Introduction to Kinematics of Machines

Second Semester

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Introduction to Machine

Machine : -

A machine (or mechanical device) is a mechanical structure that uses power to apply forces and control movement to perform an intended action.

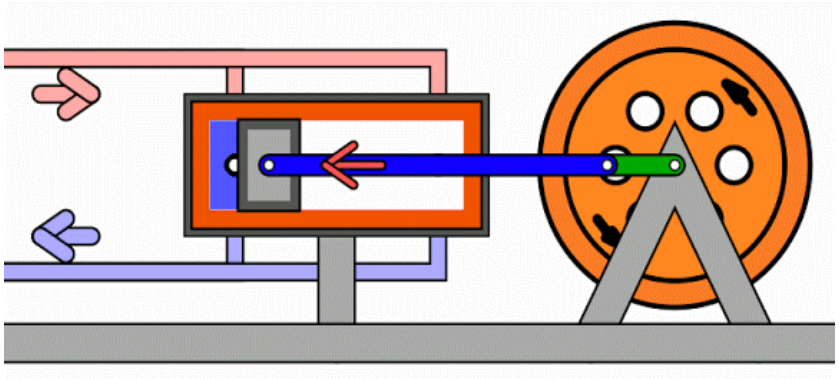


Fig 1.0 Rotary Machine

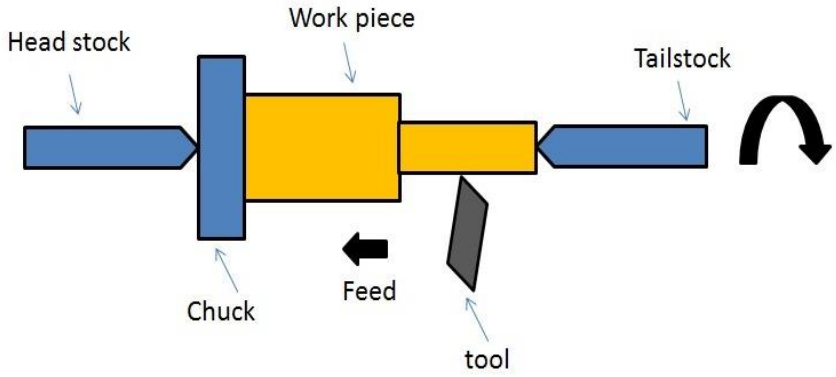


Fig 2.0 Lathe Machine

Source : https://www.mechanicalbooster.com/

Difference between Machine and Structure

- The parts of a machine move relative to one another, whereas the members of a structure do not move relative to each other.

- The machine transforms the available energy into useful work, whereas in a structure no energy is transformed into useful work.

- The links of a machine may transmit both motion and power, while the members of a structure transmits forces only.

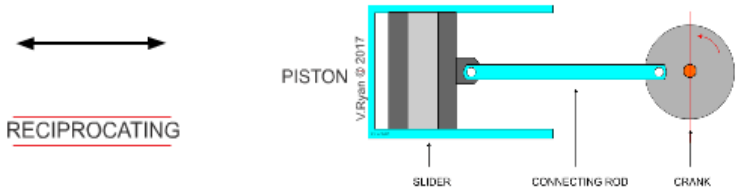
- Machine : - Lathe, shaper, prime mover
- Structure : - Bridge, Buildings

Classification of Motion

- Continuous Rotary Motion

- Linear Motion / Rectilinear Motion

- Reciprocating Motion



- Oscillating Motion

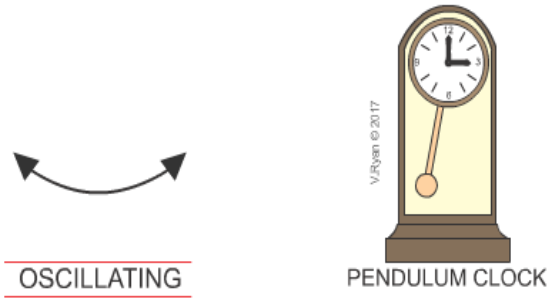


Fig 3.0 Type of motions

Source: https://technologystudent.com/forcmom/motion1.html

Important Terminologies

- Link or Element
- Kinematic pair
- Kinematic chain
- Mechanism, Machine & Structure
- Degrees of Freedom (D.O.F)
- Gruber’s criterion
- Inversion

Kinematic Link

Kinematic Link / Element : -

I. Each part of a machine, which moves relative to some other part, is known as a kinematic link or element.

. II. A link may consist of several parts, which are rigidly fastened together, so that they do not move relative to one another.

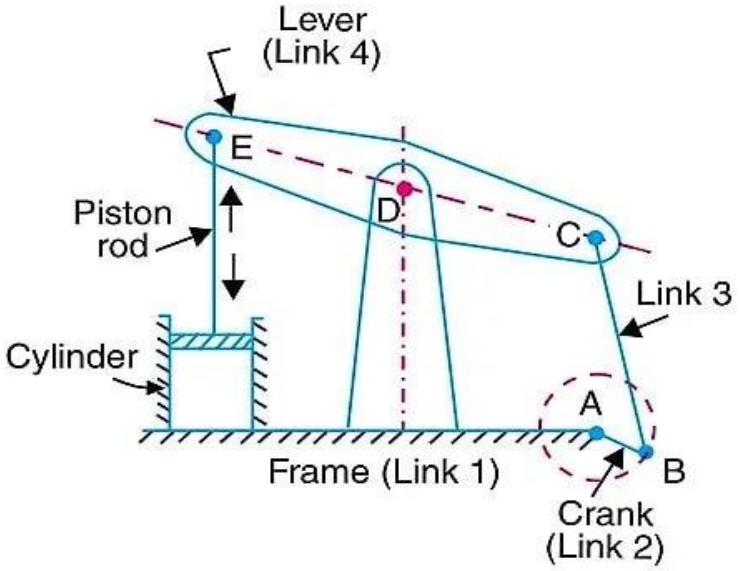


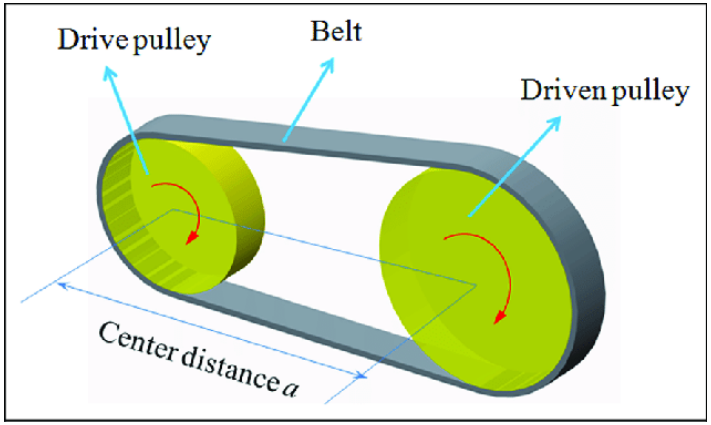
Fig 4.0 Kinematic links in a mechanism

Source: https://technologystudent.com/forcmom/motion1.html

Types Link

I. Rigid Link : A link which doesn't go any deformation while transmitting motion.

II. Flexible Link : A link which is partly deformed in a manner not to affect the transmission of motion.
e.g. : Belts, rope, chain drive



III. Fluid Link : A link which is formed by having a fluid in a receptacle and the motion is transmitted through the fluid by pressure or compression

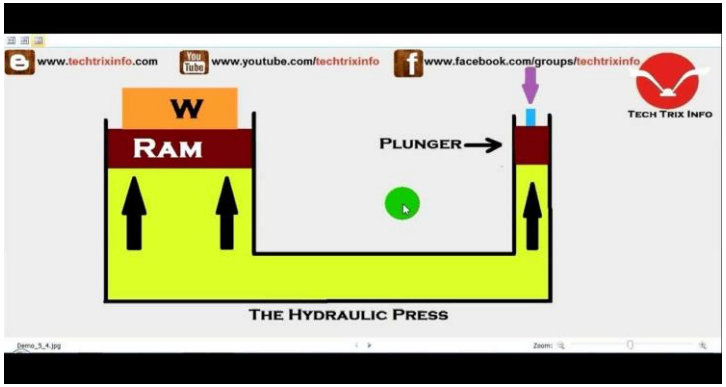


Fig 5.0 Different type of links
Source:

Classification of Links

I. Unary Link : A link consisting of one node.

II. Binary Link : A link connected to other links at two points.

III. Ternary Link : A link connected to other links at three points.

IV. Quaternary Link : A link connected to other links at four points.

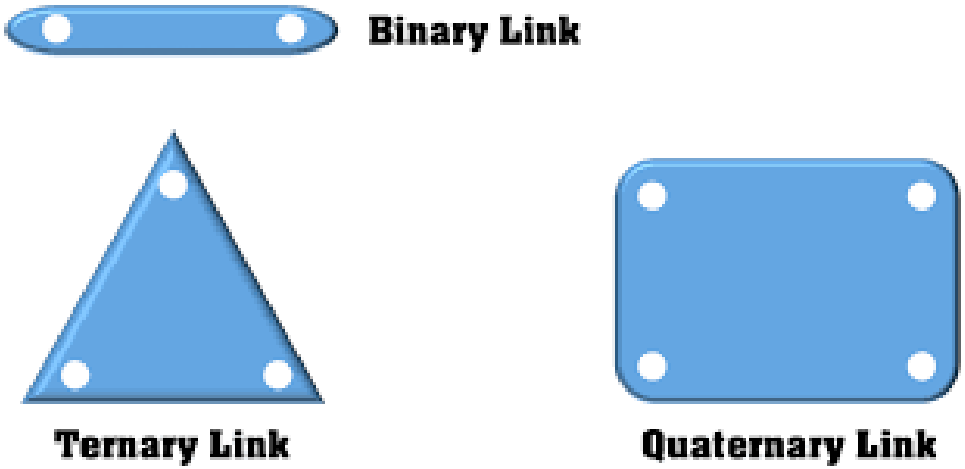
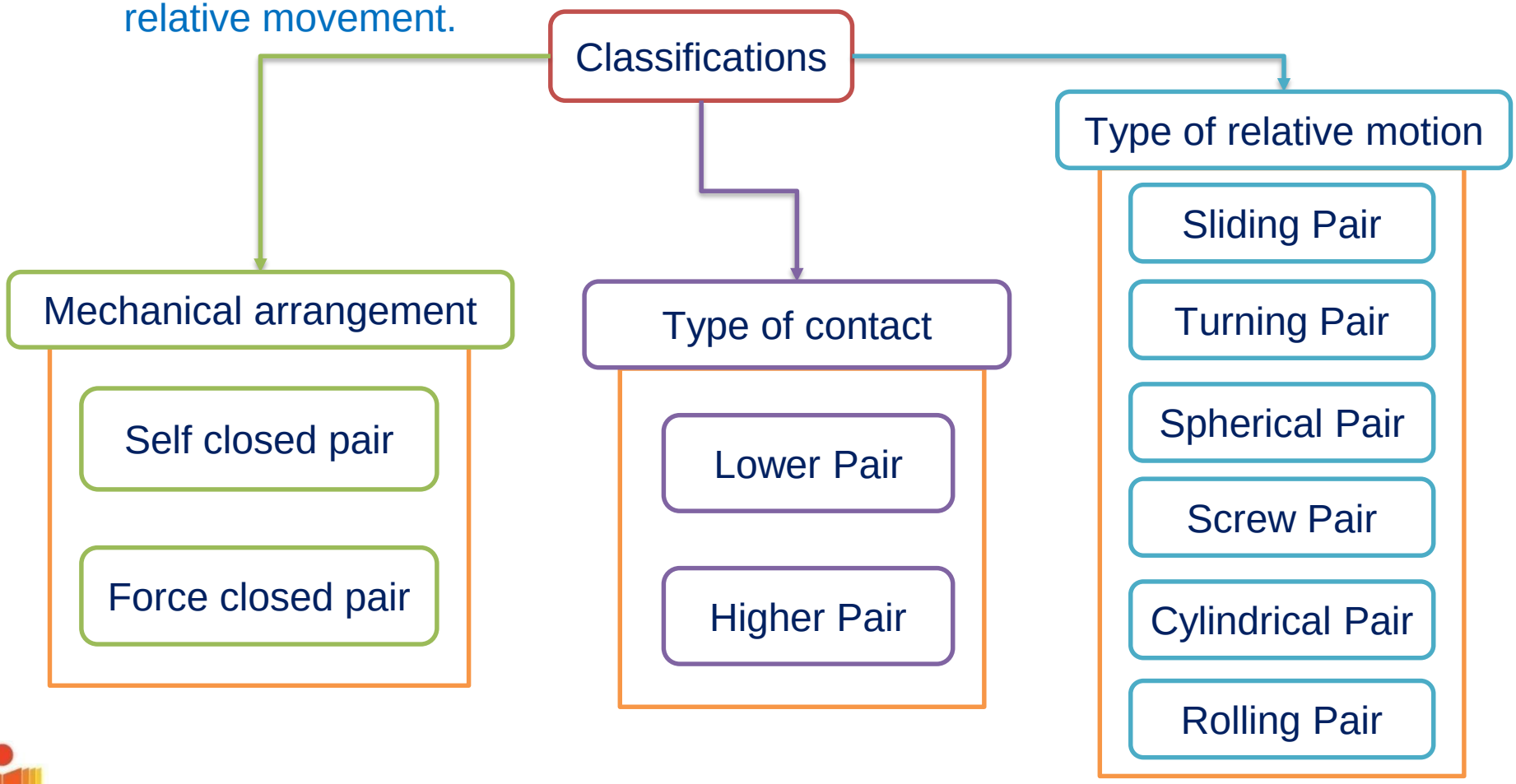


Fig 6.0 Different types of link

Kinematic Pair

- Two links or elements of a machine connected to each other are said to form a pair, if the connection between them imposes constrains on their relative movement.



Type of Constrained Motions

I. Completely constrained motion :

When the motion between a pair is limited to a definite direction irrespective of the directions of force applied, then the motion is called completely constrained motion

- Example :

i) Motion of square bar in a square hole.

ii) Motion of a shaft with collars at each end of the hole.

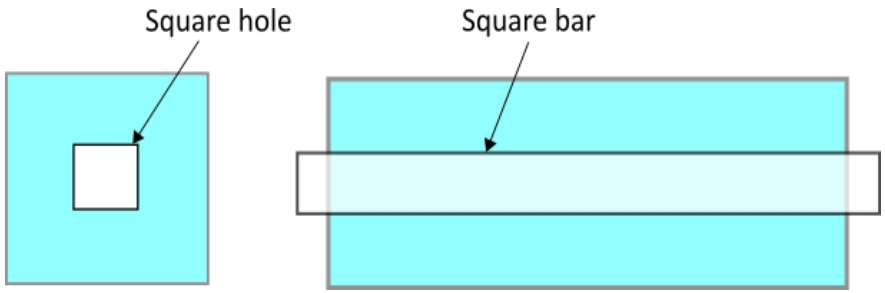


Fig 7.0 Square bar

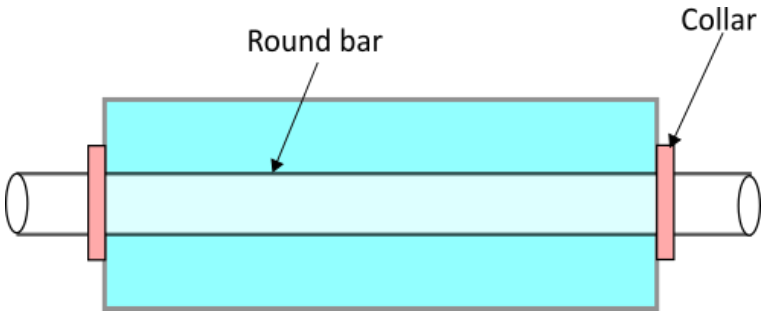


Fig 8.0 Circular bar

II. Incompletely constrained motion :

When the motion between a pair can take place in more than one direction, then it is termed as incompletely constrained motion

- Example :

i) Motion of circular bar or shaft in a circular hole. It can freely rotate or translate.

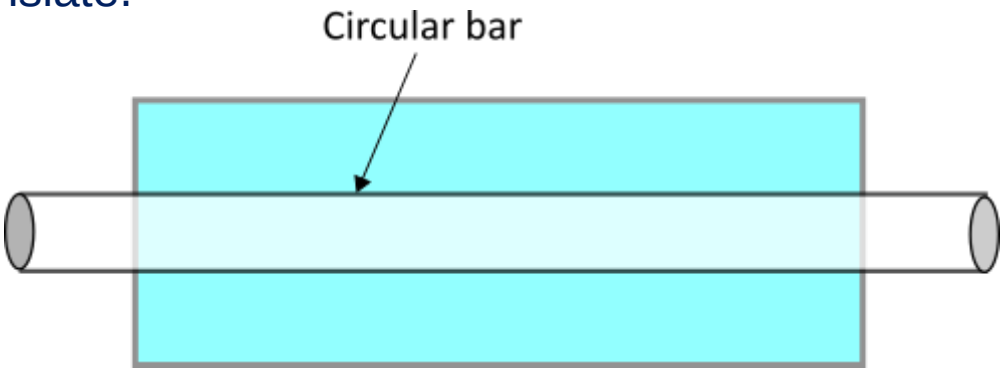


Fig 9.0 Circular bar in circular hole

III. Successfully constrained motion :

When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself but by some other means.

- Example :
  - i) Shaft in foot-step bearing
  - ii) Piston inside the cylinder

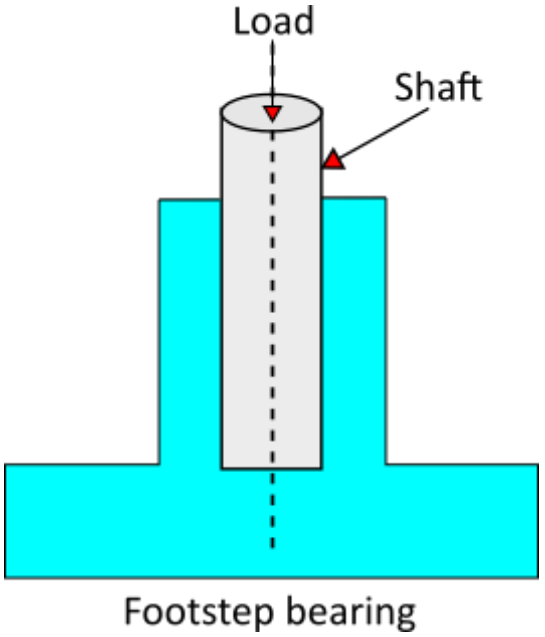


Fig 10.0 Footstep Bearing

Classification of Kinematic pair - I

1. Sliding pair :

   When two elements of pair are connected in such a way that one can only slide relatively to other, having completely constrained motion.

- Example : (D.O.F = 1)

  Piston cylinder arrangement, ram and its guide in shaper

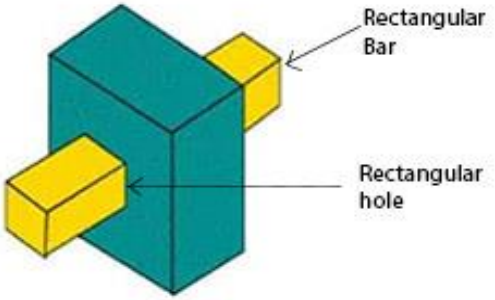


Fig 11.0 Sliding pair

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2. Turning pair / Revolute pair :

When two elements of pair are connected in such a way that one can only turn or revolve about a fixed axis of another link.

- Example : (D.O.F = 1)

Lathe spindle supported in head stock.

Cycle wheels turning over their axles.

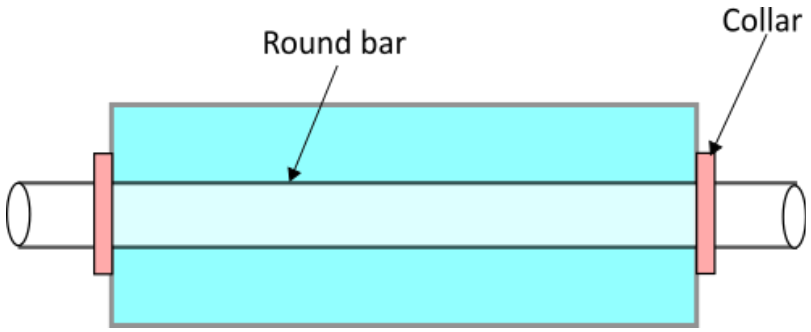

Fig 12.0 Turning pair

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3. Spherical pair:

When two elements of pair are connected in such a way that one element turns or swivels about the other fixed element.

- Example : (D.O.F = 3)

Ball and socket joint.

Car mirror attachment.

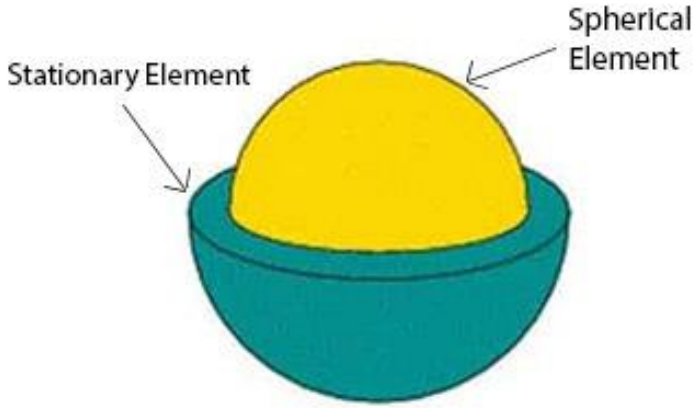

Fig 13.0 Spherical pair

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4. Screw pair:

When two elements of pair are connected in such a way that one element can turn about the other by screw threads.

- Example : (D.O.F = 1)

Lead screw of a lathe with nut.

Bolt with nut.

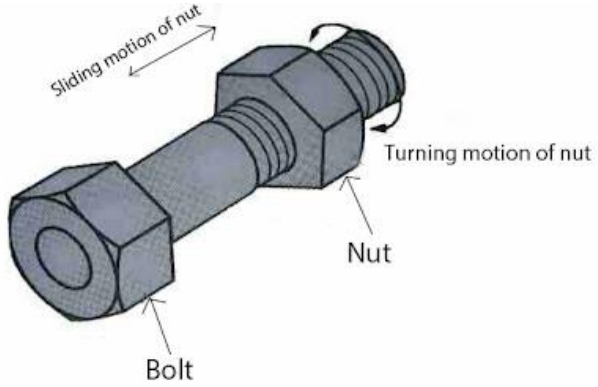


Fig 14.0 Screw pair

Cont…

5. Cylindrical pair:

If the relative motion between the pairing elements is the combination of turning and sliding , then it is called as cylindrical pair.

- Example : (D.O.F = 2)

Lead screw of a lathe with nut.

Bolt with nut.

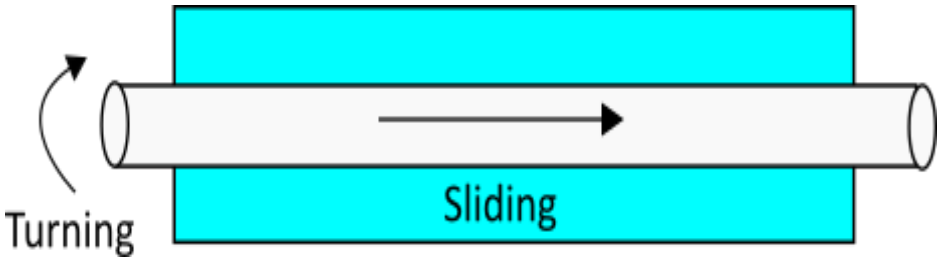


Fig 15.0 Cylindrical pair

Cont…

6. Rolling pair:

When two elements of a pair are connected in such a way that one rolls over another fixed link.

- Example : (D.O.F = 1)

  Ball and roller bearing.

  Railway wheel rolling over a fixed rail.

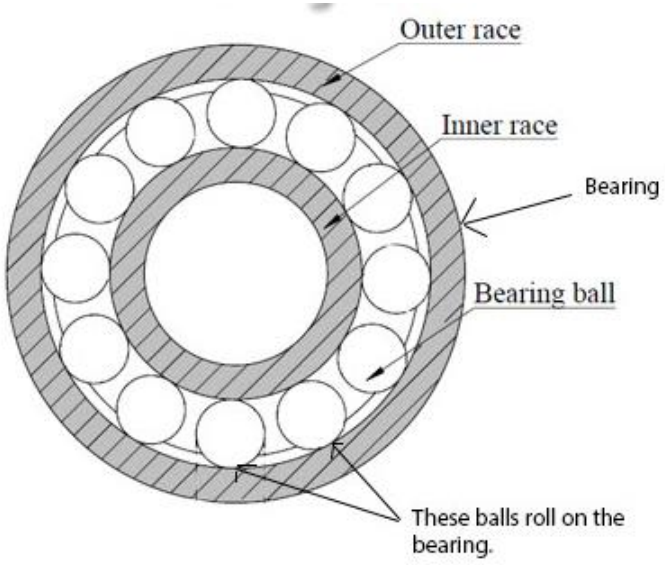


Fig 16.0 Rolling pair

Classification of Kinematic pair - II

1. Lower pair :

   When two elements of pair have a surface contact, and the surface of one element slides or rolls over the surface of the other.

- Example :

  Sliding pairs, turning pair, & screw pair

2. Higher pair :

   When two elements of a pair have a line or point contact, and the motion between the two elements is partly turning and sliding.

- Example:

  Toothed gear, ball and roller bearing, cam and follower mechanism

Classification of Kinematic pair - III

1. Self closed pair :

   When two elements of pair are connected together mechanically in such a way that only required relative motion occurs.

- Example :

  All Lower pairs

2. Force closed pair :

   When two elements of a pair are kept in contact by the action of external forces, the pair is called force closed pair.

- Example:

  cam and follower mechanism

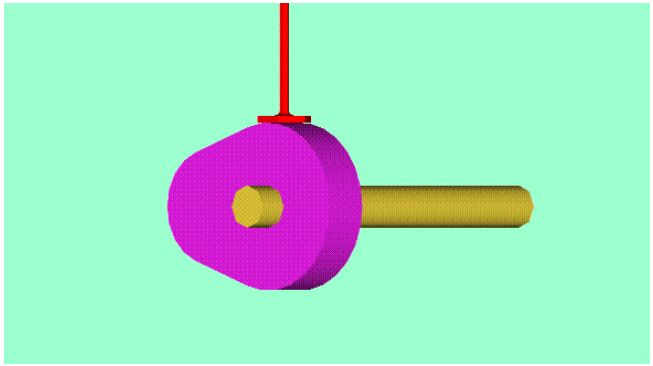


Fig 17.0 Cam and follower mechanism
source : https://www.pinterest.com

Kinematic Chain

- Kinematic chain is an assembly of rigid bodies connected by joints to provide constrained or desired motion for a mechanical system.

Or

- When the kinematic pairs are coupled in such a way that the last link is connected to the first link to transmit definite motion (completely or successfully constrained), it is called a kinematic chain.

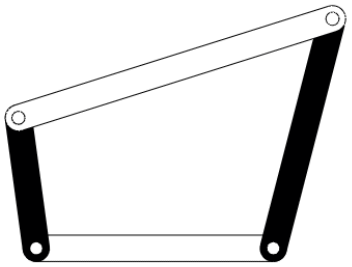
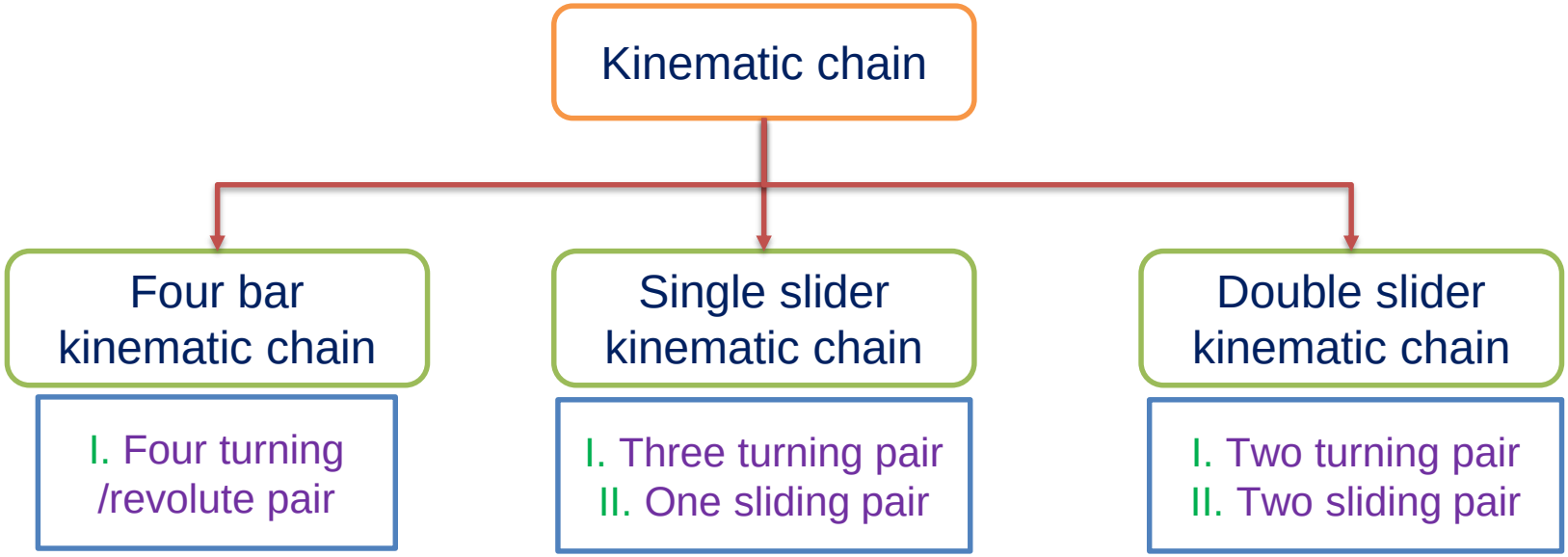
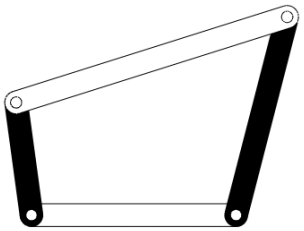
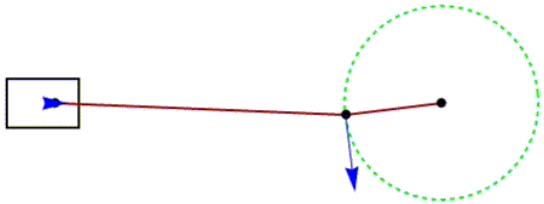


Fig 18.0 Kinematic chain
Source : https://extrudesign.com/kinematic-chain-types/

Types of Kinematic Chain







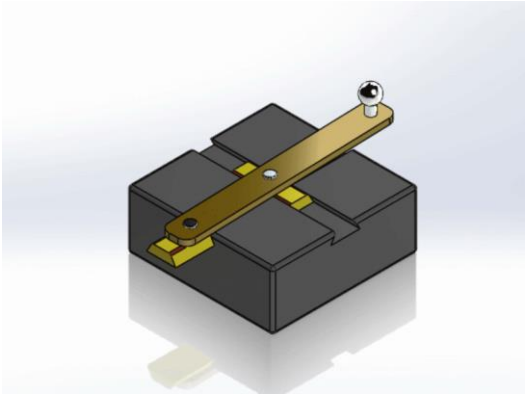


Fig 19.0 Different kinematic chain
Source : https://extrudesign.com/kinematic-chain

Mechanism

- When one of the links of a kinematic chain is fixed, the chain is termed as mechanisms.
- It is used for transmitting or transforming motion.

  Example : Printing machine, robot arms

- A mechanism may be regarded as a machine in which each part is reduced to the simplest form to transmit the required motion.

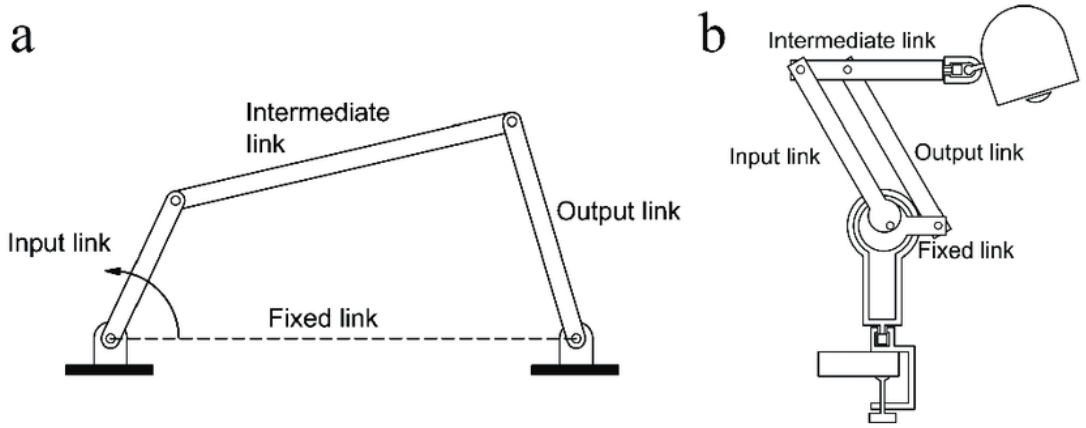


Fig 20.0 Different mechanisms

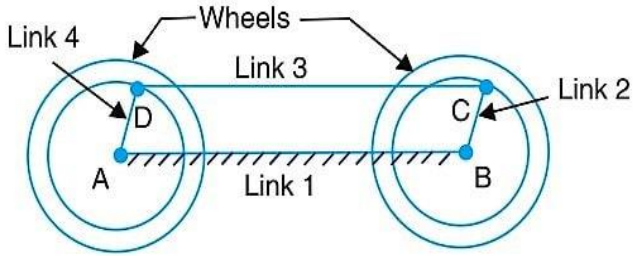
Source : https://www.researchgate.net/figure/Four-bar-Mechanism

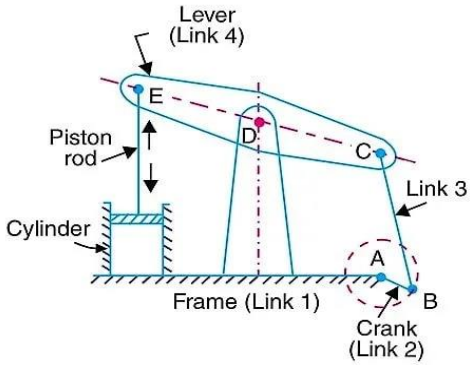
Inversion of Mechanism - 1

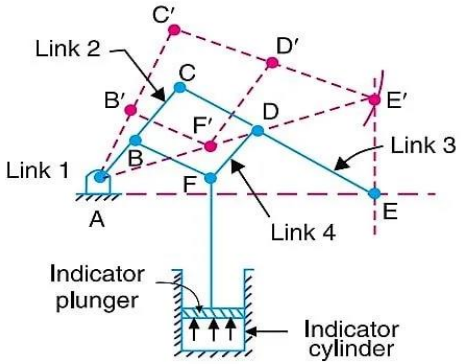
- Different mechanisms can be obtained by fixing different links of the same kinematic chain.

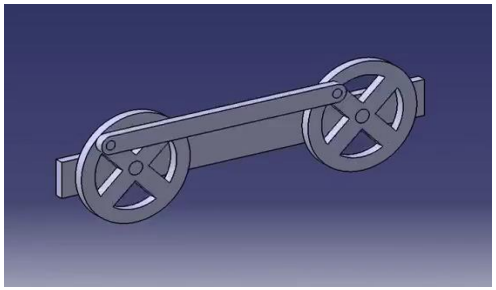
Inversion of Four bar chain

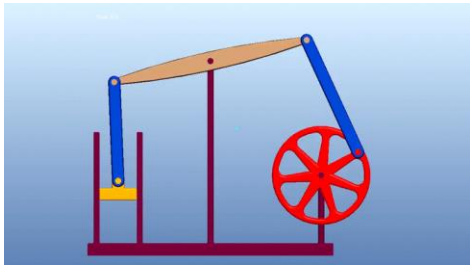
Double crank mechanism	Coupling rod of a locomotive	Crank and lever mechanism	Beam engine	Double lever mechanism	Watt's indicator











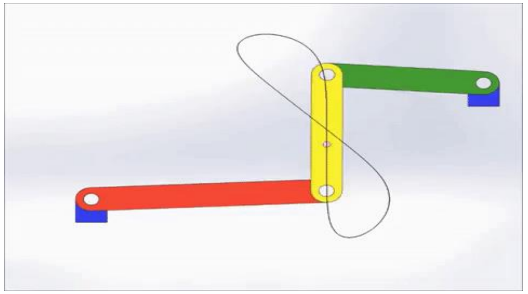
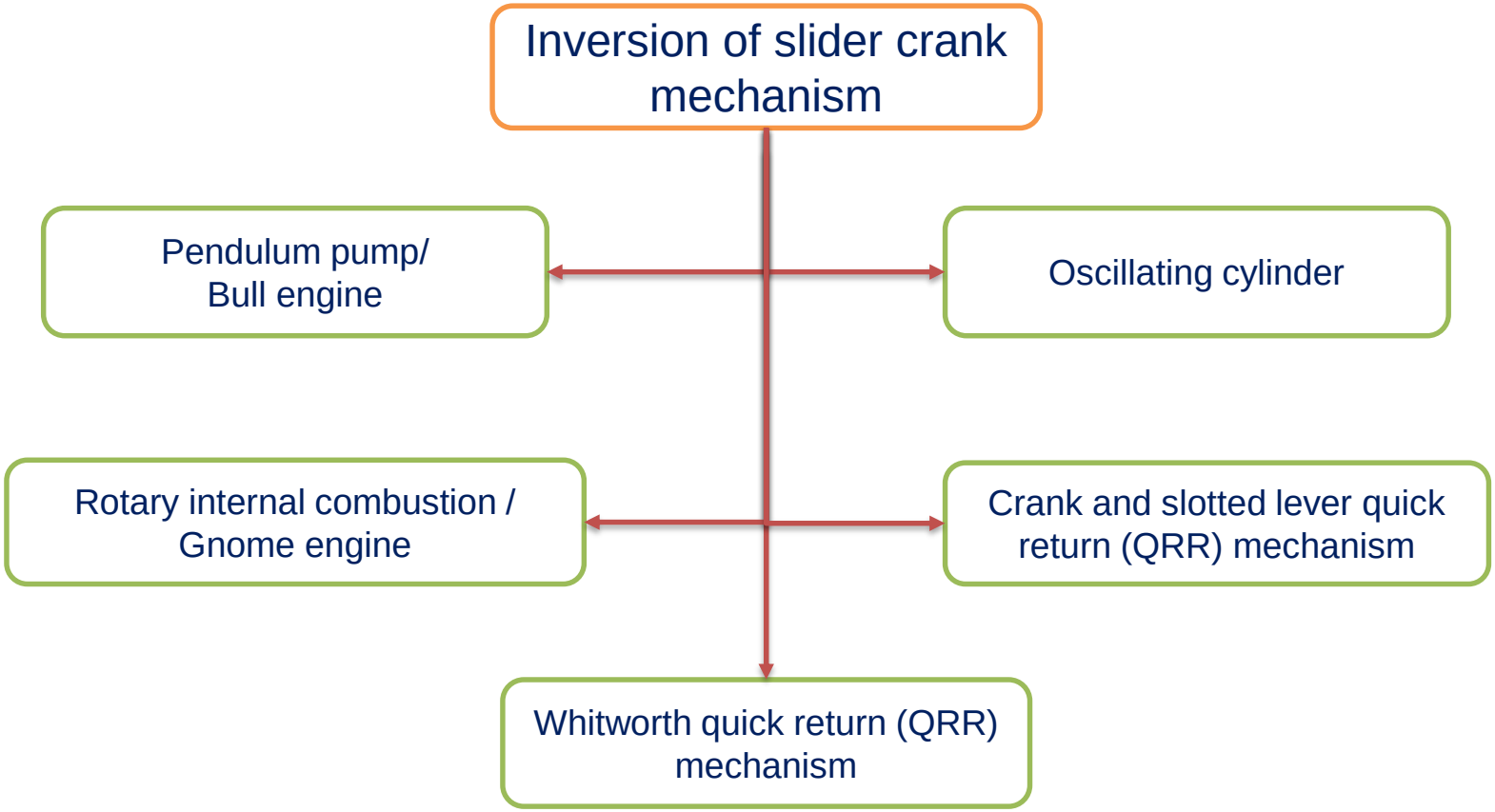


Fig 21.0 Inversion mechanisms
Source : https://extrudesign.com/four-bar-mechanism-inversions/

Inversion of Mechanism - 2

- Different mechanisms can be obtained by fixing different links of the same kinematic chain.



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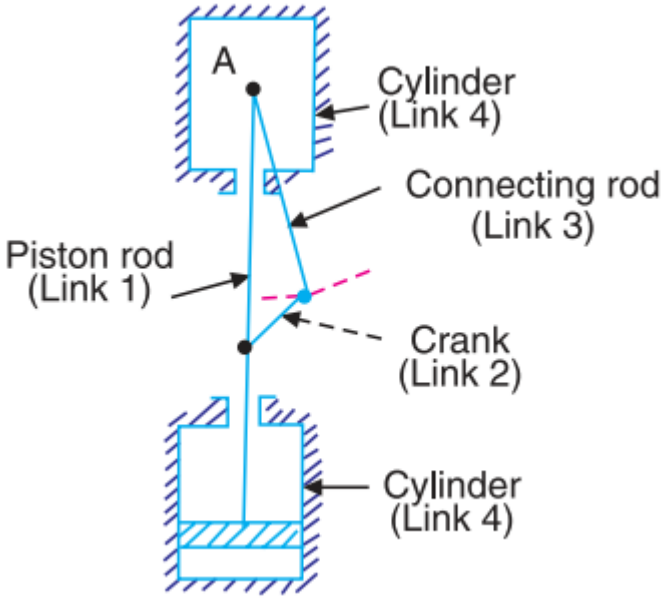
1. Pendulum pump / Bull engine :



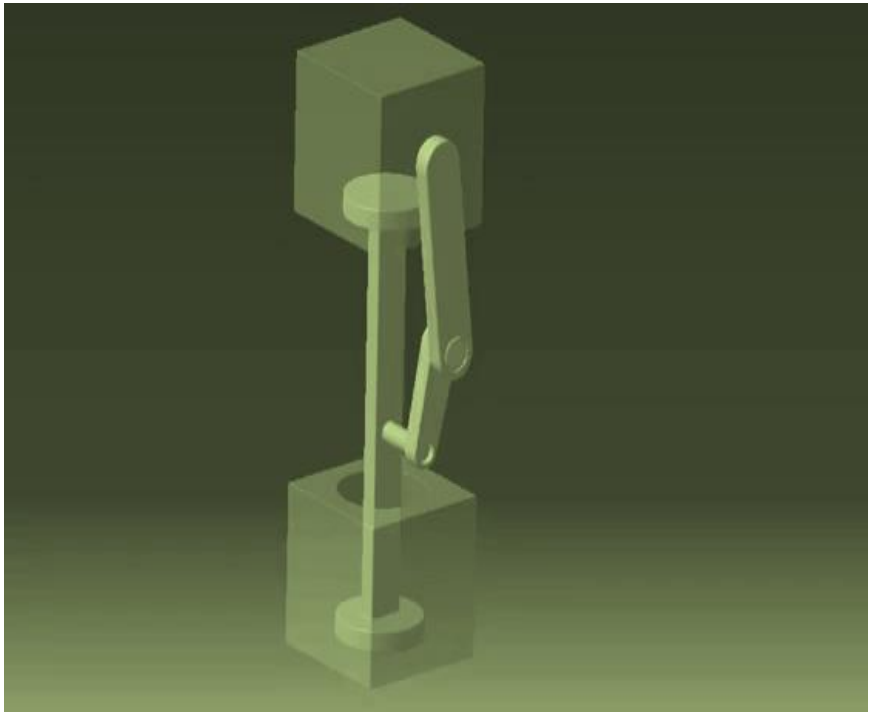


Fig 22.0 Pendulum pump
Source : https://extrudesign.com/four-bar-mechanism-inversions/

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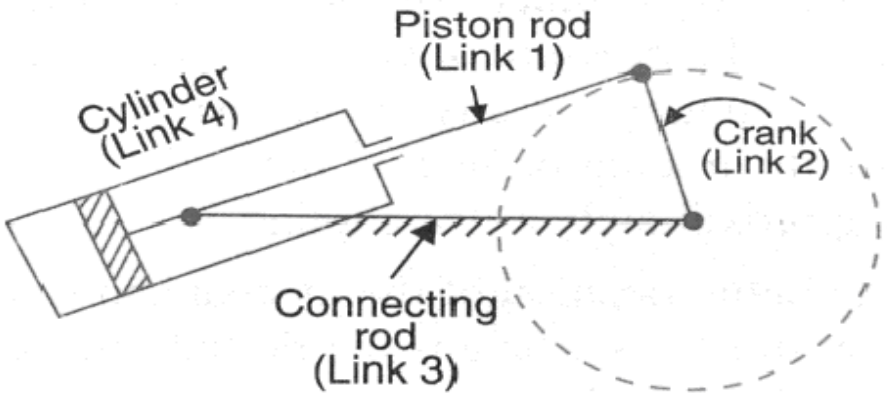
2. Oscillating cylinder :



Application : Steam engine

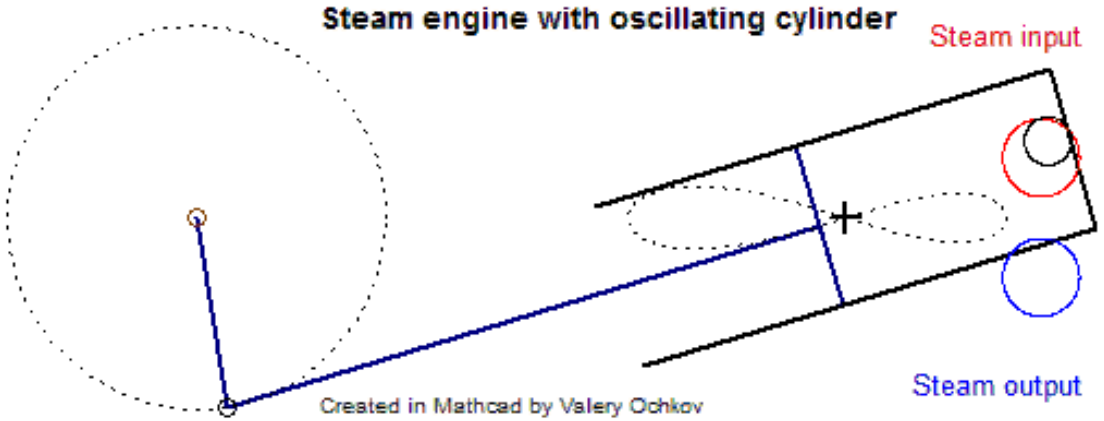


Fig 23.0 Oscillating cylinder
Source : https://extrudesign.com/four-bar-mechanism-inversions/

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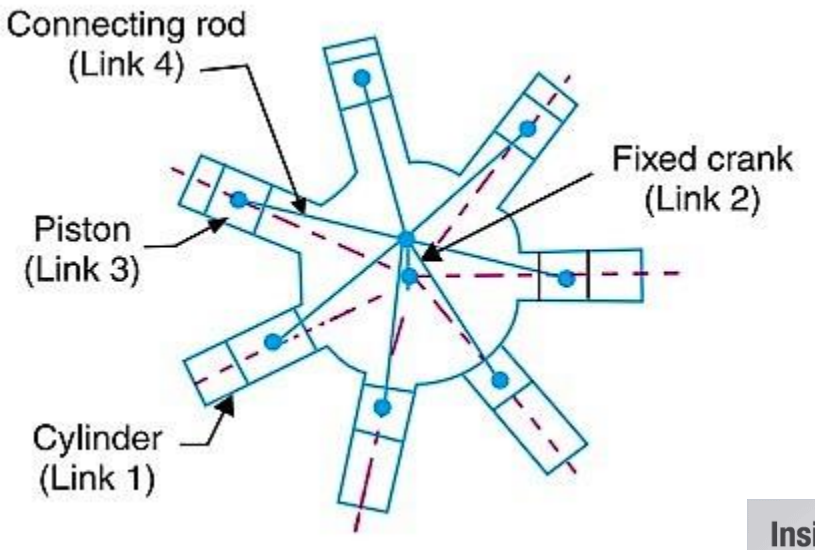
3. Gnome engine :



Application : Radial engine

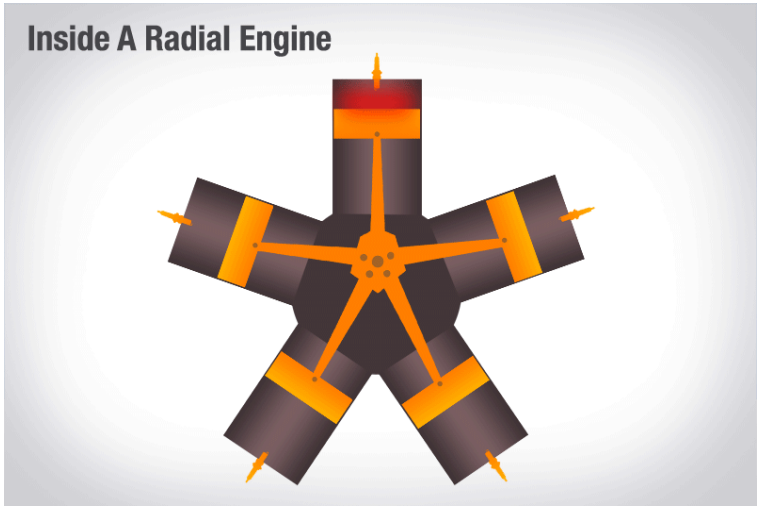


Fig 24.0 Gnome engine
Source : https://extrudesign.com/four-bar-mechanism-inversions/

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4. Crank and slotted QRR:

Application : Shaper machine,

Cutting machines

5. Whitworth QRR:

Application : High velocity impact

press, slotting machines

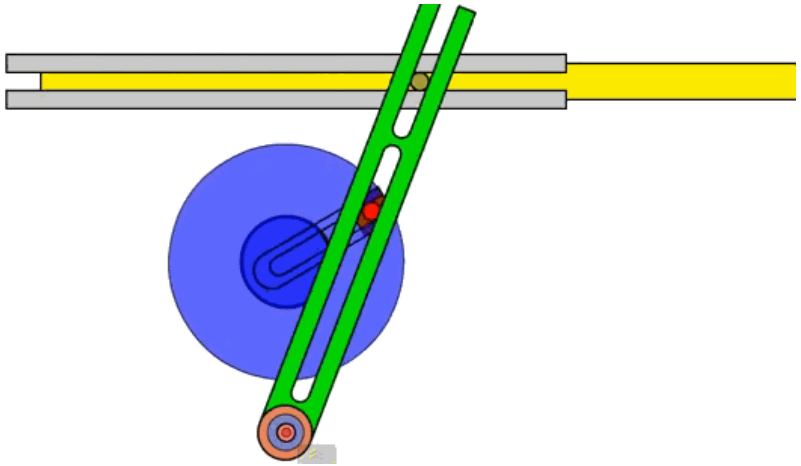

Fig 25.0 QRR mechanism
Source : https://skill-lync.com/