

## EXPERIMENT 1

AIM: To study inversions of four bar mechanism, Single and double slider crank mechanisms.

### Theory of Inversion;

A mechanism is one in which one of the links of a kinematic chain is fixed. Different mechanisms can be obtained by fixing different links of the same kinematic chain. These are called as inversions of the mechanism. It is made clear that possible number of inversions are same as the number of links in a mechanism.

Three Mechanism will be studied here for their inversions.

- Four Bar Mechanism
- Single Slider Mechanism
- Double Slider Mechanism

### 1. Inversion of Four bar Mechanism

A four-bar mechanism consists of four rigid link which are linked in the form of Quadrilateral by four pin joints. A link that makes complete revolution is called *crank*, the link opposite to the fixed link is the *coupler* and fourth link is a *lever* or *rocker* if oscillates or another crank if rotates.

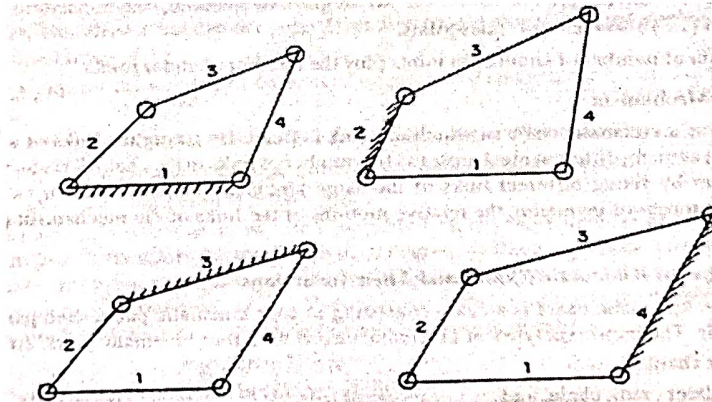


Fig 2.1

In case of four-bar mechanism, the following points must be remembered:

- (i) If the length of one of the links is greater than the sum of the lengths of the other three links, four-bar mechanism is not possible.
- (ii) The four links may be of different lengths. But according to Grashof's law for a four-bar mechanism, the sum of the lengths of the shortest and longest link should not be greater than

the sum of lengths of the remaining two links for continuous relative motion between the two links.

(iii) One of the links (shortest link) should make a complete revolution relative to the other three links.

The three type of inversions are obtained by changing the position of shortest link; such as frame, crank, coupler. Due to this following type of inversion can be found.

- By fixing Shortest Link: We get Double Crank Mechanism
- Shortest Link as Crank/ follower: Crank lever mechanism
- Shortest link as Coupler: Rocker –Rocker Mechanism

**Activity: To demonstrate the above mechanism, let us assume the length of links as; 40, 60, 110, 120 mm.**

Assuming initial position of four bar mechanism as 45 degree. We can draw the four-bar mechanism. By fixing shortest link check the movability of the crank and follower.

To do that proceed as;

- I. Draw a Four bar mechanism ABCD, taking 40mm frame, crank as 60 mm, coupler as 110 and follower as 120mm. Draw Crank at 45 degree. Let us assume AD is frame.
- II. Now draw circles of 60 mm radius from point A. and 110 mm from D.
- III. Divide the crank circle in equal parts after angle 45 deg as 0, 1, 2, 3, 4..... From point 1, Mark distant 120 mm from circumference of crank circle to the circumference of follower circle. Join the points, four bar mechanism obtained.
- IV. Keep marking points till full revolution of crank and follower is obtained.
- V. It is seen here that as crank moves in anti-clockwise, follower also moves (rotates) in same direction.
- VI. Each time distance 120 mm is cut on follower circle. For each point at crank circle, there is a unique point on the follower circle at distance of 120mm (coupler Distance).
- VII. This way we get double crank mechanism.

**Note: Study for other two types of mechanism; Crank-Rocker and Rocker-Rocker can be obtained by similar way.**

## 2. Inversion of Single Slider Mechanism

**1<sup>st</sup> Inversion:** When link 1 is fixed, link 2 is made crank and link 4 is made slider, then first inversion of single slider crank chain is obtained.

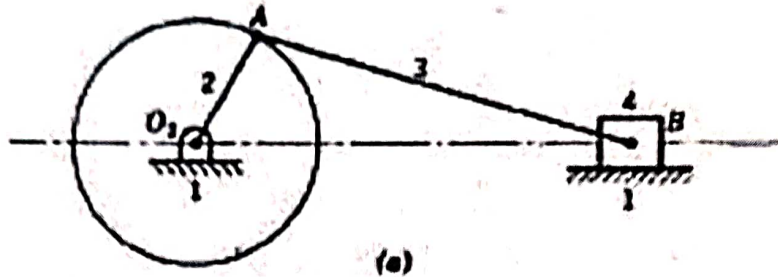


Fig 2.2

**2<sup>nd</sup> Inversion:** When link 2 (or crank) of Fig.2.2 is fixed, the second inversion of single slider crank obtained as shown in Fig. 2.3. Link 3 along with the slider at its end C, becomes a crank. Hence link 3 along with slider (link 4) rotates about B. By doing so, the link 1 rotates about A along with the slider (link 4) which reciprocates on link 1. This inversion is used in Whitworth quick-return mechanism and rotary engine.

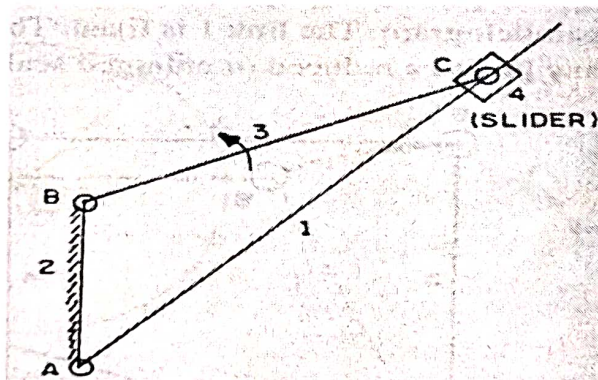


Fig 2.3

**a) Whitworth Quick-Return Mechanism.**

This mechanism is used in workshops to cut metals. The forward stroke cuts the metal whereas the return stroke is idle. The forward stroke takes a little longer period whereas the return stroke takes a shorter period. Fig.2.4 shows this mechanism in which link 2 is fixed. The link 3 along with its slider (i.e. link 4) rotates in a circle about B. By doing so, the link 1 rotates about A along with the slider which reciprocates on link 1. On the link 1, produced downward there is a point D, where link 5 is connected. The other end of the link 5 is connected to the tool (link

6). The forward stroke of the tool cuts the metal whereas the return stroke is idle. The point D rotates in a circle about point A.

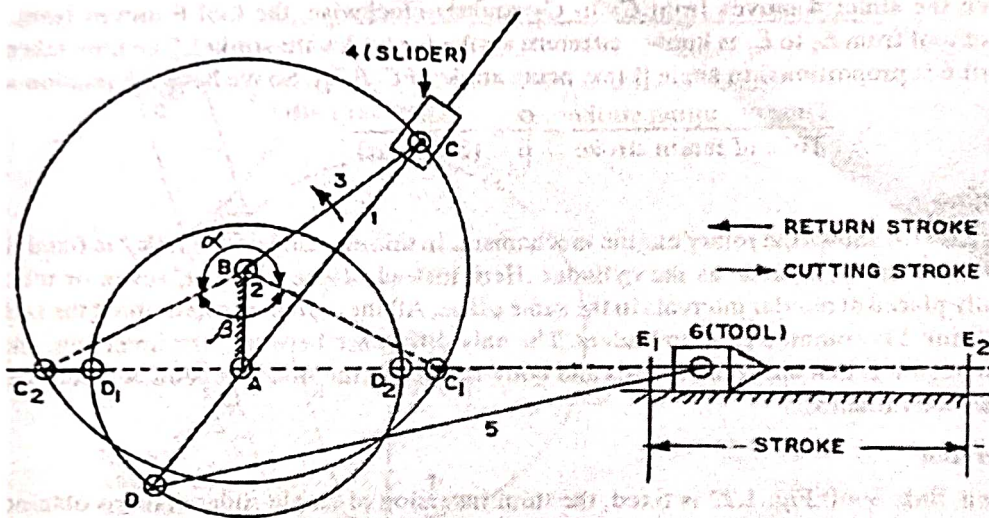


Fig 2.4

**b) Rotary Engine**

Fig.2. 5 shows the rotary engine mechanism. In this mechanism the link 2 is fixed. Link 4 is made as the piston and link 1 is made as the cylinder. Here instead of one cylinder, seven or nine cylinders are symmetrically placed at regular intervals in the same plane. All the cylinders rotate about the same fixed centre A. The fixed link 2 is common to all cylinders. The only difference between first inversion, and this example of second inversion is that the crank rotates and body is fixed in the first inversion, whereas here the crank is fixed and the body rotates.

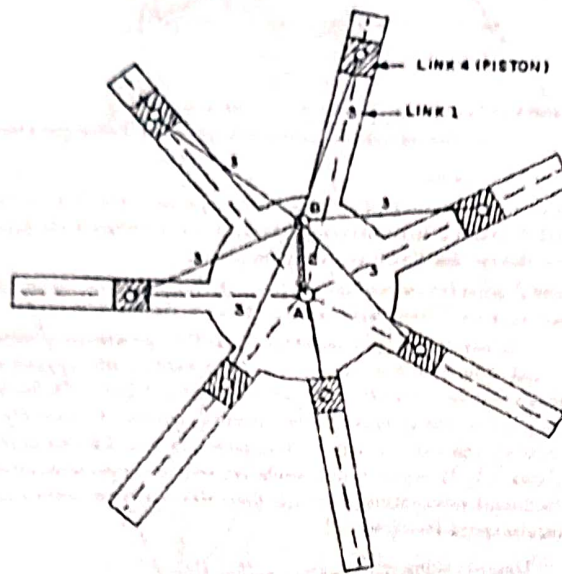


Fig: 2.5

**3<sup>rd</sup> Inversion :** When link 3 of Fig. 2.2 is fixed, the third inversion of single slider crank is obtained. This inversion is used in oscillating cylinder engine and crank and slotted-lever mechanism as shown in fig 2.6

### Crank and Slotted-Lever Mechanism

Fig. 2.6 shows a crank and slotted lever mechanism, in which link 1 is a slider which slides in a slotted lever which is link 4. Link 3 is fixed and link 2 is a crank which rotates in clockwise direction about point B in a circle. Due to this the link 4 oscillates about the point C. Link 4 is extended to point D to which link DE (i.e. link 5) is connected. At the end of link 5, cutting tool i.e. link 6 is attached. Link 6 is constrained to slide as shown in Fig.2.6 shows the two extreme position of the crank. The first position is when the crank (i.e. link 2) is at right angles to link 4 (or link 4 is tangential to crank radius circle at point A1). The remaining corresponding points in this position will be D1 and E1 as shown in Fig.2.6. The stroke of the cutting tool starts from point E1. The crank is rotating in clockwise direction. The end of the cutting stroke is marked by point E2' when again crank after having rotated through an angle  $\alpha$  in the

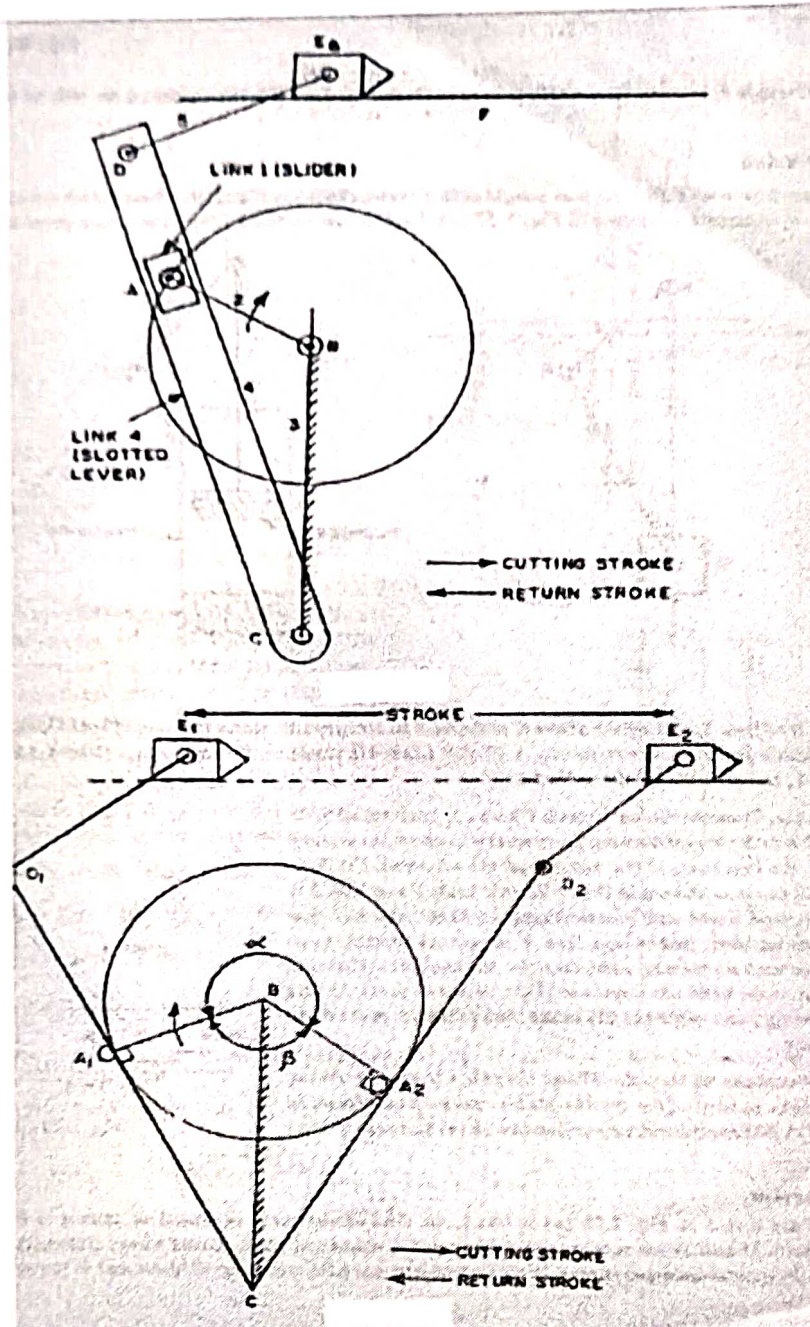


Fig: 2.6

#### Fourth Inversion

When link 4 of Fig.2.7 (i.e. single slider crank chain) is 'fixed, the fourth inversion of single slider crank chain is obtained as shown in Fig.2.7 (a). Link 3 can oscillate about the fixed point C on link 4. This makes end B of link 2 to oscillate about C and end A to reciprocate along the

axis of fixed link 4. This inversion is used in hand-pump as shown in Fig. 2.7 (b). Link 4 is made in the form of a cylinder and a plunger fixed to the link 1, reciprocates in the cylinder.

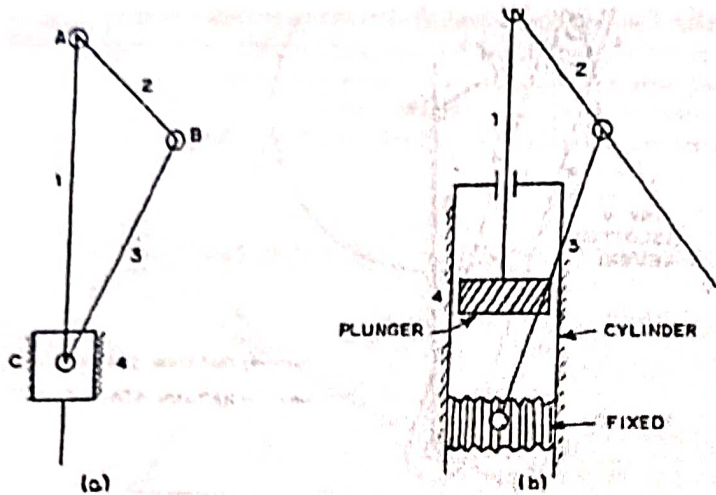


Fig 2.7

### 3. DOUBLE-SLIDER CRANK CHAIN.

It consists of four pairs out of which two are turning pairs and two others are sliding pairs. Also the two pairs of the same kind are adjacent. Double slider crank chain is shown in Fig. Link 1 and link 2 is sliding pair, link 2 and link 3 is turning pair, link 3 and link 4 is second turning pair, link 4 and link 1 is second sliding pair. Hence there are two turning pairs and two sliding pairs. Also, the pairs of the same kind are adjacent. Two adjacent pairs 23 and 34 are turning pairs whereas the other two pairs 12 and 14 are sliding pairs.

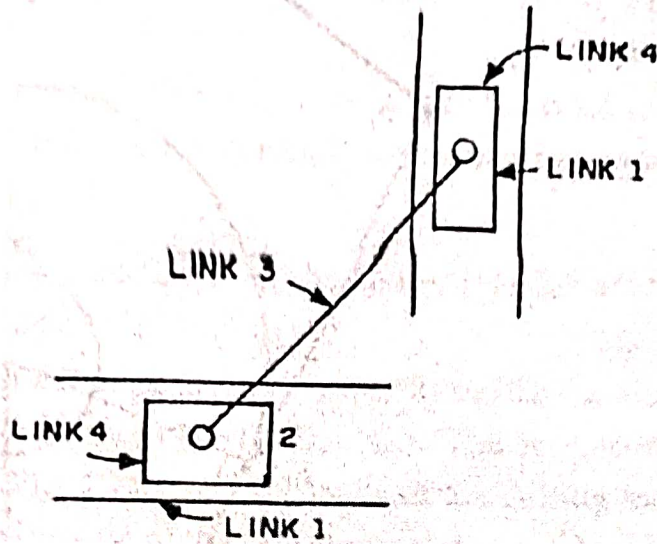


Fig 2.8

**Inversions of Double-Slider Crank Chain.**

By fixing different links in turn of the double-slider crank chain shown in Fig.2.8 different mechanism (known as inversions) will be obtained.

**First version**

When link 1 of Fig.2.8 is fixed, the first inversion is obtained as shown in Fig.2.9

(b). Two adjacent pairs 23 and 34 are turning pairs whereas the other two pairs 12 and 14 are sliding pair.

This inversion is used in Elliptical trammel which is an instrument used for drawing ellipses and is shown in Fig. 2.9 (b). The fixed link 1 has two straight grooves cut in it, at right angles to each other. With the movement of the sliders any point C on the link 3 (except the midpoint of AB) will trace an ellipse on a fixed plate. The midpoint of AB will trace a circle.

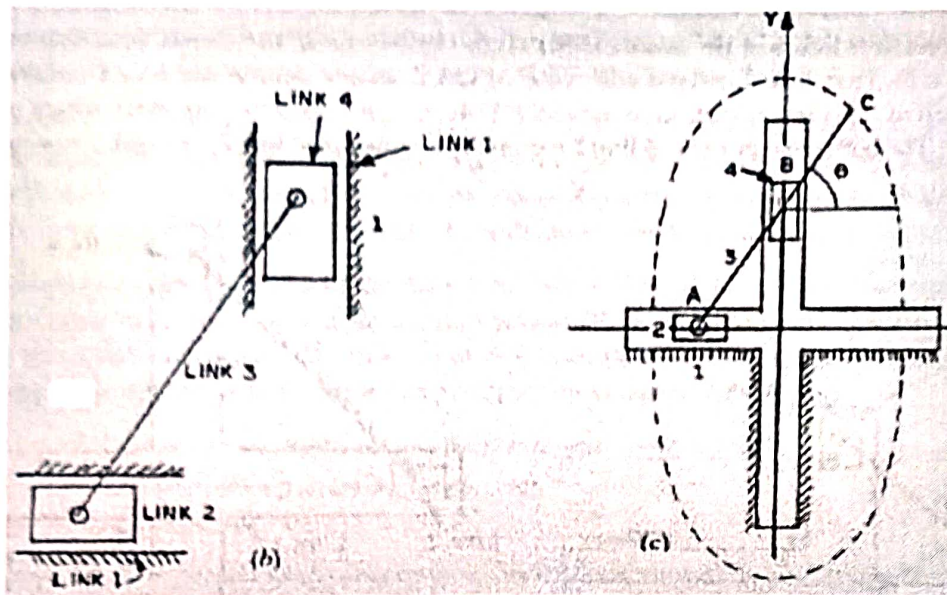


Fig 2.9

### Second Inversion

When link 2 or link 4 of the double-slider crank chain is fixed, the second inversion is obtained as shown in Fig. 2. 10. Here link 2 is fixed and end B of link 3 rotates about A and link 1 reciprocates in the horizontal direction. This inversion is used in Scotch yoke, which is used to convert the rotary motion into a sliding motion. The horizontal portion of link 1 reciprocates in the fixed link 2, as crank 3 rotates.

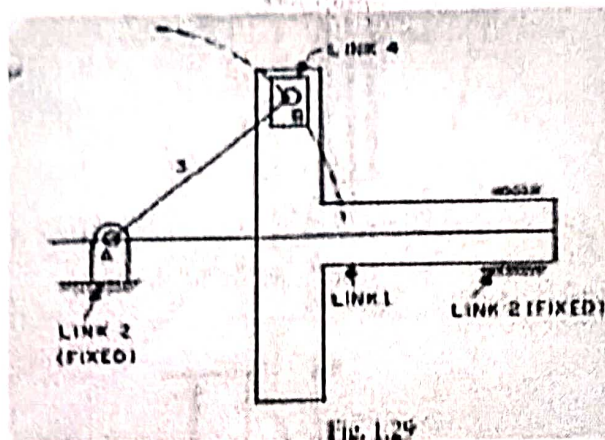


Figure 1.9

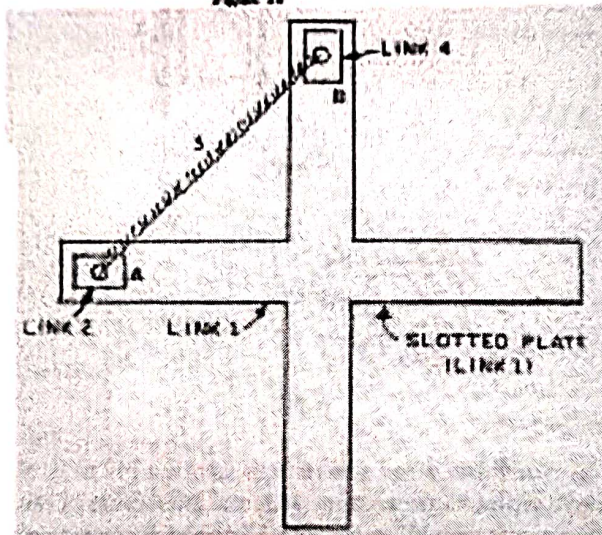


Fig 2.10

### Third Inversion

When link 3, of the double slider crank chain shown in Fig. 2.8, is fixed and link 1 is free to move, third inversion is obtained which is shown in Fig. 2.11. In this case each of slide blocks (i.e. link 2 and link 4) can turn about the pins A and B. If one slide block (say link 2) is turned through a definite angle, the frame (i.e. link 1) and the other block (i.e. link 4) must turn through the same angle.

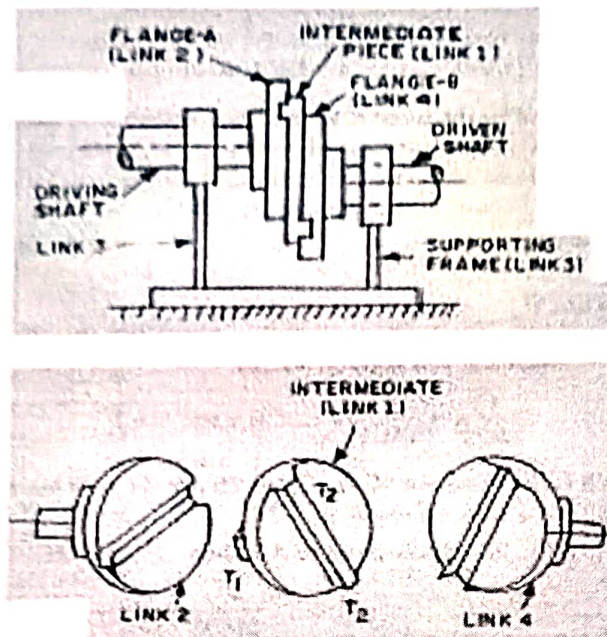


Fig 2.11

This inversion is used in Oldham's Coupling (shown in Fig. 2.11) which is used for connecting two parallel shafts: when the distance between the two shafts is small. The two shafts to be connected have flanges at their ends which are rigidly fastened by forging to the shafts. These flanges form links 2 and 4. Each of these links forms a turning pair with link 3. There is a diametrical slot cut in the inner faces of these flanges.

An intermediate piece is a circular disc (link 1) which has two tongues T1 and T2 on each face at right angles to each other. These tongues can slide-fit in the slots in the two flanges (link 2 and 4). The link 1 can slide or reciprocate in the slots in the flanges. Frame and bearings form the link 3 which is fixed.

When the driving shaft is rotated, the flange A (i.e. link 2) connected rigidly to the driving shaft also rotates by the same angle, the intermediate piece also rotates by the same angle through which flange A has rotated. Due to the rotation of the intermediate shaft, the flange B (i.e. link 4) connected to the driven shaft, also rotates by the same angle. Hence links 2, 4 and 1 have the same angular velocity at every instant. The distance between the axes of the shafts is constant and hence the centre of the intermediate piece will describe a circle of diameter equal to the distance between the axes of the shafts. There is a sliding motion between the link 1 and each of the other links 2 and 4. The maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the centre of the disc along its circular path.

## Experiment 4

**Aim:** To study various type of cam and follower arrangements.

**Principal:** Cam and Follower are used in conjunction of each other. Cam imparts rotary motion and the follower connected with cam executes the reciprocating motion. The motion of follower is utilised to get intermittent motion of a component in any arrangement. A cam and the follower combination belong to the category of higher pairs. Necessary elements of a cam mechanism are:

- . A driver member known as the cam.
- . A driven member called the follower
- . A frame which supports the cam and guides the follower.

**Activities to be performed:**

Draw a neat and self-explanatory diagram of the Simple arrangements of Cam and Followers

**Types of CAM**

I. Wedge and Flat Cams

A wedge cam has a wedge W which, in general, has a translational motion

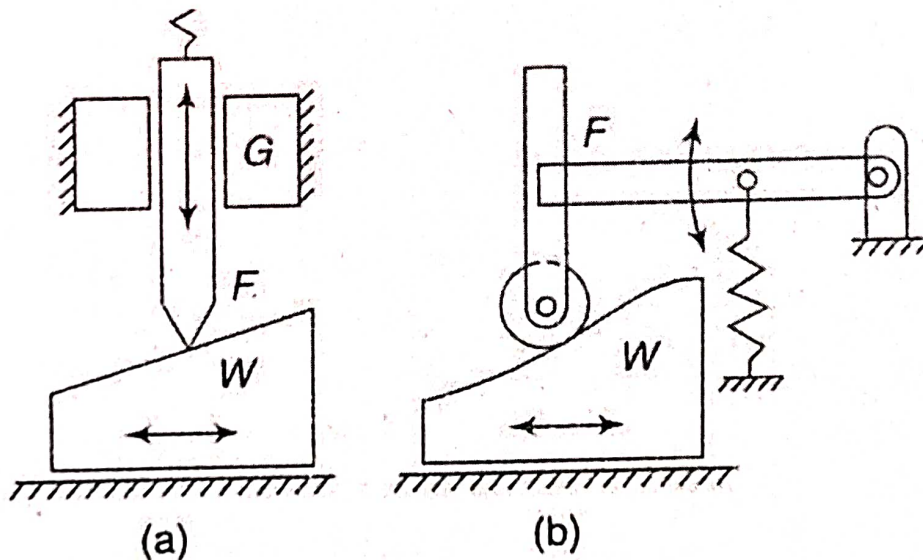


Fig 9.1

[Figs 9.1 (a) and (b)]. The follower F can either translate [Fig.9.1 (a)] or oscillate [Fig. 1(b)]. A spring is, usually, used to maintain the contact between the cam and the follower. In Fig. 9.1(c), the cam is stationary and the follower constraint or guide G causes the relative motion of the cam and the follower. Instead of using a wedge, a flat plate with a groove can also be used. In the groove, the follower is held as shown in Fig.9. 2. Thus, a positive drive is achieved without the use of a spring.

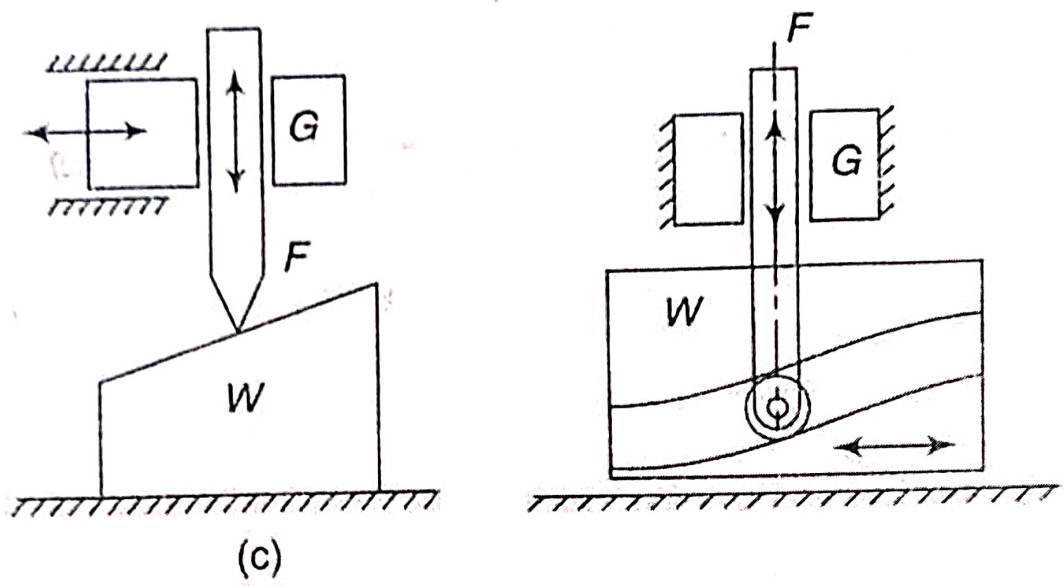


Fig9. 2

**2. Radial or Disc Cams**

A cam in which the follower moves radially from the centre of rotation of the cam is known as a radial or a disc cam [Figs9. 3(a) and (b)]. Radial cams are very popular due to their simplicity and compactness.

Figure

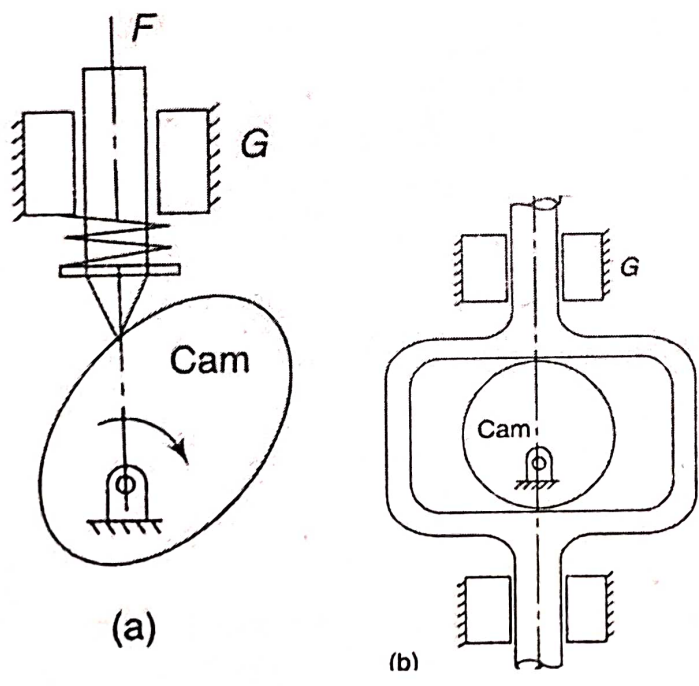


Fig9. 3

### 3. Spiral Cams

A spiral cam is a face cam in which a groove is cut in the form of a spiral as shown in Fig. 9.4. The spiral groove consists of teeth which mesh with a pin gear follower. The velocity of the follower is proportional to the radial distance of the groove from the axis of the cam. The use of such a cam is limited as the cam has to reverse the direction to reset the position of the follower. It finds its use in computers.

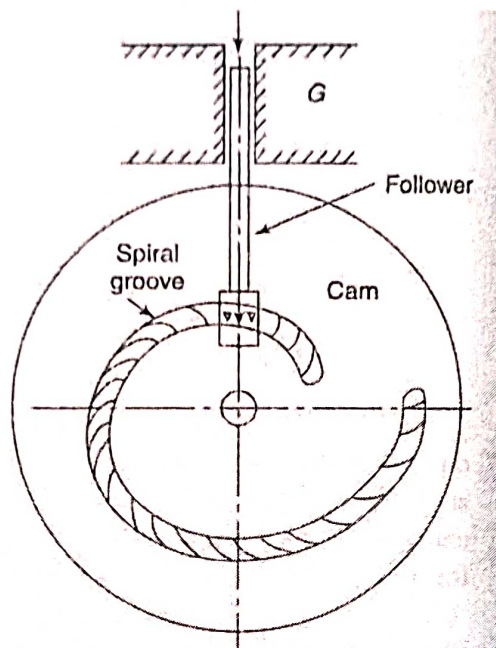


Fig 9.4

### 4. Cylindrical cam

In a cylindrical cam, a cylinder which has a circumferential contour cut in the surface, rotates about its axis. The follower motion can be of two types as follows:

In the first type, a groove is cut on the surface of the cam and a roller follower has a Constrained (or positive) oscillating motion [Fig. 9.5(a)]. Another type is an end or face cam in which end of the cylinder is the working surface [Fig. 9.5(b)]. A spring-loaded follower translates along or parallel to the axis of the rotating cylinder. Cylindrical cams are also known as barrel or drum cams.

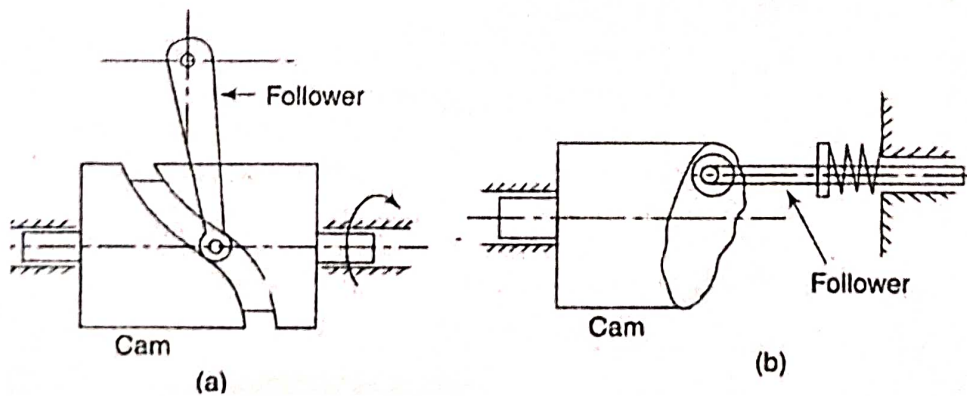


Fig 9.5

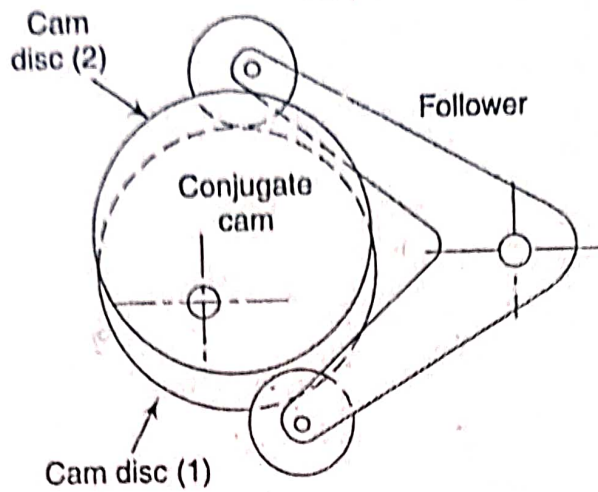


Fig9. 6

### 6. Globoidal Cams

A globoidal cam can have two types of surfaces, convex and concave. A circumferential contour is cut on the surface of rotation of the cam to impart motion to the follower which has an oscillatory motion. (Fig.9. 7). The application of such cams is limited to moderate speeds and where the angle of oscillation of the follower is large.

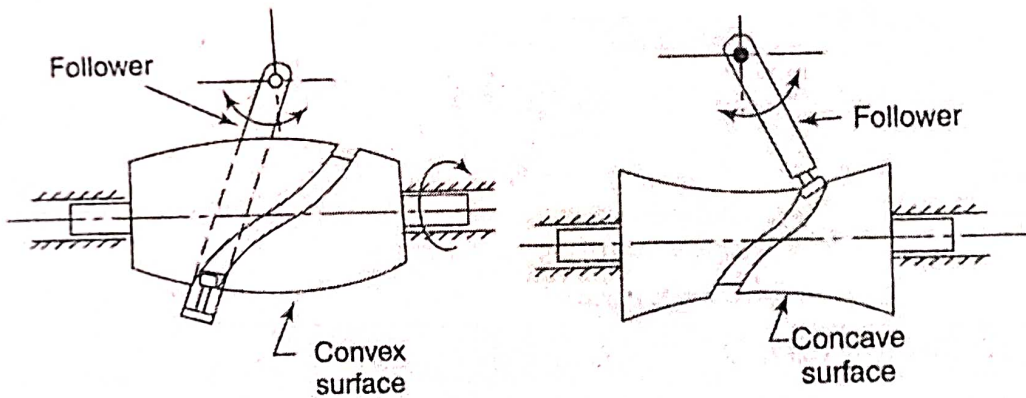


Fig 9. 7

### 7. Spherical Cams

In a spherical cam, the follower oscillates about an axis perpendicular to the axis of rotation of the cam. Note that in a disc cam, the follower oscillates about an axis parallel to the axis of rotation of the cam. A spherical cam is in the form of a spherical surface which transmits motion to the follower (Fig. 9.8).

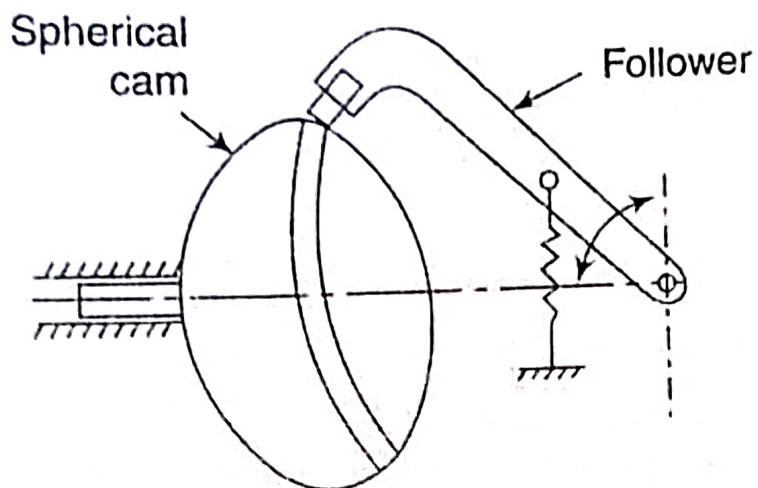


Fig 9. 8

### Types of Followers

Followers can also be classified according to shape as discussed below:

**Knife-edge Follower** It is quite simple in construction. Figure 9.9 (a) shows such a follower. However, its use is limited as it produces a great wear of the surface at the point of contact.

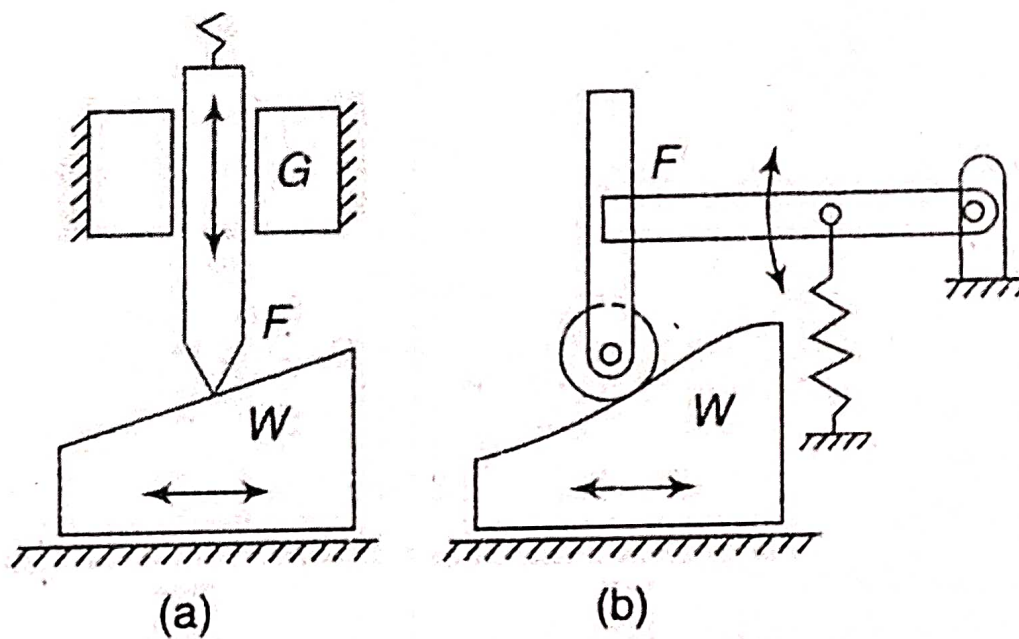


Figure 9. 9

### Roller Follower

It is a widely used cam follower and has a cylindrical roller free to rotate about a pin joint [Figs 9.9 (b)]. At low speeds, the follower has a pure rolling action, but at high speeds, some sliding also occurs. In case of steep rise, a roller follower jams the cam and, therefore, is not preferred.

### 3. Mushroom Follower

A mushroom follower (Fig 9.10) has the advantage that it does not pose the problem of jamming the cam. However, high surface stresses and wear are quite high due to deflection and misalignment if a flat-faced follower is used [Fig. 9.10 (a)]. These disadvantages are reduced if a spherical-faced follower [Fig. 9.10 (b)] is used instead of a flat-faced follower.

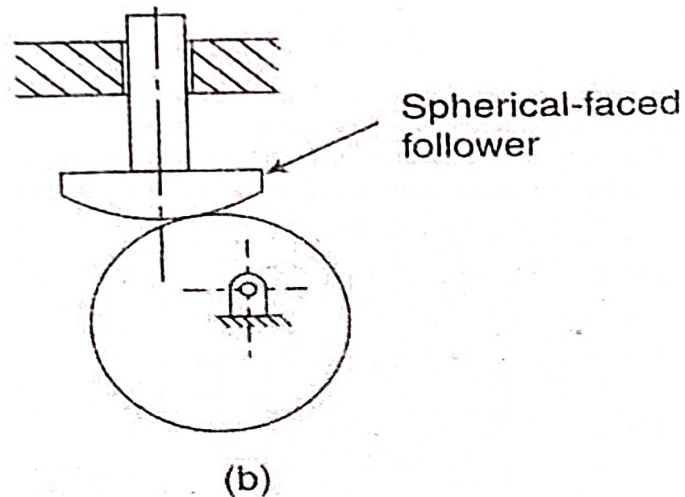


Fig 9. 10