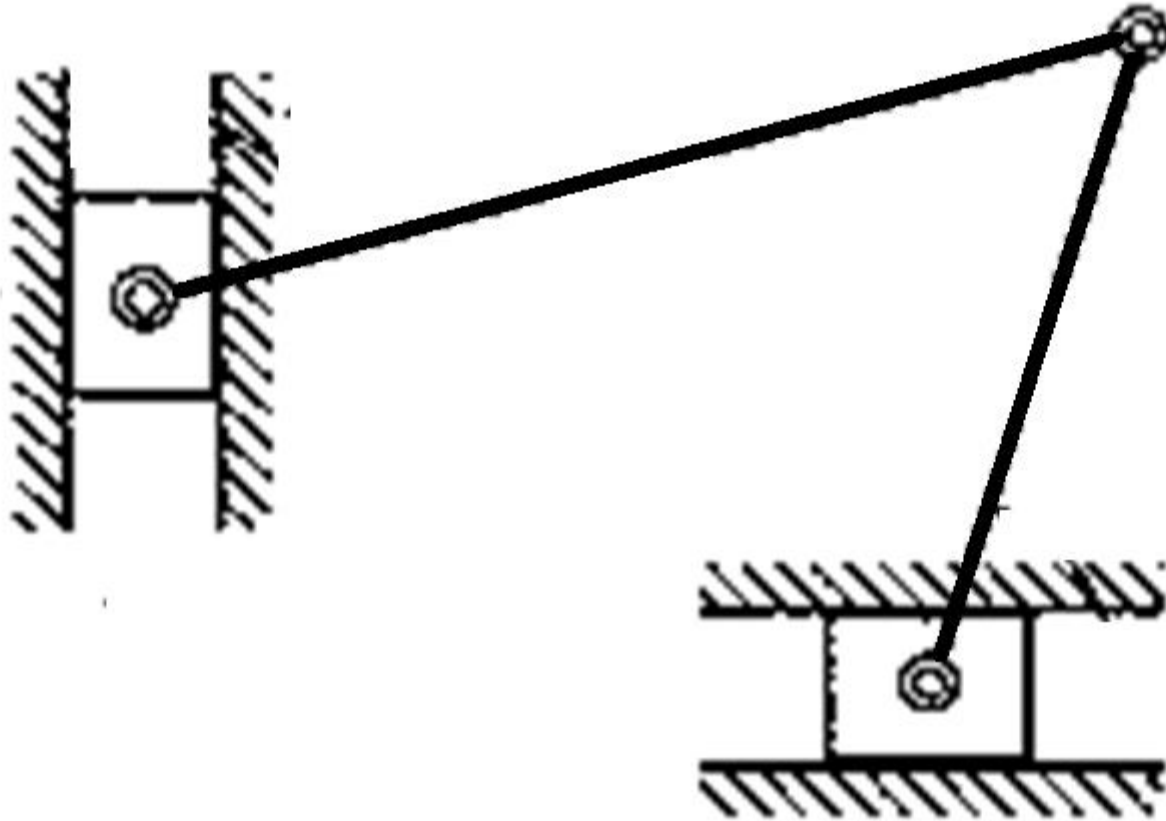
Exercício 4



Exercício 5



Exercício 6



Exercício 7

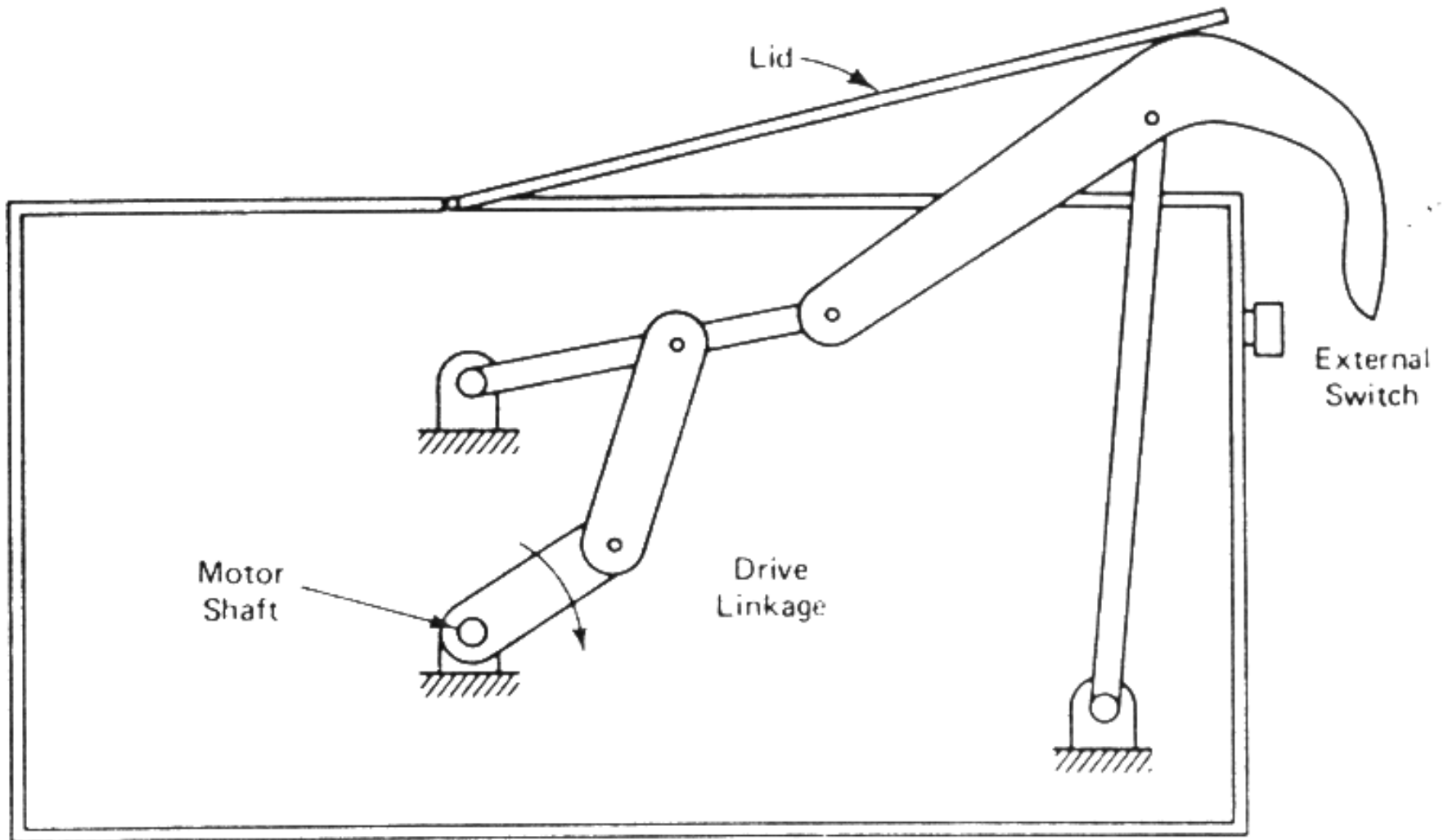
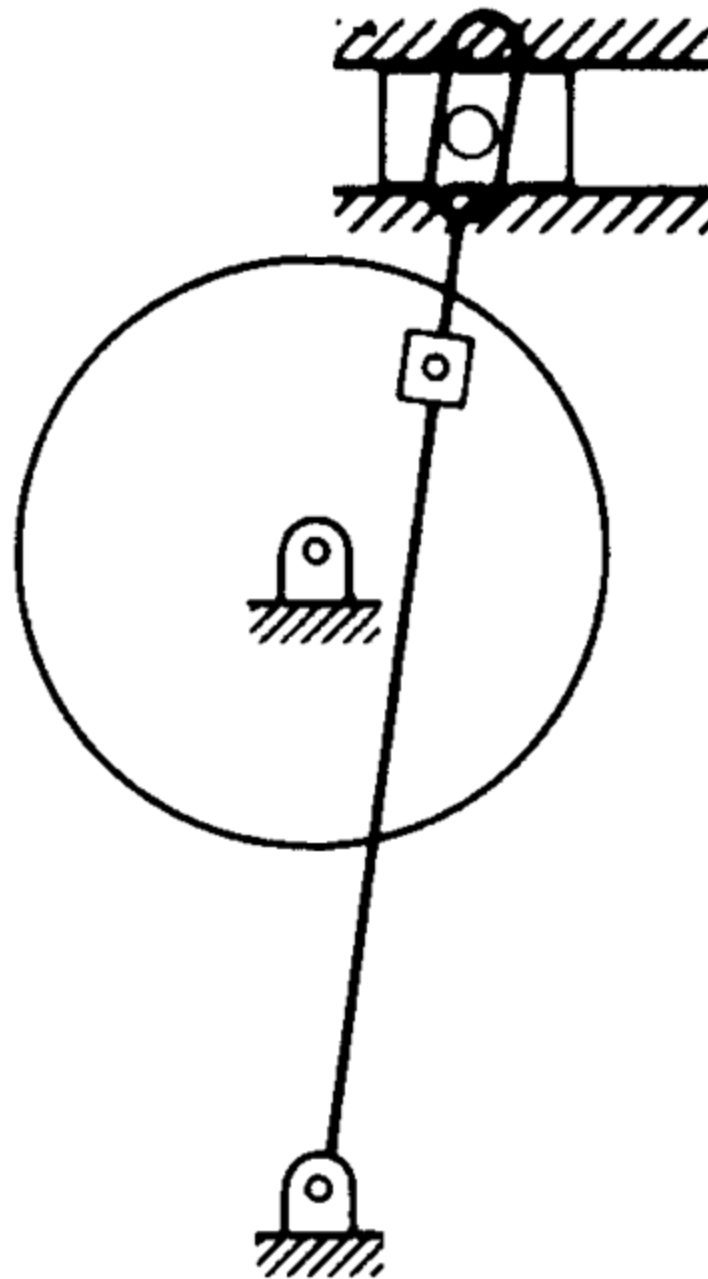
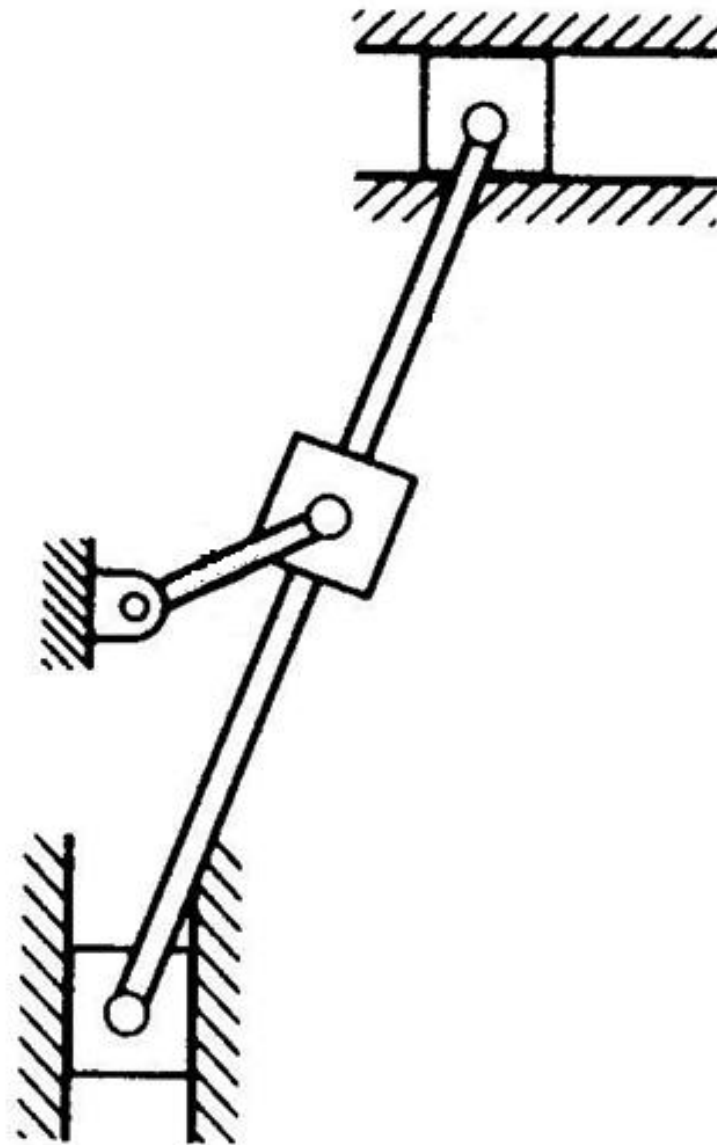


Figure P1.21

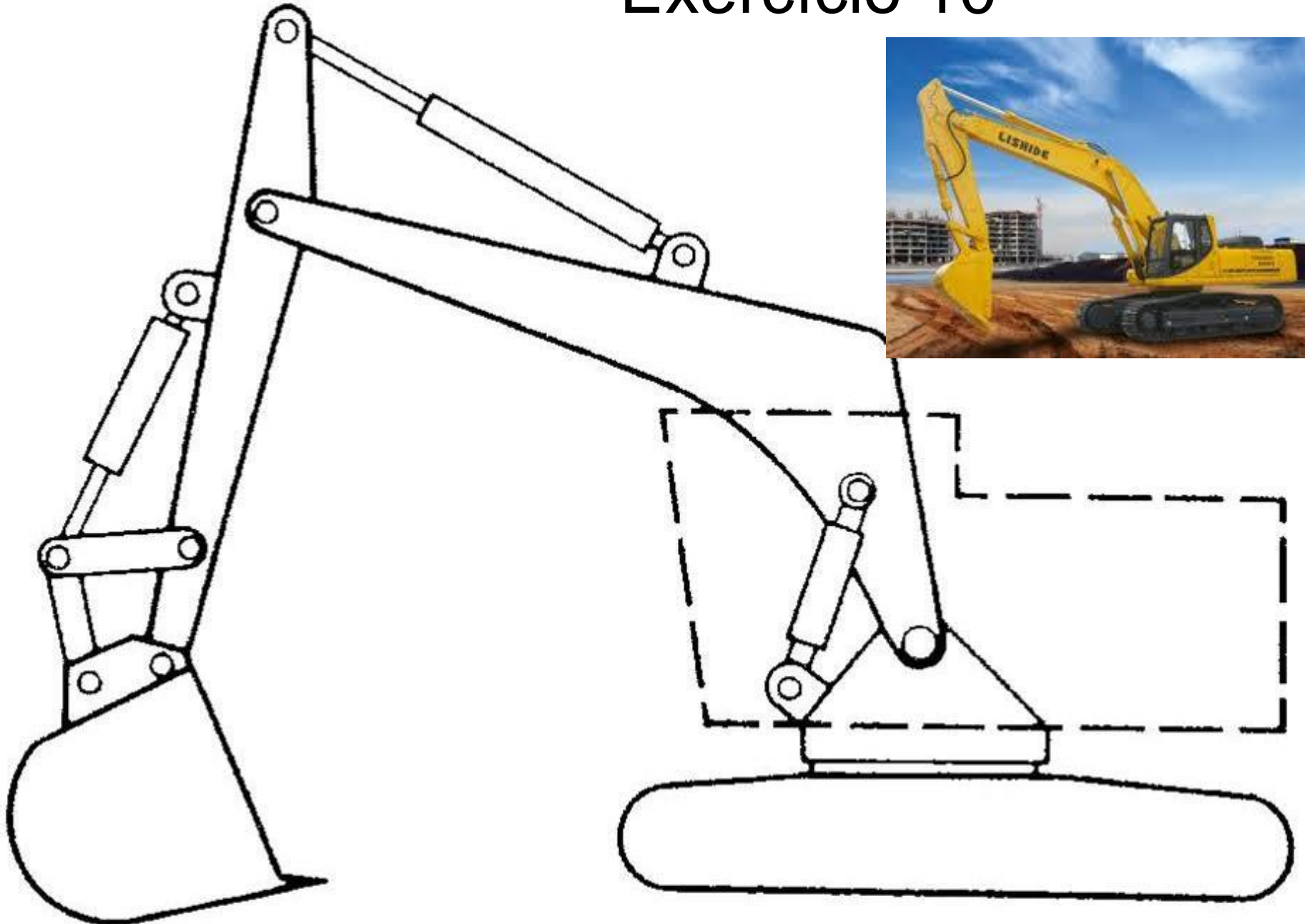
Exercício 8



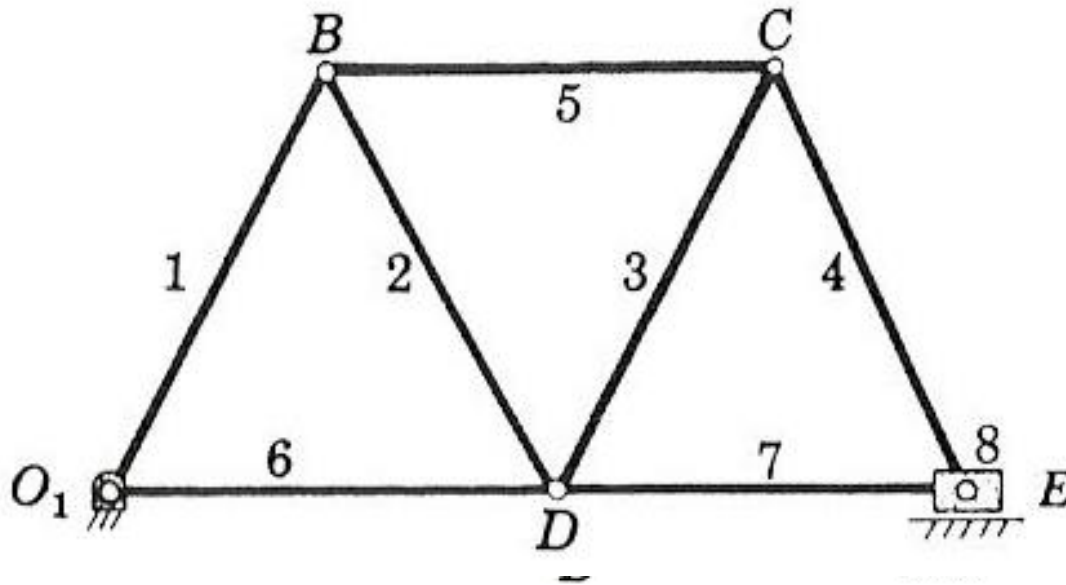
Exercício 9



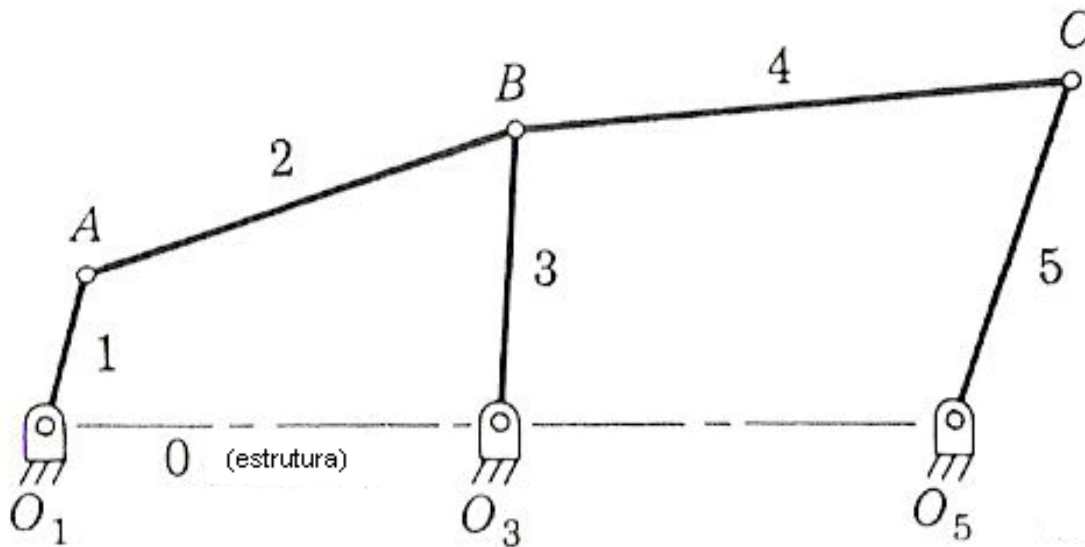
Exercício 10



Exercício 11



Comparar



Referência

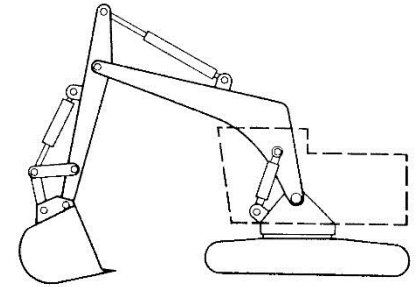


FIGURE 3.4 Pictorial Representation of a Power Shovel

Norton, R. L.. **Cinemática e Dinâmica dos Mecanismos.** Bookman, 2010.

Wilson, C. E. & Sadler, J. P.. **Kinematics and Dynamics of Machinery.** Harper Collins College Publishers, 2nd Edition, 1993.

Doughty, S.. **Mechanics of Machines.** New York: John Wiley, 1988.

Próxima aula

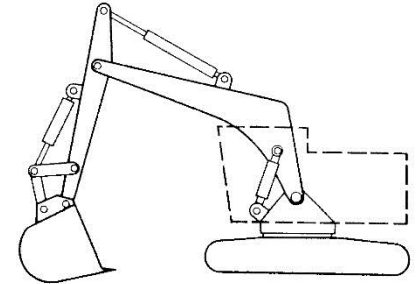


FIGURE 3.4 Pictorial Representation of a Power Shovel

Análise cinemática geral de mecanismos planos com 1 grau de liberdade

1. Posição

- a) Solução algébrica
- b) Solução numérica