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

ME 341
Mechanics of Machines

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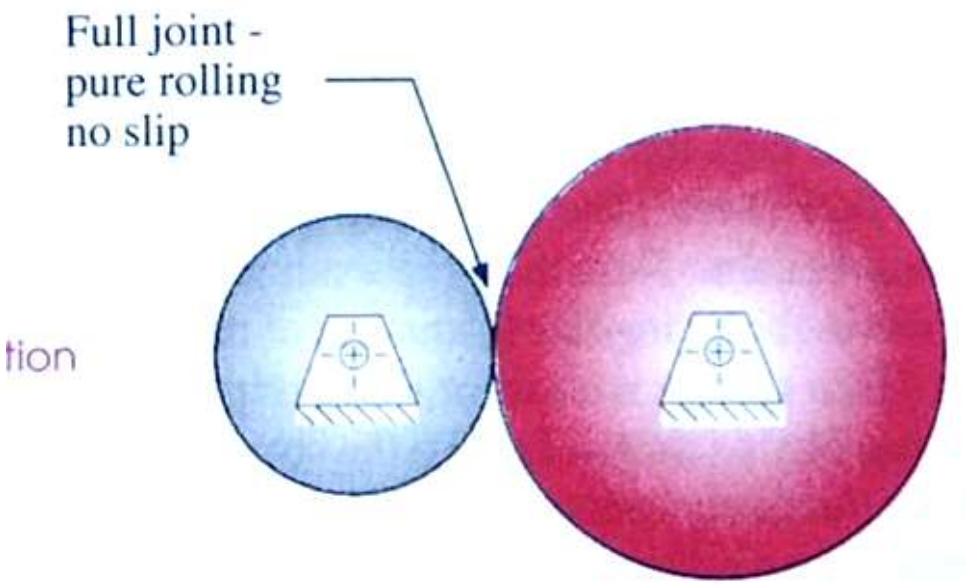
Paradoxes

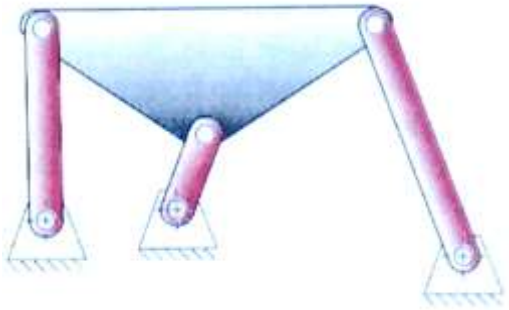
- Because the Gruebler criterion pays no attention to link size or shapes, it can give misleading results in the face of unique geometric configurations



Disagree Greubler Equation which predicts DOF = 0 While the DOF = 1

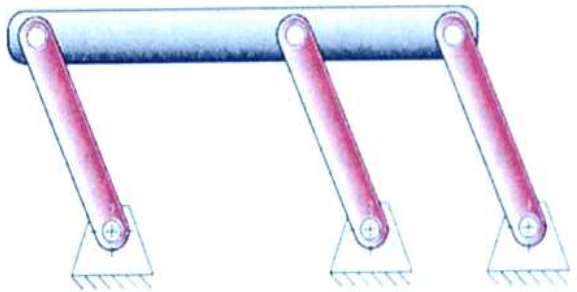
Agree Greubler Equation

DOF = 0



Disagree Greubler Equation

DOF = 1

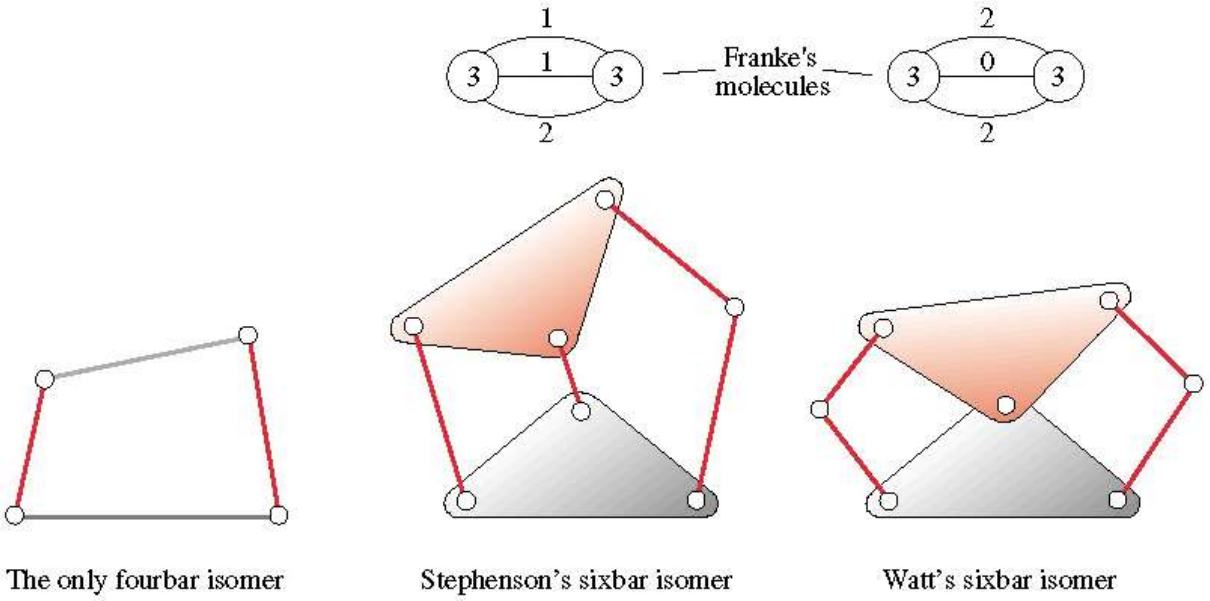


Isomers

- From Greek meaning "*Having Equal Parts*"
- Isomers in chemistry are compounds that have the same number and type of atoms but which are interconnected differently and thus have different physical properties
- Linkage isomers are analogous to these chemical compounds in that the links have various nodes (electrons) available to connect to other links' nodes
- The assembled linkage is analogous to the chemical compound

Isomers

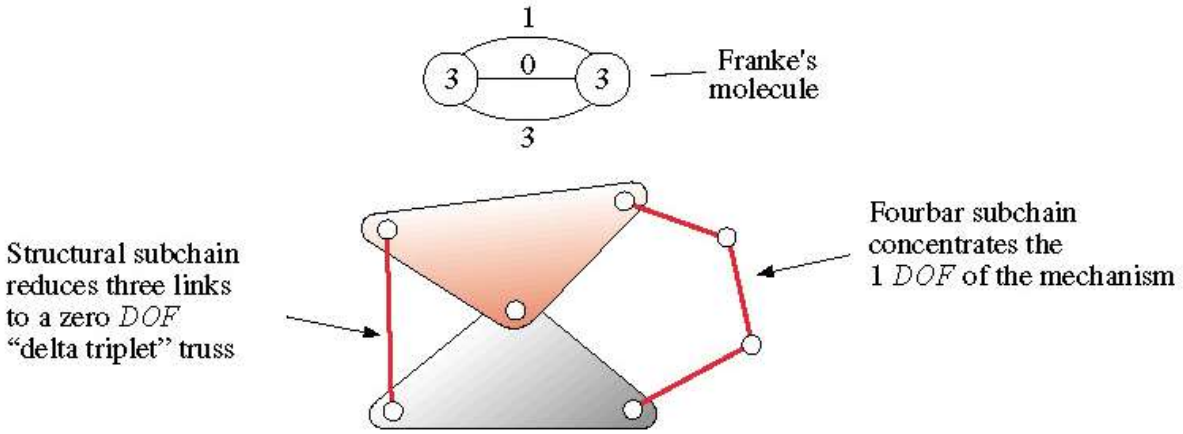
- Figure shows all the isomers for the simple cases of one DOF with 4 and 6 links
- Only way to construct a fourbar isomer is to have one binary link next to another binary link.
- The 6-link case of 4 binaries and 2 ternaries has only two valid isomers
- These are known as Watt's chain and Stephenson's chain



(b) All valid isomers of the fourbar and sixbar linkages

Isomers

- There is also a third potential isomer for this case of six links, but it fails the test of distribution of degree of freedom, which requires that the overall DOF (here 1) be uniformly distributed throughout the linkage and not concentrated in a subchain
- This structure had a structural subchain of DOF = 0 in the triangular formation of the two ternaries and the single binary connecting them
- This creates a truss, or delta triplet
- The remaining three binaries in series form a four bar chain (DOF = 1)



(c) An invalid sixbar isomer which reduces to the simpler fourbar

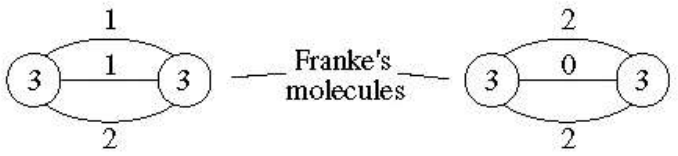
IGURE 2-9

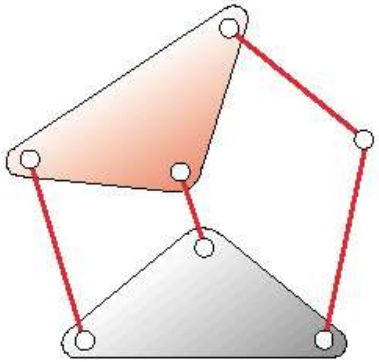
Isomers: Franke’e molecules

- Franke’s “condensed notation for structural synthesis” method can be used to help find the isomers of any collection of links that includes some links of higher order than binary
- Each higher order link is shown as a circle with its number of nodes written in it as shown
- These circles are connected with a number of lines emanating from each circle equal to its valence
- A number is placed on each line to represent the quantity of binary links in that connection
- This gives a ‘molecular’ representation of the linkage and allows exhaustive determination of all possible binary link interconnections among the higher links

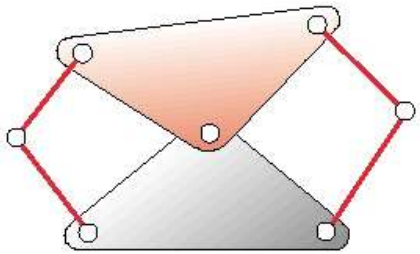
Isomers: Franke'e molecules

- Note the correspondence in the figure between the linkages and their respective Franke' molecule
- The only combinations of three integers (including zero) that add to 4 are: (1,1,2), (2,0,2), (0,1,3) and (0,0,4)
- The first two are the Stephen's and Watt's linkages; the third is the invalid isomer
- The fourth combination is also invalid as it results in a 2-DOF chain of 5 binaries in series with the 5th binary comprised of the two ternaries locked together at two nodes in a preloaded structure with a subchain DOF of -1





Stephenson's sixbar isomer



Watt's sixbar isomer

Linkage Transformation

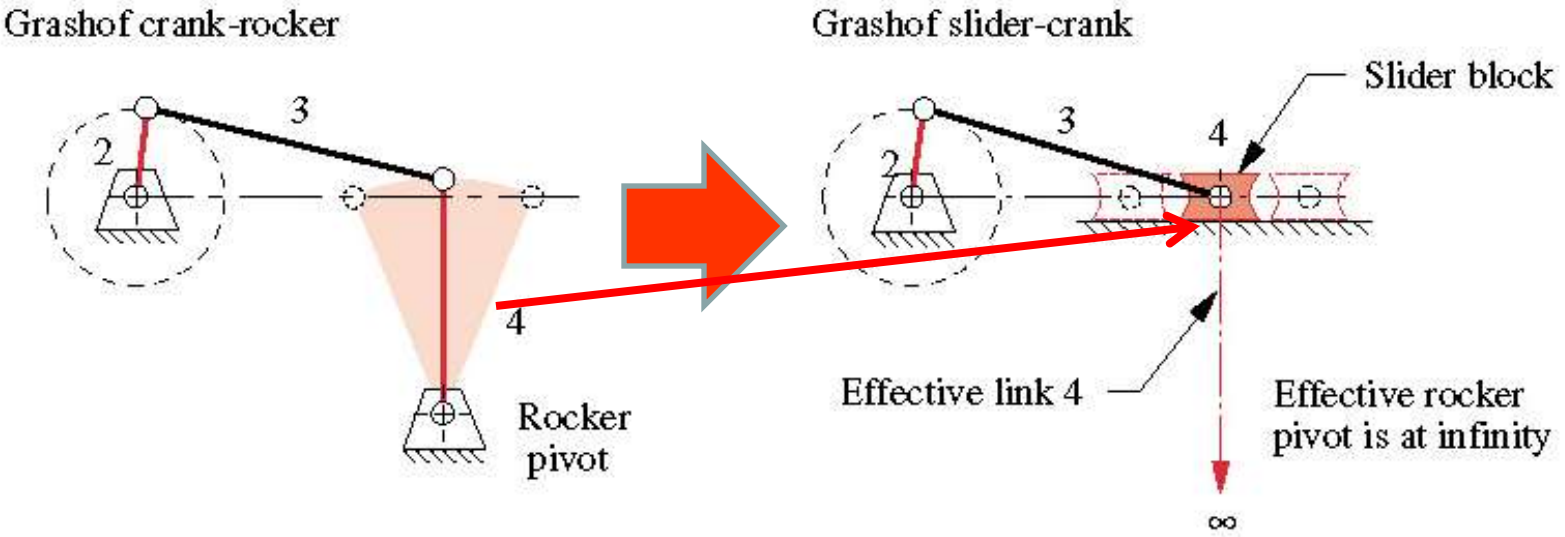
- The number synthesis technique give the designer a toolkit of basic linkages of particular DOF.
- If the arbitrary constraint is relaxed that restricted to only revolute joint, these basic linkages can be transformed to a wider variety of mechanisms with even greater usefulness

Linkage Transformation

- There are certain transformation rules that can be applied to planar kinematic chains
  1. Revolute joints in any loop can be replaced by prismatic joints with no change in DOF of the mechanism, provided that at least two revolute joints remain in the loop
  2. Any full joint can be replaced by a half joint, but this will increase the DOF by one
  3. Removal of a link will reduce the DOF by one
  4. The combination of rule 2 and 3 will keep the original DOF unchanged
  5. Any ternary or higher-order link can be partially "shrunk" to a lower-order link by coalescing nodes. This will create a multiple joint but will not change the DOF of the mechanism
  6. Complete shrinkage of a higher-order link is equivalent to its removal. A multiple joint will be created and the DOF will be reduced

Linkage Transformation: Example 1

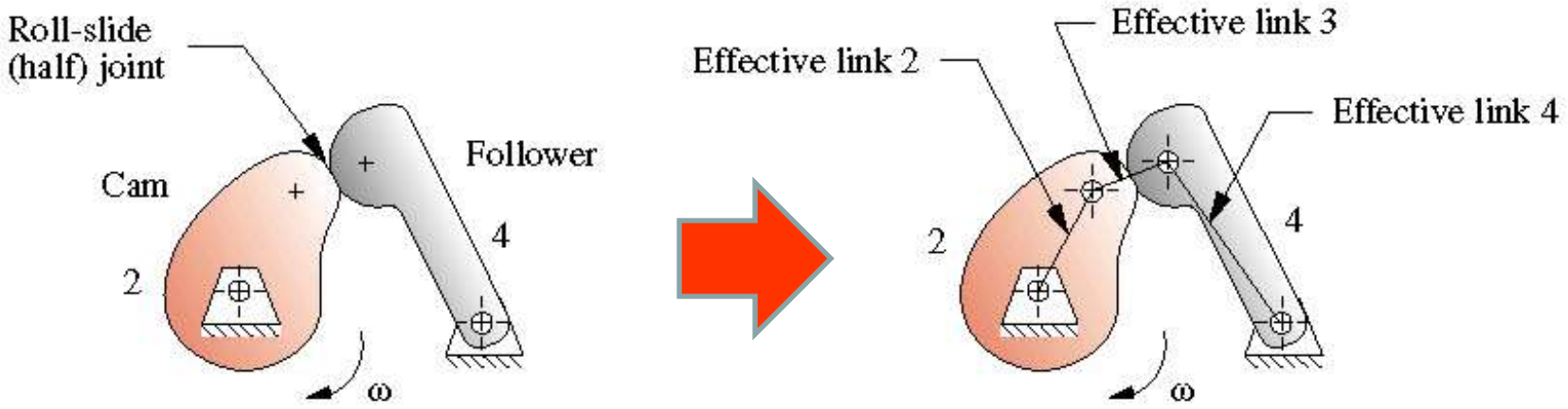
- A four-bar crank-rocker linkage transformed into the four-bar slider by the application of rule #1
- It is still a fourbar linkage
- Link 4 has become a sliding block
- The Gruebler's equation is unchanged at one DOF because the slider block provides a full joint against link 1, as did the pin joint it replaces



(a) Transforming a fourbar crank-rocker to a slider-crank

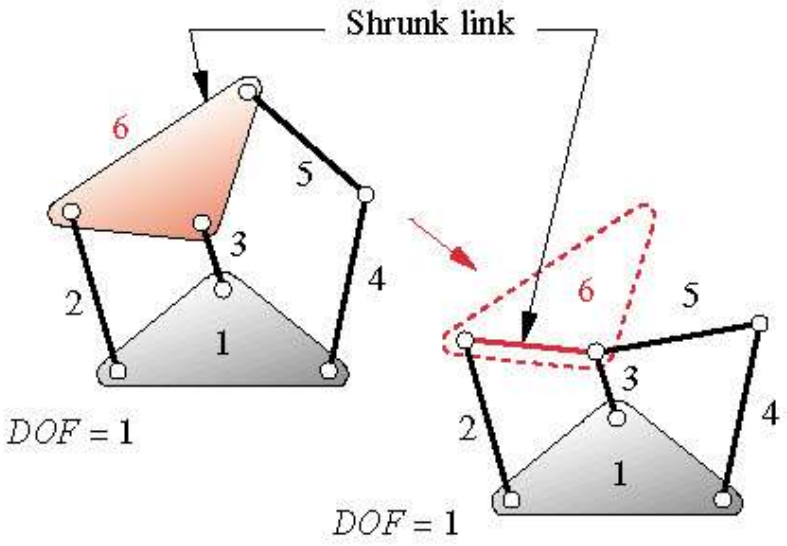
Linkage Transformation: Example 2

- Fourbar slider-crank mechanism transformed via rule # 4 by the substitution of a half joint for the coupler



Linkage Transformation: Example 3

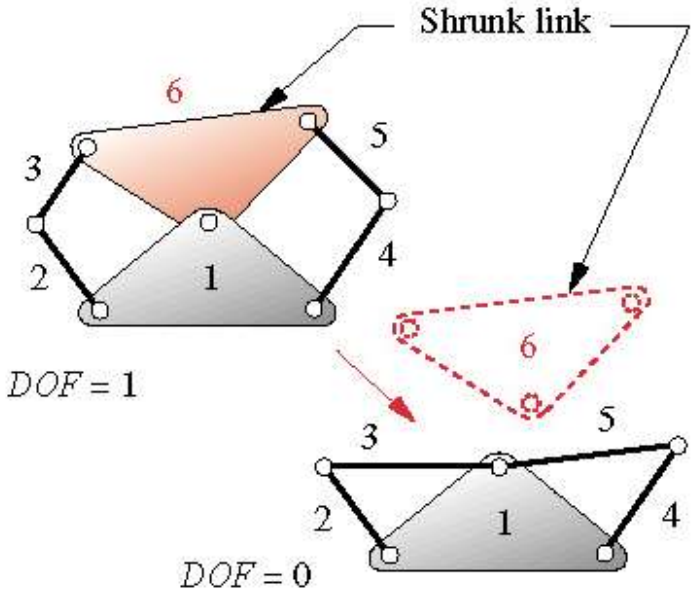
- Stephenson's sixbar chain transformed by partial shrinkage of a ternary link (rule # 5) to create a multiple joint. It is still a one-DOF Stephenson's sixbar



(a) Partial shrinkage of higher link retains original *DOF*

Linkage Transformation: Example 4

- Watt's sixbar chain with one ternary link completely shrunk (Rule # 6) to create a multiple joint. DOF is also reduced

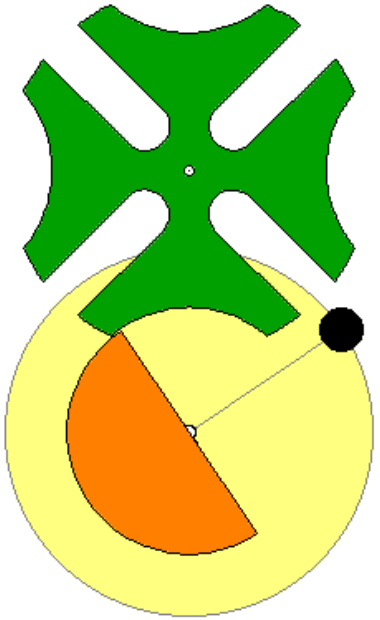


Intermittent Motion

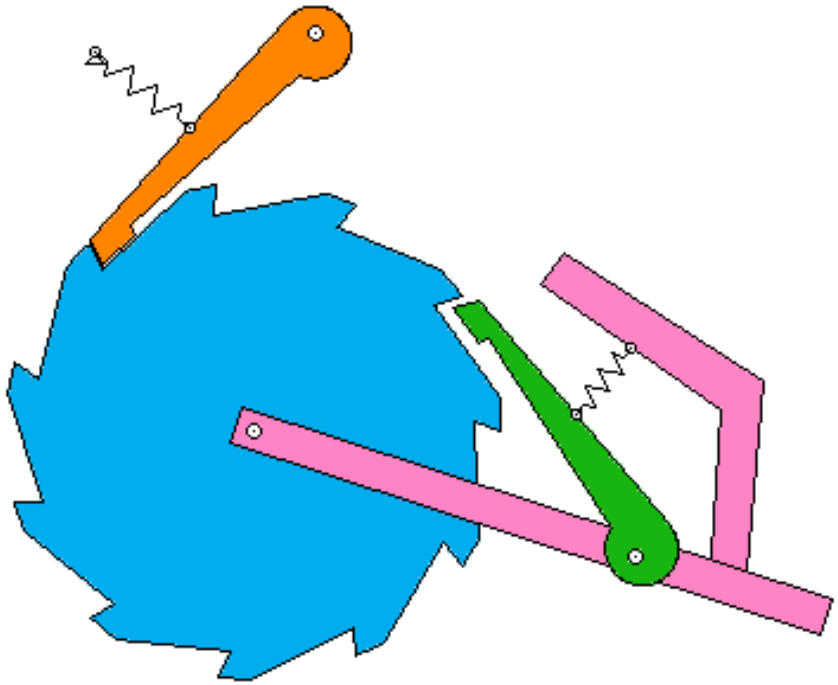
- A sequence of motions and dwells
- A dwell is a period in which the output link remains stationary while the input link continues to move
- There are many applications in machinery that require intermittent motion
- The cam-follower variation on the fourbar linkage is often used in these situations

Geneva Mechanism

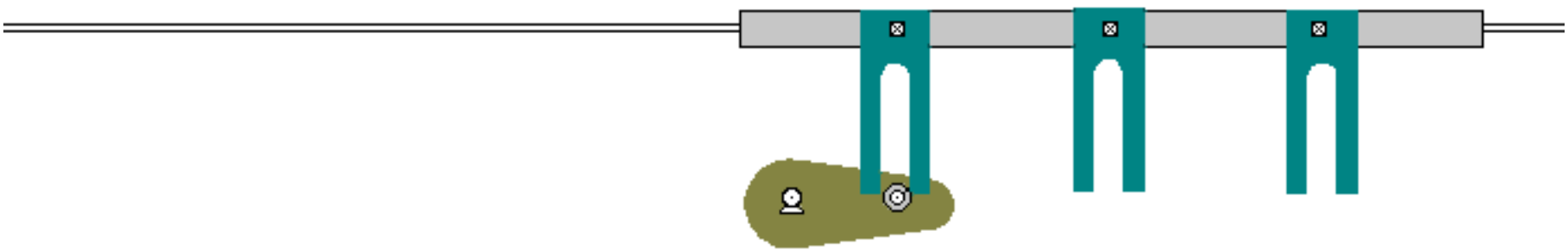
- A common form of intermittent motion device is the Geneva mechanism



Ratchet and Pawl



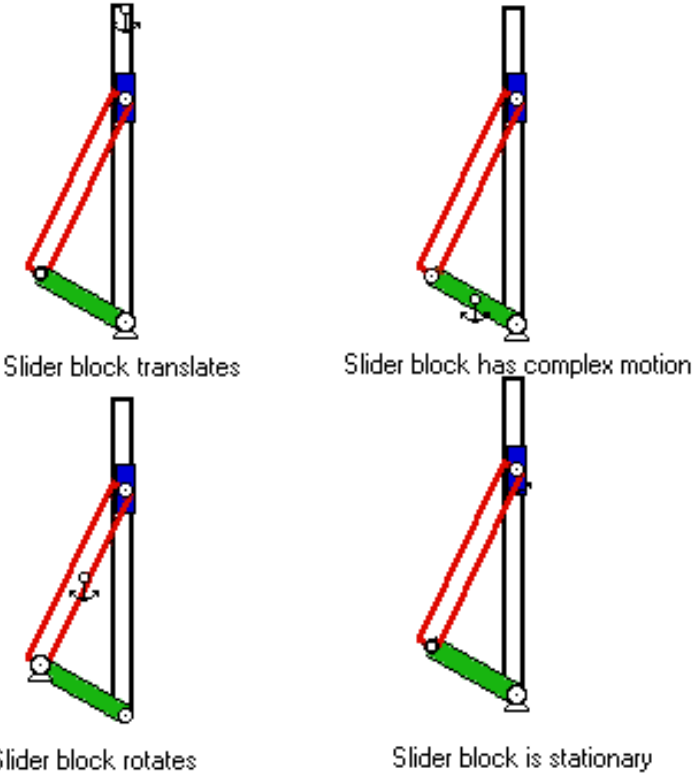
Linear Geneva Mechanism



Inversion

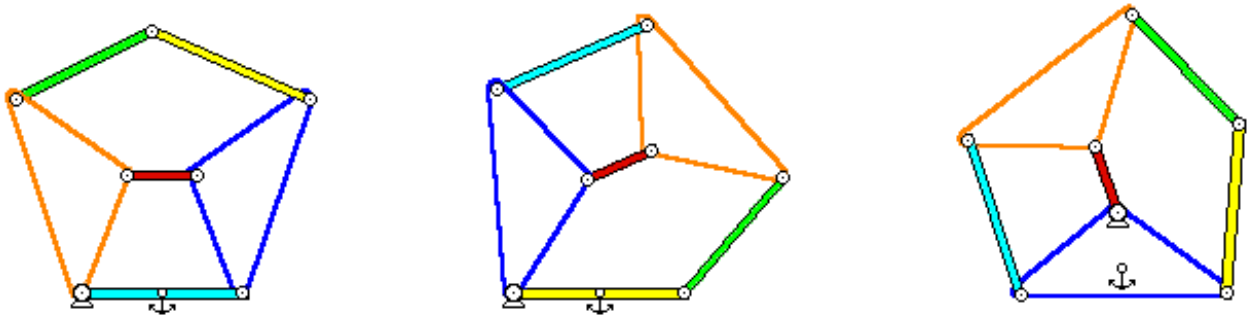
- An inversion is created by grounding a different link in the kinematic chain
- The motion resulting from each inversion can be quite different, but some inversions of a linkage may yield motions similar to other inversions of same linkages
- In these cases only some of the inversions may have distinctly different motions
- Here only inversions that have distinctly different motion are denoted as distinct inversions

Slider inversion



Stephenson's sixbar

- Stephenson's sixbar has three distinct inversions



Watt's Sixbar chain

- Watt's sixbar chain has two distinct inversions