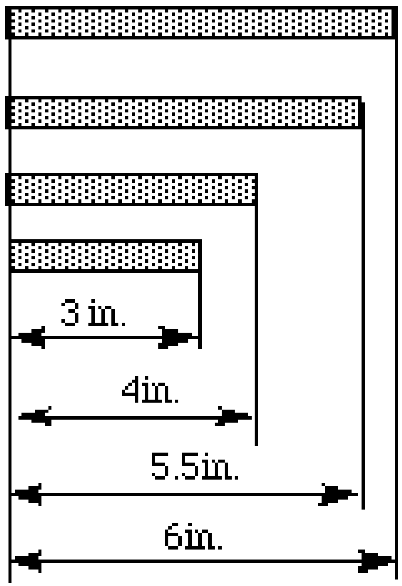
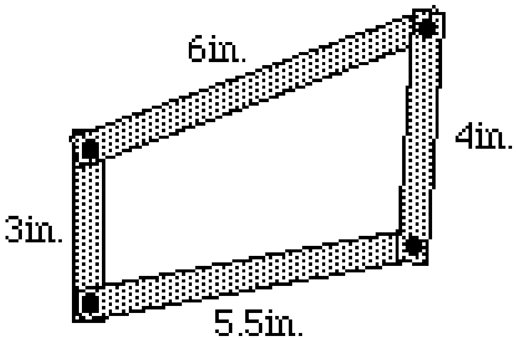
Do-it-yourself four bar linkage mechanism

- Let's make a simple mechanism with similar behavior to that of wiper mechanism.
- Take some cardboard and make four strips as shown in Figure a.
- Take 4 pins and assemble them as shown in Figure b.



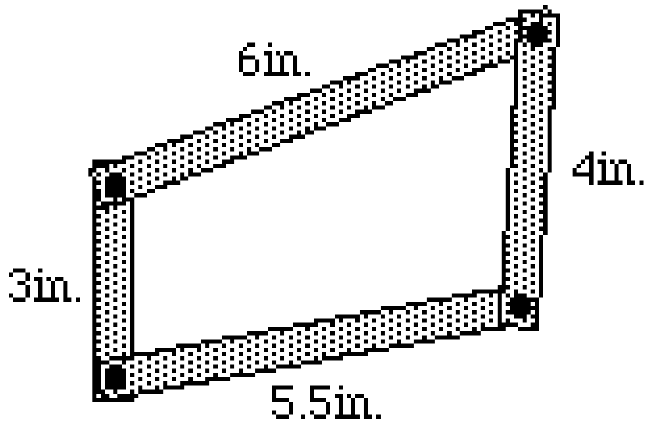
a



b

Do-it-yourself four bar linkage mechanism (contd.)

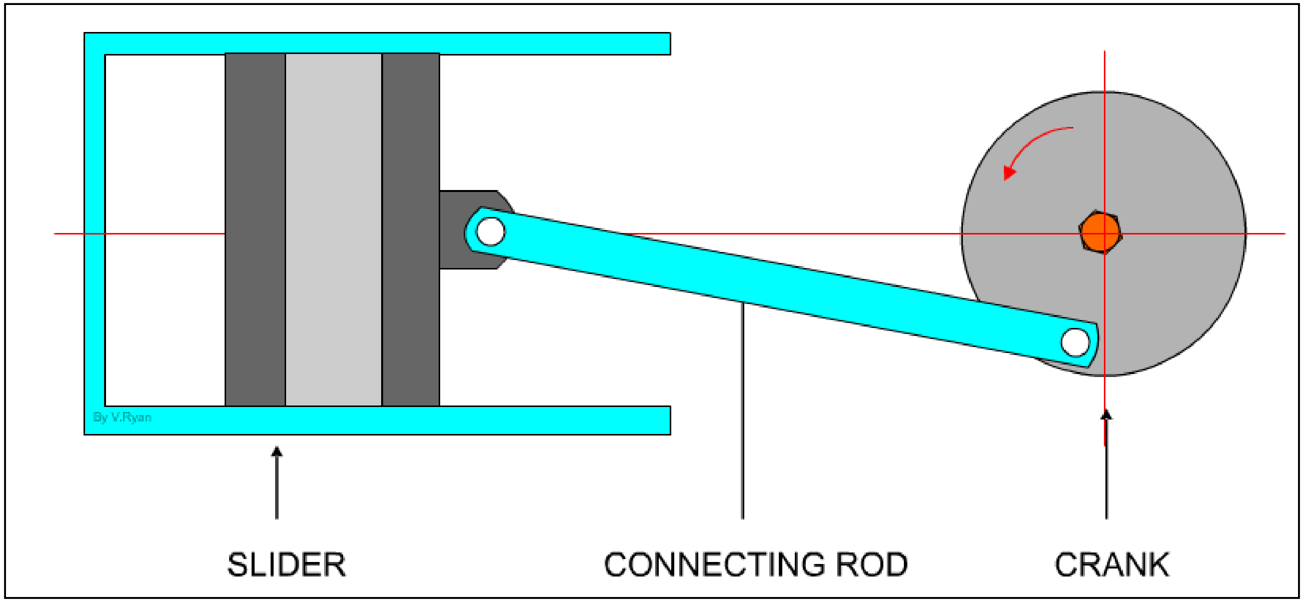
- Now, hold the 6in. strip (i.e. fixed link) so it can't move and turn the 3in. Strip (i.e. input-crank link) . You will see that the 4in. strip (output – rocker link) oscillates.



Examples: Slider-crank Mechanism

This mechanism is composed of three important parts:

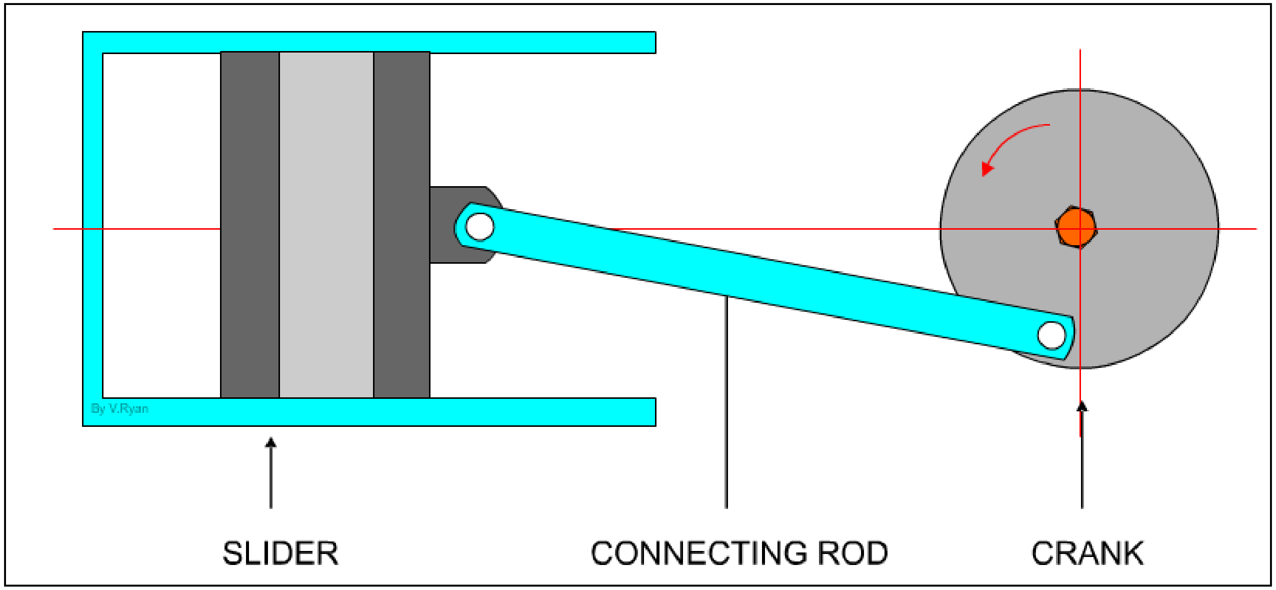
- The crank which is the rotating disc, the slider which slides inside the tube and the connecting rod which joins the parts together.



Slider-crank Mechanism (contd.)

- As the slider moves to the right the connecting rod ***pushes*** the wheel round for the first 180 degrees of wheel rotation.

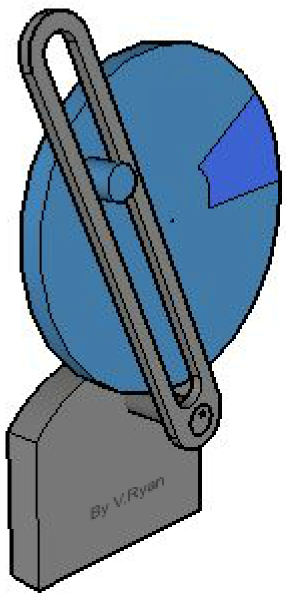
- When the slider begins to move back into the tube, the connecting rod ***pulls*** the wheel round to complete the rotation.

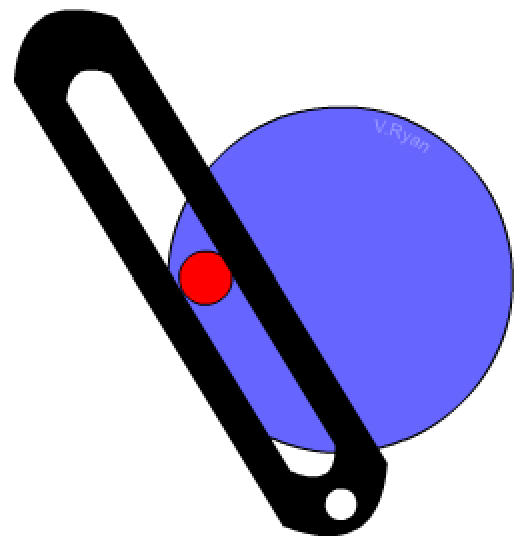


- Animation : http://www.technologystudent.com/cams/crkslid1.htm

Quick Return Mechanism

- A quick return mechanism such as the one seen below is used where there is a need to convert rotary motion into reciprocating motion.



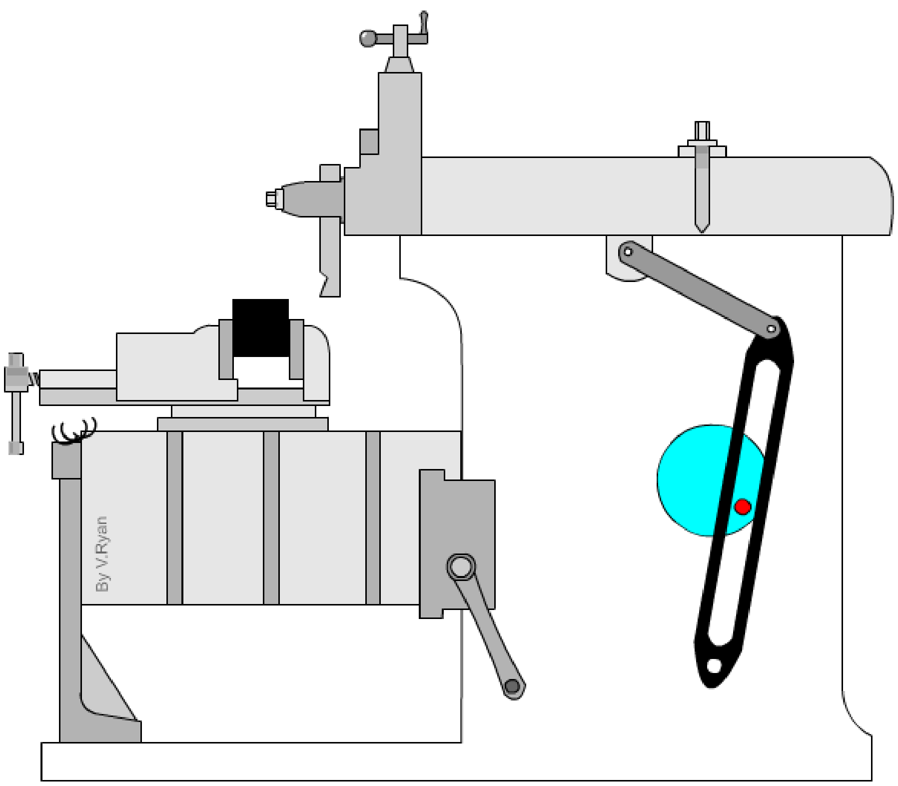


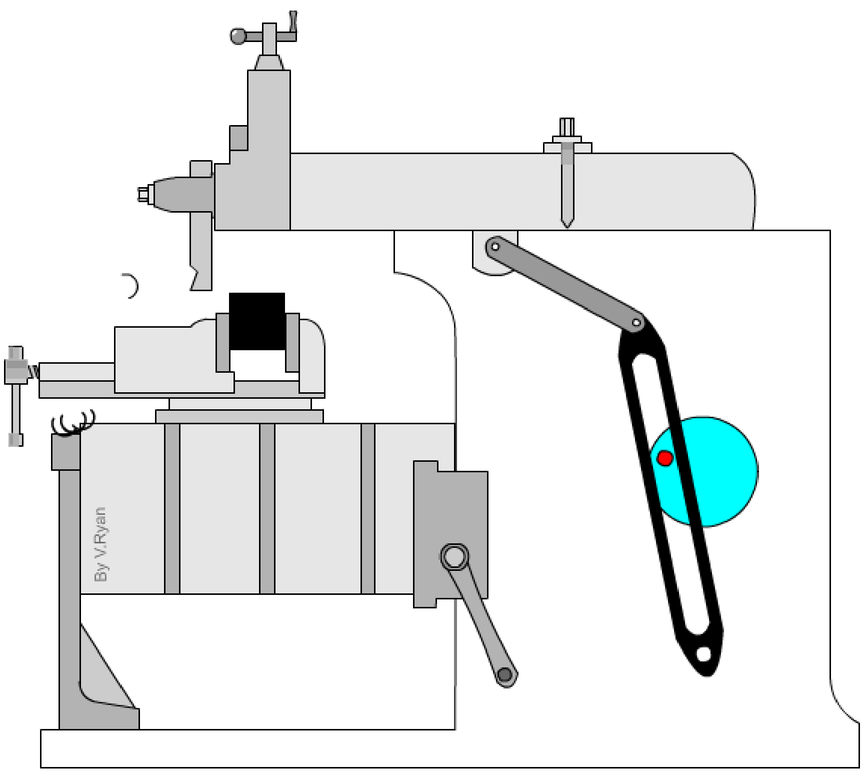
http://www.technologystudent.com/cams/crank1.htm

- As the disc rotates the black slide moves forwards and backwards. Many machines have this type of mechanism , such as shaping machine.

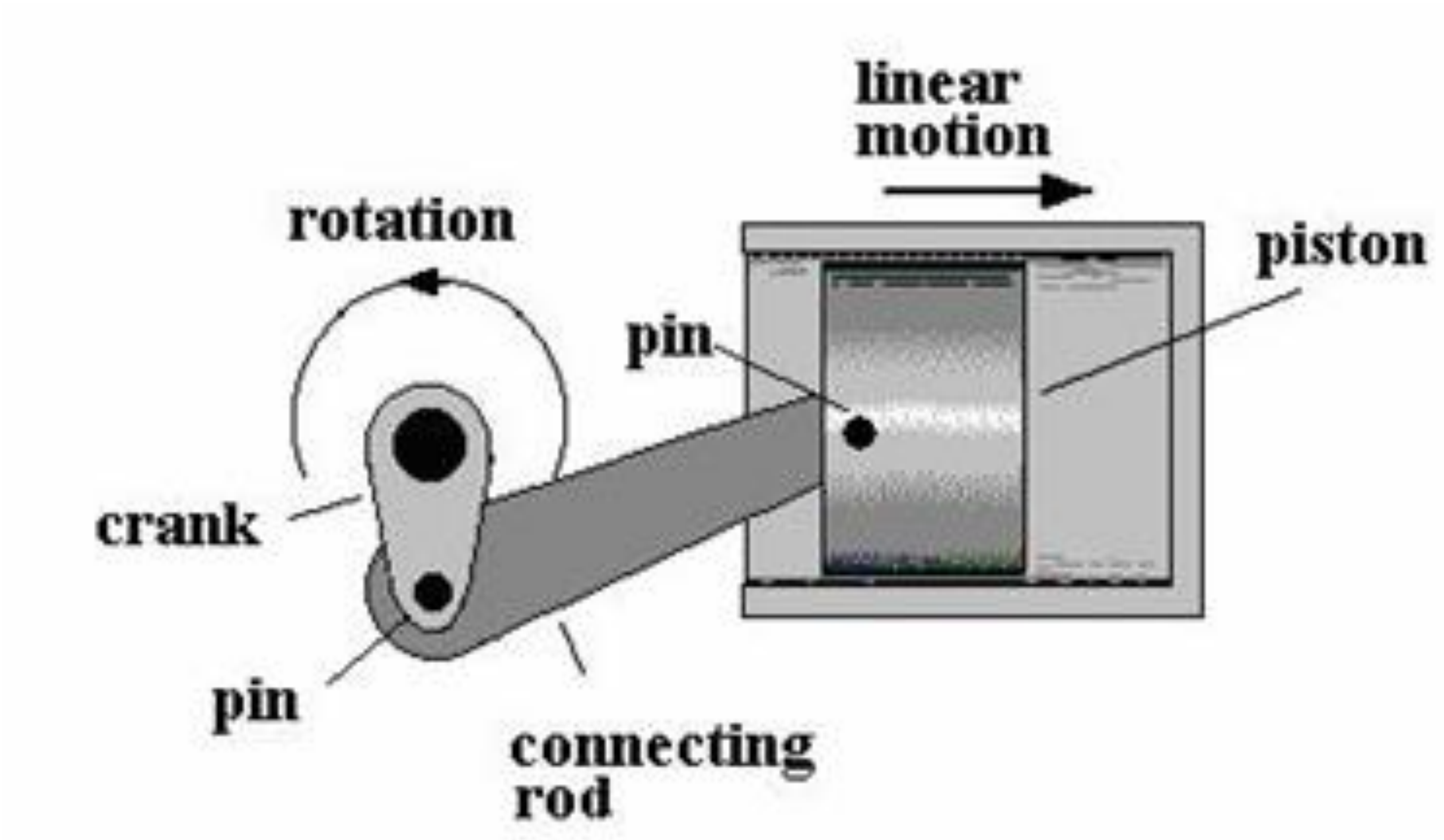
Example: Shaping Machine

- As the disc rotates the top of the machine moves forwards and backwards, pushing a cutting tool.
- Animation: http://www.technologystudent.com/cams/crank2.htm





Example: crank, connecting rod and piston mechanism



Example: crank, connecting rod and piston mechanism (contd.)

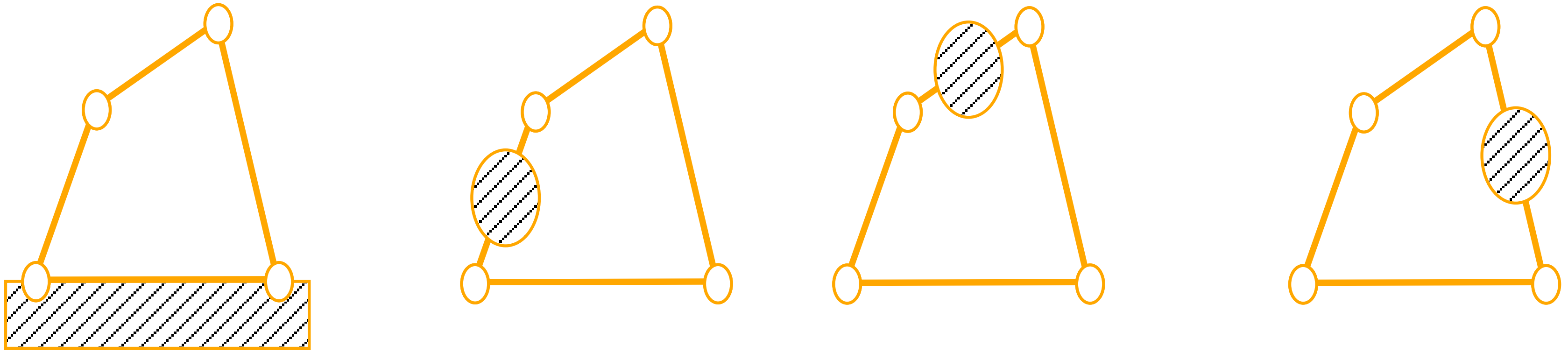
- If the crank is turned, angular motion is converted into linear motion of the piston and input torque is transformed into force on the piston.

- If the piston is forced to move, the linear motion is converted into rotary motion and the force into torque.

- Thus, the *crank and connecting rod* are connected via a revolute joint, whereas *connecting rod and piston* are connected via a prismatic joint.

Kinematic Inversion

- The process of choosing different links of a kinematic chain as the fixed or ground link, for generating new mechanisms is called Kinematic Inversion



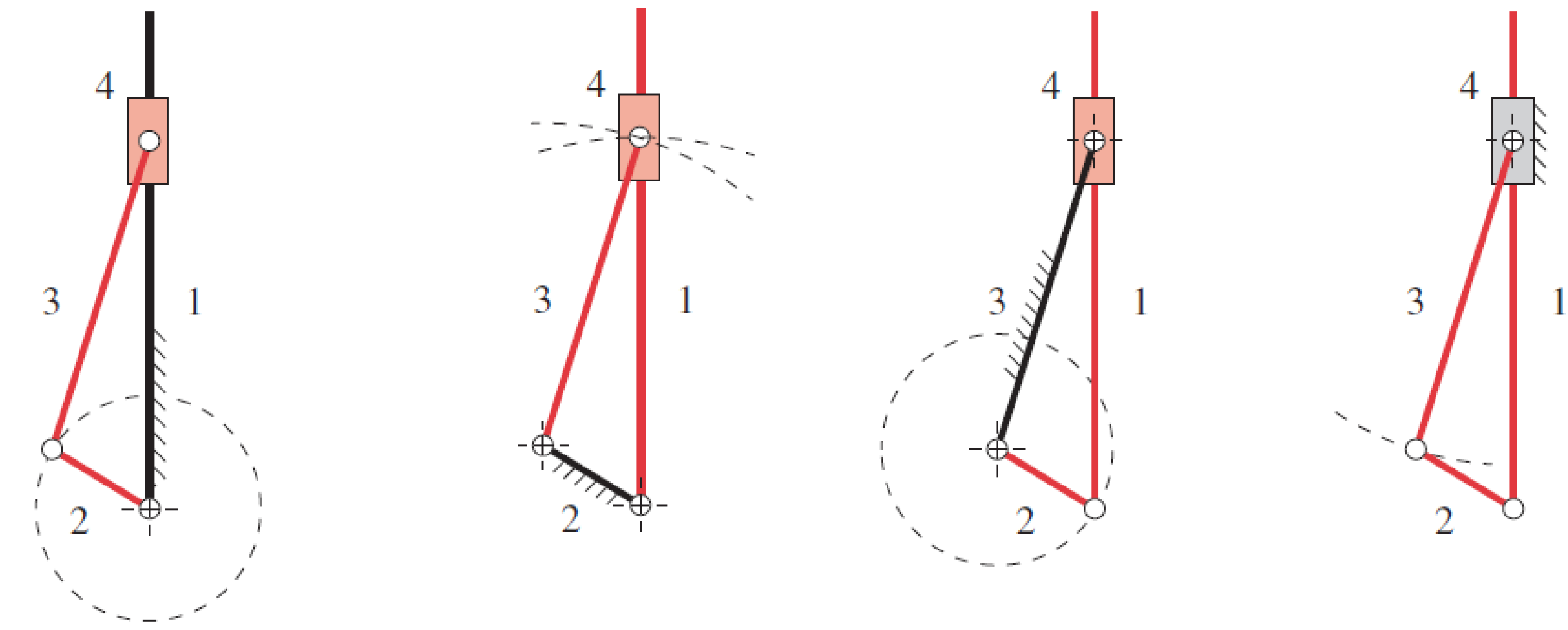
Kinematic Inversion (contd.)

- Thus there are as many inversions of a given linkage as it has links.

- It should be noted that, the ***relative*** motion b/w various links are not altered, but their ***absolute*** motions (those measured w.r.t. fixed link) may change dramatically.

Inversions of slider-crank linkage

- Figure shows the four inversions of the fourbar slider-crank linkage, all of which have distinct motions.



(*a*) Inversion # 1 slider block translates

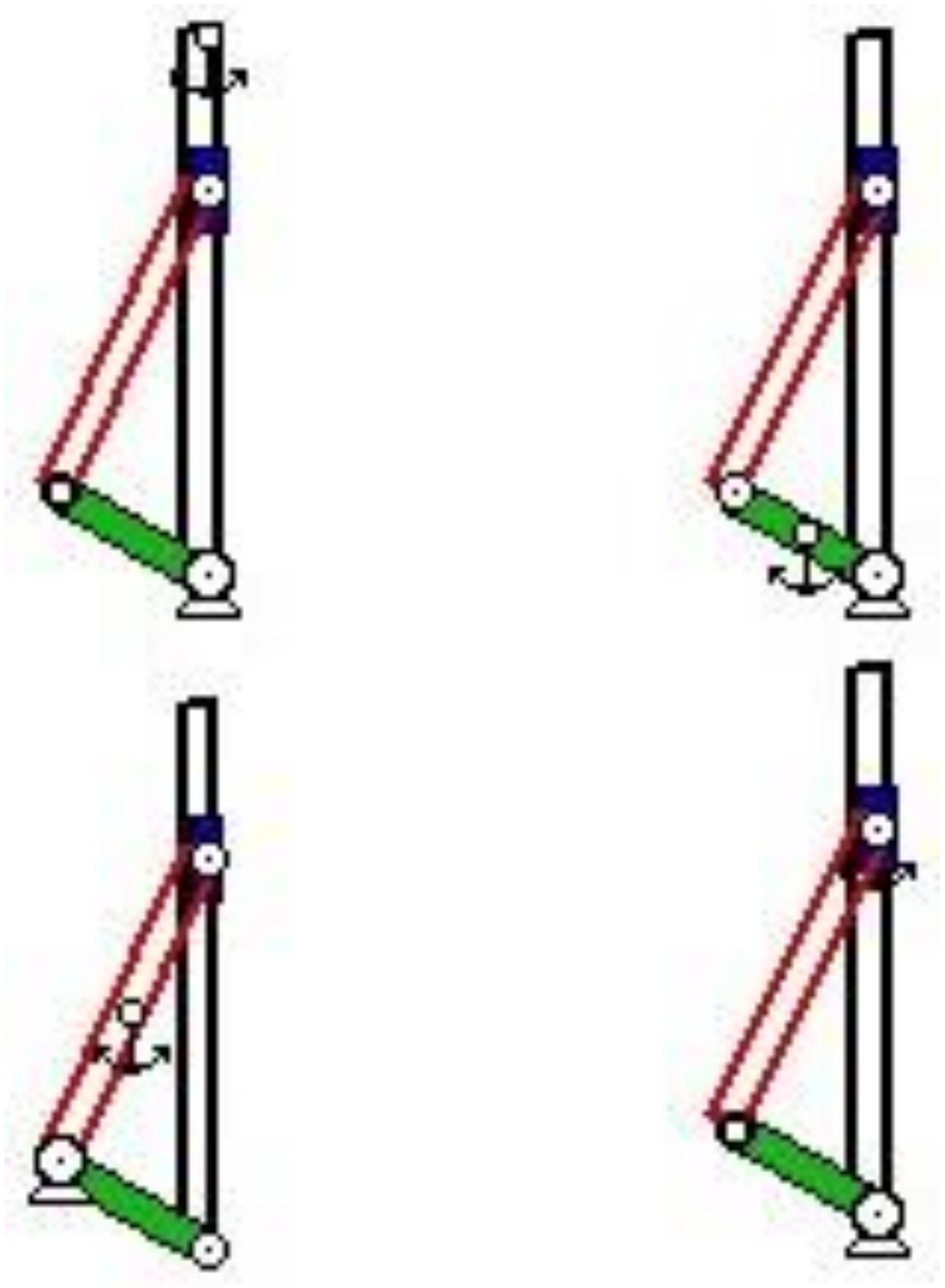
(*b*) Inversion # 2 slider block has complex motion

(*c*) Inversion # 3 slider block rotates

(*d*) Inversion # 4 slider block is stationary

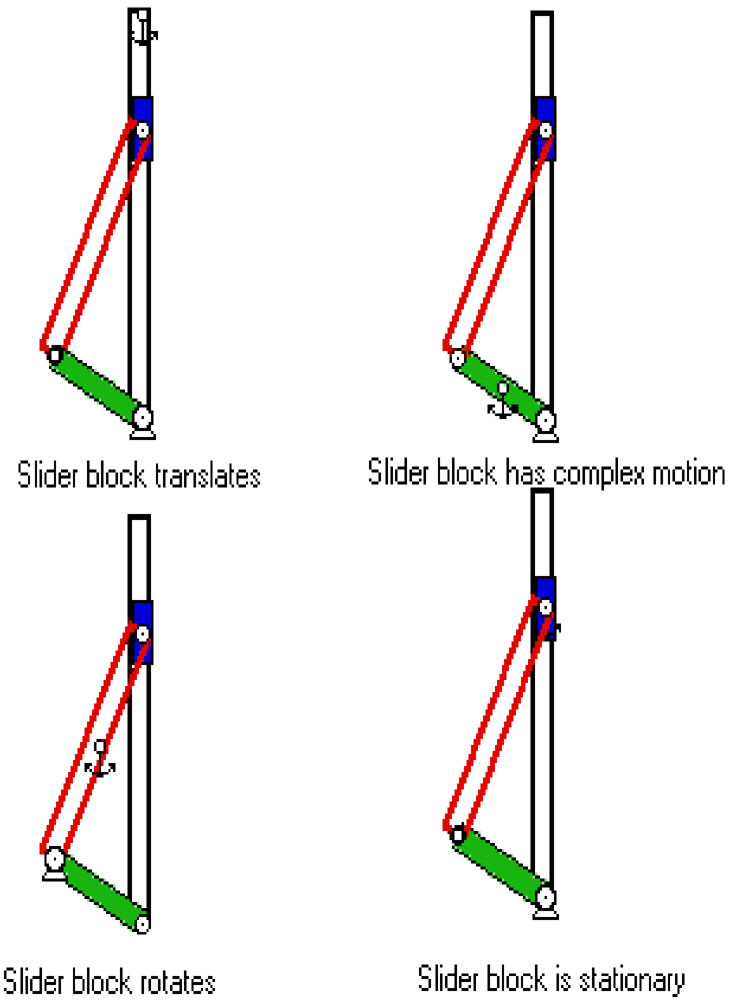
Animation

- The four links - crank (in green), coupler (in red), slider (in blue), and track (in black) - are successively fixed (shown with an anchor) in each of the inversion.



Animation

- The four links - crank (in green), coupler (in red), slider (in blue), and track (in black) - are successively fixed (shown with an anchor) in each of the inversion.



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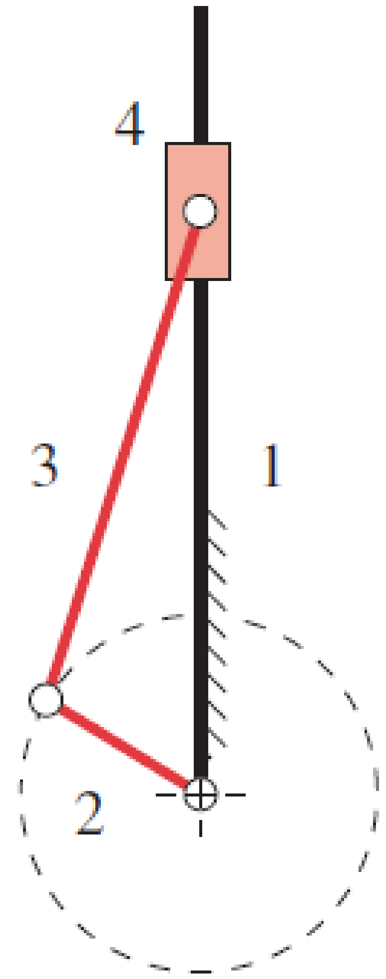
Inversion # 1

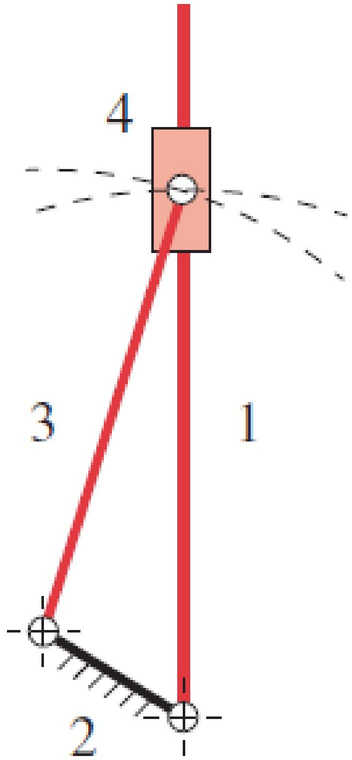
- Inversion #1, with link 1 as ground and its slider block in pure translation, is the most commonly seen and is used for producing rotary motion of the wheels, crank etc.



(a) Inversion # 1 slider block translates

Inversion # 2

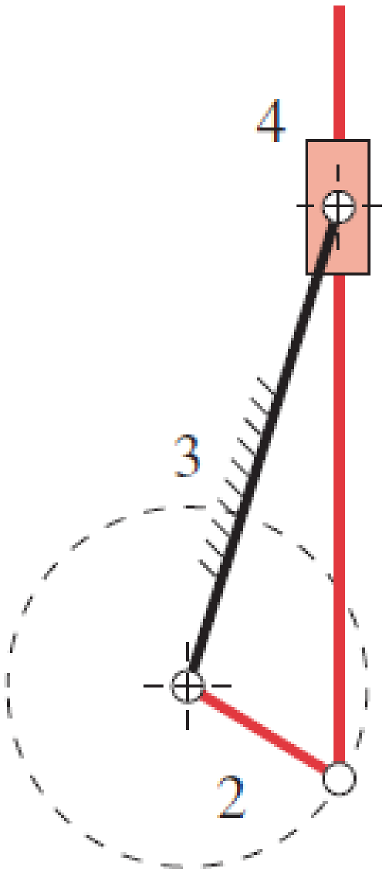
- Inversion #2 is obtained by grounding link 2 and gives the Whitworth or crank-shaper quick-return mechanism, in which the slider block has complex motion.



(b) Inversion # 2
slider block has
complex motion

Inversion # 3

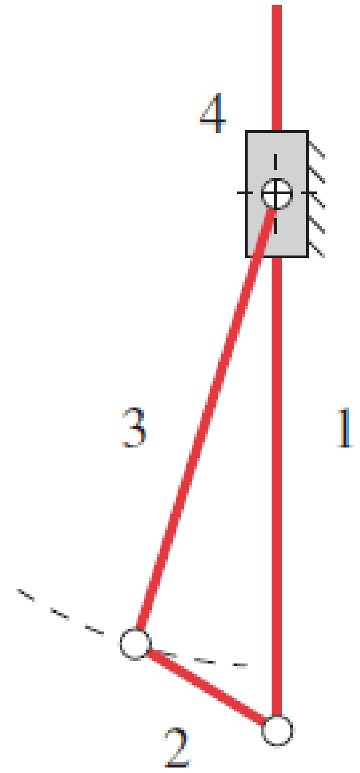
- Inversion #3 is obtained by grounding link 3 and gives the slider block pure rotation.



(c) Inversion # 3 slider block rotates

Inversion # 4

- Inversion #4 is obtained by grounding the slider link 4 and is used in hand operated, **well pump** mechanisms, in which the handle is link 2 (extended) and link 1 passes down the well pipe to mount a piston on its bottom. (It is upside down in the figure.)



(a) Inversion # 4
slider block
is stationary

Grashof's Law

- The **Grashof Condition** is a relationship that predicts the *rotation behavior of the inversions of a fourbar linkage* based only on the lengths of the links:

- S = length of shortest link
- L = length of longest link
- P = length of one remaining link
- Q = length of other remaining link

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

$\Rightarrow$ Linkage is Grashof

Grashof's Law (contd.)

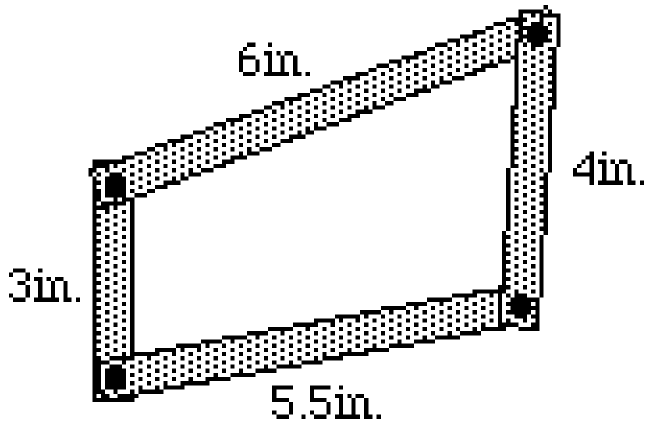
Then if $S + L \leq P + Q$

$\Rightarrow$ Linkage is Grashof

- If $S+L \leq P+Q$ the linkage is Grashof :at least one link is capable of making a complete revolution
- Otherwise the linkage is non-Grashof : no link is capable of making a complete revolution

Do you Remember !!!

- Now, hold the 6in. strip (i.e. fixed link) so it can't move and turn the 3in. Strip (i.e. input-crank link) . You will see that the 4in. strip (output – rocker link) oscillates.



Grashof’s Law (contd.)

- It should be noted that nothing in Grashof's law specifies the order in which the links are to be connected or which link of the four-bar chain is fixed.

- That is, the determination of the Grashof’s condition can be made on a set of unassembled links.

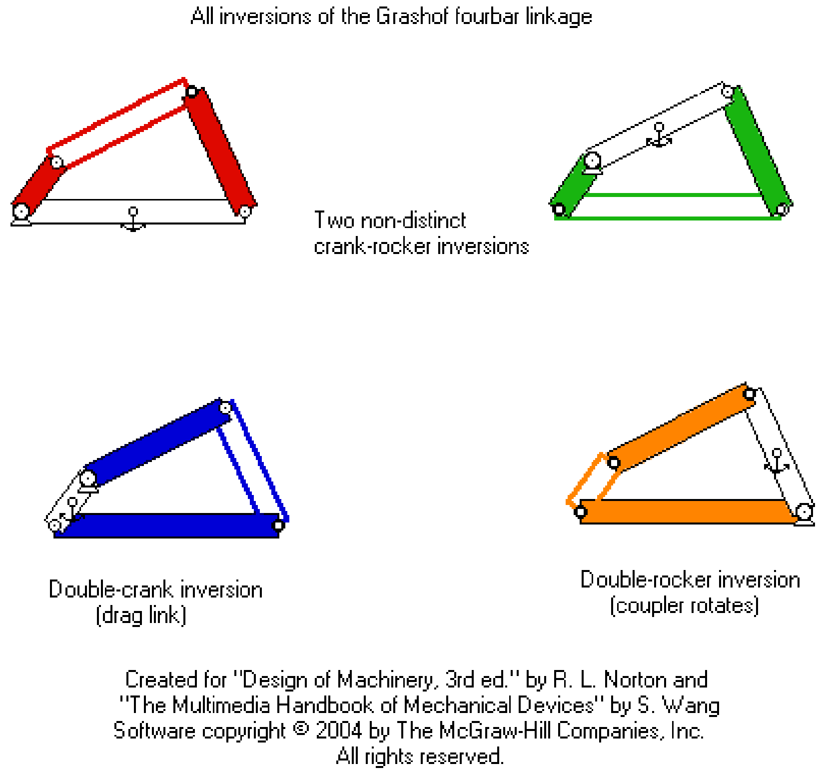
- Whether they are later assembled into a kinematic chain in S, L, P, Q, or S, P, L, Q or any other order, will not change the Grashof’s condition.

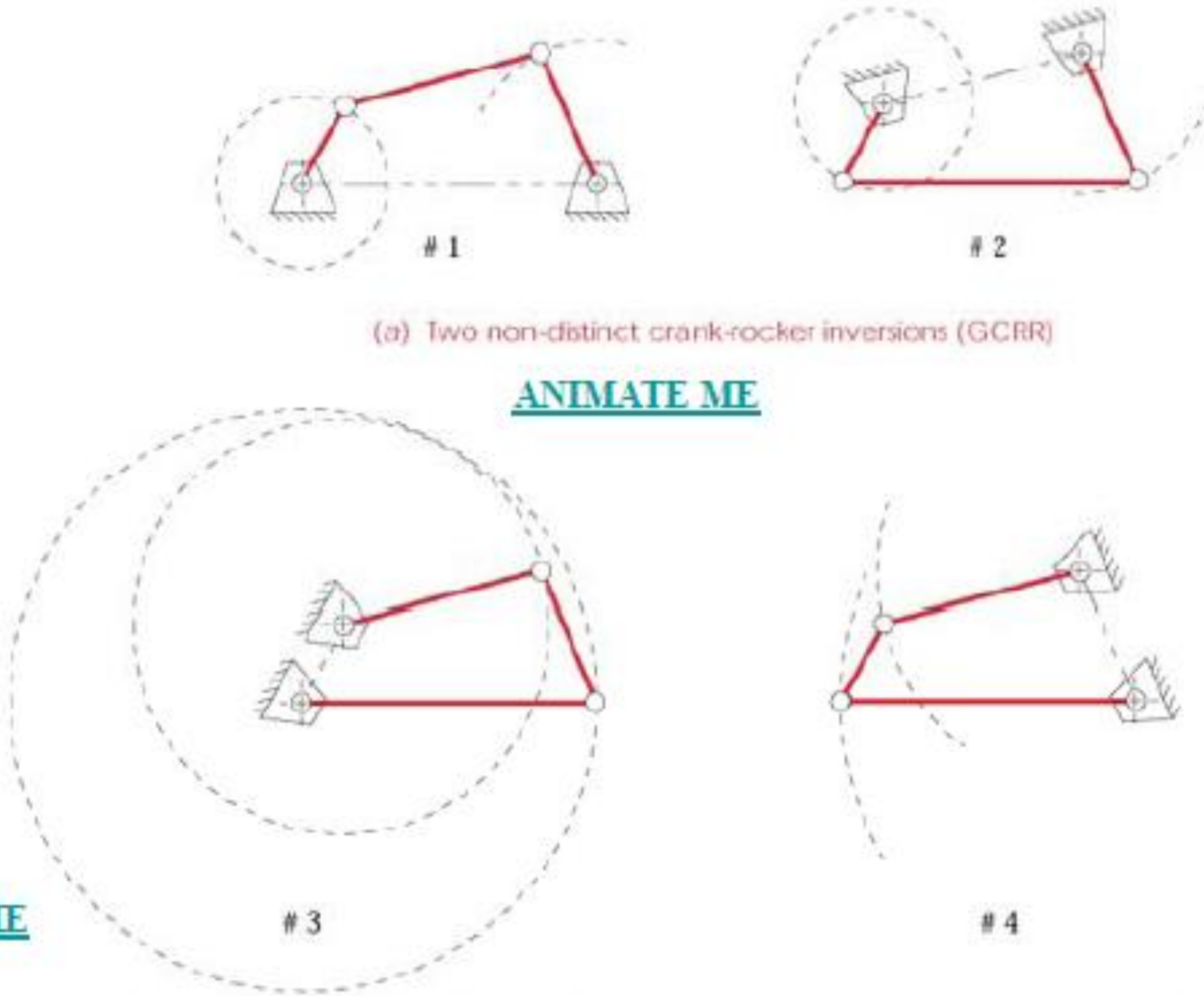
Grashof’s Law (contd.)

- We are free, therefore to fix or ground any of the four links.
- When we do so, we create the four inversions of the four linkage illustrated in next slide.
- The **motions 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.

For S+L<P+Q

- Crank-rocker if either link adjacent to shortest is grounded
- Double crank if shortest link is grounded
- Double rocker if link opposite to shortest is grounded





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

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(b) Double-crank inversion (GCRC)
(drag link mechanism)

(c) Double-rocker inversion (GRCR)
(coupler rotates)

FIGURE 2-15

All inversions of the Grashof fourbar linkage

Grashof’s Law (contd.)

- All of these (inversions shown on previous slide) fit Grashof's law, and in each the link ***s*** makes complete revolution relative to the other links.
- The different inversions are distinguished by the location of the link ***s*** relative to the fixed link.

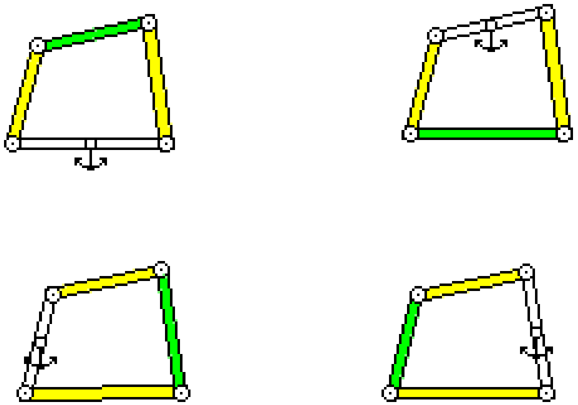
If we pay attention !!

- There are as many inversions as links, but *not all inversions will have distinct motions*.

- For example, a Grashof Fourbar has only 3 distinct inversions, 2 crank-rockers, 1 double-crank, and 1 double-rocker as shown in earlier slide.

For S+L > P+Q

- All inversions will be double rockers
- No link can fully rotate



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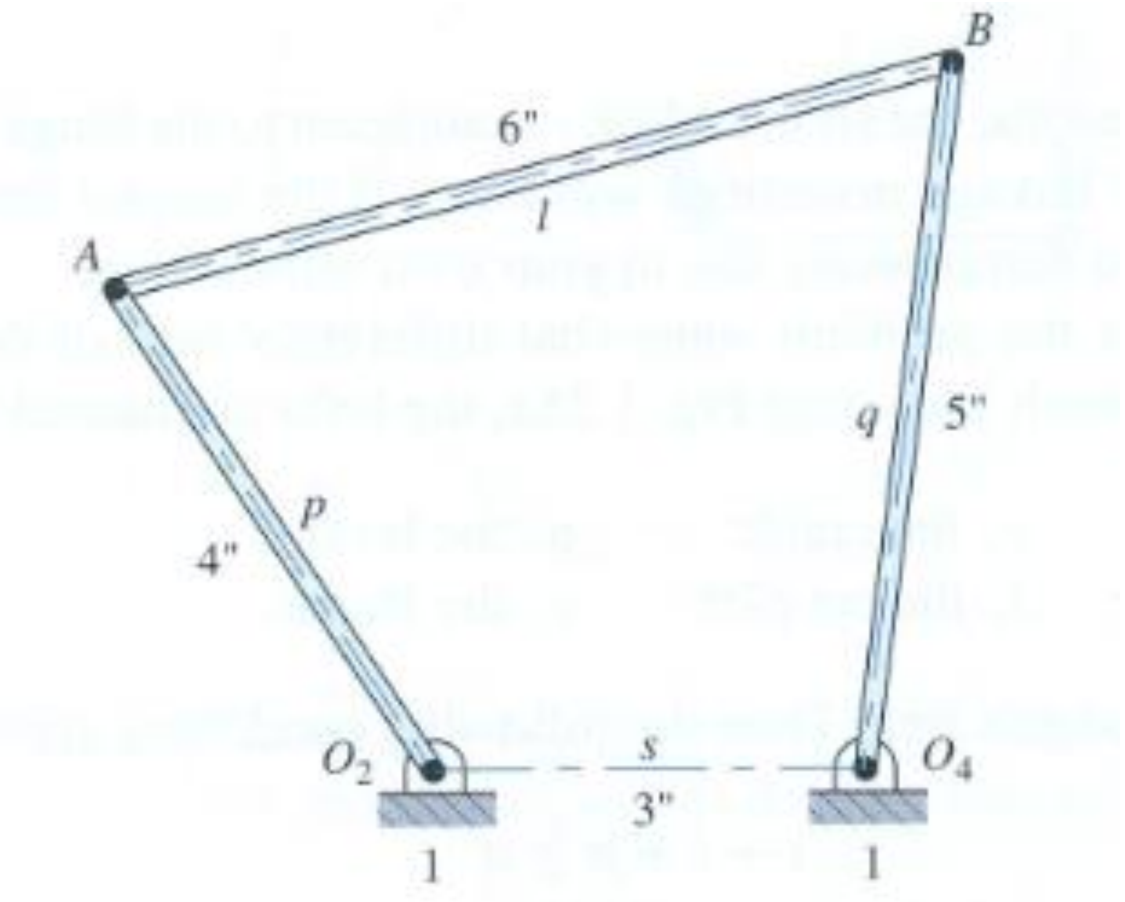
Example: 1

- Determine whether the four-bar linkage illustrated below is a crank-rocker four-bar linkage, a double-rocker four-bar linkage or double-crank four-bar linkage.



Example: 1 (contd.)

- Substituting the link lengths into Grashof's Eq: gives

$$3\,\boldsymbol{in} + 6\,\boldsymbol{in} \;\le\; 4\,\boldsymbol{in} + 5\,\boldsymbol{in}$$

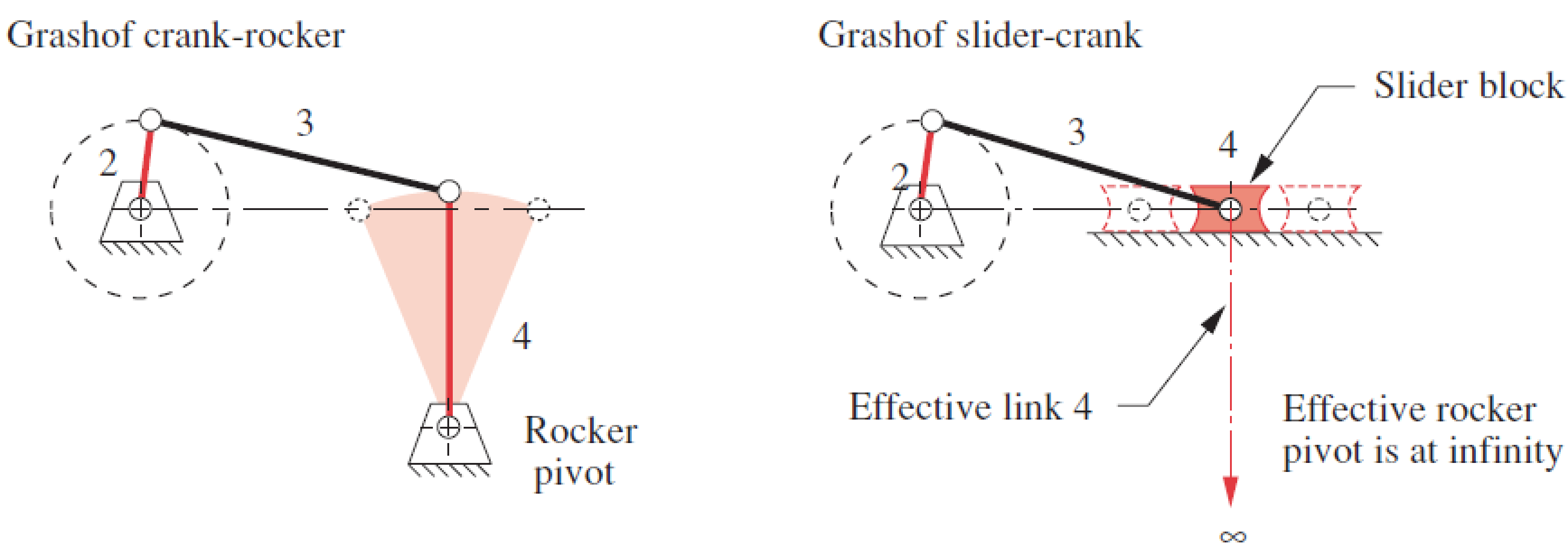
$$9\,\boldsymbol{in} \le 9\,\boldsymbol{in}$$

if $S + L \le P + Q$

Linkage is Grashof

- Therefore, the given four-bar linkage satisfies Grashof's law; that is, the linkage is a Grashof four-bar linkage.
- Because the **shortest link of the four-bar linkage is grounded**, the two links adjacent to the shortest link can both rotate continuously (as shown earlier) and both are properly described as cranks.
- Therefore, this four-bar linkage is a double-crank

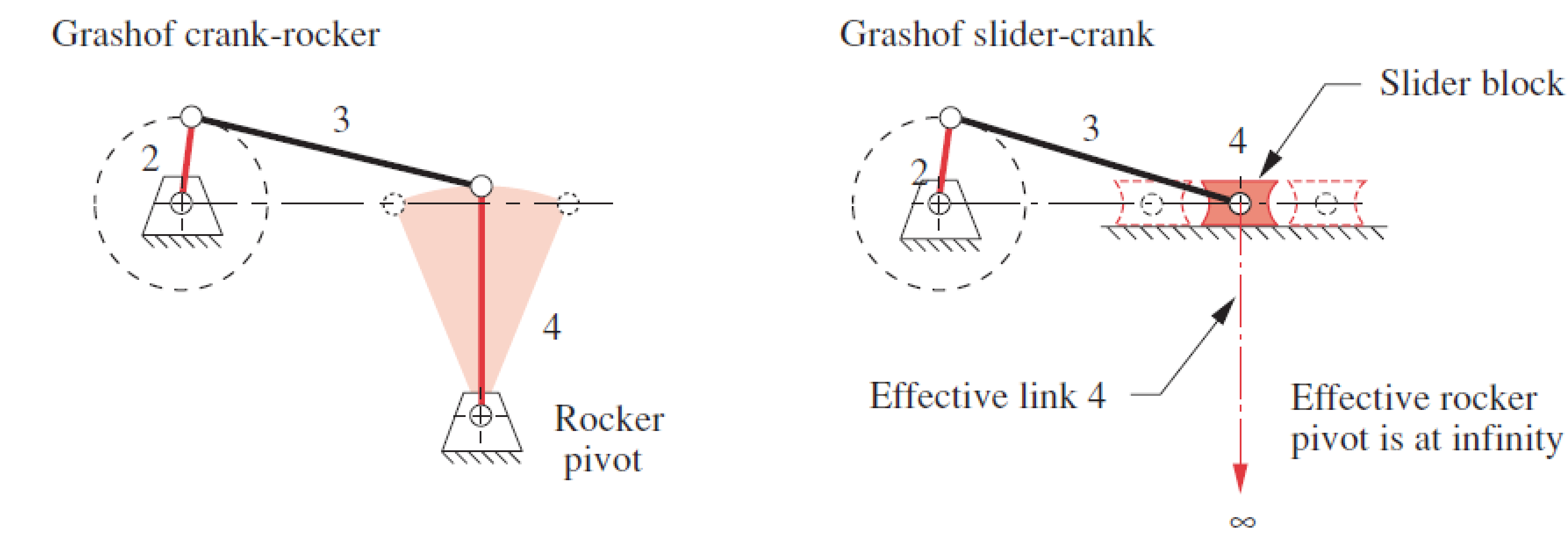
Linkage transformation



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

- The crank-slider (right) is a transformation of the fourbar crank rocker, by replacing the revolute joint at the rocker pivot by a prismatic joint, maintaining the same one degree of freedom. Note, slider block is actually Link 4.

Linkage transformation (contd.)



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

- Replacing revolute joints in any loop by prismatic joints does not change the DOF, provided that at least two revolute joints remain in the loop