Taibah University – Yanbu Branch
College of Engineering at Yanbu
Mechanical Engineering Department

ME 341
Mechanics of Machines

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- The **fourbar linkage** is the *simplest possible pin-jointed mechanism* for single degree of freedom controlled motion.

- It also appears in various disguises such as the **slider-crank** and the **cam-follower.** It is infact the most common and ubiquitous device used in machinery.

- It is also extremely versatile in terms of the types of motion which it can generate.

- *Simplicity is one mark of good design.*

The fewest parts that can do the job will usually give the least expensive and most reliable solution.

- Thus the **fourbar linkage** should be among the first solutions to motion control problems to be investigated.

The Grashof Condition

- The Grashof condition is a very simple relationship that predicts the rotation behaviour or rotatability of a fourbar linkage's inversions based only on the link lengths

Let: S = length of shortest link

L = length of longest link

P = length of one remaining link

Q = length of other remaining link

Then if: $S + L \leq P + Q$

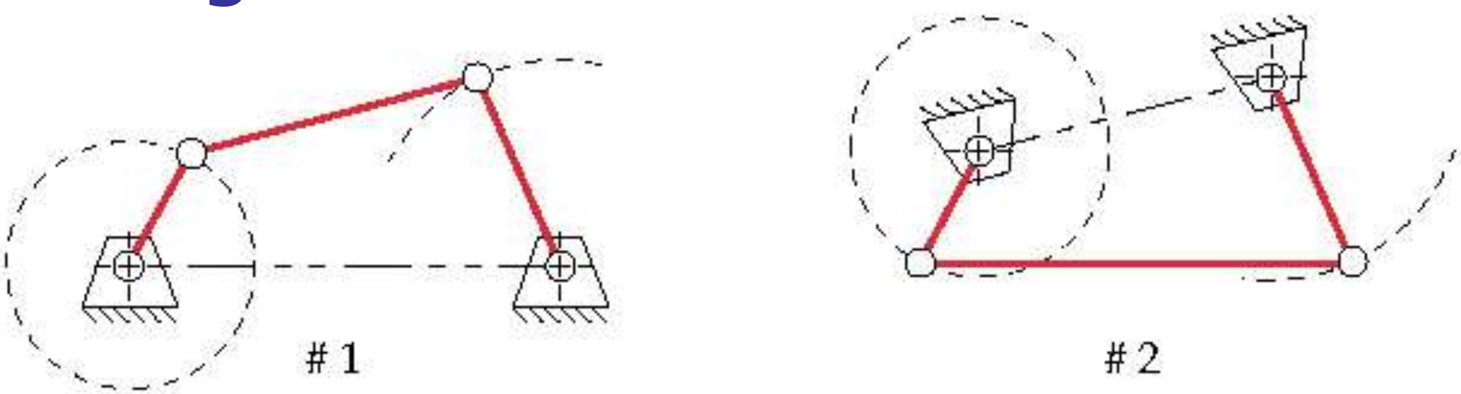
The linkage is Grashof and atleast one link will be capable of making a full revolution with respect to the ground plane, and is called Class I kinematic Chain.

The Grashof Condition

- If the inequality is not true, then the linkage is non-Grashof and no link will be capable of a complete revolution relative to any other link. This is called a Class II kinematic chain
- The Grashof condition apply regardless of the order of assembly of the links, i.e., the determination of Grashof condition can be made on a set of unassembled links
- The motion possible from a fourbar linkage will depend on both the Grashof condition and the inversion chosen
- The inversions will be defined with respect to the shortest link

Grashof Motions

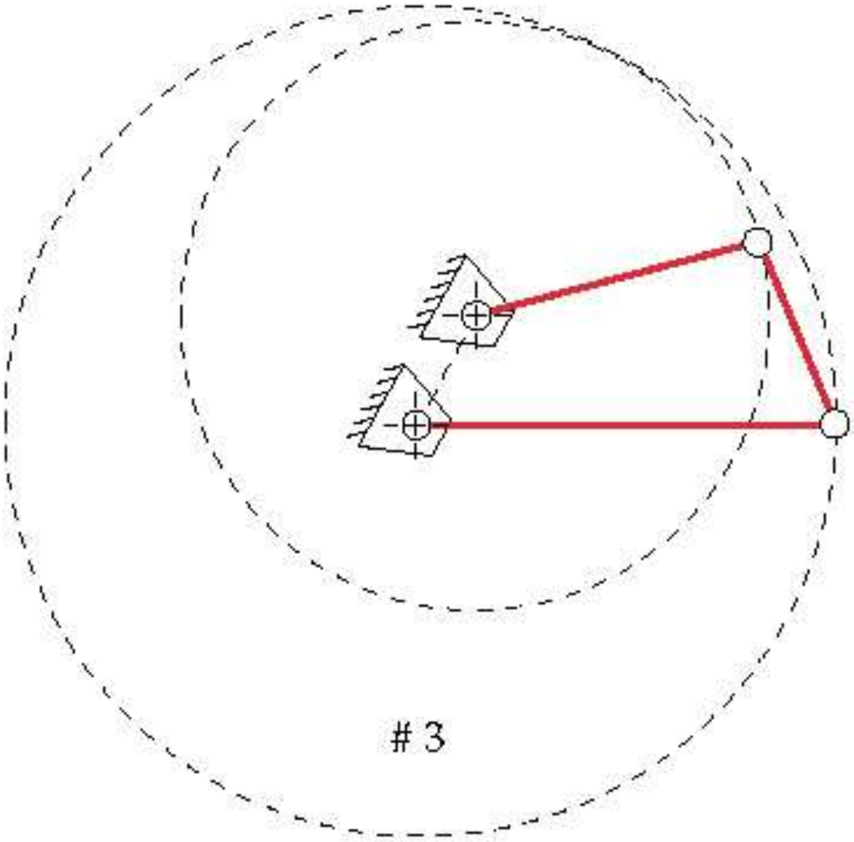
- For the Class I case, $S + L < P + Q$
- Ground either link adjacent to the shortest and a crank-rocker link is formed, in which the shortest link will fully rotate and the other link pivoted to the ground will oscillate



(a) Two non-distinct crank-rocker inversions (GCRR)

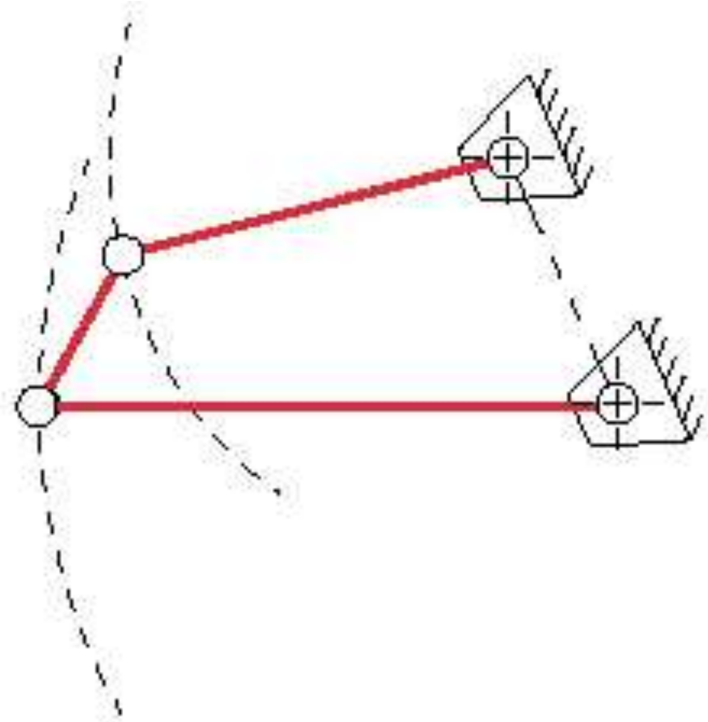
Grashof Motions

- Ground the shortest link and this will form a double-crank, in which both links pivoted to ground make complete revolutions

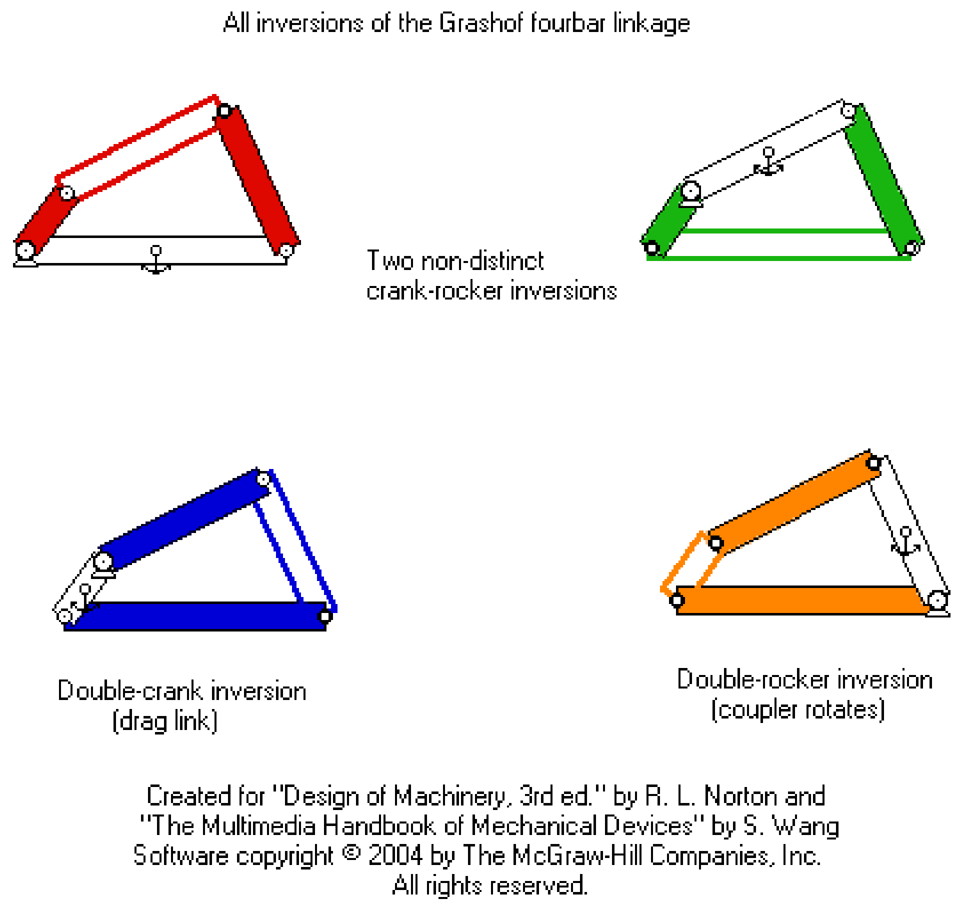


Grashof Motions

- Ground the link opposite the shortest and it forms a Grashof double-rocker, in which both links pivoted to ground oscillate and only the coupler makes a full revolution



Inversions of Grashof fourbar linkage

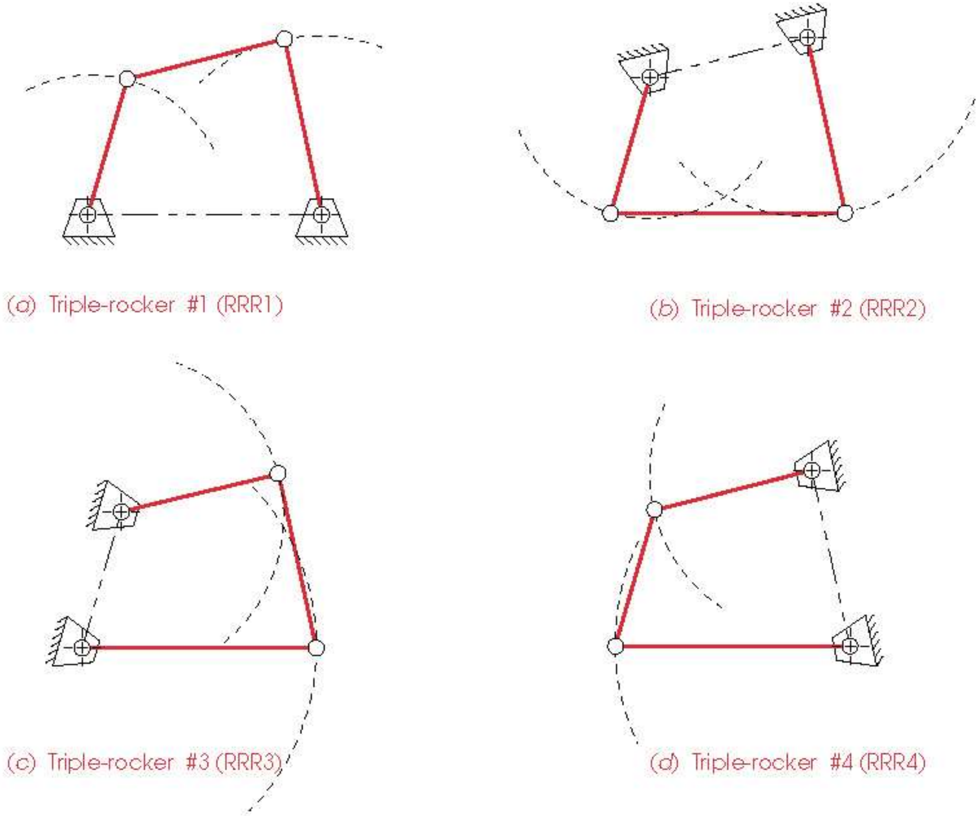


Grashof Condition

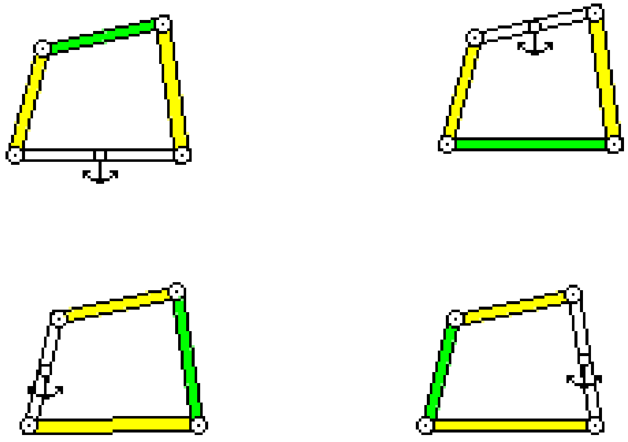
- For the class II case,

  $S + L > P + Q$

- All inversions will be triple-rockers in which no link can fully rotate



Non-Grashof fourbar linkage

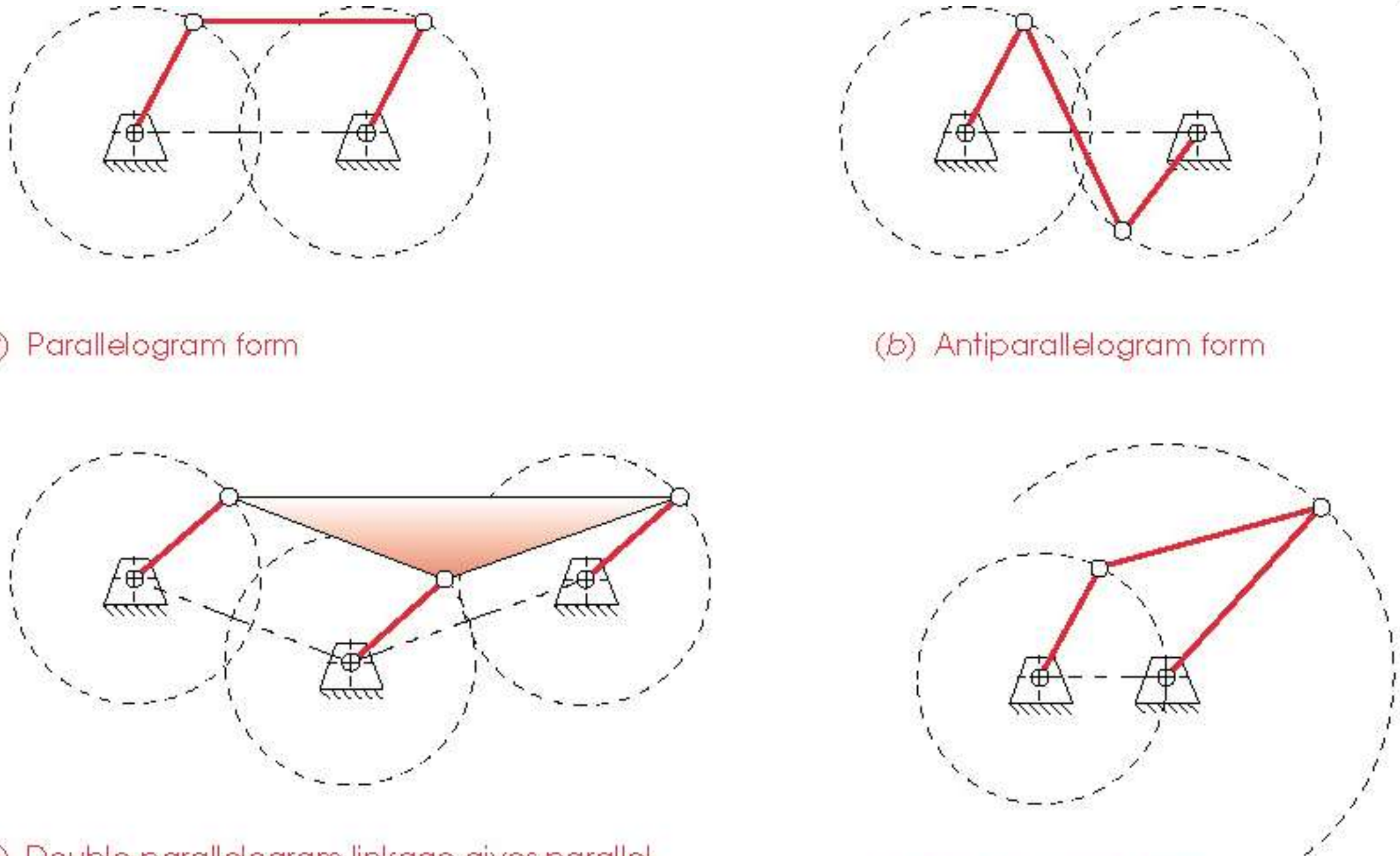


Created for "Design of Machinery, 3rd ed." by R. L. Norton and "The Multimedia Handbook of Mechanical Devices" by S. Wang

Grashof Condition

- For the class III case, S + L = P + Q
- Referred to as special-case Grashof and also as a Class III kinematic chain, all inversions will be either double-cranks or crank-rockers but will have "change points" twice per revolution of the input crank when the links all become collinear

Special-case Grashof Linkage



(a) Parallelogram form

(b) Antiparallelogram form

(c) Double-parallelogram linkage gives parallel motion (pure curvilinear translation) to coupler and also carries through the change points

(d) Deltoid or kite form

TABLE 2-4 **Barker's Complete Classification of Planar Fourbar Mechanisms**

Adapted from ref. (10). s = shortest link, l = longest link, Gxxx = Grashof, RRRx = non-Grashof, Sxx = Special case

Type	$s + l$ vs. $p + q$	Inversion	Class	Barker's Designation	Code	Also Known As
1	$<$	$L_1 = s$ = ground	I-1	Grashof crank-crank-crank	GCCC	double-crank
2	$<$	$L_2 = s$ = input	I-2	Grashof crank-rocker-rocker	GCRR	crank-rocker
3	$<$	$L_3 = s$ = coupler	I-3	Grashof rocker-crank-rocker	GRCR	double-rocker
4	$<$	$L_4 = s$ = output	I-4	Grashof rocker-rocker-crank	GRRC	rocker-crank
5	$>$	$L_1 = l$ = ground	II-1	Class 1 rocker-rocker-rocker	RRR1	triple-rocker
6	$>$	$L_2 = l$ = input	II-2	Class 2 rocker-rocker-rocker	RRR2	triple-rocker
7	$>$	$L_3 = l$ = coupler	II-3	Class 3 rocker-rocker-rocker	RRR3	triple-rocker
8	$>$	$L_4 = l$ = output	II-4	Class 4 rocker-rocker-rocker	RRR4	triple-rocker
9	$=$	$L_1 = s$ = ground	III-1	change point crank-crank-crank	SCCC	SC* double -crank
10	$=$	$L_2 = s$ = input	III-2	change point crank-rocker-rocker	SCRR	SC crank-rocker
11	$=$	$L_3 = s$ = coupler	III-3	change point rocker-crank-rocker	SRCR	SC double-rocker
12	$=$	$L_4 = s$ = output	III-4	change point rocker-rocker-crank	SRRC	SC rocker-crank
13	$=$	two equal pairs	III-5	double change point	S2X	parallelogram or deltoid
14	$=$	$L_1 = L_2 = L_3 = L_4$	III-6	triple change point	S3X	square

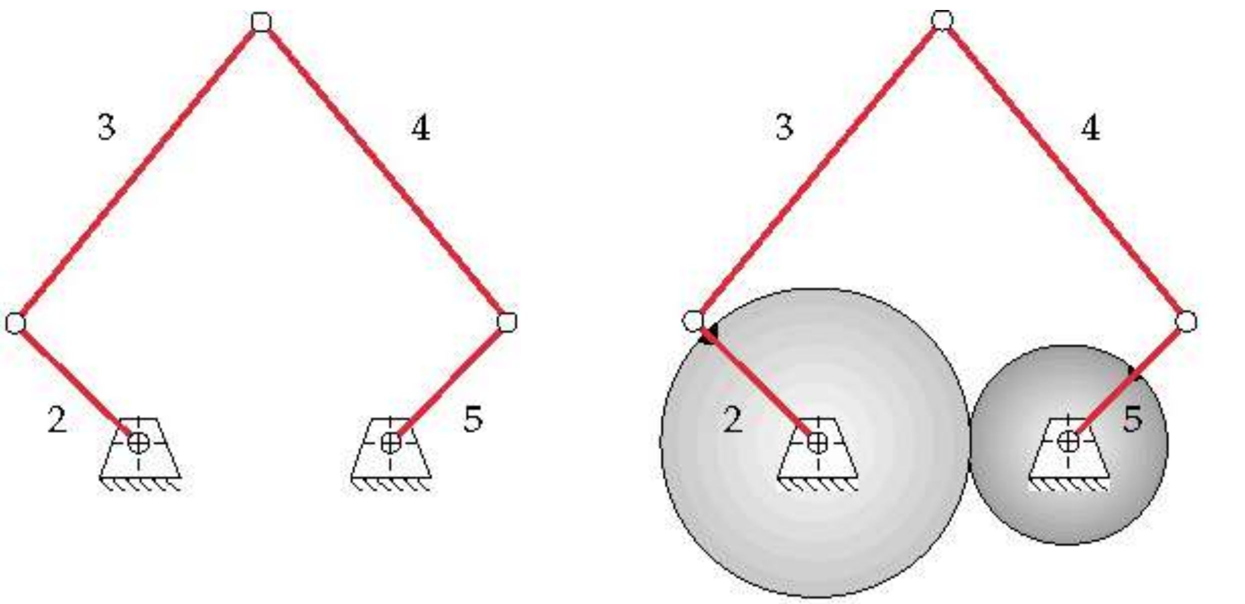
* SC = special case.

Linkages of more than four bars

- Geared Fivebar Linkages
- Sixbar Linkages

Geared Fivebar Linkages

- There will be cases when a more complicated solution is necessary
- Adding one links and one joint to form a fivebar will increase the DOF by one, to two
- By adding a pair of gears to tie two links together with a new half joint, the DOF is reduced again to one, and the Geared fivebar mechanism (GFBM) is created

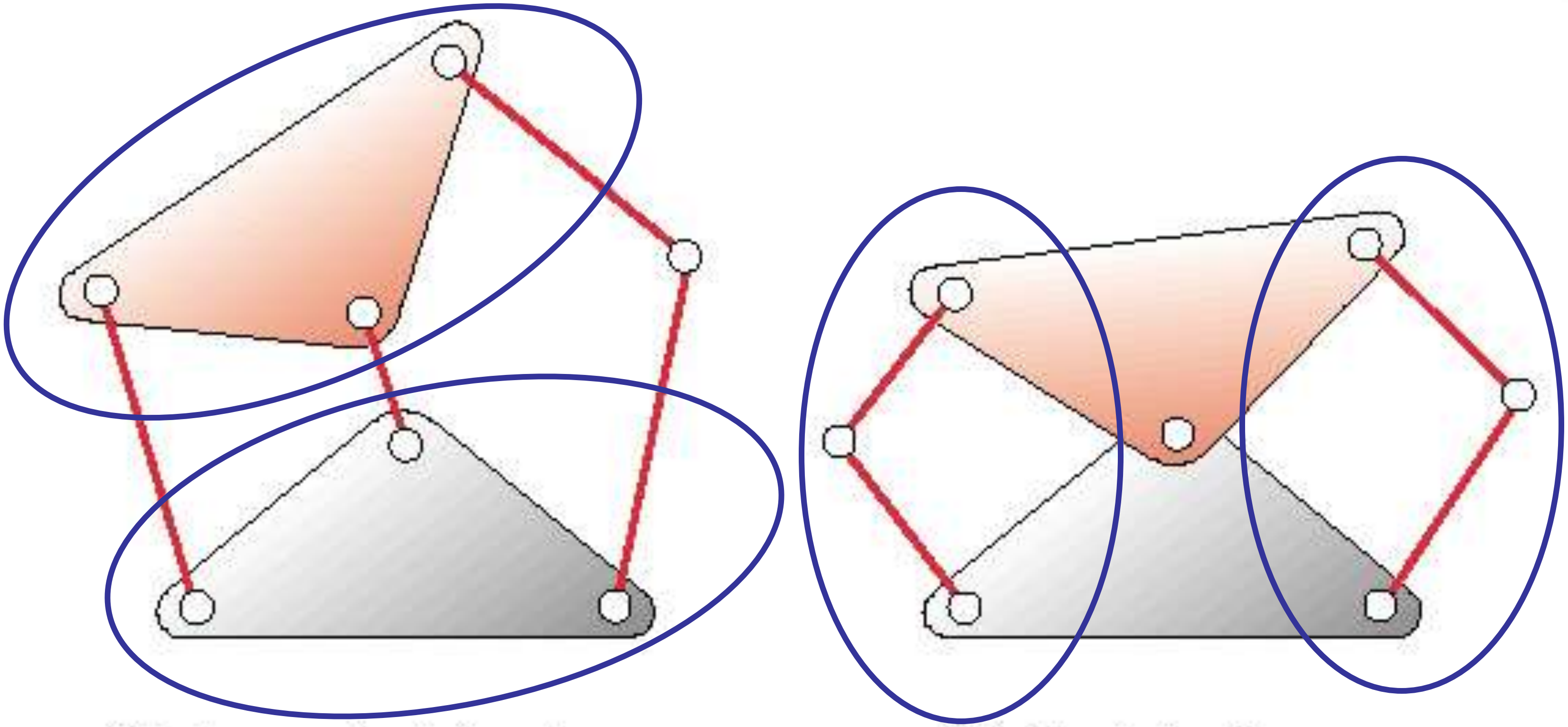


(a) Fivebar linkage—2 *DOF*   (b) Geared fivebar linkage—1 *DOF*

Sixbar Linkage

- The Watt's sixbar can be thought of as two fourbar linkages connected in series and sharing two links in common
- The Stephenson's sixbar can be thought as two fourbar linkages connected in parallel and sharing two links in common
- Many linkages can be designed by the technique of combining multiple fourbar chains as basic building blocks into more complex assemblies
- Many real design problems will require solutions consisting of more than fourbars

Six bar as combination of two fourbars

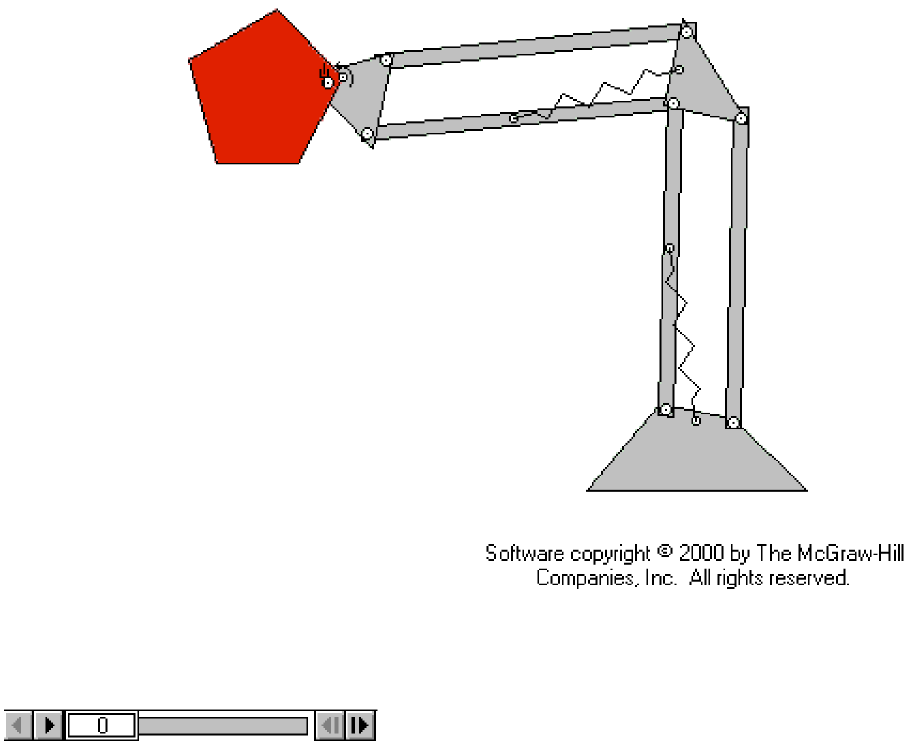


Stephenson's sixbar isomer   Watt's sixbar isomer

Springs as links

- As long as the spring provides the right amount of force, and hold the parts at the required place, it reduces the DOF of the system to zero, as it is holding the system in static equilibrium
- However, the DOF can be restored by overcoming the spring force

Spring as Link



Home Work deadline Week 11

- Compliant Mechanisms
- Micro electro-mechanical systems (MEMS)
- Practical Considerations
- Motors and Drivers

Write 1-2 pages about these topics.