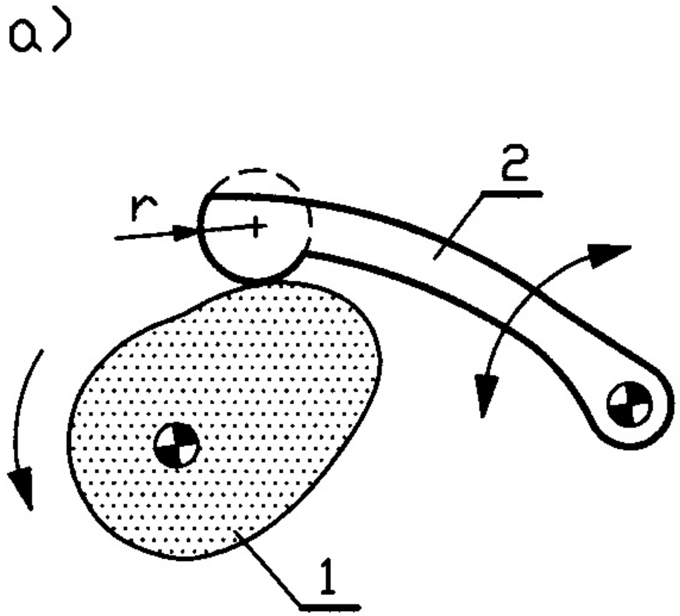


$$k = 2$$

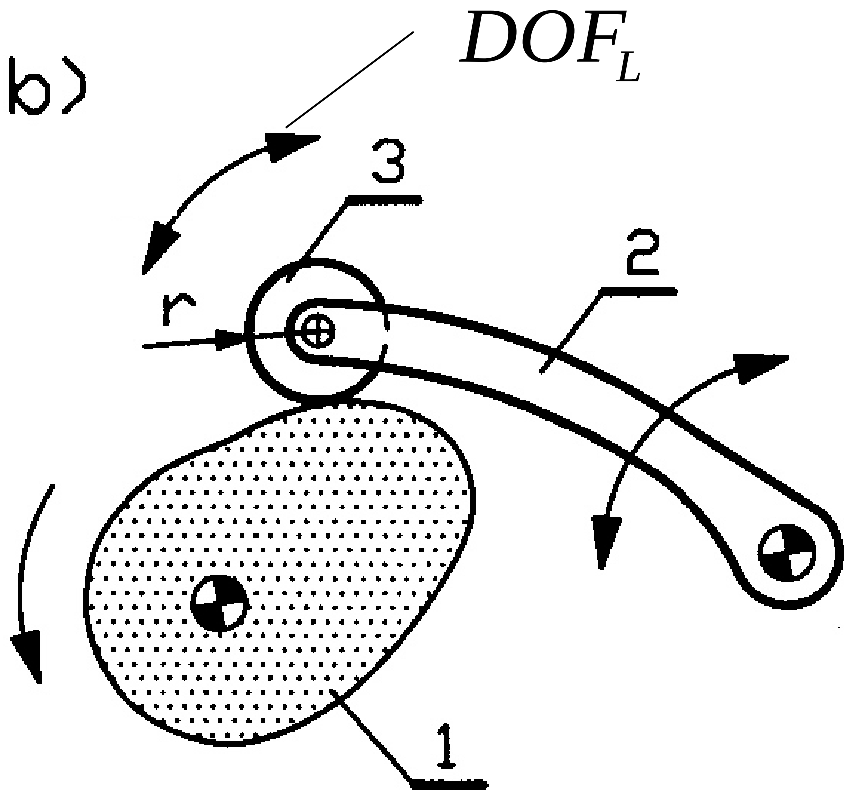
$$p_1 = 2$$

$$p_2 = 1$$

$$W_T = 3(n-1) - 2p_1 - 1p_2 =$$

?

$$W_T = 1 \longleftrightarrow W_{REAL} = 1$$



$$k = 3$$

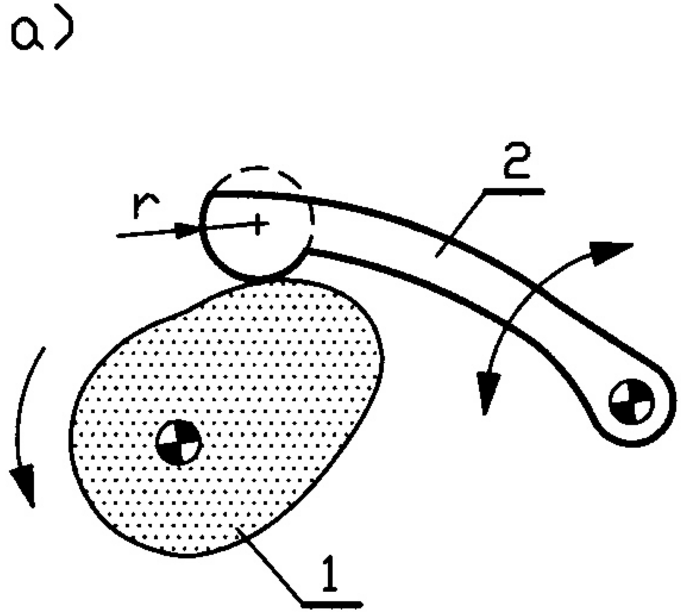
$$p_1 = 3$$

$$p_2 = 1$$

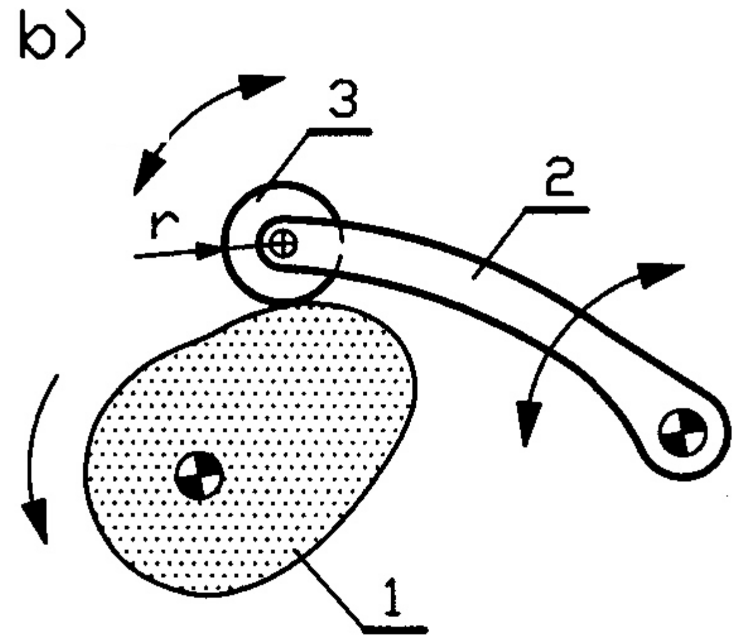
$$W_T = 2$$

$$W_{REAL} = 1$$

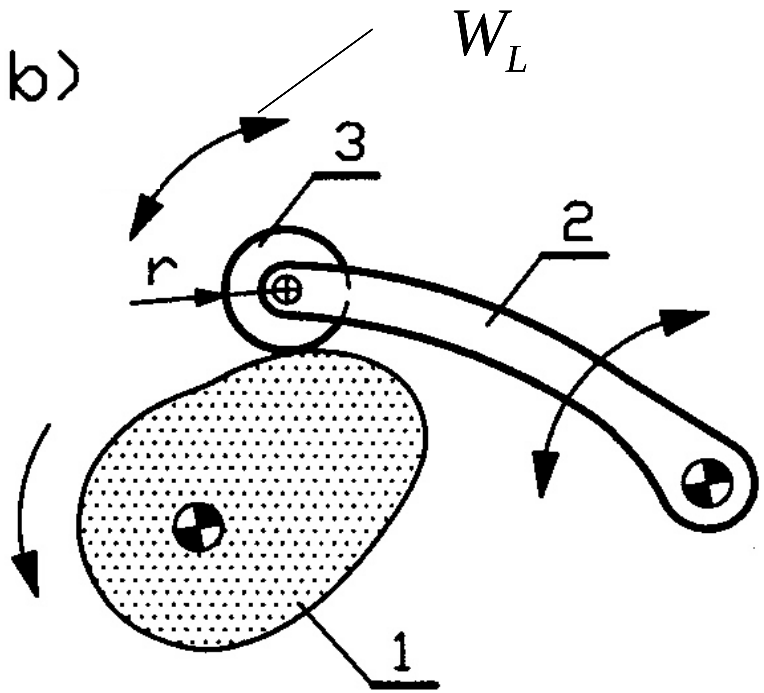
COMPARISON



$$W_T = 1$$



$$W_T = 2$$



$$k = 3$$

$$p_1 = 3$$

$$p_2 = 1$$

$$W_T = 2$$

IDLE (LOCAL MOBILITY) OF LINK 3 – ROLLER 3 CAN ROTATE AROUND ITS CENTER

$$W_L = 1 \qquad W_R = 1$$

idle = inactive

REAL MOBILITY:

$$W_R = W_T - W_L$$

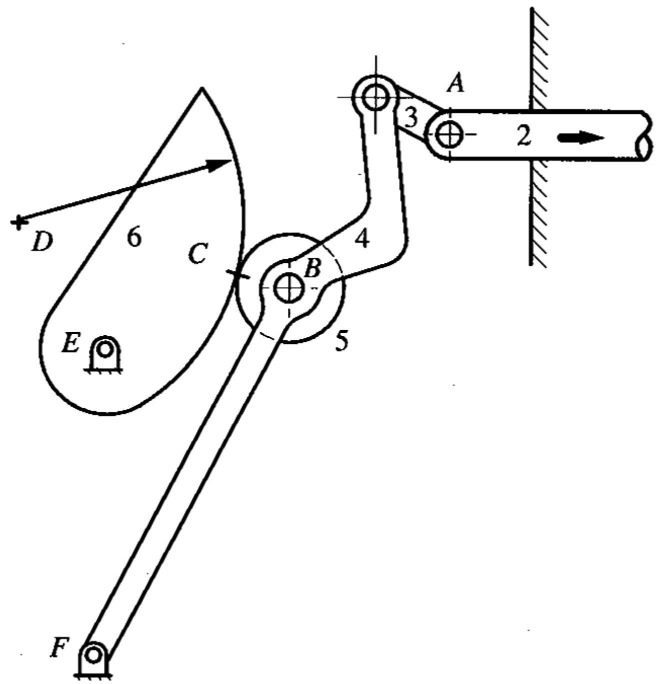
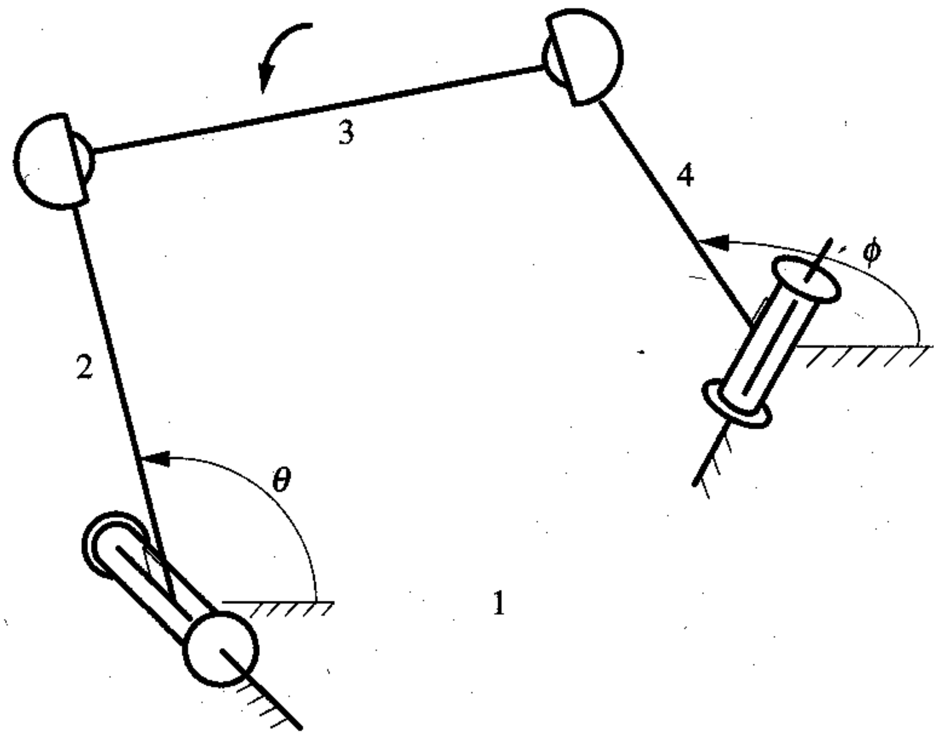


Figure 1.30 Planar mechanism with an idle degree of freedom.

$W_R =$

$W_T =$

$W_L =$

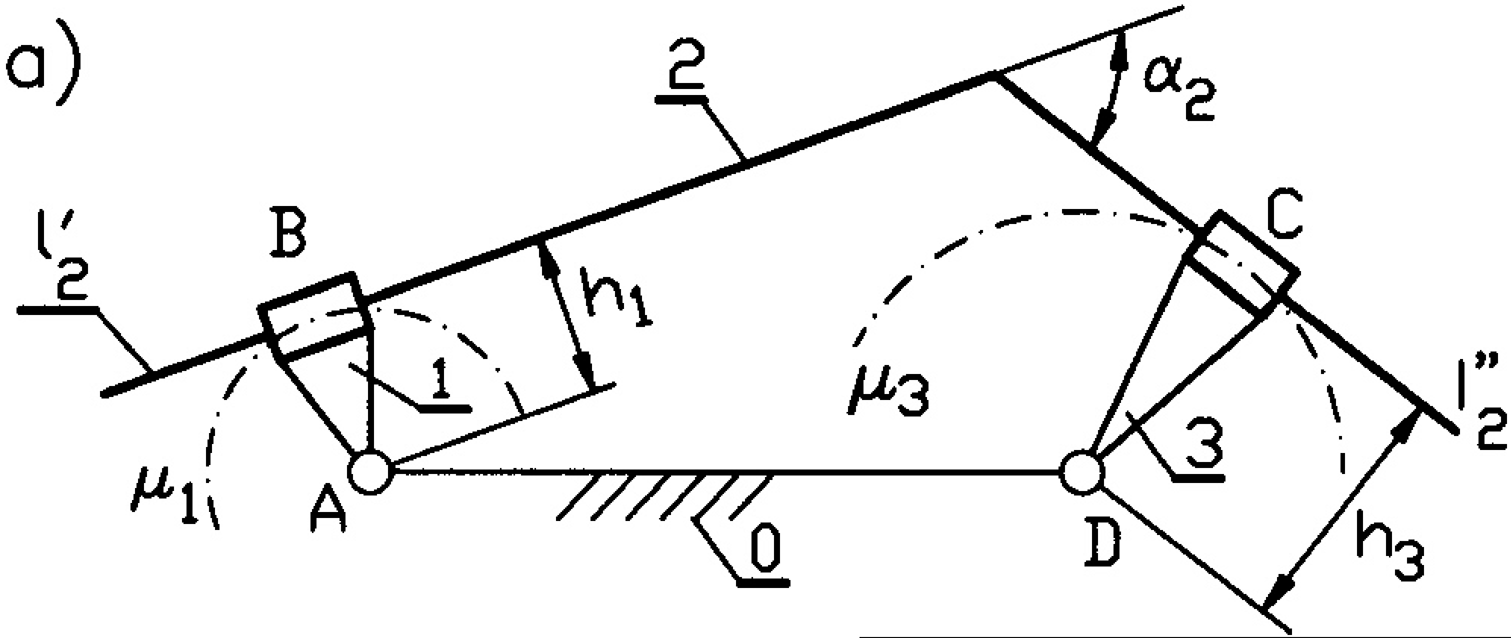


$$W_R = \ldots$$

$$W_T = \ldots$$

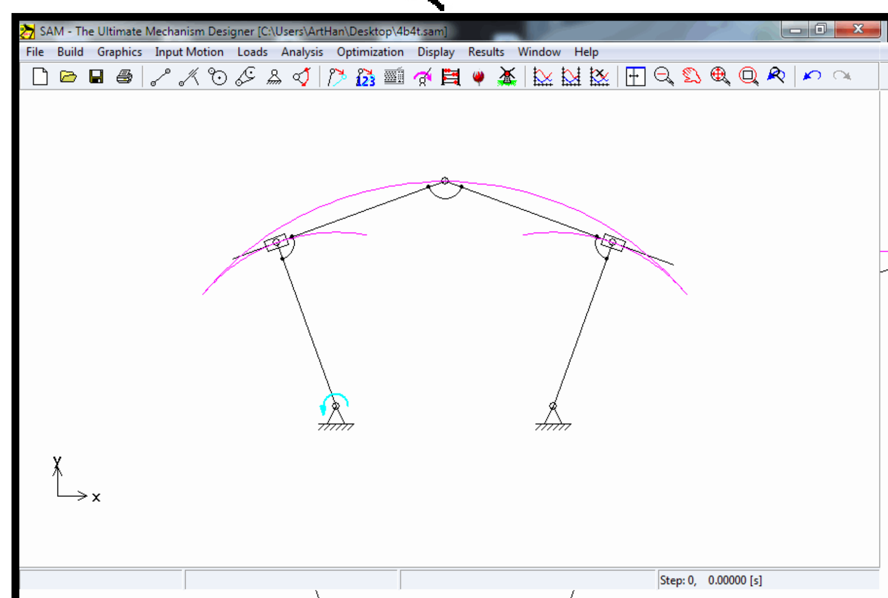
$$W_L = \ldots$$

Figure 1.28 A spatial four-member, four-joint linkage. Two of the joints are revolutes. The other two are spherical joints. θ is the input joint angle and ϕ is the output joint angle. The linkage has an idle degree of freedom since member 3 can spin about the line joining the centers of the spherical joints without affecting the relationship between θ and ϕ.


a)
2
α_2
l'_2
B
C
h_1
1
μ_3
l''_2
3
μ_1
A
0
D
h_3

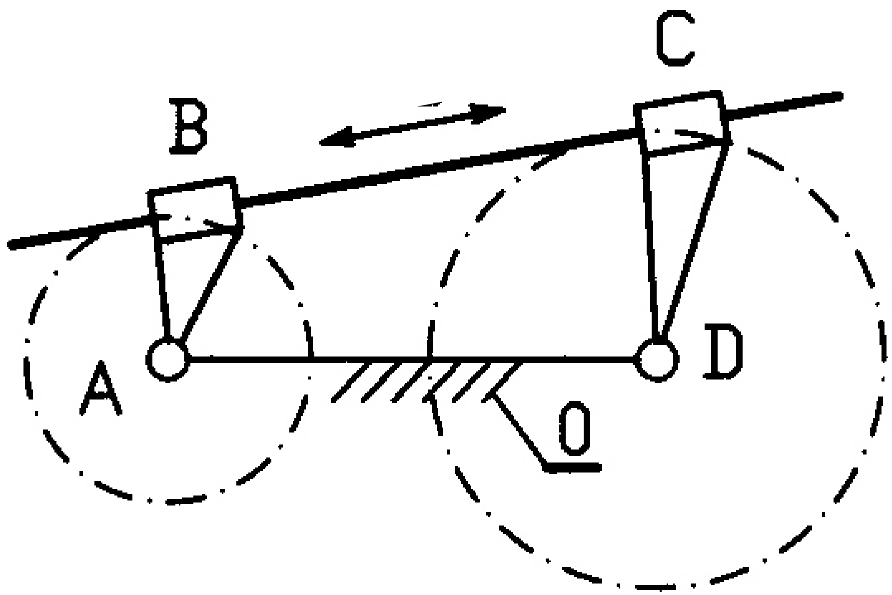
$$W_R =$$

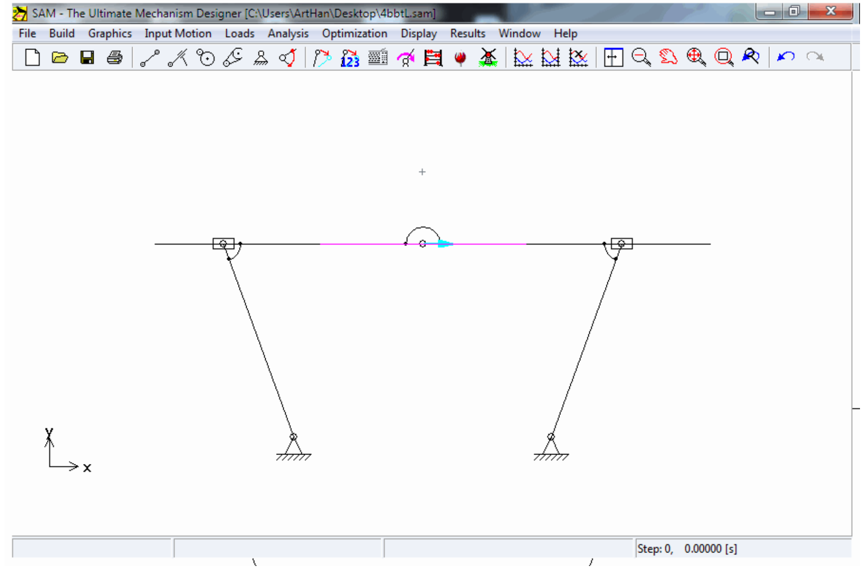
$$W_R = W_T - W_L$$


SAM - The Ultimate Mechanism Designer [C:\Users\ArtHan\Desktop\4b4t.sam]
File Build Graphics Input Motion Loads Analysis Optimization Display Results Window Help
Step: 0, 0.00000 [s]

Special geometry:

Link BC = stright line



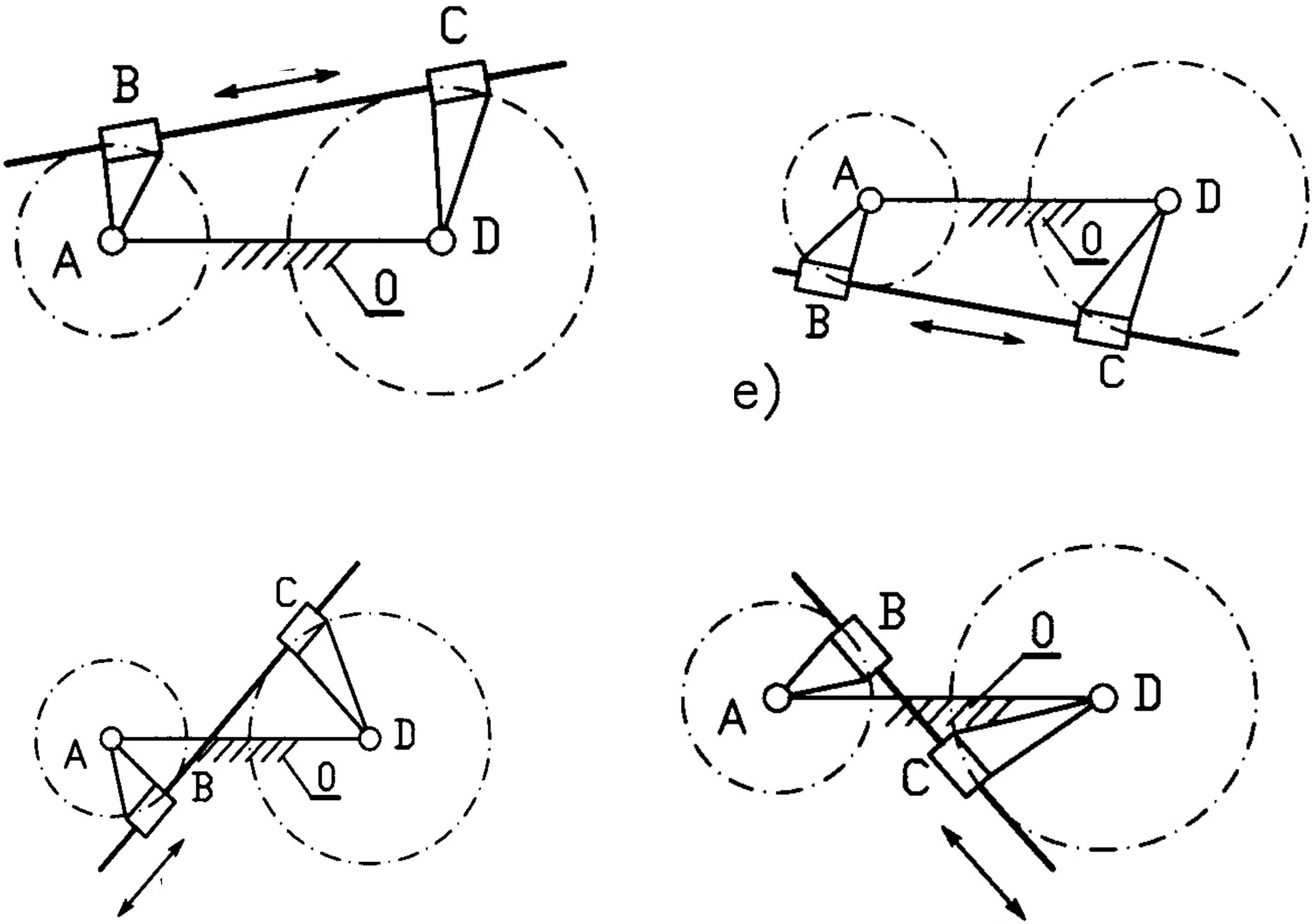


$$W_R = 0$$

$$W_R = W_T - W_L = 1 - 1$$

This mechanism can only be assembled in 4 configurations !

This mechanism can only be asambled in 4 configurations !



IDLE MOBILITY ALWAYS REDUCES TOPOLOGICAL (THEORETICAL) MOBILITY

$$W_R = W_T - W_L$$

IDLE MOBILITY IS THE RESULT OF SPECIAL GEOMETRY OF LINKS

HOMEWORK

Draw a kinematic system (a real one) having at least 4 links

Number the links, classify joints, calculate mobility

SUMMARY:

Link:
solid body which can move in relation to other links

Joint (kinematic pair):
class I, II, III, IV and V (according to number of DOF)

lower and higher joints (type of contact: surface, point, line)

Kinematic system (mechanism, machine)

Mobility:
DOF number of independent coordinates (parameters) to define a system position (motion)

W_T - topological (theoretical) mobility

Planar systems (2D)

$$W_T = 3(n-1) - 2p_1 - 1p_2$$

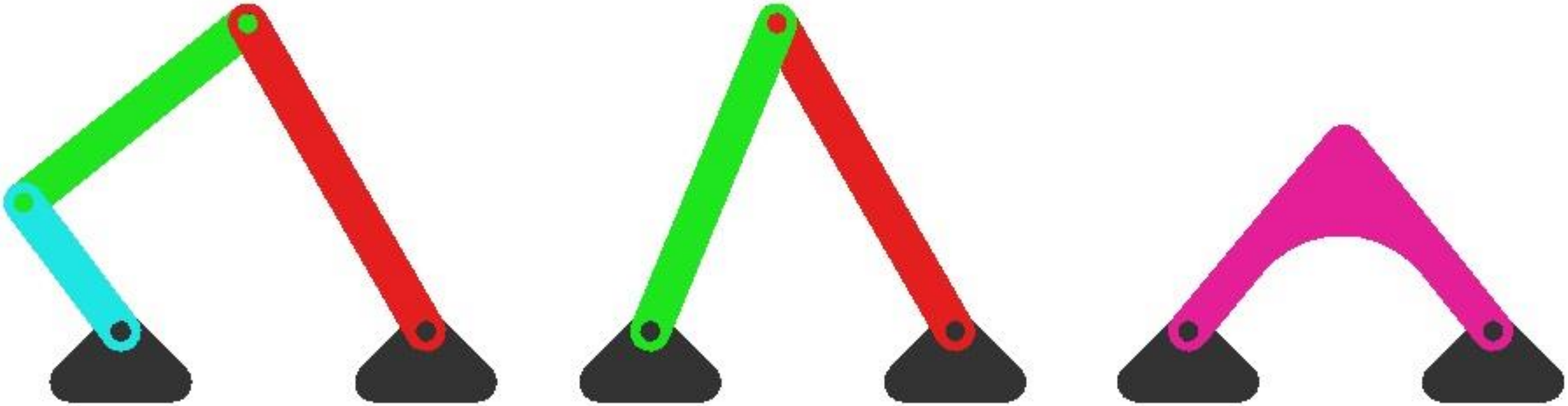
Spatial systems (3D)

$$W_T = 6(n-1) - 5p_1 - 4p_2 - 3p_3 - 2p_4 - 1p_5$$

W_R – real (practical) mobility

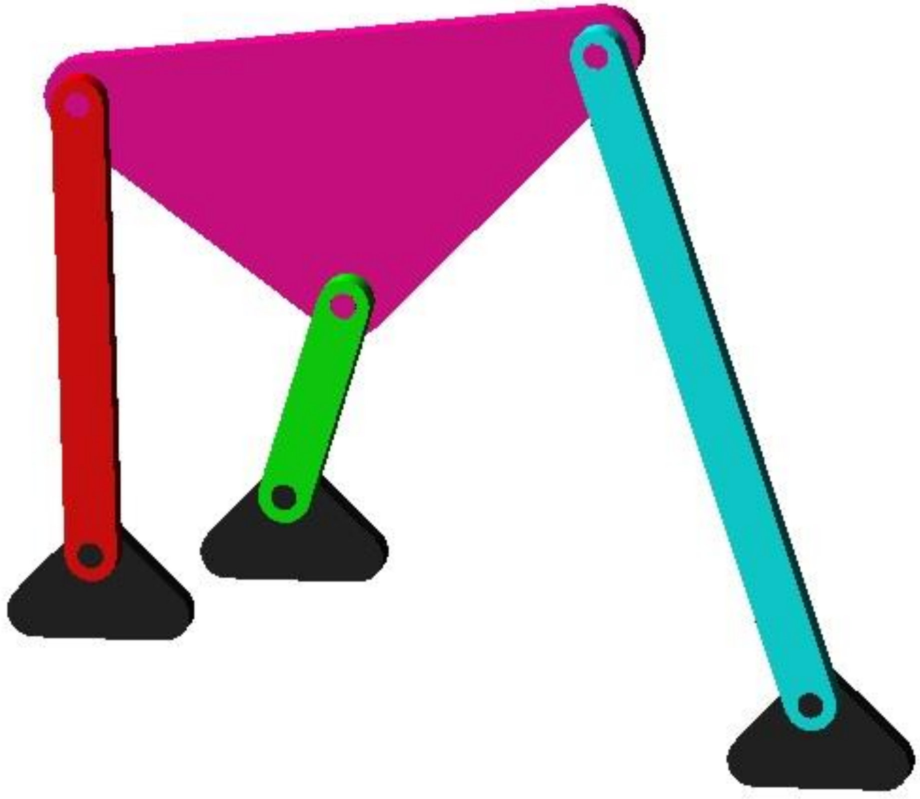
W_L – idle (local) mobility (in case of special geometry)

$$W_R = W_T - W_L$$



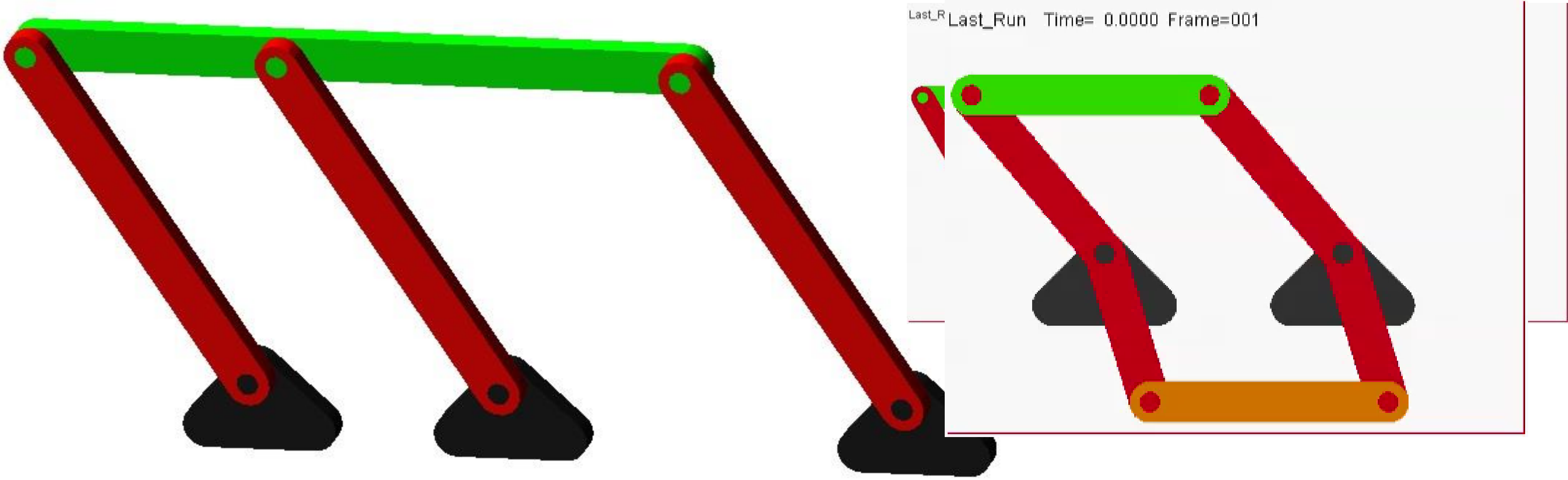
$W_T = +1$ $\quad$ $W_T = 0$ $\quad$ $W_T = -1$

Because mobility criterion pays no attention to link sizes or shapes it can give misleading results in the face of unique geometric conditions



$W_T=0$ ⟷ $W_R= 0$

In general if $W_T = 0$ relative motion of links is not allowed !



$W_T=0$ ⟷ $W_R= 1$

the results (W) disagree - motion is possible due to unique geometry:

- ternary links are straight and parallel and with equispaced nodes,
- the three binaries are equal in length

Kinematic systems having:

$$W_T \leq 0 \qquad and \qquad W_R = 1(or\ more)$$

are called

- mechanisms with redundant constraints (passive constraints)

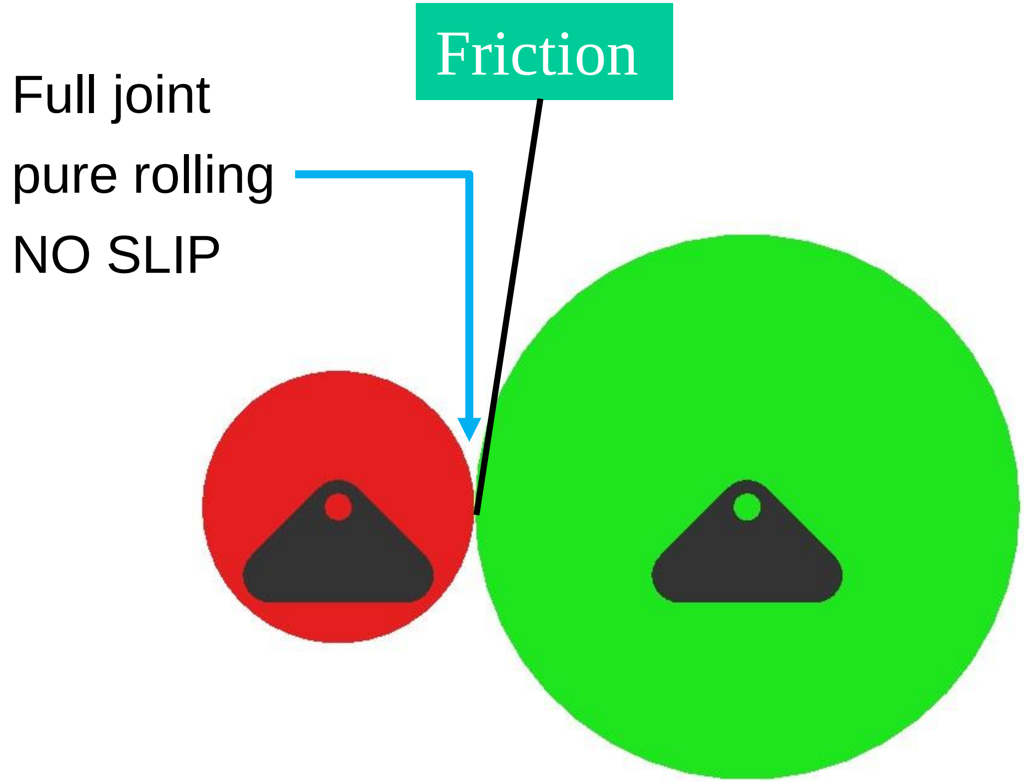
or

- paradoxical mechanisms

Number of redundant constraints (R_C) must satisfy equation:

$$W_R = W_T - W_L + R_C$$

Transmission of angular motion between two wheels

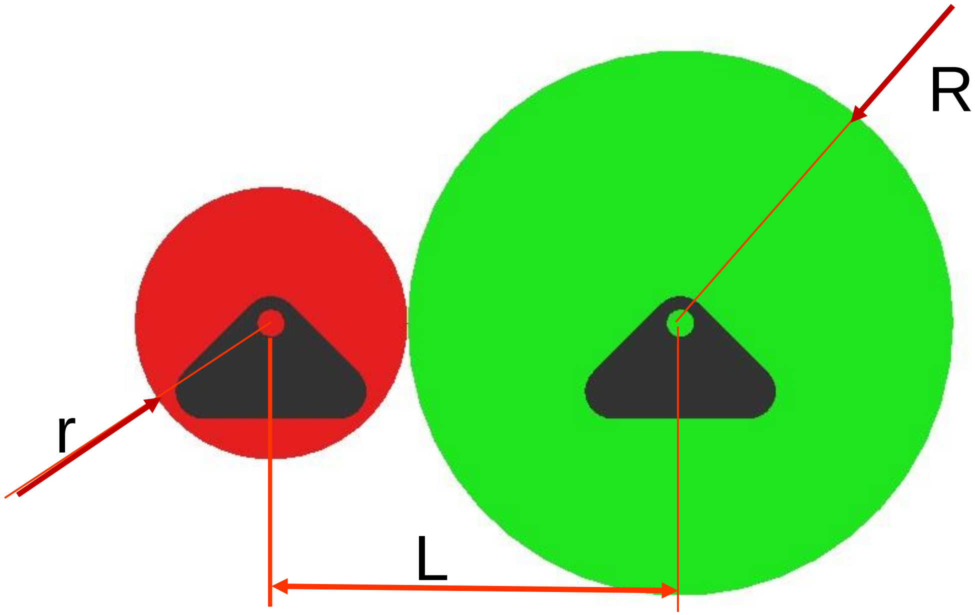


k = 2

$p_1 = 3, p_2 = 0$

↓

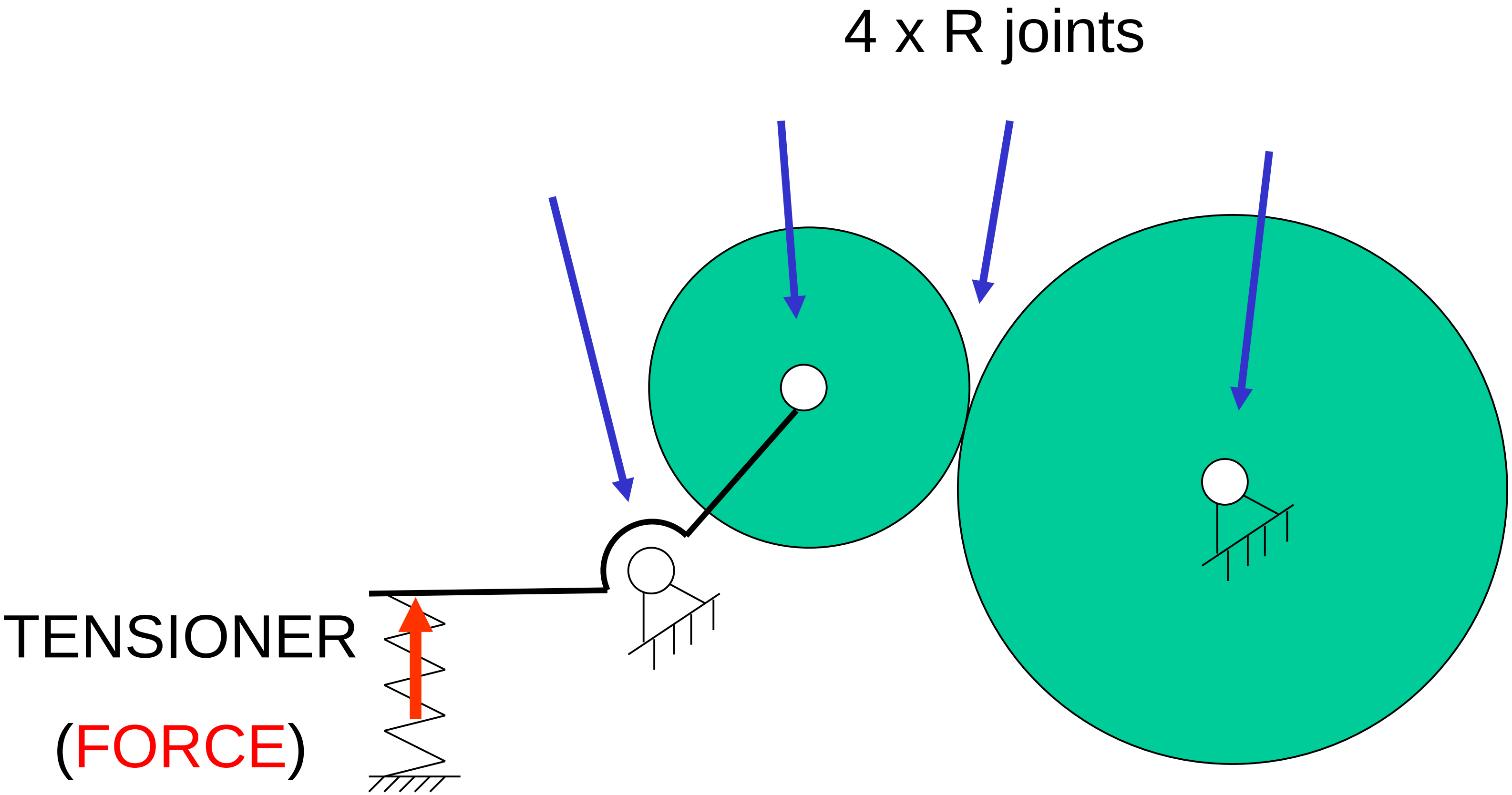
$$W_T = 0 \qquad and \qquad W_R = 1$$



Motion allowed if: $L = R + r$

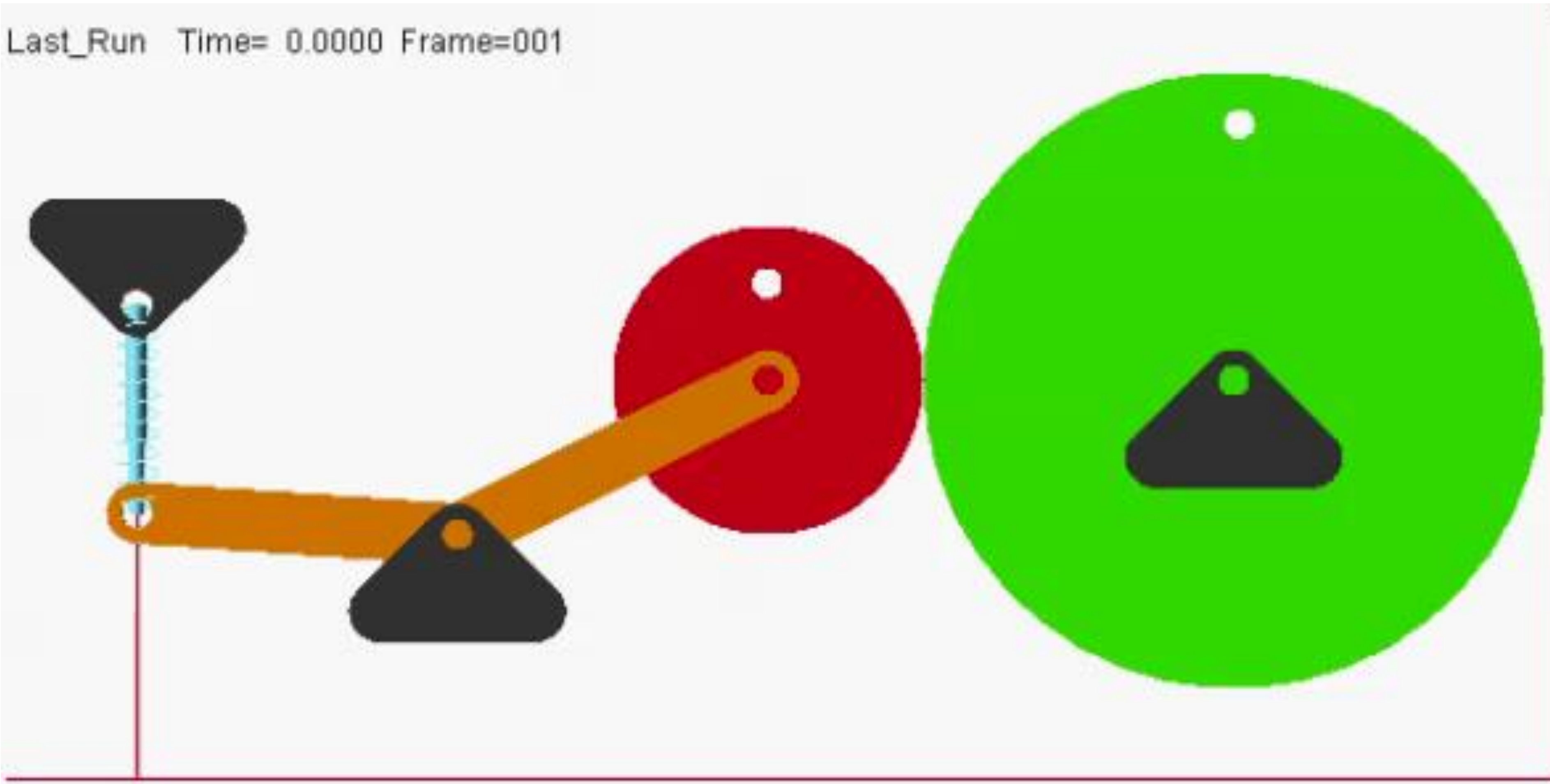
If $L > R + r$ joint disappears (no contact)

If $L < R + r$ mechanism can not be assembled

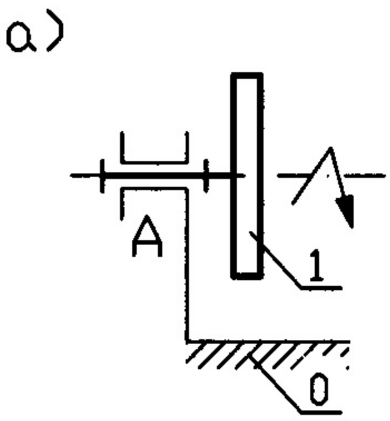


$$W_R = 1$$

$$R_C = 0$$


Last_Run Time= 0.0000 Frame=001

Rotating disc



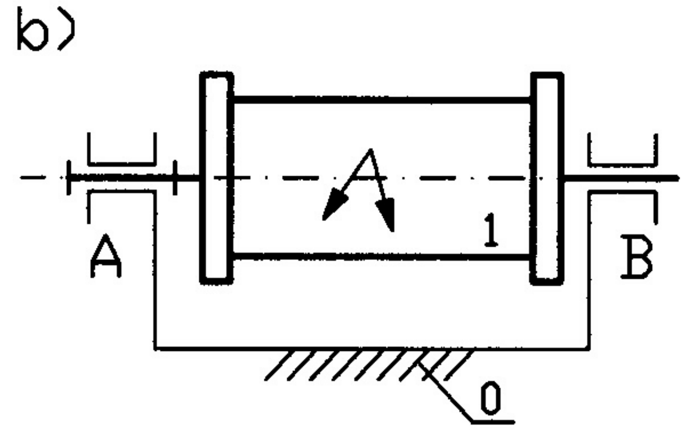
$W_R = 1$

$W_T = 1$

$W_L = 0$

$R_C = 0$

Rotor



$W_R = 1$

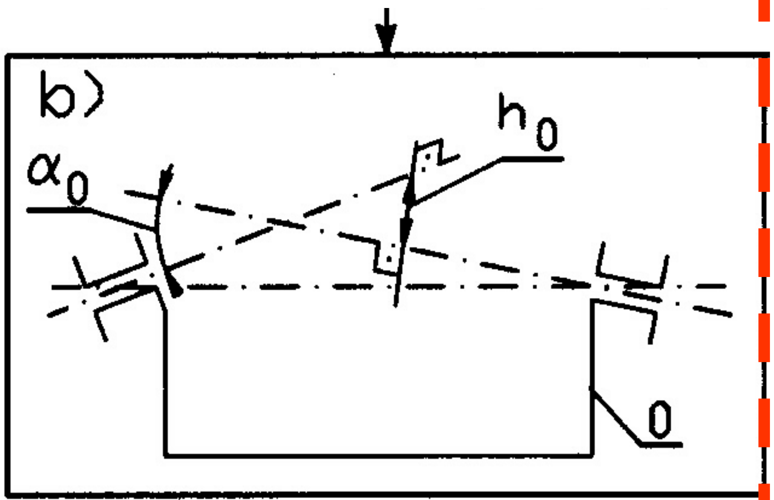
$W_T = -3$

$W_L = 0$

$R_C = 4$

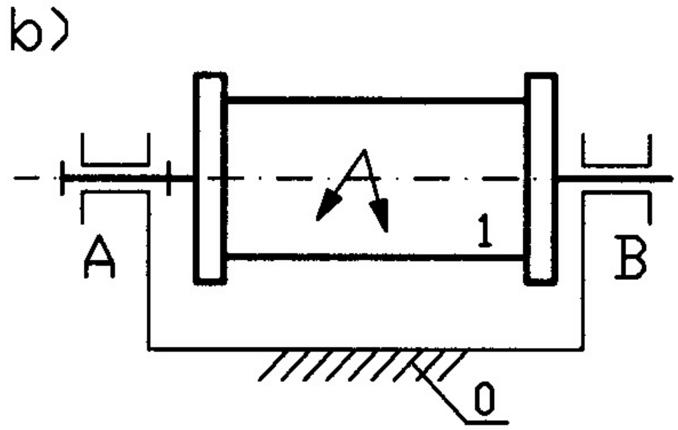
Geometrical conditions of motion

frame



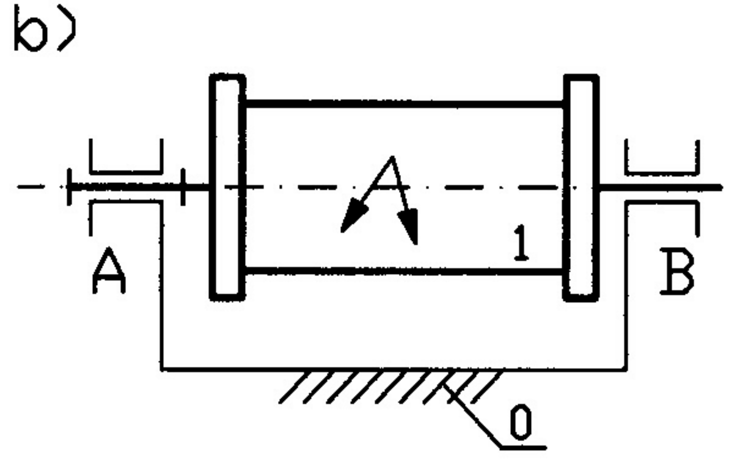
$\alpha_0 = 0$ $h_0 = 0$

Rotor



What can be modified to improve topology ???

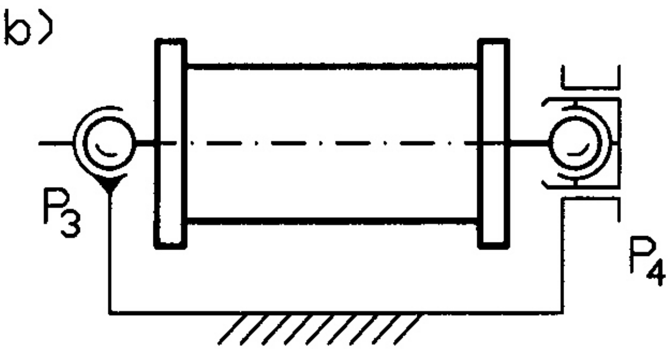
Improvement by changing jonts A and B (joint classes)



The goal is:

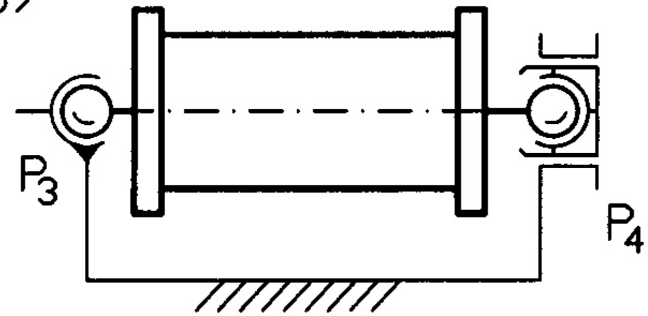
$$W_T = W_R = 1; \quad R_C = 0; \quad W_L = 0$$

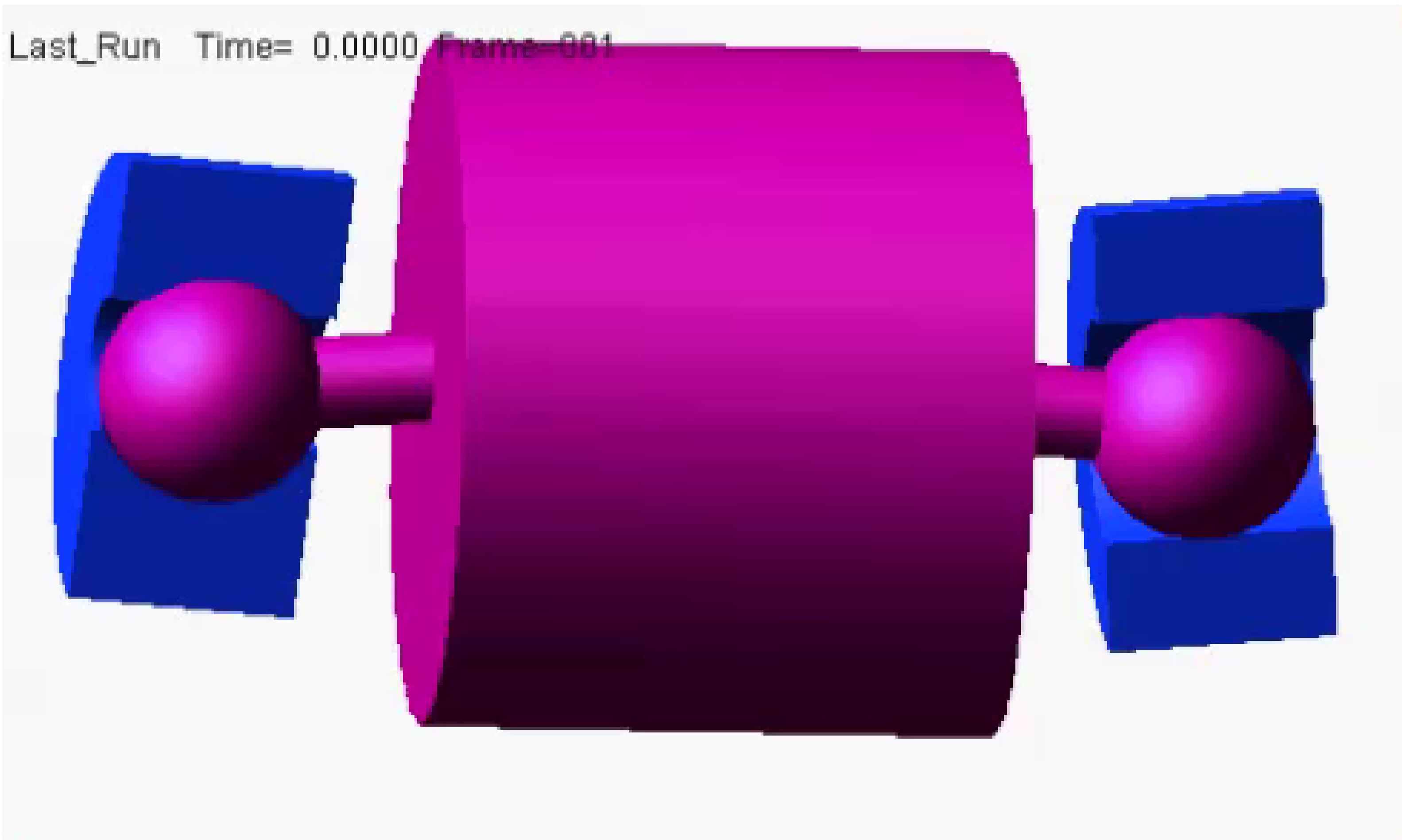
W_T	=	6k	$-5p_1$	$-4p_2$	$-3p_3$	$-2p_4$	$-1p_5$
1	=	6*1	-5*0	-4*1	-3*0	-2*0	-1*1
1	=	6*1	-5*0	-4*0	-3*1	-2*1	-1*0



Spherical joint (self-aligning bearing)

Spherical joint with translation allowed b)





For mechanism with redundant constraints:

because of manufacturing errors

assembly needs forces (elastic deformations)

→ friction in joints increases

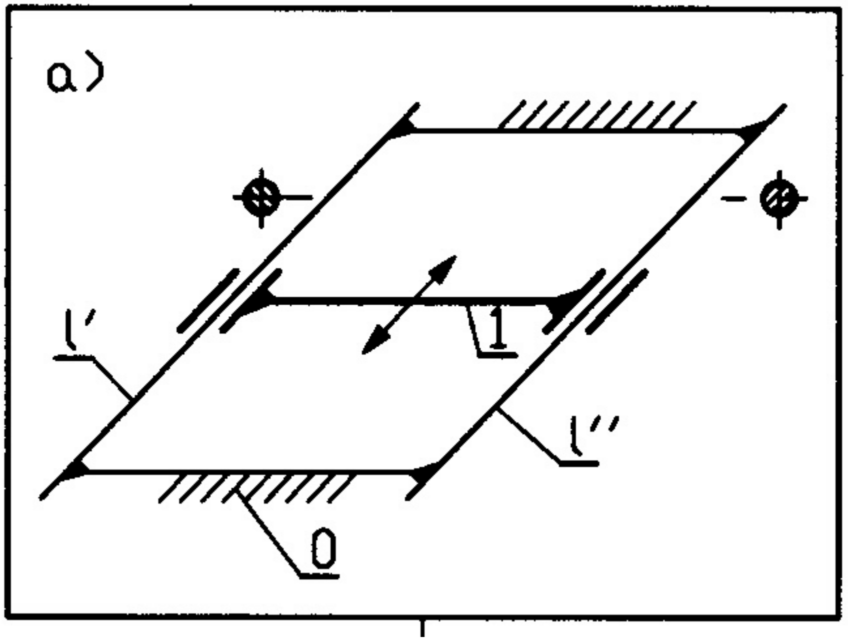
→ resistance of motion increases

→ both efficiency and reliability decreases

Mechanisms with redundant constraints are called

IRRATIONAL KINEMATIC SYSTEMS

SYSTEMS WITH WRONG TOPOLOGY



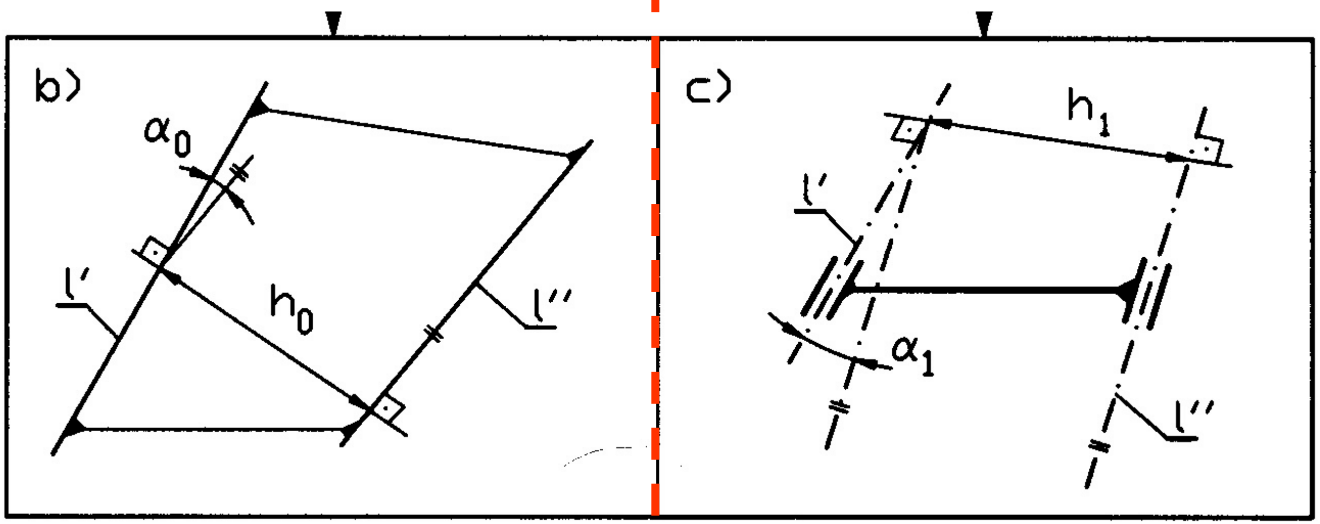
$W_R = 1$

$W_T = -2$

$W_L = 0$

$R_C = 3$

frame 0 | slider 1



$$\alpha_0 = 0$$

$$\alpha_1 = 0$$

$$h_0 = h_1$$

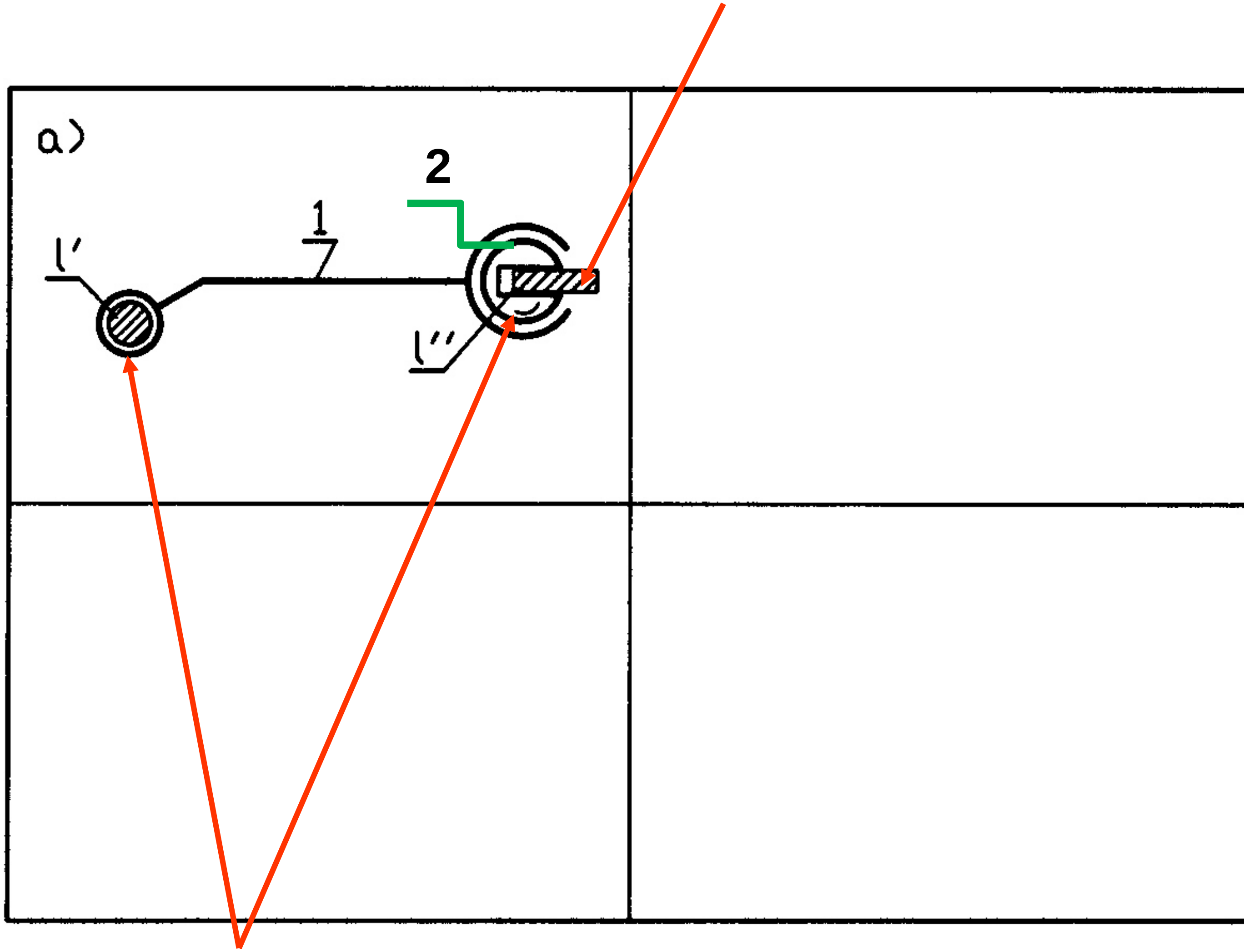
Rational topology - examples

$$k = 2$$

$$p_2 = 2$$

$$p_3 = 1$$

Planar joint

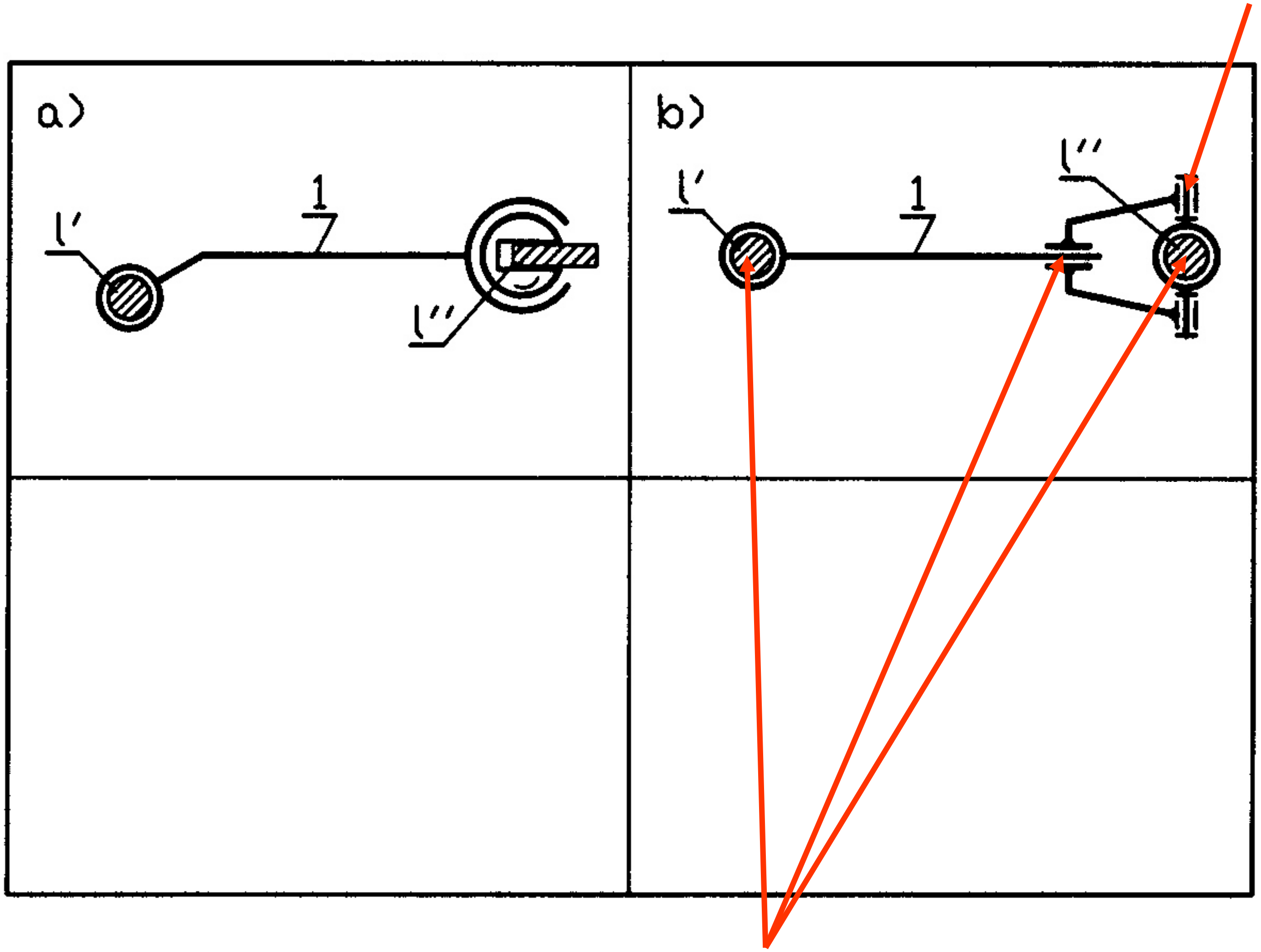


Cylindrical joint (linear bearing)

Rational topology - examples

$$k = 2$$
$$p_2 = 2$$
$$p_3 = 1$$

Revolute joint



$$k = 3$$
$$p_1 = 1$$
$$p_2 = 2$$

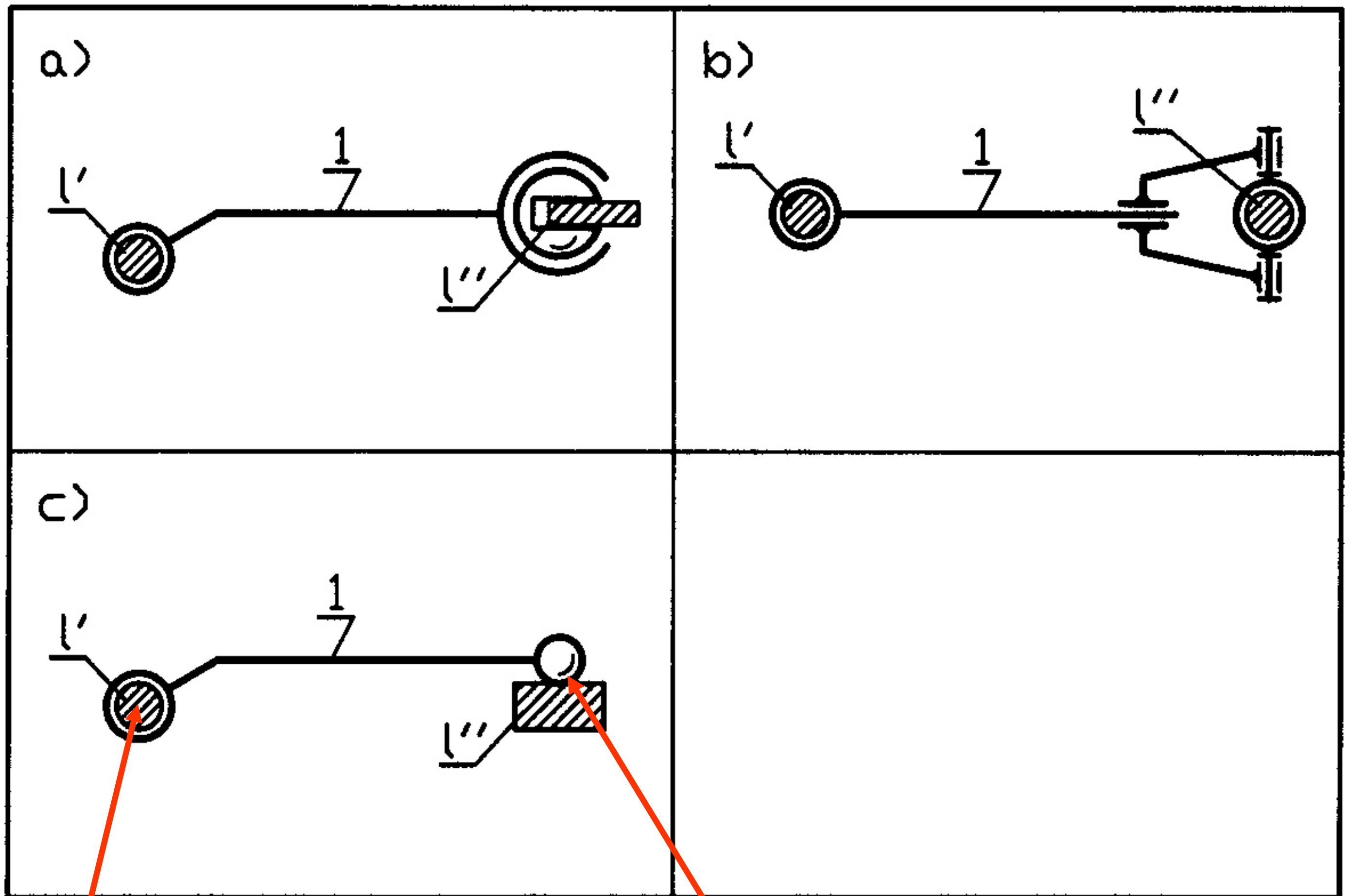
Cylindrical joint (linear bearing)

Rational topology - examples

$k=2$

$p_2=2$

$p_3=1$



$k=3$

$p_1=1$

$p_2=2$

$p_2=1$

$p_5=1$

Cylindrical joint (linear bearing)

Point to surface joint

Rational topology - examples

$k = 2$

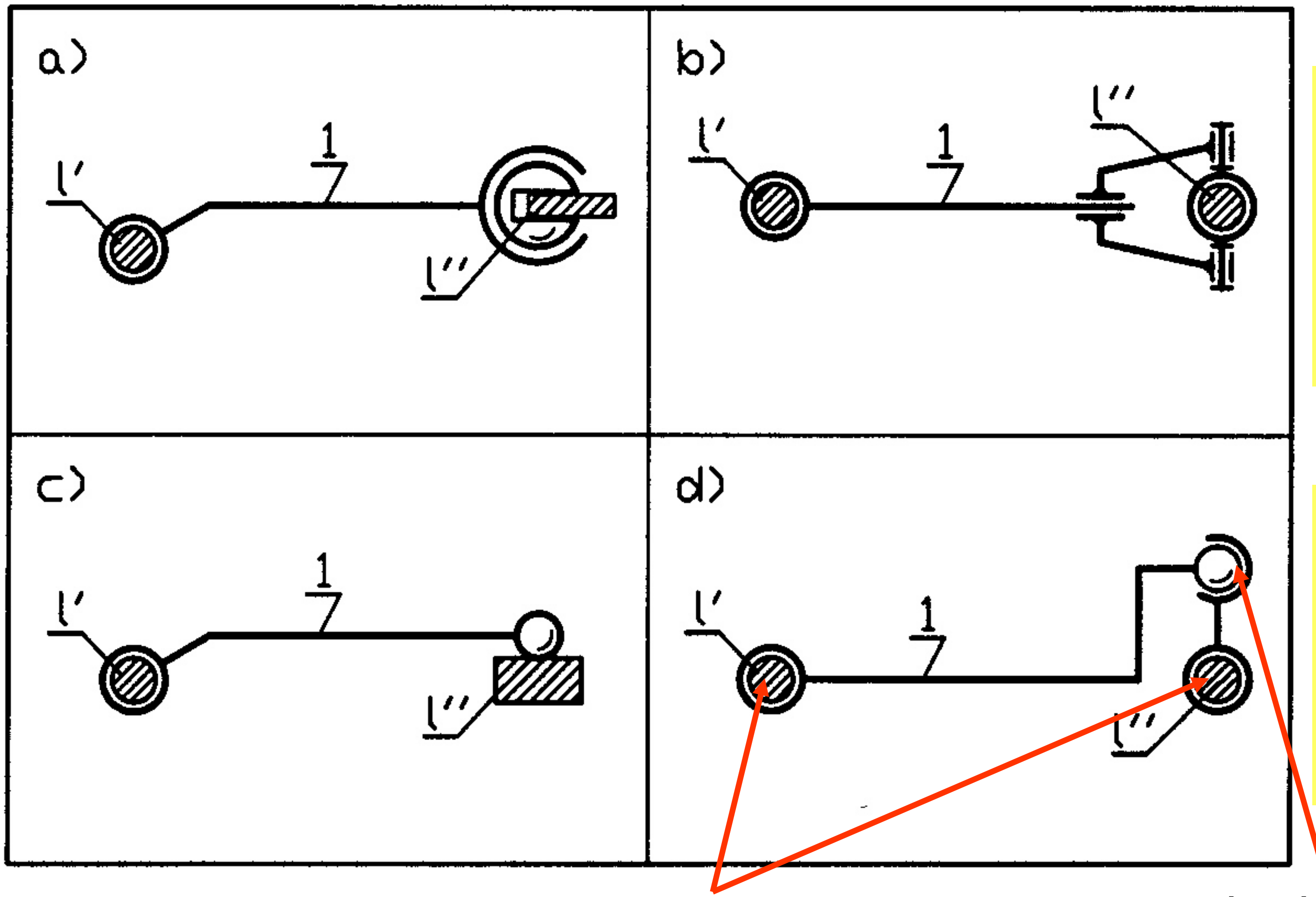
$p_2 = 2$

$p_3 = 1$

$k = 3$

$p_1 = 1$

$p_2 = 2$



$p_2 = 1$

$p_5 = 1$

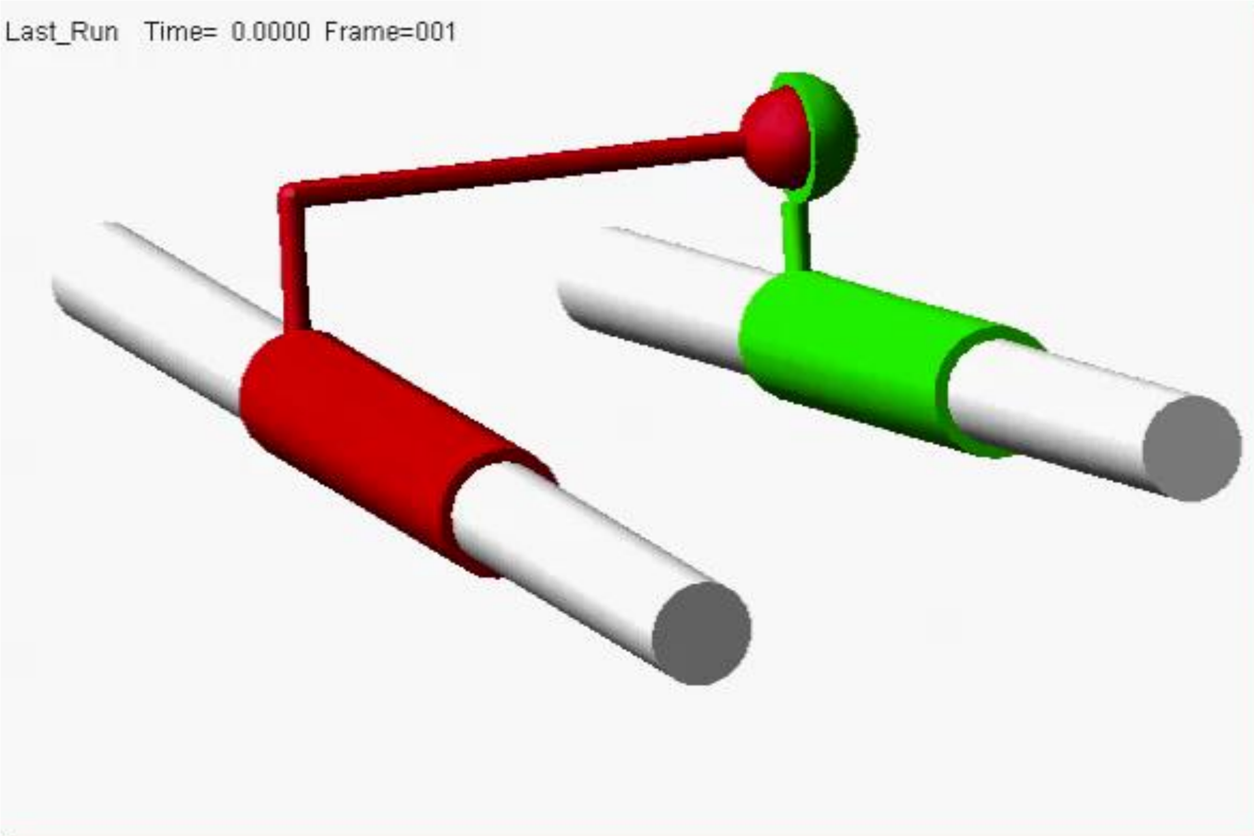
$k = 2$

$p_2 = 2$

$p_3 = 1$

Cylindrical joint (linear bearing)

Spherical joint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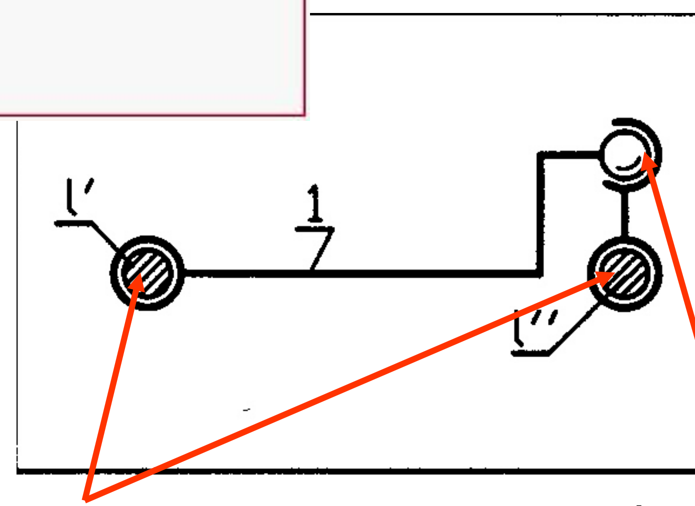
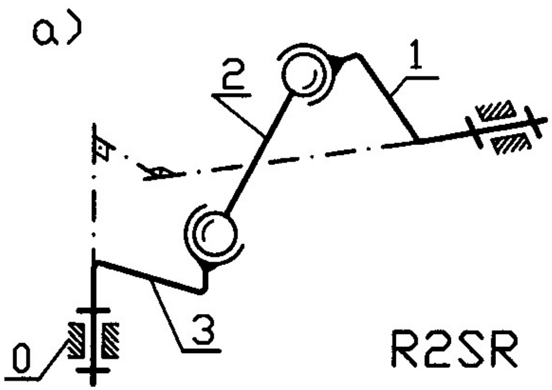

1'
1
1''
Cylindrical joint (linear bearing)
Spherical joint

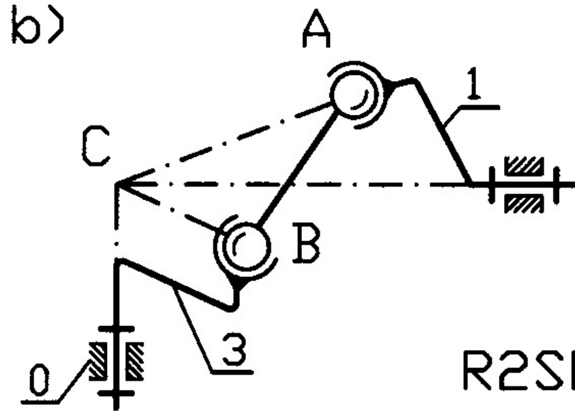
$k = 2$

$p_2 = 2$

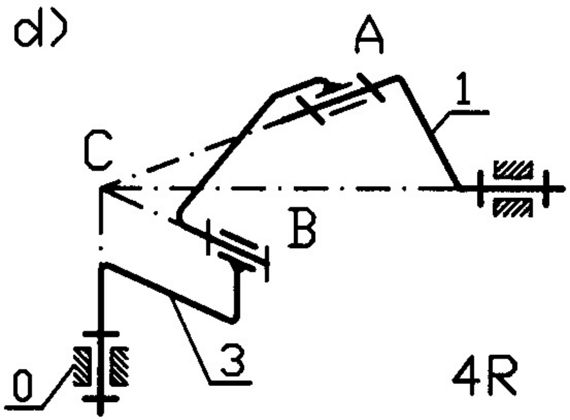
$p_3 = 1$



3D 4 bar (general)



3D 4 bar (input (1) & output (3) axes intersect)



3D 4 bar (all joint axes intersect at point)