	BRCM COLLEGE OF ENGINEERING & TECHNOLOGY BAHAL, BHIWANI Practical Experiment Instructions Sheet	**Lab Manual**
KOM Lab	**ME- 212 F KINEMATICS OF MACHINES LAB**	**BRANCH-ME**

List of Experiments :

1. To study various types of Kinematic links, pairs, chains and Mechanisms.

2. To study inversions of 4 Bar Mechanisms, Single and double slider crank mechanisms.

3. To plot slider displacement, velocity and acceleration against crank rotation for single slider crank mechanism.

4. To find coefficient of friction between belt and pulley.

5. To study various type of cam and follower arrangements.

6. To plot follower displacement vs cam rotation for various Cam Follower systems.

7. To generate spur gear involute tooth profile using simulated gear shaping process.

8. To study various types of gears – Helical , cross helical worm, bevel gear.

9. To study various types of gear trains – simple, compound, reverted, epicyclic and differential.

10. To find co-efficient of friction between belt and pulley.

11. To study the working of Screw Jack and determine its efficiency.

12. Create various types of linkage mechanism in CAD and simulate for motion outputs and study the relevant effects.

13. Creation of various joints like revolute, planes, spherical, cam follower and study the degree of freedom and motion patterns available.

14. To design a cam profile by using the requirement graph using on-line engineering handbook and verify the same using a 3D mechanism on CAD.

Note :

1. At least Ten experiments are to be performed in the Semester.

2. At least eight experiments should be performed from the above list. However these experiments should include experiments at Sr. No. 12, 13 and 14. Remaining two experiments may either be performed from the above list or as designed & set by the concerned institution as per the scope of the syllabus.

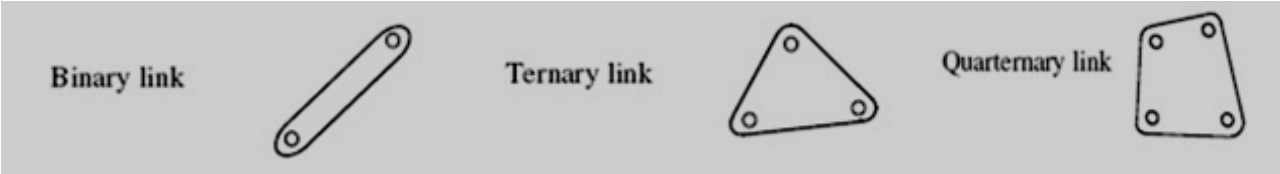
APPARATUS USED: - Kinematics links, pairs, chains & Mechanisms. (Kinematic Pair Board)

THEORY: -

Kinematic Link:

A link is defined as a member or a combination of members of a mechanism connecting other members and having relative motion between them. The link may consist of one or more resistant bodies. A link may be called as kinematic link or element. Eg: Reciprocating steam engine.

Classification of kinematic link is binary, ternary and quaternary



Kinematic pair: Kinematic pair is a joint of two links having relative motion between them. The types of kinematic pair are classified according to

- Nature of contact (lower pair, Higher pair)
- Nature of mechanical contact (Closed pair, unclosed pair)
- Nature of relative motion (Sliding pair, turning pair, rolling pair, screw pair, spherical pair)

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 it is called a kinematic chain.

Eg: The crank shaft of an engine forms a kinematic pair with the bearings which are fixed in a pair, the connecting rod with the crank forms a second kinematic pair, the piston with the connecting rod forms a third

pair and the piston with the cylinder forms the fourth pair. The total combination of these links is a kinematic chain.

Eg: Lawn mover

Here, we had to check whether the given link is a kinematic chain We can use two formulas

1. $l = 2p-4$

2. $j= (3/2)l – 2$

Mechanism:

If motion of any of the movable links results in definite motions of the others the linkage is known as mechanism

Machine:

When a mechanism is required to transmit power or to do some particular type of work it then becomes a machine.

APPARATUS USED: - Single slider crank mechanism & double slider crank mechanism.

THEORY: -

FOUR BAR MECHANISM: - A four bar link mechanism or linkage is the most fundamental of the plane kinematics linkages. Basically it consists of four rigid links which are connected in the form of a quadrilateral by four pin joints.

INVERSIONS OF SINGLE SLIDER–CRANK CHAIN :-

Different mechanisms obtained by fixing different links of a kinematics chain are known as its inversions. A slider – crank chain has the following inversions :-

- **First inversion (**i.e; Reciprocating engine and compressor)
- **Second inversion** (i.e., Whitworth quick return mechanism and Rotary engine)
- **Third inversion** (i.e., Oscillating cylinder engine and crank & slotted – lever mechanism)
- **Fourth inversion** (Hand pump)

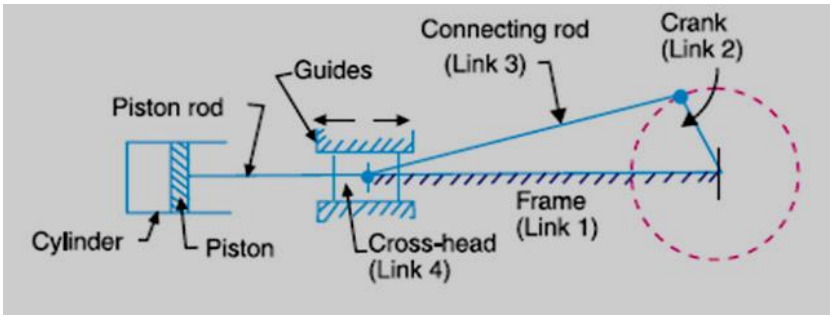
INVERSIONS OF DOUBLE-SLIDER CRANK-CHAIN:

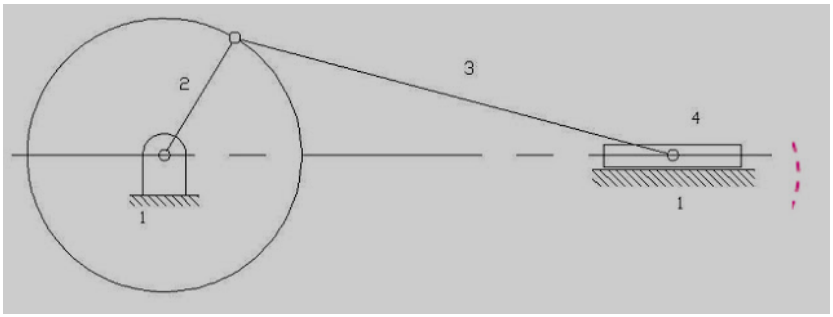
A four-bar chain having two turning and two sliding pairs such that two pairs of the same kind are adjacent is known as a double-slider-crank chain. The following are its inversions:

- **First inversion** (i.e., Elliptical trammel)
- **Second inversion** (i.e., Scotch yoke)
- **Third inversion** (i.e., Actual Oldham's coupling)

PROCEDURE:

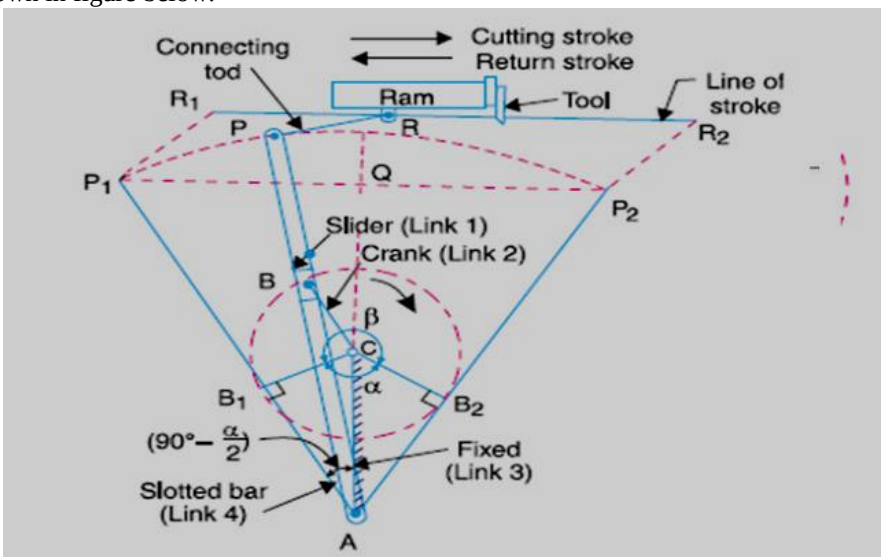
Reciprocating engine mechanism: In the first inversion, the link 1 i.e., the cylinder and the frame is kept fixed. The fig below shows a reciprocating engine.





slotted link 1 is fixed. When the crank 2 rotates about O, the sliding piston 4 reciprocates in the slotted link 1. This mechanism is used in steam engine, pumps, compressors, I.C. engines, etc.

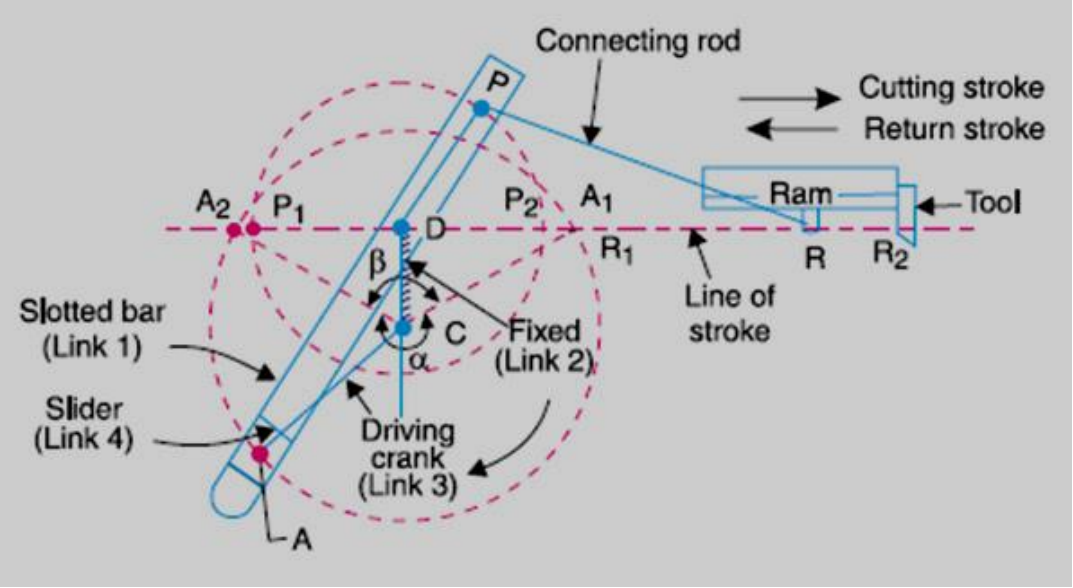
Crank and slotted lever mechanism: It is an application of second inversion. The crank and slotted lever mechanism is shown in figure below.



This mechanism is used in shaping machines, slotting machines and in rotary engines.

In this mechanism link 3 is fixed. The slider (link 1) reciprocates in oscillating slotted lever (link 4) and crank (link 2) rotates. Link 5 connects link 4 to the ram (link 6). The ram with the cutting tool reciprocates perpendicular to the fixed link 3. The ram with the tool reverses its direction of motion when link 2 is
perpendicular to link 4. Thus the cutting stroke is executed during the rotation of the crank through angle α and the return stroke is executed when the crank rotates through angle β or 360 – α. Therefore, when the crank rotates uniformly, we get,

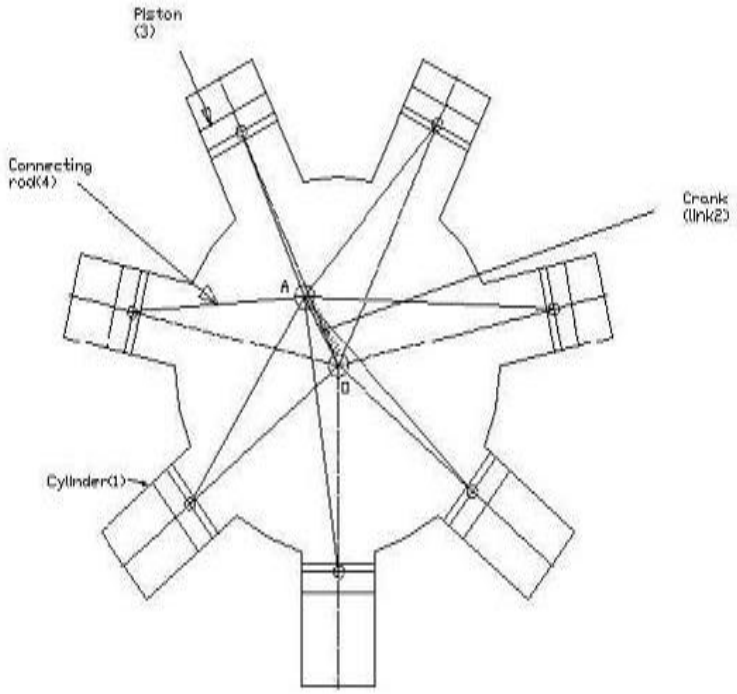
Whitworth quick return motion mechanism:



Third inversion is obtained by fixing the crank i.e. link 2. Whitworth quick return mechanism is an application of third inversion.

Rotary engine mechanism or Gnome Engine:

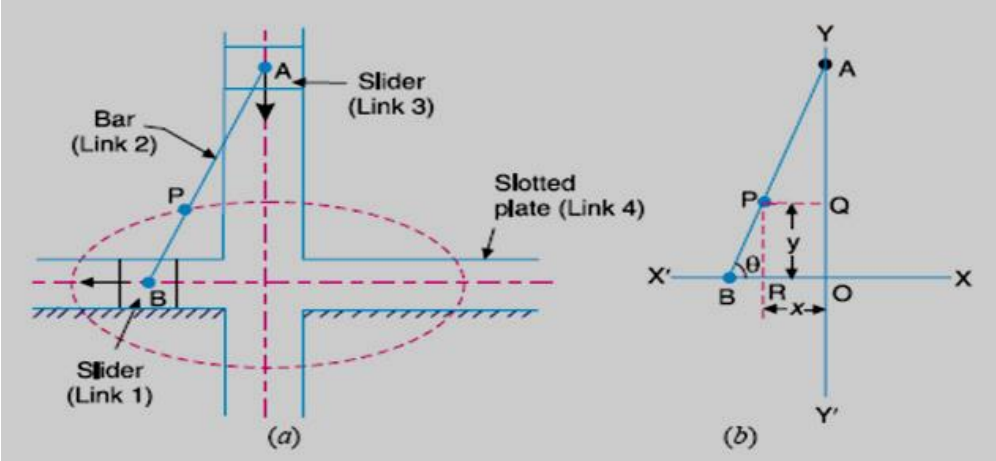
Rotary engine mechanism or gnome engine is another application of third inversion. It is a rotary cylinder V – type internal combustion engine used as an aero – engine.



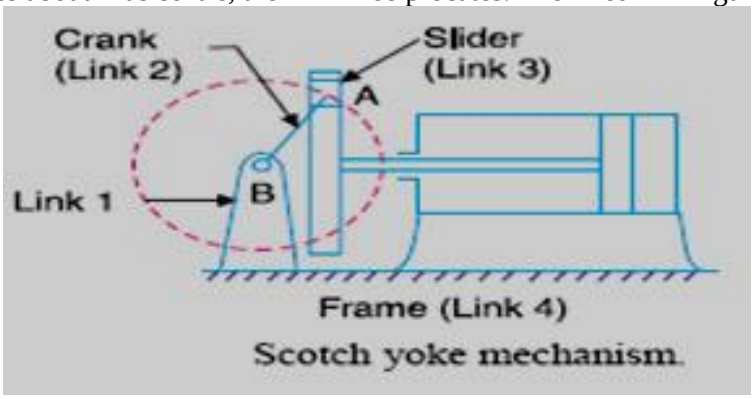
Double Slider Crank Chain: A four bar chain having two turning and two sliding pairs such that two pairs of the same kind are adjacent is known as double slider crank chain.

Inversions of Double slider Crank chain: It consists of two sliding pairs and two turning pairs. There are three important inversions of double slider crank chain. 1) Elliptical trammel. 2) Scotch yoke mechanism. 3) Oldham's Coupling.

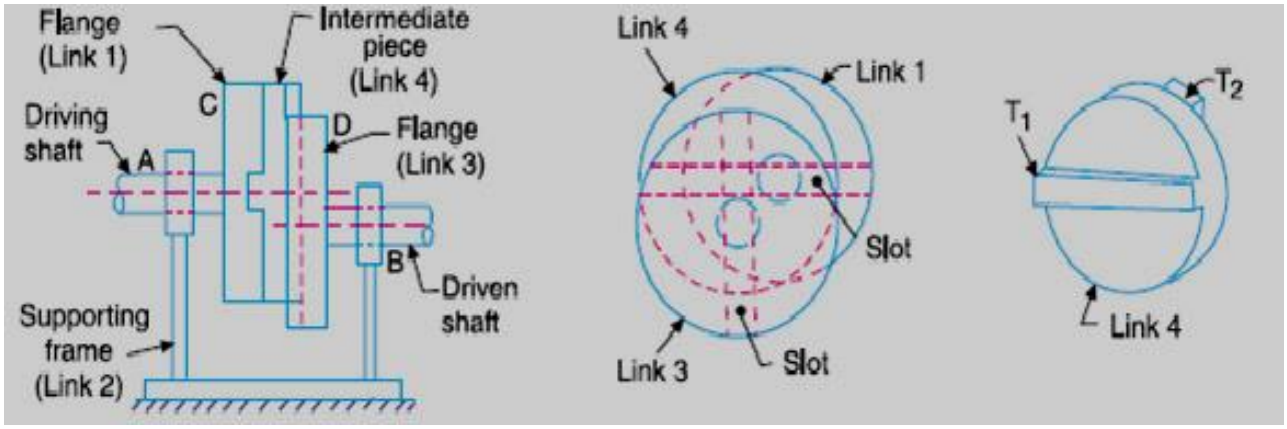
Elliptical Trammel: This is an instrument for drawing ellipses. Here the slotted link is fixed. The sliding block P and Q in vertical and horizontal slots respectively. The end R generates an ellipse with the displacement of sliders P and Q.



Scotch yoke mechanism: This mechanism is used to convert rotary motion in to reciprocating motion.The inversion is obtained by fixing either the link 1 or link 3. Link I is fixed. In this mechanism when the link 2 rotates about B as centre, the link 4 reciprocates. The fixed link 1 guides the frame.



Oldham's coupling: The third inversion of obtained by fixing the link connecting the 2 blocks P & Q. If one block is turning through an angle, the frame and the other block will also turn through the same angle. It is shown in the figure below.



APPARATUS USED:- Belt & Pulley System.

THEORY:-

Belt: - Power is transmitted from one to another by means of belts.

- Belts are used where the distance between the shafts is large.
- Belts are flexible type of connectors.
- The flexibility of belts and ropes is due to the property of their materials.
- Belts transmit power due to friction between them and the pulleys.
- If the power transmitted exceeds the force of friction, the belt slips over the pulley.
- Belts are strained during motion as tensions are developed in them.
- Owing to slipping and straining action, belts are not positive type of drives.

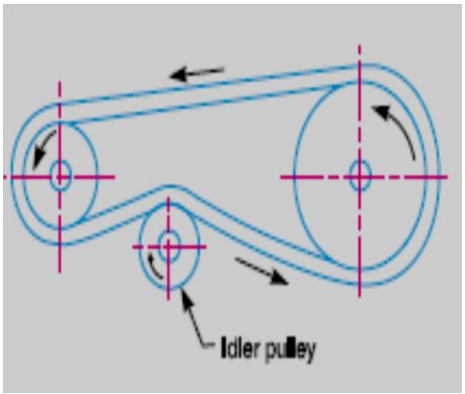
Types of belts :-

1. Flat belt
2. V-belt

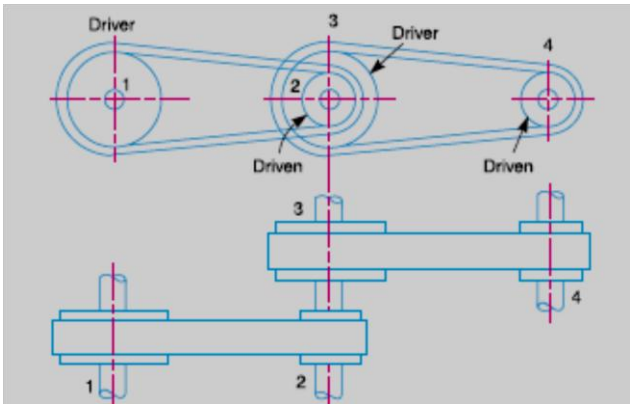
Material for belts :- Usual materials are leather, canvas, cotton and rubber.

PULLEY :- Pulley are mounted on the two shafts. The speed of the driven shaft can be varied by varying the diameters of the pulleys.

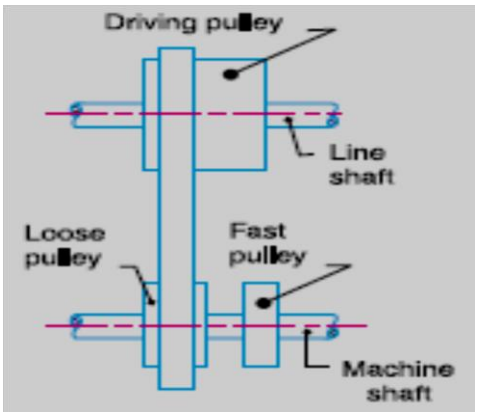
Types of pulleys :-



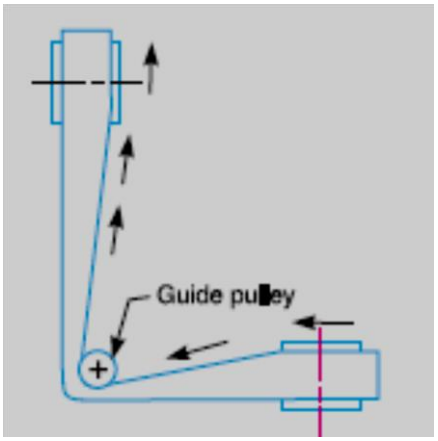
Idler pulleys.



Intermediate pulleys



Loose and fast pulleys



Guide pulleys

FORMULAE USED:-

$T1/T2 = e^{\mu\theta}$

(N/m2)

Where T1 = Tension at the tight side of the belt

T2 = Tension at the slack side of the belt (N/m2)

μ = Co-efficient of Friction between belt and pulley

θ = Arc of contact(rad)

OBSERVATION TABLE :-

Sl. No.	**T1 (N/m2)**	**T2 (N/m2)**	**θ**		**μ = (1/θ)log (T1/ T2)**
			(in degree)	**(in rad.)**	

CALCULATION :- μ = (1/θ)log (T1/ T2)

PROCEDURE:-

1. **Note the angle of contact.**
2. **Hang some weight on one side of the belt and put some weight on other side of the belt, till the belt just slide.**
3. **Note down the values of T1 and T2.**
4. **Vary T1 and correspondingly determine the values of T2.**
5. **Now calculate the value of μ.**

CONCLUSION:- μ (Co-efficient of Friction between belt and pulley) =

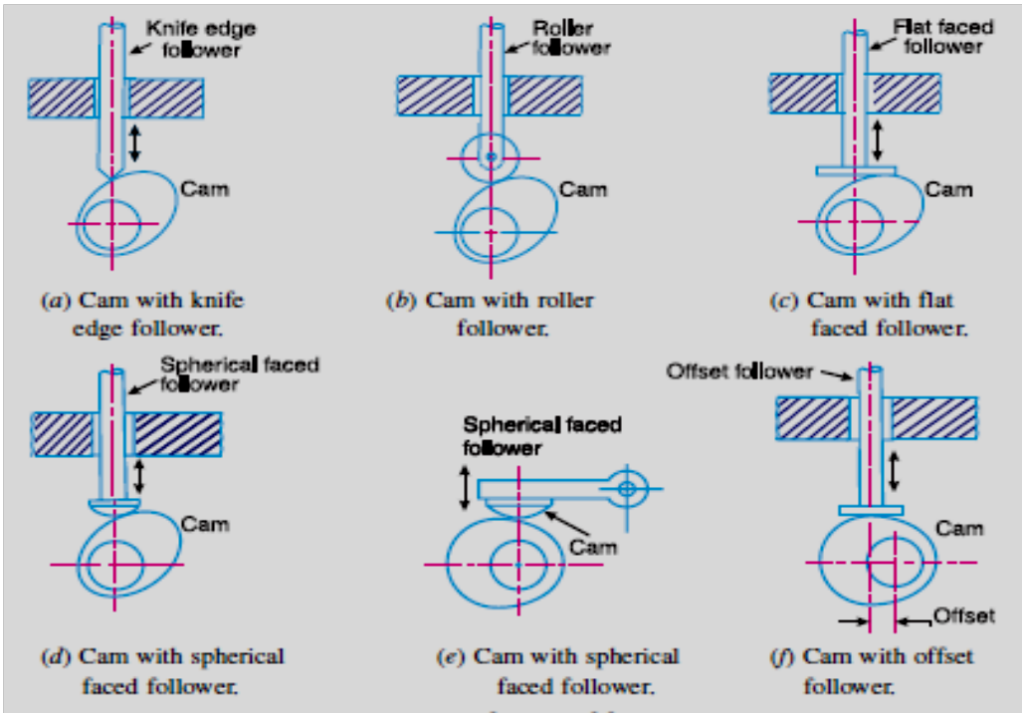
APPARATUS USED: - Cam and follower arrangements.

THEORY: -

CAM & FOLLOWER :- A cam is a mechanical member used to impart desired motion to a follower by direct contact. The cam may be rotating or reciprocating whereas the follower may be rotating, reciprocating or oscillating. A cam and the follower combination belong to the category of higher pairs.

- A driver member known as the cam.
- A driven member called the follower

TYPES OF CAMS:



➢ **According to shape**

I. **wedge and flat Cams :-** A wedge cam has a wedge W which, ingeneral, has a translational motion. The follower. The follower F caneither translate or oscilate.

II. **Radial or Disc Cams :-** A cam in which the follower moves radiallyfrom the centre of rotation of the cam is known as a radial or a disc cam.

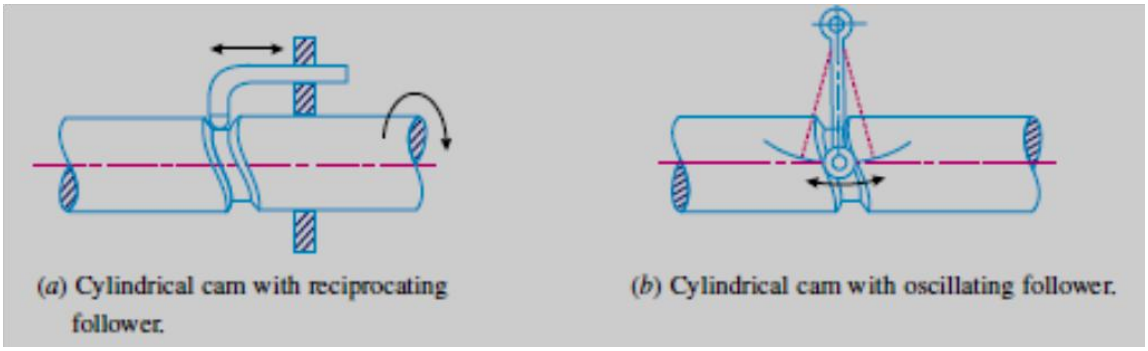
III. **Spiral cams :-** A spiral cam is a face cam in which a groove is cut inthe form of a spiral as shown in fig. the spiral spiral groove consists of teeth which mesh with a pin gear follower.

IV. **Cylindrical cams :-** In a cylindrical cam, a cylinder which has acircumferential contour cut in the surface, rotate about its axis.

V. **Conjugate cams :-** A conjugate cam is a double – disc cam, the twodiscs being keyed together and are in constant touch with the tworollers of a follower. It is used for low noise, high speed and dynamic loads.

VI. **Globoidal cams :-** A globoidal cam can have two types of surfaces,convex or concave. A circumferential contour is cut on the surfaceof rotation of the cam to impart motion to the follower which has an oscillatory motion.

VII. **Spherical cams :-** In a spherical cam, the follower oscillates about anaxis perpendicular to the axis of rotation of the cam.



(*a*) Cylindrical cam with reciprocating follower.

(*b*) Cylindrical cam with oscillating follower.

➢ **According to Follower Movement**

I. **Rise-Return-Rise (R-R-R) :-** In this, there is alternate rise andreturn of the follower with no periods of dwells. Its use is verylimited in the industry. The follower has a linear or an angular displacement.

II. **Dwell-Rise-Return-Dwell (D-R-R-D) :-** In such a type of cam, thereis rise and return of the follower after a dwell. This type is used more frequently than the R-R-R type of cam

III. **Dwell-Rise-Dwell-Return (D-R-D-R) :-** It is most widely used type of cam. The dwelling of the cam is followed by rise and dwell and subsequently by return and dwell.

➢ **According to Manner of Constraint of the Follower**

I. Pre-loaded Spring Cam
II. Positive-Drive Cam
III. Gravity Cam

Types of Followers :-

1. According to shape

- Knife-edge Follower
- Roller Follower
- Mushroom Follower

2. According to Movement

- Reciprocating Follower
- Oscillating Follower

3. According to Locating of Line of Movement

- Radial Follower
- Offset Foolower

APPARATUS USED :- Arrangement of gear system.

THEORY :-

CLASSIFICATION OF GEAR :- Gears can be classified according to the relative position of their shaft axis are follows:

A: PARALLEL SHAFT
(i) Spur gear
(ii) Spur rack and pinion
(iii) Helical gears or Helical spur gear
(iv) Double- helical and Herringbone gear

B: INTER SECTING SHAFT
(i) Straight bevel gear
(ii) Spiral bevel gear
(iii) Zerol bevel gear

C: SKEW SHAFT
(i) Crossed- helical gear
(ii) Worm gears(Non-throated, Single throated, Double throated)

SPUR GEAR:- They have straight teeth parallel to the axes and thus are not subjected to axial thrust due to teeth load. Spur gears are the most common type of gears. They have straight teeth, and are mounted on parallel shafts. Sometimes, many spur gears are used at once to create very large gear reductions. Each time a gear tooth engages a tooth on the other gear, the teeth collide, and this impact makes a noise. It also increases the stress on the gear teeth. ***Spur gears*** are the most commonly used gear type. They are characterized by teeth, which are perpendicular to the face of the gear. Spur gears are most commonly available, and are generally the least expensive.

HELICAL GEARS:- In helical gears, the teeth are curved, each being helical in shape. Two mating gears have the same helix angle, but have teeth of opposite hands. At the beginning of engagement, contact occurs only at the point of leading edge of the curved teeth. As the gears rotate, the contact extends along a diagonal line across the teeth.

Thus the load application is gradual which result in now impact stresses and reduction in noise. Therefore, the helical gears can be used at higher velocities then the spur gears and have greater load – carrying capacity. The teeth on helical gears are cut at an angle to the face of the gear. When two teeth on a helical gear system engage, the contact starts at one end of the tooth and gradually spreads as the gears rotate, until the two teeth are in full engagement. This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears. For this reason, helical gears are used in almost all car transmission. Because of the angle of the teeth on helical gears, they create a thrust load on the gear when they mesh. Devices that use helical gears have bearings that can support this thrust load.

DOUBLE HELICAL AND HERRING BONE GEARS :- A- double- helical gear is equivalent to a pair of helical gears secured together, one having a right – hand helix and the other a left hand helix. The tooth of two raw is separated by a grooved used for too run out.

If the left and the right inclinations of a double – helical gear meet at a common apex and there is no groove in between, the gear is known as herring bone gear.

CROSSED – HELICAL GEAR :- The used of crossed helical gear or spiral gears is limited to light loads. By a suitable choice of helix angle for the mating gears, the two shaft can be set at any angle.

WORM GEAR :- Worm gear is a special case of spiral gear in which the larger wheel, usually, has a hollow or concave shape such that a portion of the pitch diameter is the other gear is enveloped on it. The smaller of two wheels is called the worm which also has larger spiral angle. ***worm gear****:* Worm gears are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater.

BEVEL GEAR :- Kinematically, the motion between two intersecting shafts is equivalent to the rolling of two cones, assuming no slipping. The gears, in general, are known as bevel gear. When teeth formed on the cones are straight, the gear are known as straight bevel and when inclined, they are known as spiral or helical bevel.

APPARATUS USED: - Models of Gear train system.

THEORY: -

GEAR TRAIN :- A gear train is a combination of gears used to transmit motion from one shaft to another. It becomes necessary when it is required to obtain large speed reduction within a small space. The following are the main types of gear trains:

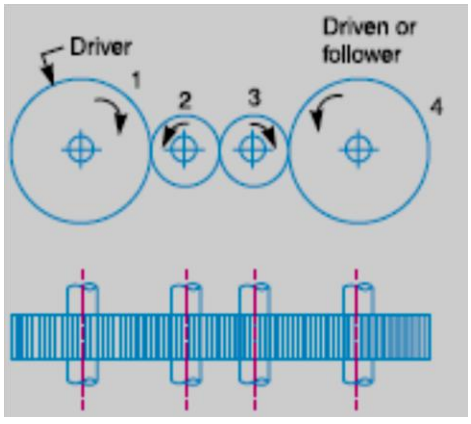
(i) Simple gear train
(ii) Compound gear train
(iii) Reverted gear train
(iv) Planetary gear train

SIMPLE GEAR TRAIN :- A series of gears, capable of receiving and transmitting motion from one gear to another is called a simple gear train. In it, all the gear axes remain fixed relative to the frame and each gear is on a separate shaft.

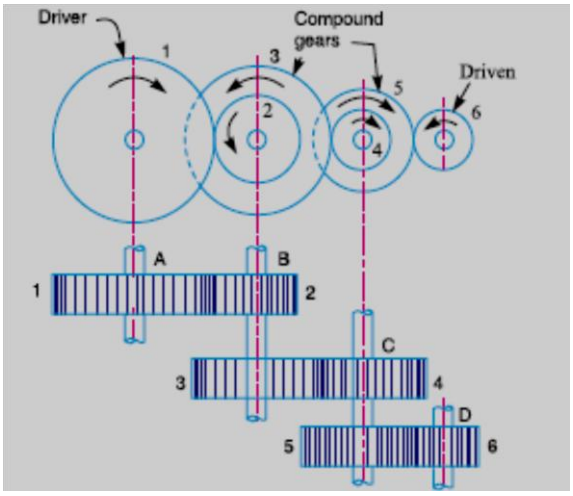
Train Value = Number of teeth on driving gear / Number of teeth on driven gear

COMPOUND GEAR TRAIN :- When a series of gears are connected in such a way that two or more gears rotate about an axis with the same angular velocity, it is known as compound gear train. In this type, some of the intermediate shafts.

Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear



SIMPLE GEAR TRAIN DIAGRAM



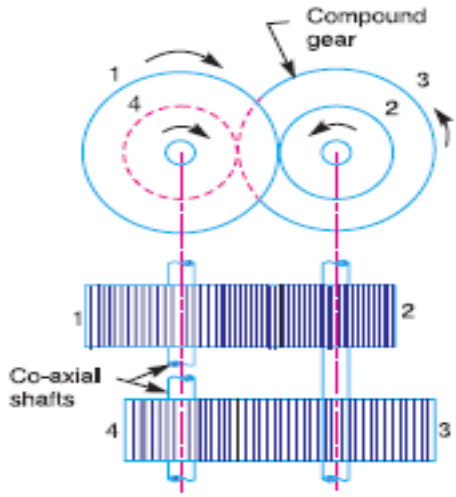
COMPOUND GEAR TRAIN DIAGRAM

REVERTED GEAR TRAIN :- If the axes of the first and last wheels of a compound gear coincide; it is called a reverted gear train. Such an arrangement is used in clocks and in simple lathes where 'back gear' is used to give a slow speed to the chuck.

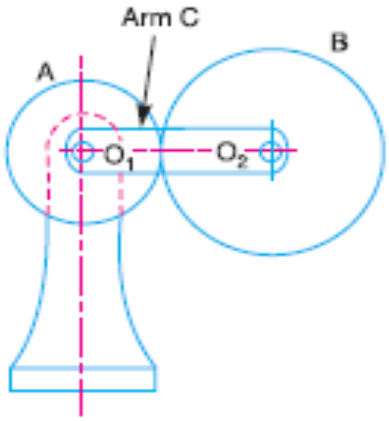
Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear

PLANETARY OR EPICYCLIC GEAR TRAIN :- When there exists a relative motion of axis in gear train, it is called a planetary or an epicyclic gear train (or simply epicyclic gear or train). Thus in an epicyclic train, the axis of at least one of the gears also moves relative to the frame.

Consider two gear wheels S and P, the axis of which are connected by an arm a. if the arm ‘a’ is fixed, the wheels S and P constitute a simple train. However, if the wheel s is fixed so that the arm can rotate about the axis of S, the wheel P would also move around S. therefore, it is an epicyclic train.



REVERTED GEAR TRAIN DIAGRAM



PLANETARY OR EPICYCLIC GEAR TRAIN DIAGRAM

APPARATUS USED:- Screw jack

THEORY :-

Screw Jack :- It is a device employed for lifting heavy loads with help of a small effort applied at its handle. The loads are usually centrally loaded upon it. Screw jacks of three types :

1. Simple screw jack
2. Compound Screw jack
3. Differential Screw jack

A simple screw jack consists of a nut, a screw square threaded and a handle fitted to the head of the screw. The nut also forms the body of the jack. The load to be lifted is placed on the head of the screw. Here the axial distance between corresponding points on two consecutive threads is known as pitch. If 'p' be the pitch of the screw and 't' is the thickness of thread, then p = 2t.

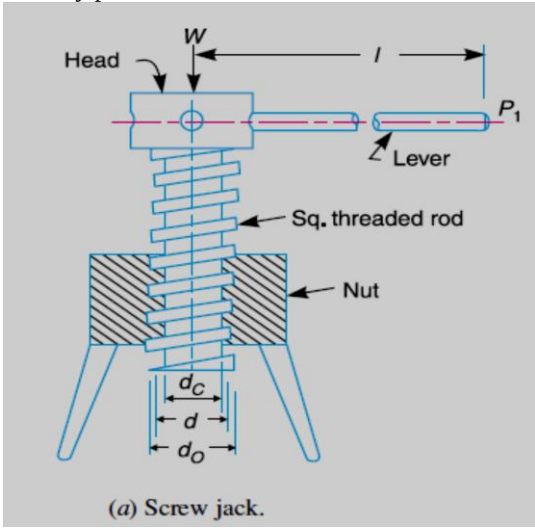
V.R. = Distance moved by the effort/Distance moved by the load

$= 2\pi l / p$

Now M.A. = W / P

PROCEDURE :-

When we are moving the handle horizontal direction the screw is also moved it attached with screw and load is lifted by pitch of the screw, in one revolution of the handle.



(a) Screw jack.

OBSERVATION :-

For simple Screw Jack :

S.No.	Load (W) in Nt.	Effort (P) (P) in Nt.	Length of Lever lever	Pitch of screw screw	V.R.	M.A.	Efficiency

CALCULATION :-

M.A. = W/P

V.R. = Distance moved by effort/Distance moved by load

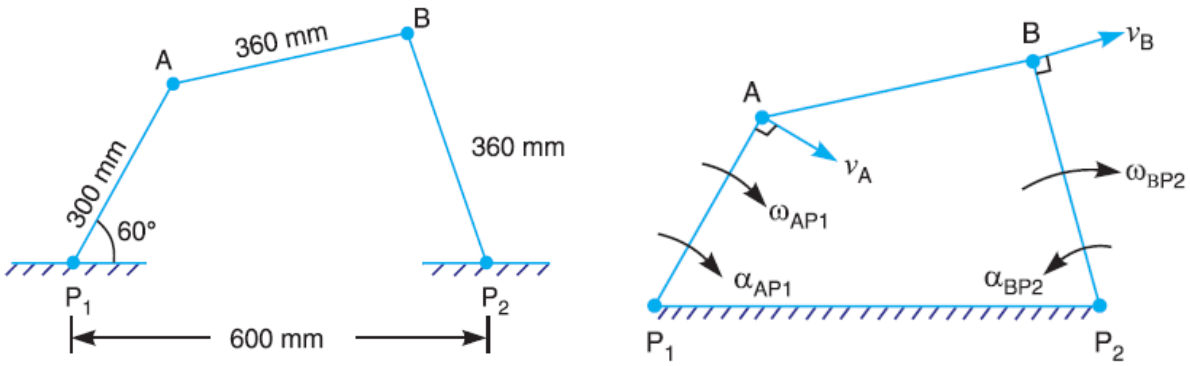
Efficiency = M.A. / V.R.

Conclusion: Hence the efficiency of screw jack is _____.

Solution:

Given : ω_{AP1} = 10 rad/s ; α_{AP1} = 30 rad/s2; P_1A = 300 mm = 0.3 m ; P_2B = AB =360 mm = 0.36 m
We know that the velocity of A with respect to P_1 or velocity of A,

$V_{AP1} = V_A = \omega_{AP1} \times P_1A = 10 \times 0.3 = 3$ m/s



VELOCITY DIAGRAM:

1. Choosing appropriate scale; draw vector ap (V_{AP1}=3 m/s).
2. Draw fixed point P1 & P2 by single point in velocity diagram.
3. From point a, draw vector ab perpendicular to AB to represent velocity of B with respect to A.
4. from point p_2 draw vector p_2b perpendicular to P_2B to represent the velocity of B with respect to P_2 or velocity of B.
5. The vectors ab and p_2b intersect at b.
6. By measurement, we find that p_2b = 2.2 m/s
7. We know that angular velocity of P_2B,and angular velocity of AB,

$$\omega_{P2B} = \frac{v_{BP_2}}{P_2B} = \frac{2.2}{0.36} = 6.1 \text{ rad/s (Clockwise)}$$

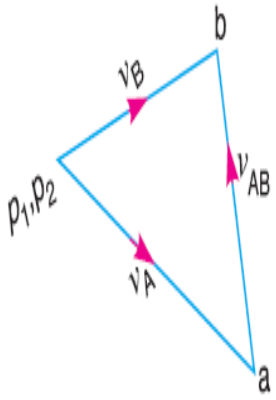
$$\omega_{AB} = \frac{v_{BA}}{AB} = \frac{2.05}{0.36} = 5.7 \text{ rad/s (Anticlockwise)}$$

ACCELERATION DIAGRAM:

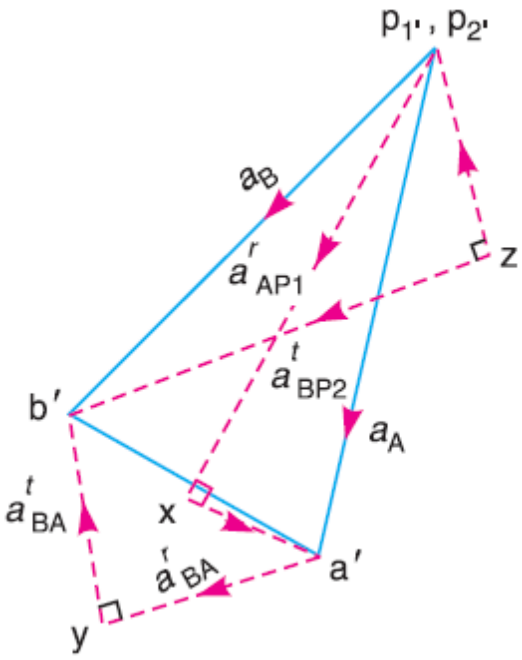
1. Since P_1 and P_2 are fixed points, therefore these points will lie at one place, in the acceleration diagram. Draw vector $p_1' x$ parallel to P_1A, to some suitable scale, to represent the radial component of the acceleration of A with respect to P_1.
2. From point x, draw vector xa' perpendicular to P_1A to represent the tangential component of the acceleration of A with respect to P_1.
3. Join $p_1' a'$. The vector $p_1' a'$ represents the acceleration of A. By measurement, we find that the acceleration of A.
4. From point a', draw vector $a' y$ parallel to AB to represent the radial component of the acceleration of B with respect to A
5. From point y, draw vector yb' perpendicular to AB to represent the tangential component of the acceleration of B with respect to A
6. Now from point p'_2 ,draw vector p'_2z parallel to P_2B to represent the radial component of the acceleration B with respect to P_2.
7. From point z, draw vector zb' perpendicular to P_2B to represent the tangential component of the acceleration of B with respect to P_2.
8. The vectors yb' and zb' intersect at b'. Now the vector $p_2' b'$ represents the acceleration of B with respect to P_2 or the acceleration of B.

$$\alpha_{P2B} = \frac{a^t_{BP_2}}{P_2B} = \frac{26.6}{0.36} = 73.8 \text{ rad/s}^2 \text{ (Anticlockwise)}$$

$$\alpha_{AB} = \frac{a^t_{BA}}{AB} = \frac{13.6}{0.36} = 37.8 \text{ rad/s}^2 \text{ (Anticlockwise)}$$



VELOCITY DIAGRAM



ACCELERATION DIAGRAM

THEORY:

Types of Follower motion:

(1)Simple Harmonic Motion

(2) Uniform Velocity

(3) Uniform Acceleration and Retardation

(4) Cycloidal Motion

1. Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Velocity:

The displacement, velocity and acceleration diagrams when a knife-edged follower moves with uniform velocity are shown in Fig.1

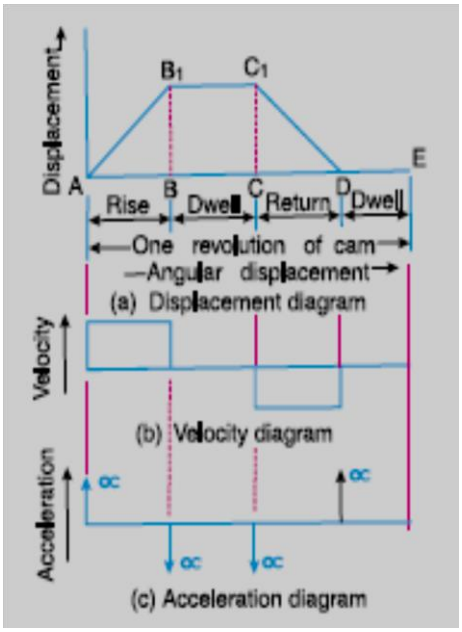


Fig.1

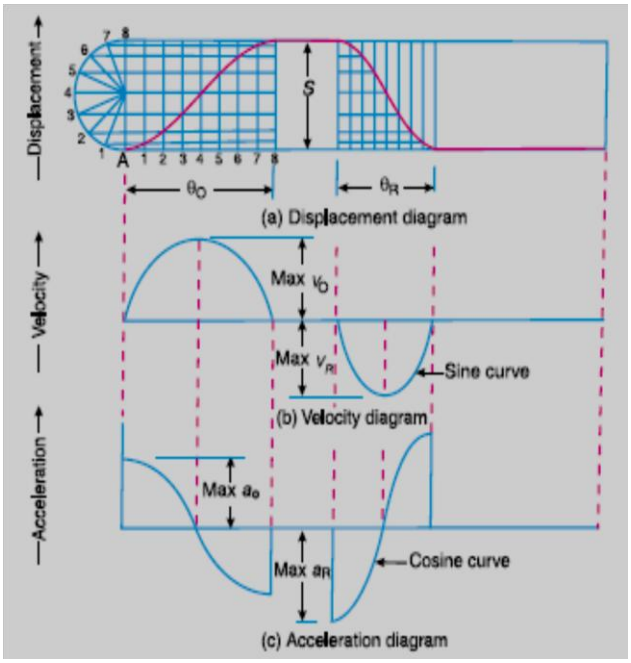


Fig.2

2.Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Simple Harmonic Motion:

The displacement, velocity and acceleration diagrams when the follower moves with simple harmonic motion are shown in above Fig.2

3. Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Acceleration and Retardation:

The displacement, velocity and acceleration diagrams when the follower moves with uniform acceleration and retardation are shown in Fig.3

4 <u>Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Cycloidal Motion:</u>

The displacement, velocity and acceleration diagrams when the follower moves with cycloidal motion are shown in Fig.4

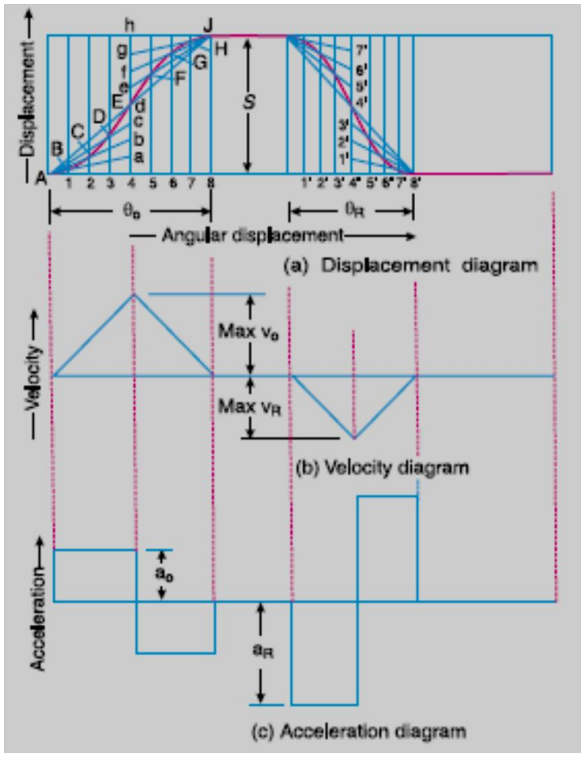


Fig.3

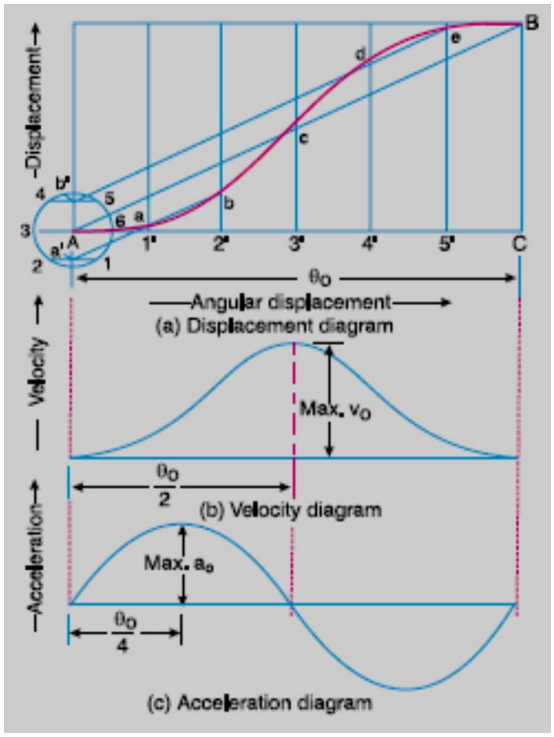
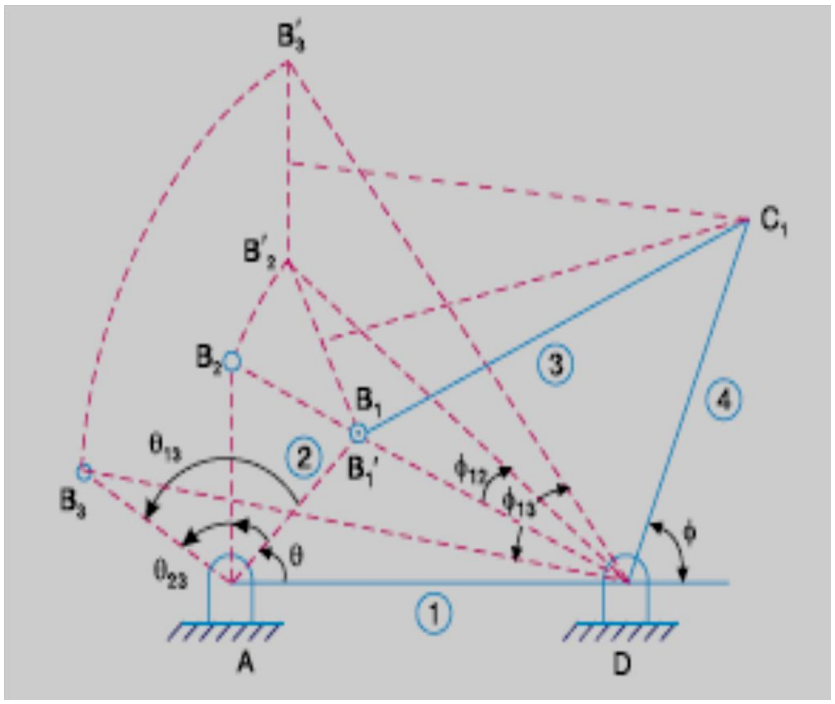


Fig.4

THEORY:

1. Draw *AD* equal to the known length of fixed link, as shown in Figure.
2. At *A*, draw the input link 1 in its three specified angular positions AB_1, AB_2 and AB_3.
3. Since we have to invert the mechanism on link 4, therefore draw a line B_2D and and rotate it clockwise (in a direction opposite to the direction in which link 1 rotates) through an angle ϕ_{12} (*i.e.* the angle of the output link 4 between the first and second position) in order to locate the point B'_2.
4. Similarly, draw another line B_3D and rotate it clockwise through an angle ϕ_{13} (*i.e.* angle of the output link between the first and third position) in order to locate point B'_3.
5. Since the mechanism is to be inverted on the first design position, therefore B_1 and B'_1 are coincident.
6. Draw the perpendicular bisectors of the lines $B'_1B'_2$ and $B'_2B'_3$ These bisectors intersect at point C_1.
7. Join B'_1X_1 and C_1D . The figure AB'_1C_1D is the required four bar mechanism. Now the length of the link 3 and length of the link 4 and its starting position (ϕ) are determined.



Two position synthesis of four bar chain