# GOVT CO-ED POLYTECHNIC

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**LABMANUAL**

Branch: Mechanical Engineering

Year & Semester:2nd Year / 4th Semester

THEORY OF MACHINE LAB
(2037461(037)

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**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.

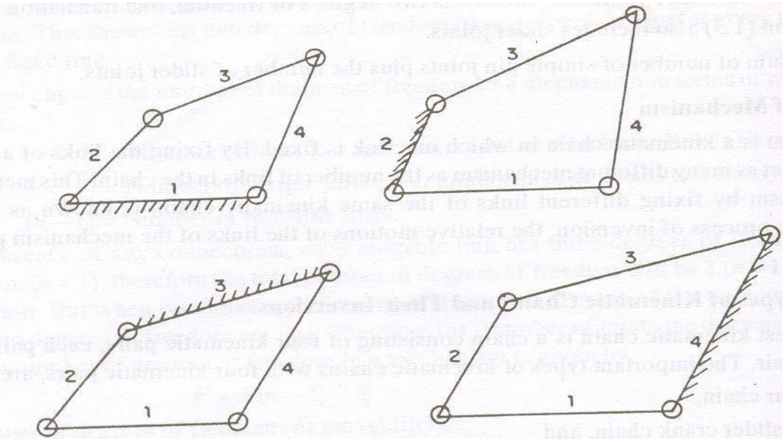



Fig 2.1

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

**1st 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.

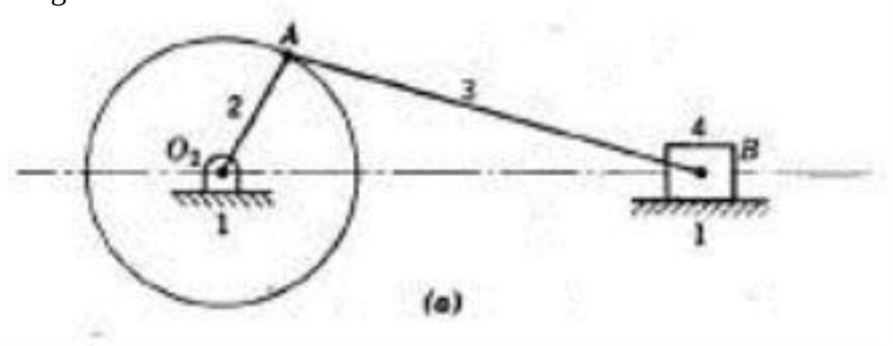



**Fig 2.2**

**2nd 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. Link3 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 Whiteworth quick-return mechanism and rotary engine.

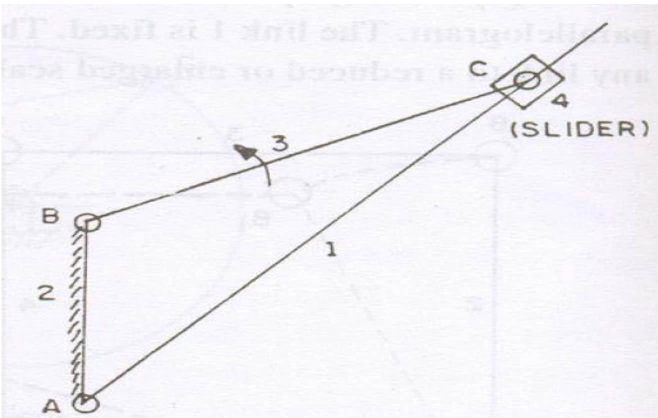



Fig 2.3

**a) Whiteworth 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.

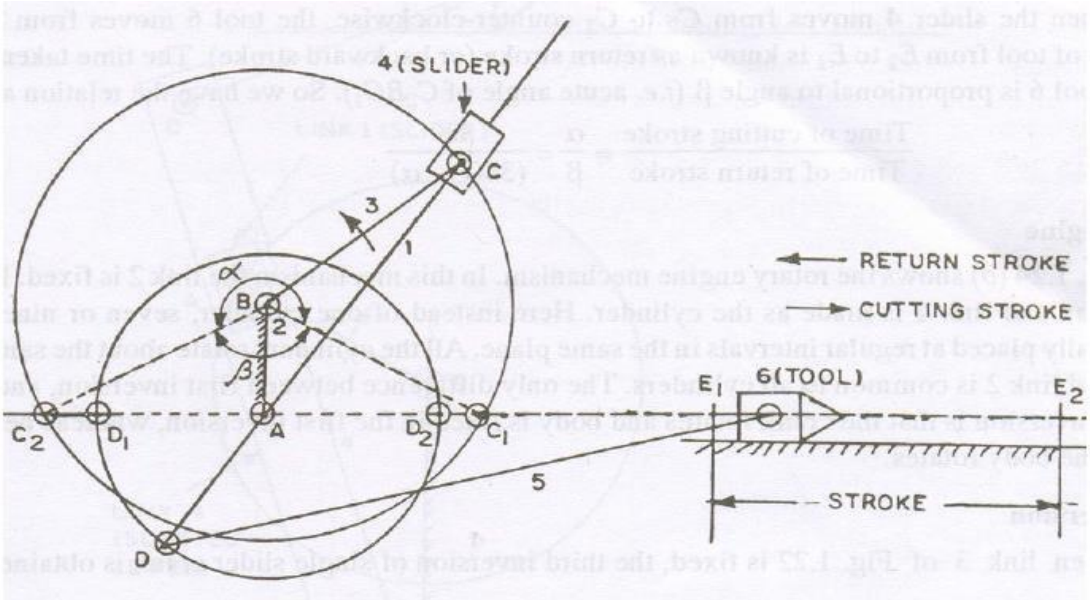



Fig 2.4

**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.

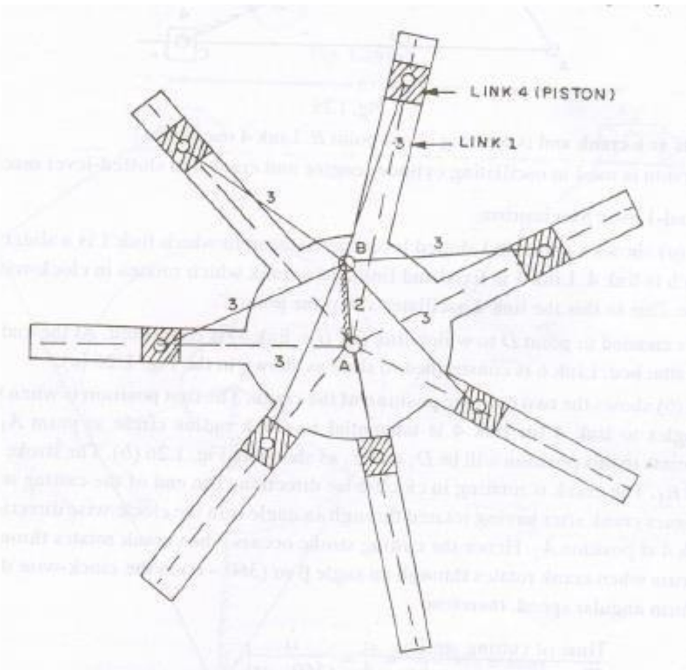
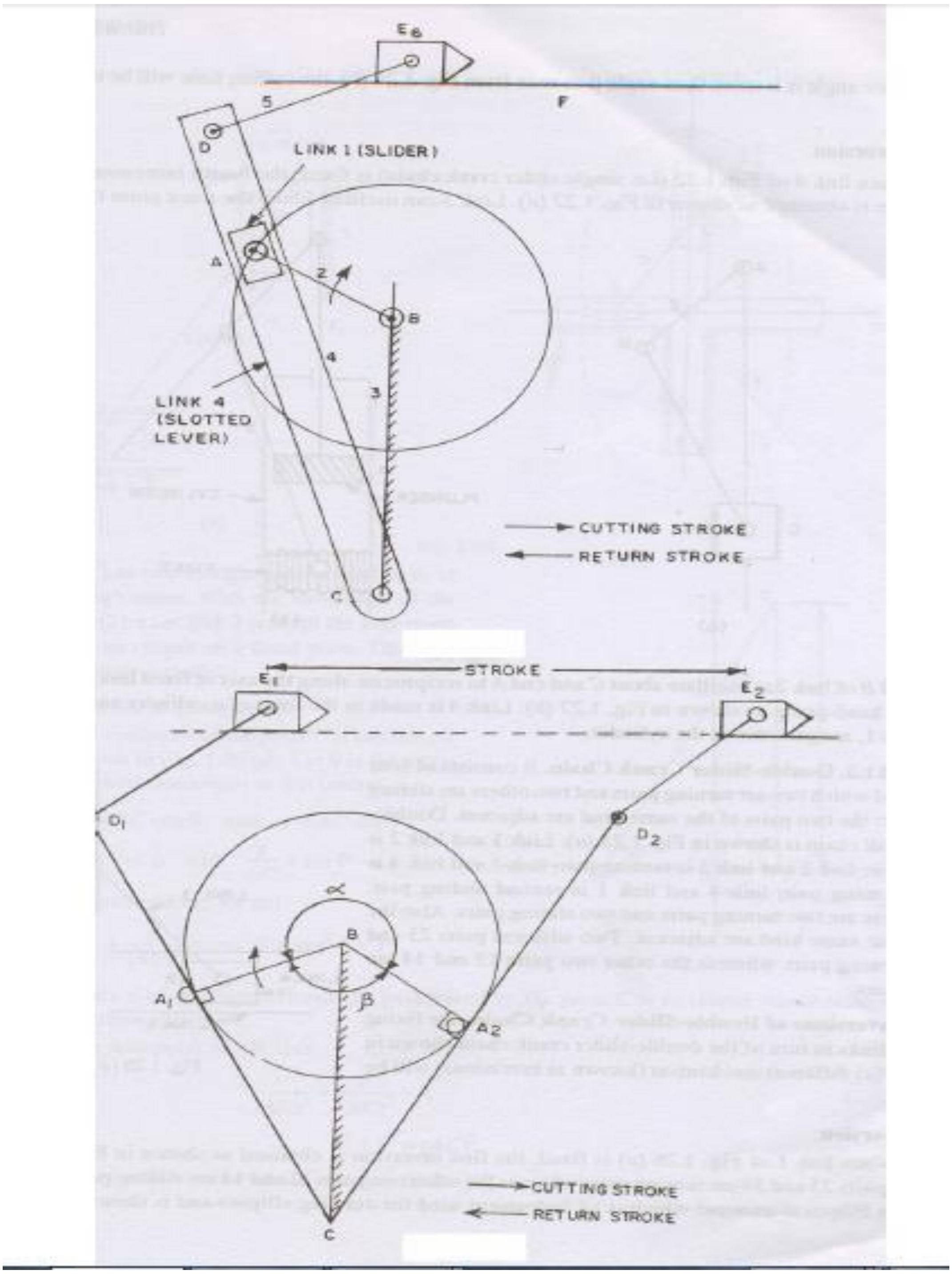


Fig: 2.5

**3rd 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 clock-wise 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 clock-wise direction. The end of the cutting stroke is marked by point E2' when again crank after having rotated through an angle a 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.

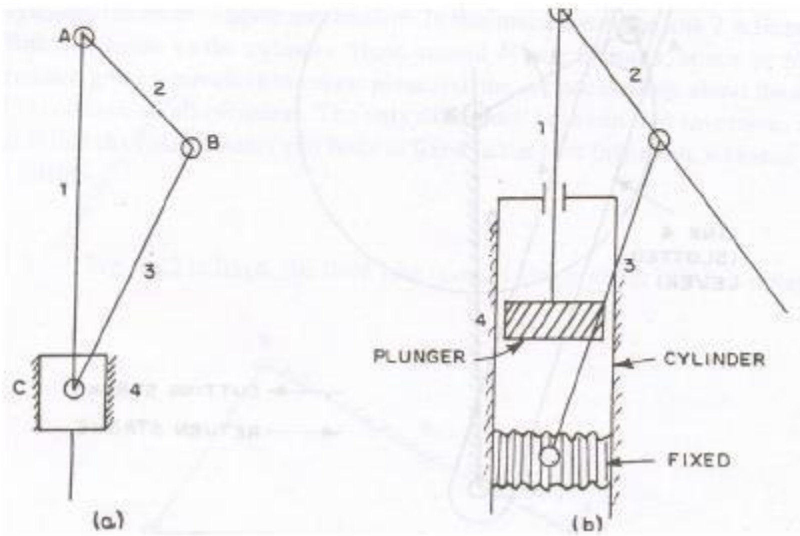



**Fig 2.7**

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.

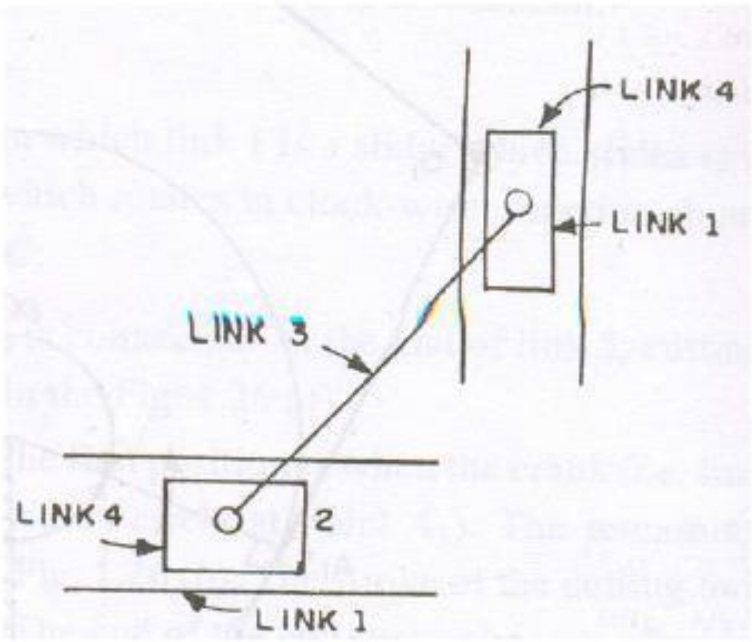



Fig 2.8

**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 mid-point of AB) will trace an ellipse on a fixed plate. The midpoint of AB will trace a circle.

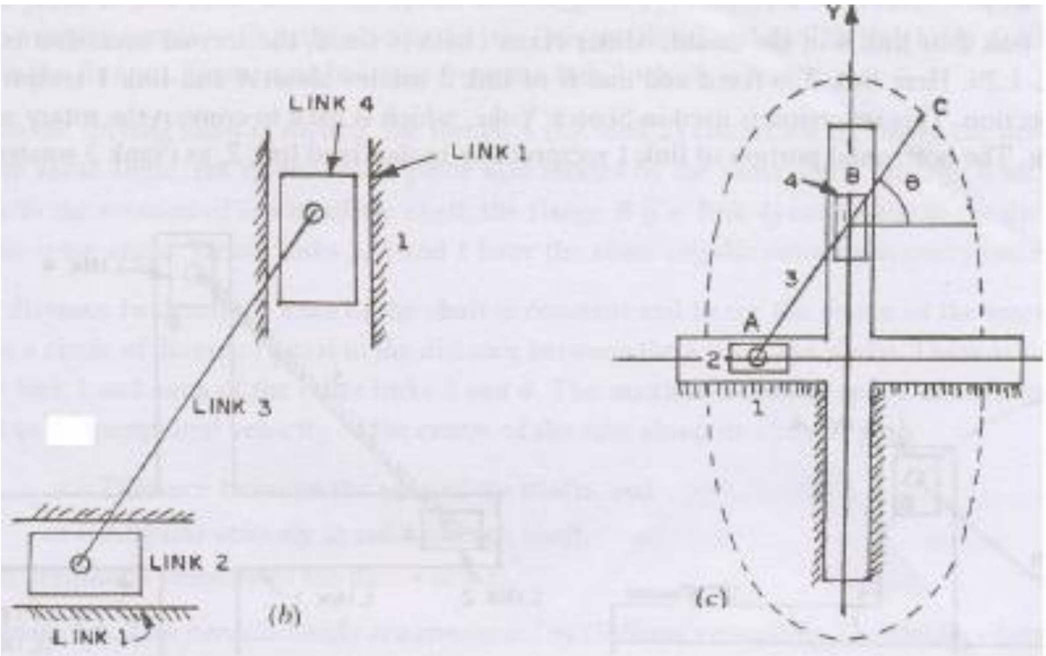



Fig 2.9

**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 I reciprocate in the fixed link 2, as crank 3 rotates.

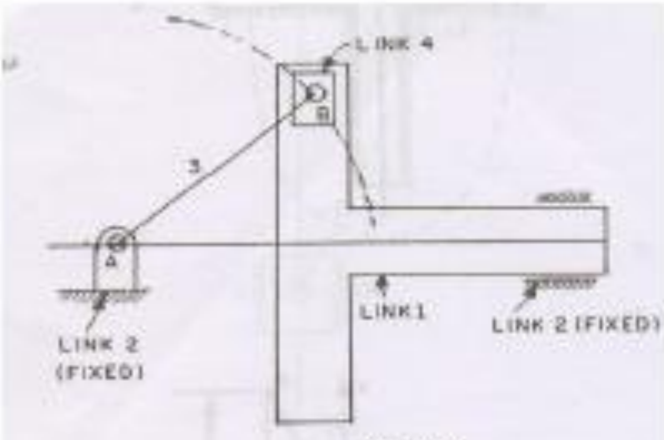



Fig. 1.29

Figure 10

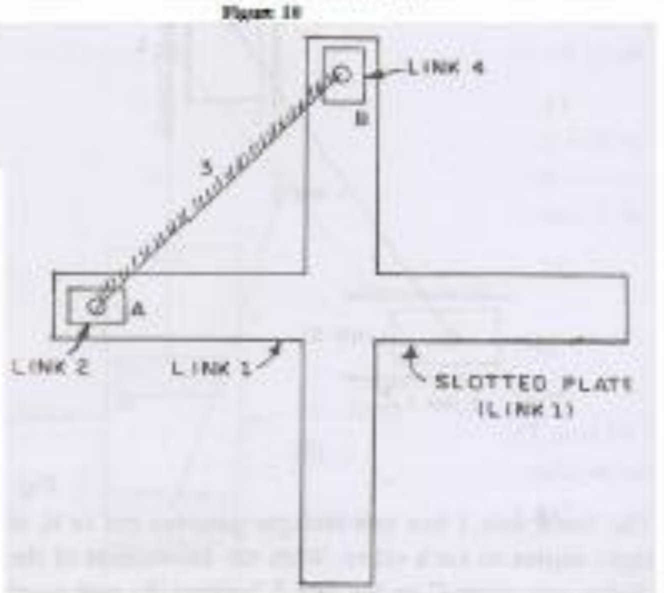



Fig 2.10

**Third Inversion**

When link3, 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.

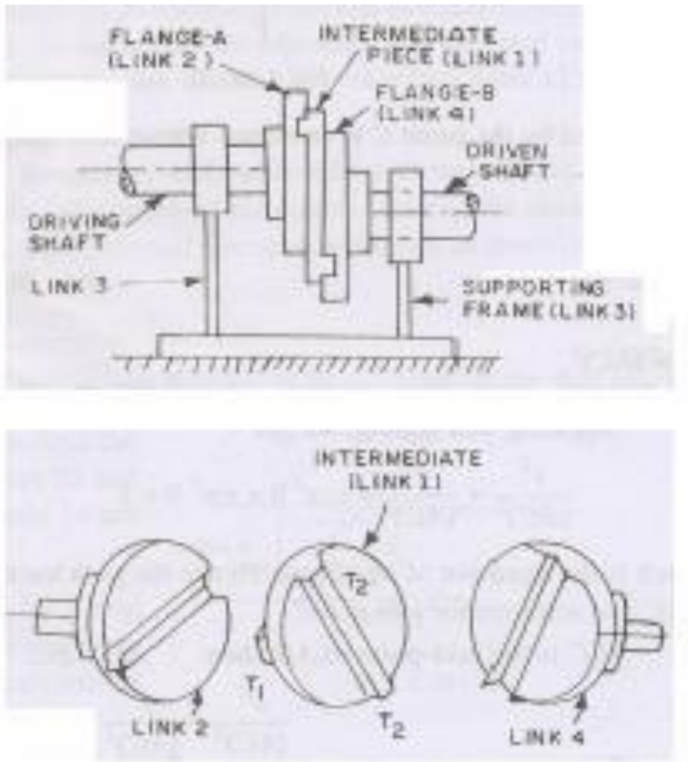



Fig 2.11

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 forms links 2 and 4. Each of these links forms a turning pair with link 3. There is diametrical slot cut in the inner faces of these flanges.

An intermediate piece is a circular disc (link 1) has two tongues T1 and T2 on each face at right angles to each other. These tongues can slide-fit in the slot., 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 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 shaft 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 2

**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

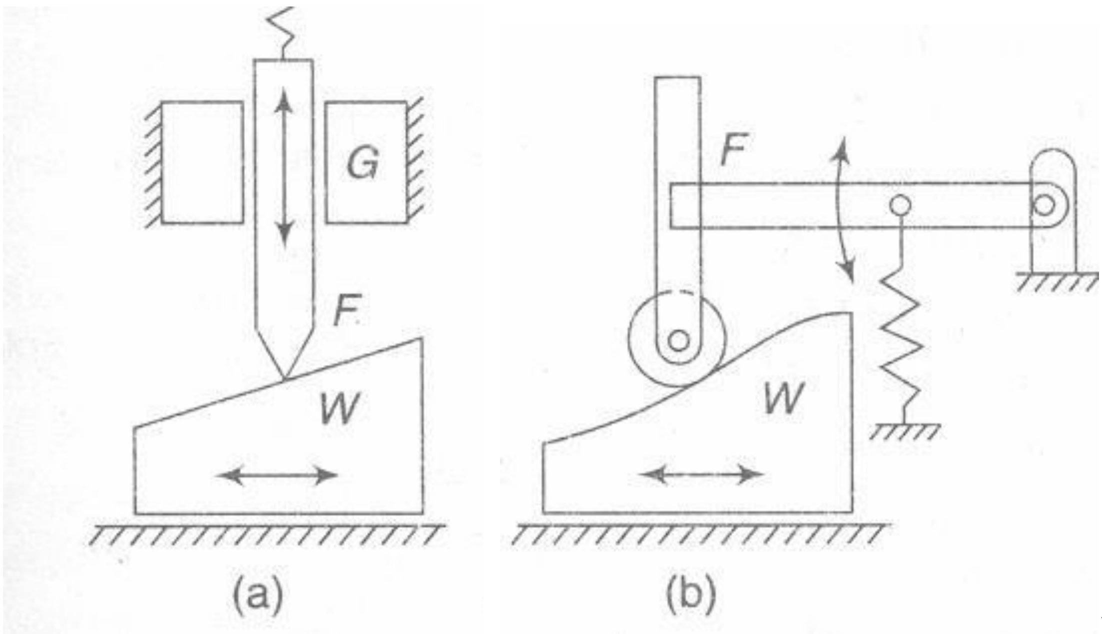



Fig 9.1

[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.

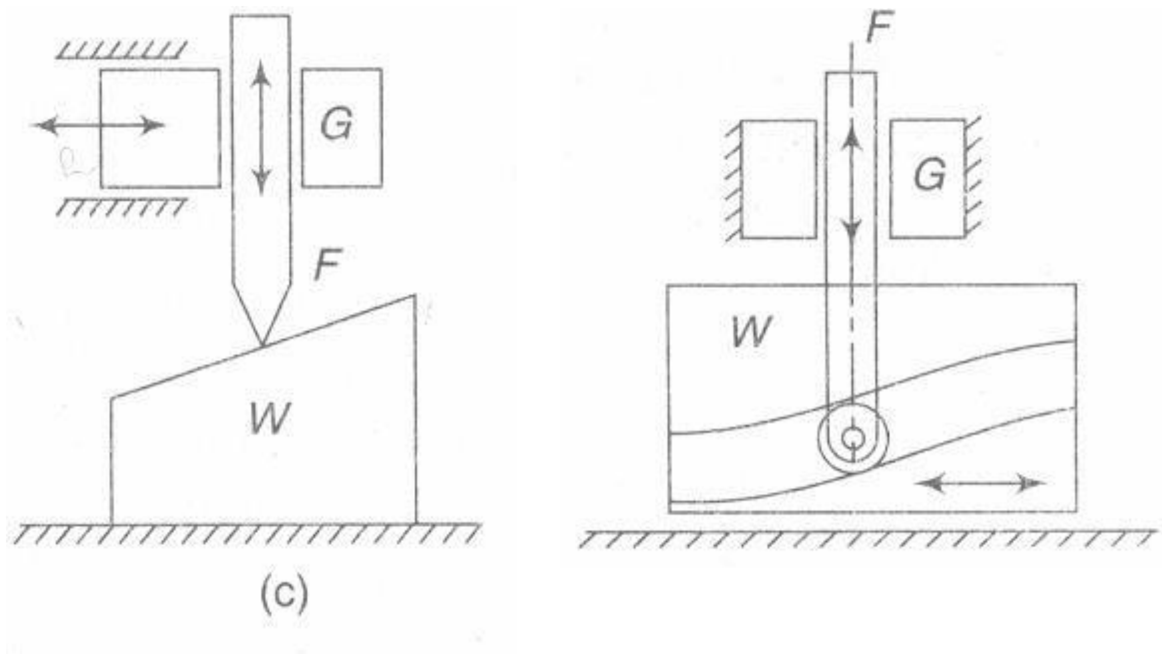



Fig9. 2

**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

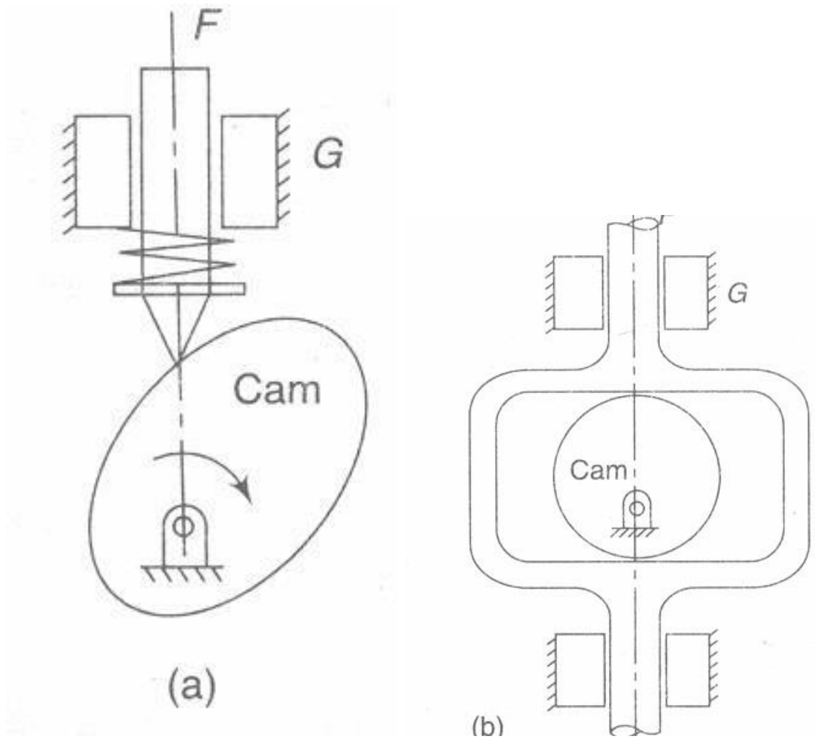



Fig9. 3

**3. Spiral Cams**

A spiral carn 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.

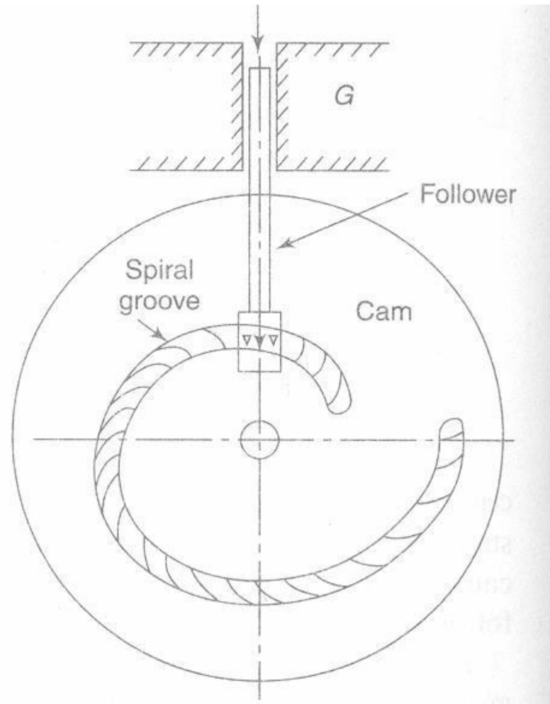



**Fig 9.4**

**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.

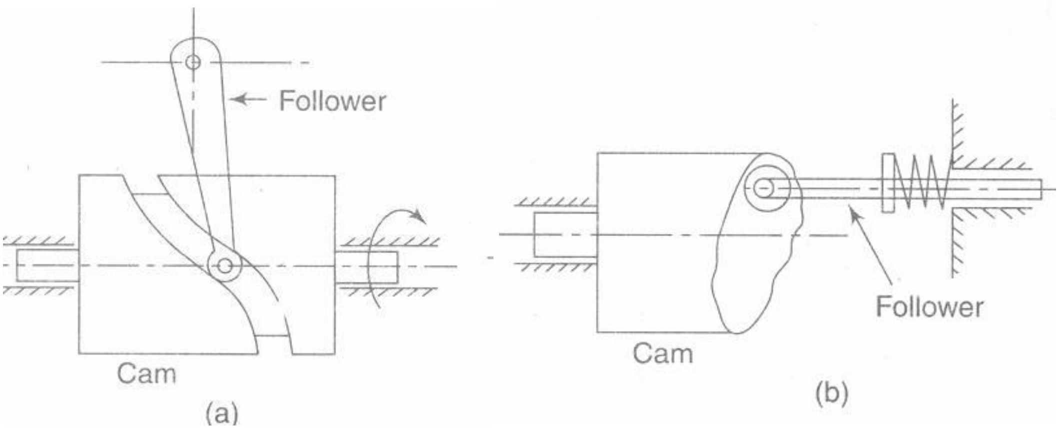



Fig 9.5

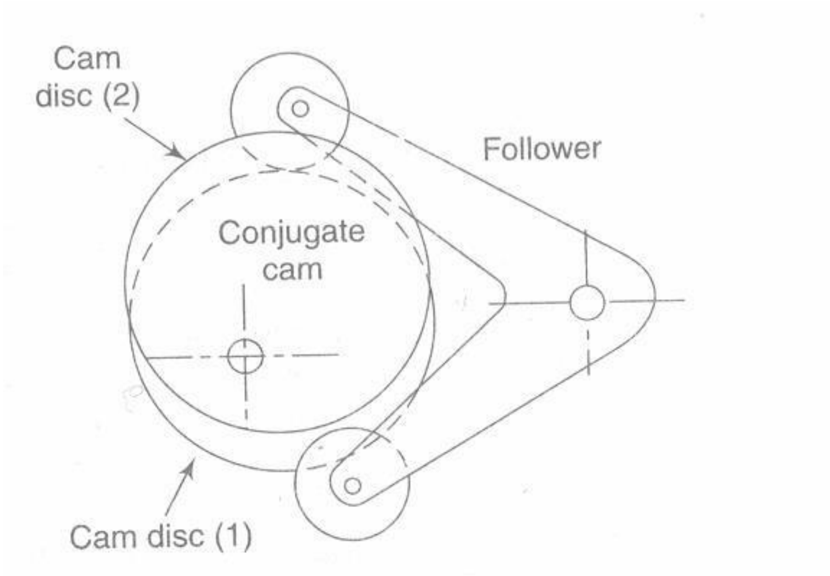



**Fig9. 6**

**6. Globoidal Cams**

A globoidal earn can have two types of surfaces, convex and concave. A circumferential contour is cut on the surface of rotation of the earn 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.

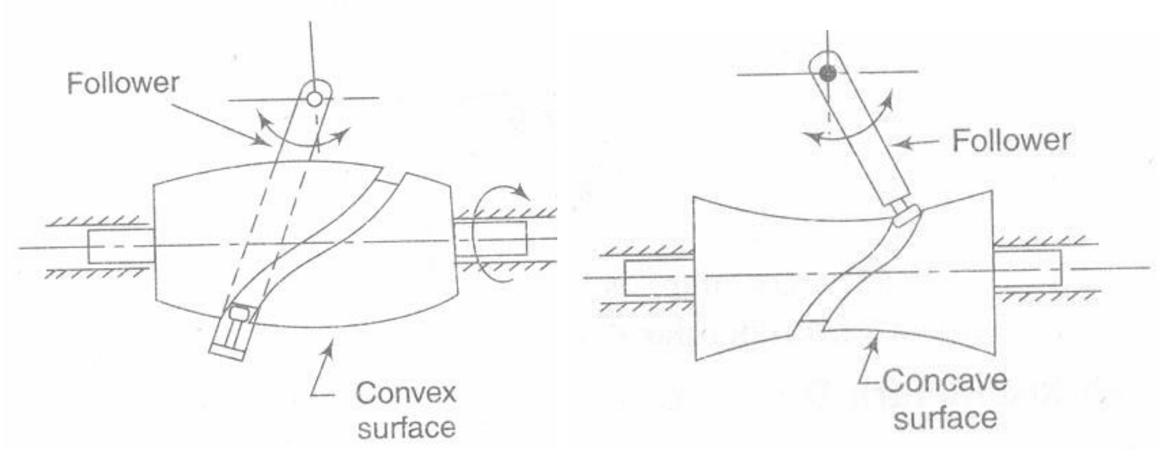



**Fig 9. 7**

**7. Spherical Cams**

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

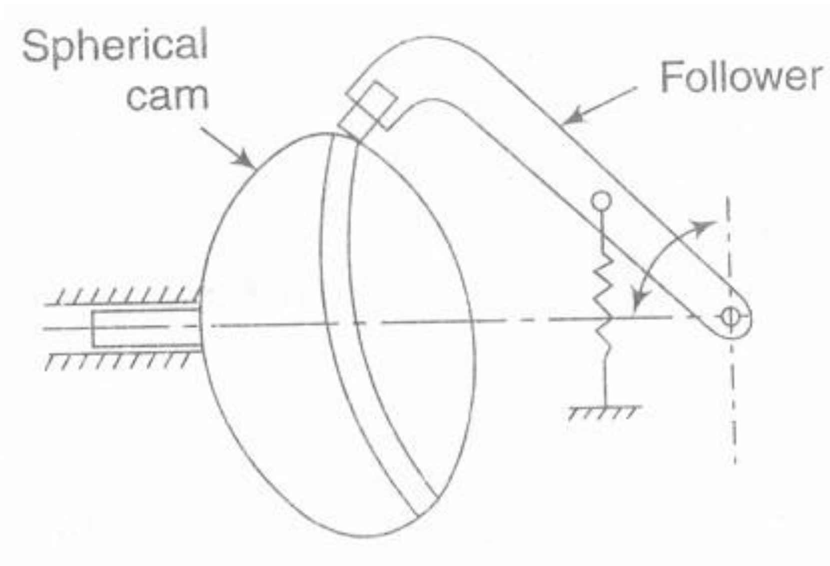



Fig 9. 8

**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.

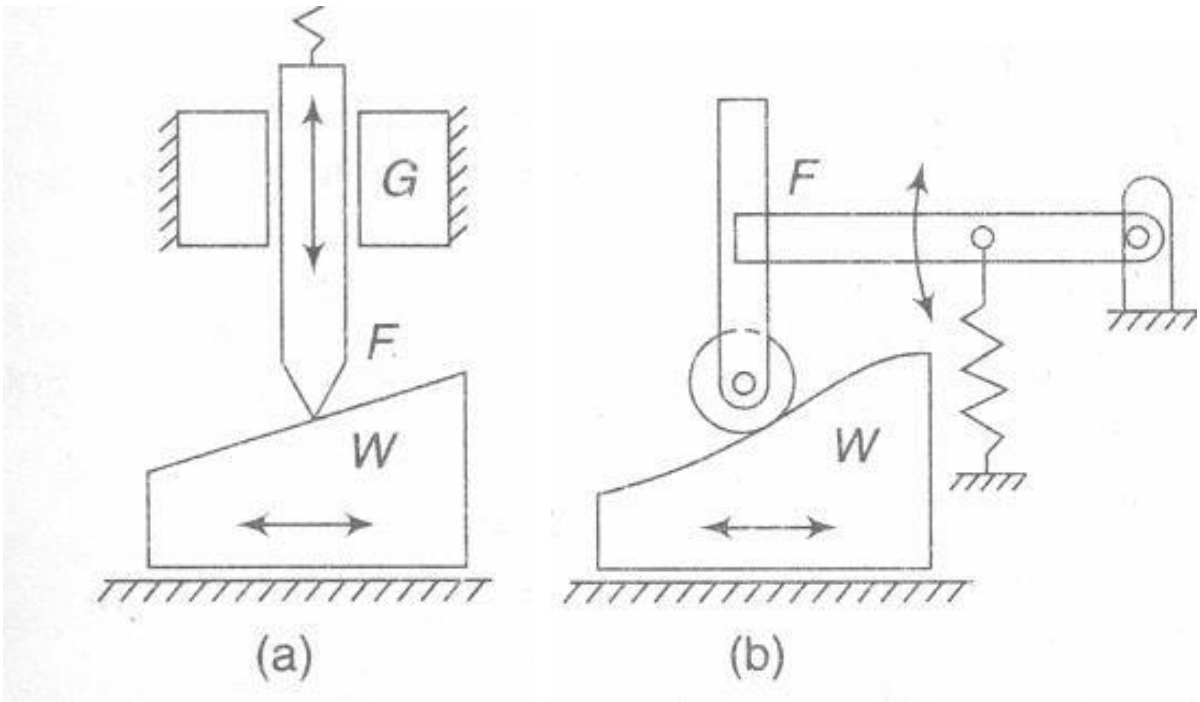



Figure 9. 9

**Roller Follower**

It is a widely used cam follower and has a cylindrical roller free to rotate about a pin joint [Figs9. 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.

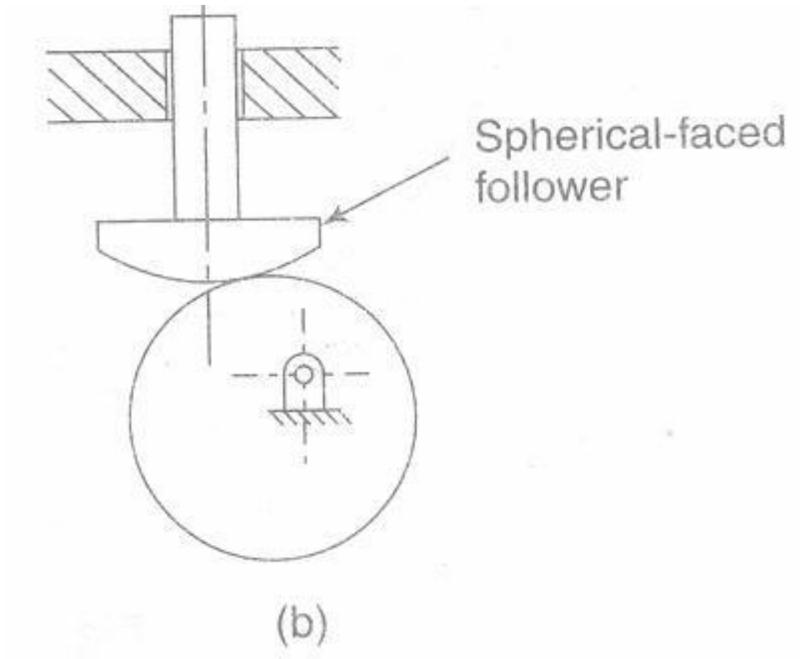



Fig 9. 10

## Experiment 3

**Aim: To plot follower displacement vs cam rotation for various cam Follower systems.**

**Principles:** The rotation of CAM imparts reciprocating motion in follower. This motion will vary as per the shape and type of follower. The displacement curve of the specified shape will vary in pattern. Mainly There are four phases of motion of a follower.

7. Rise
8. Dwell
9. Return
10. Dwell

The graph of displacement, velocity and acceleration in all four phases of motion will be depending upon the type of followers used, as mentioned in previous experiments.

### Experimental Set Up

For this experiment, arrange the set up as shown in Fig. 10.1. The exact profile of the cam can be obtained by taking observations n V s θ. Where n = displacement of the follower from rotation initial position and θ. = angle of cam rotation with reference from axis of symmetry chosen. By differentiating the n- θ. curve once and twice, the velocity and acceleration curves can be plotted for the follower and cam under study.

The apparatus is designed to study the cam profile and performance of cam and follower system. Apparatus is a motorized unit consisting of a camshaft driven by a variable speed D. C. Motor. The shaft is supported in a double ball bearing. At the free end of the camshaft, a cam (interchangeable) can be easily mounted. A push rod assembly is supported vertically and various types of followers (interchangeable) can be attached to this push rod. As the follower is properly guided in gunmetal bushes and the type of the follower can be changed to suit the cam under test. A graduated circular protractor is fitted coaxial with the shaft and a dial gauge can be fitted to note the follower displacement for the angle of cam rotation. A spring is used to provide controlling force to the follower system. Weights on the follower rod can be adjusted as per the requirements. The arrangement of speed regulation is provided. A set of cams is provided consisting of as eccentric, tangent and circular arc type. A set of followers is also provided consisting of mushroom, roller and knife-edge type

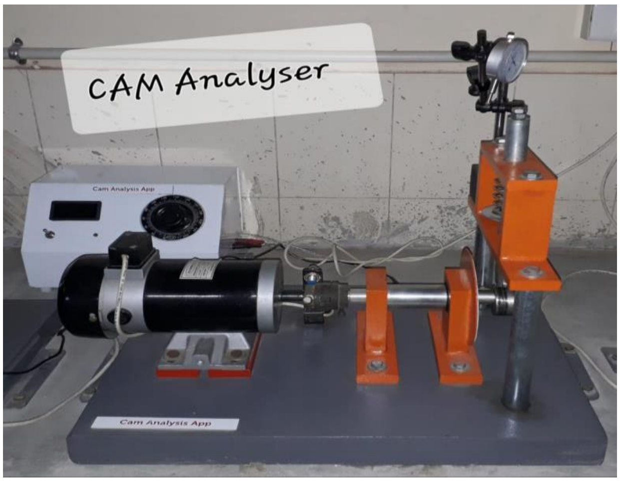
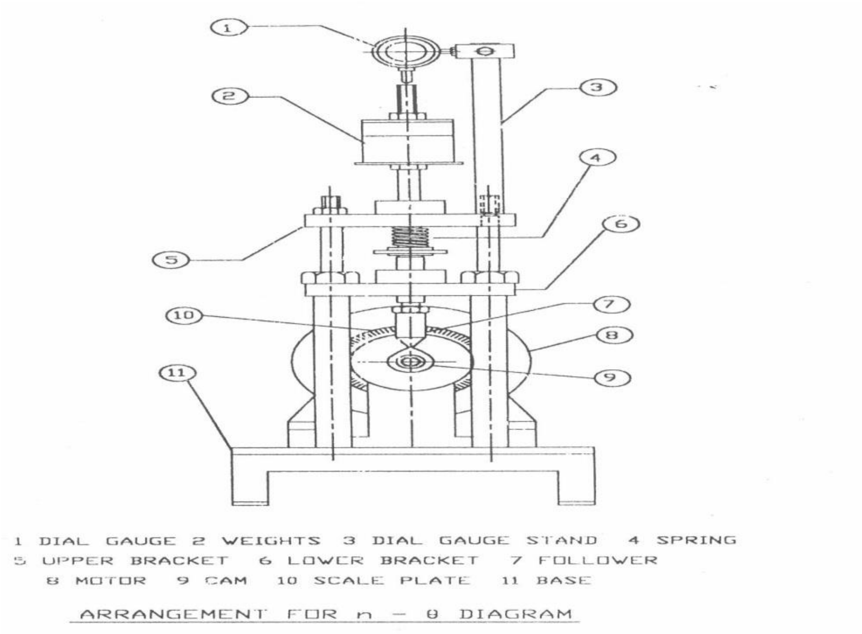



Fig 10.1 (Actual Image of Cam analyser)




**Suggested Experimental Work:**

Step 1: Select a suitable cam and follower combination. Step2:

Fix the cam on the driving shaft.

Step3: Fix the follower on push rod and properly tighten the check nut, such that knife edge of follower (or axis of roller in case of roller follower) is parallel to axis of camshaft. Step4: Give required initial compression to the spring. In order that initial compression is not lost during operation, the check nut is to be tightened against spring seat

Step 5: Choose suitable amount of weight to be added to the follower. Weights with central hole can be inserted from the top end of push rod. A rest plate for the weights should be firstly screwed to the lowest position, tightened against it, so that there will be no loosening of the rest plate after adding required weights. Tighten the second nut from the top to secure the weights tightly to the push rod.

Step6: See the knob of dimmerstat is at zero position.

Step7: Now switch ON the supply and increase the speed of the motor gradually with the help of dimmerstat.

**Results & Discussions:**

1. The exact profile of the cam can be obtained by taking observations n V s θ. Where n = displacement of the follower from rotation initial position and _ = angle of cam rotation with reference from axis of symmetry chosen.

2. Plot n v/s θ. (follower displacement Vs. Angle of cam rotation) curve for different cam follower pairs.

Precautions:

1. While assembling following precautions should be taken.

(a) The horizontality of the upper and lower glands should be checked by a spirit level.

(b) The supporting pillars should be properly tightened with the lock nuts provided.

2. Lubrication: It is imperative, that to minimize the sliding forces at the two bearing surfaces, lubrication is a must. Before starting, continuous supply of oil should be provided. The cam is to be lubricated by oil before starting.

## EXPERIMENT - 4

**AIM : Measurement of Kinematic Data of Mechanisms**

### I. Practical Significance

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. By changing the fixed link, the number of mechanisms which can be obtained is equal to the number of links. The inversion of a mechanism does not change the motion of its links relative to each other.

### II. Relevant Program Outcomes (POs)

**PO 2.** Discipline knowledge: Apply Mechanical engineering knowledge to solve broad-based mechanical engineering related problems.

**PO 3.** Experiments and practice: Plan to perform experiments and practices to use the results to solve broad-based Mechanical engineering problems.

**PO 8.** Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

### III. Competency and Skills

This practical is expected to develop the following skills for the industry identified competency ' ***Use principles of kinematics and dynamics in maintenance of various equipment.*** '

a) Collect the kinematic data from given mechanism
b) Identify the inversions of Mechanism

### IV. Relevant Course Outcome(s)

- Identify various links in popular mechanisms.

### V. Practical Outcomes

- Estimate important kinematic data related to following mechanisms and sketch them.
  a. Single slider Crank mechanism
  b. Scotch Yoke Mechanism

### VI. Relevant Affective Domain Unrelated Outcomes

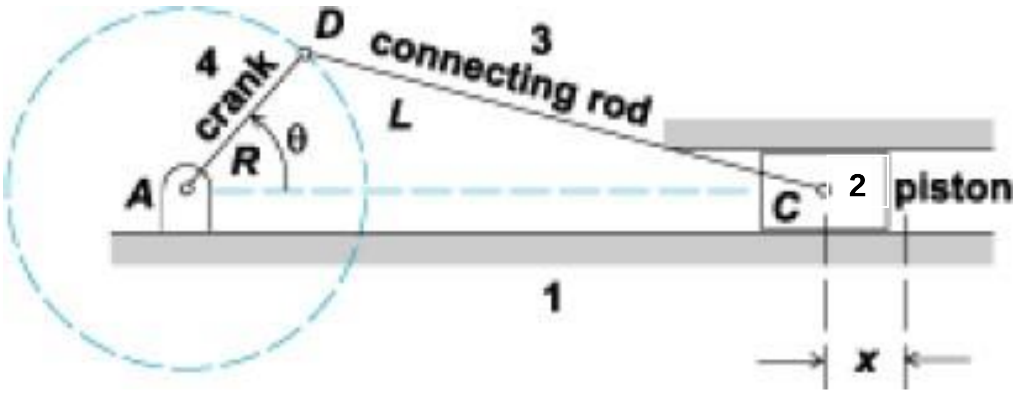
A. Follow safety practices.
B. Practice good housekeeping.
C. Demonstrate working as a leader/a team member.
D. Maintain tools and equipment.
E. Follow ethical Practices

**VII. Minimum Theoretical Background**

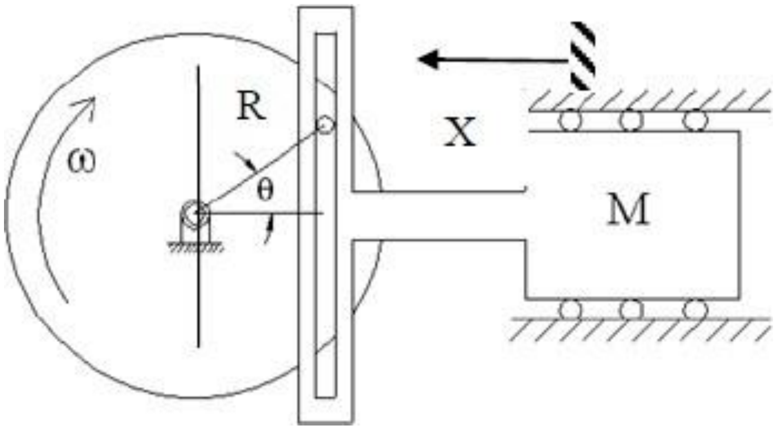
It is important to study the Kinematic response of the mechanism because of practical applications. It is also useful in determining the Kinematic equivalents of other mechanisms. While the motion of a Scotch-yoke mechanism is purely sinusoidal, that of the Slider-crank mechanism is not. Kinamatic data such as displacement, velocity and acceleration of a simple Slider-crank mechanism can be obtained and compare the same with Scotch yoke Mechanism.

**VII. Experimental setup**

a) Single Slider Crank Mechanism




b) Scotch yoke Mechanism



## VIII. Resources Required

| S. No. | Name of Resource | Suggested Broad Specification | Quantity |
|---|---|---|---|
| 1 | Working Model of Single slider Crank mechanism | Scale for Displacement, Angle measuring arrangement,1/4 HP motor | 1 |
| 2 | Working Model of skotch Yoke Mechanism | Scale for Displacement, Angle measuring arrangement,1/4/HP motor | 1 |
| 3 | Tachometer | Range speed upto 2000RPM | 1 |

## IX. Precautions to be followed

1. Do not rotate the Mechanism with high speed

## X. Procedure

1. Set the slider crank at 0 mm for the connecting rod, and 0° for the rotating disk.
2. Measure L the length of the connecting rod and R the radius for the rotating disk.
3. Change the angle for the disk by 30° each time until 360°, and each time measure X.
4. Plot the graphs of linear displacement, ‘X’, velocity ‘V’ and acceleration ‘a’ versus angular displacement.
5. Repeat the procedure for Scotch-Yoke mechanism.

## XI. Resources Used

| S. No | Name of Resource | Broad Specifications | | Quantity | Remarks (If any) |
|---|---|---|---|---|---|
| | | Make | Details | | |
| 1. | | | | | |
| 2. | | | | | |
| 3. | | | | | |

**EXPERIMENT-5**

**AIM: Assembly and Disassembly of Clutches**

**I. Practical Significance**

Clutches are used in for engaging and disengaging the prime over and power transmission systems. These are commonly used in most of the automobiles and many industrial systems.

**II. Relevant Program Outcomes (POs)**

**PO 2.** Discipline knowledge: Apply Mechanical engineering knowledge to solve broad-based mechanical engineering related problems.

**PO 3.** Experiments and practice: Plan to perform experiments and practices to use the results to solve broad-based Mechanical engineering problems.

**PO 8.** Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

**III. Competency and Skills**

This practical is expected to develop the following skills for the industry identified competency ***'• Use principles of kinematics and dynamics in maintenance of various equipment.'***

**IV. Relevant Course Outcome(s)**

- Select relevant brakes and clutches for various applications

**V. Practical Outcome**

Assemble and dissemble different clutches

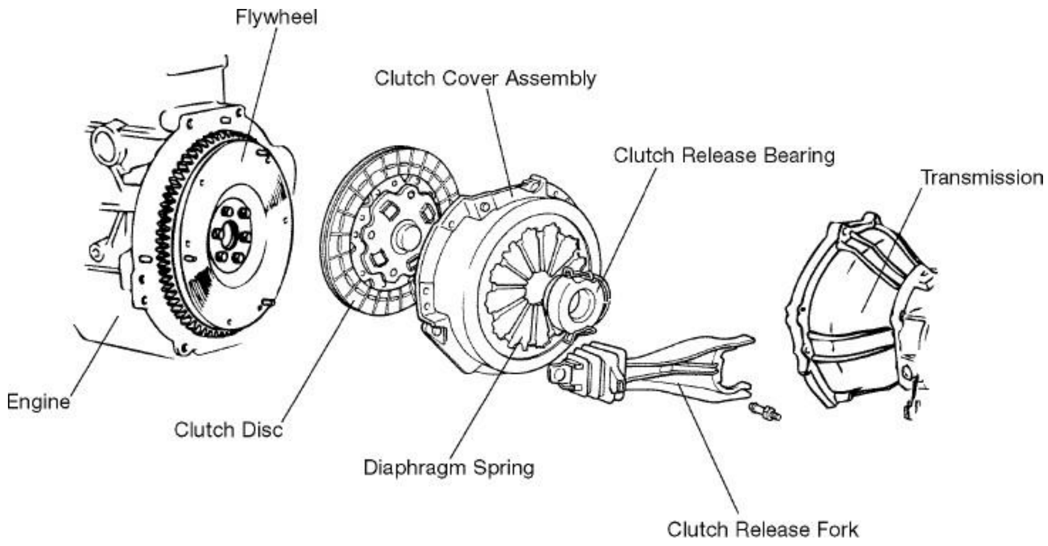
**VI. Relevant Affective Domain Unrelated Outcomes**

1. Follow safety practices.
2. Practice good housekeeping.
3. Demonstrate working as a leader/a team member.
4. Maintain tools and equipment.

**VII. Minimum Theoretical Background**

The clutch disc is connected to the input shaft of the transmission, and is located between the flywheel and clutch cover assembly. The flywheel is connected to the engine crankshaft and the clutch cover assembly is attached to the flywheel. The clutch release fork forces the clutch release bearing against the diaphragm spring of the clutch cover assembly.

## VIII. Experimental setup




## IX. Resources Required

| S. No. | Name of Resource | Suggested Broad Specification | Quantity |
|---|---|---|---|
| 1 | Single plate clutch | | 1 |
| 2 | Tool Box | | 1 |

## X. Precautions to be followed

1. Due safety precautions while dismantling the clutch.
2. Carefully handle the different tools

## XI. Procedure

1 Clean the single plate clutch thoroughly.
2 Carefully dismantle the single plate clutch step by step.
3 Arrange the components sequentially in a clean tray during dismantling process.
4 Note constructional features of each part and its role in working of clutch.
5 Loosely assemble the components in the clutch housing and observe the changes occurring inside
6 The assembly during engagement and disengagement.
7 Observe and understand the mechanism of power transmission.
8 Reassemble the unit and ensure its smooth working.

## XII. Resources Used

| S. No. | Name of Resource | Broad Specifications | | Quantity | Remarks (If any) |
|---|---|---|---|---|---|
| | | Make | Details | | |
| 1. | | | | | |
| 2. | | | | | |
| 3. | | | | | |

## EXPERIMENT - 6

**AIM : Governor Characteristics**

**I. Practical Significance**

The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. On the other hand, when the load on the engine decreases, its speed increases and thus less working fluid is required .The governor controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

**II. Relevant Program Outcomes (POs)**

**PO 2.** Discipline knowledge: Apply Mechanical engineering knowledge to solve broad-based mechanical engineering related problems.

**PO 3.** Experiments and practice: Plan to perform experiments and practices to use the results to solve broad-based Mechanical engineering problems.

**PO 8.** Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

**III. Competency and Skills**

This practical is expected to develop the following skills for the industry identified competency ***Use principles of kinematics and dynamics in maintenance of various equipment.***'

- Operate governor of a given system
- Measure the lift of sleeve
- Plot a graph between position of sleeve and rotational speed

**IV. Relevant Course Outcome(s)**

- Select suitable flywheel and governor for various applications

**V. Practical Outcome**

- Measure radius and height of all types of governors for different rotational speeds, mass of balls and spring stiffness

**VI. Relevant Affective Domain Unrelated Outcomes**

1. Follow safety practices.
2. Practice good housekeeping.
3. Demonstrate working as a leader/a team member.
4. Maintain tools and equipment.
5. Follow ethical Practices

## VII. Minimum Theoretical Background

The centrifugal governors are based on the balancing of centrifugal force on the rotating balls by an equal and opposite radial force, known as the controlling force. It consists of two balls of equal mass, which are attached to the arms .These balls are known as governor balls or fly balls. The balls revolve with a spindle, which is driven by the engine through bevel gears. The upper ends of the arms are pivoted to the spindle, so that the balls may rise up or fall down as they revolve about the vertical axis. The arms are connected by the links to a sleeve, which is keyed to the spindle. This sleeve revolves with the spindle; but can slide up and down. The balls and the sleeve rises when the spindle speed increases, and falls when the speed decreases. In order to limit the travel of the sleeve in upward and down-ward directions, two stops S, are provided on the spindle. The sleeve is connected by a bell crank lever to a throttle valve. The supply of the working fluid decreases when the sleeve rises and increases when it falls.

The following terms used in governors are important from the subject point of view;

1. **Height of a governor**. It is the vertical distance from the center of the ball to a point where the axes of the arms intersect on the spindle axis. It is usually denoted by h.
2. **Equilibrium speed.** It is the speed at which the governor balls, arms etc., are in complete
   equilibrium and the sleeve does not tend to move upwards or downwards.
3. **Mean equilibrium speed.** It is the speed at the mean position of the balls or the sleeve.
4. **Maximum and minimum equilibrium- speeds.** The speeds at the maximum and minimum radius of rotation of the balls, without tending to move either way are known as maximum and minimum equilibrium speeds respectively.

## VIII. Experimental setup

## IX. Resources Required

| S. No. | Name of Resource | Suggested Broad Specification | Quantity |
|---|---|---|---|
| 1 | Centrifugal Governor Test bench | A test bench comprising of following A centrifugal governor, electrical motor, arrangement for regulating speed of the driving motor and a suitable mounting frame. Arrangement for measurement displacement of slider.<br>Note:- Various manufacturers offer such test bench with their own proprietary design. Hence the institutes are advised to purchase any suitable bench for measuring the slip of belt. | 1 |
| 2 | Tachometer | Range 0-3000 RPM | 1 |

## X. Precautions to be followed

1. Do not increase the speed of governor exceeding maximum limit.

## XI. Procedure

1) Switch on the control unit and rotate the speed control knob slowly.
2) Increase the governor speed until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale.
3) Measure the sleeve position and speed. Speed may be determined using a tachometer on the spindle.
4) The governor speed is then increased in steps to give suitable sleeve movement, and readings be taken at each interval throughout the range of sleeve movement.
5) While closing the test bring the dimmer to zero position and then switch off the motor.
6) Plot the graph of radius of rotation Vs. speed to study governor characteristics

## XII. Observations and Calculations

1 Length of arm ‘ L‘ =.............mm.

2. Initial height of governor ‘ h ‘ =.............mm.

3. Initial radius of rotation ‘r ‘ = ............. mm.

4. Diameter of sleeve, D =..............mm.

**Calculations**

Height ‘ H ‘ = Initial height of governor - Sleeve displacement / 2

$H = h - X/2 =$

Find angle α, using $\cos \alpha = H / L$

Radius of rotation ‘ R ‘ = $D/2 + (L \sin \alpha)$

Where, D = Diameter of sleeve at which arms are attached.

## EXPERIMENT-7

## AIM: Balancing of Masses

### I. Practical Significance

In many engineering systems, various masses are rotating in either a single plane or in different planes. Due to this, a system of forces is in existence which may have imbalanced forces. These imbalanced forces cause vibrations, noise and other mechanical failures. Hence, for longer life of the system and its operation with minimum vibration and noise, the balancing of masses is essential.

### II. Relevant Program Outcomes (POs)

**PO 2.** Discipline knowledge: Apply Mechanical engineering knowledge to solve broad-based mechanical engineering related problems.

**PO 3.** Experiments and practice: Plan to perform experiments and practices to use the results to solve broad-based Mechanical engineering problems.

**PO 8.** Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

### III. Competency and Skills

This practical is expected to develop the following skills for the industry identified competency ***Use principles of kinematics and dynamics in maintenance of various equipment.***'

- Identify causes of Unbalancing of rotary element

### IV. Relevant Course Outcome(s)

- Select suitable flywheel and governor for various applications.

### V. Practical Outcome

- Perform balancing of rotating unbalanced system

### VI. Relevant Affective Domain Unrelated Outcomes

1. Follow safety practices.
2. Practice good housekeeping.
3. Demonstrate working as a leader/a team member.
4. Maintain tools and equipment.
5. Follow ethical Practices.

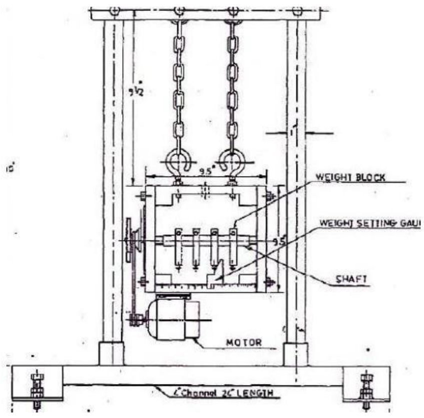
### VII. Minimum Theoretical Background

When several masses revolve in different planes, they may be transferred to a reference plane, which may be defined as the plane passing through a point on the axis of rotation and perpendicular to it. The effect of transferring a revolving mass (in one plane) to a reference plane is to cause a force of magnitude equal to centrifugal force of the revolving mass to act in the reference plane, together with a couple of magnitude equal to the product of the force and the distance between the plane of rotation and the reference plane. In order to have a complete balance of the several revolving masses in different planes, the following conditions must be satisfied:

1. The forces in the reference plane must balance i.e. the resultant force must be zero.

2. The couple about the reference plane must balance, i.e. the resultant couple must be zero.

## VIII. Experimental setup




## IX. Resources Required

| S. No. | Name of Resource | Suggested Broad Specification | Quantity |
|---|---|---|---|
| 1 | Static & Dynamic Balancing Machine | Single phase motor connected to a shaft, containing 4 rotating masses. Each rotating mass has a facility to insert. Pulley is provided to add weights to balance the unbalance shaft | 01 |

## X. Precautions to be followed

1. Do not run the motor at low voltage i.e. less than 180 volts.
2. Increase the motor speed gradually

## XI. Procedure

1. Insert all the weights in sequence 1-2-3-4 from pulley side.
2. Fix the pointer and pulley on shaft.
3. Fix the pointer on 0° ($\theta 2$) on the circular protractor scale.
4. Fix the weight no.1 in horizontal position.
5. Rotate the shaft after loosening previous position of pointer and fix it on $\theta 3$.
6. Fix the weight no. 2 in horizontal position.
7. Loose the pointer and rotate the shaft to fix pointer on $\theta 4$.
8. Fix the weight no.3 in horizontal position.
9. Loose the pointer and rotate the shaft to fix pointer on $\theta 1$.
10. Fix the weight no. 4 in horizontal position.
11. Now the weights are mounted in correct position.
12. For static balancing, the system will remain steady in any angular position.

13. Now put the belt on the pulleys of shaft and motor.
14. Supply the main power to the motor through dimmer stat.
15. Gradually increase the speed of the motor. If the system runs smoothly andwithout vibrations, it shows that the system is dynamically balanced.
16. Gradually reduced the speed to minimum and then switch off the main supply tostop the system.

**XII. Observations and Calculations**

Mass of 1 = m1 gms = Plane 1 = Weight

No. =Mass of 2 = m2 gms = Plane 2 = Weight

No. =Mass of 3 = m3 gms= Plane 3 = Weight

No. =Mass of 4 = m4 gms = Plane 4 =

Weight No. = Radius 1, 2, 3, 4=

r cm. (Same radius)

Angle between 2 & 3 = θ3 Angle between 2 & 4 = θ4 Angle between 2 & 1 = θ1