MECHANICAL ENGINEERING DEPARTMENT

LABORATORY MANUAL

THEORY OF MACHINES

ME-VI

List of Experiments

1. Study of Links/Models/Mechanisms.
2. Study of Inversions of mechanism.
3. Draw the velocity and acceleration diagram for the given mechanism.
4. Determine the torque on crank shaft for the given mechanism.
5. Do the static and dynamic balancing of given masses with the help of balancing machines.
6. Draw the cam profile for the given cam with the cam apparatus.
7. Plot the characteristic curve of dead weight governors.
8. Plot the characteristic curve of spring loaded governors.
9. Verify the gyroscopic effect on gyroscope.
10. To find out critical speed experimentally and to compare the whirling speed of a shaft.
11. Study of automotive braking system.

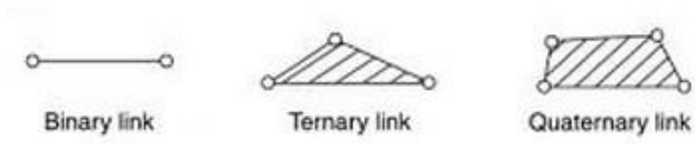
EXPERIMENT NO. 1

Object :- Study of simple linkage models/mechanisms.

Apparatus Required : Models of various Mechanisms.

Theory : **1. Link :** A resistant body or a group of resistant bodies with rigid connections preventing their relative movement is known as a link. A link may also be defined as a member or a combination of members of a mechanism, connecting other members and having motion relative to them.

A link is also known as kinematic link or element. Links can be classified into binary, ternary and quaternary depending upon their ends on which or turning pairs can be placed.



2. **Kinematic Pair :** A kinematic pair or simply a pair is a joint of two links having relative motion between them.

Types of Kinematic Pairs : Kinematic pairs can be classified according to

I. Nature of contact
II. Nature of relative motion

I. Kinematic Pairs according to Nature of Contact

(a) **Lower Pair:** A pair of links having surface or area contact between the members is known as a lower pair. The contact surfaces of two links are similar, e.g., nut turning on a screw, universal joint, etc.

(b) **Higher Pair :** When a pair has a point or line contact between the links, it is known as a higher pair. The contact surfaces of the two links are dissimilar, e.g., wheel rolling on a surface, cam and follower pair, etc.

II. Kinematic Pairs according to Nature of Relative Motion

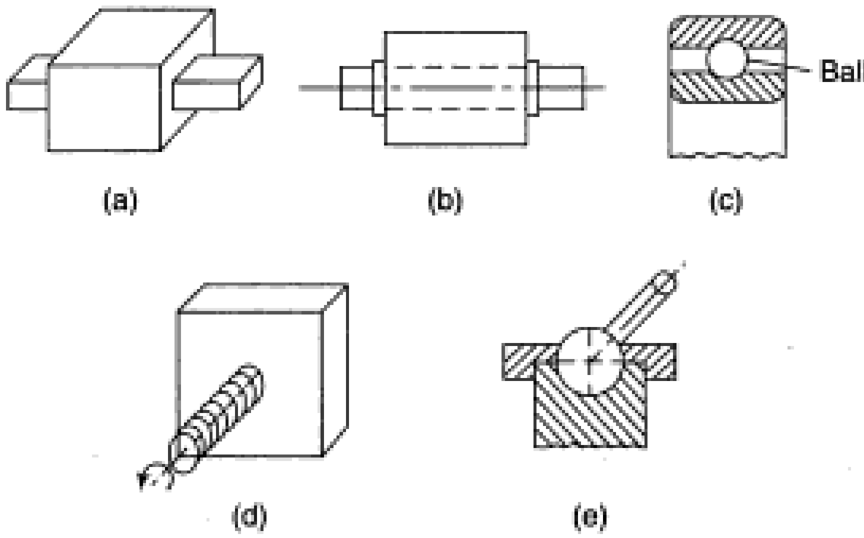
(a) **Sliding Pair :** If two links have a sliding motion relative to each other, they form a sliding pair, e.g., a rectangular rod in a rectangular hole in a prism.

(b) **Turning Pair :** When one link has a turning or revolving motion relative to the other, they constitute a turning or revolving pair, e.g., a circular shaft revolving inside a bearing.

(c) **Rolling Pair :** When the links of a pair have a rolling motion relative to each other, they form a rolling pair, e.g., a rolling wheel on a flat surface.

(d) **Screw Pair (Helical Pair) :** If two mating links have a turning as well as sliding motion between them, they form a screw pair, e.g., lead screw and nut of a lathe.

(e) **Spherical Pair :** When one link in the form of a sphere turns inside a fixed link, it is a spherical pair, e.g., ball and socket joint.



3. **Degree of Freedom:** Number of independent motion, both translational and rotational , a pair can have. An unconstrained rigid body moving in space can have following independent motion .

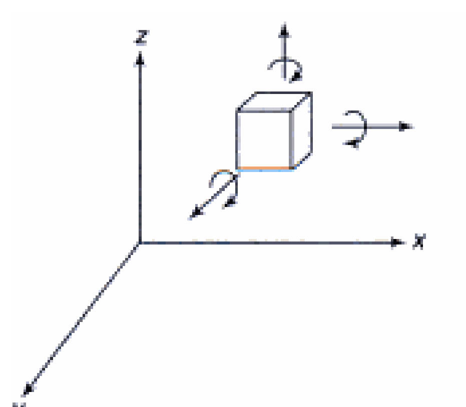
-Translational motion along any other mutually perpendicular axes x, y and z

-Rotational motions about these axes

Thus a rigid body possess 6 degree of freedom.

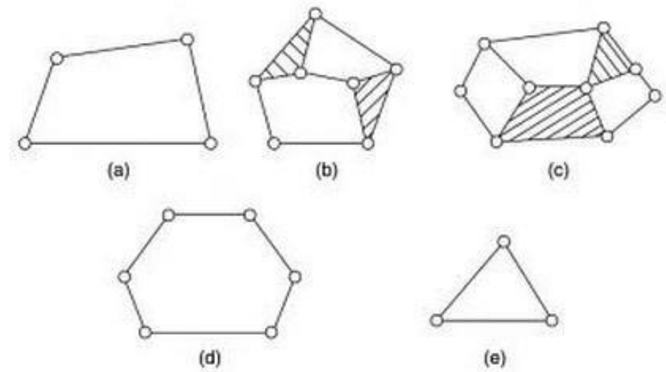
The connection of a link with another link imposes certain constraint on their relative motion.

Degree of freedom= 6-number of constraint.



4. **Kinematic Chain :** A kinematic chain is an assembly of links in which the relative motions of the links is possible and the motion of each relative to the other is definite.

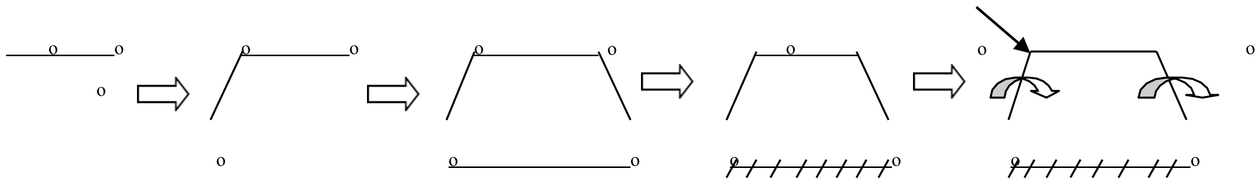
In the figure given below (a), (b) & (c) are kinematic chains while (d) is a non-kinematic chain. Figure (e) shows a redundant chain as it does not allow any motion of a link relative to the other.



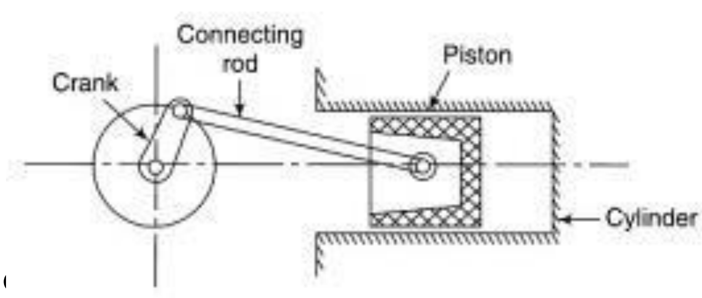
5. **Mechanism :** If number of bodies are assembled in such a way that the motion of one causes constrained and predictable motion to the others, it is known as a mechanism. A mechanism transmit and modifies a motion.

A **mechanism** is a kinematic chain with any one link fixed which is used to transmit the required motion.

6. **Machine:-**A machine is a mechanism or a combination of mechanisms which, apart from imparting definite motions to the parts also transmits and modifies the available mechanical energy into some kind of desired work. It is neither a source of energy nor a producer of work but helps in proper utilisation of the same. The motive power has to be derived from external sources.



LINK **KINEMATIC PAIR** **KINEMATIC CHAIN**
MECHANISM **MACHINE**



VIVA QUESTIONS

(1) Give the examples of kinematic chain.

(2) Difference between mechanism and machine.

(3) What is degree of freedom?

(4) Give some examples of lower and higher pairs.

EXPERIMENT NO. 2

Object: Study of inversions of mechanism.

Apparatus Used: Model of four bar, single slider crank and double slider mechanism.

Inversion of mechanism

Mechanism is a kinematic chain in which one link is fixed. By fixing the links of a kinematic chain one at a time, we get as much different mechanism as the number of links in the chain. This method of obtaining different mechanism by fixing different links of the same kinematic chain is known as INVERSION OF MECHANISM. In the process of inversion, the relative motions of the links of the mechanism produced remain constant.

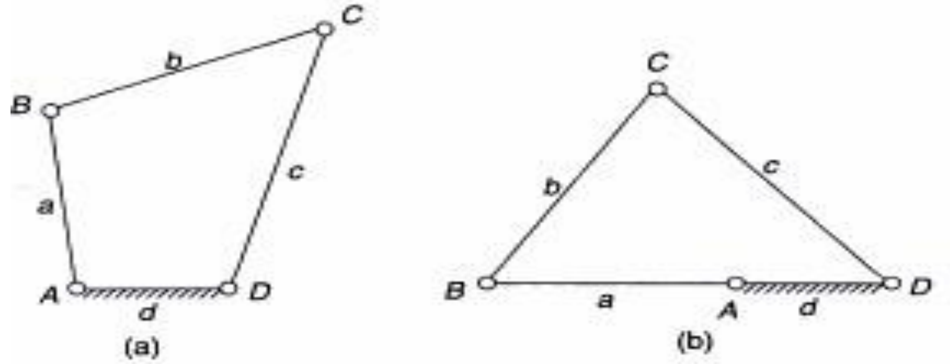
TYPES OF KINEMATIC CHAIN:

The most important type of kinematic chains are those which consist of 4 lower pairs, each pair being a sliding or turning pair. The following 3 types of kinematic chains with four lower pair are important-

1. Four bar chain
2. Single slider crank chain
3. Double slider crank chain

1) FOUR BAR CHAIN:-
This is the simplest kinematic chain. It consists of four resistant bodies links which are connected in the form of a quadrilateral by 4 pin joints
It consist of four turning pairs. A link that makes complete revolution is known as crank. The fixed link is known as frame if the mechanism. The link opposite to the fixed link is known as coupler or connecting rod. The fourth link is called as lever or rocker(if it oscillates) or an another crank (if it rotates)

If different links of the four bar mechanism are fixed, four different mechanism(inversion) will be obtained.

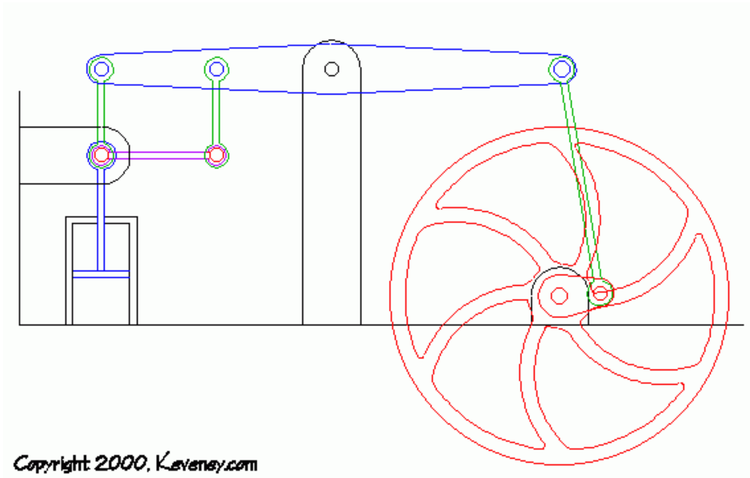


1. **First Inversions: Cranks and lever mechanism (oscillatory motion)**

The 4 links of the bar chain are 1, 2, 3 and 4.the link 1 is fixed and the lengths of the link 2,3 and 4 are proportionate in such a way that crank is able to rotate completely. Here for every complete revolution of link 2(crank)?,the link 4(lever) makes a complete oscillation.

Purpose of this mechanism is to convert rotary motion into oscillatory motion

Example – beam engine

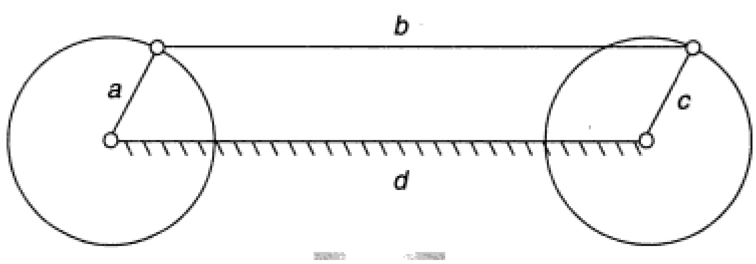


Second Inversion: Double crank mechanism (complete rotation of the crank and the follower)

The link 2 and 4 of the double crank mechanism make complete revolutions. There are two different forms of this mechanism.

(a)Parallel crank mechanism:

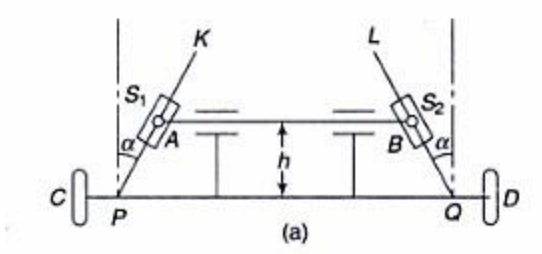
In this mechanism, the length of the fixed link is equal to the connecting rod and moreover the two cranks are of equal length. Ex- coupling rod of locomotive

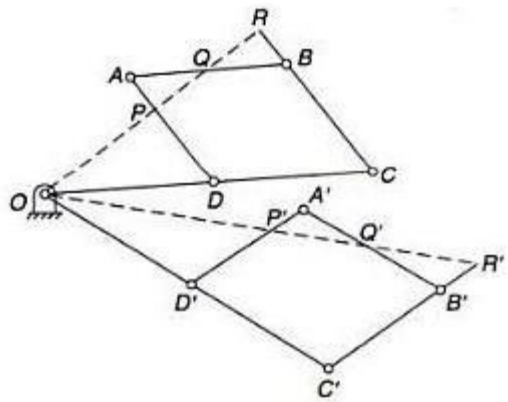


Third Inversion: Double lever mechanism

if the link opposite to shorter link fixed and the shortest link is made coupler ,the other two links 2and 4 would oscillate.

When the link 2 and 4 are of equal length and l3>l. This mechanism forms an automobile steering linkage. Ex-pantograph ,automobile steering.





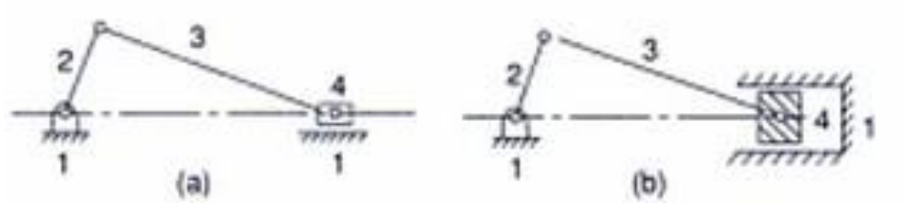
2) SLIDER CRANK MECHANISM:

It is the modification of basic 4 bar chain. It consist of four kinematic pairs out of which one is sliding pair and three are turning pairs, link 1&2 and link 2&3 form turning pair link 3 and 4 form turning pair while link 1 and 4 forms sliding pair. Or this mechanism is formed by replacing one turning pair of 4 bar mechanism.

First Inversions:

a) 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.

Ex- **Reciprocating engine, reciprocating compressor.**



Here link 1 correspond to the frame which is fixed .link 2 correspond to the crank ,link 3 correspond to the connecting rod and link 4 correspond to the slider (piston)

In reciprocating engine link 4 is the driver and link 2 is the follower and vice versa reciprocating compressor.

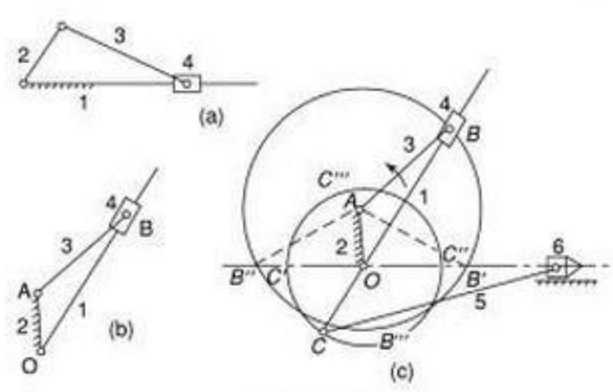
b) second inversion:

When link 2 is fixed, the second inversion is obtained of single slider crank chain, then link 3 along with the slider at its end c becomes a crank. Here link 3 along with slider (link 4) which reciprocates on link 1.

Ex whit worth quick return mechanism.

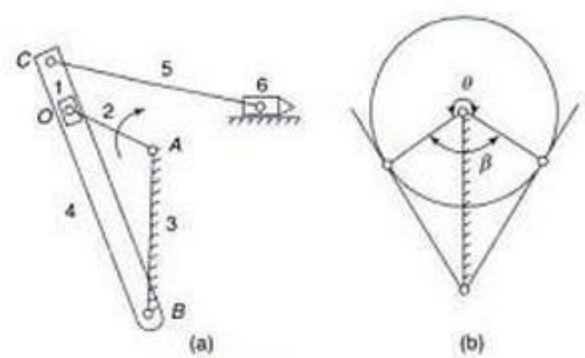
WHITWORTH QUICK RETURN MECHANISM:

This mechanism is used in workshop to cut metal. The forward stroke to cut the metal whereas return stroke is idle .The forward stroke takes a little longer periods whereas the return stroke takes a shorter period as shown in fig. 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,produces downward there Is a point D ,where link 5 is connected.The other end of the link 5 is connected to the tool. The forward stroke of the tools cuts the metal whereas the return stroke is idle .The point D rotates in a circle point A .



c) Third inversion:

When link3 is fixed, the third inversion of a single slider crank is obtained.
Link 2 act as a crank rotates about point b link 4 oscillates .Ex. Quick Return Mechanism.



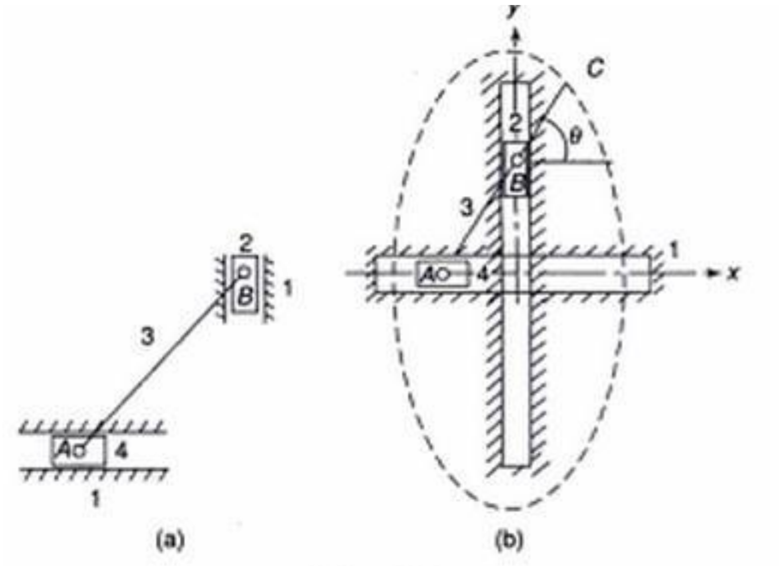
3) DOUBLE SLIDER CRANK CHAIN

A kinematic chain which consists of two turning pair and two sliding pair Is known as double slider crank chains. Here two pairs of same kind are adjacent.

a) First inversion

This inversion is obtained when link 1 is fixed and two adjacent pairs 2,3 and 4 are turning pairs and the other two pairs 1,2 and 4,1 hiding pairs.
Application:

Elliptical trammel-In this mechanism the fixed link 1 is in the form of guides for sliders 2 and 4.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 mid point of AB will trace a circle .

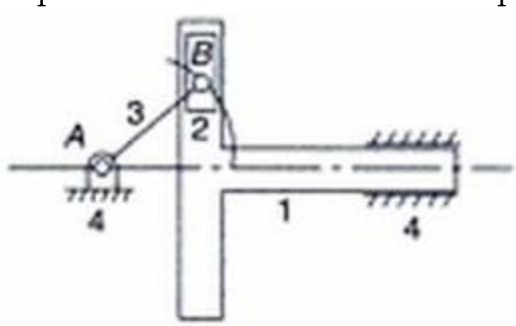


b) Second inversion

If any of the slide blocks of the first inversion is fixed ,frame is kept free.The second inversion of the double slider crank chain is obtained .When link 4 is fixed ,end B of crank 3 rotates about A and LINK 1 RECIPROCATES IN THE HORIZONTAL DIRECTION.

Application-

Scotch yoke mechanism is used to convert the rotary motion into a sliding motion.As crank 3 rotates, the horizontal portion of link 1 slides or reciprocates in the fixed link 4.

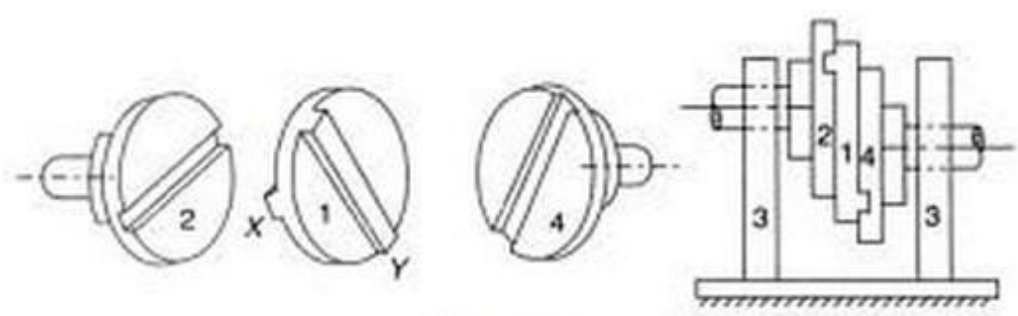


c) Third inversion:

This inversion is obtained when link 3 of the first inversion is fixed and link 1 is free to move.

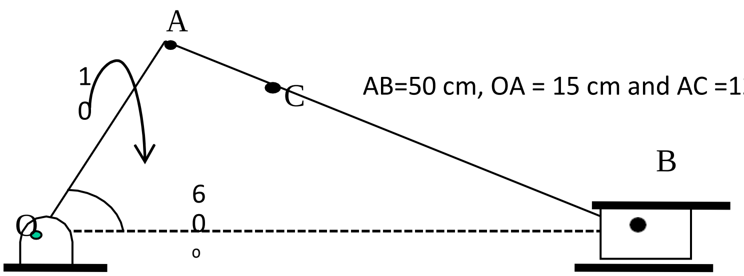
Application:

Old ham's coupling



EXPERIMENT NO. 3

Object: Find out velocity and acceleration for the given mechanism by all method.



Velocity and acceleration of Point in a Mechanism:

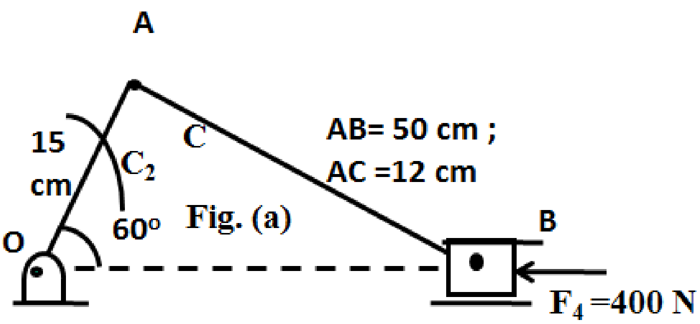
Velocity and acceleration of various point can be determined by

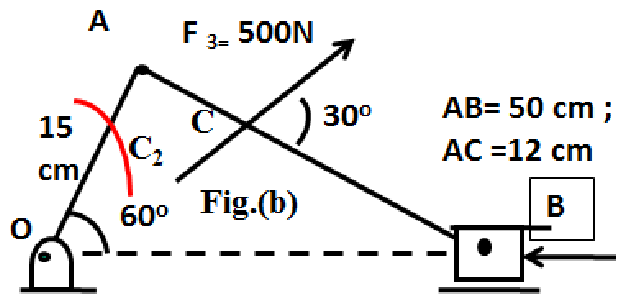
1. Analytical Method
2. Relative Velocity Method
3. I-Centre Method
4. Kleins Construction

S. No.	Velocity of Piston	Acceleration of Piston	Angular Velocity of Connecting Rod	Angular Acceleration of Connecting Rod	Velocity of Point C
Analytical Method					
Relative Velocity Method					
I-Centre Method					
Kleins Construction					

EXPERIMENT NO. 4

Object: Determine the torque on crank shaft for the given mechanism.



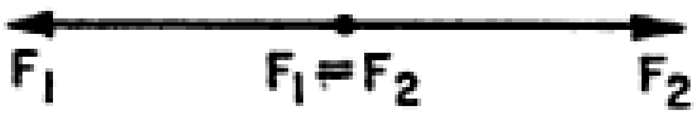


Force Equilibrium: A body is subjected to a system of forces that lie in the x-y plane. When in equilibrium, the net force and net moment acting on the body are zero . This can be represented by the three equilibrium equations:

$\sum F_x = 0$ $\sum F_y = 0$ $\sum M_O = 0$

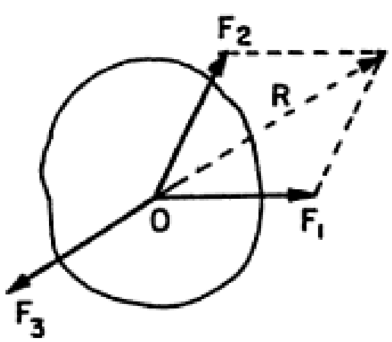
Where point O is any arbitrary point.

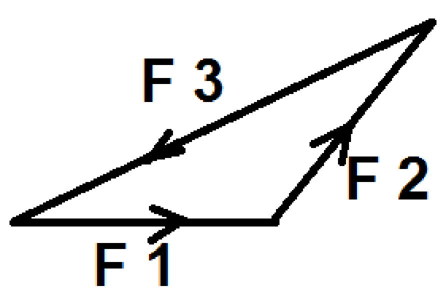
Two Force Member: When a body is subjected to two forces , then the body is in equilibrium if two forces are collinear, equal and opposite.



Two Force and a Couple: When a body is subjected to two force s and a torque then the body is in equilibrium if two forces equal ,opposite and parallel to each other and couple produced by these forces will be equal to applied torque.

Three Force Member: When a body is subjected to three forces ,then body will be in equilibrium if these forces meet to a common point and they should make a close force polygon.





EXPERIMENT NO. 5

Object :- To check experimentally the normal method of calculating the position of counter balancing weight in rotating mass systems.

Apparatus Used:- Static & Dynamic balancing machines, a set of 6 blocks of different weights

Theory:-

Static Balancing: A system of rotating masses is said to be in static balance if the combined mass centre of the system lies on the axis of rotation. Whenever a certain mass is attached to a rotating shaft, it exerts some centrifugal force, whose effect is to bend the shaft and to produce vibrations in it.

Dynamic Balancing: When several messes rotates in different planes, the centrifugal force, in addition to being out of balance, also forms couples. A system of rotating masses is in dynamic balance when there does not exit any resultant centrifugal force as well as resultant couple

.In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft. The process of providing the second mass in order to counteract the effect of the centrifugal force of the first mass, is called balancing of rotating masses. The following cases are important from the subject point of view :

1 Balancing of a rotating mass in the same plane.(Static Balancing)
2 Balancing of a rotating mass in different planes. (Dynamic Balancing)

PROCEDURE:-

Static Balancing: Remove the belt, the value of weight for each block is determined by clamping each block in turn on the shaft and with the cord and container system suspended over the protractor disc, the number of steel balls, which are of equal weight are placed into one of the containers to exactly balance the blocks on the shaft. When the block becomes horizontal, the number of balls N will give the value of wt. for the block. For finding out Wr during static balancing proceed as follow:

1 Remove the belt.
2 Screw the combined hook to the pulley with groove. This pulley is diff. than the belt pulley.
3 Attached the cord end of the pans to above combined hook.
4 Attached the block no.-1 to the shaft at any convenient position and in vertical downward direction.
5 Put steel balls in one of the pans till the blocks starts moving up. (upto horizontal position).
6 Number of balls gives the Wr value of block-1. Repeat this for 2-3 times and find the average no. of balls.
7 Repeat the procedure for other blocks.

Dynamic balancing

It is necessary to leave the machine before the experiment. Using the value of Wr, obtained as above, and if the angular positions and planes of rotation of three of four blocks are known, the student can calculate the position of the other block(s) for balancing of the complete system. From the calculations, the student finally clamps all the blocks on the shaft in their appropriate positions. Replace the motor belt , transfer the main frame to its hanging position and then by running the motor, one can verify that these calculations are correct and the balls are perfectly balanced.

Observations:-

For Static Balancing

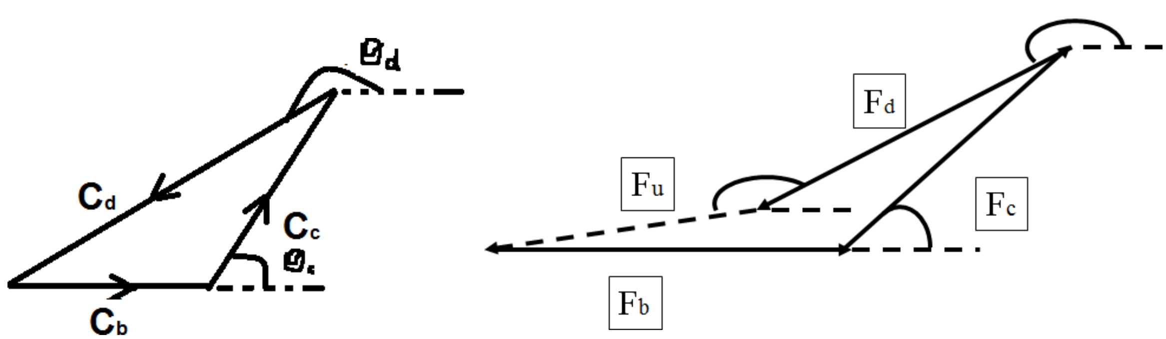
For static balancing, the Wr for unbalance are:-

Block No.	1	2	3	4	5	6
M.r						

For Dynamic Balancing

Consider the 4 blocks for finding the angular positions of these blocks for complete dynamic balancing, the table will be as follows:-

S.No.	Block No.	M.r (No. of Balls)	Distance (l)(cm)	Couple	Angular positions(θ)
1.					
2.					
3.					
4.					



Calculation: - The balancing masses and angular positions may be determined graphically as given below:-

1. First of all, draw the couple polygon from the data which are calculated in table to

some suitable scale. The vector distance represents the balanced couple. The angular position of the balancing mass is obtained by drawing, parallel to vector distance. By measurement we will find the angle.

4. Then draw the force polygon from the data, which are calculated in table to some suitable scale. The vector distance represents the balanced force. The angular position of the mass is obtained by drawing, parallel to vector distance. By measurement we will find the angle in the anticlockwise direction from x axes .

Result:-

Angular position of block are obtained from polygon and the magnitude of block U is also obtained Mr =……Adjust all angular and lateral position properly and find that the shaft rotates without vibrations.

PRECAUTIONS:-

1 Do not run the motor for more time in unbalanced position.

2 Place the weight/balls gently in the pan. While placing the balls the pan should be hold gently and check that it should not jump its position.

3 Weight setting gauge should be check gently.

4. Couple should be represented by a vector drawn perpendicular to the plane of the couple.

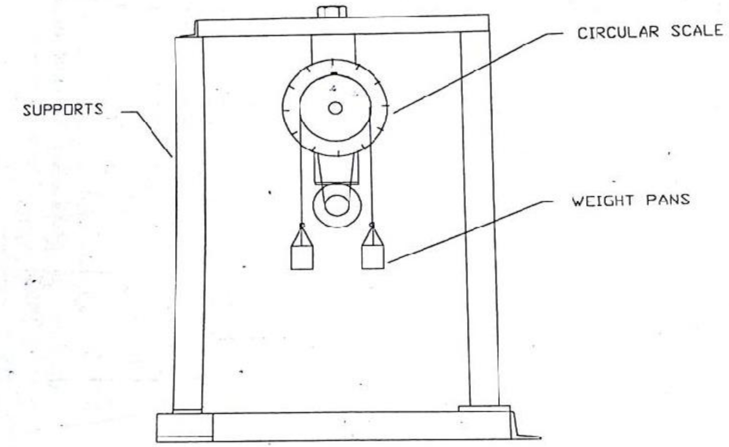
5. Angular position measure carefully in clockwise direction.

6. Vector diagram should be represent with suitable scale.

.

VIVA QUESTIONS:

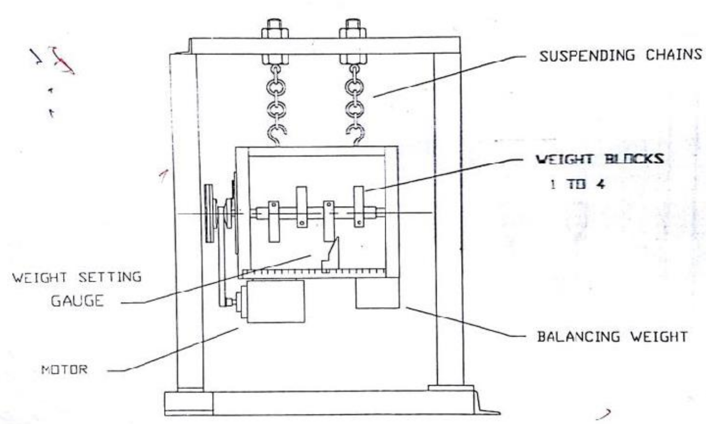
1. Why is balancing of rotating parts necessary for high speed engines ?
2. Explain the terms ‘static balancing’ and ‘dynamic balancing’. State the necessary conditions to achieve them.
3. Discuss how a single revolving mass is balanced by two masses revolving in different planes.
4. How the different masses rotating in different planes are balanced ?
5. Explain the method of balancing of different masses revolving in the same plane.
6. Why is balancing of rotating parts necessary for high speed engines ?
7. Explain the terms ‘static balancing’ and ‘dynamic balancing’. State the necessary conditions to achieve them.
8. Discuss how a single revolving mass is balanced by two masses revolving in different planes.
9. How the different masses rotating in different planes are balanced ?
10. Explain the method of balancing of different masses revolving in the same plane.



STATIC & DYNAMIC BALANCING MACHINE

Set-up for statically balancing of rotory masses

FIG. NO. 2



STATIC & DYNAMIC BALANCING MACHINE

Set-up for dynamically balancing of rotory masses

FIG. NO. 1

EXPERIMENT NO. 6

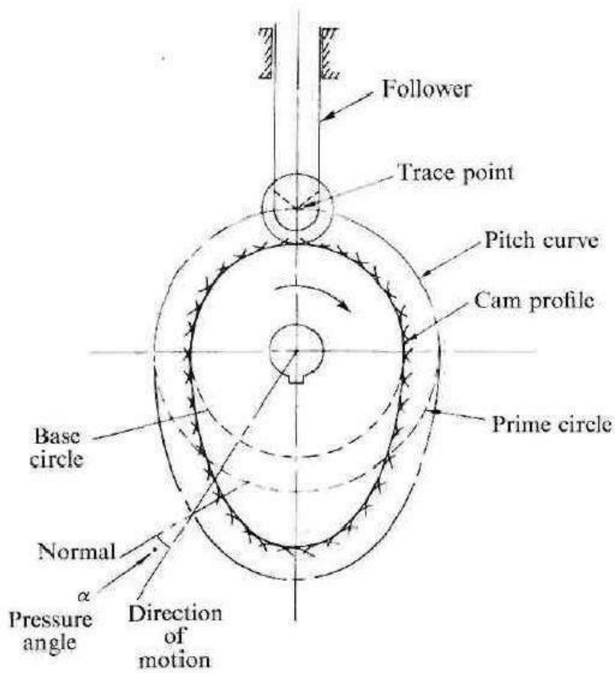
Object: a) To plot the curve between cam displacement vs. cam rotation curve.

b) To draw the cam profile.

c) To plot the curve between jerk speed vs. weight

Theory:

A cam may be defined as a rotating or a reciprocating element of a mechanism, which impart rotating, reciprocating or oscillating motion to another element termed as follower. In most of cases the cam is connected to a frame, forming a turning pair and the follower is connected to the frame to form a sliding pair.



The cam and the follower form a three link mechanism:

(a) The cam which is the driving link and has a curved or a straight contact surface

(b) The follower which is the driven link and it gets motion by contact with the surface of the cam and

(c) The frame which is used to support the cam and the guide the follower.

Types of cam

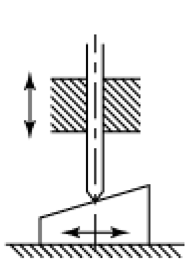
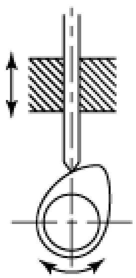
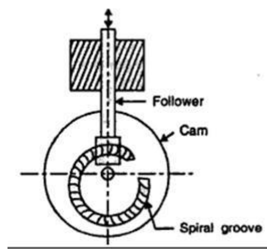
Cams are classified according to;

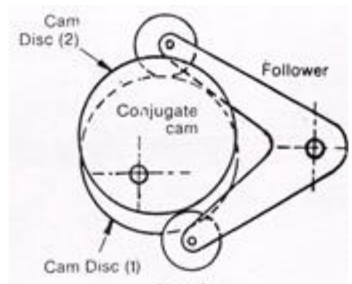
1. Shape,
2. Follower movement ,and

According to shape

1. Wedge and flat cams

A wedge cam has a wedge which, in general has a translational motion. The follower can either translate or oscillate.



2. Radial or dice cams

A cam in which the follower moves radially from the center of rotation of the cam is known as a radial disk cam.

3 spiral cams

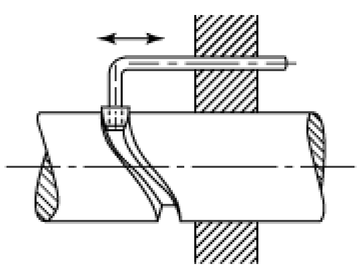
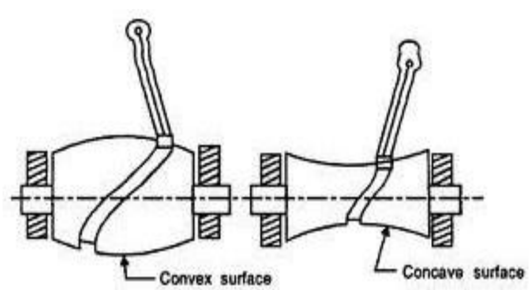
A spiral cam is face cam in which a groove is cut in the form of a spiral .the use of such cam is limited as the cam has to reversed the direction to reset the position of the follower .

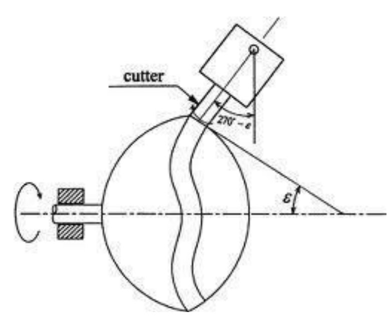
4. Conjugate cam

A conjugate cam is a double disk cam, the 2 disks being keyed together and is in constant touch with the two rulers as a follower. Thus, the follower has a positive constraint.

5. Cylindrical cam

In a cylindrical cam, a cylinder which has a circumferential counter cut in surface rotates about its axis.



6. Globoidal cams

A globoidal cam can have two types of surface, convex and concave. A circumferential counter is cut on the surface on the rotation of cam to impart motion of the follower which has an oscillatory motion.

7 spherical cams

In a spherical cam, the follower oscillates about an axis perpendicular to the axis of the cam.

Types of follower

Cam followers are classified according to the:

1. Shape
2. Movement, and
3. Location of line of movement
4.

According to the shape

1. Knife –edge follower

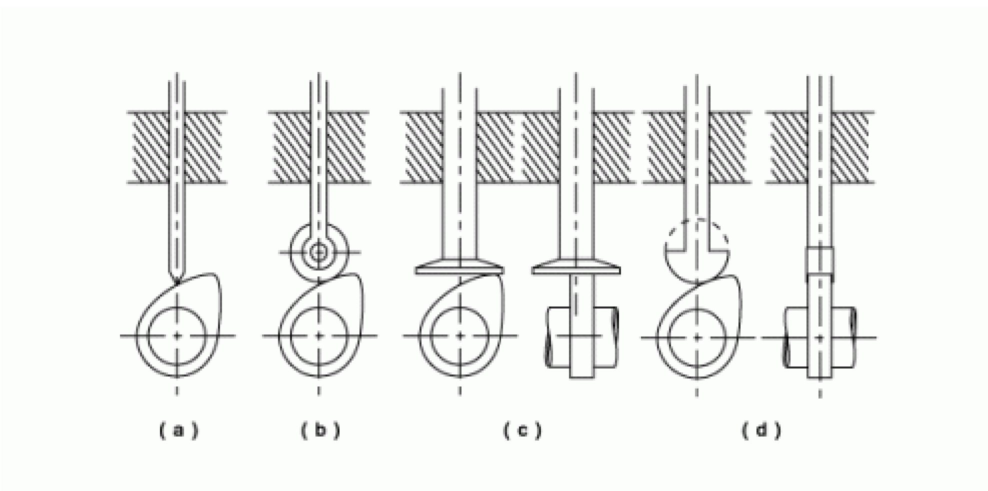
It is quite simple in construction. However, its use is limited as it produces a great wear of the surface at the point of contact.

2 Roller followers

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

3 Mushroom followers

A mushroom follower has a advantage that it does not pose the problem of jamming the cam.



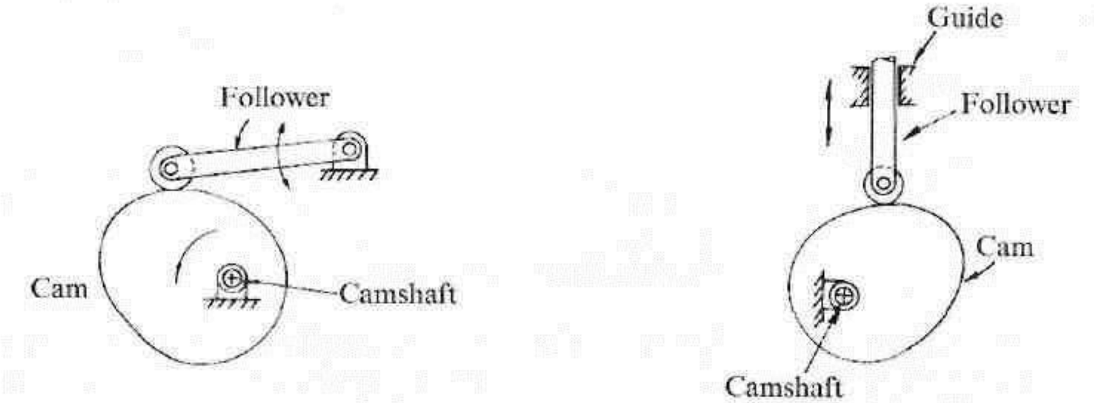
According to movement

1. Reciprocating follower

In this type, as the cam rotates, the follower reciprocates or translates in the guide.

2. Oscillating follower

The follower is provided at a suitable point on the frame and oscillates as the cam makes the rotary motion.



(a) (b)

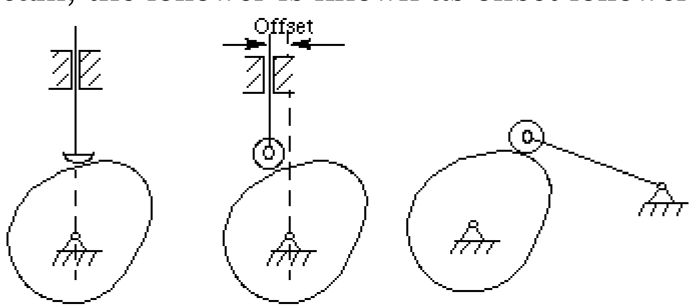
According to location of line of movement

1. **Radial follower**

The follower is a radial follower if the line of movement of the follower passes through the center of the rotation of the cam.

2. **Offset follower**

If the line of movement of the roller follower is offset from the center of the rotation of the cam, the follower is known as offset follower.



d e f

Jump phenomenon

The jump phenomenon occurs in case of cam operating under the action of compression spring load. This is a transient condition that occurs only with high speed, highly flexible cam follower systems. With jump the cam and the follower separate owing to excessively unbalanced forces exceeding the spring force during the period of negative acceleration. This is undesirable since the fundamental function of the cam-follower system to control of follower motion .

Observation:

Eccentric Cam			Tangent Cam		
S. No.	**Angle of rotation(θ)**	**Displacement**	**S. No.**	**Angle of rotation**	**Displacement**
1	0		1	0	
2	20		2	20	
3	40		3	40	
4	60		4	60	
5	80		5	80	
6	100		6	100	
7	120		7	120	
8	140		8	140	
9	160		9	160	
10	180		10	180	
11	200		11	200	
12	220		12	220	
13	240		13	240	
14	260		14	260	
15	280		15	280	
16	300		16	300	
17	320		17	320	
18	340		18	340	

Tangent Cam & Roller follower		
S. No.	**Weight(g)**	**Speed(RPM)**
1	0	
2	250	
3	500	
4	750	

Plot And Cam Profile:

Results and discussions:

1. The exact profile of the cam can be obtained by taking observation θ (cam rotation) vs. δ (follower displacement) .
2. Plot θ (cam rotation) vs. δ (follower displacement) curve for different cam follower

pairs.

3. Plot weight (w) v/s angular speed (ω) for tangent cam with roller follower.

Critical data of experiment

Cams : Circular arc cam
Base circle radius= 15 mm: Eccentric cam
: Tangent cam
Follower : Mushroom follower
: Roller follower
: Knife-edge follower

Experimental setup:

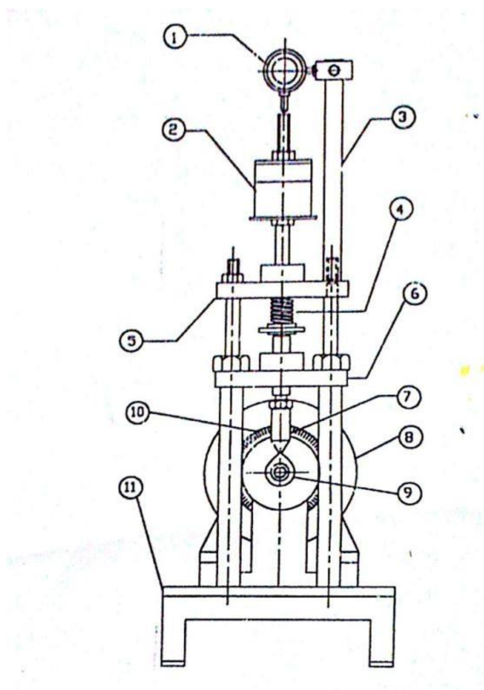
The apparatus is designed to study the cam profile and performance of cam and follower system. Apparatus is motorized unit consisting of a camshaft driven by a variable speed D.C.motor. The shaft is supported in a double ball bearing. At the free and of the camshaft, a cam (interchangeable) can be easily 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.

Precautions:

While assembling following precautions should be taken.

a. The horizontally of the upper and lower glans should be checked by a spirit level.
b. The supporting pillars should be properly tightened with the lock nuts provided.
c. 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.

1.


1 DIAL GAUGE 2 WEIGHTS 3 DIAL GAUGE STAND 4 SPRING
5 UPPER BRACKET 6 LOWER BRACKET 7 FOLLOWER
8 MOTOR 9 CAM 10 SCALE PLATE 11 BASE

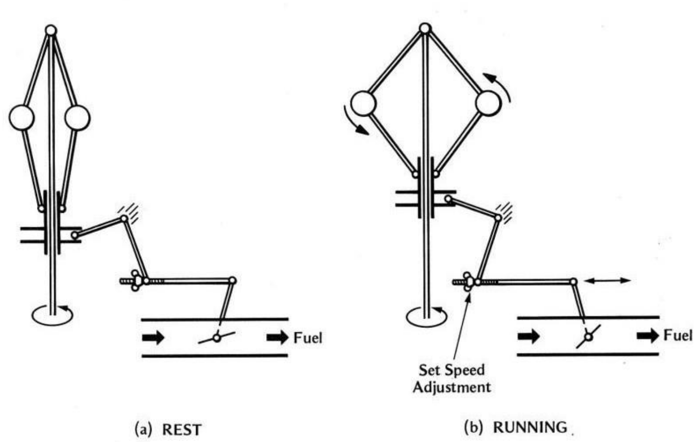
EXPERIMENT NO. 7

Object: (a) Determination of characteristic curve of a governor(spindle) speed against sleeve displacement.(For Porter Governor)

(b) Plotting of governor characteristic curves of radius of rotation of the ball centre against controlling force. (For Porter Governor)

Apparatus used: - Porter Governors.

Introduction & theory:-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. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

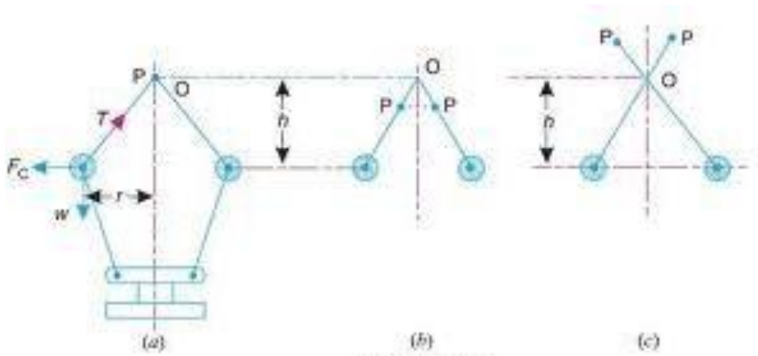


The governors may, broadly, be classified as
1. Centrifugal governor
2. Inertia governor

The centrifugal governors, may further be classified as follows:

(1) **Dead weight**: Watt, Porter governor and Proell governor
(2) **Spring controlled governors**: Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor

1. Watt Governor:-The simplest form of a centrifugal governor is a Watt governor. It is basically a conical pendulum with links attached to a sleeve of negligible mass. The arms of the governor may be connected to the spindle in the following three ways :
1. The pivot P, may be on the spindle axis.
2. The pivot P, may be offset from the spindle axis and the arms when produced intersect at O.
3. The pivot P, may be offset, but the arms crosses the axis at O.



Watt governor.

2. Porter Governor: - The porter governor is a modification of a Watt's governor, with central load attached to the sleeve. The load moves up down the central spindle. This additional downward force increases the speed of revolution required to enable the balls to rise to any to any pre-determined level.

2. **Proell Governor: -** It is a modification of a Porter governor, in which balls are mounted on the extension of lower arms. Under normal conditions extension of lower arms remains vertical however it changes position with variation in speed.This governor is more sensitive than porter governor.

Calculation :- Radius of rotation r can be calculated as follows:

a) Find height $h = (ho-x/2)$
b) Find α by using $\cos \alpha = h/L$
c) Then $r = 50 + L \sin \alpha$

$N^2 = 895/h$ (For watt governor)

Force can be calculated as follows: a) Find the angular velocity ω of the spindle
By $2\pi N/60$
Where N is the speed of spindle.

b) Find the centrifugal force acting on the ball
Force $F = m\omega^2 r$
For Hartnell Governor

Radius of rotation $r = ro + x.a/b$
Where a, b are length pof bell crank lever

$N^2 = \frac{m + M(1+q)/2}{m} \times \frac{895}{h}$ (For porter governor), where, $q = \tan\beta / \tan\alpha$

Observation:- For watt and porter governor

Mass of the ball (m) = o.6 kg.
Length of each link (L) = 125 mm

Initial height of the governor (ho) = 94mm.
Initial radius of rotation (ro)= 136 mm
Weight of sleeve(M) = 0.6 kg

For Watt Governor

S. No.	Sleeve displacement(X) ,mm	Avg. Speed(RPM)	Height(h)	Cos α	r = 50 + L Sin α	Force F
1	10					
2	20					
3	30					
4	40					
5	50					

For Porter Governor

a) Weight of Sleeve= 0.5 kg

S. No.	Sleeve displacement(X) ,mm	Avg. Speed(RPM)	Height(h)	Cos α	r = 50 + L Sin α	Force F
1	10					
2	20					
3	30					
4	40					
5	50					

a) Weight of Sleeve= 1 kg

S. No.	Sleeve displacement(X) ,mm	Avg. Speed(RPM)	Height(h)	Cos α	r = 50 + L Sin α	Force F
1	10					
2	20					
3	30					
4	40					
5	50					

a) Weight of Sleeve= 1.5 kg

S. No.	Sleeve displacement(X) ,mm	Avg. Speed(RPM)	Height(h)	Cos α	r = 50 + L Sin α	Force F
1	10					
2	20					
3	30					
4	40					
5	50					

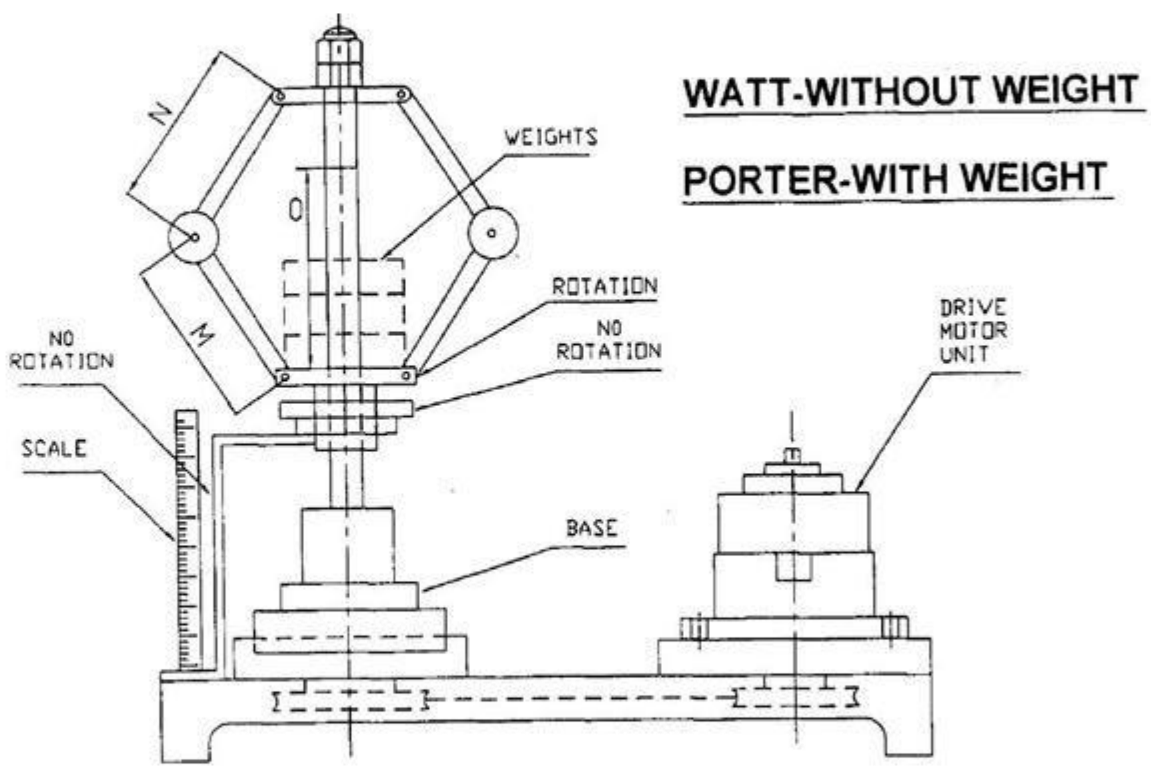
Performance Characteristic Curve: speed vs height of governor
Force vs radius of rotation

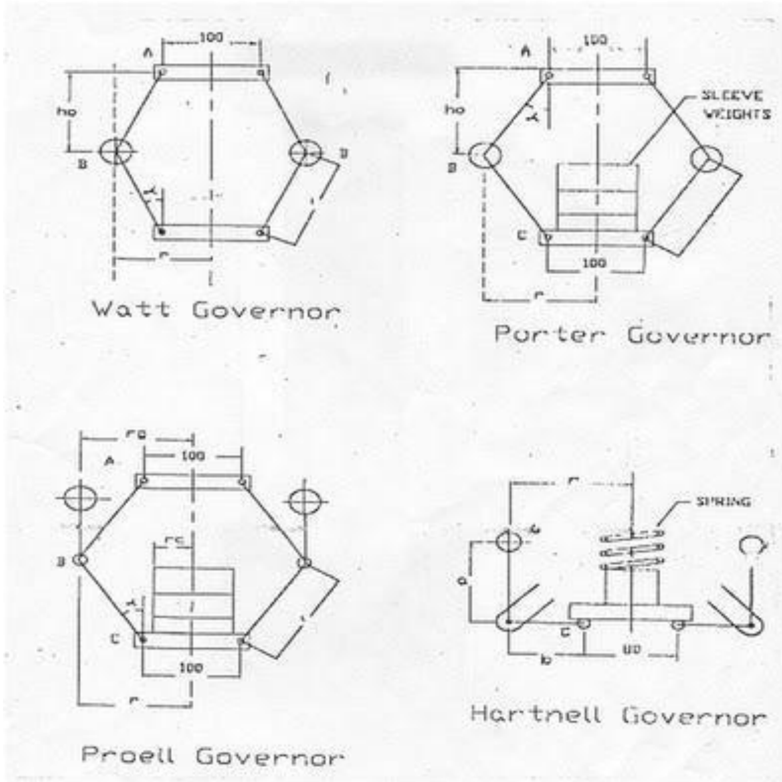
Precautions :-

- DO NOT KEEP THE MAINS ON when trial is complete
- increase the speed gradually.
- take the sleeve displacement reading when the pointer remain steady.
- see that at higher speed the load on sleeve does not hit the upper sleeve of the governor .
- while closing the test bring the dimmer to zero position and then switch OFF

VIVA – QUESTIONS:

1. What is the function of a governor ?
2. How does it differ from that of a flywheel ?
3. State the different types of governors.
4. What is the difference between centrifugal and inertia type governors ?
5. Explain the term height of the governor.
6. What are the limitations of a Watt governor ?
7. What is the stability of a governor ?
8. Define the Sensitiveness of governor.
9. Which of the governor is used to drive a gramophone ?
10. The power of a governor is equal to -------- --.
11. What is hunt?




Watt Governor
Porter Governor
SLEEVE WEIGHTS
Proell Governor
SPRING
Hartnell Governor

EXPERIMENT NO. 8

Object: - (a) Determination of characteristic curve of a governor(spindle) speed against sleeve displacement.(For Hartnell Governor)

(b) Plotting of governor characteristic curves of radius of rotation of the ball centre against controlling force. (For Hartnell Governor)

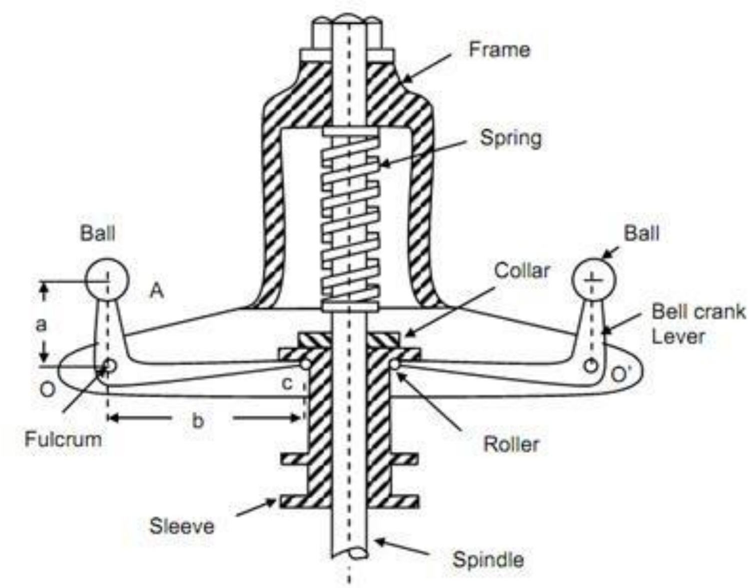
Apparatus used: - Hartnell governor.

Introduction & theory:-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. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

The governors may, broadly, be classified as
1. Centrifugal governor
2. Inertia governor

The centrifugal governors may further be classified as follows:

(1) **Dead weight**: Watt, Porter governor and Proell governor
(2) **Spring controlled governors**: Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor



Hartnell Governor :-A Hartnell governor is a spring loaded governor as shown in fig.-. It consists of two bell crank levers pivoted at the points A and D to the frame. The frame is attached to the governor spindle and therefore rotates with it. Each lever carries a ball at the end of the vertical arm and a roller at the end of the horizontal arm . A helical spring in compression provides equal downward forces on the two rollers through a collar on the sleeve. The spring force be adjusted by screwing at nut up or down on the sleeve.

$$\therefore \qquad (F_C)_2 - (F_C)_1 = \left(\frac{b}{a}\right)^2 \frac{(r_2 - r_1)}{2} s$$

or stiffness of spring 's' $= 2\left(\frac{a}{b}\right)^2 \frac{(F_C)_2 - (F_C)_1}{(r_2 - r_1)}$

For ball radius 'r'

$$s = 2\left(\frac{a}{b}\right)^2 \frac{F_C - (F_C)_1}{r - r_1} = 2\left(\frac{a}{b}\right)^2 \left\{\frac{(F_C)_2 - (F_C)_1}{(r_2 - r_1)}\right\}$$

$$F_C = (F_C)_1 + \frac{(r - r_1)}{(r_2 - r_1)} \{(F_C)_2 - (F_C)_1\}$$

Calculation :-

For Hartnell Governor

Radius of rotation r = ro + x.a/b
Where a, b are length pof bell crank lever

Observation :-

Mass of the each ball (m) = 0.6 kg.
Length of vertical arm (a) = 77 mm
Length of vertical arm (b) = 122 mm
Initial radius of rotation (ro)= 177.5 mm
Weight of sleeve(M) = 0.6 kg
Free Height of spring =102 mm
Spring stiffnes s = 5 and 10 kg/cm
Initial compression of spring =..

S. No.	**Sleeve displacement(X) ,mm**	**Avg. Speed(RPM)**	**Radius of rotation r = ro + x.a/b**	**Force F = mω².r**
1	5			
2	10			
3	15			
4	20			
5	25			

Performance Characteristic Curve: speed vs height of governor
Force vs radius of rotation

Precautions :-

- DO NOT KEEP THE MAINS ON when trial is complete
- increase the speed gradually.
- take the sleeve displacement reading when the pointer remain steady.
- see that at higher speed the load on sleeve does not hit the upper sleeve of the governor .
- while closing the test bring the dimmer to zero position and then switch OFF the

hartnell governor**VIVA – QUESTIONS :**

1. What is the function of a governor ?
2. How does it differ from that of a flywheel ?
3. State the different types of governors.
4. What is the difference between centrifugal and inertia type governors ?
5. Explain the term height of the governor.
6. What are the limitations of a Watt governor ?
7. What is the stability of a governor ?
8. Define the Sensitiveness of governor.
9. Which of the governor is used to drive a gramophone ?
10. The power of a governor is equal to -------- --.
11. What is hunt?

EXPERIMENT NO. 9

Object: Experimental justification of the equation $C = I\omega . \omega p$ for calculating the gyroscopic couple by observation and measurements of results for independent variation in applied couple C and precession angular speed ω_p.

Apparatus:

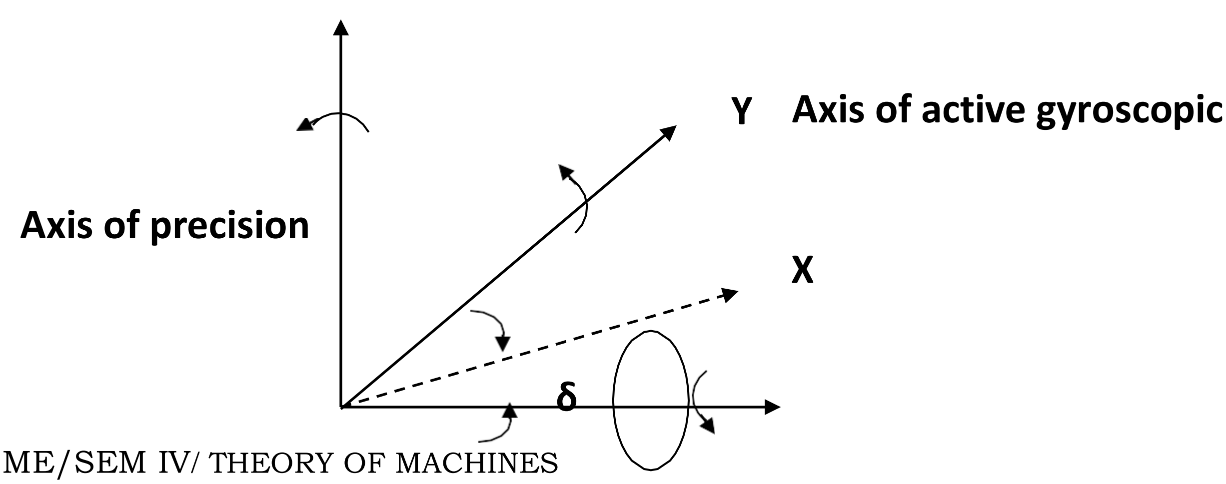
The motorized gyroscope with freedom of rotation about three perpendicular axis. Angular scale and pointer fitted to frame helps to measure precession rate. In steady position, frame no.1 is balanced by providing a weight pan on the opposite side of the motor.

Theory:

The credit of the mathematical foundation of the principles of gyroscopic motion goes to Euler who derived a set of dynamic equation related to applied mechanics between moment inertia, angular acceleration and angular velocity in many machines. The rotary components are forced to turn about their axis other than their own axis of rotation and gyroscopic effects are thus setup. The gyroscopes are used in ships to minimize the rolling & pitching effects of water.

Gyroscope:

Gyroscope is a body while spinning about an axis is free to rotate in other directions under the action of external forces. For example locomotive, automobile and aero plane making a turn. In certain cases the gyroscopic effect may be utilized in developing desirable forces. Balloons use Gyroscope for controlling direction.



X Axis of spin

Fig.1: Axis of Spin, Couple and Precession

Fig.2: Gyroscopic couple of a spinning disc

Let, ω is the angular velocity of disk about OX,
dΘ/dt = ωp, the angular velocity of the precession of yoke, which is uniform and is about axis OZ
Thus, we get Gyroscopic couple (C) = Iω.ωp

The direction of the *couple applied* on the body is anticlockwise when looking in the direction YY' and in the limit this is perpendicular to the axis of ω and ωp.
In the supplied apparatus, the reaction couple exerted by the body on its frame is *equal* in magnitude to that, but *opposite* in the direction.

Observation:

Weight of rotor, kg :
Rotor diameter, mm :
Rotor thickness, mm :
Moment of inertia of
disc, coupling and motor rotor about the central axis, I, kg cm sec
Distance of the bolt of :
Weight pan from disc centre, L, cm

S.No.	Weight, W (kg)	Time required for precession, (sec)	Speed, N (rpm)	Angle of precession, dΘ (degree)	Gyroscopic Couple(C)	
1						
2						
3						

Critical data of experiment

Weight of rotor, kg : 6.7
Rotor diameter, mm : 300
Rotor thickness, mm : 10.0
Moment of inertia of : m X r^2

disc, coupling and motor rotor about the central axis, I, kg cm^2
Distance of the bolt of : 19.0
Weight pan from disc centre, L, cm

Motor : Fractional H.P. single phase. 6000 rpm-AC/DC Type

Autotransformer provided for speed regulation.

Sample Experimental data

S.No.	Weight, W (kg)	Time required for precession, dt (sec)	Speed, N (rpm)	Angle of precession, dΘ (degree)
1.	0.5	14	1730	45

APPENDIX-3:Data Analysis

Angular velocity of disc in rad/sec

$\omega = \dfrac{2\pi}{}$

$\omega = \dfrac{2\pi \times 1730}{60}$

= 181.17 rad/sec

Angular velocity of precession of yoke in ωp rad/sec

$\omega p = \dfrac{}{}$

Where dΘ is in radian = 45 x π/180

= 0.785 rad

ωp = 0.785/14

= 0.0561 rad/sec

Experimental justification of the equation:

C = Iω.ωp

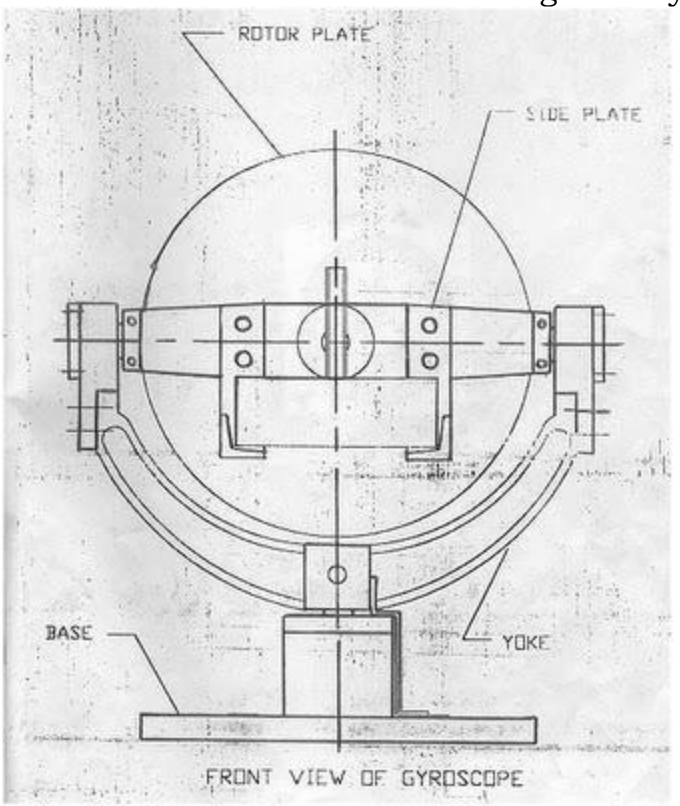
Cactual = W x L

=

$\% \text{ error} = \dfrac{C_{actual} - C}{C} \times 100\%$

Precautions:

1. ωp is to be calculate for short duration of time, as the balance of rotation of disc about the horizontal axis YY due to application of torque, because of which ωp goes on reducing gradually.
2. Avoid using the tachometer while taking the reading of time as it will reduce the time taken for precession.
3. Autotransformer should be varied gradually.



VIVA – QUESTIONS :

1. Write a short note on gyroscope.
2. What do you understand by gyroscopic couple ? Derive a formula for its magnitude.
3. Explain the application of gyroscopic principles to aircrafts.
4. Discuss the effect of the gyroscopic couple on a two wheeled vehicle when taking a turn.
5. When the pitching of a ship is upward, the effect of gyroscopic couple acting on it will be to move the ship towards port side or to move the ship towards star-board.

EXPERIMENT NO. 10

Object: To find out critical speed experimentally and to compare the whirling speed of a shaft.

Appratus: Tachometer, shaft, End fixing arrangement etc.

Theory: This apparatus is developed for the demonstration of a whirling phenomenon. The shaft can be tested for different end conditions. The apparatus consists of a frame to support its driving motor, end fixing and sliding blocks etc. A special design is provided to clear out the testing of bearing of motor spindle from these testing shafts. The special design features of this equipment are as follow:

a. Coupling
A flexible shaft is used to drive the test shaft from motor.

b. Ball bearing fixing ends.
The end fixes the shaft while it rotates. This can be replaced within a short time with the help of this unit. The fixing ends provide change of end fixing condition of the rotating shaft as per the requirement.

Shaft supplied with the equipment
Polished steel shaft is supplied with the machine. The dimensions being as under:

Shaft no.	Diameter (approx)	Length(approx)
1.	4.0 mm	900 mm
2.	4.7 mm	900 mm

End fixing arrangement

At motor end as well as tail end different end conditions can be developed by making use of different fixing blocks.

1. Supported end conditions - make use of end block with single self-aligning bearings.
2. Fixed end condition - make use of end block with double bearing.

Guard's d1 and d2 and d3:
The guard's d1, d2 and d3 can be fixed at any position on the supporting bar frame which fits on side supports. Rotating shafts are to be fitted in blocks in a and b stands.

Speed control of driving motor:
The driving motor is 230v, dc 1/6 hp, 3000 rpm, universal motor and speed control unit is a dimmer state of 240v, 2 amps, 50 c/s.

Measurement of speed:
To measure the speed of the rotating shaft a simple tachometer may be used on the opposite side of the shaft extension of the motor.

Whirling of Elastic Shaft:

if L = length of the shaft in cm.
E = young's module kg/cm^2 = 2.060 x 10^6
I = 2nd moment of inertia of the shaft cm^4
w = weight of the shaft per unit length kg/cm.
g = acceleration due to gravity of cm/sec^2 =981

Then the frequency of vibration for the various modes is given by the equation:

$f = k \times \sqrt{(EIG/wL^4)}$

End condition	**value of k**	
	1st mode	2nd mode
fixed , supported fixed , fixed	1.47 1.57	2.56 2.46

Data:

shaft dia	**i = cm^4**	**w = kg/cm**
4.0 mm 4.7 mm	x 10^{-4} x 10^{-4}	0.15 x 10^{-2} 0.19 x 10^{-2}

Calculations:

a) Both ends of shafts free (supported) 1st and 2nd mode of vibration can be observed of shafts with both rods.
b) One end of shaft fixed and the other free; 1st and 2nd mode of vibration can be observed on shaft with 4.0 mm rod.
c) Both ends of shaft fixed- 2nd mode of vibration cannot be observed on any of the shafts as the speeds are very high and hence beyond the range of the apparatus.

Fixed – fixed
Diameter of rod = 0.4 cm
Weight = 150 grams =0.0015 kg/cm
Young modulus e = 2.06 x 10^6

s.no.	speed rpm 1stmode	value of k	$i=(\pi d^4)/64$	weight in kg/ cm	fth = $\sqrt{(EIG/wL^4)}$	fact = rpm/time
1						
2						

Diameter of rod = 0.47 cm

Weight = 190 gram = kg/cm = 0.0019
Young modulus e = 2.06×10^6

S.no.	Speed rpm 2^{nd} mode	Value of k	$I=(\pi d^4)/64$	weight in kg/ cm	Fth = $\sqrt{(EIG/wL^4)}$	fact = rpm/time
1						
2						

Supported – fixed

Diameter of rod = 0.4 cm

Weight = 150 gram = kg/cm = 0.0015

Young modulus e = 2.06 x 10^6

S.no.	Speed rpm 1^{st} mode	Value of k	$I=(\pi d^4)/64$	weight in kg/ cm	Fth = $\sqrt{(EIG/wL^4)}$	fact = rpm/time
1						
2						

Diameter of brass rod = 0.47 cm

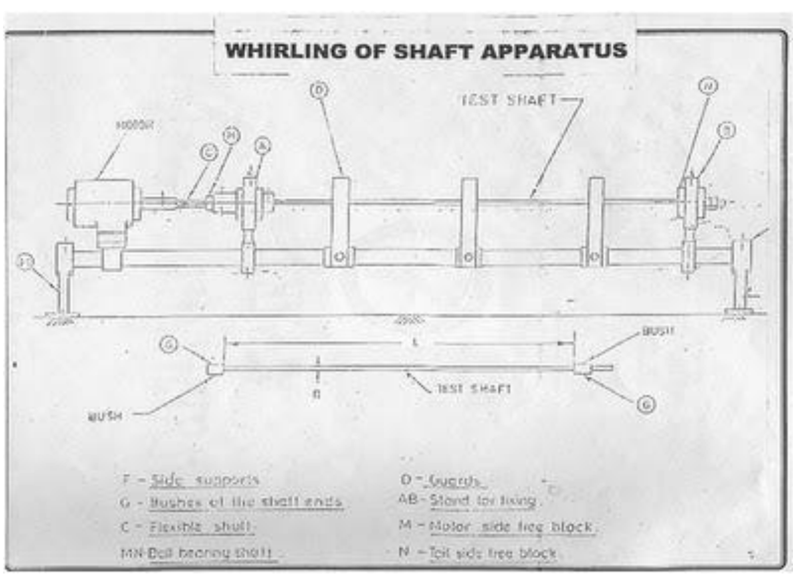
Weight = 190 gram = kg/cm = 0.0019

Young modulus e = 2.06 x 10^6

S.no.	Speed rpm 2^{nd} mode	Value of k	$I=(\pi d^4)/64$	weight in kg/ cm	Fth = $\sqrt{(EIG/wL^4)}$	fact = rpm/time
1						
2						

Result : % Error

Preacautions:



EXPERIMENT 11

Object: -To study Automotive Braking system.

Theory

It goes without saying that brakes are one of the most important control components of vehicle. They are required to stop the vehicle within the smallest possible distance and this is done by converting the kinetic energy of the vehicle into the heat energy which is dissipated into the atmosphere.

Braking requirements:

1 The brakes must be strong enough to stop the vehicle within a minimum distance in an emergency. But this should also be consistent with safety. The driver must have proper control over the vehicle during emergency braking and the vehicle must not skid.
2 The brakes must have good antifade characteristics i.e. their effectiveness should not decrease with constant prolonged application e.g. while descending hills. This requirement demands that the cooling of the brakes should be very efficient.

Types of Brakes:

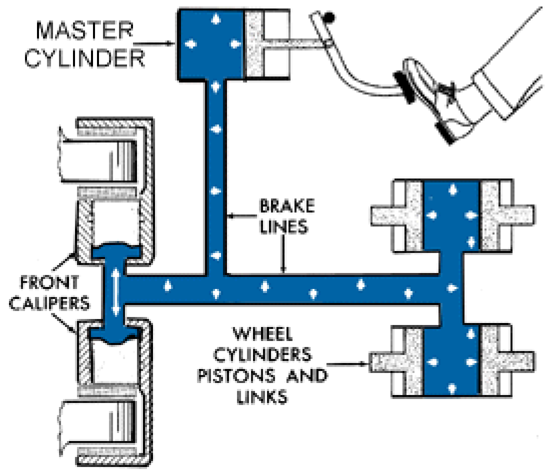
A) Hydraulic and pneumatic brake systems
B) Drum brake system
C) Disc brake system

Hydraulic brakes

Most of the cars today use hydraulically operated foot brakes on all the four wheels with an additional hand brake mechanically operated on the rear wheels. An outline of the hydraulic braking system is shown in fig. The main component in this is the master cylinder which contains reservoir for the brake fluid. Master cylinder is operated by the brake pedal and is further connected to the wheel cylinders in each wheel through steel pipe lines, unions and flexible hoses. In case of hindustan ambassador car, on front wheels each brake shoe is operated by separate wheel cylinder (thus making the brake two shoe leading) whereas in case of rear wheels there is only one cylinder on each wheel which operates both the shoes (thus giving one leading and one training shoe brakes.) As the rear wheel cylinders are also operated mechanically with the hand brake, they are made floating. Further, all the shoes in the ambassador car are of the floating anchor type.

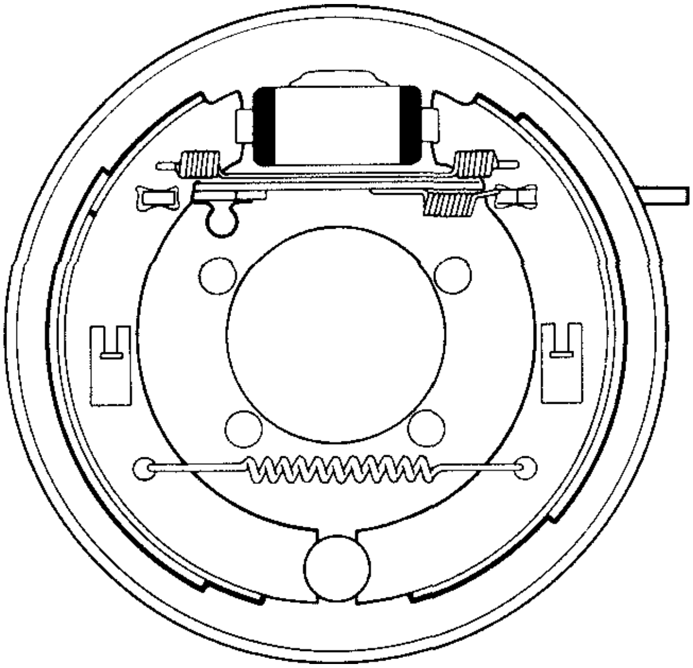
The system is so designed that even when the brakes are in the released position, a small pressure of about 50 kpa is maintained in the pipe lines to ensure that the cups of the wheel cylinder are kept expanded. This prevents the air from entering the wheel cylinders when the brakes are released. Besides, this pressure also serves the following purposes.
(i) it keeps the free travel of the pedal minimum by opposing the brake shoe retraction springs.
(ii) during bleeding, it does not allow the fluid pumped into the line to return, thus

quickly purging air from the system.



Drum brakes

In this type of brakes, a brake drum is attached concentric to the axle hub whereas on the axle casing is mounted a back plate. In case of front axle, the back plate is bolted to the steering knuckle. The back plate is made of pressed steel sheet and is ribed to increase rigidity and to provide support for the expander, anchor and brake shoes. It also protects the drum and shoe assembly from mud and dust. Moreover, it absorbs the complete torque reaction of the shoes due to which reason it is sometimes also called torque plate. Two brake shoes are anchored on the back plate as shown in fig. Friction linings are mounted on the brake shoes. One or two retractor springs are used which serve to keep the brake shoes away from the drum when the brakes are
Not applied. The brake shoes are anchored at one end, whereas on the other ends force f is applied by means of some brake actuating mechanism which forces the brake shoe against the revolving drum, thereby applying the brakes. An adjuster is also provided to compensate for wear of friction lining with use. The relative braking torque obtained at the shoes for the same force applied at the pedal varies depending upon whether the expander (cam or toggle lever) is fixed to the back plate or it is floating, whether the anchor is fixed or floating and whether the shoes are leading or trailing.



Disc brakes

As shown in fig. A disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle, like the axle casing or the sub axle and is cast in two parts, each part containing a piston. In between each piston and disc, there is friction pad held in position by retaining pins, spring plates etc. Passages are drilled in the caliper for the fluid to enter or leave each housing. These passages are also connected to another one for bleeding. Each cylinder and contains a rubber sealing ring between the cylinder and the piston.

When the brakes are applied, hydraulically actuated pistons move the friction pads into contact with the disc, applying equal and opposite forces on the later. On releasing the brakes, the rubber sealing rings act as return springs and retract the pistons and the friction pads away from the disc.

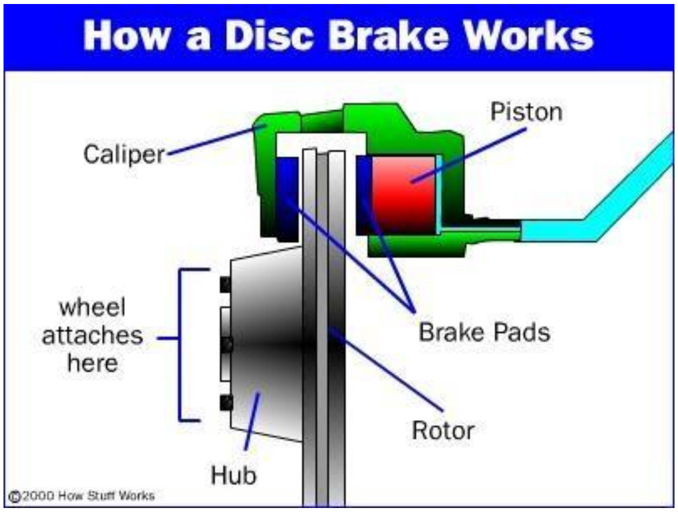
For a brake of this type T = 2μpar Where

μ = coefficient of friction

P = fluid pressure

A = cross sectional area of one piston

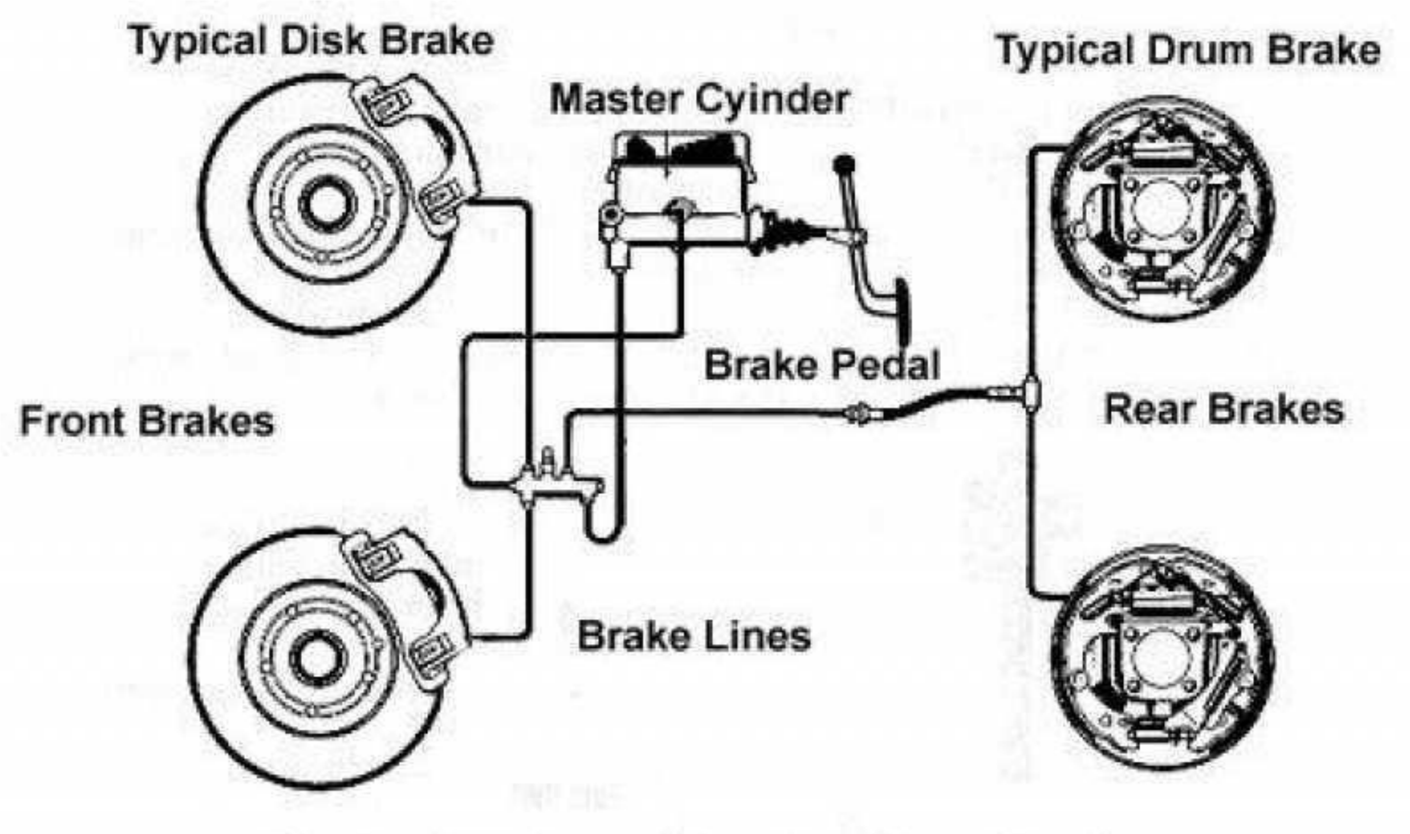
R = distance of the longitudinal axis of the piston from the wheel axis


How a Disc Brake Works
Piston
Caliper
wheel
attaches
here
Brake Pads
Rotor
Hub
©2000 How Stuff Works

Brake system for maruti (suzuki) 800 car

The front wheel brakes are of the disc type, whereas for rear wheels drum type brakes (leading trailing shoes) are employed. Parking brake is mechanically operated by a wire and link system and works on the rear wheels only. Same brake shoes are used for service and parking brakes. The layout of the system is shown in fig.

A tandem master cylinder is employed. The hydraulic pressure produced there is applied to two independent circuits. One circuit is for front left and rear right brakes, whereas the other is for front right and rear left brakes. Due to this reason, the braking system in the maruti has greater safety because even if a pressure leak occurs in the brake line of one circuit, the other braking circuit works, due to which a certain degree of braking is still available to the vehicle.



Typical Automotive Braking System