Theory of Mechanisms and Manipulators

lectures 2h every week (**EGZAMINATION**);

project 2h/week

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The course concerns with

kinematic systems – mechanical systems of bodies connected <u>in the way enabling their relative motion</u>

mechanisms, robots, manipulators

car suspension, linkages, transmissions, …

The main topics:

topology (structure), kinematics and dynamics

TOPOLOGY (STRUCTURE)

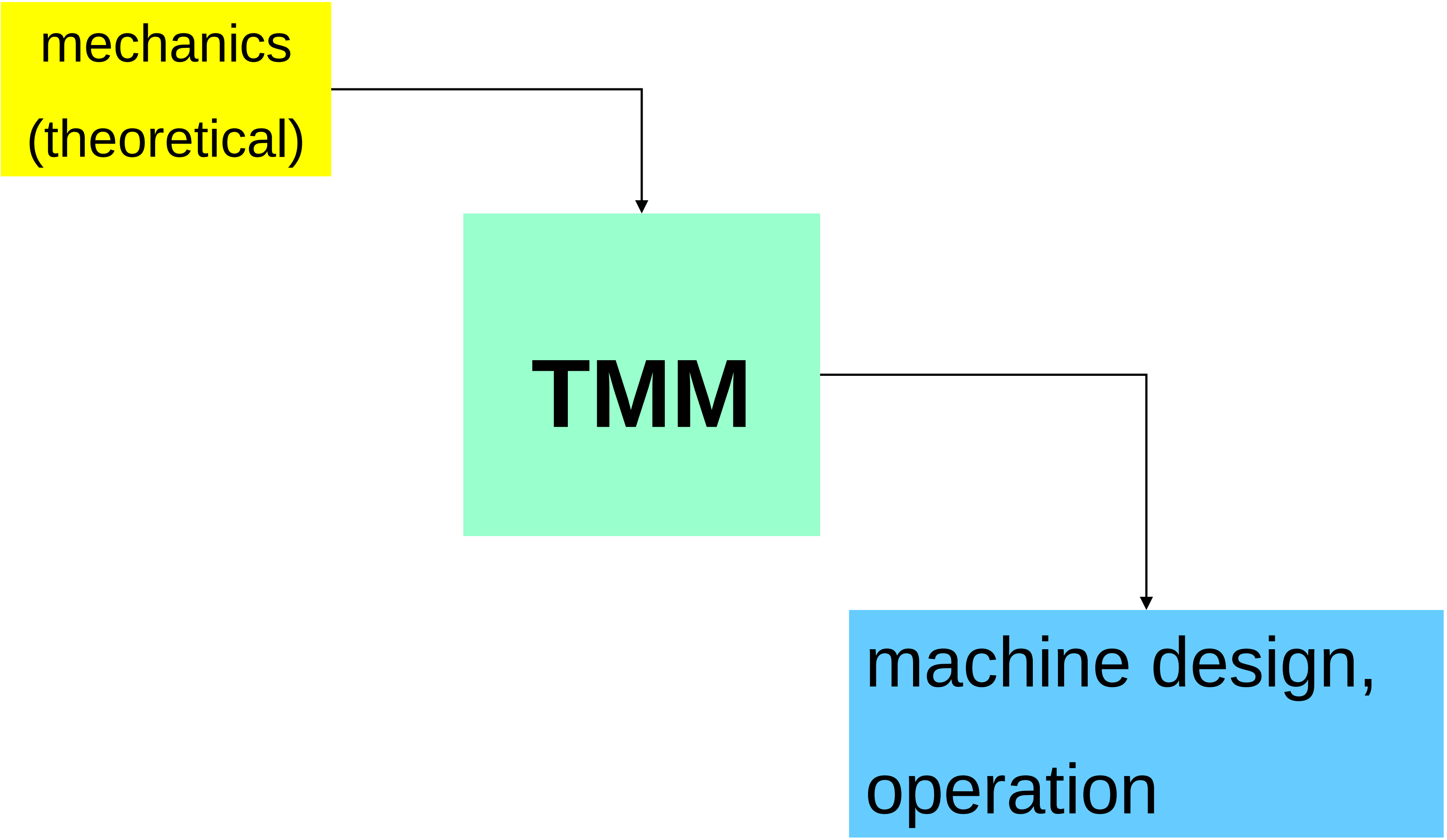
Describes the properties of kinematic systems (mechanisms) resulting from the number and kinds of elements - links, (members) and joints

KINEMATICS
Branch of TMM dealing with the geometry of motion, irrespective of the causes that produce the motion

KINEMATIC ANALYSIS
Analysis of the kinematic aspects of mechanisms

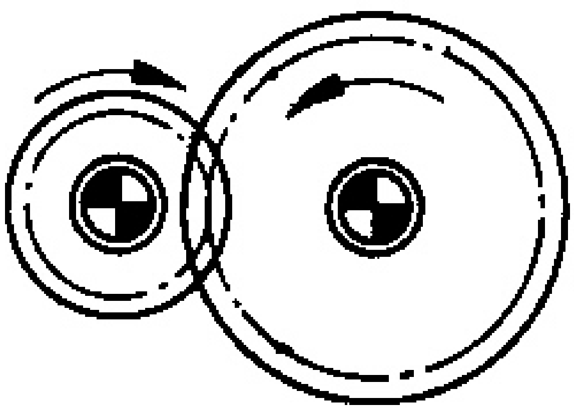
DYNAMICS
Branch of TMM dealing with the motion and equilibrium of bodies and mechanisms under the action of forces.

Sometimes the terms KINETICS and KINETOSTATICS are applied to the same field or some aspects of it



TMM = APPLIED MECHANICS

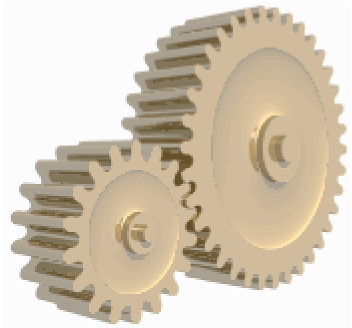
SIMPLE KINEMATIC SYSTEMS



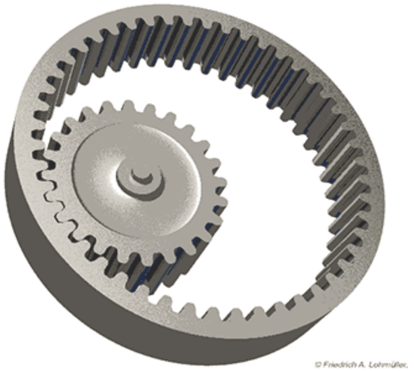
spur gears

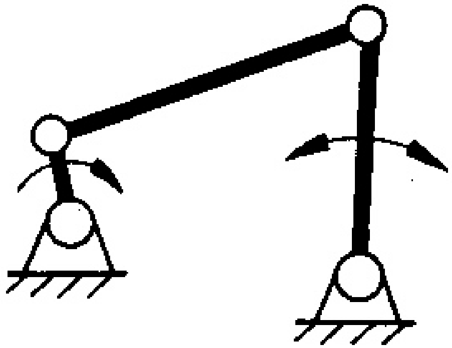
SPUR GEAR – cylindrical gear

with external teeth



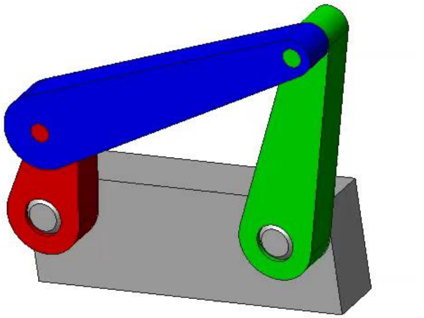
with internal teeth





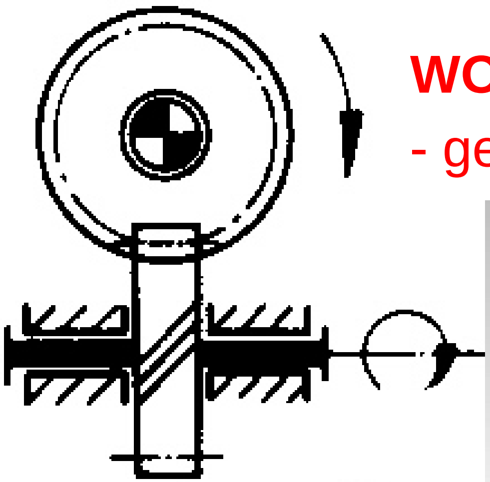
planar (2D) 4 bar

BAR - link that carries only revolute joints



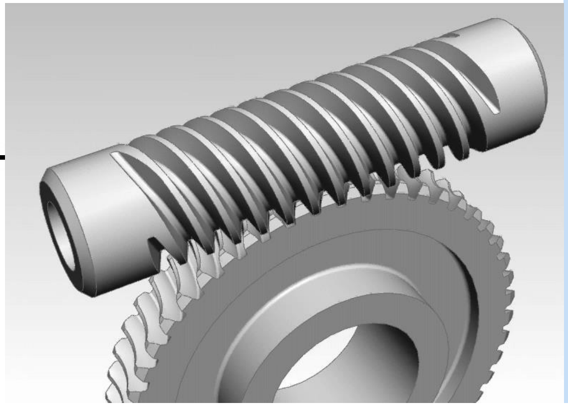
worm gears

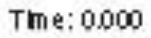
WORM GEAR - gear with one or more teeth wrapped helically on a cylinder (or a globoid)

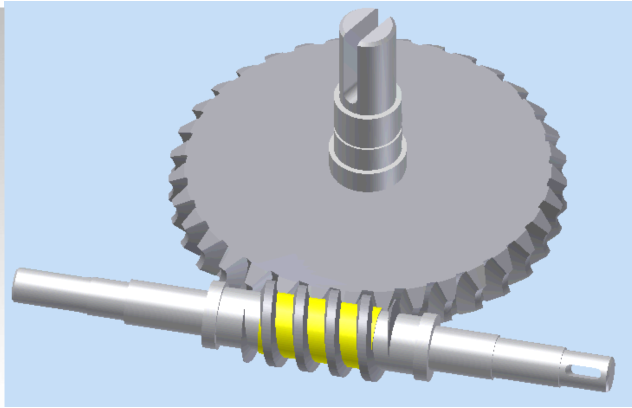


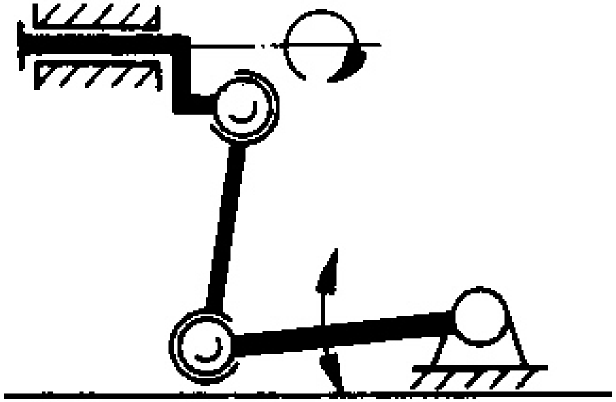
WORM WHEEL

- gear that mates with a worm gear

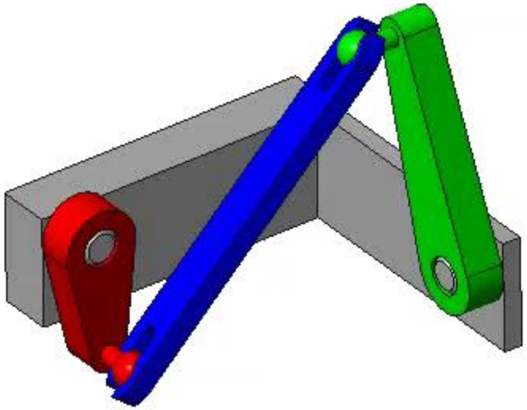


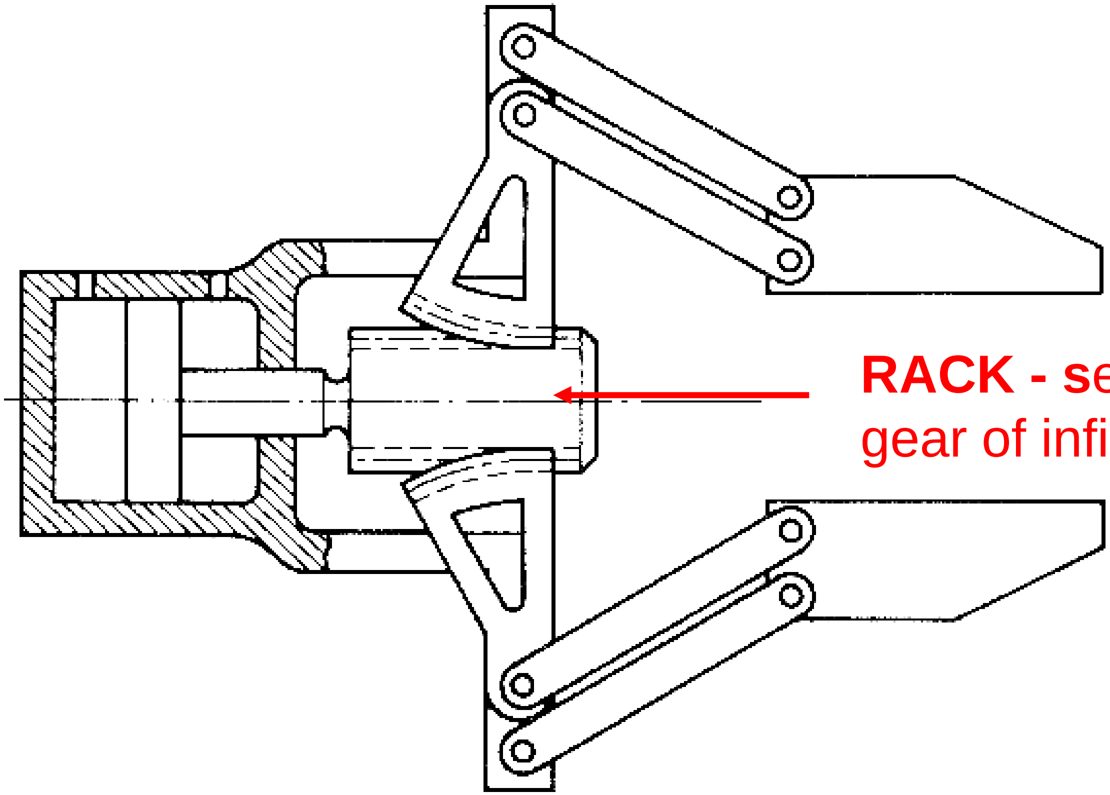




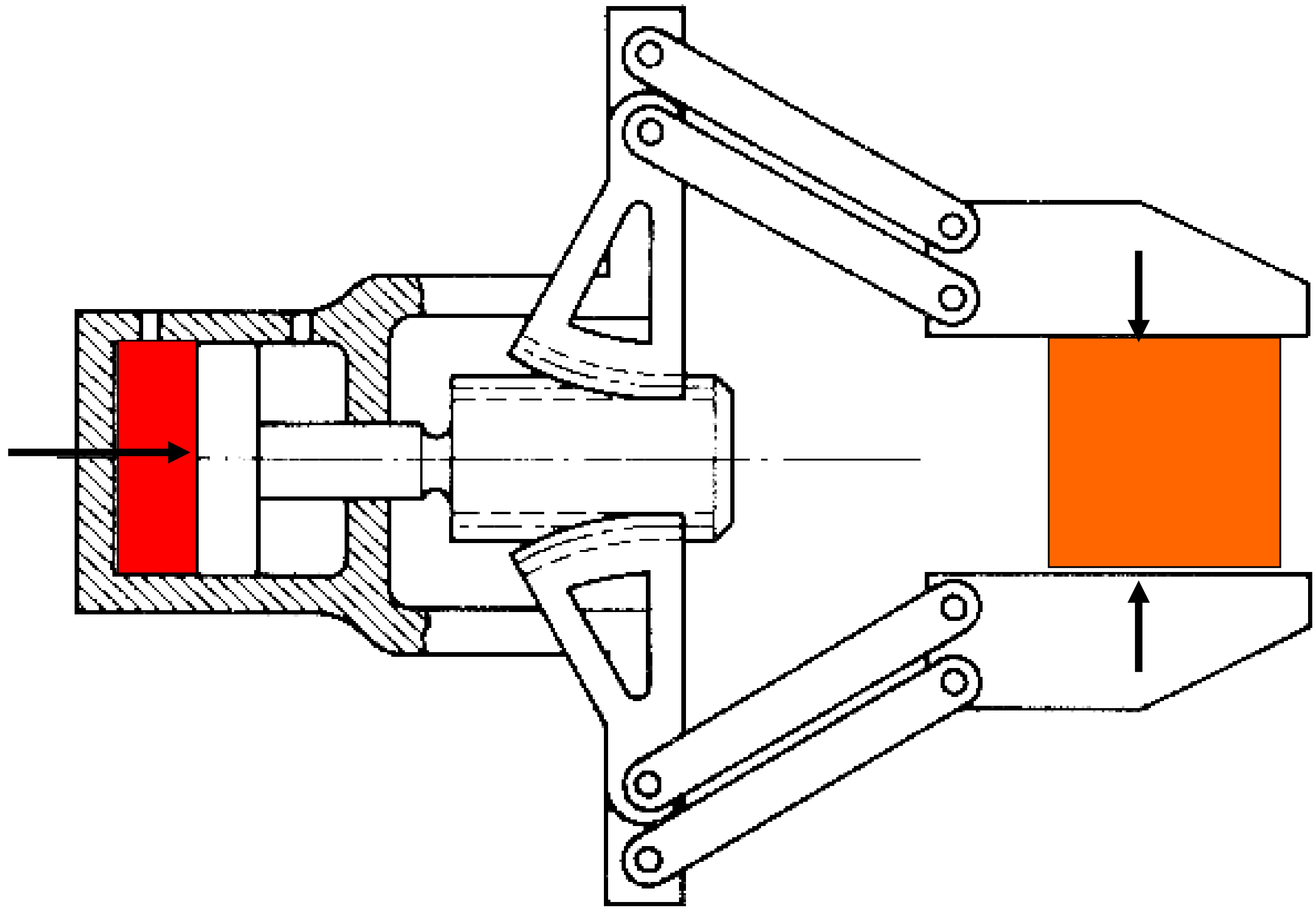


Spatial (3D) 4 bar





Gripper of dual gear-and-rack type actuated by pneumatic source



Dump truck system

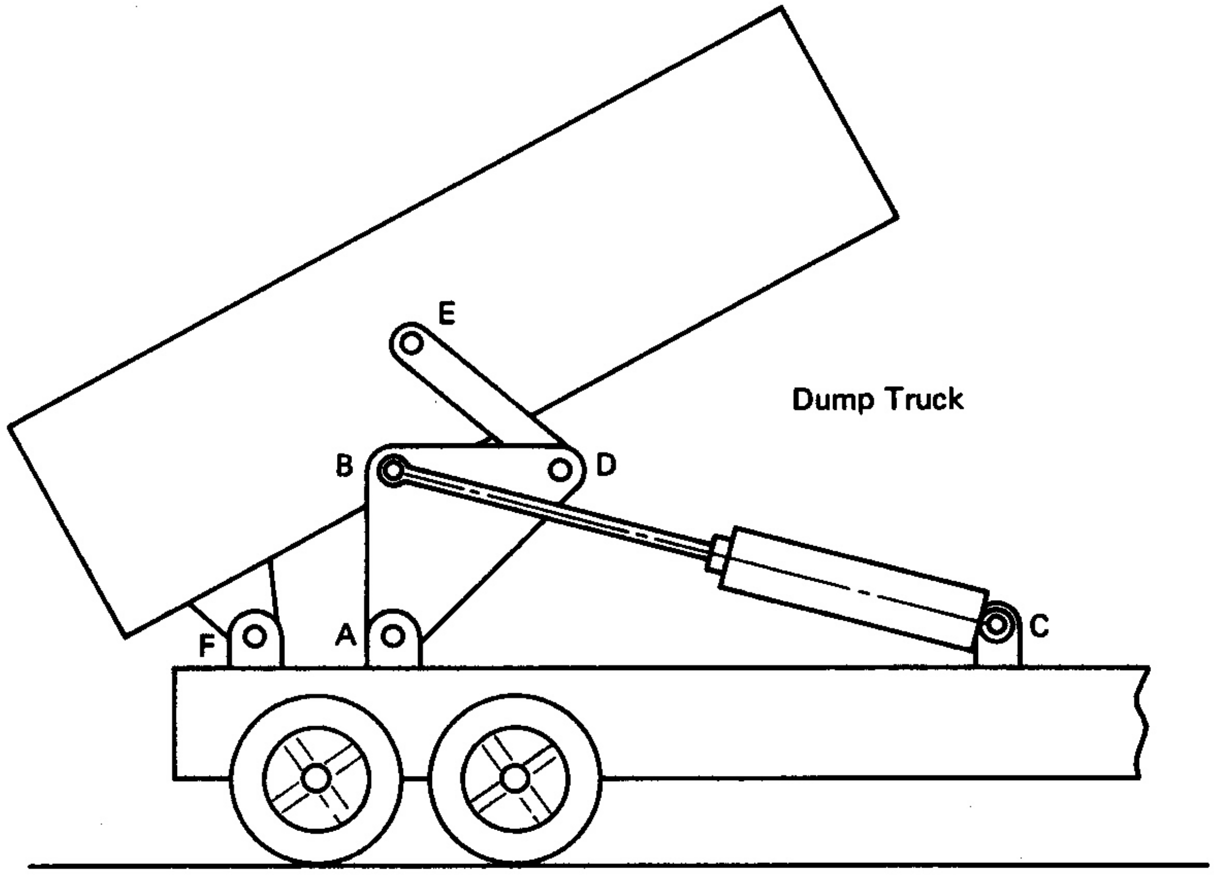
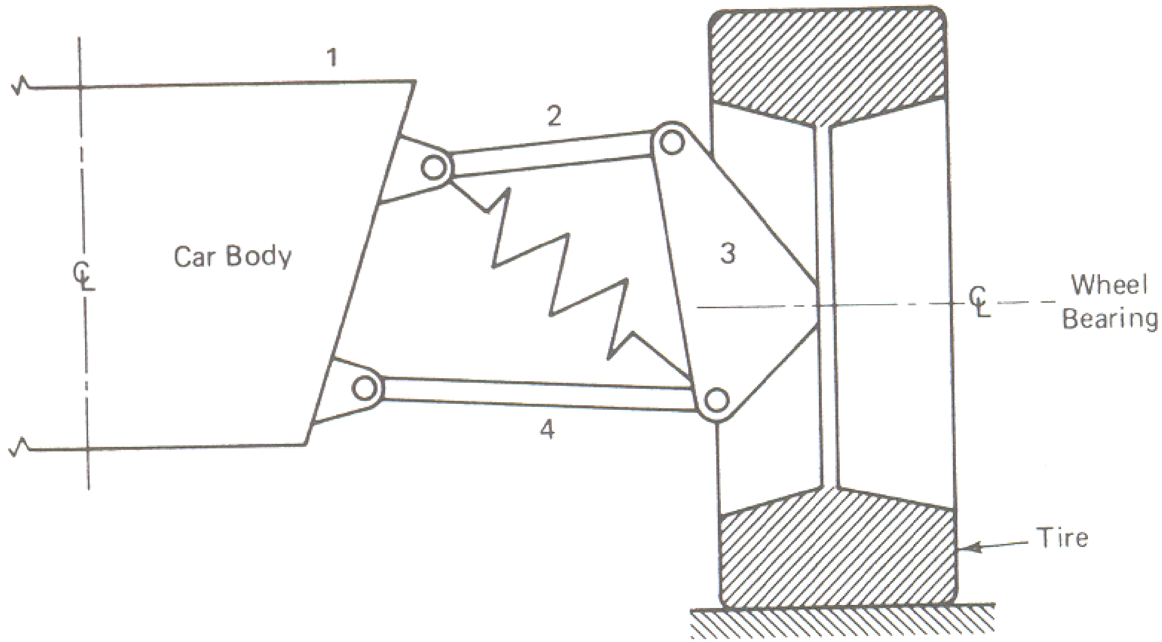
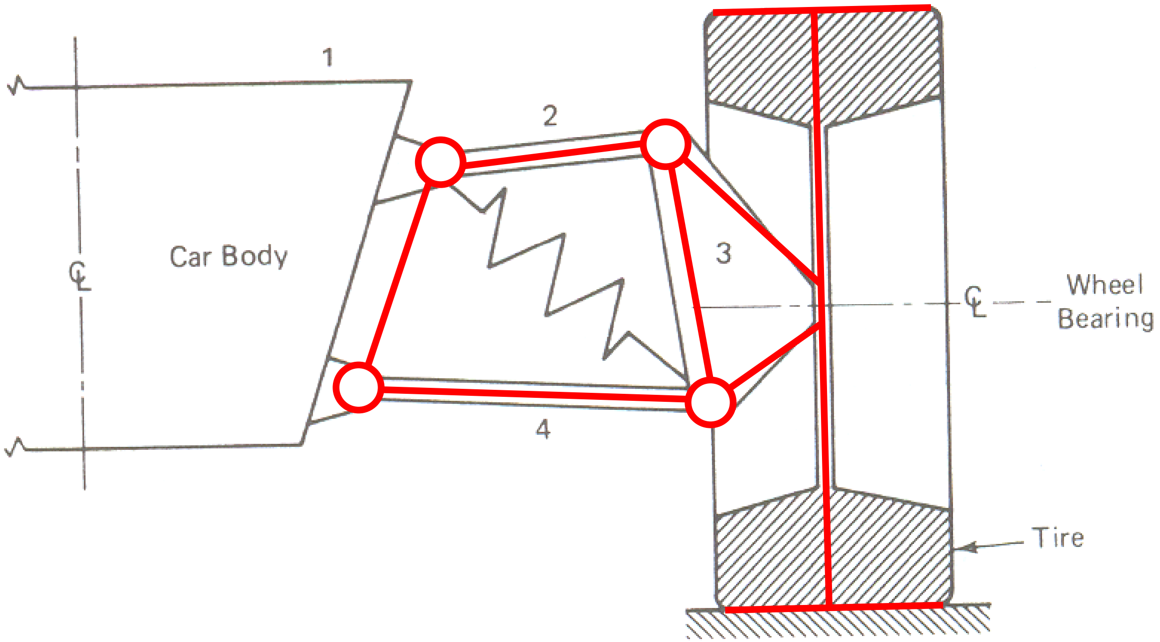


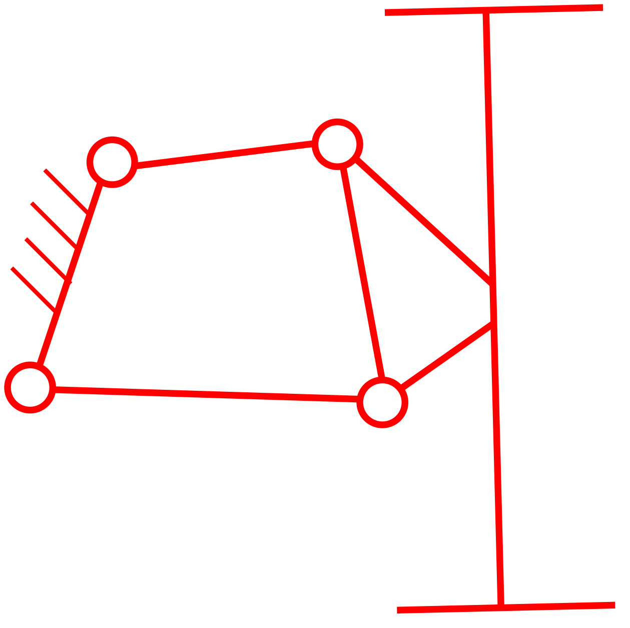
Figure P1.3



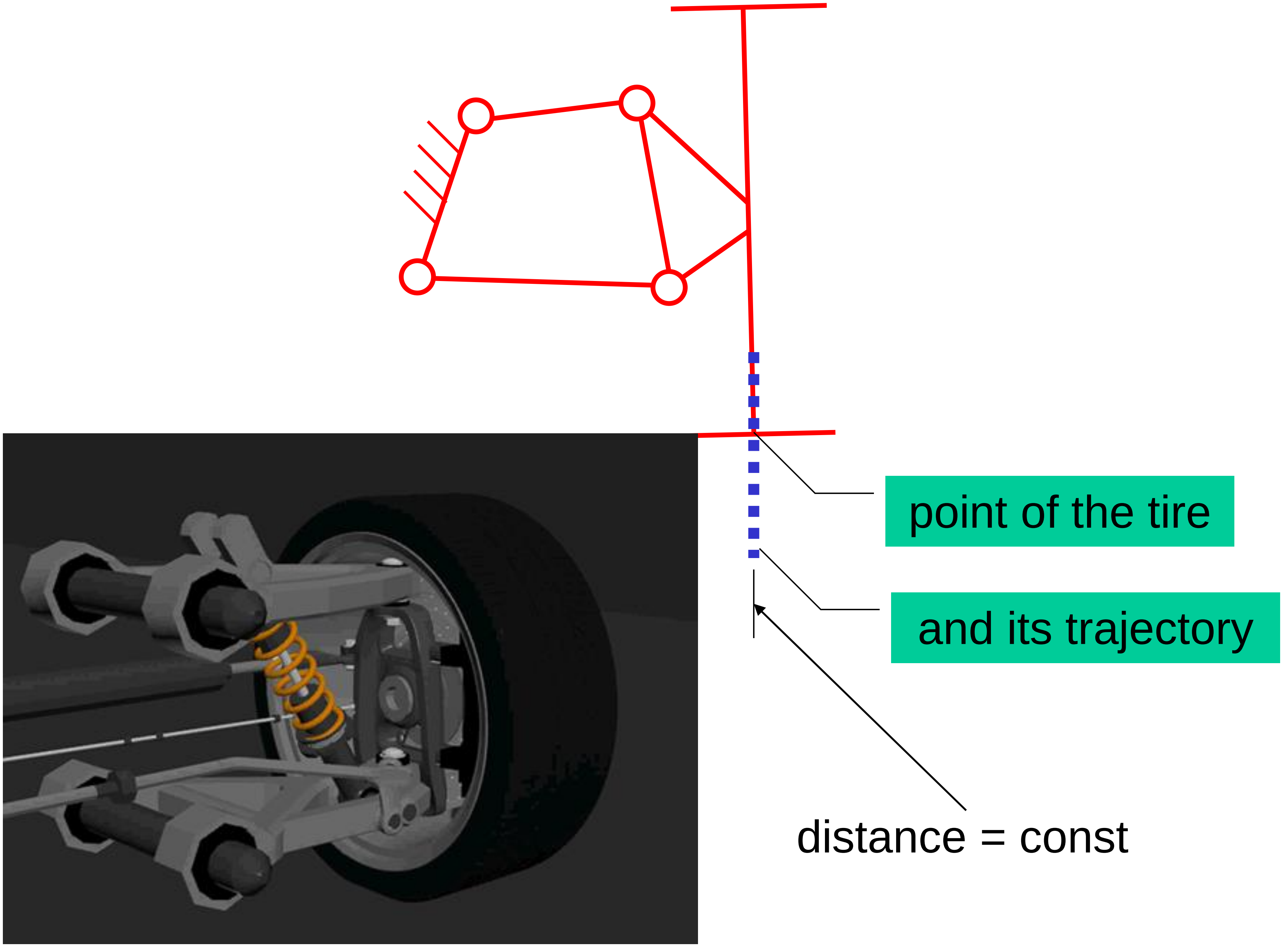
Automotive suspension system



Automotive suspension system



KINEMATIC SCHEME of automotive suspension system


point of the tire
and its trajectory
distance = const

DEGREES OF FREEDOM

Any mechanical system can be classified according to the number of degrees of freedom (DOF) which it possesses.

The system's DOF is equal to the number of independent parameters which are needed to uniquely define its position at any instant of time

DOF is defined with respect to a selected frame of references

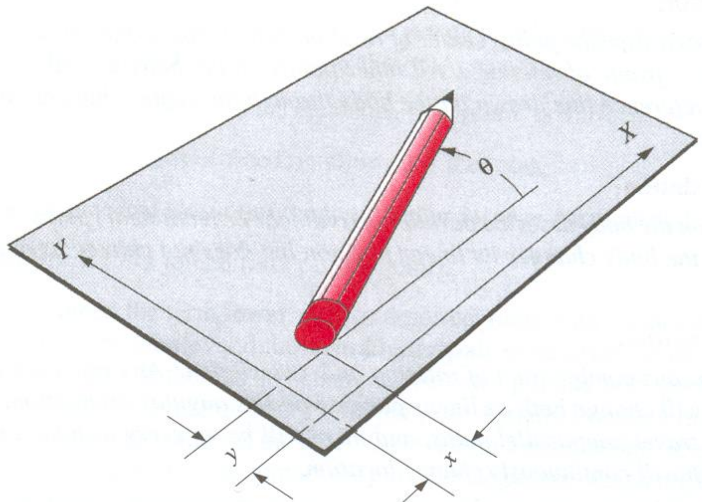


FIGURE 2-1
A rigid body in a plane has three *DOF*

Two bodies: frame with x-y coordinate system and a pencil

To define pencil's position on the plane x-y three parameters (3 DOF) are required: two linear coordinates (x, y) and one angular (Θ)

The pencil in a plane has three DOF

A **link**, as shown in Figure 2-2, is an (assumed) rigid body which possesses at least two **nodes** which are *points for attachment to other links*.

Binary link - *one with two nodes.*

Ternary link - *one with three nodes.*

Quaternary link - *one with four nodes.*

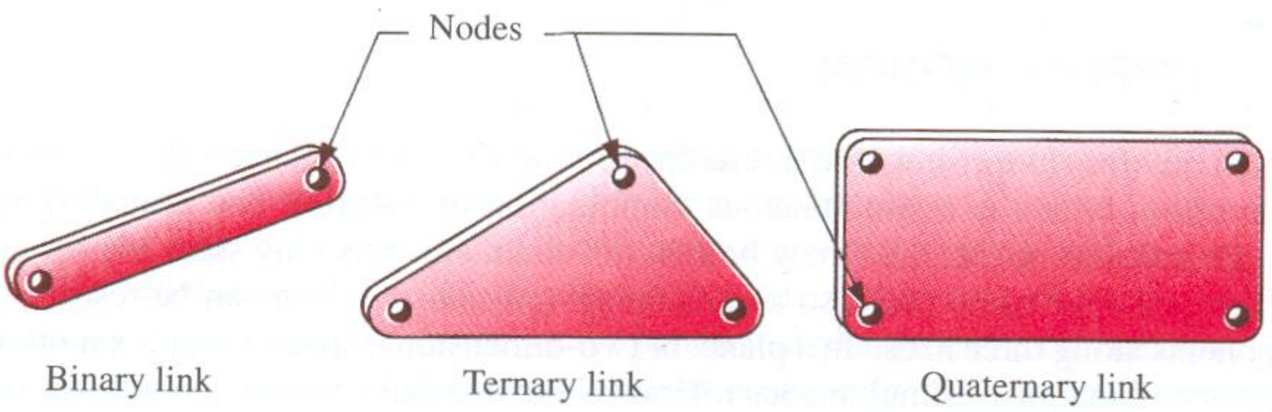
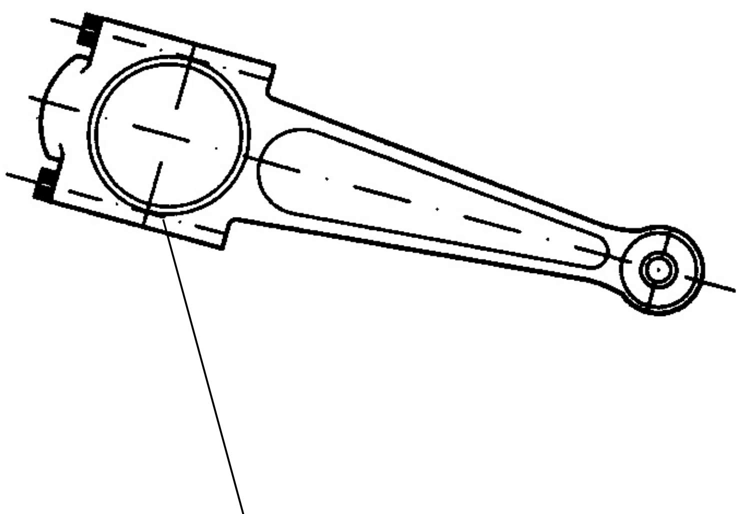


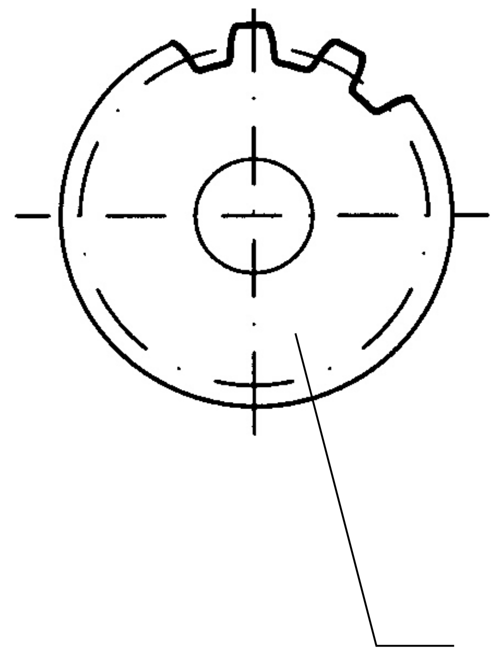
FIGURE 2-2

Links of different order

Links - examples

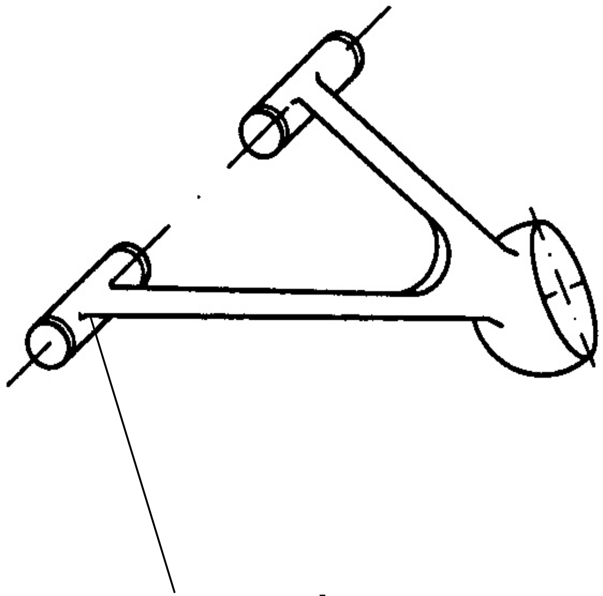


connecting rod



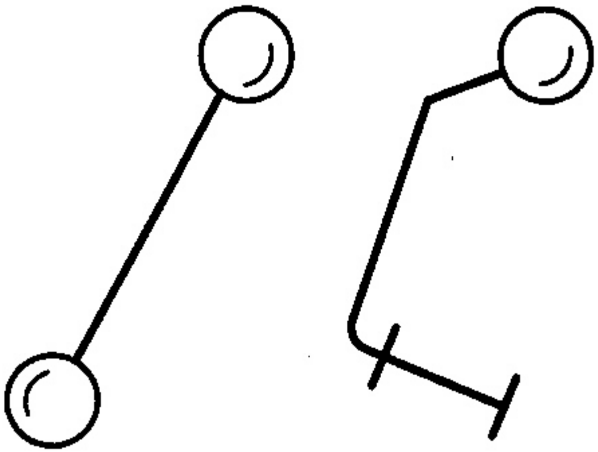
gear

Links - examples

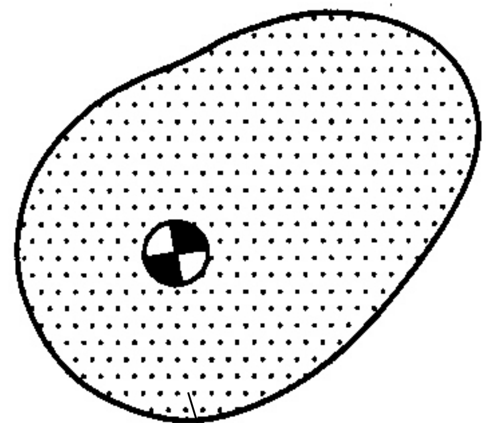


rocker

Links - examples



couplers



cam

JOINT = KINEMATIC PAIR

A joint is a connection between two links (bodies) at their nodes, which allowes some motion between connected links

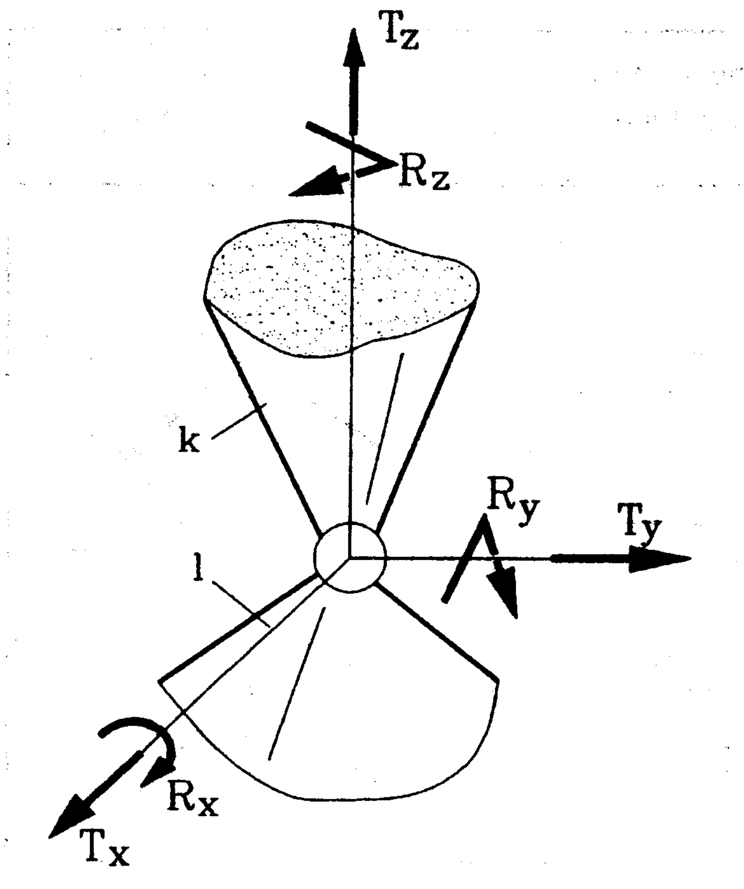
Joints are mostly classified in two ways:

- by the number of degrees of freedom allowed at the joint,
- by the type of contact between two elements: point, line or surface

Sometimes we can meet joint classification by the type of physical closure of the joint: either **force** or **form** closed

A most useful joint classification is

by number of degrees of freedom that they allow between the two elements joined



f – number of DOF (link k relativly to l)

f = 6: no connection

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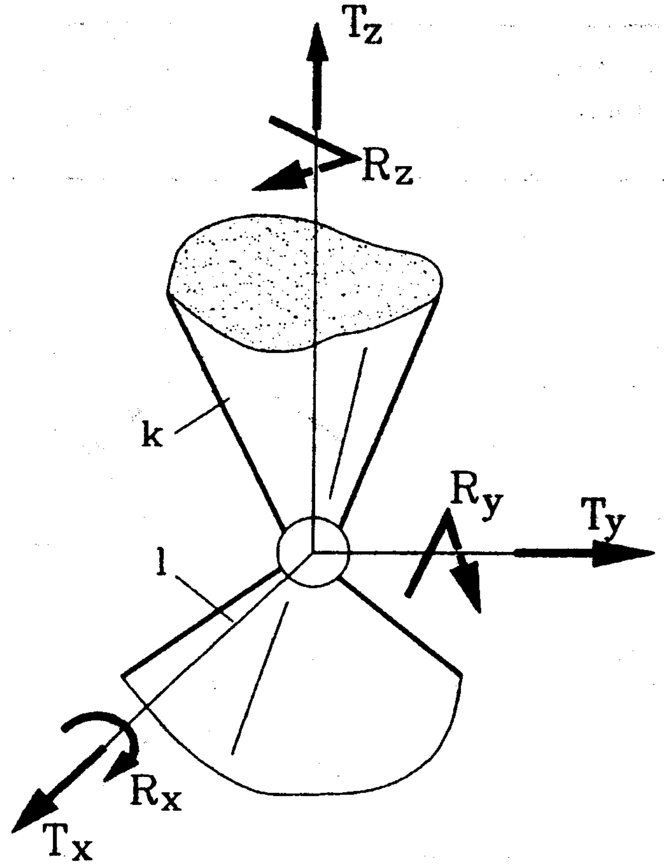
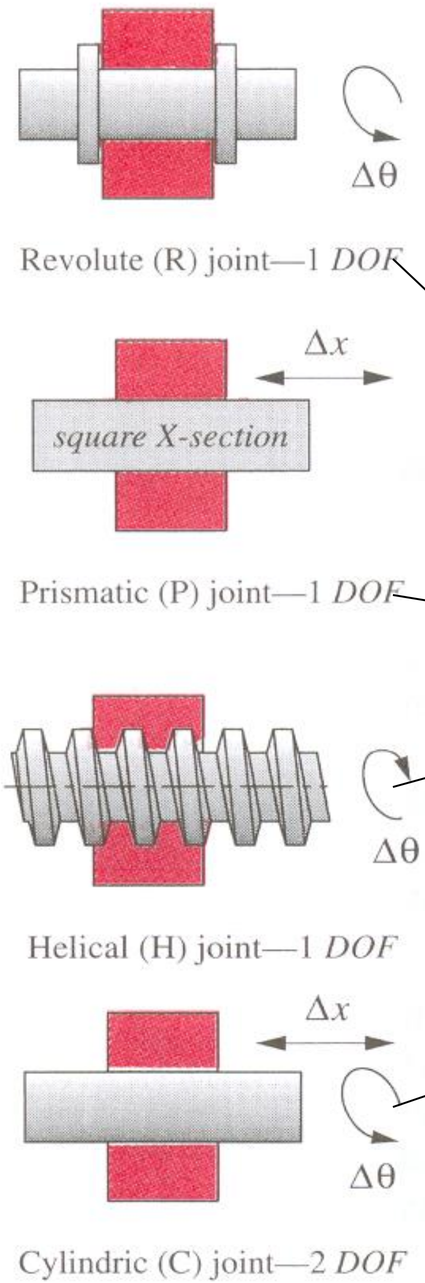
f = 5: → V class joint

f = 4: → IV class joint

....

f = 1: → I class joint





REVOLUTE (R)

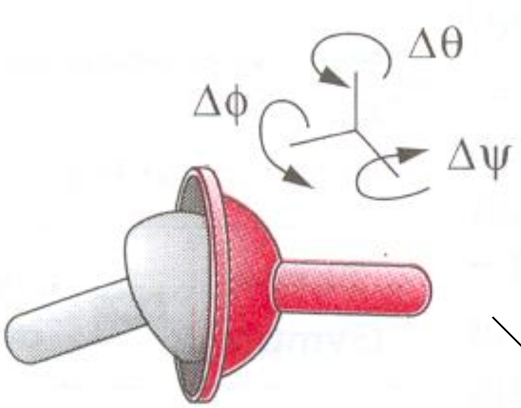
PRISMATIC (T) (translation)

1 DOF = I class joints

HELICAL (H)

2 DOF = II class joint

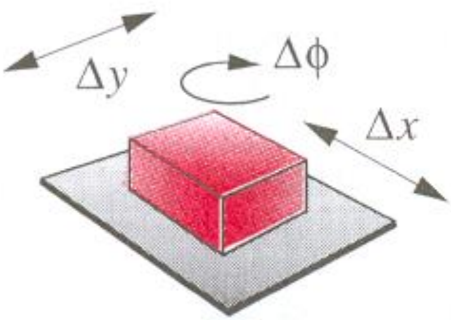
CYLINDRIC (C)



Spherical (S) joint—3 *DOF*

SPHERICAL (S)

3 DOF = III class joints



Planar (F) joint—3 *DOF*

PLANAR (F)

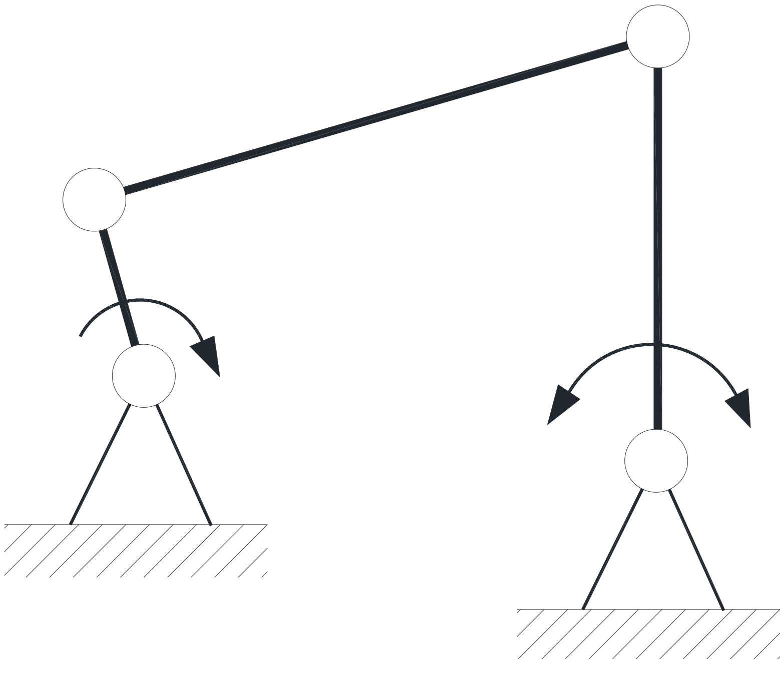
Kinematic chain: An assemblage of links and joints

Mechanism: *A* kinematic chain in which at least one link has been grounded or attached to the frame of reference, designed to provide a controlled output motion in response to a supplied input motion

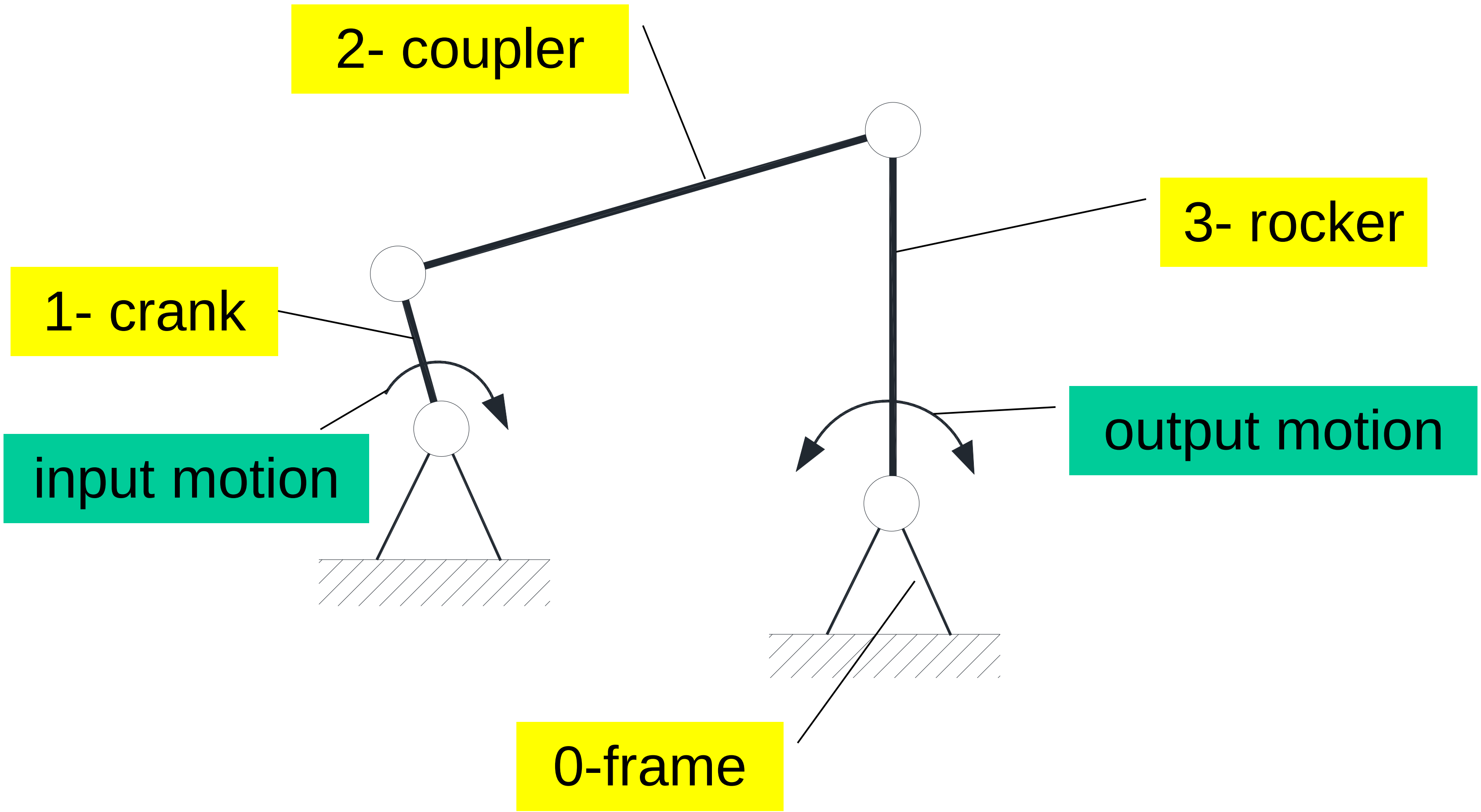
Manipulator: Device for gripping and the controlled movement of objects

Machine: A combination of resistant bodies arranged to compel the mechanical forces of nature to do work accompanied by determinate motion

A mechanism – 4 bar linkage

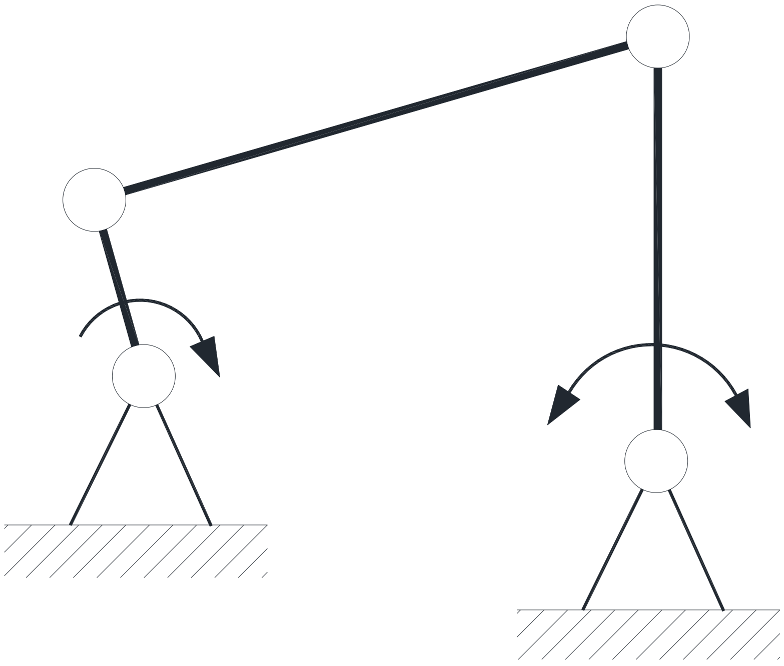


A mechanism – 4 bar linkage



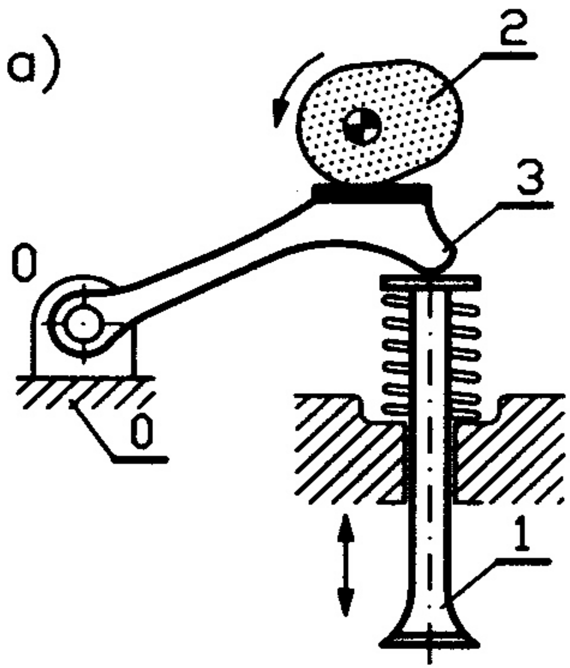
Mobility of a mechanism: W

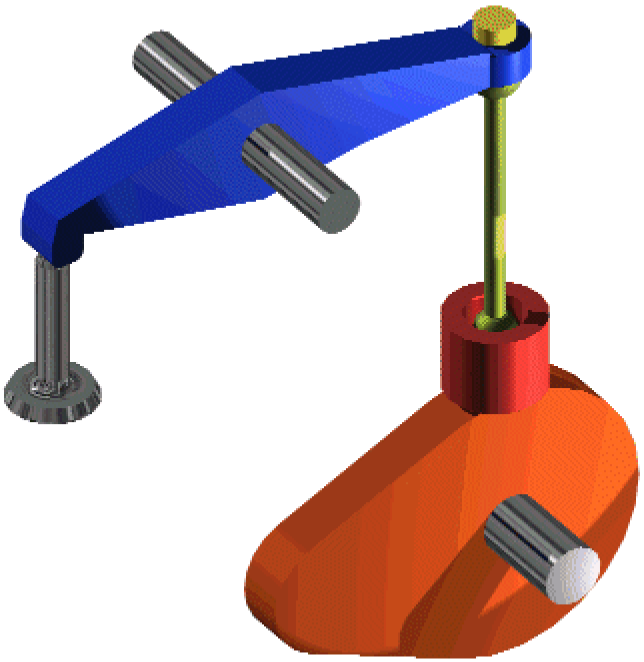
W is a number of DOF of all links in relation to the frame



Mobility of a mechanism: W

W is a number o DOF of all links in relation to the frame



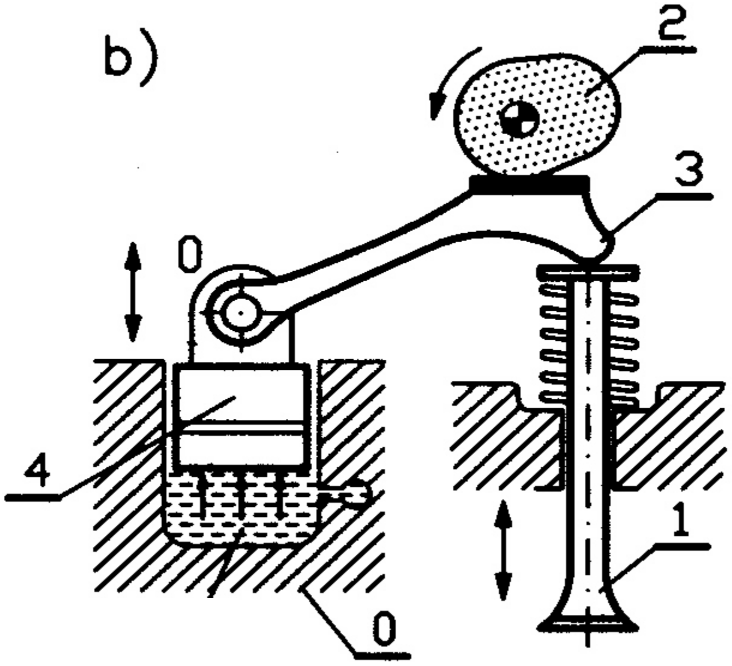


W = 1

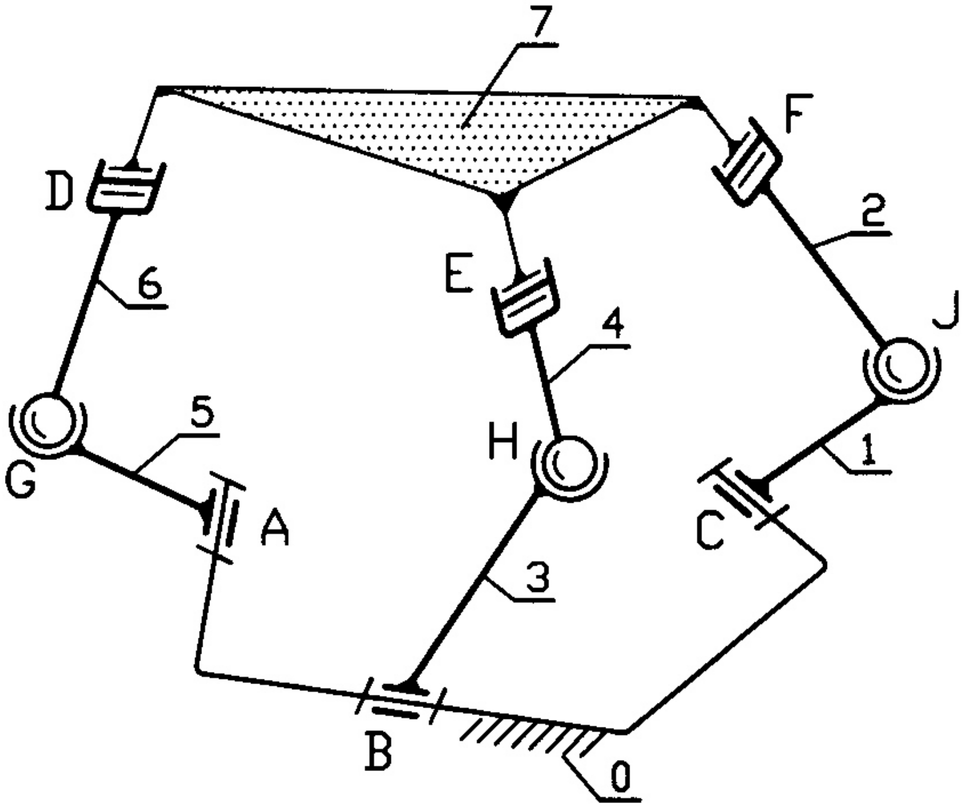
Mobility of a mechanism

a number o DOF of all links in relation to the frame

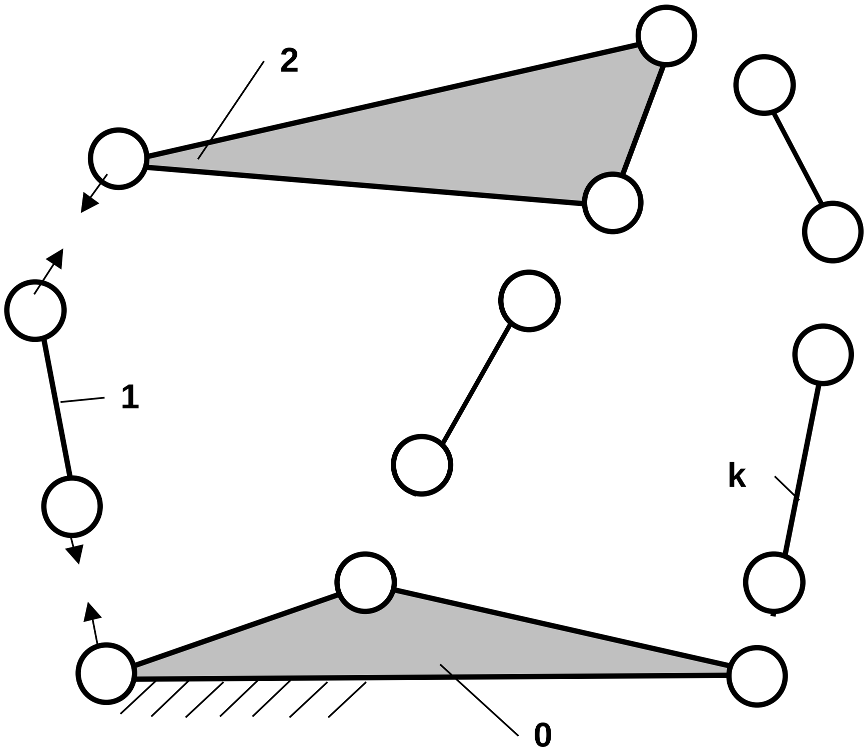
W = 2



W = ?



Mobility of kinematic system



Planar systems (2D):

k – number of movable links

n = k + 1 – all links

p_1 – number of I class joints

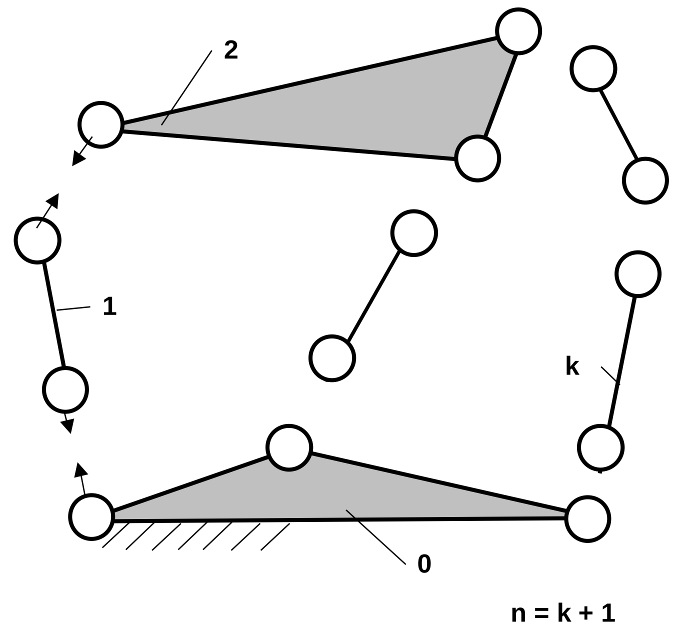
p_2 – number of II class joints

Planar systems (2D):

single link has 3 DOF (<u>in a plane</u>)

k links have $3k = 3(n-1)$ DOF

connecting two links by means of i-th class kinematic pair (joint) we reduce number of DOF by (3-i)



Planar systems (2D)

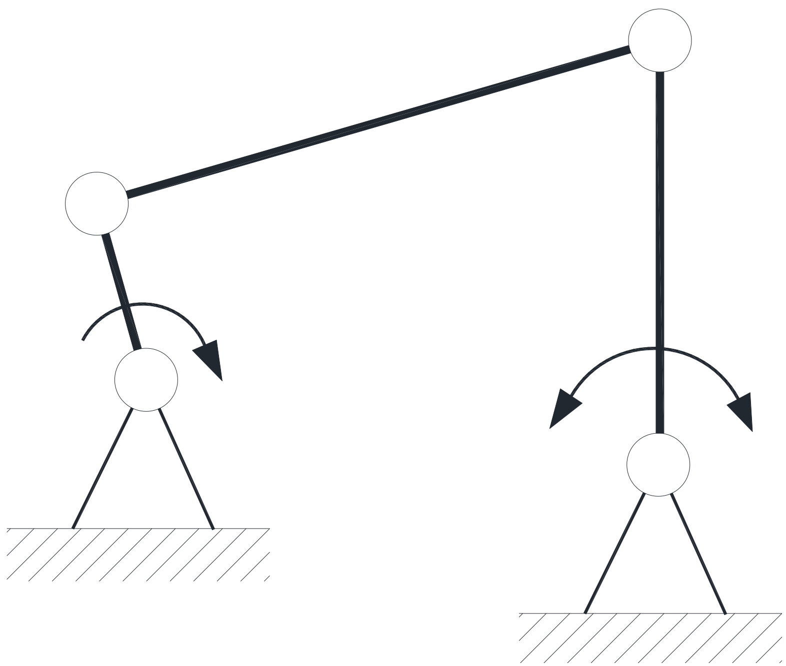
$$\boxed{W_T = 3(n-1) - 2p_1 - 1p_2}$$

Spatial systems (3D)

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

W_T - theoretical (topological) mobility !!!

$$\boxed{W_T = 3(n-1) - 2p_1 - 1p_2}$$



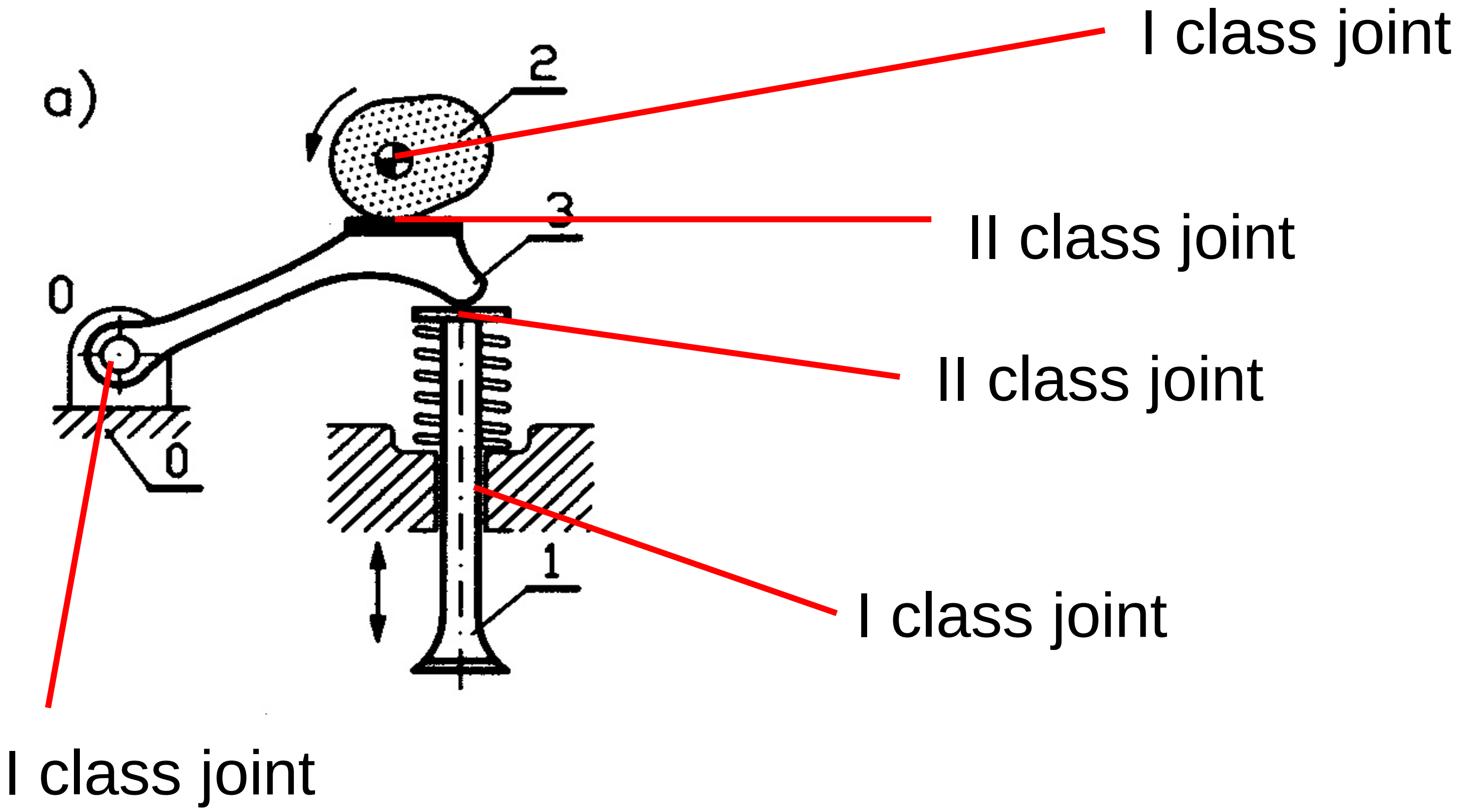
$k =$

$p_1 =$

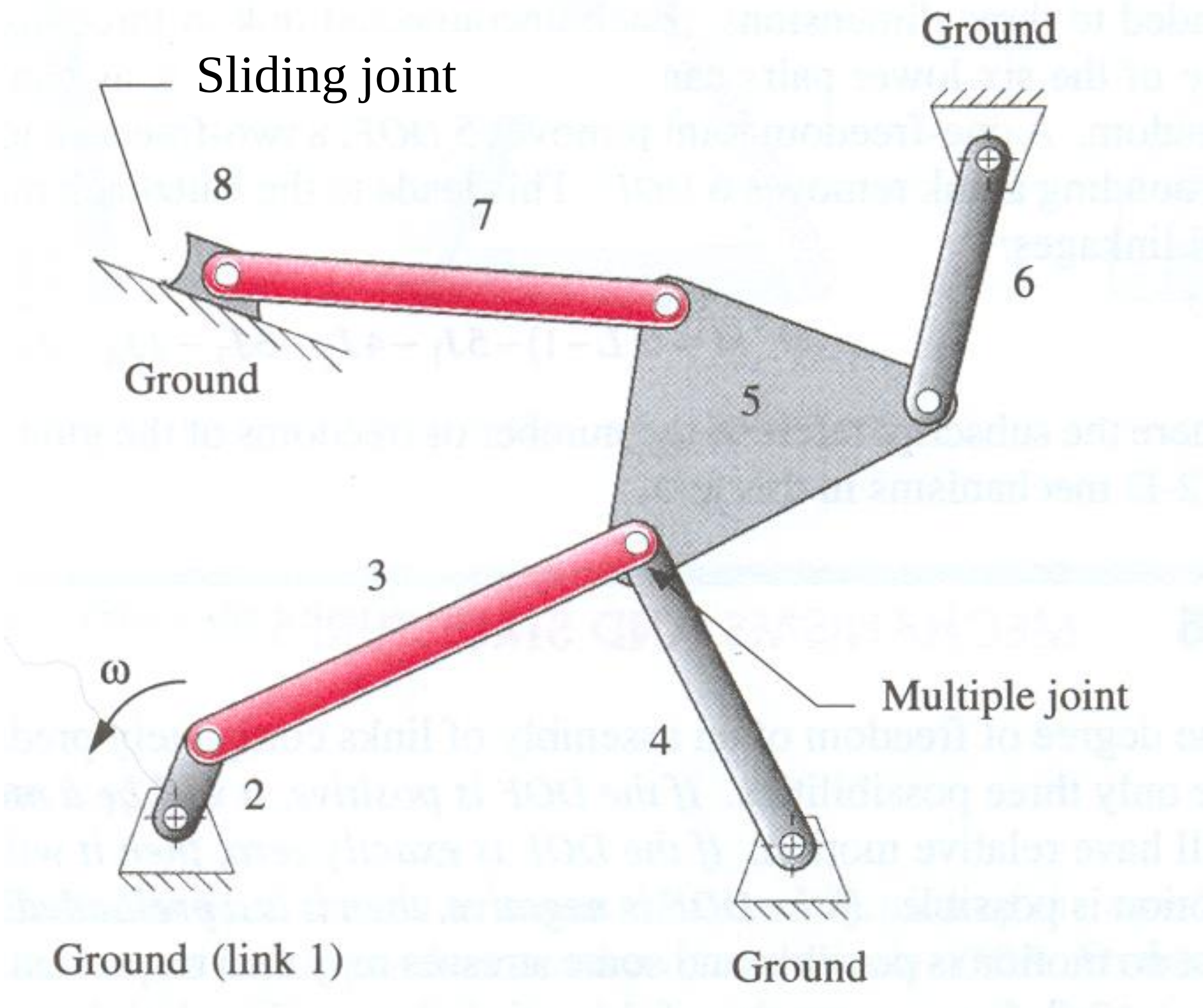
$p_2 =$

$$W_T = 3k - 2p_1 - p_2 =$$

Planar system (2D)



$$W_T = 3(n-1) - 2p_1 - 1p_2 = 3(4-1) - 2*3 - 1*2 = 1$$

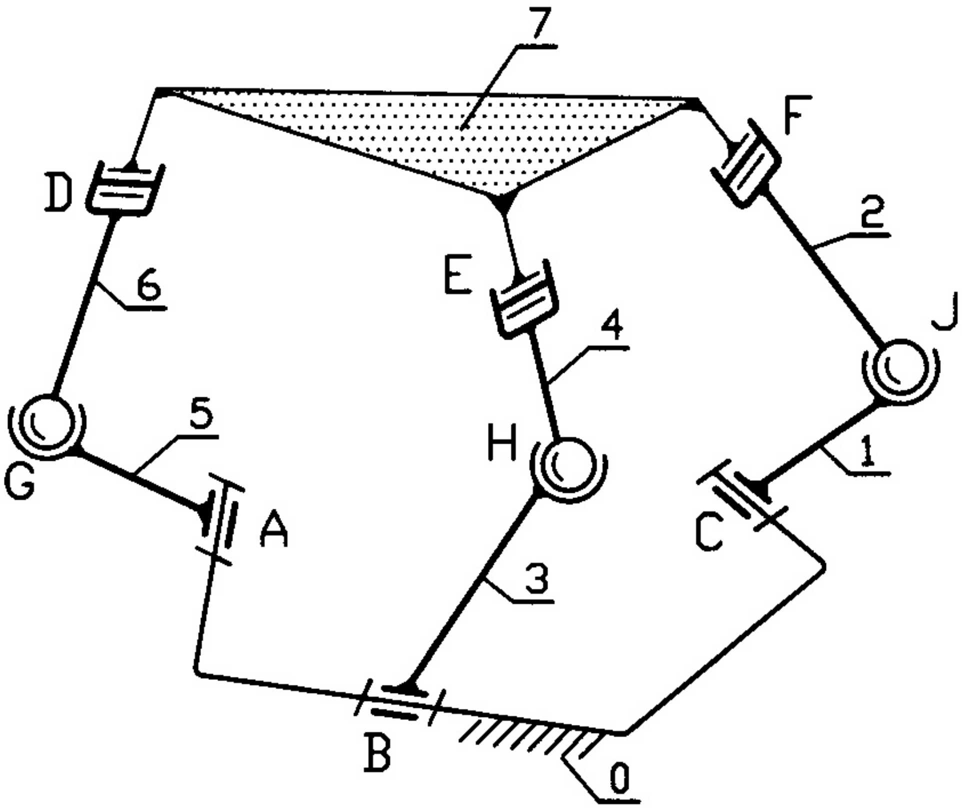


$k =$

$p_1 =$

$p_2 =$

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



$k =$

$p_1 =$

$p_2 =$

$p_3 =$

$p_4 =$

$p_5 =$

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

$$=$$