Mechanisms & machines

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Kinematics

- It relates to study of relative motion between the part of machine.
- It is study of Position, displacement, rotation speed, velocity & acceleration.

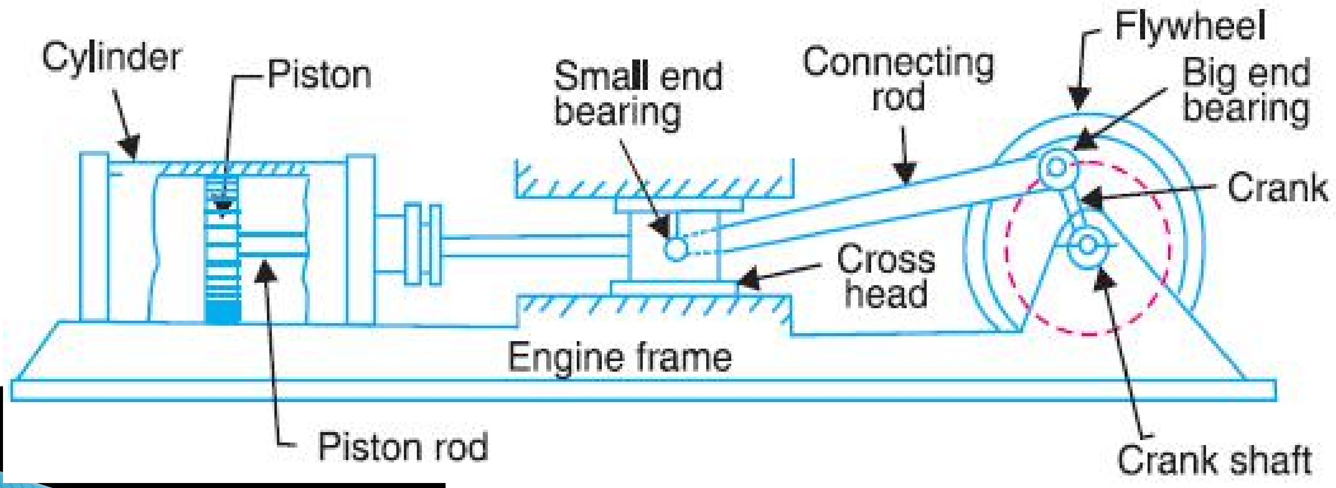
Machine

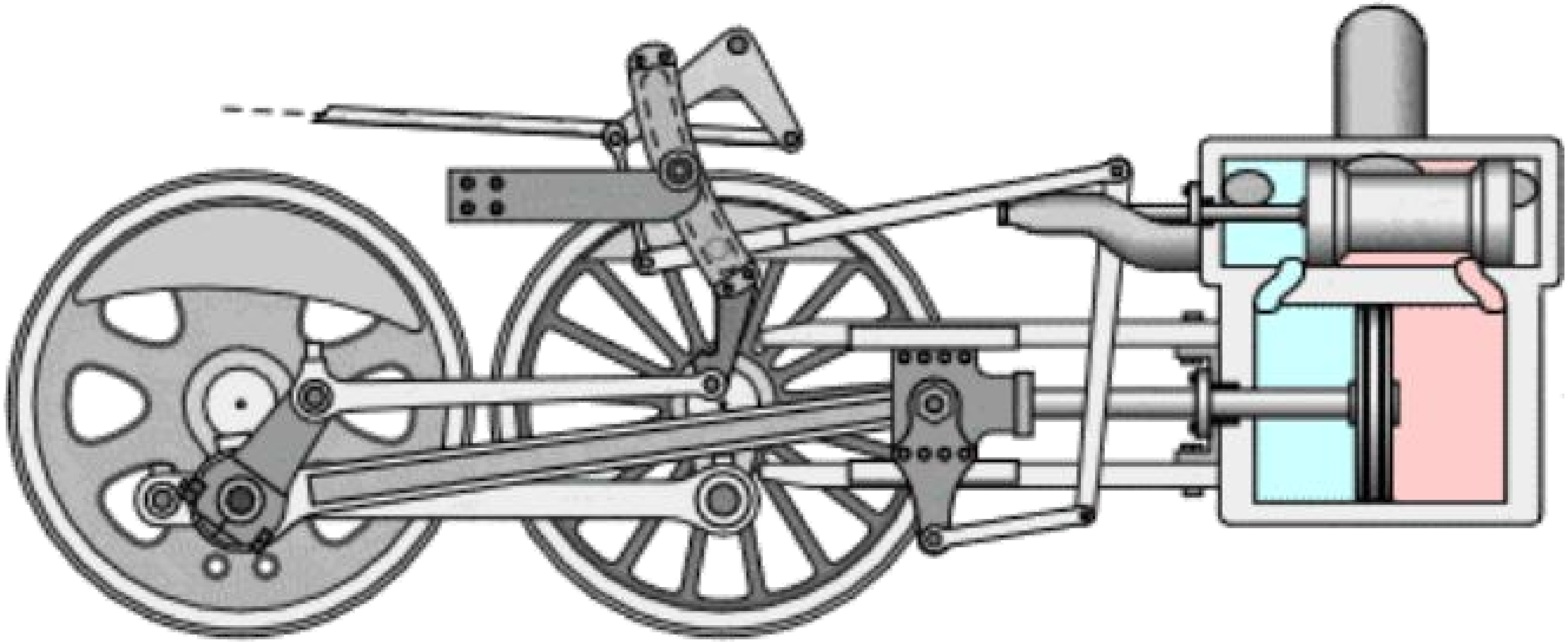
- Machine is a device which receives energy and transforms it into some useful work.
- A machine consists of a number of parts or bodies.
- This is done by making one of the parts as fixed, and the relative motion of other parts is determined with respect to the fixed part.

Kinematic Link or Element

- Each part of a machine, which moves relative to some other part, is known as a kinematic link (or simply link) or element.
- A link may consist of several parts, which are rigidly fastened together, so that they do not move relative to one another.
- For example, in a reciprocating steam engine, as shown in Fig.,

- Piston, piston rod and crosshead constitute one link ;
- Connecting rod with big and small end bearings constitute a second link ;
- Crank, crank shaft and flywheel a third link
- Cylinder, engine frame and main bearings a fourth link.





- A link or element need not to be a rigid body, but it must be a *resistant body.*
- *A* body is said to be a resistant body if it is capable of transmitting the required forces with negligible deformation.
- Thus a link should have the following two characteristics:

1. It should have relative motion, and
2. It must be a resistant body.

Types of Links

- In order to transmit motion, the driver and the follower may be connected by the following three types of links

1. *Rigid link.*

- A rigid link is one which does not undergo any deformation while transmitting motion.
- Rigid links do not exist. However, as the deformation of a connecting rod, crank etc. of a reciprocating steam engine is not appreciable, they can be considered as rigid links.

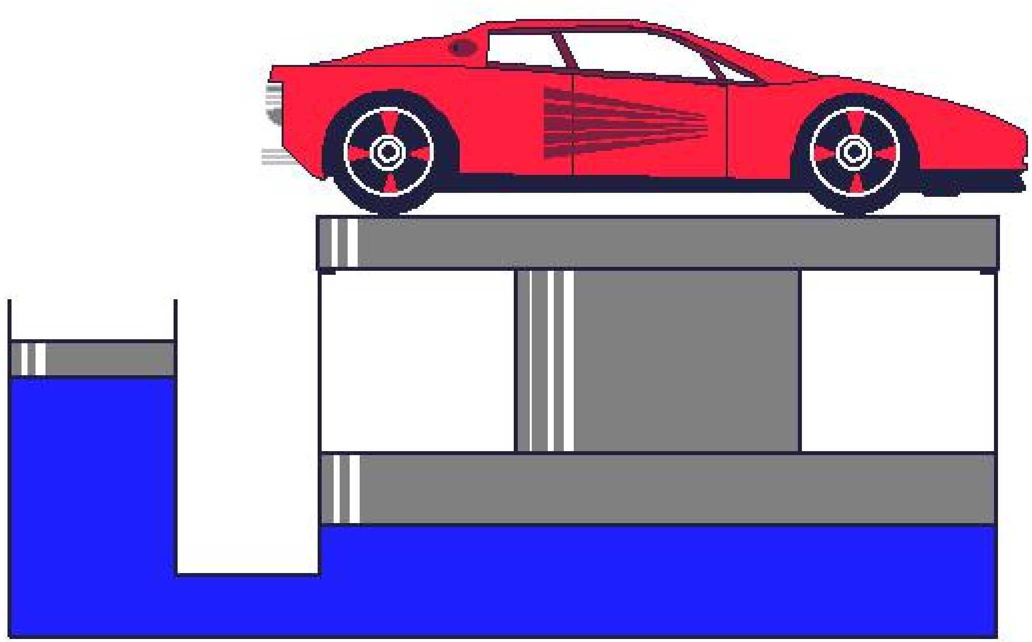
2. Flexible link.

- A flexible link is one which is partly deformed in a manner not to affect the transmission of motion.
- For example, belts, ropes, chains and wires are flexible links and transmit tensile forces only.

3. Fluid link.

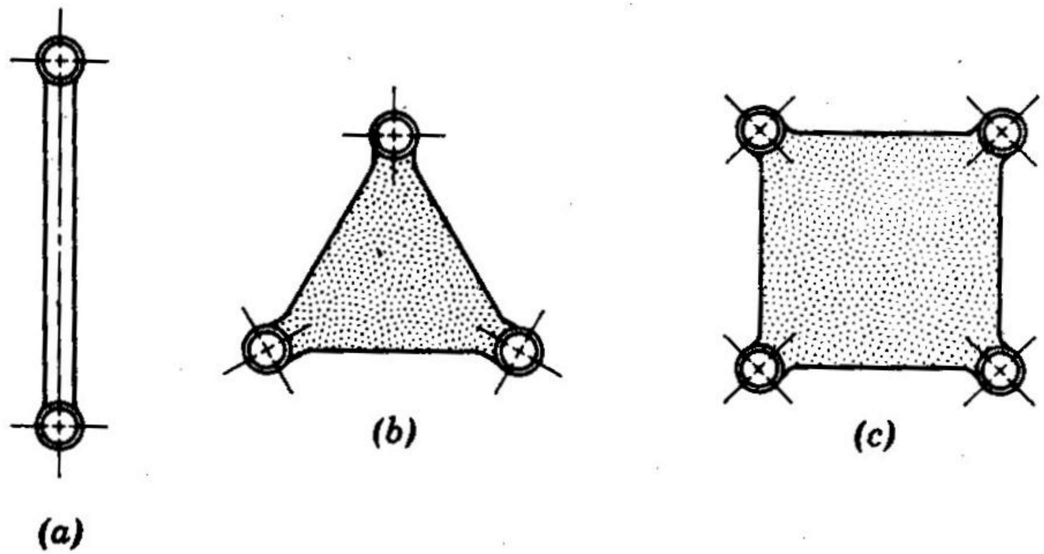
A fluid link is one which is formed by having a fluid in a container and the motion is transmitted through the fluid by pressure or compression only,

In the case of hydraulic presses, jacks and brakes.



Link or element

- **Binary link:** Link which is connected to other links at two points. (Fig. a)
- **Ternary link:** Link which is connected to other links at three points. (Fig. b)
- **Quaternary link:** Link which is connected to other links at four points. (Fig. c)



Structure

- It is an assemblage of a number of resistant bodies (known as members) having no relative motion between them and meant for carrying loads having straining action.
- A railway bridge, a roof truss, machine frames etc., are the examples of a structure.

Difference Between a Machine and a Structure

1. The parts of a machine move relative to one another, whereas the members of a structure do not move relative to one another.
2. A machine transforms the available energy into some useful work, whereas in a structure no energy is transformed into useful work.
3. The links of a machine may transmit both power and motion, while the members of a structure transmit forces only.

Kinematic Pair

- The two links or elements of a machine, when in contact with each other, are said to form a pair.

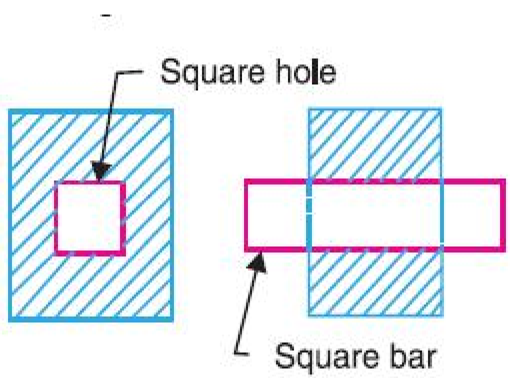
- If the relative motion between them is completely or successfully constrained (i.e. in a definite direction), the pair is known as [redacted]r.

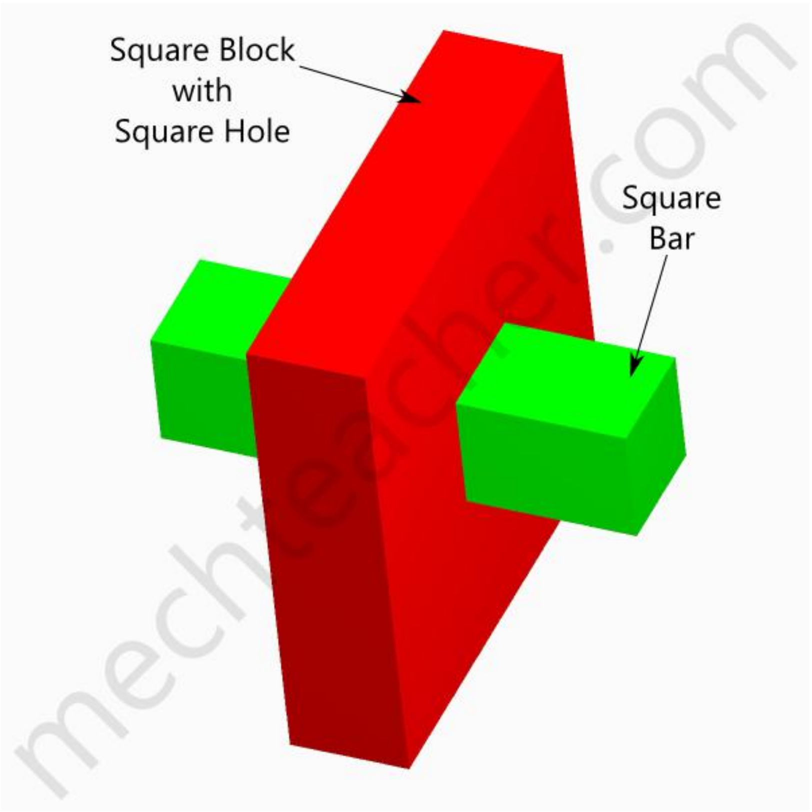
Types of Constrained Motions

1. Completely constrained motion.

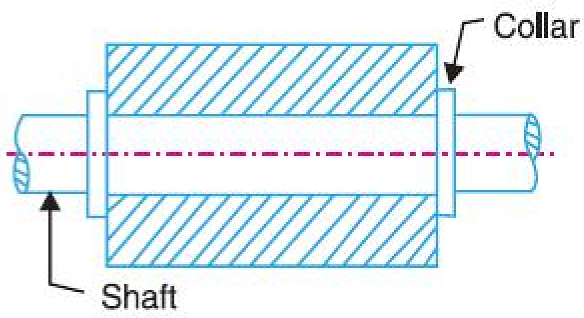
- When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.
- For example, the piston and cylinder (in a steam engine) form a pair and the motion of the piston is limited to a definite direction (*i.e. it will only reciprocate) relative to the* cylinder irrespective of the [redacted]n of the crank

- The motion of a square bar in a square hole, as shown in Fig.

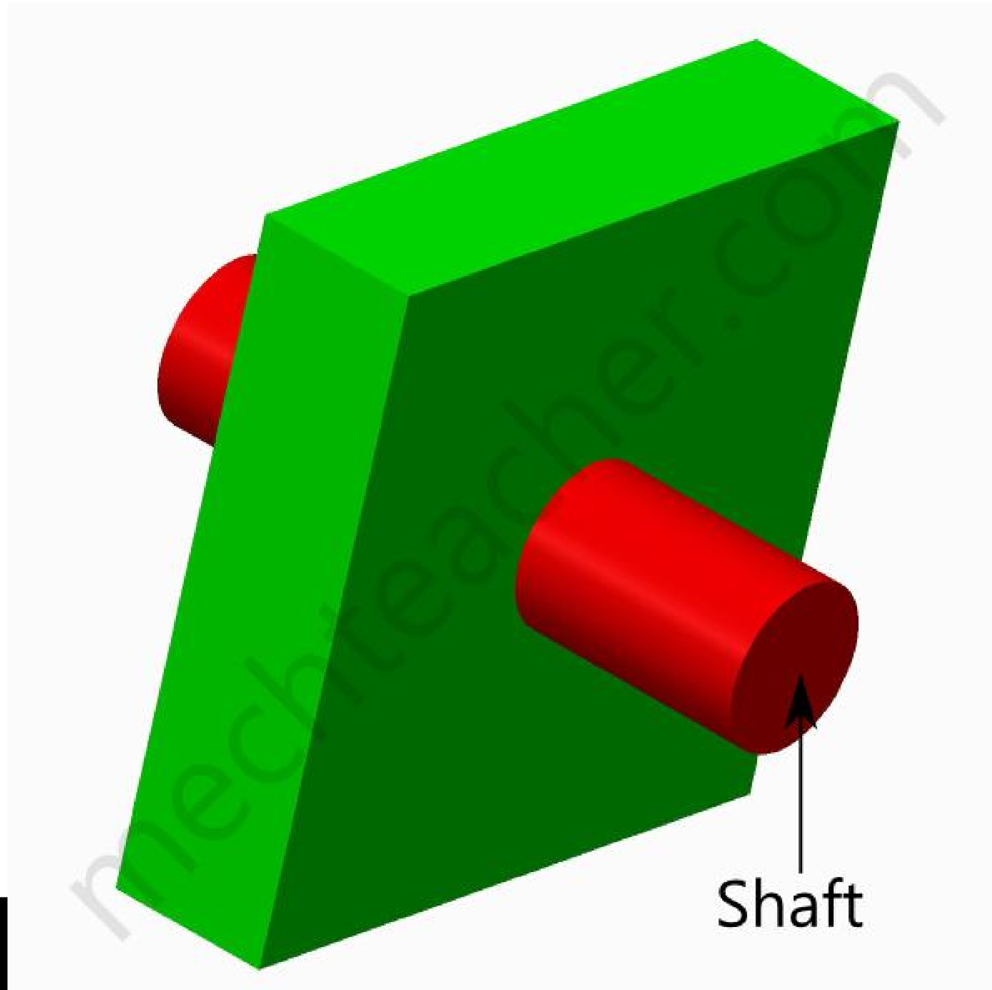




- The motion of a shaft with collars at each end in a circular hole, as shown in Fig. are also examples of completely constrained motion.

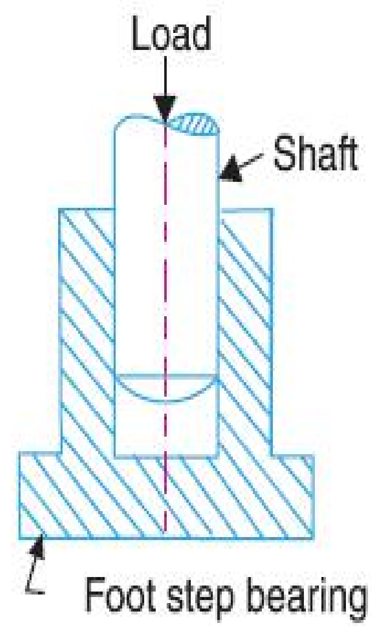


2. Incompletely constrained motion.



3. 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, then the motion is said to be successfully constrained motion.
- Consider a shaft in a foot-step bearing as shown in Fig. The shaft may rotate in a bearing or it may move upwards. This is a case of incompletely constrained motion.
- But if the load is placed on the shaft to prevent axial upward movement of the [redacted] motion of the pair is said t[redacted]essfully constrained motion.

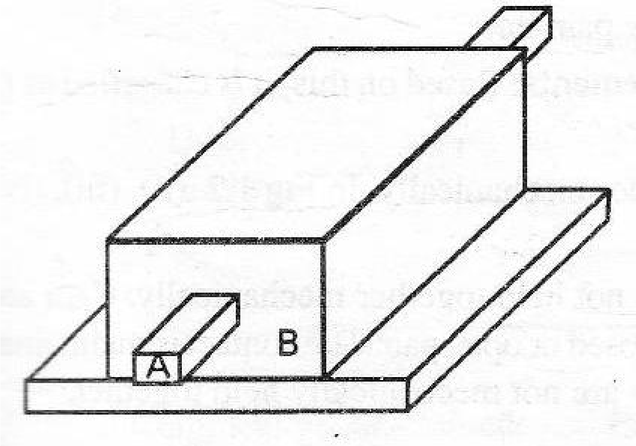


Classification of Kinematic Pairs

1. According to the type of relative motion between the elements.
2. According to the type of contact between the elements.
3. According to the type of closure.

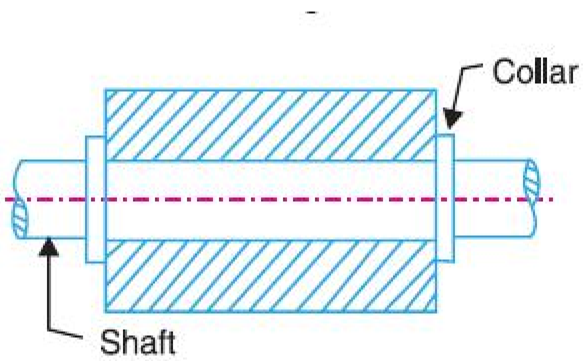
Sliding pair.

- When the two elements of a pair are connected in such a way that one can only slide relative to the other, the pair is known as a sliding pair.
- The piston and cylinder, ram and its guides in shaper, tail stock on the lathe bed etc. are the examples of a sliding pair.
- A little consideration will show, that a sliding pair has a completely constrained motion.



Turning pair.

- When the two elements of a pair are connected in such a way that one can only turn or revolve about a fixed axis of another link, the pair is known as turning pair.
- A shaft with collars at both ends fitted into a circular hole, lathe spindle supported in head stock, cycle wheels turning over their axles etc. are the examples of a turning pair.
- A turning p ly constrained motion.

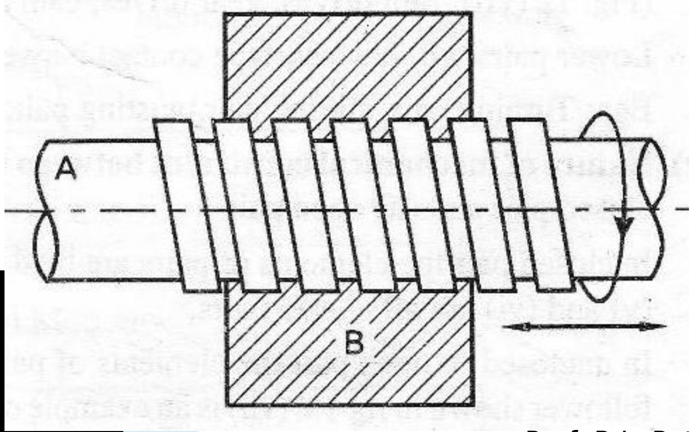


Rolling Pair.

- When the two elements of a pair are connected in such a way that one rolls over another fixed link, the pair is known as rolling pair.
- Ball and roller bearings are examples of rolling pair.

Screw Pair

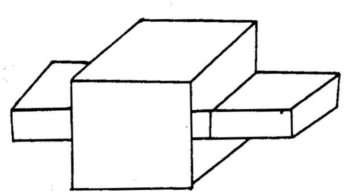
- When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads, the pair is known as screw pair.
- The lead screw of a lathe with nut, and bolt with a nut are examples of a screw pair.

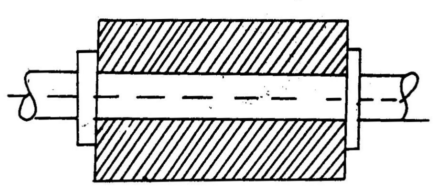


According to the type of contact between the elements.

1. Lower pair.

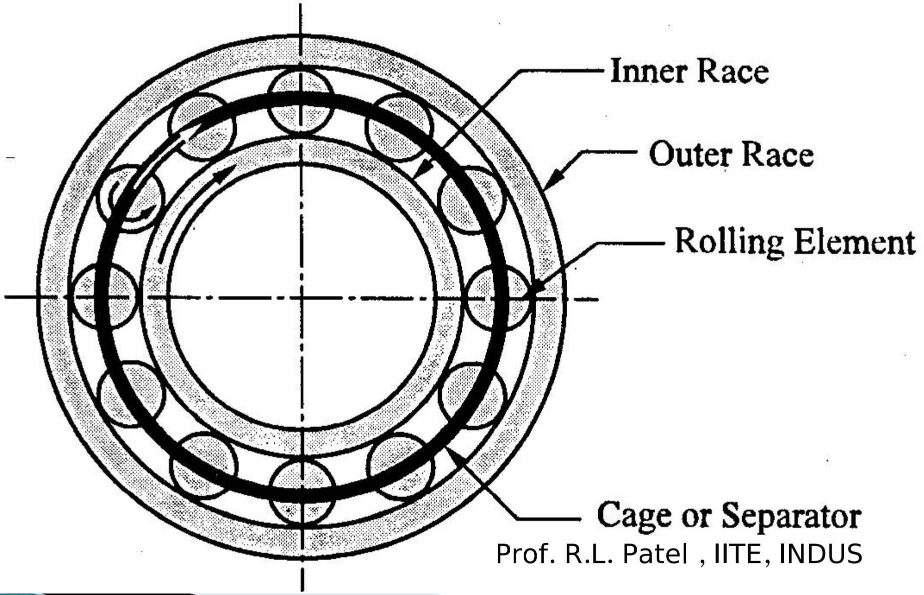
- When the two elements of a pair have a surface contact when relative motion takes place.
- surface of one element slides over the surface of the other, the pair formed is known as lower pair.
- It will be seen that sliding pairs, turning pairs and screw pai





Higher pair.

- When the two elements of a pair have a line or point contact when relative motion takes place.
- Motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair.
- A pair of friction discs, toothed gearing, belt and rope drives, ball and roller bearings and cam and follower are the examples of higher pairs.



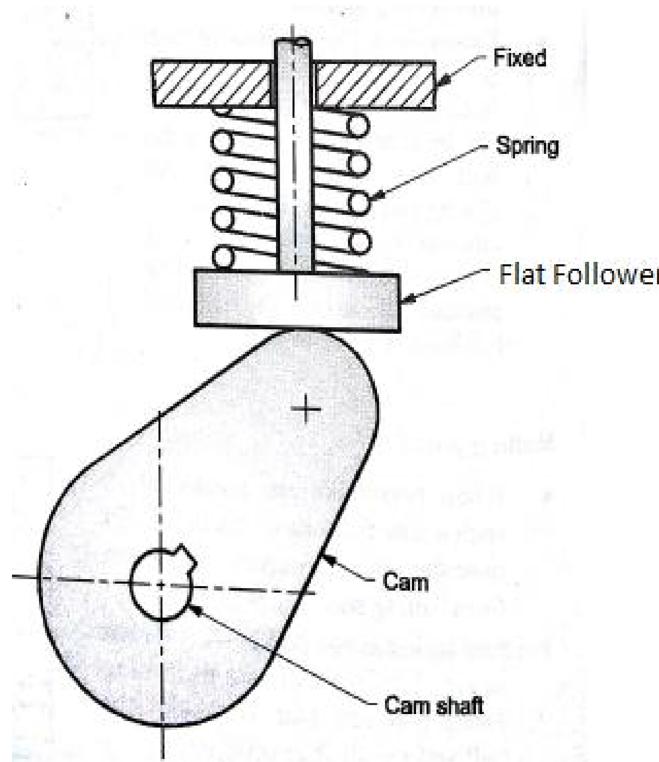
According to the type of closure.

1. Self closed pair.

- When the two elements of a pair are connected together mechanically in such a way that only required kind of relative motion occurs, it is then known as self closed pair.
- The lower pairs are self closed pair.

Force - closed pair

- When the two elements of a pair are not connected mechanically but are kept in contact by the action of external forces, the pair is said to be a force-closed pair.
- The cam and follower is an example of force closed pair, as it is kept in contact by the [redacted] by spring and gravity.



Kinematic Chain

- When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (*i.e. completely or* successfully constrained motion), it is called a ***kinematic chain.***
- kinematic chain may be defined as a combination of kinematic pairs, joined in such a way that each link forms a part of two pairs and the relative motion between the links or elements is completely or [redacted]strained.

- If each link is assumed to form two pairs with two adjacent links,
- Then the relation between the number of pairs (p) forming a kinematic chain and the number of links (l) may be expressed in the form of an equation :
  - $l = 2p - 4$

- Consider the arrangement of three links AB, BC and CA with pin joints at A, B and C as shown in Fig.

Number of links, $l = 3$

Number of pairs, $p = 3$

and number of joints, $j = 3$

From equation *(i)*, $l = 2p - 4$

or $3 = 2 \times 3 - 4 = 2$

i.e. L.H.S. > R.H.S.

Now from equation *(ii)*,

$$j = \frac{3}{2}l - 2 \quad \text{or} \quad 3 = \frac{3}{2} \times 3 - 2 = 2.5$$

L.H.S. > R.H.S.

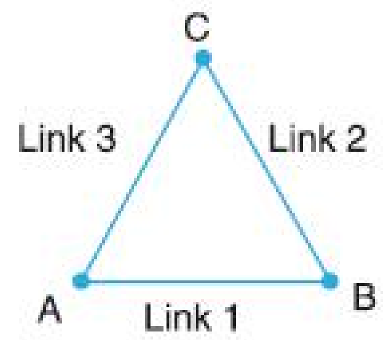


Fig. Arrangement of three links.

- Since the arrangement of three links, as shown in Fig, does not satisfy the equations (i) and (ii) .
- The left hand side is greater than the right hand side, therefore it is not a kinematic chain and hence no relative motion is possible.
- Such type of chain is called locked chain and forms a rigid frame or structure which is used in bridges and trusses.

2. Consider the arrangement of four links AB, BC, CD and DA as shown in Fig.

$l = 4, p = 4, \text{ and } j = 4$

From equation *(i)*, $l = 2p - 4$

$4 = 2 \times 4 - 4 = 4$

i.e. L.H.S. = R.H.S.

From equation *(ii)*, $j = \frac{3}{2} l - 2$

$4 = \frac{3}{2} \times 4 - 2 = 4$

i.e. L.H.S. = R.H.S.

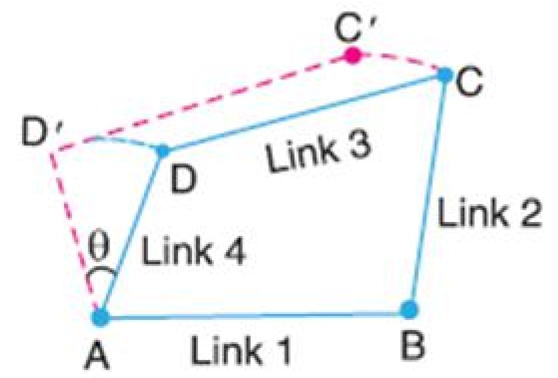


Fig. Arrangement of four links.

- Since the arrangement of four links, as shown in Fig. satisfy the equations ***(i) and (ii),*** therefore it is a ***kinematic chain of one degree of freedom.***

3. Consider an arrangement of five links, as shown in Fig.

$$l = 5, p = 5, \text{ and } j = 5$$

From equation (*i*),

$$l = 2p - 4 \quad \text{or} \quad 5 = 2 \times 5 - 4 = 6$$

i.e. L.H.S. < R.H.S.

From equation (*ii*),

$$j = \frac{3}{2}l - 2 \quad \text{or} \quad 5 = \frac{3}{2} \times 5 - 2 = 5.5$$

i.e. L.H.S. < R.H.S.

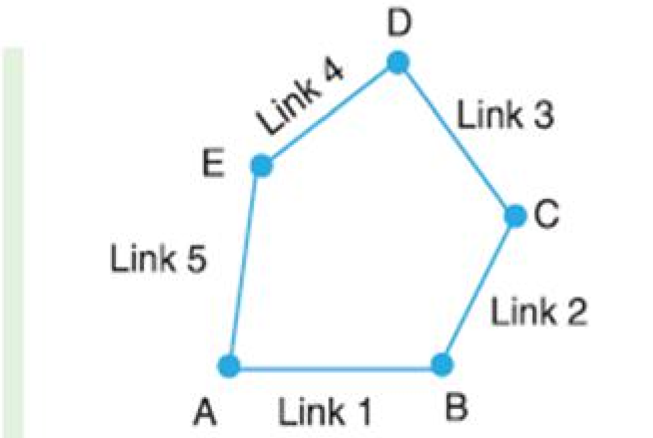


Fig. Arrangement of five links.

- Since the arrangement of five links, as shown in Fig. does not satisfy the equations.
- left hand side is less than right hand side, therefore it is not a kinematic chain.
- [redacted]ain is called **unconstrained chain**

- Consider an arrangement of six links, as shown in Fig. This chain is formed by adding two more links in such a way that these two links form a pair with the existing links as well as form themselves a pair.
- In this case *$l = 6$, $p = 5$, and $j = 7$*

From equation (*i*),

$$l = 2p - 4 \quad \text{or} \quad 6 = 2 \times 5 - 4 = 6$$

i.e. L.H.S. = R.H.S.

From equation (*ii*),

$$j = \frac{3}{2} l - 2 \quad \text{or} \quad 7 = \frac{3}{2} \times 6 - 2 = 7$$

i.e. L.H.S. = R.H.S.

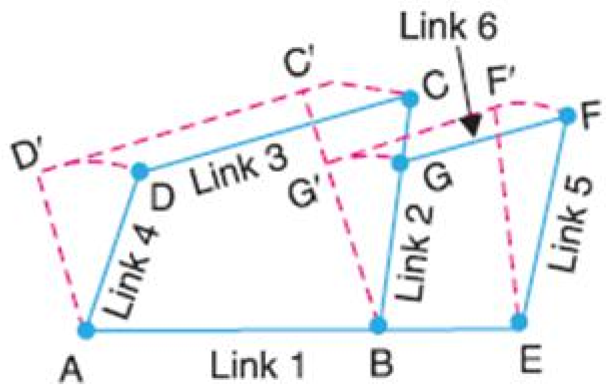
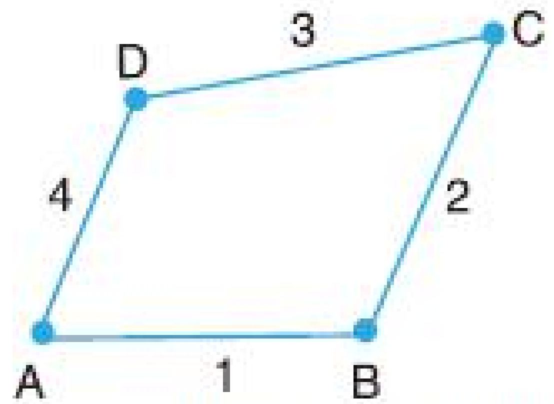


Fig. Arrangement of six links.

- Since the arrangement of six links, as shown in Fig. satisfies the equations (*i.e. left hand side is equal to* [redacted] therefore it is a kinematic chain.

Types of Joints in a Chain

- When two links are joined at the same connection, the joint is known as binary joint.
- For example, a chain as shown in Fig, has four links and four binary joins at *A, B, C and D.*
- In order to determine the nature of chain, *i.e. whether* the chain is a locked chain (or structure) or kinematic chain or unconstrained chain.
- Re[redacted]umber of links and the number o[redacted]nts, as given by A.W. Klein, may be used :



Kinematic chain with all binary joints.

$$j + \frac{h}{2} = \frac{3}{2} l - 2$$

j = Number of binary joints,
h = Number of higher pairs, and
l = Number of links.

$$j + \frac{h}{2} = \frac{3}{2} l - 2 \quad \text{... } (i)$$

j = Number of binary joints,

h = Number of higher pairs, and

l = Number of links.

When $h = 0$, the equation (*i*), may be written as

$$j = \frac{3}{2} l - 2$$

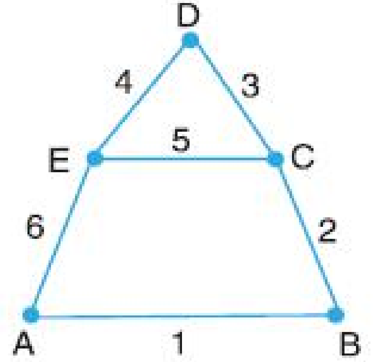
Applying this equation to a chain, as shown in Fig. where $l = 4$ and $j = 4$, we have

$$4 = \frac{3}{2} \times 4 - 2 = 4$$

Since the left hand side is equal to the right hand side, therefore the chain is a kinematic chain or constrained chain.

Ternary *joint*.

- When three links are joined at the same connection, the joint is known as ternary joint.
- It is equivalent to two binary joints as one of the three links joined carry the pin for the other two links.
- For example, a chain, as shown in Fig. has six links.
- It has three binary joints at *A, B and D and two ternary joints at C and E.*
- *Since one ternary joint is* equivalent to two binary joints,
- Therefore equivalent binary joints in a [redacted] Fig, are 3 + 2 × 2 = 7



Kinematic chain having binary and ternary joints.

- Let us now determine whether this chain is a kinematic chain or not.
- We know that *l = 6 and j = 7, therefore from* equation *(iii)*

$$j = \frac{3}{2} l - 2$$

$$7 = \frac{3}{2} \times 6 - 2 = 7$$

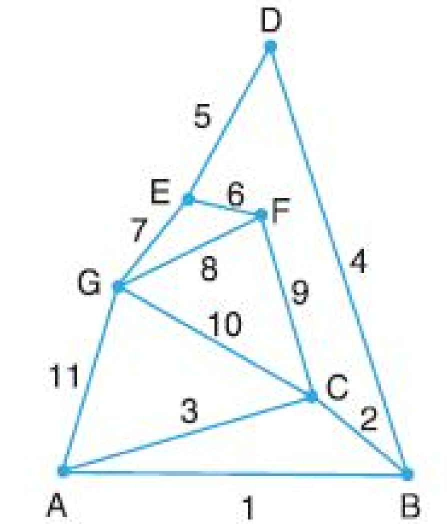
- Since left hand side is equal to right hand side, therefore the chain, as shown in Fig. a kinematic chain or constrained chain.

Binary joint.

- When two links are joined at the same connection to form a kinematic chain, the joint is called a binary joint.
- For Example, in four bar chain all four joints are binary.

Quaternary joint.

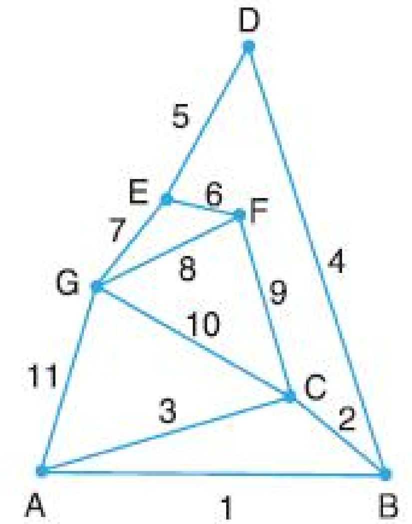
- When four links are joined at the same connection, the joint is called a quaternary joint.
- It is equivalent to three binary joints.
- when l number of links are joined at the same connection, the joint is equivalent to (l – 1) binary [redacted]



(*a*) Looked chain having binary, ternary and quaternary joints.

Quaternary joint.

- For example consider a chain having eleven links, as shown in Fig.
- It has one binary joint at D, four ternary joints at A, B, E and F, and two quaternary joints at C and G.
- Since one quaternary joint is equivalent to three binary joints and one ternary joint is equal to two binary joints, [redacted]al number of [redacted]n a chain, as shown in [redacted]e



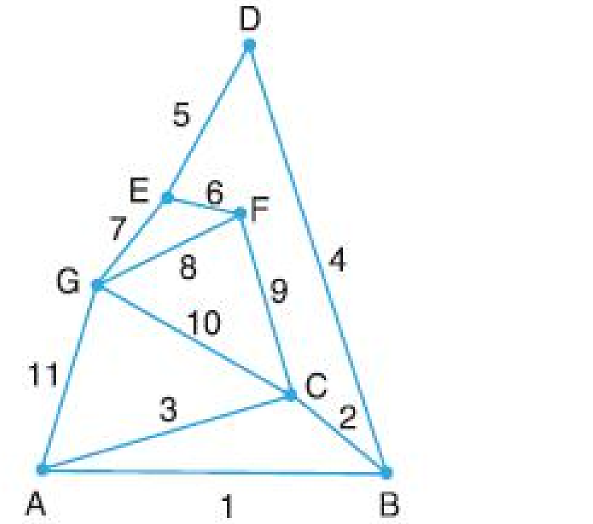
(*a*) Looked chain having binary, ternary and quaternary joints.

$$1 + 4 \times 2 + 2 \times 3 = 15$$

- Let us now determine whether the chain, as shown in Fig. (*a), is a kinematic chain or* not.
- *l = 11 and j = 15.*

$$j = \frac{3}{2} l - 2,$$

$$15 = \frac{3}{2} \times 11 - 2 = 14.5, \text{ i.e., L.H.S.} > \text{R.H.S.}$$



(*a*) Looked chain having binary, ternary and quaternary joints.

Since the left hand side is greater than right hand side, therefore the chain, as shown in Fig. *is not a kinematic chain.*

[redacted]in is called locked chain and forms a rigid [redacted]ture.

Mechanism

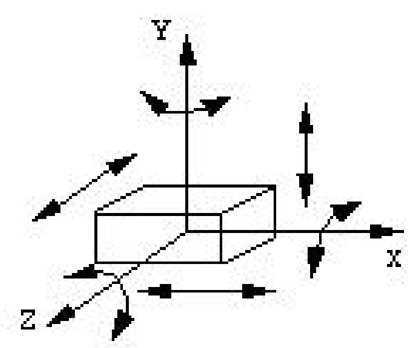
- When one of the links of a kinematic chain is fixed, the chain is known as *mechanism.*
- *It may* be used for transmitting or transforming motion
- A mechanism with four links is known as *simple mechanism, and the mechanism with more* than four links is known as *compound mechanism.*
- *When a mechanism is required to transmit power* or to do some particular type of work, it then becomes a *machine.*
- *In such cases, the various links or* elements have to be [redacted]nd the forces (both static and kinetic) safely.

Degrees of Freedom

- Degrees of freedom is the one of the most important concept in mechanics.
- This concept is widely used in robotics and kinematics.
- D.O.F means How many variables are required to determine position of a mechanism in space.

Degrees of freedom of a rigid body

- An unrestrained rigid body in space has six degrees of freedom:
- Three translating motions along the *x*, *y* and *z* axes and
- Three rotary motions around the *x*, *y* and *z* axes respective



Degrees of freedom of a rigid body in space

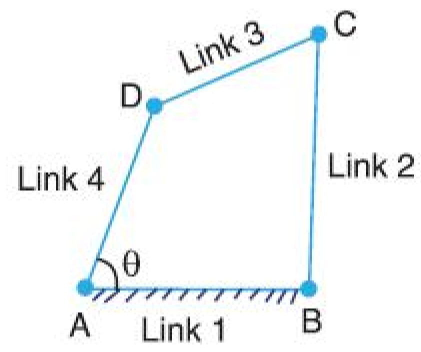
Number of Degrees of Freedom for Plane Mechanisms

- In the design or analysis of a mechanism, one of the most important concern is the number of degrees of freedom (also called movability) of the mechanism.

Consider a four bar chain, as shown in Fig.

A little consideration will show that only one variable such as θ is needed to define the relative positions of all the links.

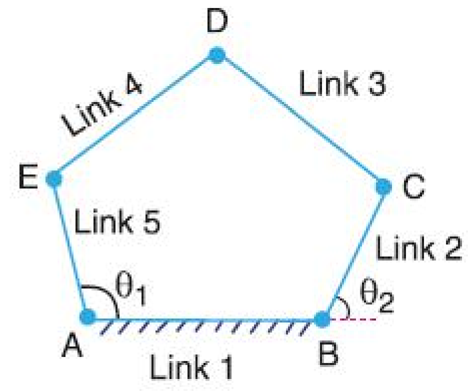
[redacted] say that the number of degre [redacted] of a four bar chain is one.



(*a*) Four bar chain.

Now, let us consider a five bar chain.

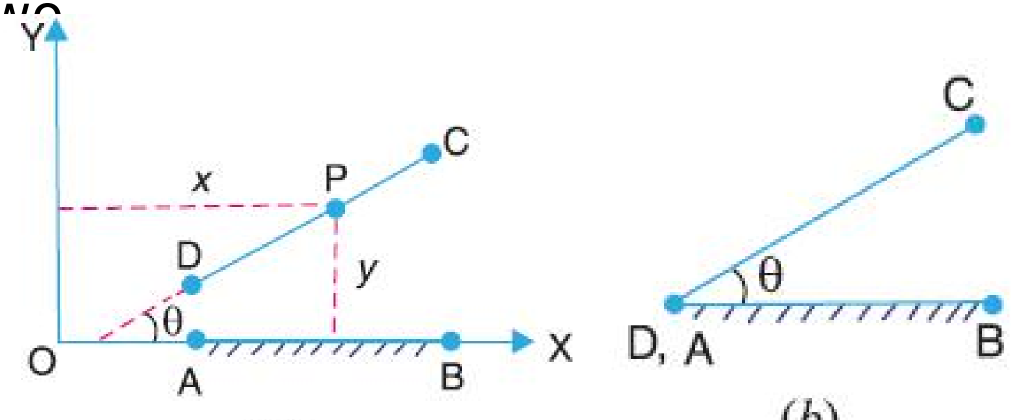
In this case two variables such as θ1 *and* θ2 *are needed to define completely* the relative positions of all the links.



(*b*) Five bar chain.

Thus, we say that the number of degrees of freedom is * two.

In order to develop the relationship in general, consider two links A B and CD in a plane motion.

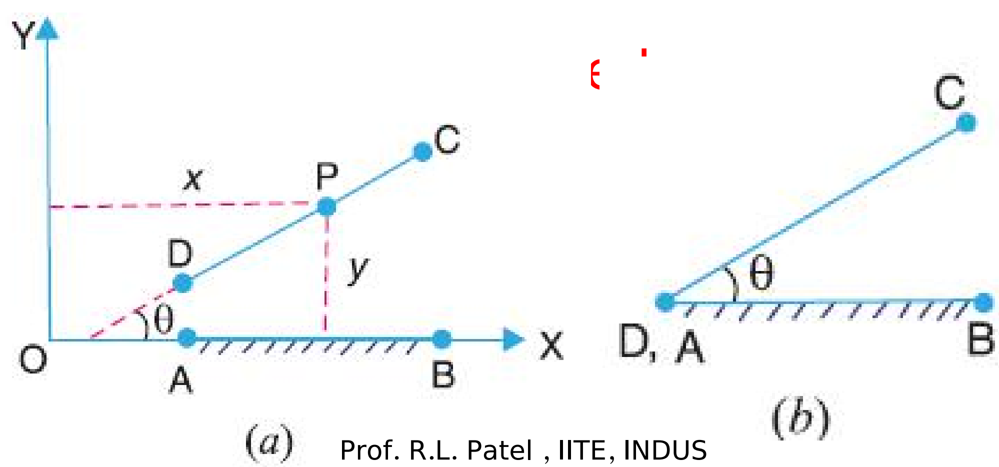


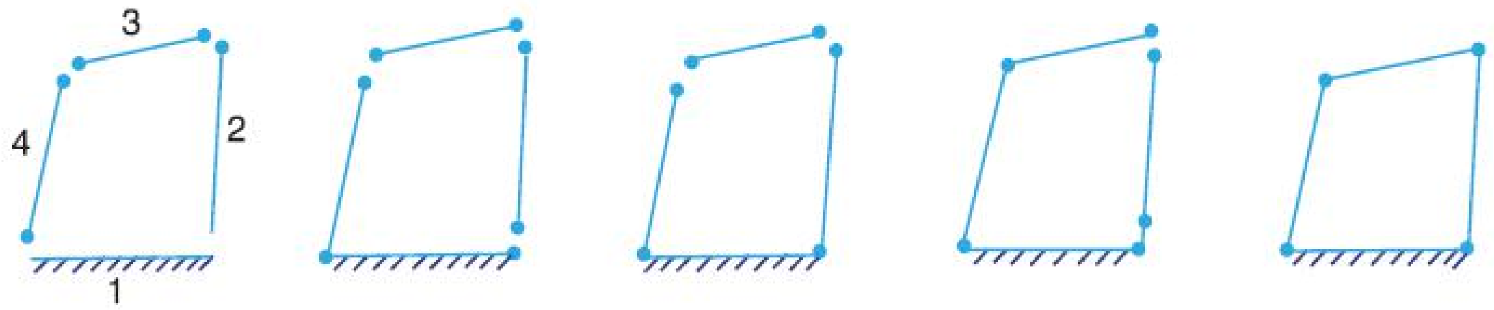
(*a*) (*b*)

Each link of a mechanism has three degrees of freedom before it is connected to any other link.

But when the link CD is connected to the link A B by a turning pair at A, as shown in Fig. the position of link CD is now determined by a single variable θ and thus has one degree of freedom.

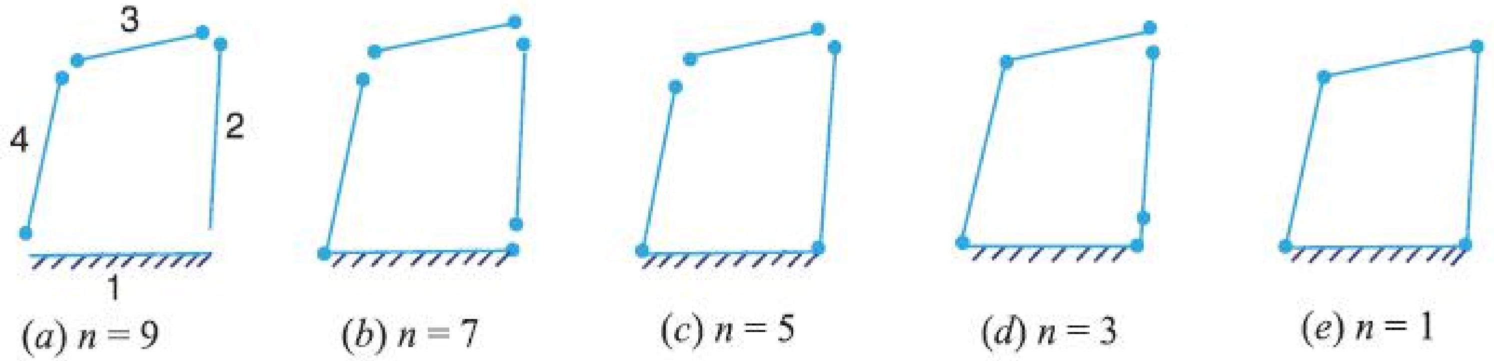
when a link is connected to a fixed link by a turning pair (i.e. lower pair), two degrees





Plane mechanism with l number of links.

Since in a mechanism, one of the links is to be fixed, therefore the number of movable links will be (l – 1) and thus the total number of degrees of freedom will be 3 (l – 1) before they are connected to any other link.



Plane mechanism with l number of links.

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Mechanism with l number of links connected by j number of binary joints or lower pairs (i.e. single degree of freedom pairs) and h number of higher pairs (i.e. two degree of freedom pairs), then the number of degrees of freedom of a mechanism is given by

$$n = 3 (l - 1) - 2 j - h$$

- This equation is called Kutzbach criterion for the movability of a mechanism having plane motion.
- If there are no two degree of freedom pairs (*i.e. higher pairs), then h = 0. Substituting*
- [redacted]*), we have*
  - $n = 3 (l - 1) - 2 j$

Application of Kutzbach Criterion to Plane Mechanisms

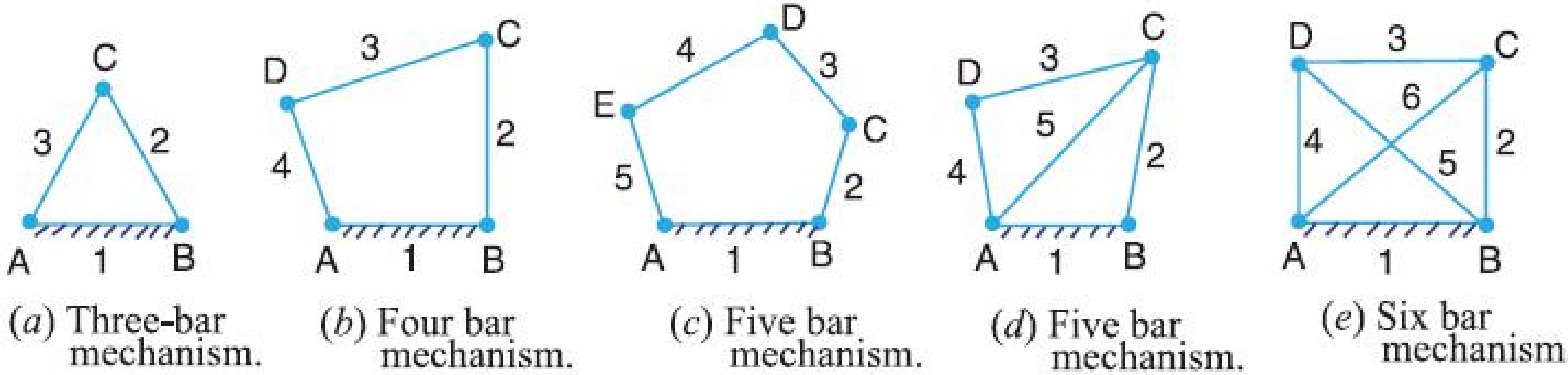
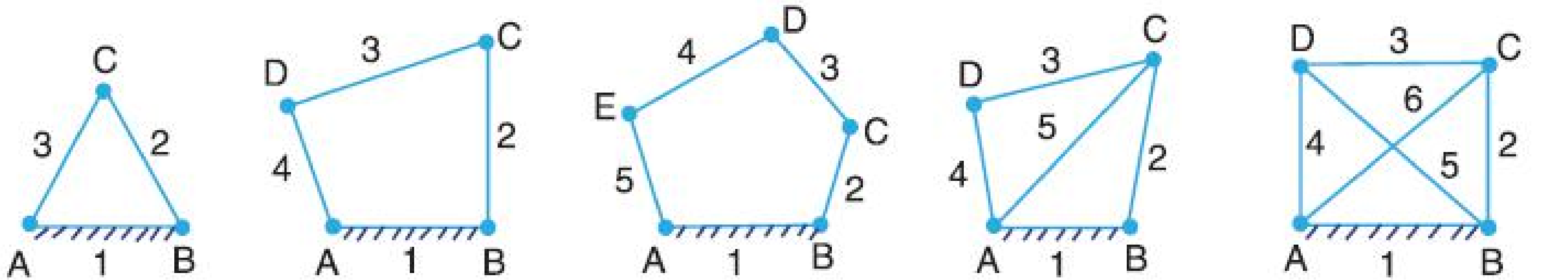


Fig. Plane mechanisms.

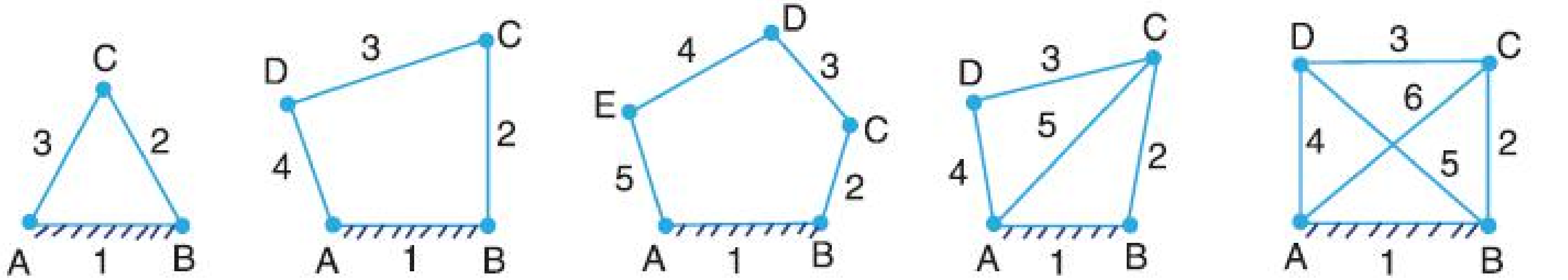
- The mechanism, as shown in Fig. (*a*), *has three links and three binary joints, i.e. l = 3 and j = 3.*
  - $n = 3\ (3 – 1) – 2 \times 3 = 0$
- The mechanism, as shown in Fig. (*b*), *has four links and four binary joints, i.e. l = 4 and j = 4.*
  - [redacted] $= 3\ (4 – 1) – 2 \times 4 = 1$



(*a*) Three-bar mechanism. (*b*) Four bar mechanism. (*c*) Five bar mechanism. (*d*) Five bar mechanism. (*e*) Six bar mechanism.

Fig. Plane mechanisms.

- The mechanism, as shown in Fig. (*c*), *has five links and five binary joints, i.e. l = 5, and j = 5.*
  - $n = 3\ (5 - 1) - 2 \times 5 = 2$
- The mechanism, as shown in Fig. (*d*), *has five links and six equivalent binary joints* (because there are two binary joints at *B and D, and two ternary joints at A and C), i.e. l = 5 and j = 6.*
  - $n = 3\ (5 - 1) - 2 \times 6 = 0$
- The mechanism, as shown in Fig. (*e*), *has six links and eight* [redacted]*oints* (because there are four ternary jo[redacted]*d D), i.e. l = 6 and j = 8.*
  - [redacted] $= 3\ (6 - 1) - 2 \times 8 = -1$



(*a*) Three-bar mechanism. (*b*) Four bar mechanism. (*c*) Five bar mechanism. (*d*) Five bar mechanism. (*e*) Six bar mechanism.

Fig. Plane mechanisms.

- When n = 0, then the mechanism forms a structure and no relative motion between the links is possible, as shown in Fig. (a) and (d).
- When n = 1, then the mechanism can be driven by a single input motion, as shown in Fig.(b).
- When n = 2, then two separate input motions are necessary to produce constrained motion for the mechanism, as shown in Fig. (c).
- When n = – 1 or less, then there are redundant constraints [redacted]forms a statically indeterminate structure, as [redacted]

Fig. Mechanism with a higher pair.

- The application of Kutzbach's criterion applied to mechanisms with a higher pair or two degree of freedom joints
- In Fig.(*a*), *there are three links, two binary joints and one higher pair, i.e.* $l = 3$, $j = 2$ *and* $h = 1$.
  - $n = 3\,(3 - 1) - 2 \times 2 - 1 = 1$
- In Fig. (*b*), *there are four links, three binary* [redacted] *higher pair, i.e.* $l = 4$, $j = 3$ *and* h $= 1$
  - [redacted] $(4 - 1) - 2 \times 3 - 1 = 2$

Grubler's Criterion for Plane Mechanisms

- The Grubler's criterion applies to mechanisms with only single degree of freedom joints where the overall movability of the mechanism is unity.
- Substituting *$n = 1$ and $h = 0$ in Kutzbach* equation, we have
  - $n = 3\,(l - 1) - 2\,j - h$
  - $1 = 3\,(l - 1) - 2\,j$
  - $3l - 2j - 4 = 0$
- This equation is known as the Grubler's criterion for plane mechanisms with constrained motion.
- Plane mechanism with a movability of 1 and only single degree of freedom joints can not have odd number of links.
- The simplest possible mechanisms of this type are a [redacted]sm and a slider-crank mechanism in which [redacted]=4.

Types of Kinematic Chains

- kinematic chains are those which consist of four lower pairs, each pair being a sliding pair or a turning pair.
- Types of kinematic chains with four lower pairs are

1. Four bar chain or quadric cyclic chain,

2. Single slider crank chain

3. Double slider crank chain.

Four Bar Chain or Quadric Cycle Chain

- kinematic chain is a combination of four or more kinematic pairs, such that the relative motion between the links or elements is completely constrained.
- The simplest and the basic kinematic chain is a four bar chain or quadric cycle chain, as shown in Fig.
- It consists of four links, each of them forms a turning pair at A, B, C and D. The four links may be of different lengths.
- According to **Grashof 's law for a four bar mechanism,** the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths if there is to be continuous relative motion between the two links.

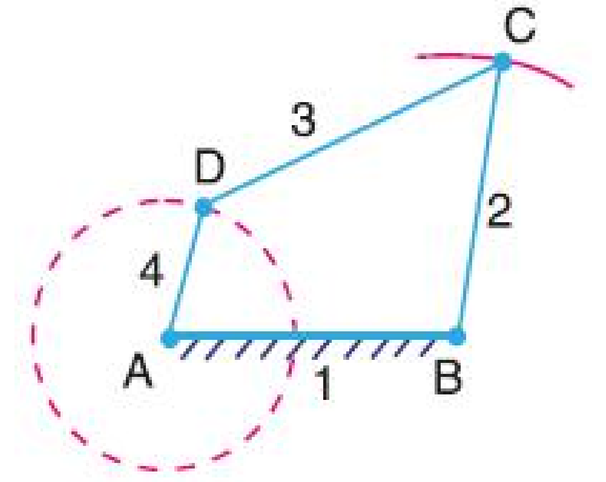


Fig. Four bar chain.

Four Bar Chain or Quadric Cycle Chain

- A very important consideration in designing a mechanism is to ensure that the input crank makes a complete revolution relative to the other links.
- In a four bar chain, one of the links, in particular the shortest link, will make a complete revolution relative to the other three links, if it satisfies the Grashof 's law. Such a link is known as crank or driver. In Fig, AD (link-4) is a crank.
- The link BC (link 2) which makes a partial rotation or oscillates is known as lever or rocker or follower.
- The link CD (link 3) which connects the crank and lever is called connecting rod or coupler.
- The fixed link AB (link 1) is known as frame of the mechanism.
- [redacted] 4) is the driver, the [redacted] rotary motion into [redacted]

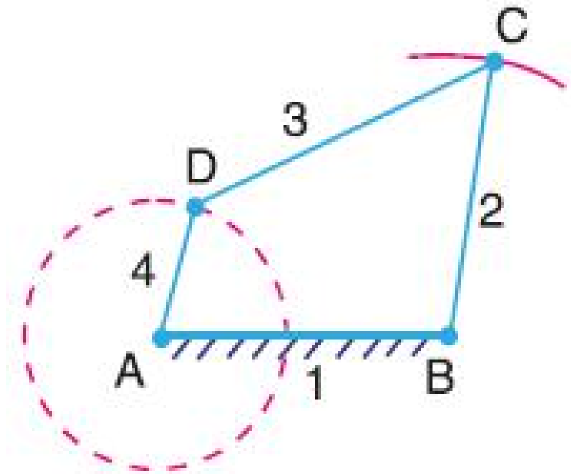
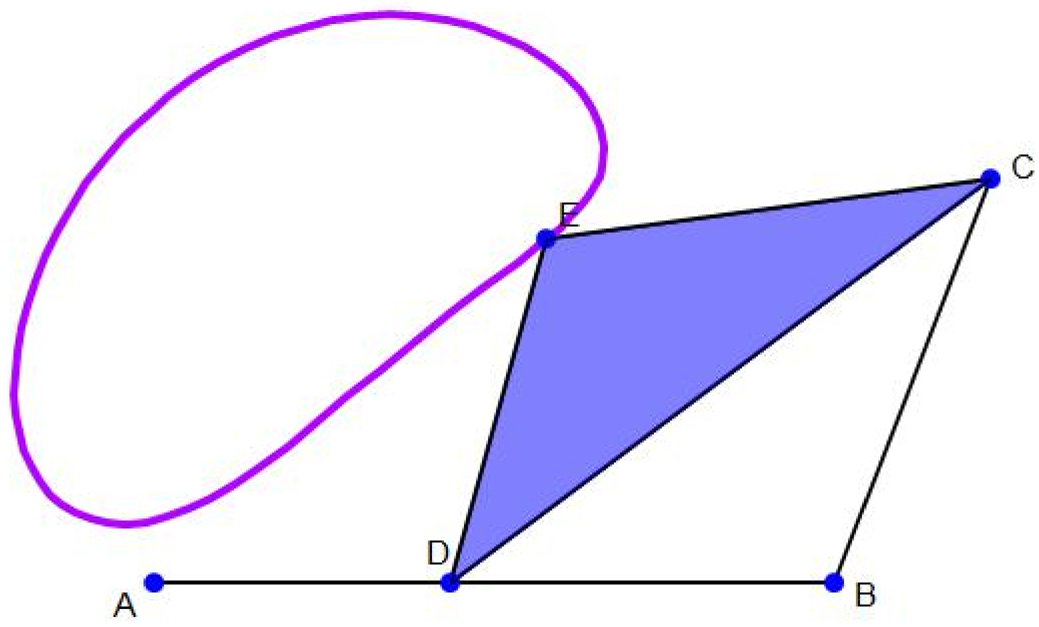
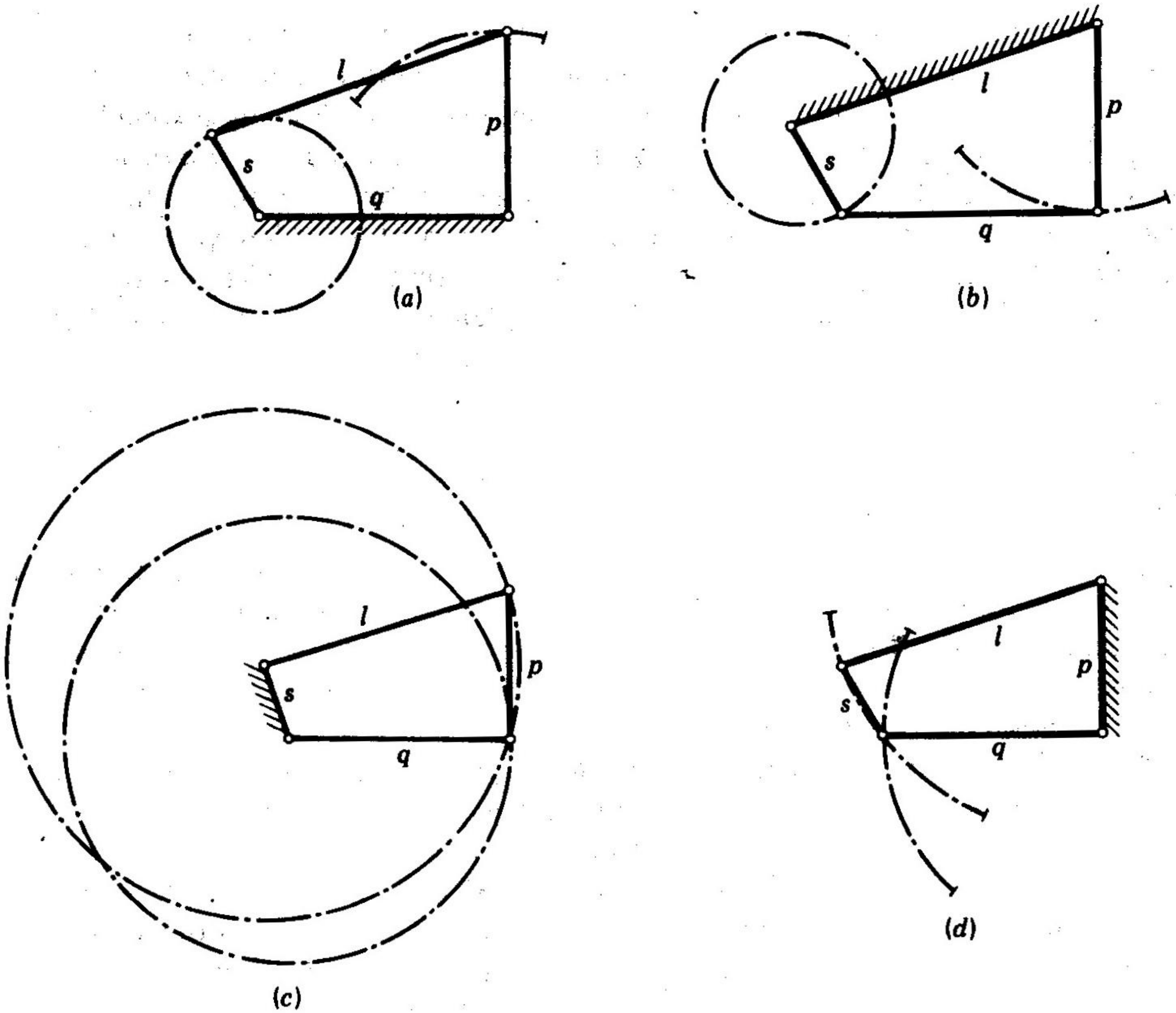


Fig. Four bar chain.

Four Bar Chain or Quadric Cycle Chain



Inversions of Four Bar Chain



Inversions of Four Bar Chain
1. Beam engine (crank and lever mechanism).

In this mechanism, when the crank rotates about the fixed centre A,

The lever oscillates about a fixed centre D.

The end E of the lever CDE is connected to a piston rod which reciprocates due to the rotation of the crank.

In other words, the purpose of this mechanism is to convert rotary motion into reciprocating [redacted]

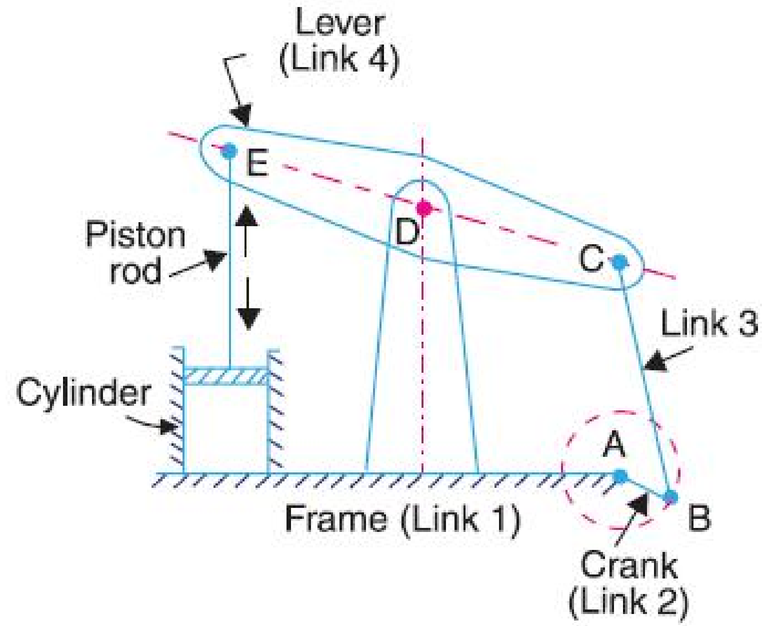
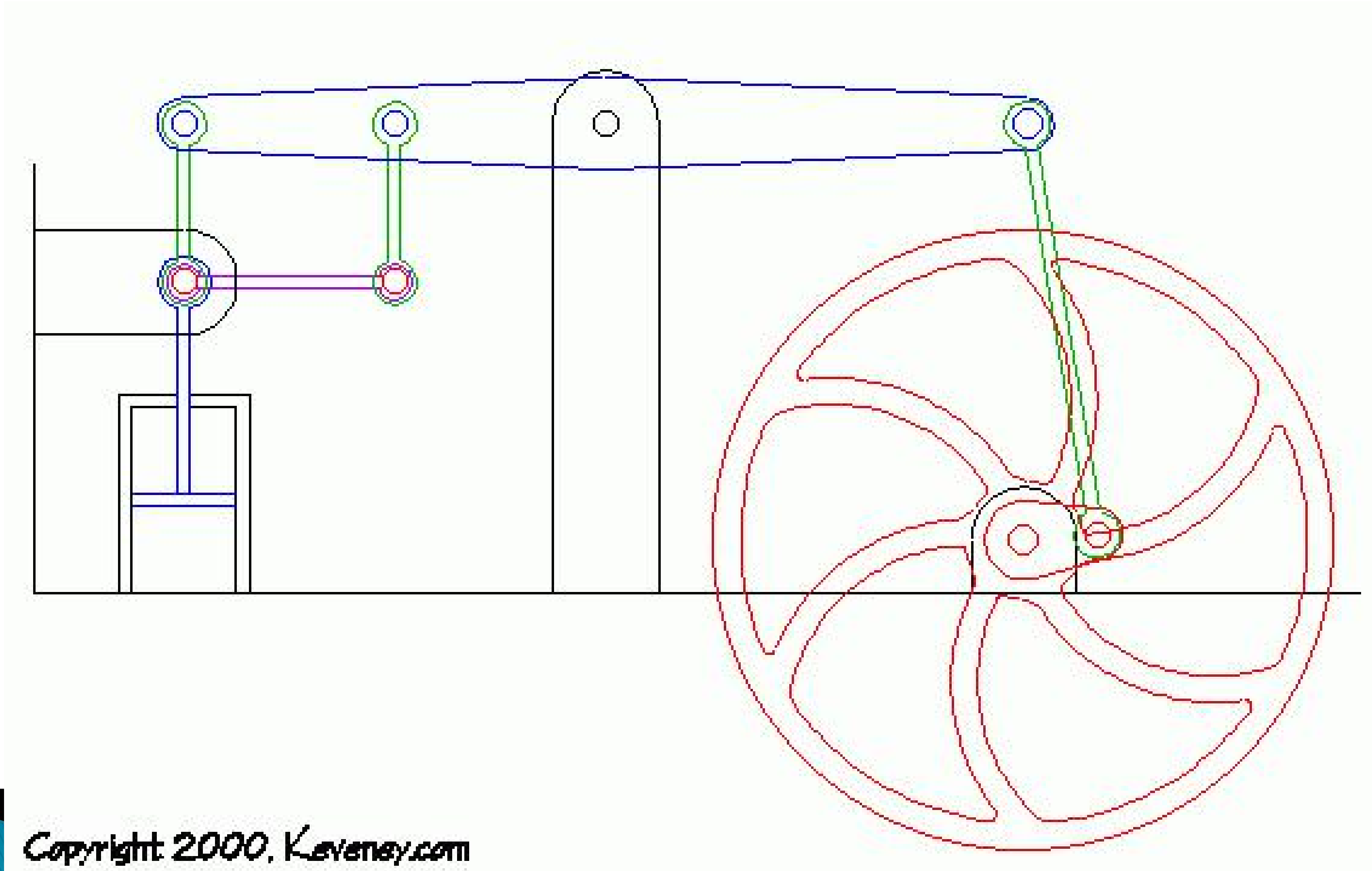


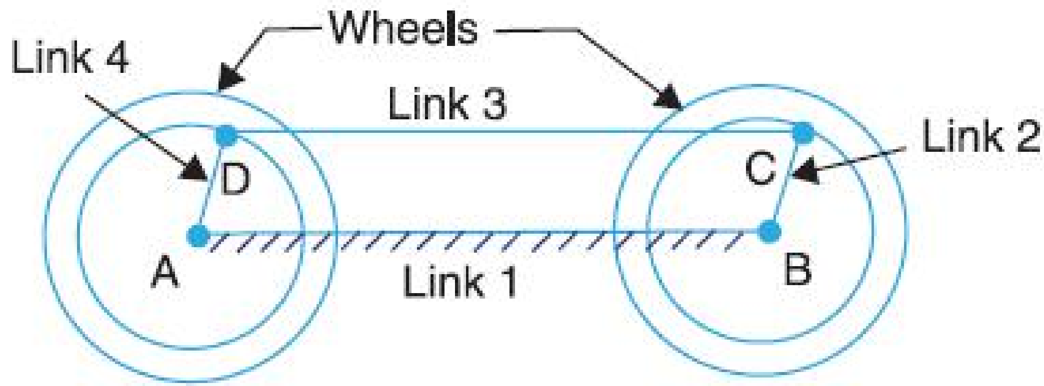
Fig. Beam engine.

Beam engine (crank and lever mechanism).

Beam engine (crank and lever mechanism).



Coupling rod of a locomotive (Double crank mechanism).



- In this mechanism, the links AD and BC (having equal length) act as cranks and are connected to the respective wheels.
- The link CD acts as a coupling rod.
- The link AB is fixed in order to maintain a constant centre to centre distance between them.
- [redacted] is meant for transmitting rotary motion from one wheel to the other wheel.

Watt's indicator mechanism (Double lever mechanism).

- The four links are : Fixed link at A, link AC, link CE and link BFD.
- It may be noted that BF and FD form one link because these two parts have no relative motion between them.
- The links CE and BFD act as levers.
- The displacement of the link BFD is directly proportional to the pressure of gas or steam which acts on the indicator plunger.
- On any small displacement of the mechanism, the tracing point E at the end of the link CE traces out approximately a straight line.

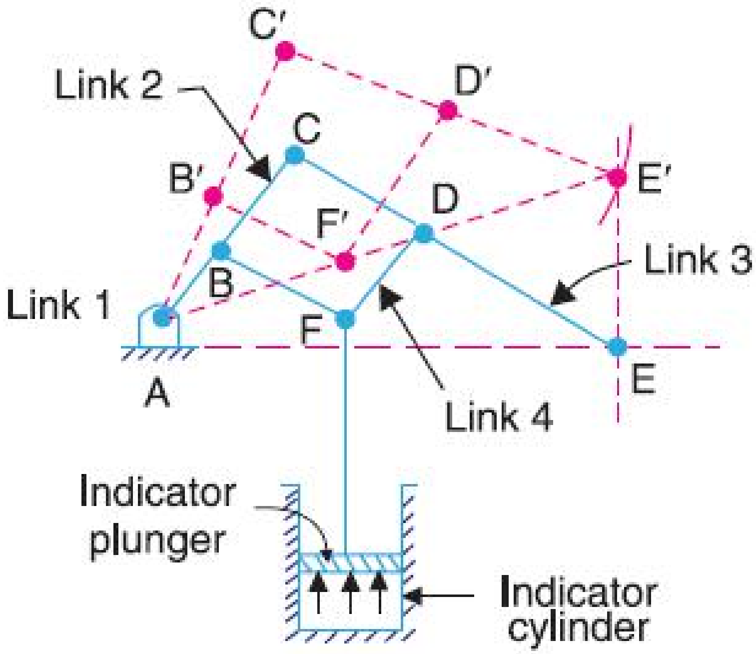


Fig. Watt's indicator mechanism.

Single Slider Crank Chain

- A single slider crank chain is a modification of the basic four bar chain.
- It consist of one sliding pair and three turning pairs. It is usually, found in reciprocating steam engine mechanism.
- This type of mechanism converts Rotary motion into Reciprocating motion and vice versa.

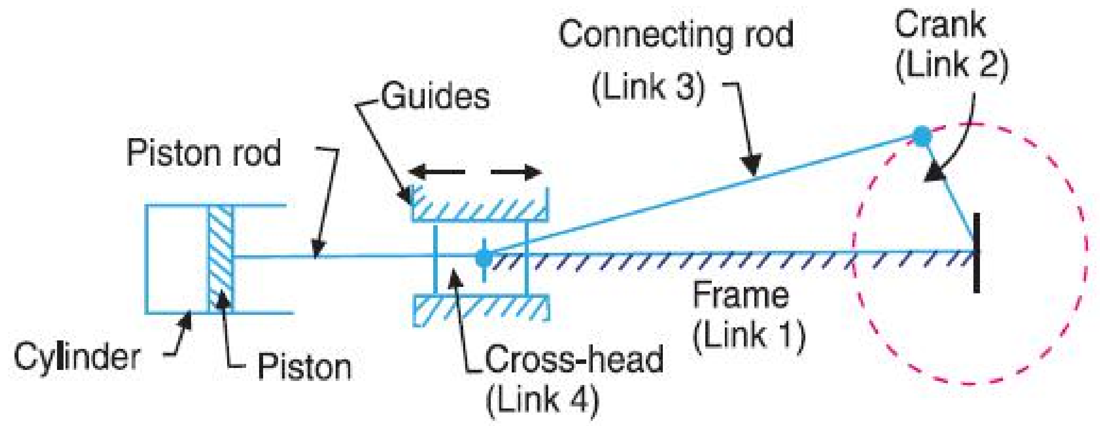
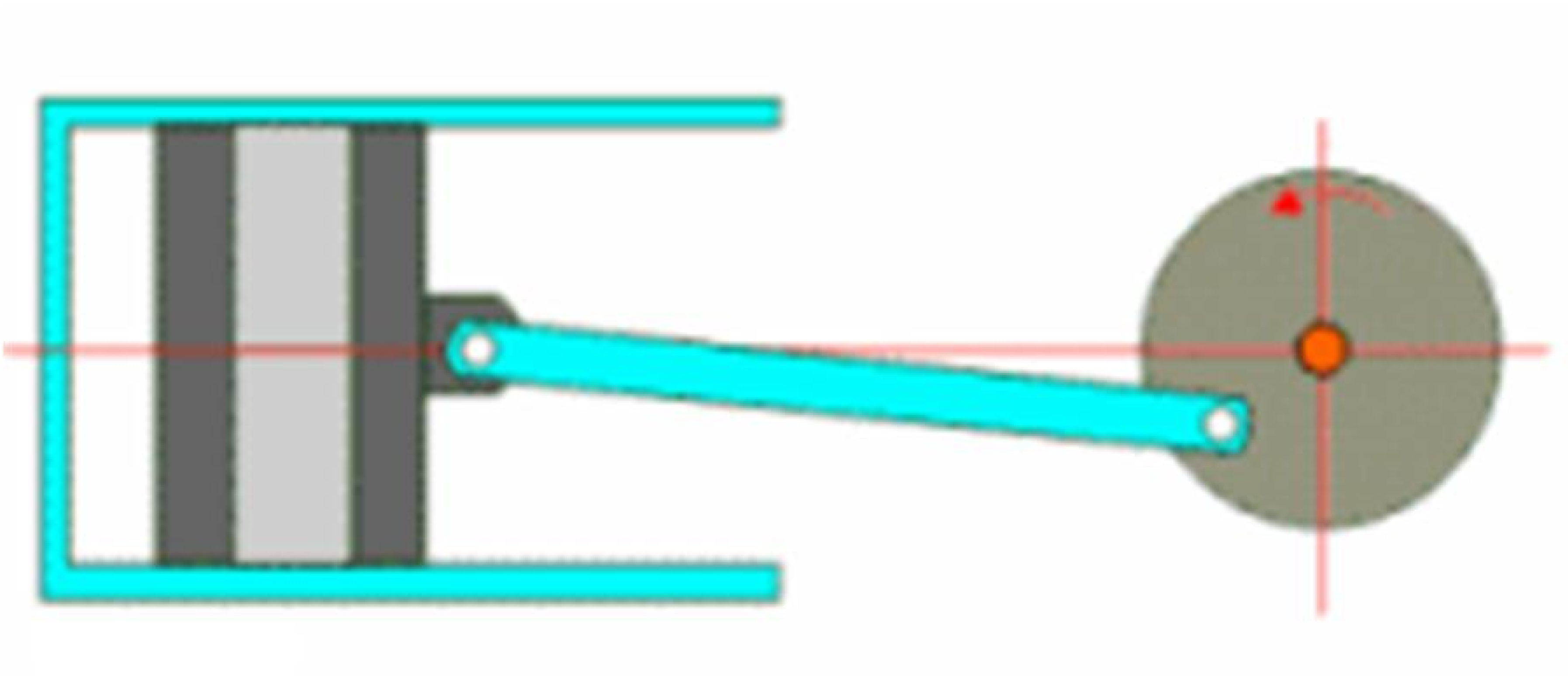


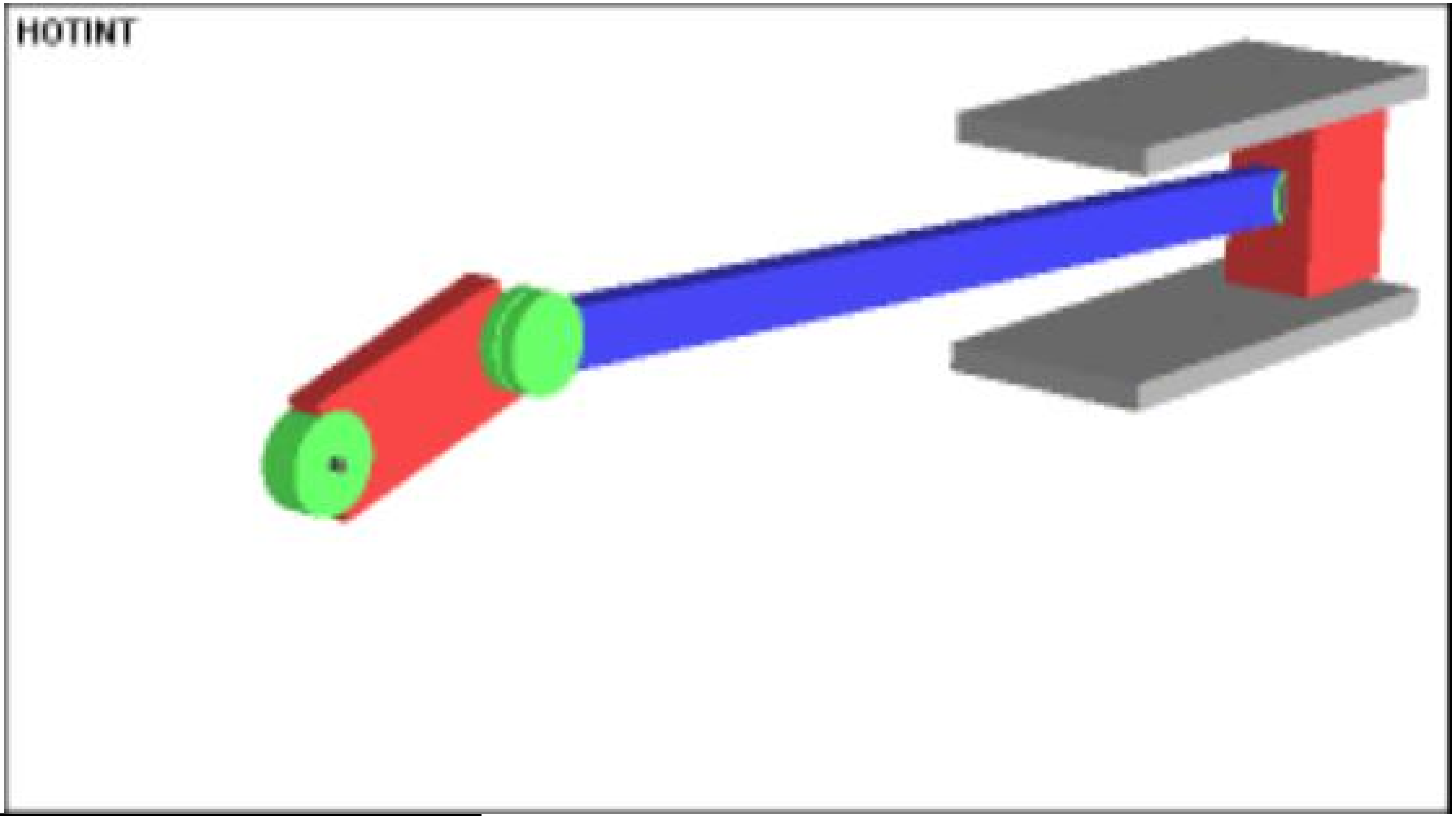
Fig. Single slider crank chain.

- In a single slider crank chain, The <u>links 1 and 2</u>, <u>links 2 and 3</u>, and <u>links 3 and 4</u> form three turning pairs.
- While the <u>links 4 and 1</u> form a sliding pair.
- The link 1 corresponds to the frame of the engine, which is fixed.
- The link 2 corresponds to the crank.
- The link 3 corresponds to the connecting rod.
- The link 4 corresponds to cross-head.
- As the crank rotates, the cross-head reciprocates in the [redacted] piston reciprocates in the cylinder.

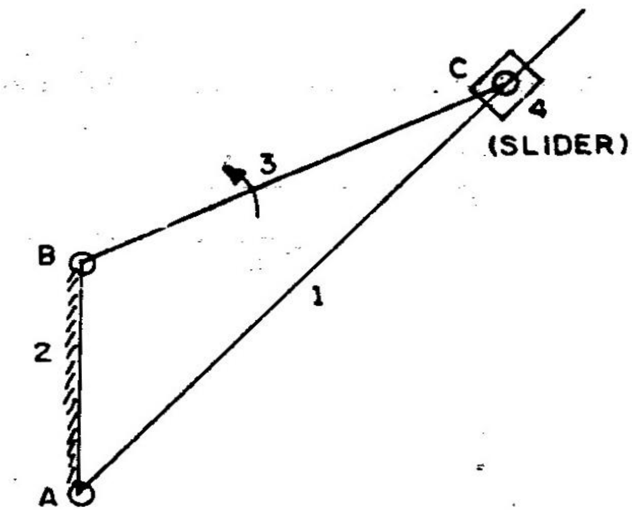
Single Slider Crank Chain

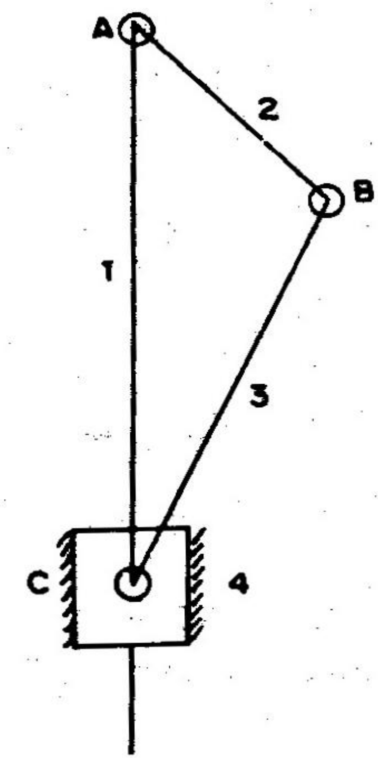


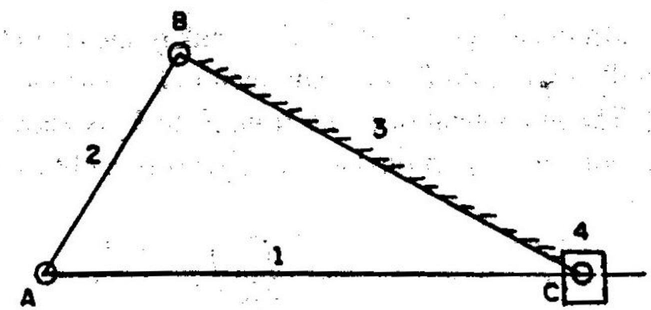
Single Slider Crank Chain



Inversions of Single Slider Crank Chain







Inversions of Single Slider Crank Chain

1. **Pendulum pump or Bull engine.**

- In this mechanism, the inversion is obtained by fixing the cylinder or link 4 (i.e. sliding pair), as shown in Fig.
- In this case, when the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at A and the piston attached to the piston rod (link 1) reciprocates.
- The duplex pump which is used to supply feed water to boilers have [redacted]d to link 1.

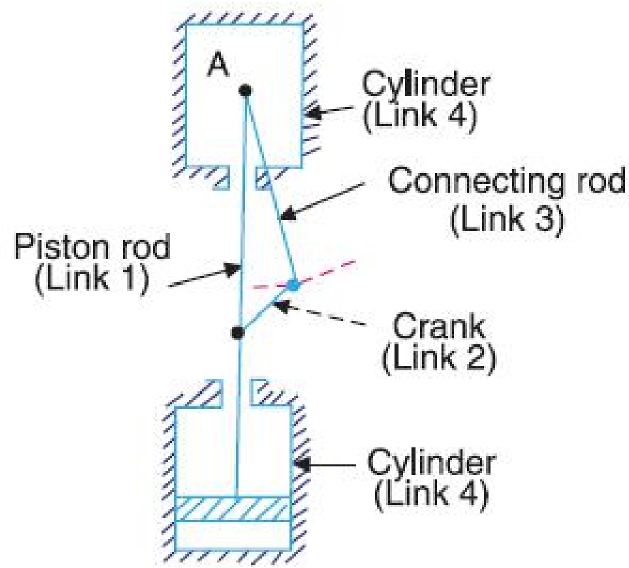
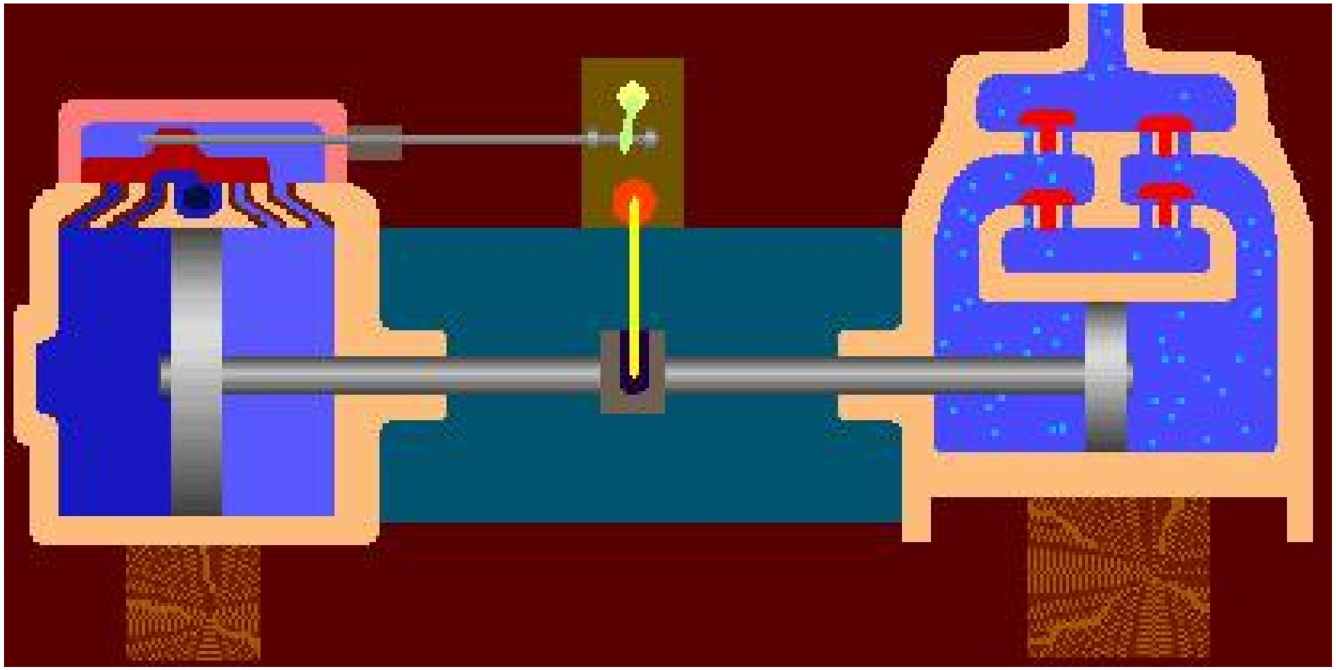


Fig. Pendulum pump.

Duplex Pump



Oscillating cylinder engine.

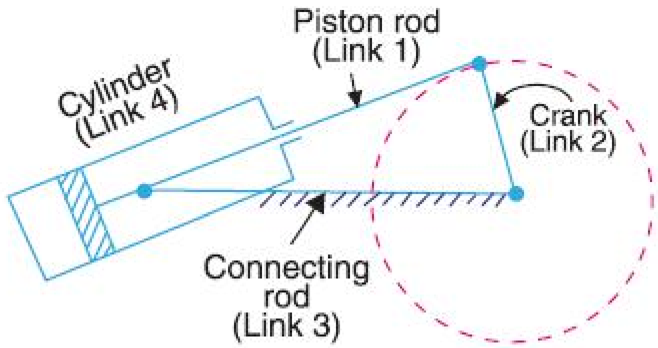
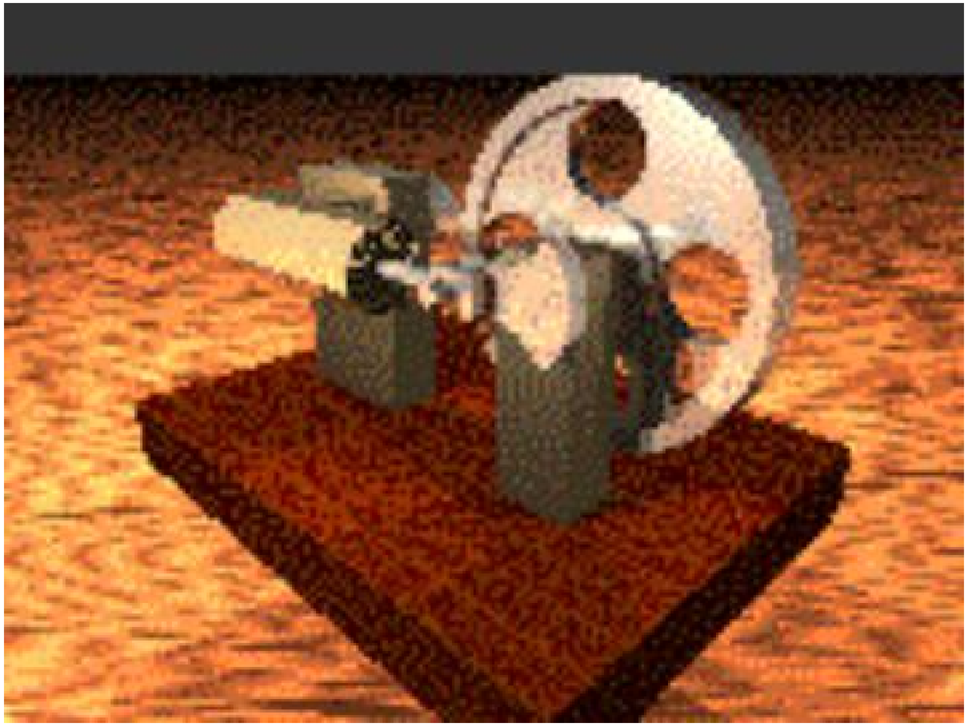


Fig. Oscillating cylinder engine.

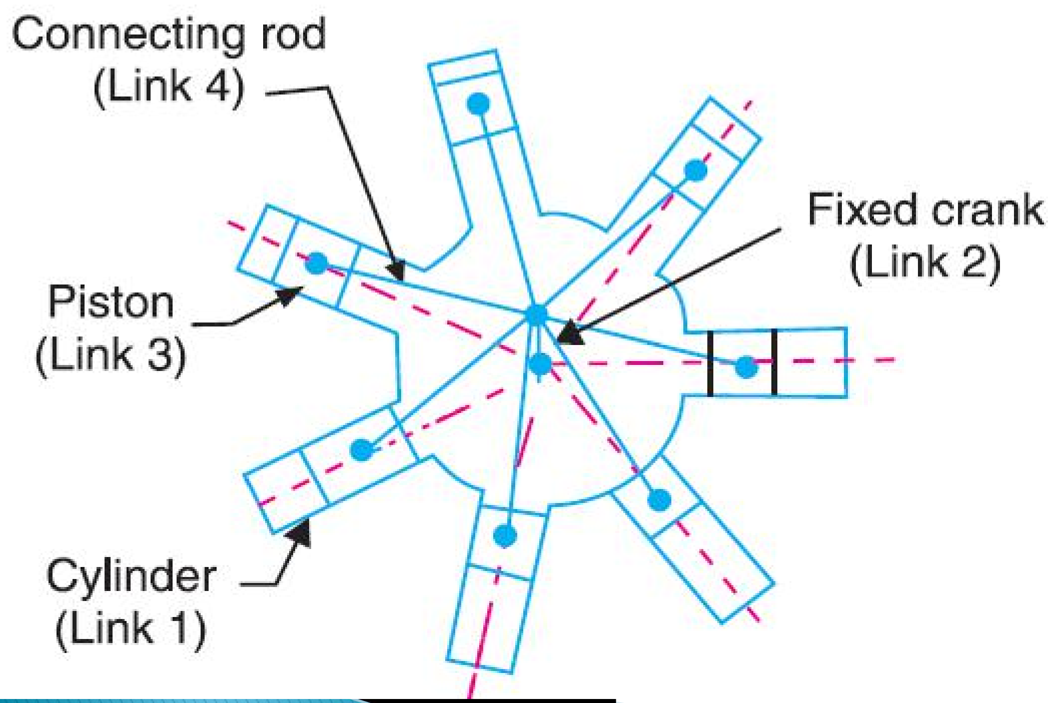
- This mechanism is used to convert reciprocating motion into rotary motion.
- In this mechanism, the link 3 forming the turning pair is fixed. The link 3 corresponds to the connecting rod of a reciprocating steam engine mechanism.
- When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at [redacted]

Oscillating cylinder engine.

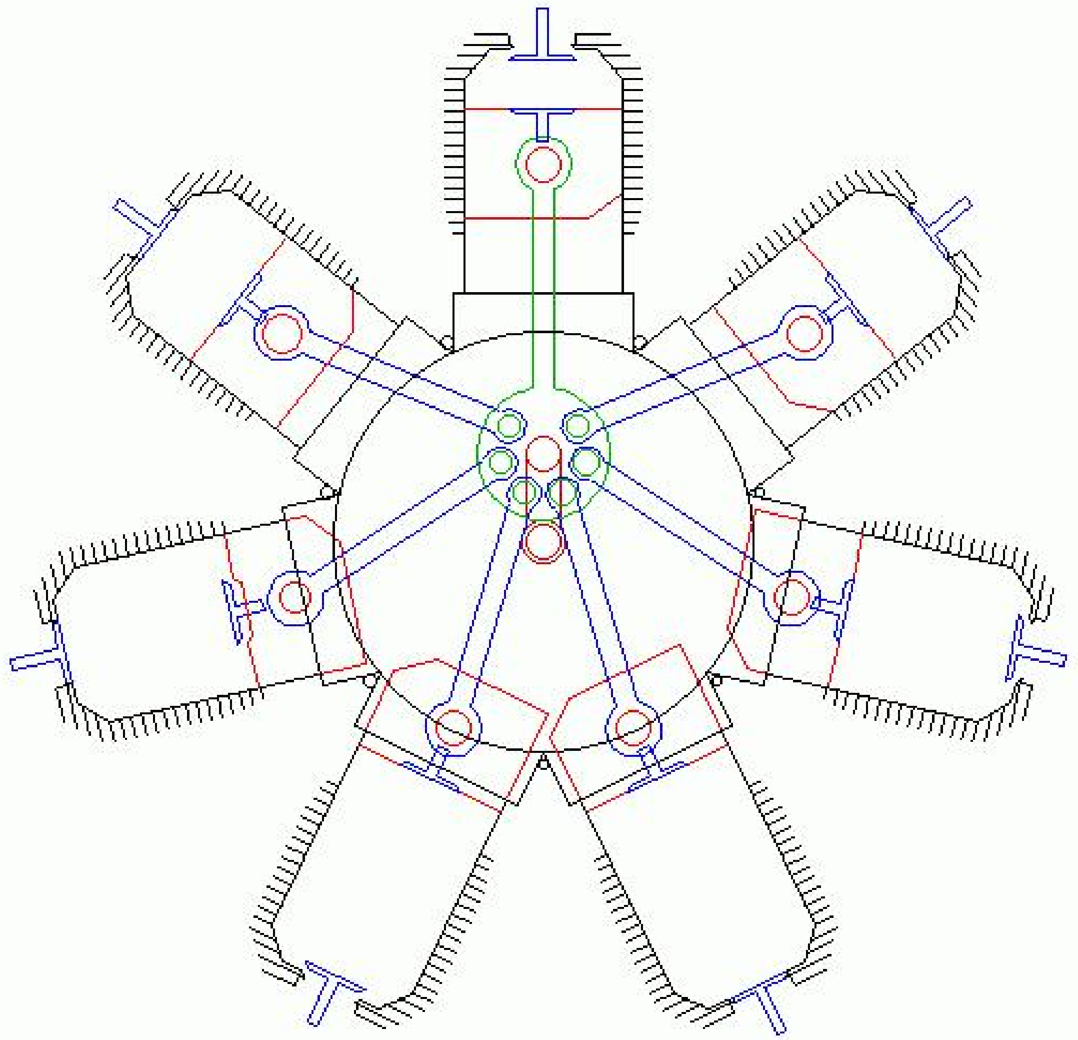


Rotary internal combustion engine or Gnome engine.

- *Sometimes back, rotary internal* combustion engines were used in aviation. But now-a-days gas turbines are used in its place.
- It consists of seven cylinders in one plane and all revolves about fixed centre *D, as shown in* Fig., while the crank (link 2) is fixed.
- In this mechanism, when the connecting rod (link 4) rotates, e



Rotary engine



Inversions of Double Slider Crank Chain

- A kinematic chain which consists of two turning pairs and two sliding pairs is known as **double slider crank chain.**
- Inversions of Double Slider Crank Chain

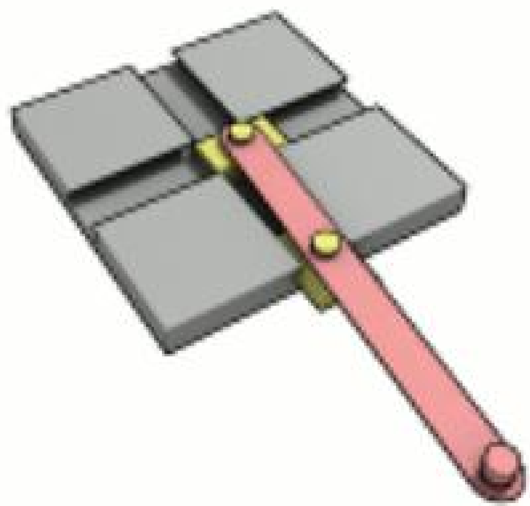
1 Elliptical trammels

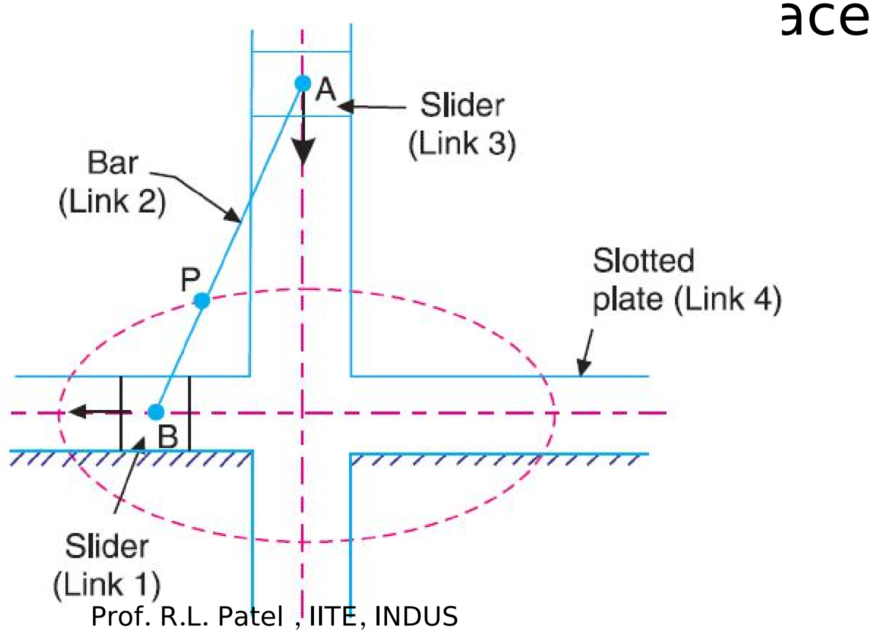
2 Scotch yoke mechanism

3 Oldham's coupling

1. ***Elliptical trammels.***

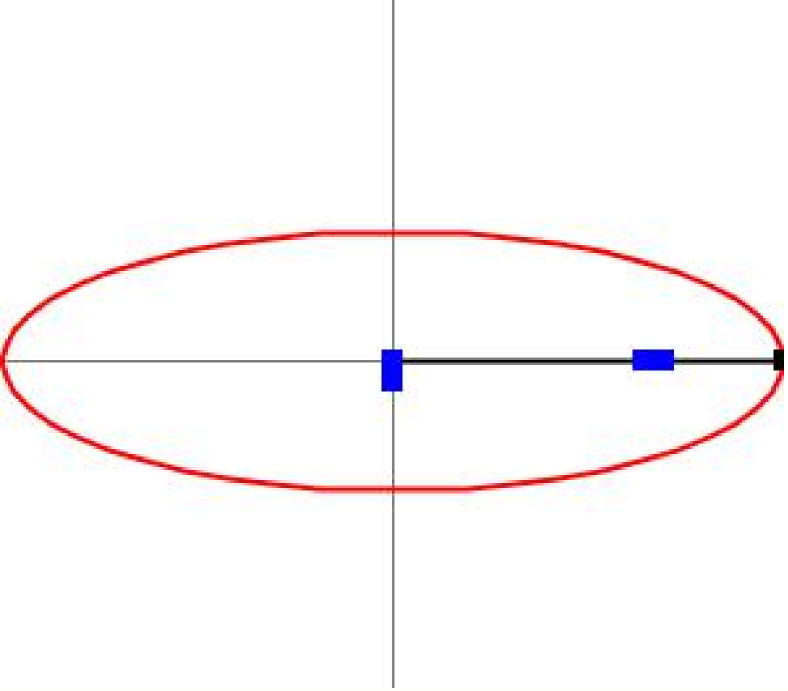
- It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4), as shown in Fig.
- The fixed plate or link 4 has two straight grooves cut in it, at right angles to each other.
- The link 1 and link 3, are sliders and form sliding pairs with link 4.
- The link AB (link 2) is a bar which forms turning pair with links 1 and 3.
- When the links 1 and 3 slide along their respective grooves, any point on the link 2 such as P trac ... ace of link 4, as shown in Fig.

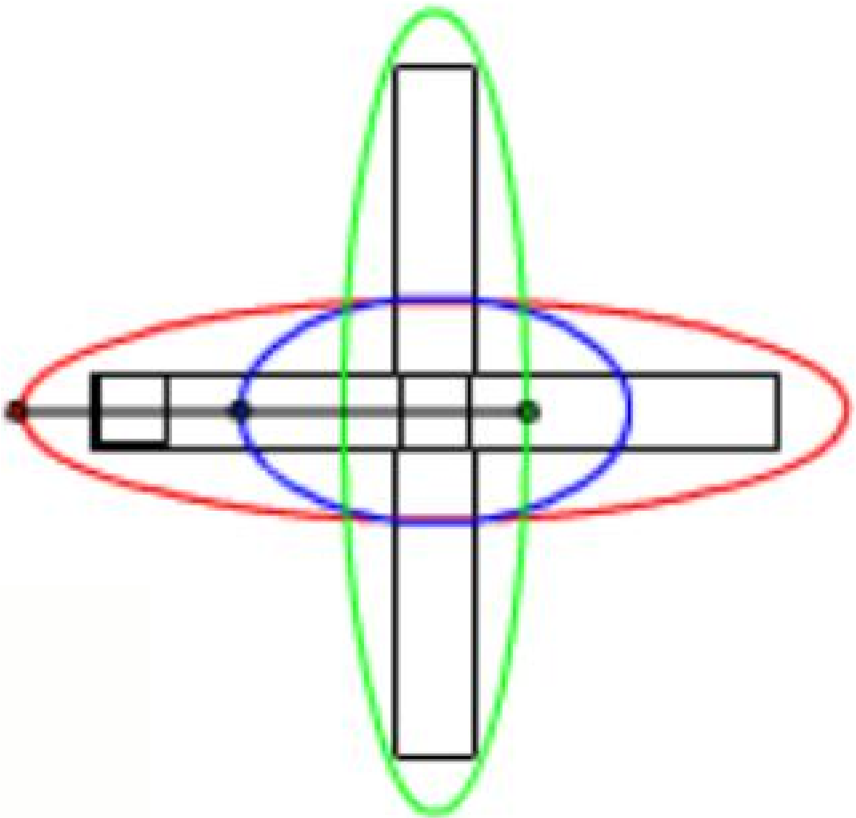


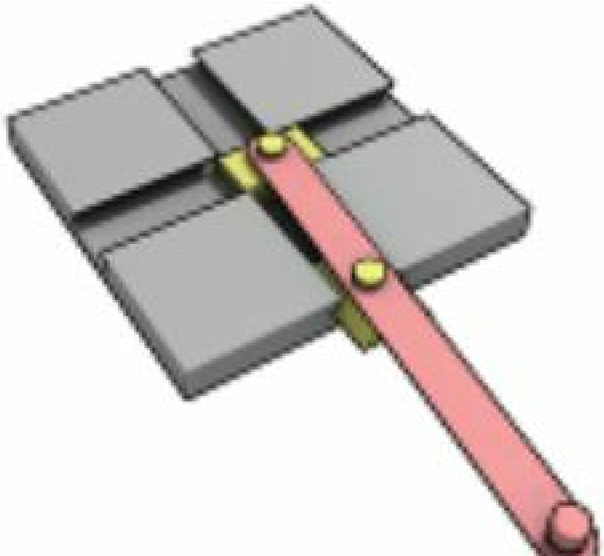


(a)

Elliptical trammels.

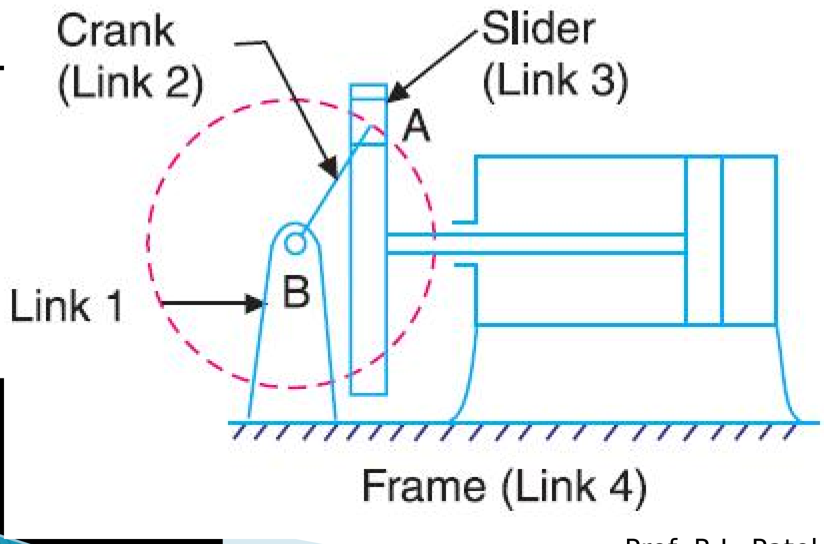




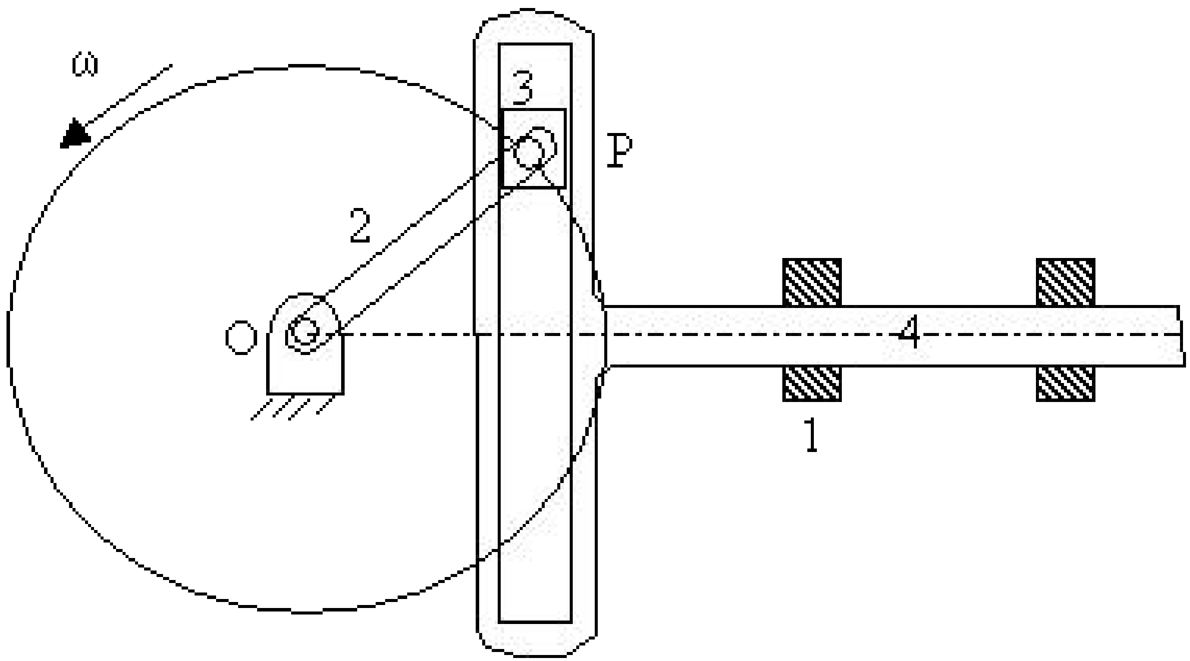


2. *Scotch yoke mechanism.*

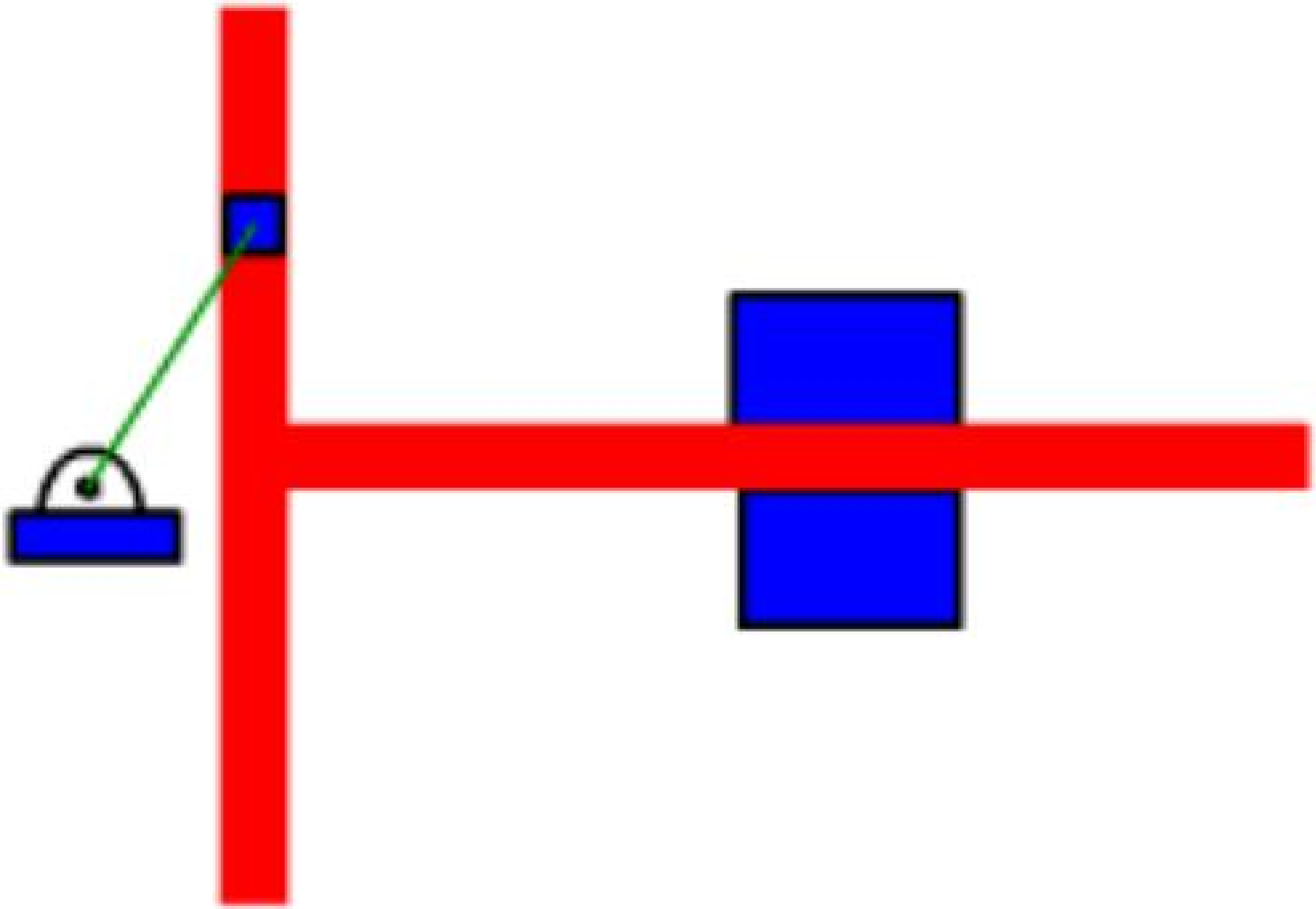
- The **Scotch yoke** is a mechanism for converting the linear motion of a slider into rotational motion or vice-versa. The piston or other reciprocating part is directly coupled to a sliding yoke with a slot that engages a pin on the rotating part.
- This mechanism is used for converting rotary motion into a reciprocating motion. The inversion is obtained by fixing either the link 1 or link 3.
- In Fig. link 1 is fixed.
- In this mechanism, when the link 2 (which corresponds to crank) rotates about B as centre, the link 4 (which corresponds to a frame) reciproc
- The fixed link 1



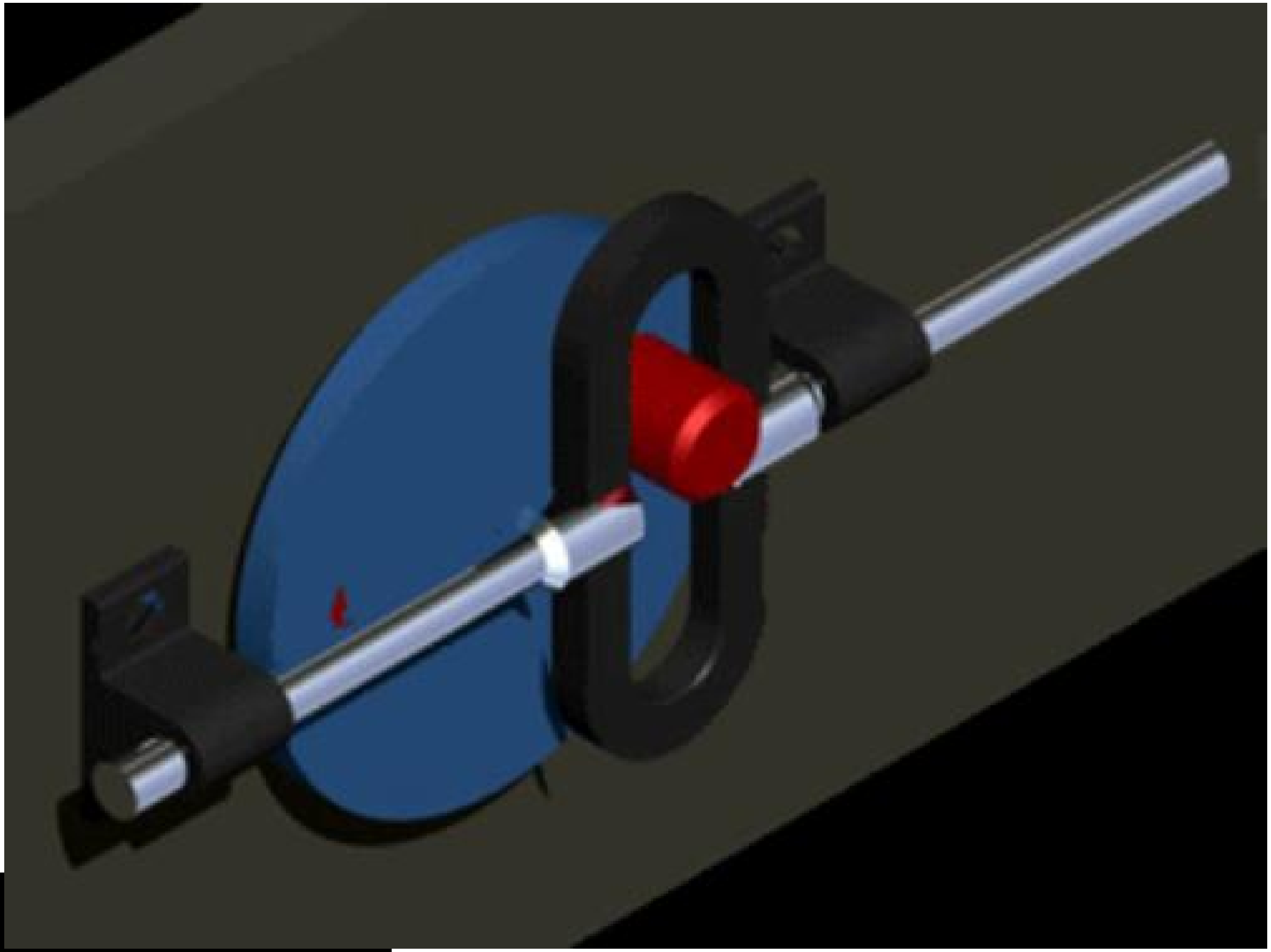
Scotch yoke mechanism.



Scotch yoke mechanism.



Scotch yoke mechanism.



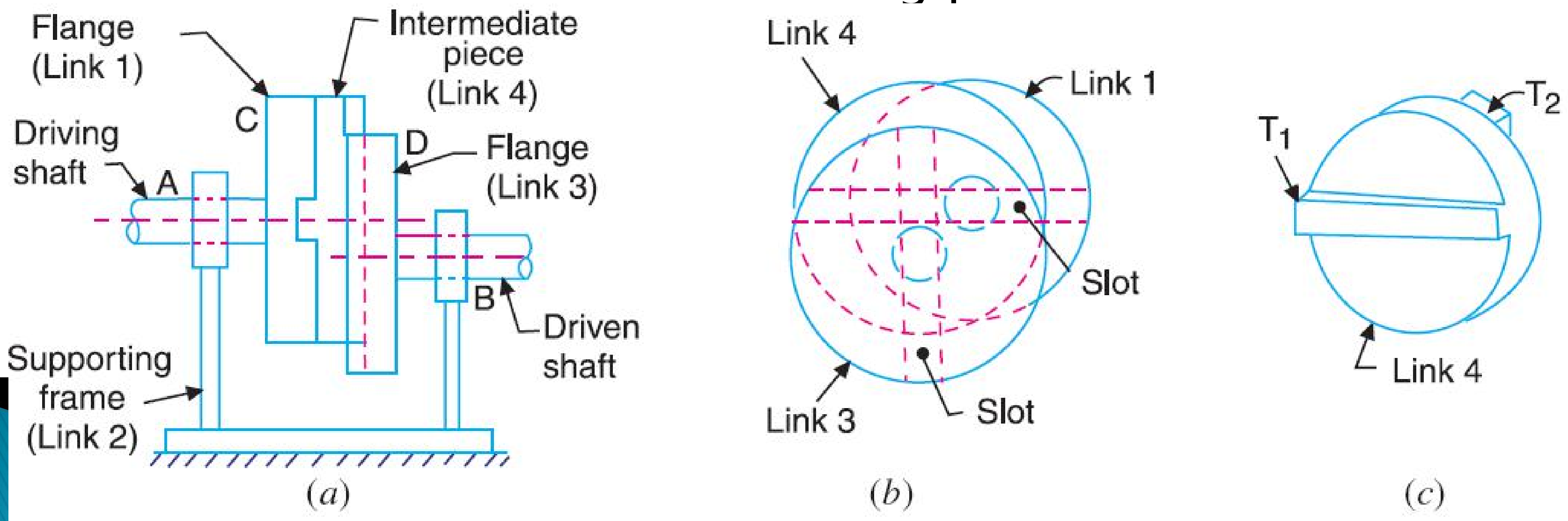
3. Oldham's coupling.

An oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart. The shafts are coupled in such a way that if one shaft rotates, the other shaft also rotates at the same speed.

This inversion is obtained by fixing the link 2, as shown in Fig (a).

The shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging.

The link 1 and link 3 form turning pairs with link 2.

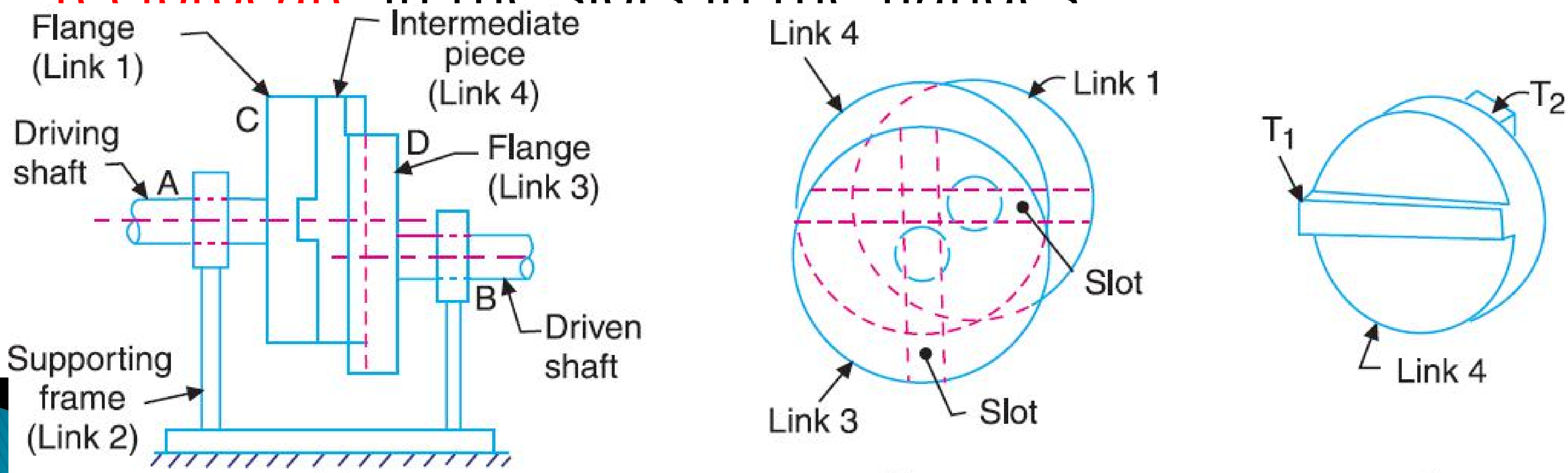


3. Oldham's coupling.

These flanges have diametrical slots cut in their inner faces, as shown in Fig.(b).

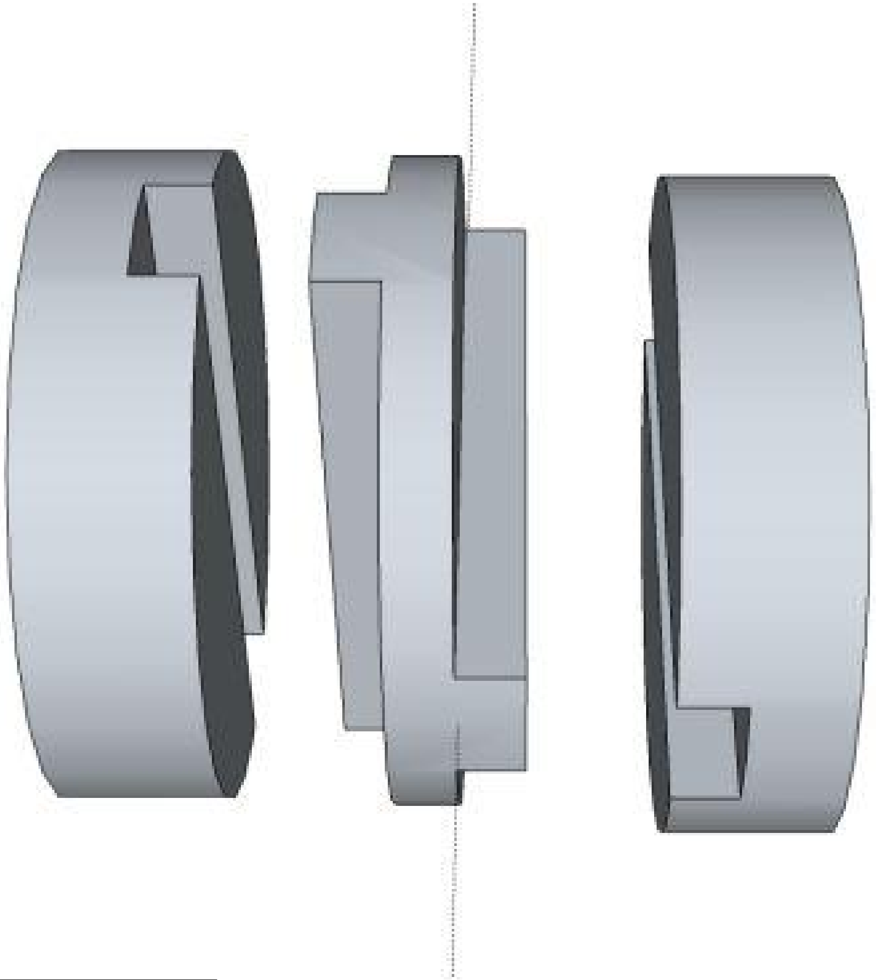
The intermediate piece (link 4) which is a circular disc, have two tongues (i.e. diametrical projections) T1 and T2 on each face at right angles to each other, as shown in Fig. (c).

The tongues on the link 4 closely fit into the slots in the two flanges (link 1 and link 3). The link 4 can slide or reciprocate in the slots in the flanges.

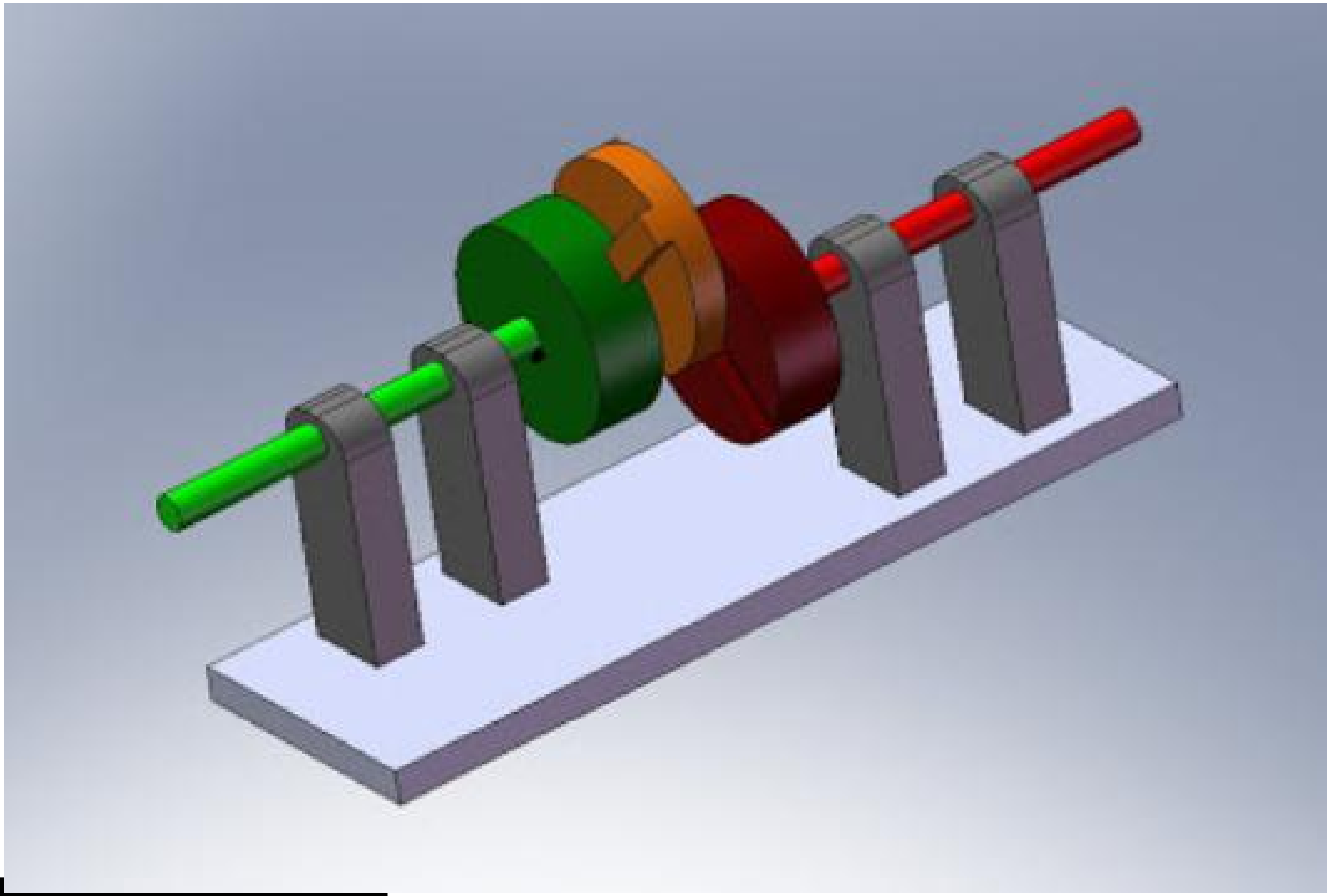


(a) (b) (c)

Oldham's coupling.



Oldham's coupling.



Oldham's coupling.