Lecture 4: Planar Mechanisms 3

ME 370 - Mechanical Design 1

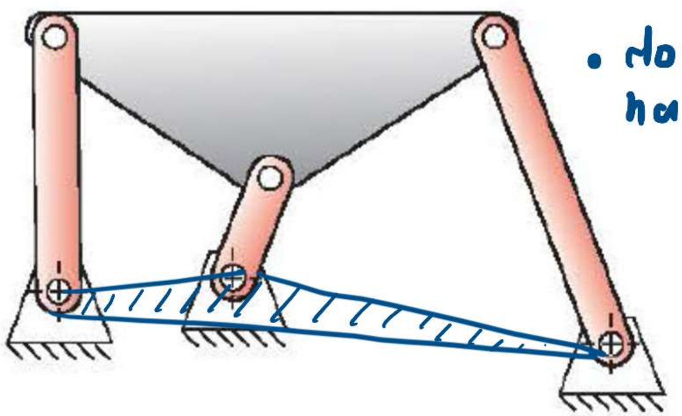
"Colibri" by Derek Hugger

** www.youtube.com/watch?v=1scj5sotD-E*

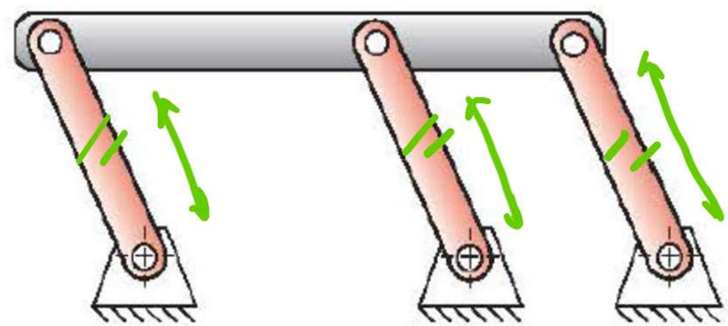
Gruebler's paradox

- How many DOF of these 5-link mechanisms?

• there are no 5-link-closed-loop mech with full joints of 1 DOF



• does not have mobility



• has mobility.

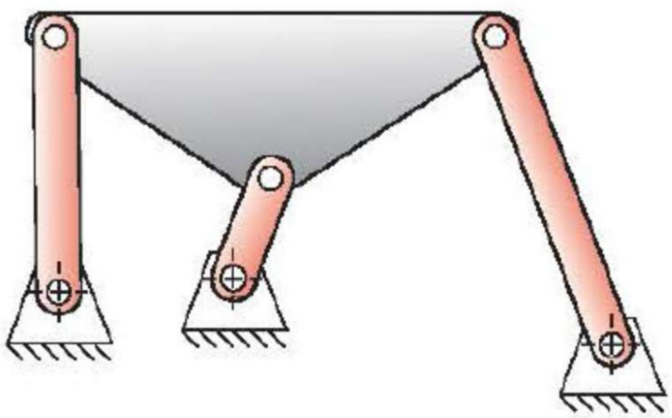
$n = 5$

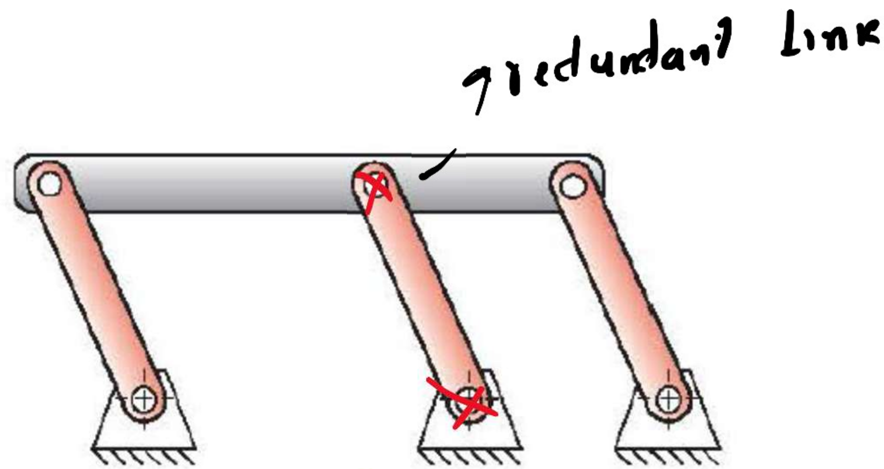
$j = 6$

$$\# DOF = 3(5-1) - 2(6)$$
$$= 12 - 12$$
$$= 0$$

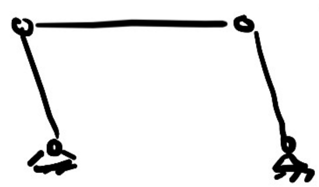
Gruebler’s paradox

- Gruebler’s equation does not account for shape, symmetry, length, redundancy
- For example: shape → parallel links





compute correct DOF



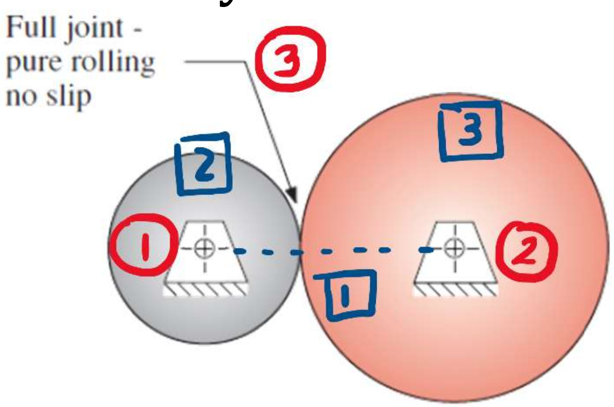
$n = 4$
$j_1 = 4$ → DOF = 1

Practice: Gruebler's paradox of shape

How many DOF from inspection?

inspection : 1 DOF

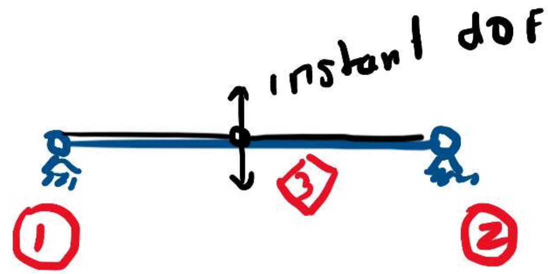
How many DOF from Gruebler's Eq?



DOF :

Ground length = sum of two radii

Gruebler's equation does not account for link size or shape.
Moral : Watch out for higher symmetry (e.g., parallel links, summed length)



$n = 3$
$J_1 = 2$
$J_2 = 1$

$$DOF = 3(3-1) - 2(2) - 1(1)$$
$$= 6 - 4 - 1 = 1$$

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Grashof condition: Mechanism length and allowed motion

Define:

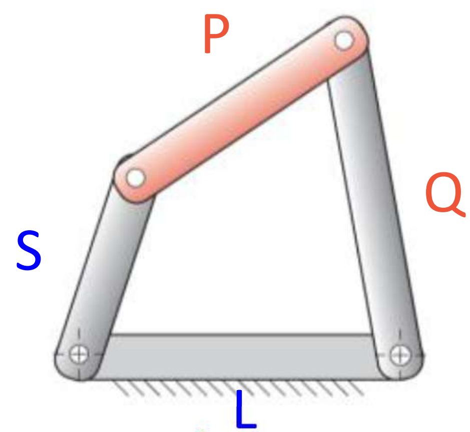
- S – shortest link
- L – longest link
- P, Q – remaining links

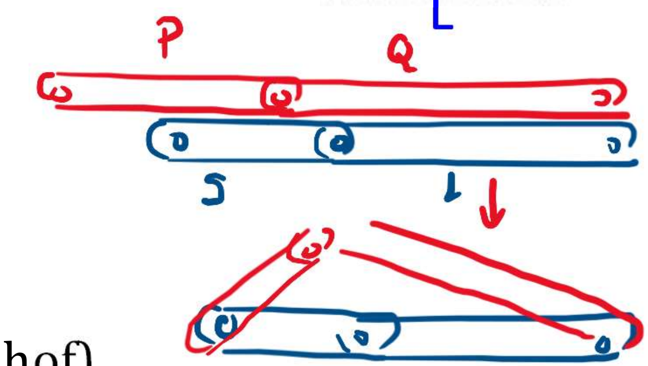
S + L ≤ P + Q : Grashof condition

S + L < P + Q : Class 1 (Grashof)

S + L > P + Q : Class 2 (non-Grashof)

S + L = P + Q : Class 3 (special-case Grashof)





allways room to build in extended config.

Class 1: $S + L < P + Q$

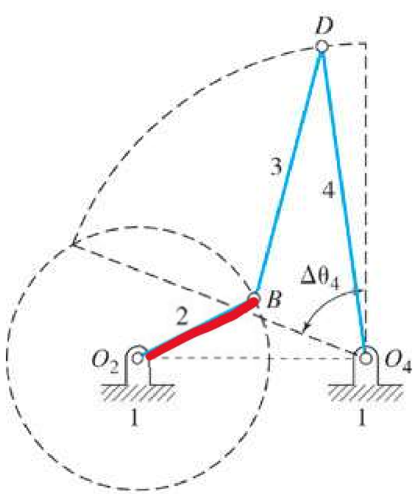
"Satisfies the Grashof condition"

- At least one link *will* be able to make a *full rotation*

Crank-Rocker

*S is always the **crank***

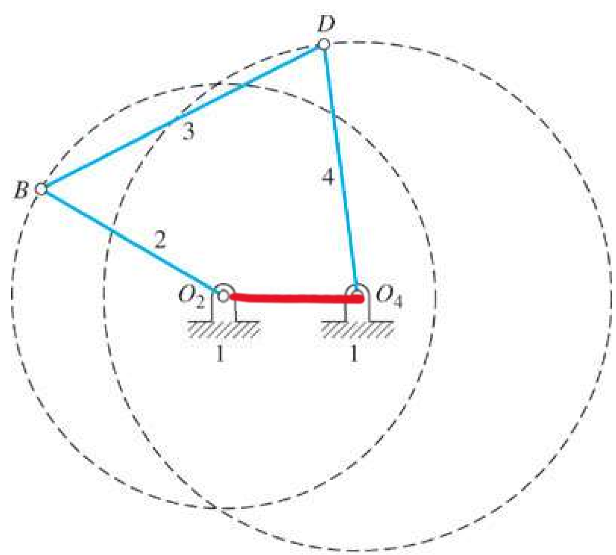
Only Link 2 rotates



Double Crank

*S is always **ground***

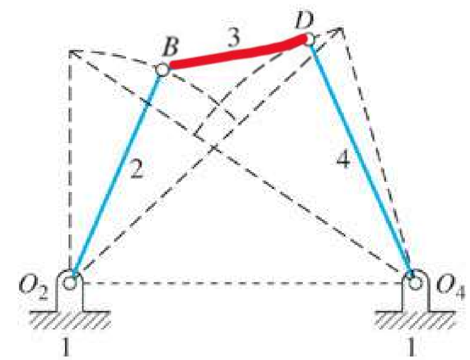
Link 2, 3, and 4 rotate



Double Rocker

*S is always the **coupler***

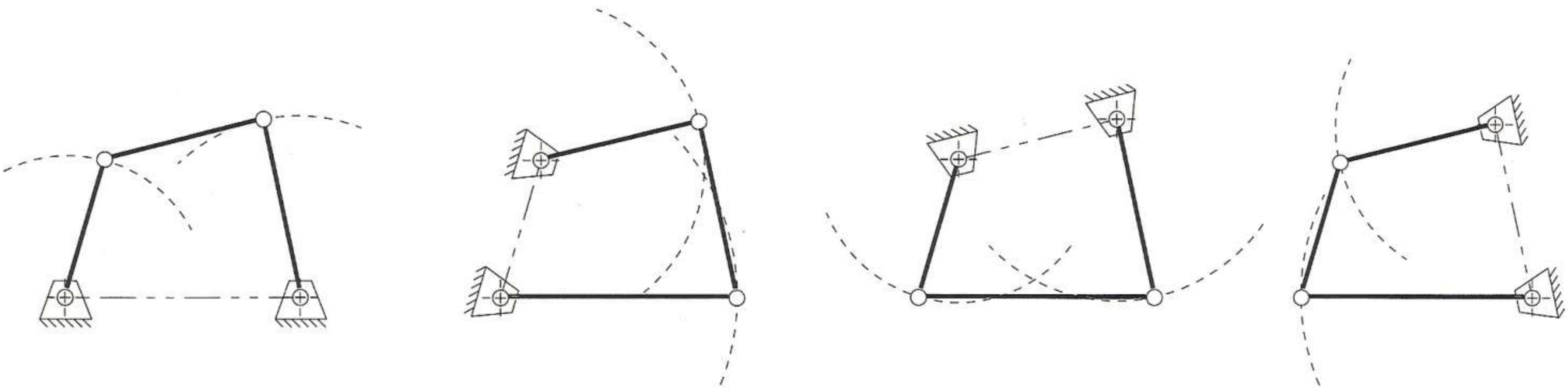
Only Link 3 rotates



Class 2: $S + L > P + Q$

"DOES NOT Satisfy the Grashof condition"

- *No link* will be able to make a full rotation.
- All four inversions are triple rockers:

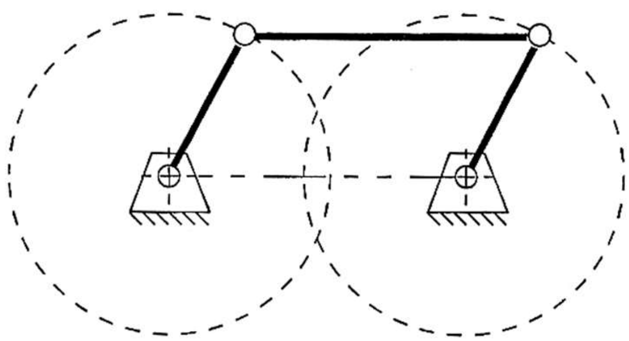


Class 3: **S + L = P + Q**

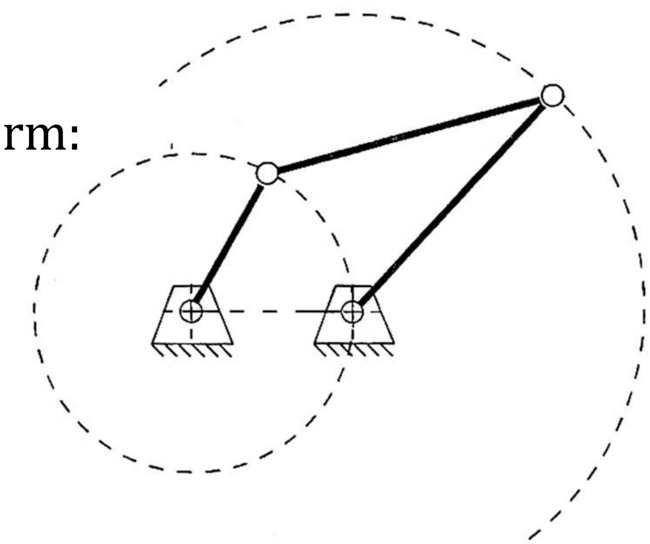
"Special Case Grashof"

- *At least one link* will make a full rotation (like Class 1). Two Forms:
  - *Parallelogram* – shortest links are opposite each other
  - *Delta* – shortest links are adjacent to each other
- *Problem*: output has a "*change point*" where links are in a line and output direction is indeterminant

Parallelogram:



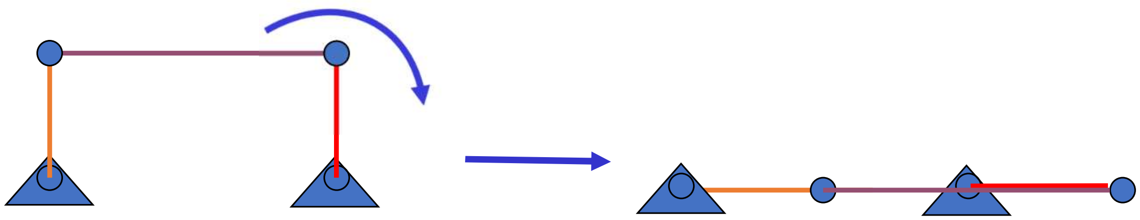
Delta Form:



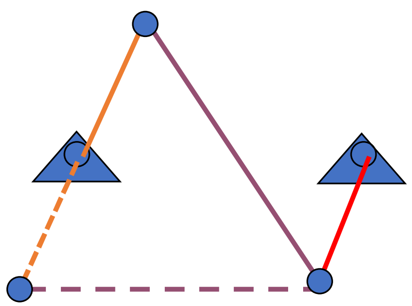
https://www.youtube.com/watch?v=h8bz4ni6mdY

Grashof Class 3: $\mathbf{S + L = P + Q}$

Will have **change points** twice per revolution, where all links become co-linear.

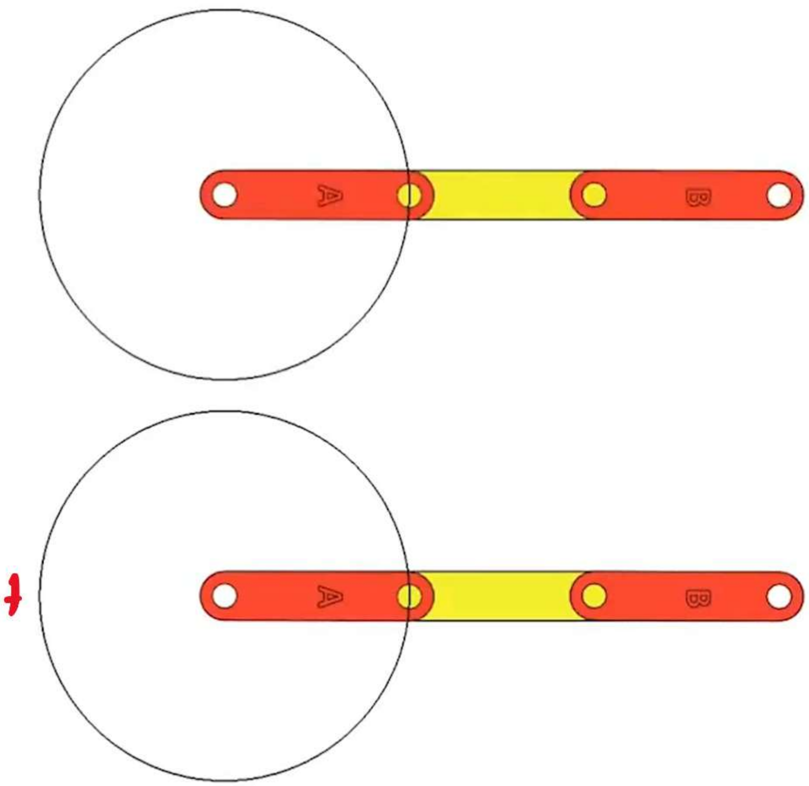


⇒ Output is indeterminate



Parallelogram or Anti-Parallelogram form

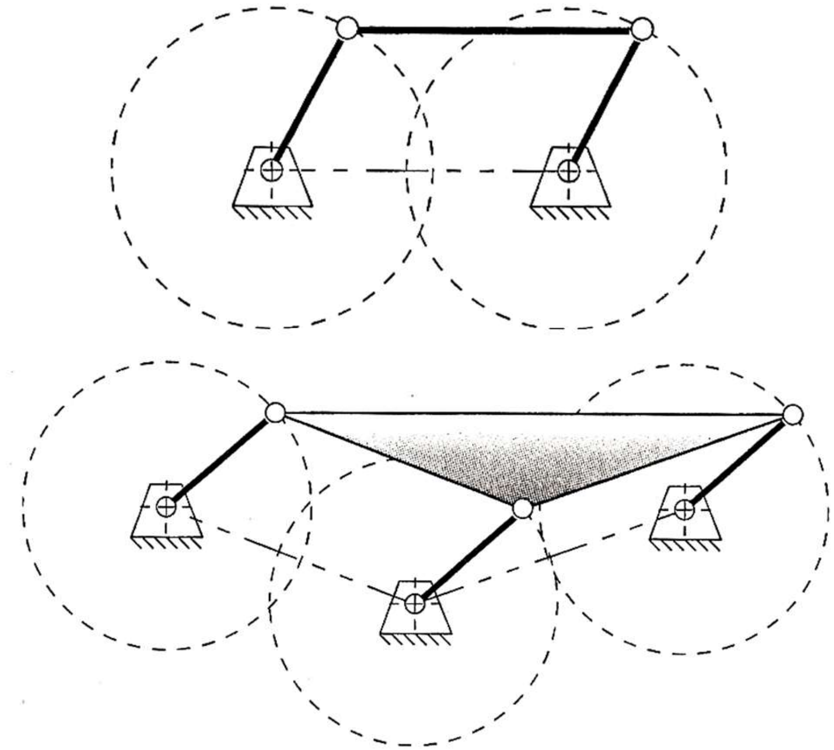
change point cannot be predicted



https://www.youtube.com/watch?v=h8bz4ni6mdY

Class 3: **S + L = P + Q**

- *Problem*: output has a "*change point*" where links are in a line and output direction is indeterminant



Solution to change point uncertainty is to add a link to the coupler:

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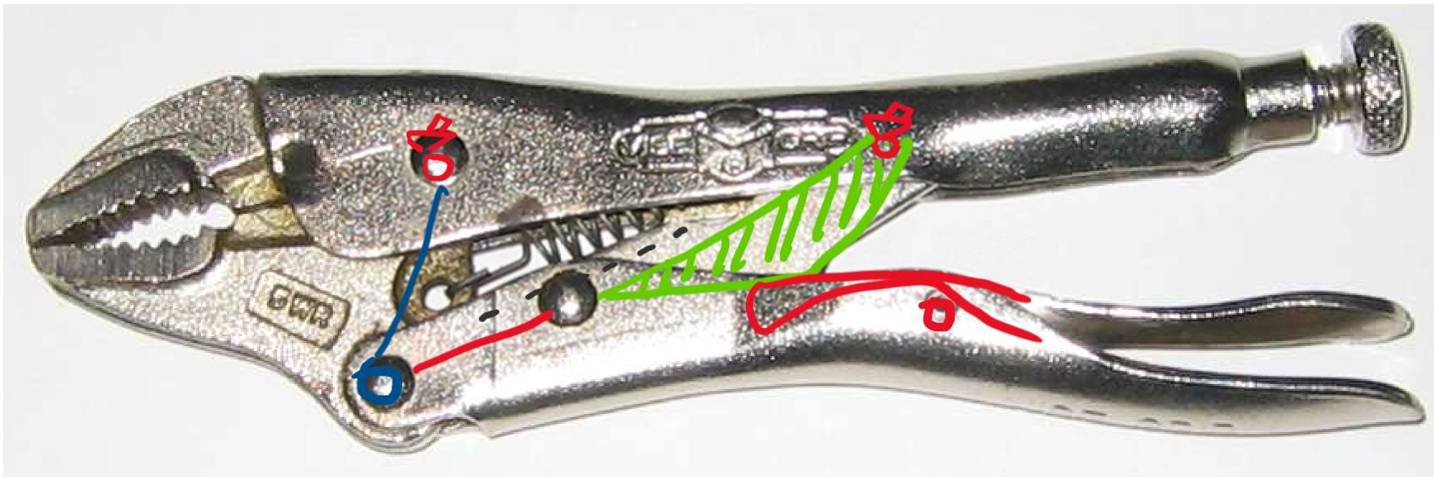
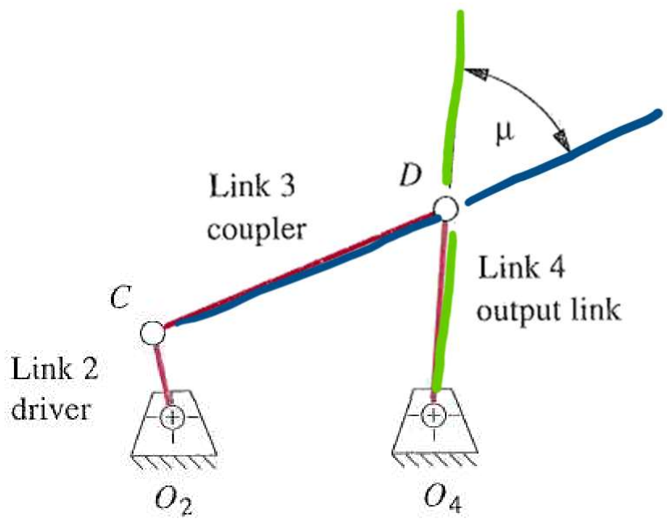
Toggle Position



- Two links are co-linear
- No further motion possible in given direction
  - Toggle position holds jaws closed
- Must drive different links to open and close
- Check designs for possible toggle positions!

Transmission angle, μ (Norton, Section 3.3)



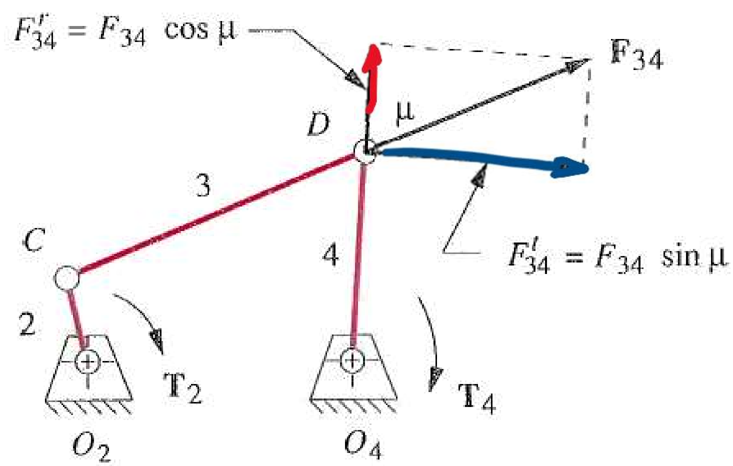
(a) Linkage transmission angle μ

- **Acute** angle between coupler and output links
- Measure of quality of force transmission at joint

Transmission angle, μ

- Coupler only transmits force along its axis (F_{34}).
  - F^t determines torque on output (rocker)
  - F^r determines tension/compression on rocker and joints D and O_4 ➔ friction
- Design rule:

  Try to keep $90^\circ > \mu > 40^\circ$



(b) Static forces at a linkage joint

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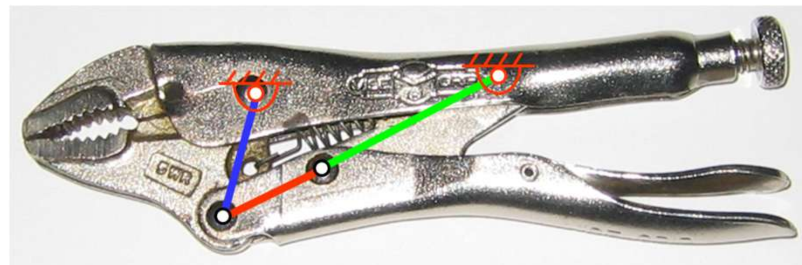
Limiting Conditions in Mechanism Motion



- Toggle positions
- Change points

- Transmission angles (more on forces later in semester)
  - Typically 90° > μ_{min} > 40°

Norton, Section 3.3

Class Excersise

Exercise: Grashof Condition and Mechanism Classification

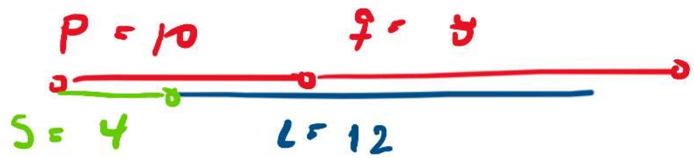
A four-bar mechanism is formed by four links with the following lengths:

•Link 1 (fixed frame): $L_1 = 12\ cm$

•Link 2 (input crank): $L_2 = 4\ cm$

•Link 3 (coupler): $L_3 = 10\ cm$

•Link 4 (output rocker): $L_4 = 8\ cm$



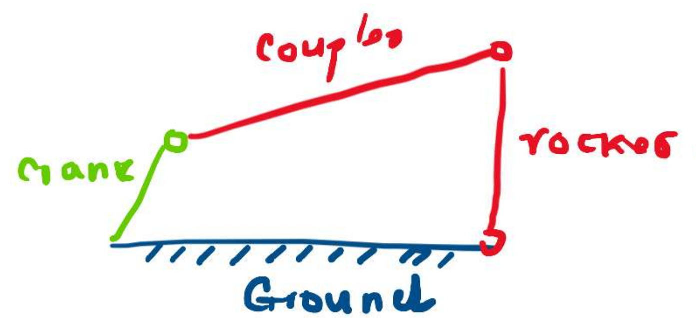
Tasks:

1.Check if the mechanism satisfies **Grashof's criterion.** Grashof ✓

2.If Grashof's condition is satisfied, classify the mechanism as one of:

1. $\boxed{\textbf{Crank-rocker}}$ S is shortest —
2. **Double-crank**
3. **Double-rocker**

3.Draw a simple sketch of the mechanism labeling the links as crank, rocker , coupler and ground.



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