MECHANISM DESIGN

CHAPTER 1:

BASIC KINEMATICS

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INTRODUCTION

Kinematics:

- Generally, it is the study of the **geometry** of **motion**.
- It focusses on how things like machine components move as a response to some input.
- **Definitions:**

Rigid Body	–	A solid body in which different points on it maintain their relative positions even as the body moves and rotates.
Link	–	A body with the aim of transmitting motion or force.

INTRODUCTION

- **Mechanisms** is the study of techniques for the analysis and dimensional synthesis of linkages, cams, gears and other moving machine elements to achieve certain motions.
- It solves **kinematic** problems.

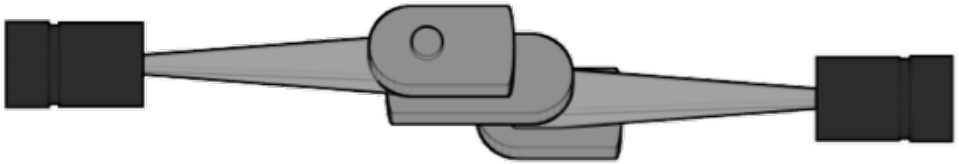
Source:
https://en.wikipedia.org/wiki/Aerial_work_platform#/media/File:TL_2000_scissor_lift.jpg

JOINTS

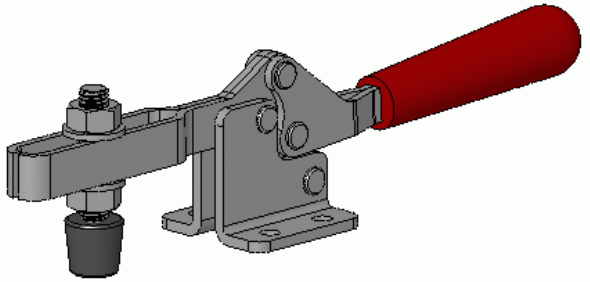
They are connections that allow movement between links.

Primary or Lower Order Pairs: Allow motion in only one line of motion.

* Pin (also called Revolute) – symbol: R
* Slider (also called Prismatic) – symbol: P



Source:
https://en.wikipedia.org/wiki/Flat_engine#/media/File:Boxerengineanimation.gif

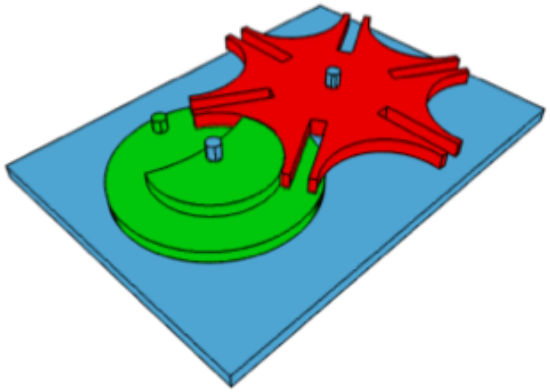


Source:
https://commons.wikimedia.org/wiki/File:Toggle-clamp_manual_horizontal_3D_animated.gif

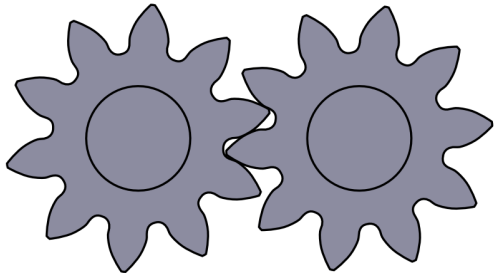
JOINTS

Higher Order Pairs: Allow motion in more than one line of motion: Cams, Gears, Pin-in-slot.

Source:
https://en.wikipedia.org/wiki/Cam#/media/File:Nockenwelle_ani.gif



Source:
https://commons.wikimedia.org/wiki/File:Geneva_mechanism_6spoke_animation.gif

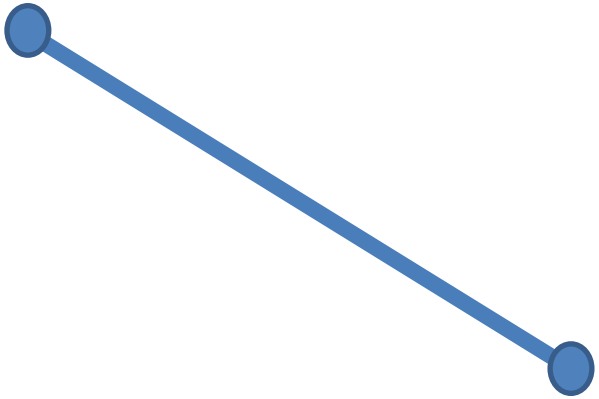


Source:
https://upload.wikimedia.org/wikipedia/commons/2/22/Spur_gears_animation.gif

JOINTS

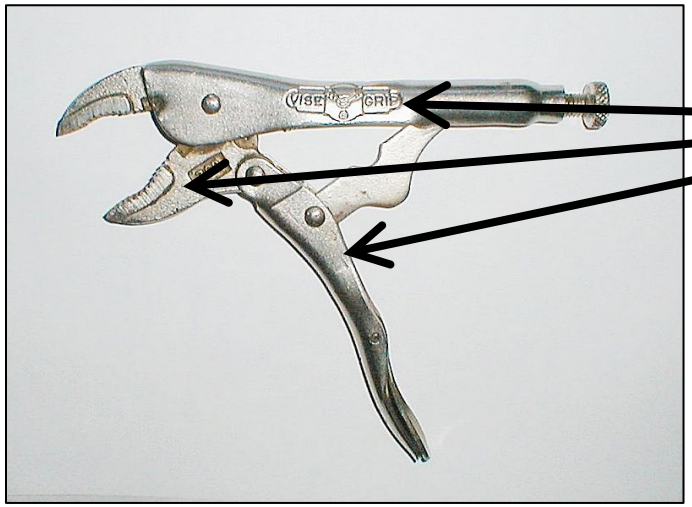
Source:
https://en.wikipedia.org/wiki/Connecting_rod#/media/File:Bielle.jpg

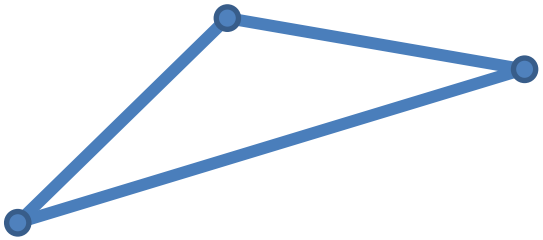
Simple or Binary Links are links with only 2 revolute (R) joints.



Kinematic representation of a binary link.

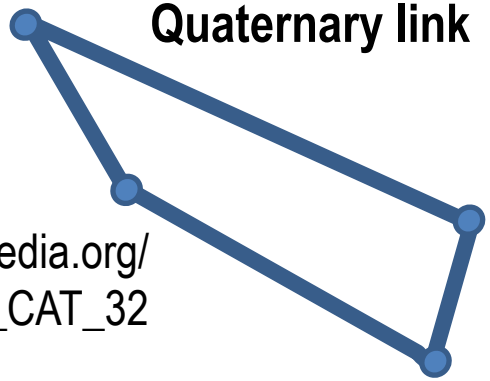
COMPLEX LINKS





Ternary link.

Source:
https://en.wikipedia.org/wiki/Linkage_(mechanical)#/media/File:Locking_pliers.jpg

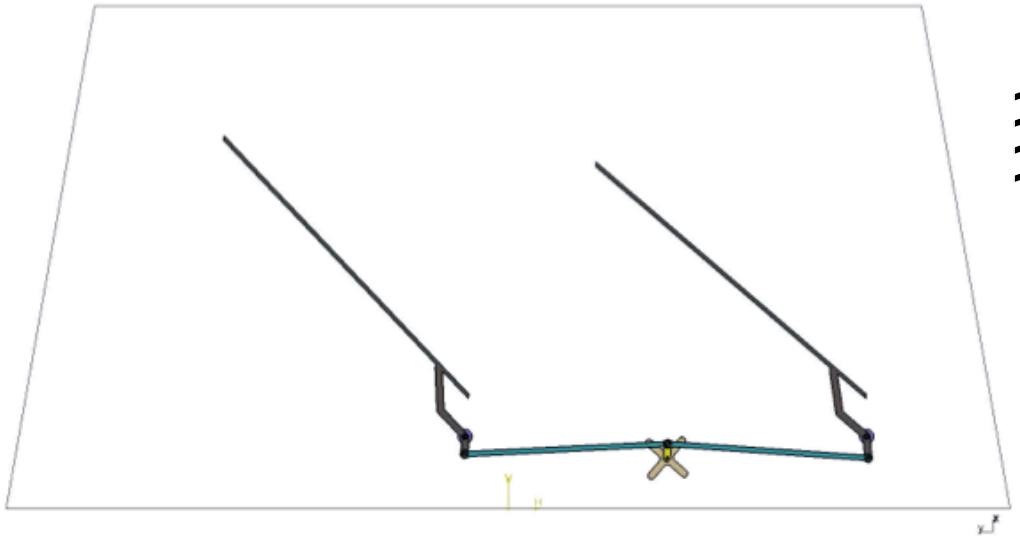


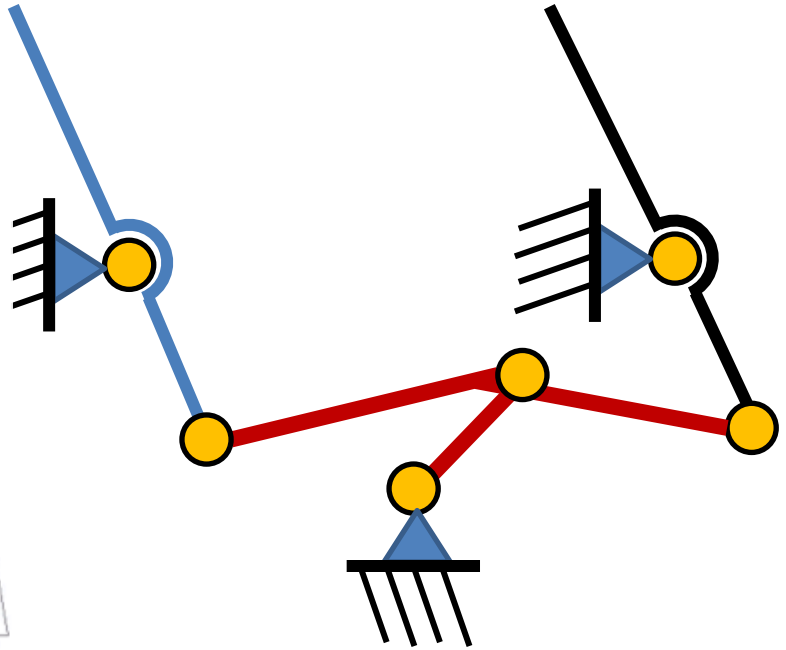
Quaternary link

Source:
https://commons.wikimedia.org/wiki/File:Kettenbagger_CAT_325C_LN.jpeg

KINEMATIC DIAGRAMS

- A **kinematic diagram** is model sketch of a mechanism that only shows crucial dimensions that influence the motion.
- It simplifies the mechanism for further kinematic analysis.



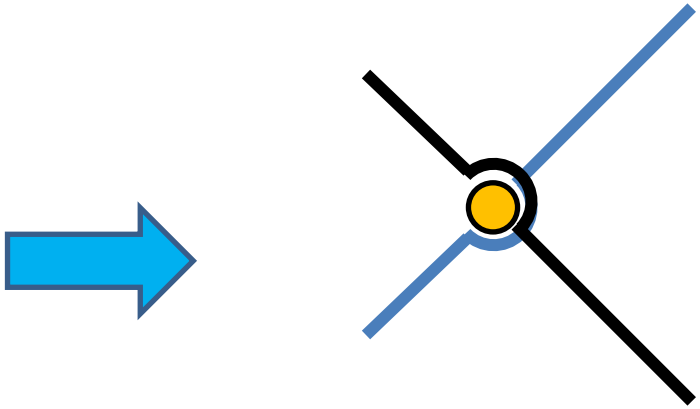


Source:
https://commons.wikimedia.org/wiki/File:Windscreen_Wiper.gif

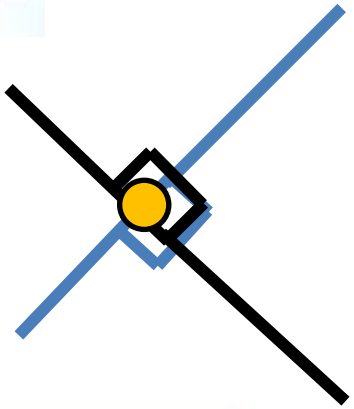
MOBILITY USING KMoGE

- Kutzbach Modification of Gruebler's Equation

Source:
https://commons.wikimedia.org/wiki/File:Skalm_2.JPG



OR



$n = 2; J_1 = 1$

Kinematic Diagrams help.

EXERCISE 1

- Determine the number of links and joints in the pliers shown below.

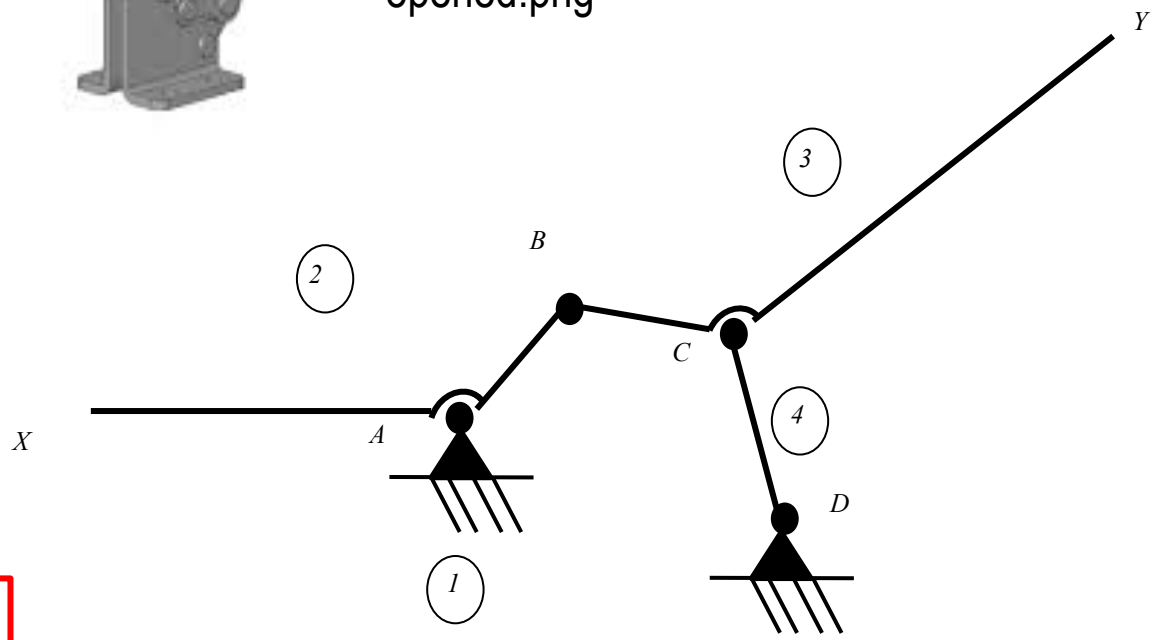
Kinematic Diagram

n = 6; J_1 = 7

Source:
https://en.wikipedia.org/wiki/Linkage_(mechanical)#/media/File:Locking_pliers.jpg

EXERCISE 2

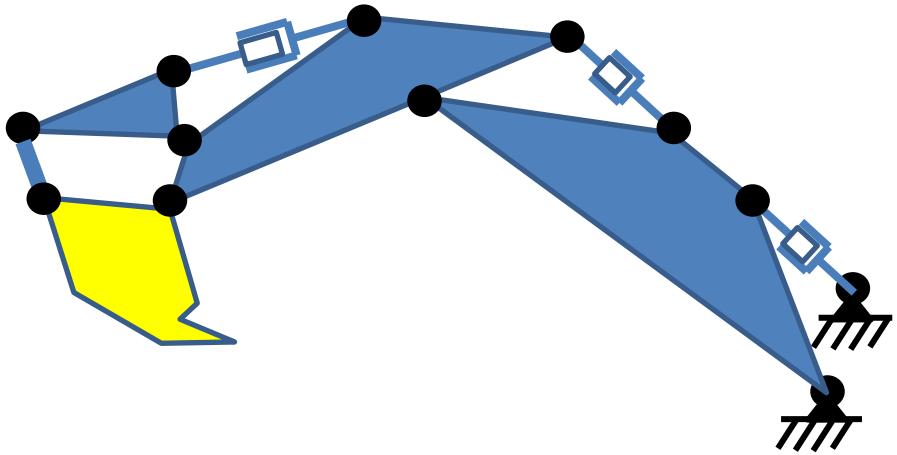
Source:
https://commons.wikimedia.org/wiki/File:Toggle-clamp_manual_horizontal_3D_animated.gif#/media/File:Toggle-clamp_manual_horizontal_3D_closed-opened.png



$n = 4; J_1 = 4$

KINEMATIC DIAGRAM

- Remove superfluous (unnecessary) info not needed in kinematic analysis.
- Parallel cylinders are shown as one since they do the same function.



Source:
https://en.wikipedia.org/wiki/Backhoe#/media/File:JCB_3CX_Backhoe_loader.jpg

OTHER JARGONS

Linkage Mechanisms are groups of rigid body links that are joined together, with one link fixed to the ground or frame.

- The components form a closed chain.
- Dedicated for a certain task. Hard to design.

Compliant Mechanisms use flexible material (non-rigid) and integrated joints. Limited in the displacement achieved and load.

Robots are **multi-actuator** mechanisms with open chain architecture.

MOBILITY EQUATION

Degrees of Freedom or DOF: –

the number of inputs or **actuators** needed to accurately locate all links of a mechanism.

It is also known as the **Kutzbach-Gruebler's equation** or **Kutzbach Modification of Gruebler's Equation (KMoGE)**. Some use *m* for mobility instead of *F* for freedom.

$$F = 3(n-1) - 2J_1 - J_2$$

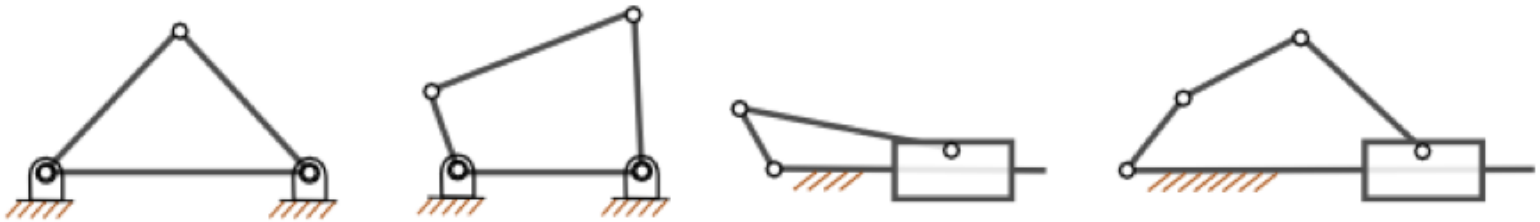
n = number of links.

J_1 = number of primary joints.

J_2 = number of higher order joints.

- $F \leq 0$ means locked mechanisms

SPECIAL CASES IN KMoGE



Truss
n=3, f=3, m=0

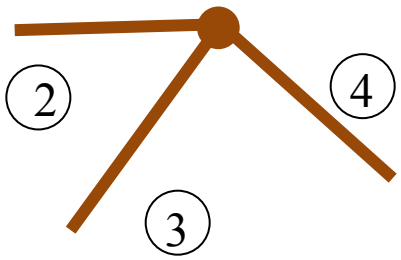
Four-bar linkage
n=4, f=4, m=1

Crank-slider
n=4, f=4, m=1

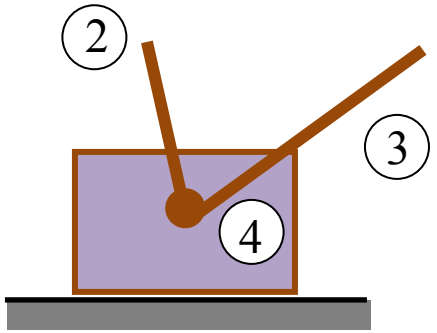
Five-bar linkage
n=5, f=5, m=2

f is J_1 a joint here

Source:
https://en.wikipedia.org/wiki/Linkage_(mechanical)



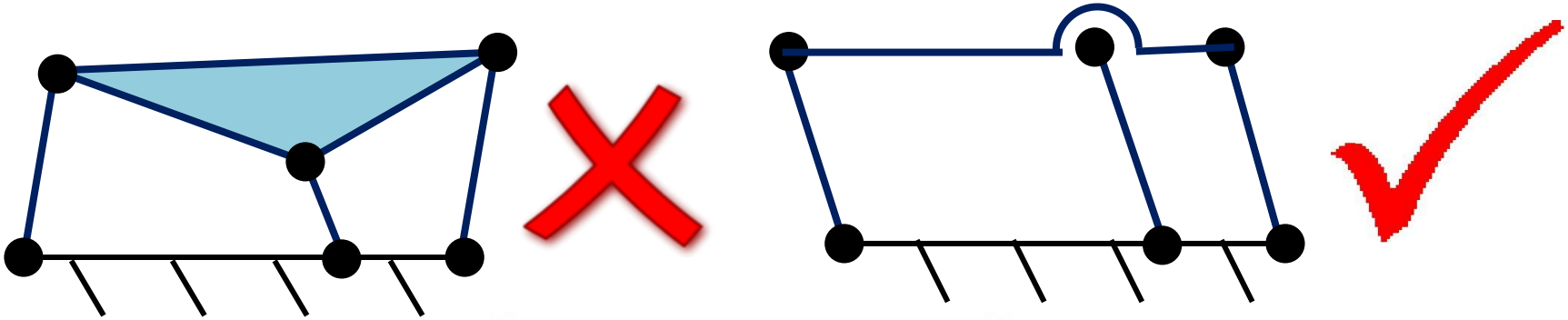
or



Usually, a revolute joint connects two links.

However, when three links are connected together, one joint holds link 2 to 3 and another connects link 2 to 4. Hence, three links are joined.

Lengths and orientations actually matter too.



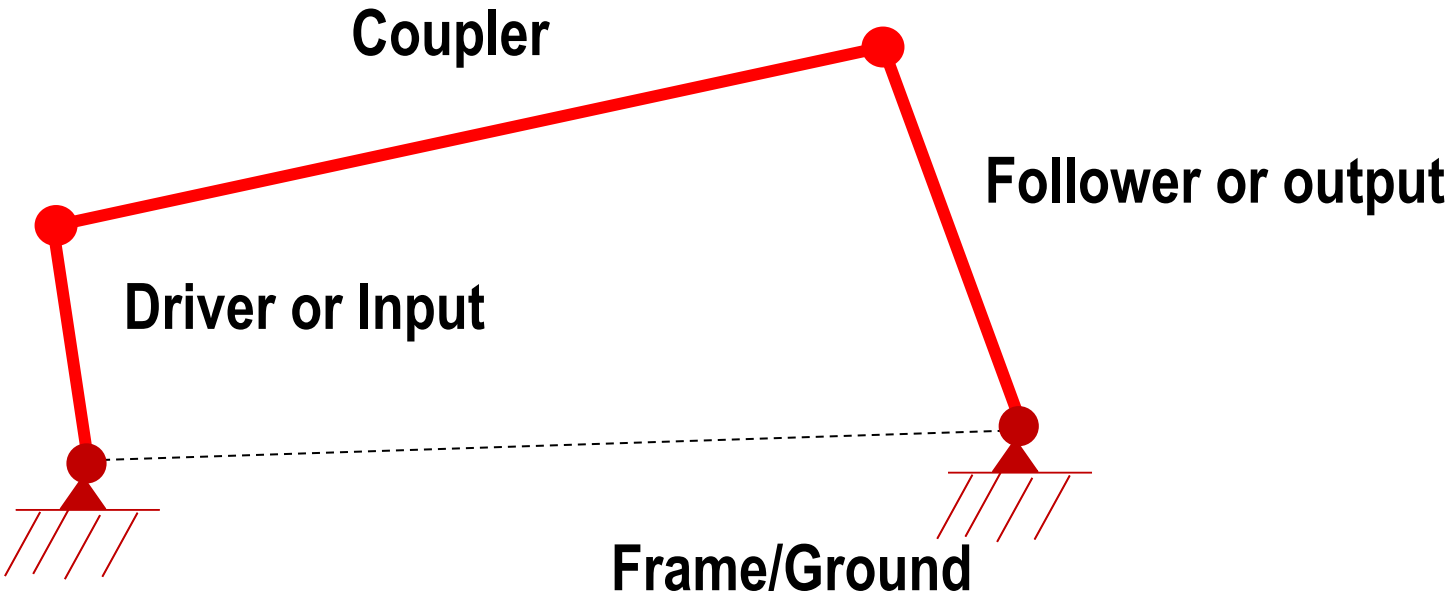
EXERCISE 3

Sketch a kinematic diagram and determine the mobility of the front loader shown below.

Source:
https://en.wikipedia.org/wiki/Loader_(equipment)#/media/File:Deutz-Fahr-40hp%2B1950.jpg

FOUR-BAR MECHANISMS

A linkage with 4 links connected by 4 pins.



GRASHOF'S CRITERION

It is a condition that if fulfilled, at least one link is able to rotate fully like a crank. The criterion is

$$s + l \leq p + q$$

where

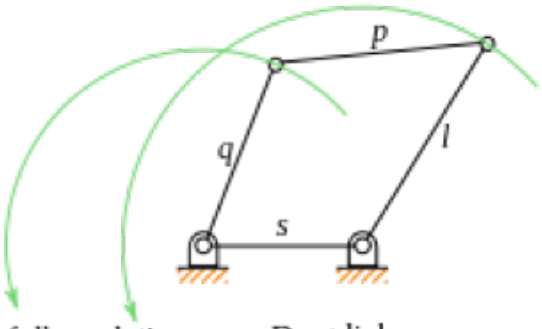
$s =$ length of the shortest link

$l =$ length of the longest link

$p =$ length of one remaining link

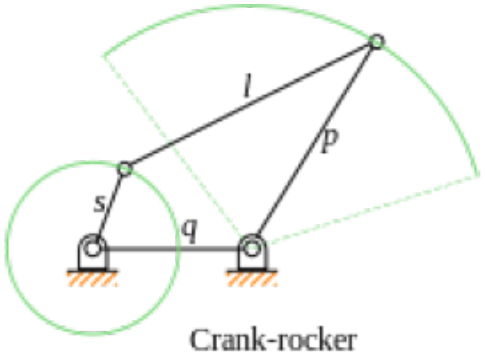
$q =$ length of the other remaining link

COMMON MOTIONS FOR FOUR-BARS

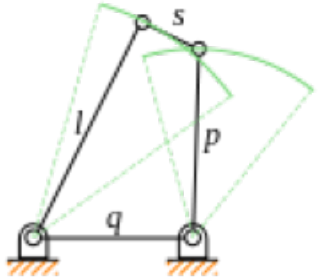


full revolution
both links

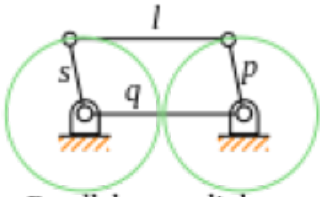
Drag-link
$s+l > p+q$
(continuous motion)



Crank-rocker
$s+l < p+q$
(continuous motion)



Double-rocker
$s+l > p+q$
(no continuous motion)

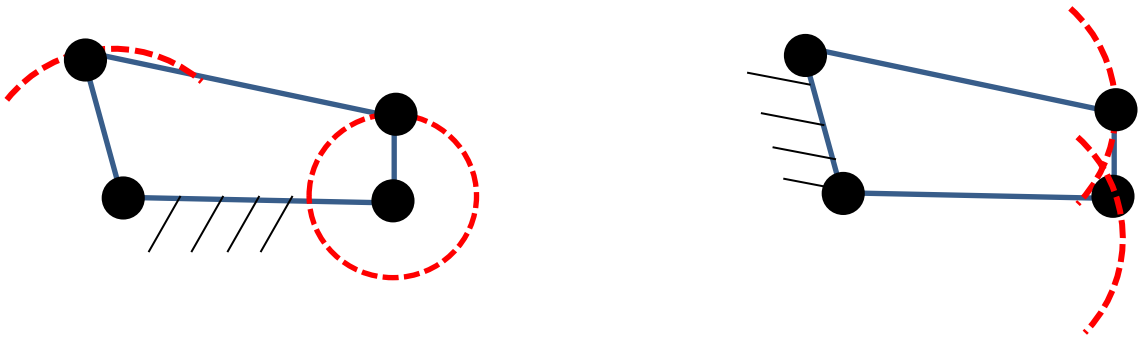


Parallelogram linkage
$s+l = p+q$
(continuous motion)

Source:
https://en.wikipedia.org/wiki/Four-bar_linkage#/media/File:Linkage_four_bar.svg

KINEMATIC INVERSIONS

The same mechanism can achieve a different motion when the fixed link is changed.



(a) (b)

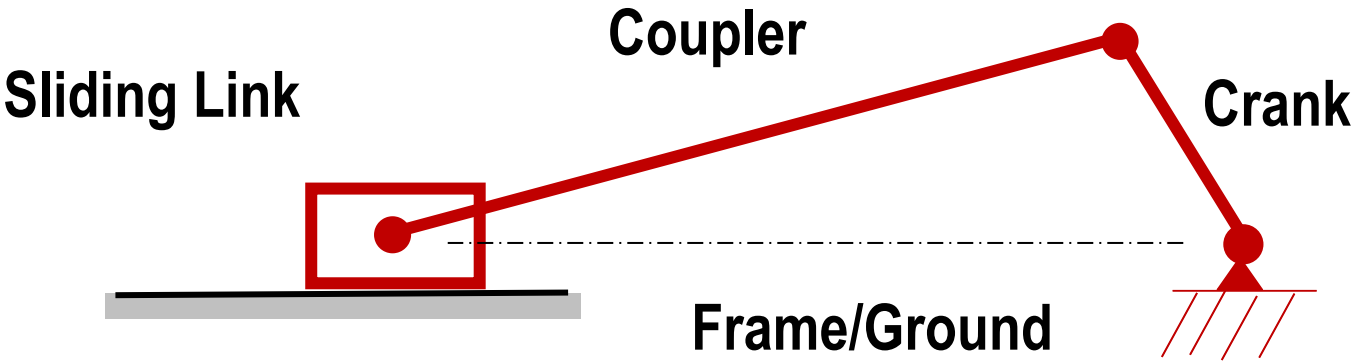
The mechanism in (a) is a rocker-crank whereas in (b) it is a rocker-rocker.

SLIDER-CRANK MECHANISMS

- A linkage mechanism with 4 links and 4 joints.
- Joint types: 3 pins (R) & 1 slider (P)

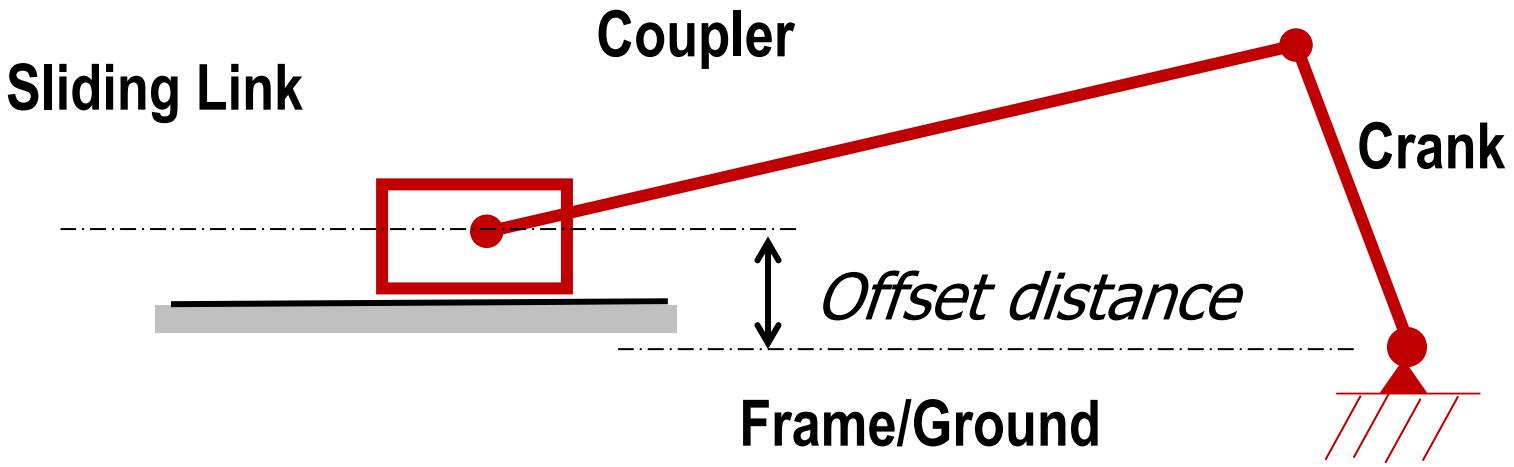
❑ In-Line Slider-Crank

R = revolute,
P = prismatic



SLIDER-CRANK MECHANISMS

❑ **Offset Slider-Crank**



Thank You

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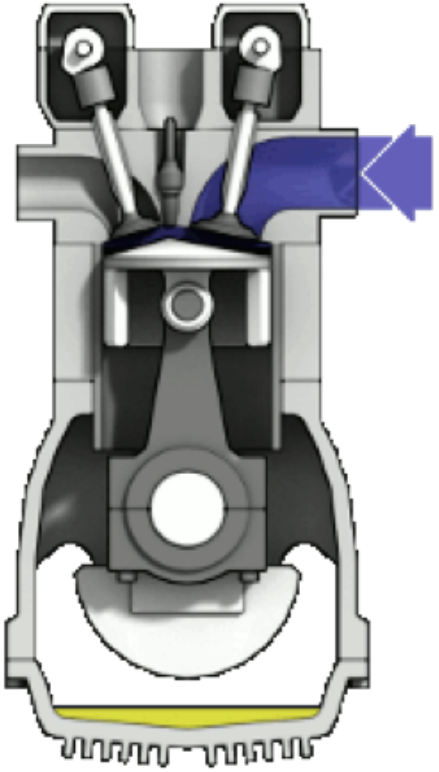

Main Reference:

Myszka, David H., 2012. Machines and mechanism: applied kinematic analysis, 4th ed., Prentice Hall, New York.

Source:
https://en.wikipedia.org/wiki/Four-stroke_engine