Dynamics of Machines
Basic Definitions

Kinematics: Study of motion without considering the casues of motion.

Dynamics: " " while " " " ...

Statics: Study of ~~bodies and~~ forces in a stationary mechanical system

Mechanism: Arrangement of bodies and joints to transmit motion

Machine: " " " ... ... force / torque

Primary engineering purpose. For example
regulator in a watch: mechanism
stone crusher } machine
arm of loader }

→ **Arrangment:** A thougtful (logical) process of creating a mechanism / machine

→ Synthesis / Design

Machine = bodies + joints

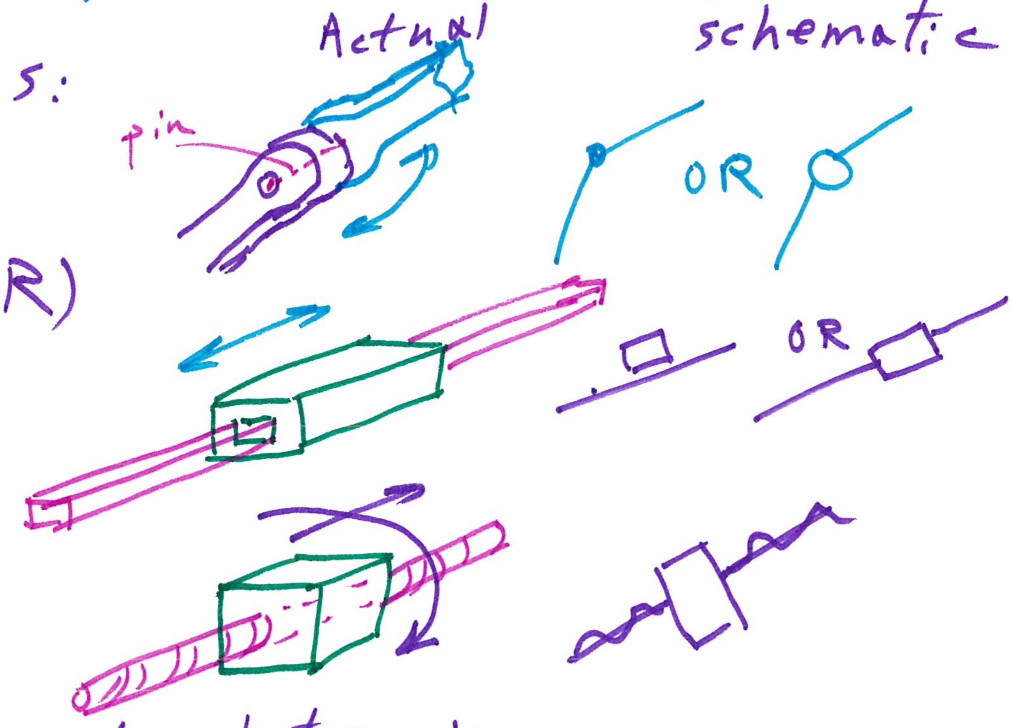
bodies → links (rigid)

joints → ?

Joint: A device that allows a specific relative motion between two links

Examples:

- Hinge / Revolute (R)
- Prismatic (P)
- Helical (H)



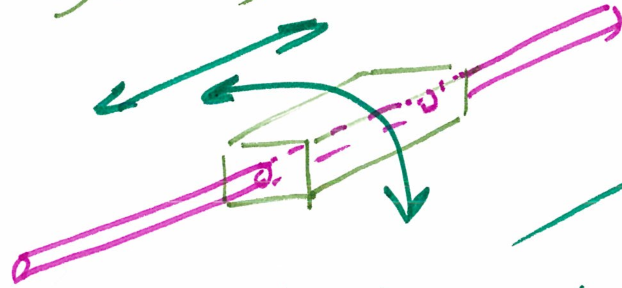
translation is function of the rotation

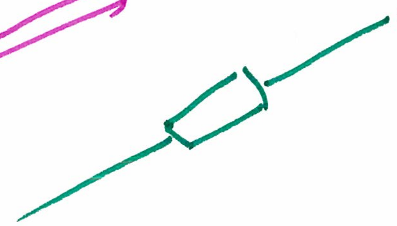
→ Allow one type of motion only

→ 1 Degree of Freedom (DOF)

2 DOF joints

Cylindrical (C)

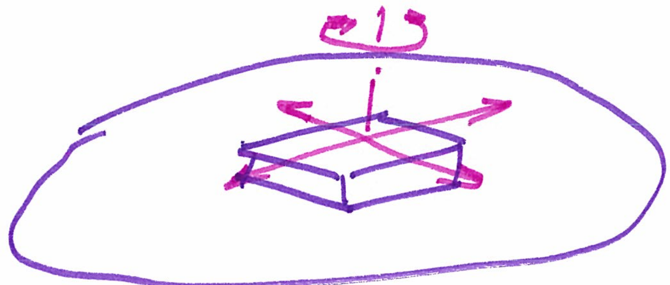


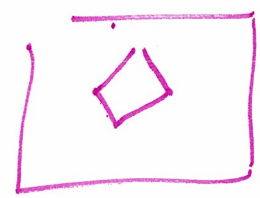


rotation & translation are independent

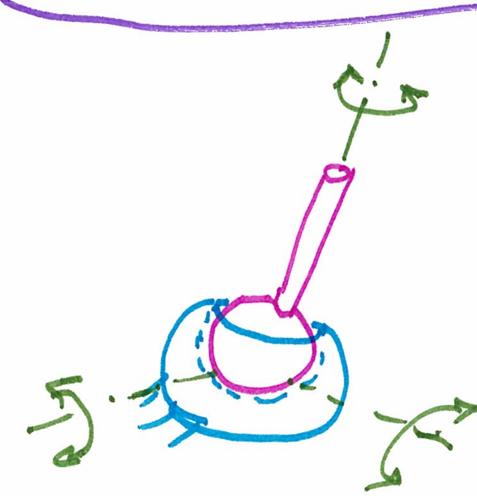
3 DOF

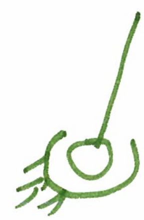
Planar (Pl)





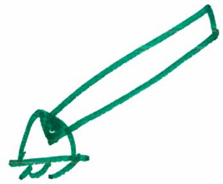
Spherical (S)



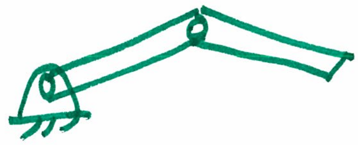


Create Mechanisms / Machines as sequence of joints

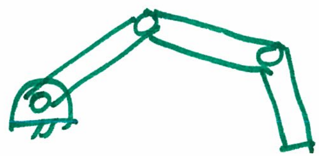
R



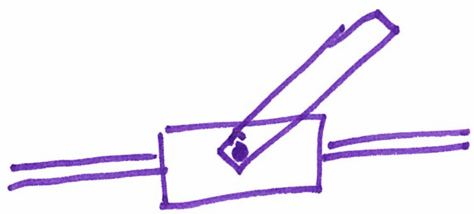
RR



RRR

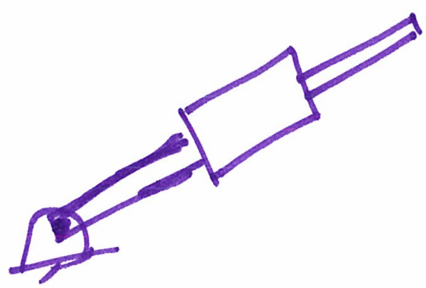


PR



≠

RP



Example:

Motorcycle suspension (rear tire)

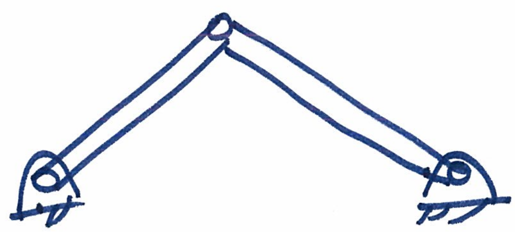
RRPR

Estimate the degree of freedom by inspecting a system

Example

RRR

DOF=0



Open-loop mechanisms

Closed-loop "

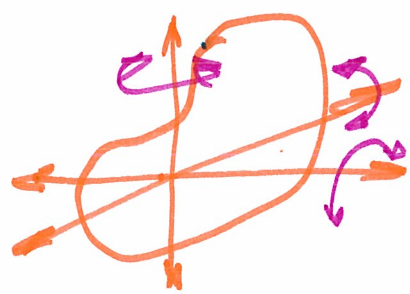
Ground: reference link, which is typically fixed

Calculating Mobility (DOF)

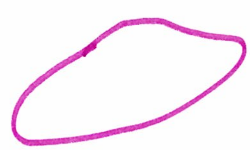
Start with general case (3D space) & go to special (planar)

Observation:

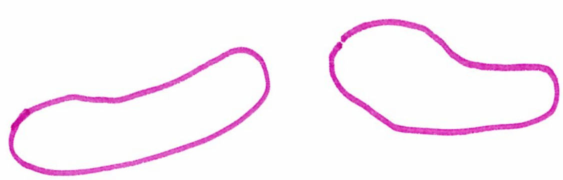
A body (link) has 6 DOF in space



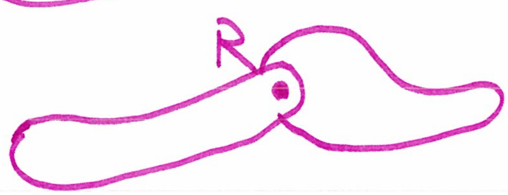
3 translation
3 rotions



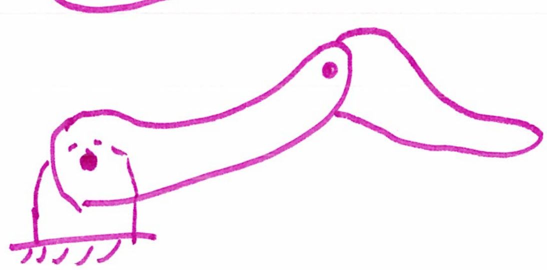
$M = 6$



$M = 2(6) = 12$



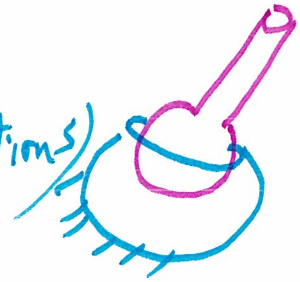
$M = 2(6) - 5 = 7$



$M = 2(6) - 2(5) = 2$

$M = 6 - 3$

(lost 3 translations)



Gruebler Criterion

$M = 6(L-1) - 5J_1 - 4J_2$

- L: number of links including the ground
- J_1: joint with 1 DOF
- J_2: Joint with 2 DOF

Special case Planar

Links have 3 DOF

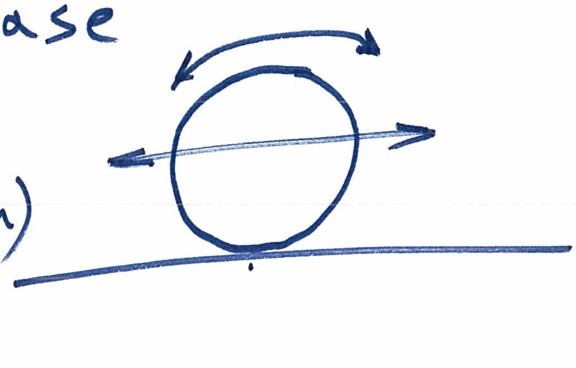
$M = 3(L-1) - 2J_1 - J_2$

Important case

Wheel

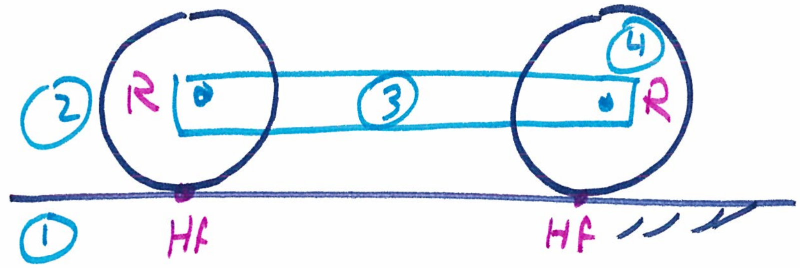
(in planar motion)

Half joint



Example

M ?



$M = 3(L-1) - 2J_1 - J_2$

$= 3(4-1) - 2(2) - 2$

$= 9 - 4 - 2$

$= 3$ → makes sense?

↳ translation

spinning of (2)

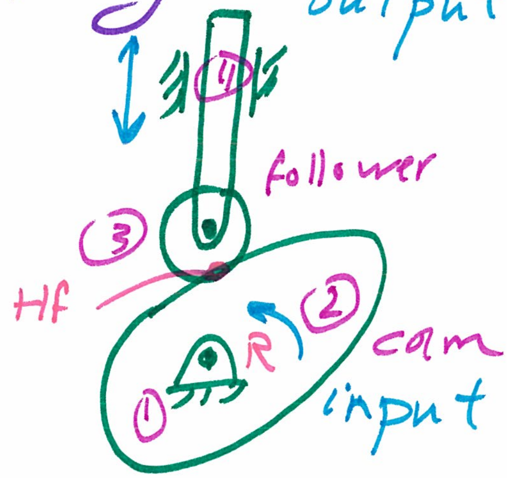
" of (4)

steps:

- label links
- label joints

Notes on Mobility

Cam

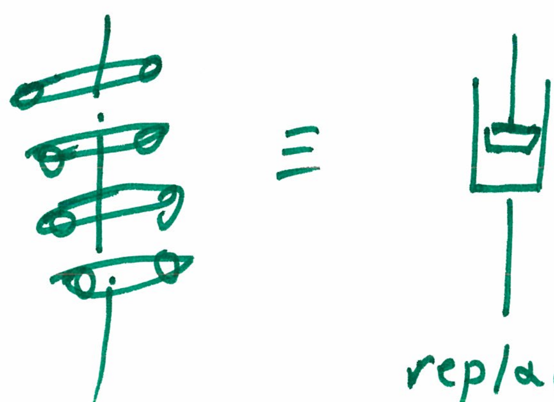


1 & 2	R
2 & 3	Hf
3 & 4	R
4 & 1	P

$$M = 3(4-1) - 2(3) - 1$$
$$= 9 - 6 - 1 = 2$$

→ oscillation of (4)
spining of (3) in place

Spring



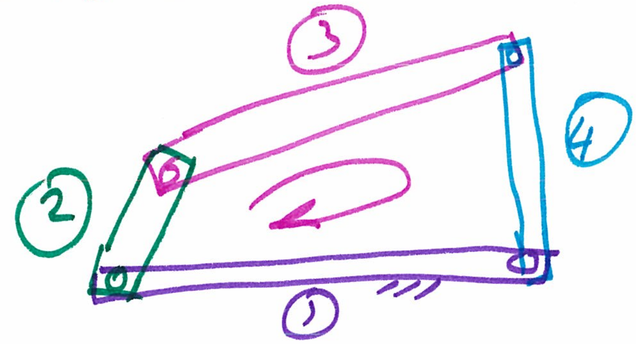
replace by two links joined by a Prismatic (P) joint

Commonly Used Mechanisms (Machines)

4-Bar Mechanism

RRRR

Closed Loop mechanism



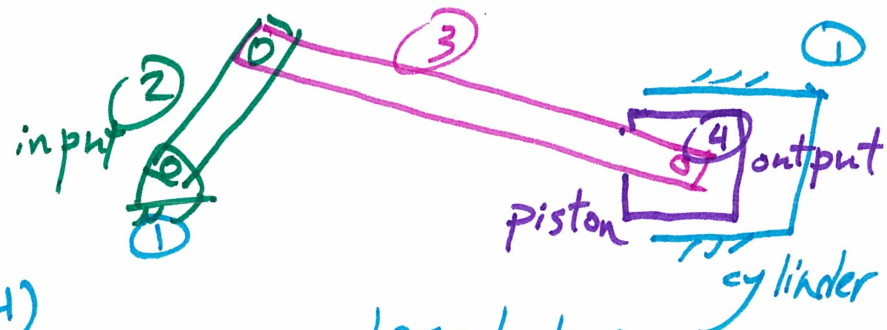
$M = 3(4-1) - 2(4)$
$= 1$

Crank-Slider

(compressor)

RRRP

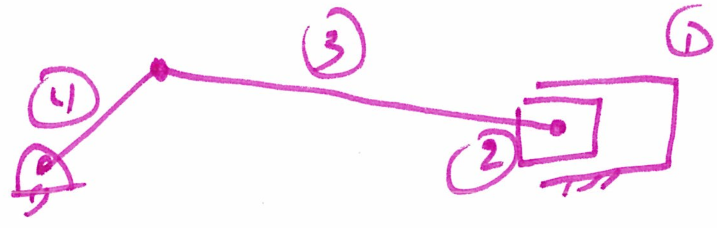
$M = 3(4-1) - 2(4)$
$= 1$



closed-loop mechanism

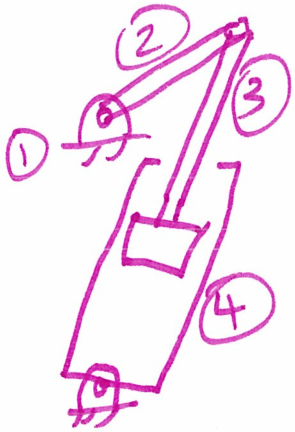
Engine

PRRR



Example

Given



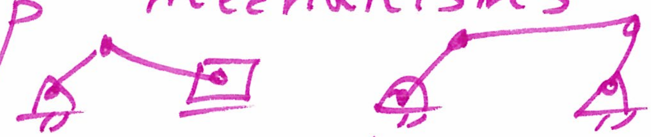
1	2	R
2	3	R
3	4	P
4	1	R

RRPR

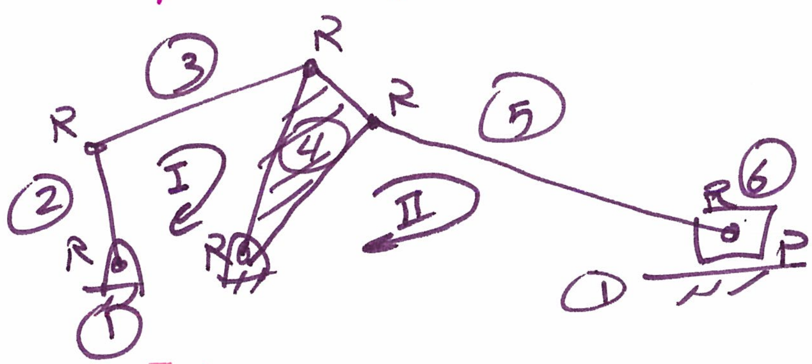
$M = 3(4-1) - 2(4) - 0$

$= 1$

↑ Single-loop mechanisms



Multiple-loop mechanisms



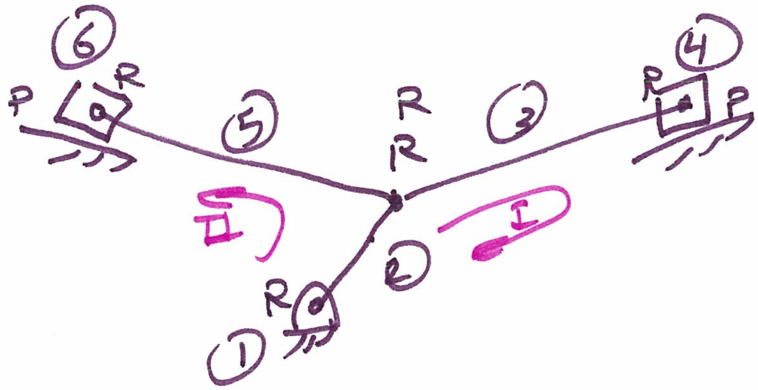
series

RRRRR R RP

$M = 3(6-1) - 2(7) - 0$

$= 15 - 14 = 1$

Parallel loops



1	2	R
2	3	R
3	4	R
4	1	P
2	5	R
5	6	R
6	1	P

RRR R P R P

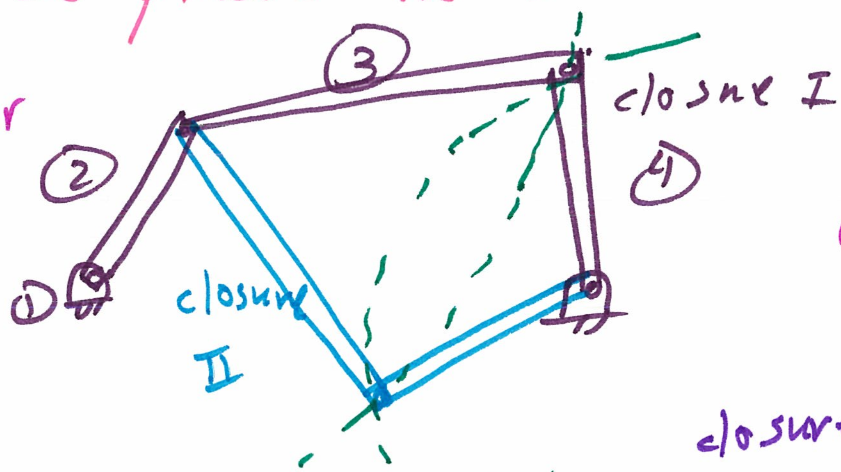
$M = 3(6-1) - 2(7) - 0 = 1$

Closures:

How many ways you can assemble a mechanism while the input link is at the same position

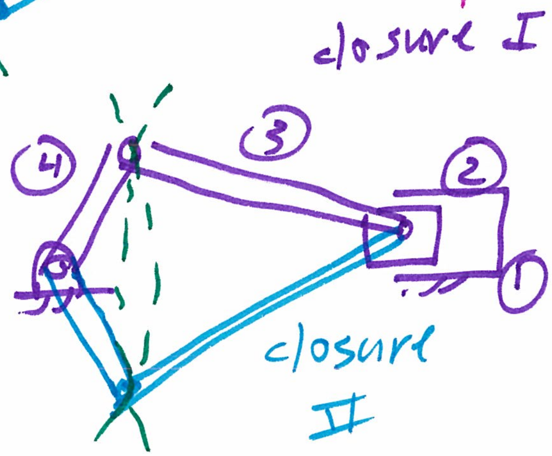
This canbe useful if the machine will be placed in a crowded environment

4-Bar

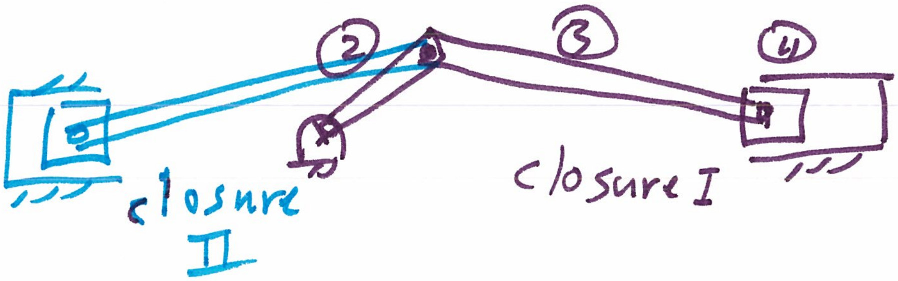


Alternative labels
① open configuration
② crossed (closed) configuration

Engine

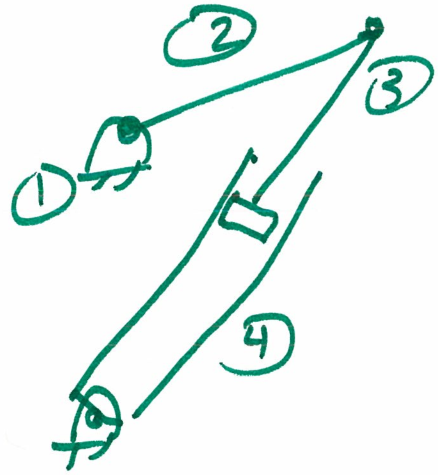


Crank-Slider (compressor)

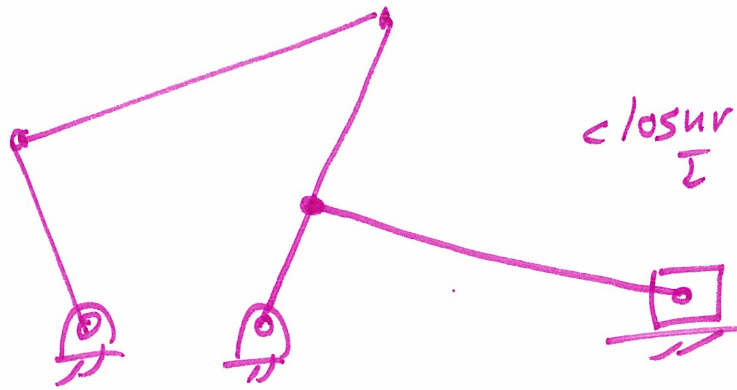


Example

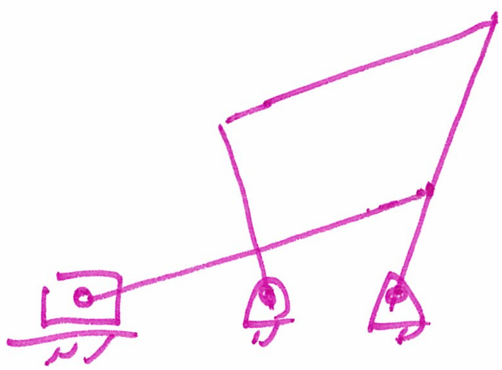
RRPR



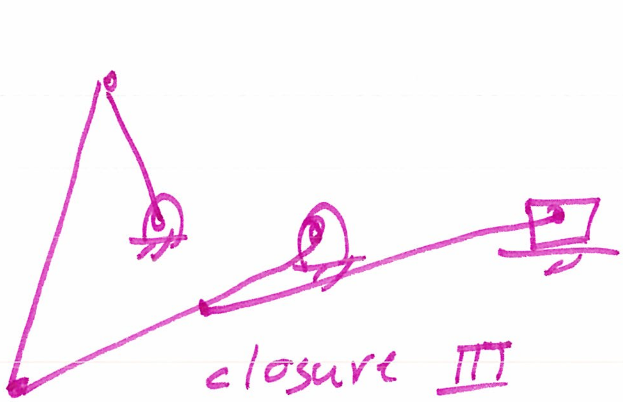
1 closure



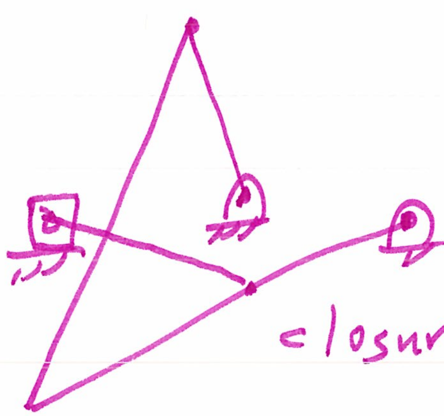
closure I



closure II



closure III



closure IV

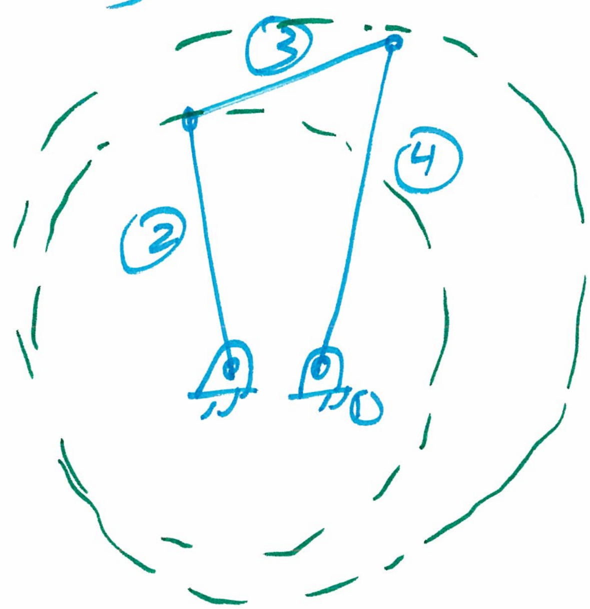
4-Bar Mechanism

① Ground
② Crank
③ Coupler
④ Output

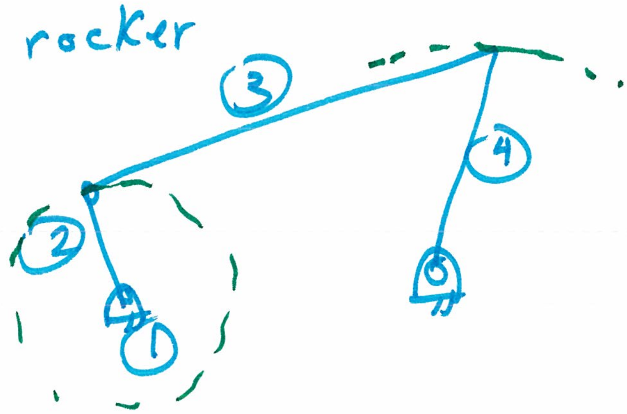
Classify according to the type of motion

* Crank-crank (Drag) (Drag link)

② & ④ rotate 360°



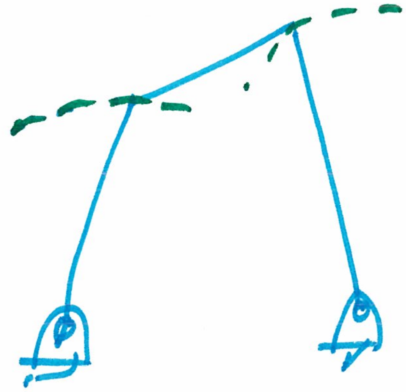
* Crank-rocker



② rotates
④ oscillat

* Rocker-Rocker

② & ④ oscillate



60°

5

H. W.

Construct a 4-bar mechanism with these dimensions:

3 8 6 7

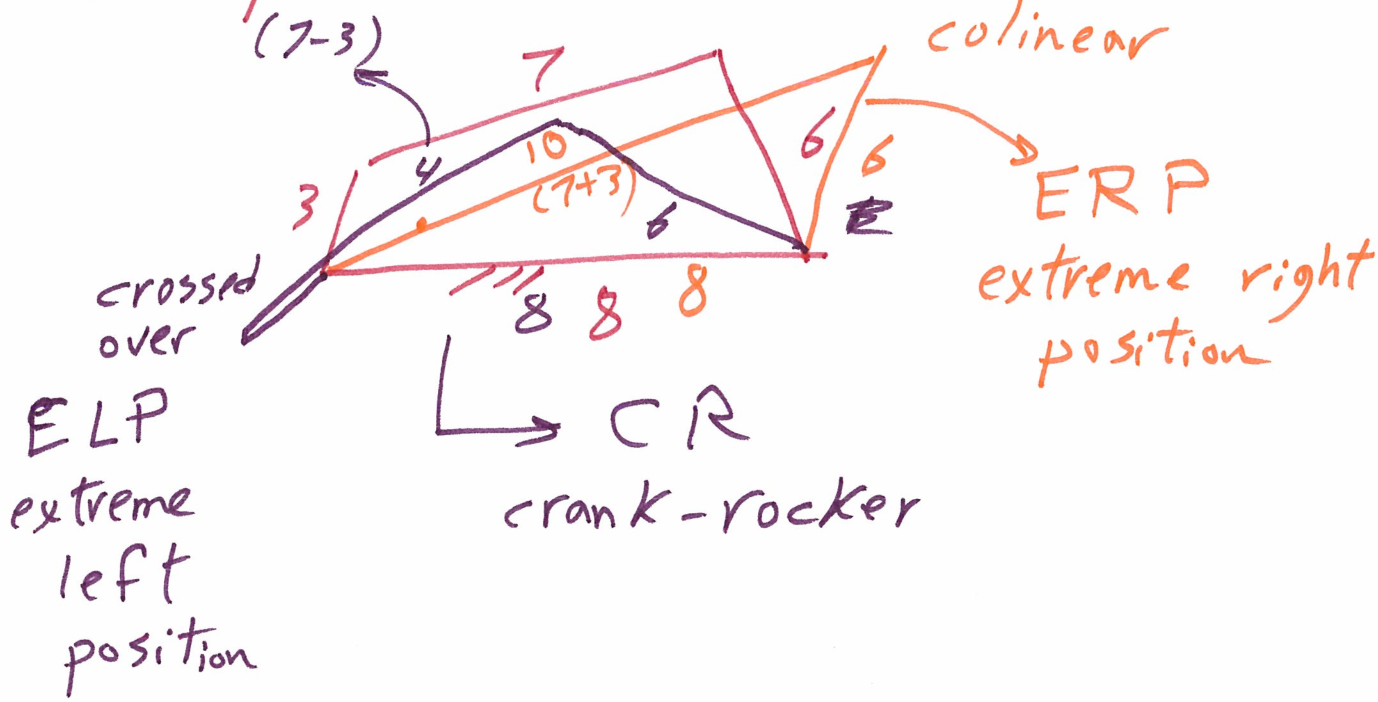
Use any material provided that the motion is not interrupted

4-Bar Mechanism Types

→ Motion classification is based on identifying motion limits of the mechanism

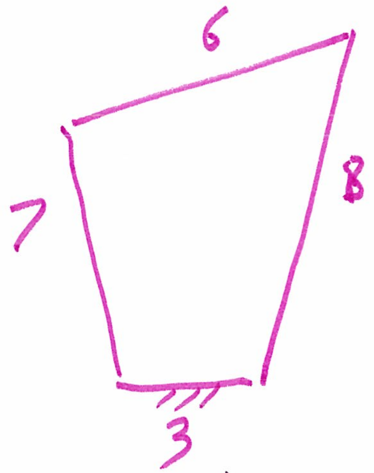
Change of Qudrilateral into Triangle

Example



→ CR

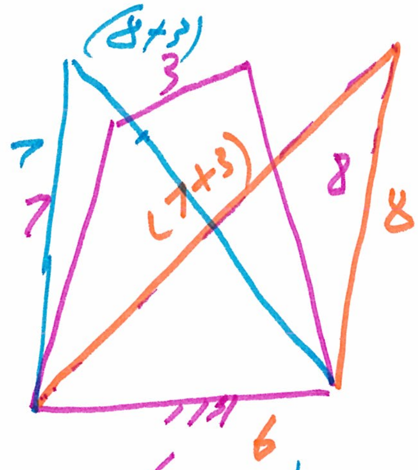
crank-rocker



(7+6), 8, 3
do not constitute
triangle

(7−6), 8, 3
" " "

→ CC
crank-crank



(7+3), 8, 6
constitute a triangle

(8+3), 7, 6
" " "

→ RR
rocker-rocker

Grashof Criteria

If the sum of the longest & shortest links < the sum of the two other links, then the 4-bar mechan is,

- Crank-crank if the shortest is the fixed
- Crank-rocker " " " " " crank
- Rocker rocke " " " " " coupler

If the mechanism does not satisfy the above inequality, it is rocker-rocker

Example:

Given 4-bar mechanism with the following dimensions 3 7 8 6.

Link 3 is the crank.

$8+3 < 7+6$ → ← inequality is satisfied

↳ CR (3 is the crank)

Link 3 is fixed

CC(3 is fixed)

Example

4-bar with these lengths:

3 3 7 6

7+3 > 6+3 → inequality is not satisfied

10 9

RR

~~3 3 4 5~~

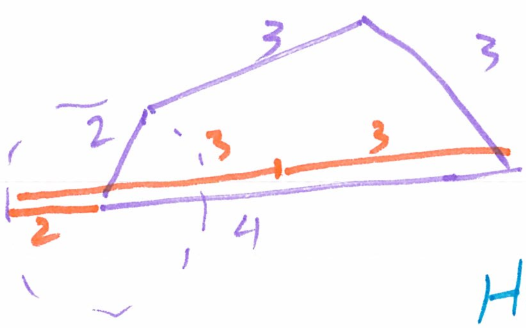
1 2 ~~1~~ 3

Special case → inequality becomes equality

2 4 3 3

2+4 = 3+3

6 6



change case

↳ RR

H.W

2.15 2.19 2.22 2.26