# Varuvan Vadivelan
## Institute of Technology

Dharmapuri – 636 703

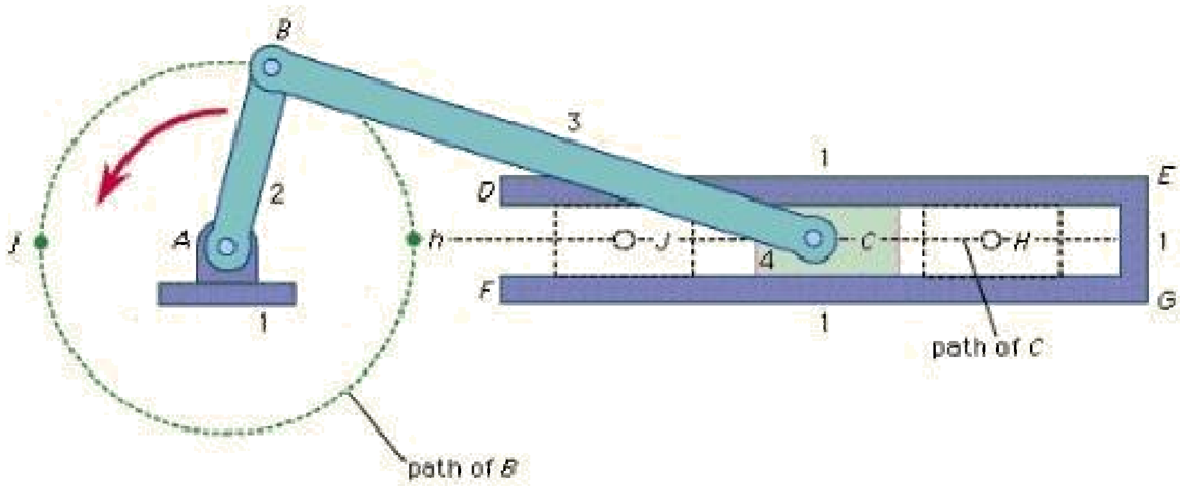
# LAB MANUAL

**Regulation** : 2013

**Branch** : B.E. – MECHANICAL ENGINEERING

**Year & Semester** : III Year / V Semester

# ME 6511 - DYNAMICS LABORATORY



## GENERAL INSTRUCTION

- All the students are instructed to wear protective **uniform, shoes** & **identity card** before entering into the laboratory.
- Before starting the exercise, students should have a clear idea about the principal of that exercise
- All the students are advised to come with completed record and corrected observation book of previous experiment.
- Don't operate any instrument without getting concerned staff member's prior permission.
- The entire instrument is costly. Hence handle them carefully, to avoid fine for any breakage.
- Utmost care must be taken to avert any possible injury while on laboratory work. In case, anything occurs immediately report to the staff members.
- One student form each batch should put his/her signature during receiving the instrument in instrument issue register.

# ANNA UNIVERSITY
# REGULATION : 2013
# SYLLABUS

## LIST OF EXPERIMENTS

1. A) Study of gear parameters.
   b) Experimental study of velocity ratios of simple, compound, Epicyclic and differential gear trains.
2. a) Kinematics of Four Bar, Slider Crank, Crank Rocker, Double crank, Double rocker, Oscillating cylinder Mechanisms.
   b) Kinematics of single and double universal joints.
3. a) Determination of Mass moment of inertia of Fly wheel and Axle system.
   b) Determination of Mass Moment of Inertia of axisymmetric bodies using Turn Table apparatus.
   c) Determination of Mass Moment of Inertia using bifilar suspension and compound pendulum.
4. Motorized gyroscope – Study of gyroscopic effect and couple.
5. Governor - Determination of range sensitivity, effort etc., for Watts, Porter, Proell, and Hartnell Governors.
6. Cams – Cam profile drawing, Motion curves and study of jump phenomenon
7. a) Single degree of freedom Spring Mass System – Determination of natural Frequency and verification of Laws of springs – Damping coefficient determination.
   b) Multi degree freedom suspension system – Determination of influence coefficient.
8. a) Determination of torsional natural frequency of single and Double Rotor systems.- Undamped and Damped Natural frequencies.
   b) Vibration Absorber – Tuned vibration absorber.
9. Vibration of Equivalent Spring mass system – undamped and damped vibration.
10. Whirling of shafts – Determination of critical speeds of shafts with concentrated loads.
11. a) Balancing of rotating masses.
    (b) Balancing of reciprocating masses.
12. a) Transverse vibration of Free-Free beam – with and without concentrated masses.
    b) Forced Vibration of Cantilever beam – Mode shapes and natural frequencies.
    c) Determination of transmissibility ratio using vibrating table.

# INDEX

# TRANSVERSE VIBRATION OF FREE-BEAM WITH & WITHOUT CONCENTRATED MASSES

***Ex. no: 1***

***Date:***

**AIM:**

To determine the natural frequency of transverse vibration system for different loading conditions

**APPARATUS REQUIRED**

I. Transverse vibration setup
II. Weight

**TECHNICAL SPECIPICATIONS**

Total length of transverse vibration setup = 78 cm

**FORMULAE**

1. Natural Frequency

$$\mathrm{F}_n = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}}\ \mathrm{Hz}$$

$$F_n = \frac{0.4985}{\sqrt{\delta}}\ \mathrm{Hz}$$

Where,

$\delta$ = deflection in m

2. Stiffness

$$\mathrm{K} = \frac{\mathrm{w}}{\delta}\ \mathrm{N/m}$$

Where,

w = weight applied in N

$\delta$ = deflection in mm

**PROCEDURE**

1. Load the tray in the vibration setup with one block of weight provided.
2. Note down the scale reading and deflection.
3. Repeat the procedures to all the given weight blocks.
4. Plot the graph as corresponding readings.

**TABULATION**

| S.No | Weight Applied (W) in | | Deflection | | Stiffness(k) N/mm | Natural Frequency [$F_n$] Hz |
|---|---|---|---|---|---|---|
| | Kg | N | mm | m | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**GRAPH**

1. Load *vs* Deflection
2. Load *vs* Natural Frequency

**RESULT**

Thus the natural frequency of transverse vibration system for different loading condition was determined by using transverse vibration setup.

1. Stiffness = N/m
2. Natural Frequency = Hz

## COMPOUND PENDULAM

***Ex. no: 2***

***Date:***

**AIM**

To determine the radius of gyration and mass moment of inertia of a shaft by compound pendulum

**APPARATUS REQUIRED**

1. A Shaft
2. Stopwatch
3. Scale

**FORMULA**

1. Frequency

$$F_n = \frac{No\ of\ cycles}{sec}. \qquad \text{Hz}$$

$$F_n = \frac{1}{2\pi}\sqrt{\frac{g}{L}} = \frac{0.4985}{\sqrt{L}}. \ \text{Hz}$$

Where,

L = Equivalent length of simple pendulum in m

2. Radius of gyration($K_G$)

$$L = \frac{{K_G}^2}{h} + h$$

3. Mass moment of inertia

$$I = m\,{K_G}^2 \ \ (\text{kgm}^2)$$

Where,

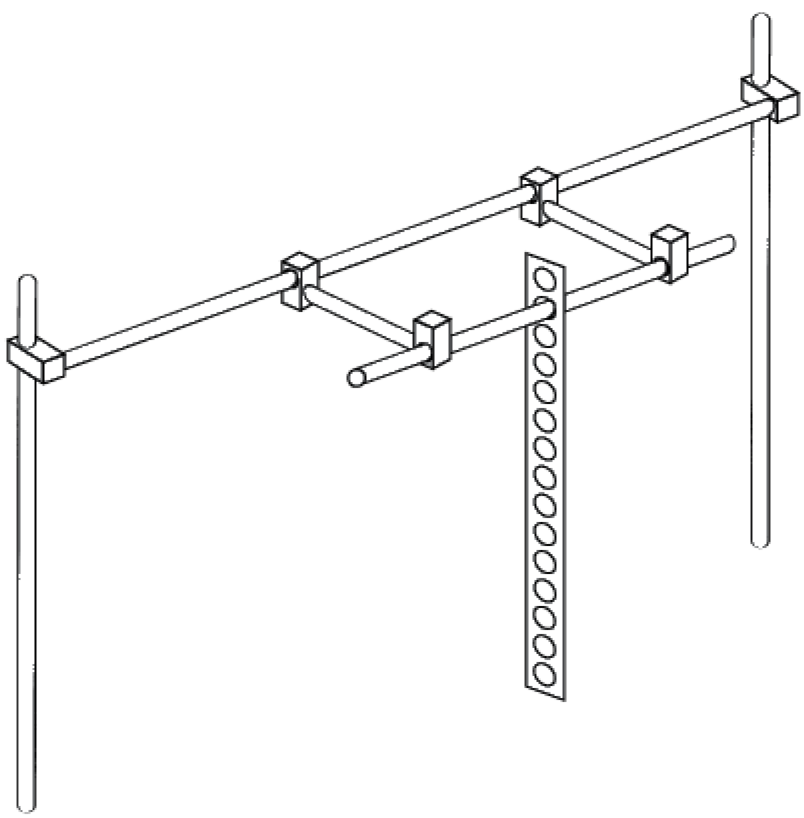
I = mass moment of inertia (kg-$m^2$)

m = mass of pendulum (kg)

**PROCEDURE**

1. Support the flywheel in any one end.
2. Note the distance of centre of gravity from the support.
3. Make the system to oscillate.
4. Note down the time for number of oscillation
5. Repeat the procedure by changing the suspension
6. Tabulate the readings
7. By using formulae calculate the radius of gyration and moment of inertia.

**DIAGRAM**



**Compound pendulum**

**TABULATION**

| S. No | Distance between point of suspension from Centre of gravity (h) | | No . of Oscillations 'n' | Time taken for n oscillation "T" *sec* | Frequency of oscillation '$F_n$' *Hz* | Radius of Gyration "$K_G$" $m^2$ | Equivalent length of simple pendulum "L" *m* | Mass moent of inertia "I" Kg-$m^2$ |
|---|---|---|---|---|---|---|---|---|
| | *mm* | *m* | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

**RESULT**

Thus the radius of gyration and Mass moment of inertia for a shaft as compound pendulum is calculated.

## WHIRLING SPEED OF SHAFT

***Ex. no: 3***

***Date:***

**AIM**

To determine the critical speed of shaft of various sizes and to compare it with the theoretical values

**APPARATUS REQUIRED**

1. Power source
2. Tachometer (Noncontact type)
3. Vernier caliper
4. Scale
5. Shaft

**TECHNICAL SPECIFICATIONS**

1. Shaft diameter (d) = 4 mm, 6 mm, 8 mm
2. Length of shaft between ends (l) = 800 mm
3. Density of material of shaft ($\rho$) = 8000 kg/m$^3$
4. Young's modulus(E) = 2.1 x $10^{11}$ N/m$^2$

**FORMULAE**

1. Moment of inertia of shaft

$$I = \frac{\pi d^4}{64} (\text{mm}^4)$$

Where,

d= diameter of the shaft (m)

2. Mass of shaft per meter length

$$M_s = A \times l \times \rho$$

Where,

A= area of shaft (m$^2$)

$$A = \frac{\pi d^2}{4} (\text{mm}^2)$$

l = length of shaft (m)

$\rho$ = density of shaft material (kg/m$^3$)

3. Static deflection due to mass of shaft

$$\delta_s = \frac{Wl^4}{382EI}. \quad \text{(m)}$$

Where,

W – Weight of the shaft (N)

4. Frequency

$$F_n = \frac{0.4985}{\sqrt{\frac{\delta_S}{1.27}}}. \quad \text{Hz}$$

5. Whirling speed of shaft

$N_{cr}$ = *frequency of shaft in rps*

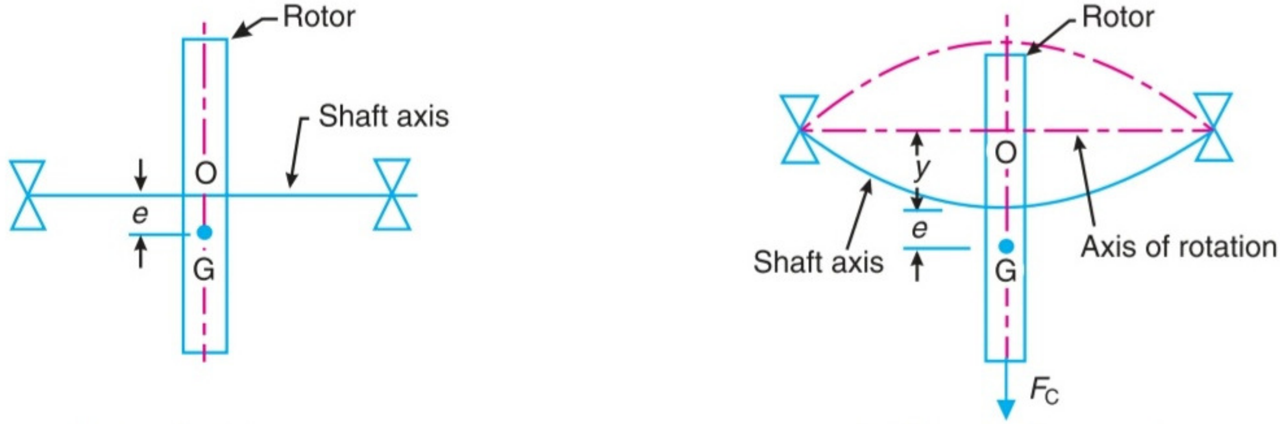
6. Efficiency of whirling shaft

$$\eta = \frac{Actual\ critical\ speed}{Therotical\ speed} \times 100$$

**PROCEDURE**

1. Take the shaft of difference diameter as 4, 6 and 8 mm
2. To fix the shaft at both ends
3. Switch on the motor and increase the speed
4. Note down the speed at which the vibration is maximum using tachometer
5. This speed is known as critical speed (or) wire ling speed
6. Repeat the same procedure for all shaft
7. Tabulate the readings and calculate the theoretical value
8. Compare the experimental value with theoretical value

**DIAGRAM**




(*a*) When shaft is stationary. (*b*) When shaft is rotating.

Critical or whirling speed of a shaft.

**TABULATION**

| S. No | Diameter of the shaft | | Diameter of shaft both 2 ends | | Actual critical speed *Rpm* | Deflection *m* | Theoretical critical speed ($N_{cr}$) *rpm* | Efficiency % |
|---|---|---|---|---|---|---|---|---|
| | *mm* | *m* | *mm* | *m* | | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |

**RESULT**

Thus the actual critical speed of the shaft is found out by tachometer and compared with the theoretical speed and the efficiency of whirling of shaft is obtained.

## VIBRATING TABLE

***Ex. no: 4***

***Date:***

## AIM

To determine the transmissibility of forced vibrations and to analyses all types of vibrations with its frequency and amplitude.

## APPARATUS REQUIRED

1. Vibrating table setup
2. Dimmer set with speedometer
3. Stopwatch
4. Recorder

## TECHNICAL SPECIFICATION

Mass of beam = 1.6 kg

Total length of beam [L] = 1 m

Mass of the exciter [M] = 5.4 kg

Stiffness of spring [k] = 1.968 N/m

Radius of the exciter [r] = 0.07 m

## FORMULA

1. Frequency

$$F_n = \frac{No\ of\ oscillations}{time\ taken}.\ \text{Hz}$$

2. Natural frequency

$$N_f = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}} = \frac{0.4985}{\sqrt{\delta}}.\ \text{Hz}$$

where,

$\delta$ = maximum deflection in m

3. Maximum force transmitted

$$F_{TR} = stiffness\ of\ the\ spring\ \times \max deflection$$

4. Maximum impressed force

$$F = mw^2 r \text{ (N)}$$

Where,

m = mass of beam + mass of exciter

$m = M + m_e$

r = radius of exciter

$\omega$ = angular velocity

5. Transmissibility

$$\in = \frac{F_{TR}}{F}$$

Where,

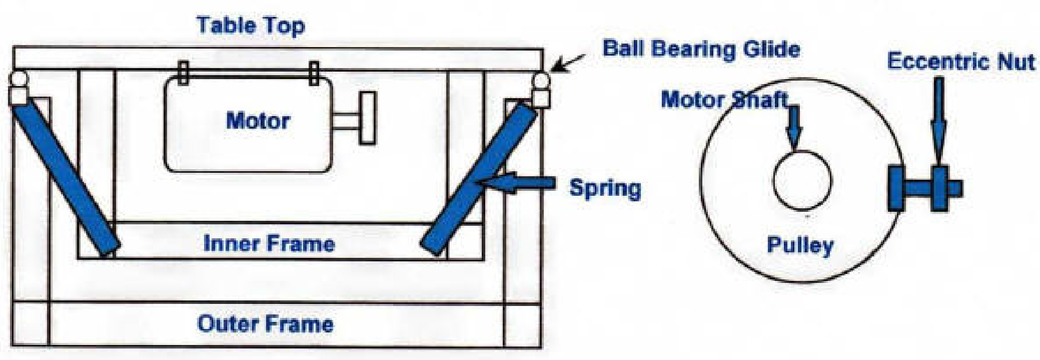
$F_{TR}$ = Maximum force transmitted (N)

F = Maximum impressed force (N)

**PROCEDURE**

1. Attach the vibrating recorder at suitable position with the pen or pencil holder slightly pressing paper.
2. Attach the damper with unit to stud.
3. Start the exciter motor and set at required speed and start the recorder motor
4. Now vibrations are recorded over the vibration recorder. Increase the speed and note the vibration.
5. At the resonance speed the amplitude of vibrations may be recorded as merged one another.
6. Hold the system and cross the speed little more than the response speed.
7. Analyse the recorded frequency and amplitude for both damped and undamped force vibrations.

**DIAGRAM**




Vibrating table

**GRAPH**

1. Speed *vs* Transmissibility
2. Speed *vs* Natural frequency

**TABUALTION**

| S. No | Speed of motor n (rpm) | Time taken for 10 oscillations (Sec) | Maximum amplitude (m) | Frequency (Hz) | Natural frequency (Hz) | Maximum force transmitted (N) | Maximum impressed force (N) | Transmissibility |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

**RESULT**

Thus the transmissibility of forced vibrations and types of vibrations with its frequency of amplitude are analysed.

## MOTORIZED GYROSCOPE

***Ex. no: 5***

***Date:***

**AIM**

To determine the gyroscopic couple of rotating masses and to verify the gyroscope rules of a plane rotating disc.

**APPARATUS REQUIRED**

1. Tachometer (contact type)
2. Set of weights
3. Dimmer set and power supply
4. Stop watch

**TECHNICAL SPECIFICATIONS**

| | |
|---|---|
| Mass of the rotor | =7 kg |
| Rotor diameter (D) | = 300 mm |
| Rotor thickness (t) | = 8 mm |
| Bolt size | = MI 08 |

**FORMULAE**

1. Angle of precision

$$\theta = \theta \times \frac{\pi}{180}$$

Where,

$\theta$ = Angle of precision (degrees)

2. Angular velocity of precision

$$w_p = \frac{d\theta}{dt} = \frac{\theta}{t} \text{ rad/s}$$

3. Angular velocity

$$\omega = \frac{2\pi N}{60} \text{ rad/s}$$

Where,

N = Speed of the motor (rpm)

4. Moment of inertia of disc

$$I = \frac{mr^2}{2} \text{ kgm}^2$$

Where,

m = mass of the disc (kg)

r = radius of disc (m)

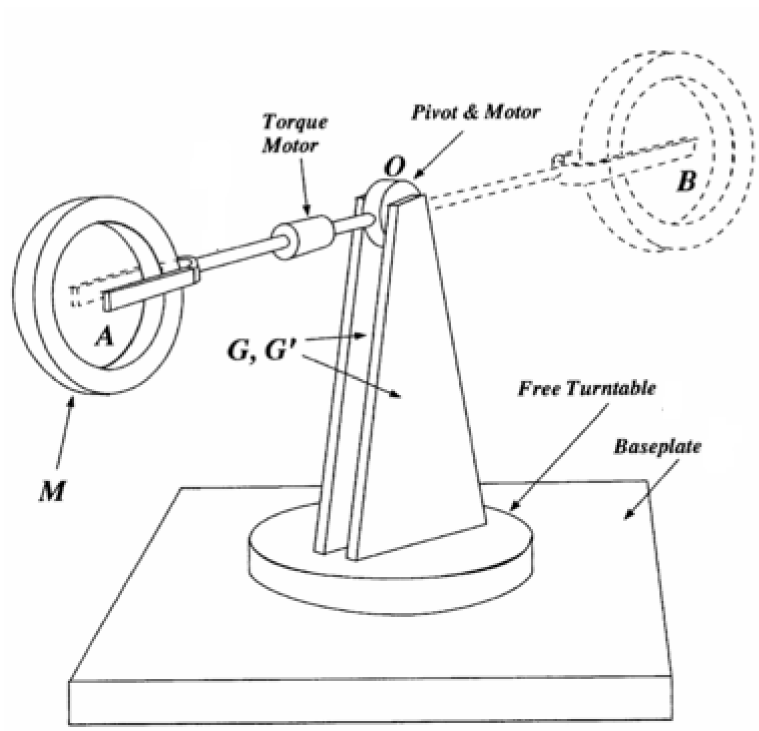
5. Gyroscopic couple (N-m)

$$C = I\omega\omega_p \text{ (Nm)}$$

**PROCEDURE**

1. Switch on the supply
2. Set the required speed by the regulator at constant
3. Add the load viz ½ kg, 1 kg,…
4. Loose the lock screw, start the stopwatch and note down.
5. Watch the angular displacement at particular time interval.
6. Take the readings for different loads.

**DIAGRAM**



**TABULATION**

| S. No | Speed of motor (rpm) | Weight applied (N) | Time taken for precision (Sec) | Angle of precision | | Angular velocity of precision ($W_p$) | Gyroscopic couple C (Nm) |
|---|---|---|---|---|---|---|---|
| | | | | Degree | Rad | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**RESULT**

Thus the value of gyroscopic couple of rotating masses and gyroscopic rules of a plane rotating disc was verified.

## WATT GOVERNOR

***Ex. no:6***

***Date:***

**AIM**

To determine the stability and controlling force of watt governor

**APPARATUS REQUIRED**

1. Governor setup
2. Speed regulator
3. Tachometer
4. Dead weight

**OBSERVATION**

Length of upper arm $L_1$ =

Length of lower arm $L_2$ =

Weight of ball $W_b$ =

Weight of sleeve $W_s$ =

**FORMULA**

1. Angular velocity

$$\omega = \frac{2\pi N}{60} \text{ rad/s}$$

2. Height of the sleeve

$$h = \frac{g}{\omega^2} \text{ (m)}$$

Where,

g = acceleration due to gravity (m/s$^2$)

3. Theoretical speed

$$N_{th} = \sqrt{\frac{895}{h}} \text{ (rpm)}$$

4. Centrifugal force

$$F_C = \frac{mgr}{h} \text{ (N)}$$

Where,

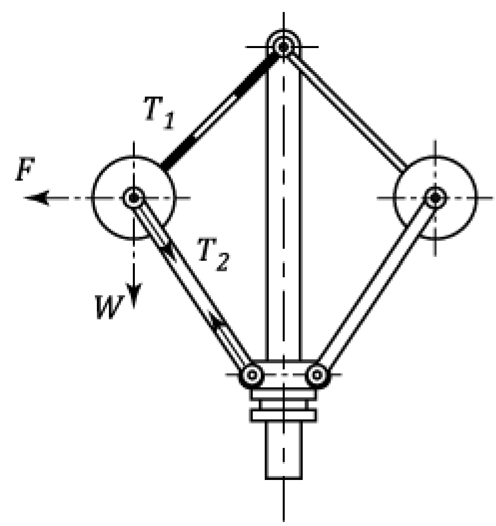
m = mass of the ball = 0.31 kg

r = radius of sleeve (m)

**PROCEDURE**

1. Switch on the motor in the dimmer setup.
2. Increase the speed slowly till the sleeve just begins in test.
3. This corresponds to the minimum speed of governor.
4. Also measure the correspond radius of rotation of ball.
5. Measure the speed of rotation such that sleeve touches it's top most position.
6. Note the speed and corresponding radius this corresponds to the maximum governor speed.
7. Repeat the procedure again

**DIAGRAM**



**TABULATION**

| S. No | Observed speed | Lift (m) | Sleeve radius (r) | Sleeve height (h) | Theoretical speed (rpm) | Centrifugal force (F) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

**RESULT**

Thus the stability and controlling force of watt governor was determined.

## PORTER GOVERNOR

***Ex. no: 7***

***Date:***

**AIM**

To determine the stability and controlling force of the porter governor

**APPARATUS REQUIRED**

1. Governor setup
2. Speed regulator
3. Tachometer
4. Dead weights

**FORMULA USED**

1. Angular velocity

$$\omega = \frac{2\pi N}{60} \text{ rad/s}$$

2. Height of the sleeve

$$h = \frac{m+M}{m} \times \frac{g}{\omega^2} \text{ (m)}$$

3. Theoretical speed

$$N_{th} = \sqrt{\frac{m \times M}{m} + \frac{895}{h}} \text{ (rpm)}$$

4. Centrifugal force

$$F_C = m\omega^2 r \text{ (N)}$$

Where,

l = upper arm length (m)

r = radius (m)

m = mass of the ball = 0.31 kg

M = mass of sleeve = 1 kg

5. Range of the governor (R)

$$R = maximum\ speed - minimum\ speed$$

6. Sensitivity of the governor

$$sensitivity = 2 \times \frac{max.speed - min.speed}{max.speed + min.speed} \times 100$$

7. Percentage increase in speed

$$C = \frac{N_2 - N_1}{N_1}$$

Where,

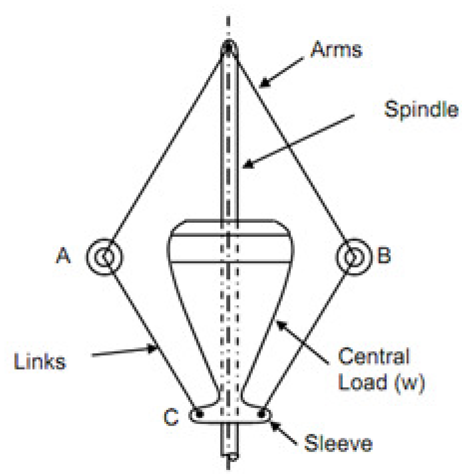
$N_2$ = Maximum speed

$N_1$ = Minimum speed

**PROCEDURE**

1. Switch on the motor in dimmer setup
2. Increase the speed slowly till the sleeve just begins in test
3. This corresponds to minimum speed of the governor
4. Also measure the corresponding radius of rotation of ball
5. Measure the speed of rotation such that the sleeve touches it's topmost position
6. Note the speed and corresponding radius, this corresponds to the maximum governor speed
7. Repeat the procedure again

**DIAGRAM**



**TABULATION**

| S. No | Lift (M) | Sleeve radius r (m) | Sleeve height h (m) | Theoretical speed (RPM) | Centrifugal force F (N) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**RESULT**

Thus the stability and controlling force of porter governor was determined.

## PROELL GOVERNOR

***Ex. no: 8***

***Date:***

**AIM**

To determine the stability and controlling force of proell governor

**APPARATUS REQUIRED**

1. Governor setup
2. Speed regulator
3. Tachometer
4. Dead weights

**OBSERVATION**

1. Length of the upper arm $L_l$ = 155 mm
2. Extension of the lower link = 110 mm
3. Weight of the ball $W_b$ = 0.31 kg
4. Weight of the sleeve $W_s$ = 1.25 kg

**FORMULA USED**

1. Angular velocity

$$\omega = \frac{2\pi N}{60} \text{ rad/s}$$

2. Theoretical speed

$$N_{th} = \sqrt{\frac{FM}{BM}\frac{m+M}{m}\frac{875}{h}} \text{ (rpm)}$$

3. Centrifugal force

$$F_C = m\omega^2 r \text{ (N)}$$

Where,

l = upper arm length (m)

r = radius (m)

m = mass of the ball = 0.31 kg

M = mass of sleeve = 1 kg

4. Range of the governor (R)

$$R = maximum\ speed - minimum\ speed$$

5. Sensitivity of the governor

$$sensitivity = 2 \times \frac{max.speed - min.speed}{max.speed + min.speed} \times 100$$

6. Percentage increase in speed

$$C = \frac{N_2 - N_1}{N_1}$$

Where,

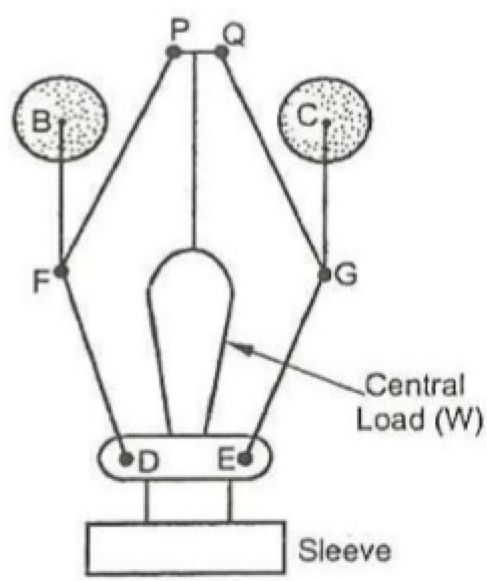
$N_2$ = Maximum speed

$N_1$ = Minimum speed

**PROCEDURE**

1. Switch on the motor in dimmer setup
2. Increase the speed slowly till the sleeve just begins in test
3. This corresponds to minimum speed of the governor
4. Also measure the corresponding radius of rotation of ball
5. Measure the speed of rotation. Such that the sleeve touches it's top most position
6. Note the speed and corresponding radius. This corresponds to the maximum governor speed.
7. Repeat the procedure again

**DIAGRAM**



**TABULATION**

| S. No | Lift<br>(m) | Sleeve radius r (m) | Sleeve height h<br>(m) | Theoretical speed<br>(rpm) | Centrifugal force F<br>(N) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**RESULT**

Thus the stability and controlling force of the proell governor was determined.

## HARTNELL GOVERNOR

***Ex. no: 9***

***Date:***

## AIM

To determine the stability and controlling forces of hartnell governor

## APPARATUS REQUIRED

1. Governor setup
2. Speed regulator
3. Tachometer
4. Dead weight

## OBSERVATION

| | | |
|---|---|---|
| Length of Horizontal arm Y | = 160 mm |
| Length of vertical arm X | = 200 mm |
| Mass of the Ball (m) | = 0.311 kg |

## FORMULA USED

1. Angular velocity

$$\omega = \frac{2\pi N}{60} \text{ rad/s}$$

2. Height of sleeve (h)

$$h = (r_2 - r_1)(^{y}/_{x}) \text{ m}$$

where,

x = length of vertical arm (m)

y = length of horizontal arm (m)

3. Centrifugal force ($F_c$)

$$F_C = m\omega^2 r \text{ (N)}$$

4. Spring force for lowest position

$$S_1 = 2F_{C1} \times \frac{x}{y} \text{ (N)}$$

5. Spring force for highest position

$$S_2 = 2F_{C2} \times \frac{x}{y} \text{ (N)}$$

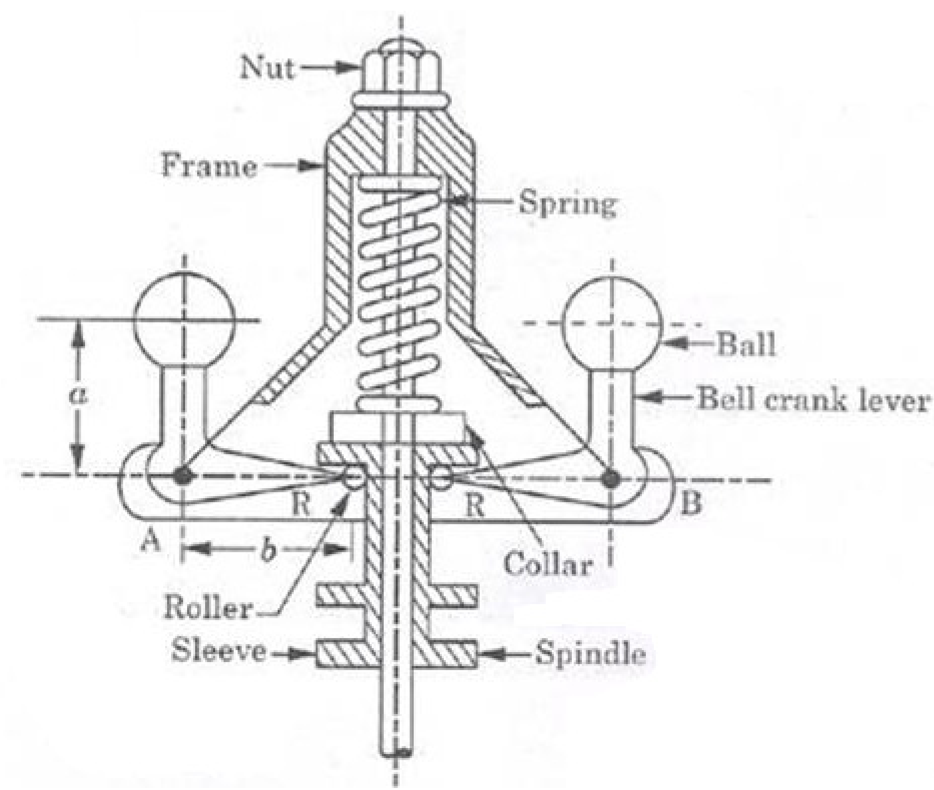
6. Stiffness of spring (S)

$$S = \frac{S_2 - S_1}{h} \quad \text{(N/m)}$$

**PROCEDURE**

1. Switch on the motor in dimmer setup
2. Increase the speed slowly till the sleeve just begins in test
3. This corresponds to minimum speed of the governor
4. Also measure the corresponding radius of rotation of ball
5. Measure the speed of rotation. Such that the sleeve touches it's top most position
6. Note the speed and corresponding radius. This corresponds to the maximum governor speed.
7. Repeat the procedure again

**DIAGRAM**



**TABULATION**

| S. No | Lift (mm) | Sleeve radius (r) | Sleeve height (h) | Theoretical speed (rpm) | Centrifugal force F (N) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**RESULT**

Thus the stability and controlling force of the Hartnell governor was determined.

**TRIFILAR SUSPENSION**

**(TORSIONAL PENDULUM)**

***Ex. no: 10***

***Date:***

**AIM**

To determine the radius of gyration and mass moment of inertia of the circular disc by trifilar suspension

**APPARATUS REQUIRED**

1. A circular disc
2. Stop watch
3. Scale

**OBSERVATION**

1. Distance of each wire from the axis of disc (r) = 0.055 m
2. Length of each wire (l) = 0.5 m
3. Mass of the disc (m) = 1 kg

**FORMULAE**

1. Frequency of oscillation (n)

$$n = \frac{no.of\ oscillations}{Time\ taken} \text{ Hz}$$

2. Also frequency of oscillation (n)

$$n = \frac{r}{2\pi K_G}\sqrt{\frac{g}{l}} \quad \text{Hz}$$

Where,

$K_G$ = Radius of gyration of disc (m)

3. Moment of inertia of disc (I)

$$I = mK_G^2 \text{ (kgm}^2\text{)}$$

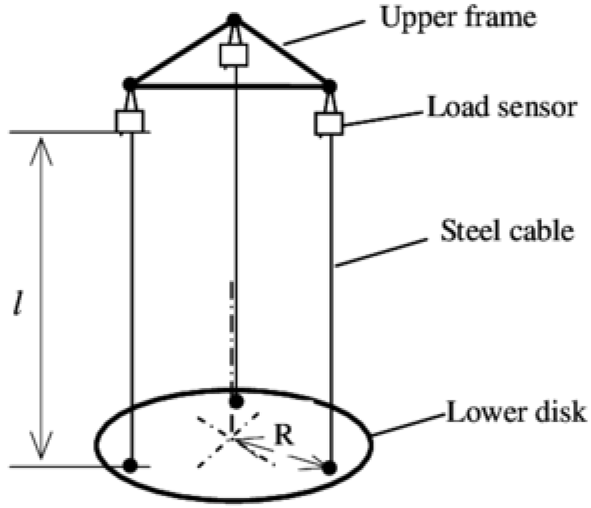
**PROCEDURE**

1. Support the disc in any one end
2. Note the distance between the suspension and center of gravity
3. Make the system to oscillate
4. Note down the time for number of oscillation
5. Repeat the procedure by changing the suspension
6. Tabulate the readings
7. By using formulae calculate radius of gyration and moment of inertia

**TABUALTION**

| S. No | No. of oscillations (n) | Time taken for ‘n’ oscillation (sec) | Frequency of oscillation (Hz) | Radius of gyration ($K_G$) | Mass moment of inertia I ($kgm^2$) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**DIAGRAM**




Trifilar suspension

**RESULT**

Thus the radius of gyration and mass moment of inertia for disc Trifilar suspension is calculated.

Radius of Gyration $K_G$ = m

Mass moment of Inertia I = $kgm^2$

## BIFILAR SUSPENSION

***Ex. no: 11***

***Date:***

**AIM**

To determine the radius of gyration and mass moment of inertia of a rectangular bar by Bifillar suspension

**APPARATUS REQUIRED**

1. A shaft (or) Rectangular bar
2. Stop watch
3. Scale

**OBSERVATION**

Distance of A from G = 0.155 m

Distance of B from G = 0.155 m

Length of each spring (l) = 0.485 m

Mass of the rectangular bar (m) = 0.88 kg

**FORMULA**

1. Frequency of oscillation ($F_n$)

$$F_n = \frac{No.of\ oscillation}{Time\ taken}. \quad \text{(Hz)}$$

2. Also frequency of oscillation

$$F_n = \frac{1}{2\pi K_G}\sqrt{\frac{gxy}{l}}. \quad \text{(Hz)}$$

Where,

$K_G$ = radius of gyration

g = acceleration due to gravity

x = distance of A from G = 0.155 m

y = distance of B from G = 0.155 m

l = length of each string = 0.435 m

3. Mass moment of inertia (I)

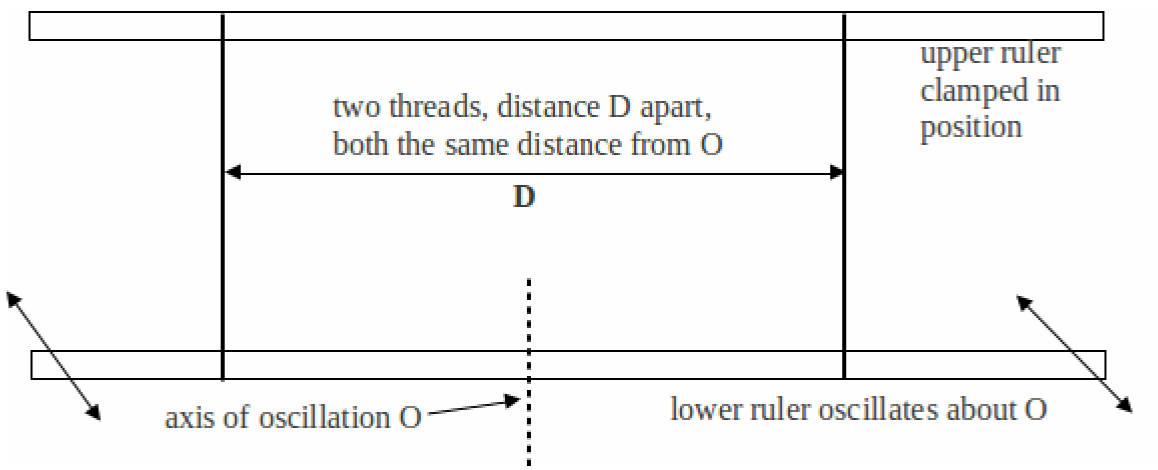
$$I = m\,{K_G}^2$$

Where, m = Mass of rectangular bar = 0.88 kg

**PROCEDURE**

1. A rectangular bar is taken and it is suspended at both the end by two flexible strings.
2. The whole setup is attached to a fixed support
3. The system is made to oscillate and the time taken is calculated for number of oscillation
4. The readings are tabulated and radius of gyration and mass moment inertia is calculated.

**DIAGRAM**




Bifilar suspension

**TABUALTION**

| S. No | No. of oscillations | Time taken for ‘n’ oscillation (sec) | Frequency of oscillation (Hz) | Radius of gyration ($K_G$) | Mass moment of inertia (I) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

**RESULT**

Thus the radius of gyration and the mass moment of inertia of rectangular bar is calculated by bifilar suspension.

Radius of Gyration, $K_G$ = m

Mass moment of inertia, I = $kgm^2$

## EXPERIMENTAL STUDY OF GEAR RATIO OF DIFFERENTIAL GEAR TRAIN

***Ex. no: 12***

***Date:***

### AIM

**To conduct** the experimental study of gear ratio of differential gear train

### APPARATUS REQUIRED

1. Differential gear train
2. Digital speed indicator
3. Speed transformer

### FORMULA USED

1. Total reduction speed in

   $Right\ Wheel\ (N_R) = \frac{N_1 - N_2}{N_1} \times 100\ in\ \%$

   $Left\ Wheel\ (N_L) = \frac{N_1 - N_2}{N_1} \times 100\ in\ \%$

   Where,

   $N_1$ = Input speed in rpm

   $N_2$ = Output speed in rpm

2. Speed ratio

   Right wheel ($N_R$) = $N_1/N_2$

   Left wheel ($N_L$) = $N_1/N_2$

### PROCEDURE

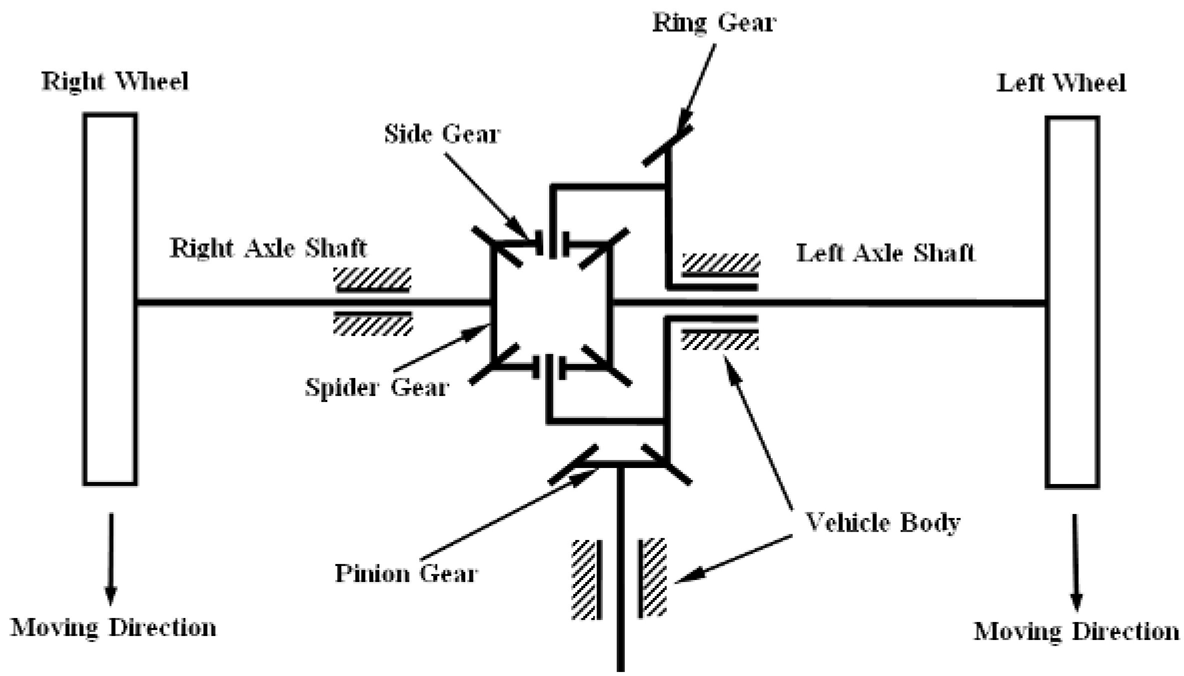
1. Connect the main chord to the 230 V, 50 Hz power supply
2. Connect the sensor 1 and sensor 2 to the respective sensor sockets provided on the front panel of electronic speed control system.
3. Connect the motor cable to the terminal socket
4. Initially keep variable speed control knob is closed position
5. Switch on the instrument
6. Adjust the speed by tuning the knob and tabulate the readings and calculate.

**TABULATION**

| S. No | Input speed ($N_1$) | Output Speed ($N_2$) rpm | | Total reduction in speed (N) in % | | Speed ratio | |
|---|---|---|---|---|---|---|---|
| | | Right wheel $N_R$ | Left wheel $N_l$ | Right wheel $N_R$ | Left wheel $N_l$ | Right wheel $N_R$ | Left wheel $N_l$ |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

**GRAPH**

Input Speed vs Output speed




Differential gear train

**RESULT**

Thus the gear ratio of a differential gear train is carried out and the graph is plotted.

## EXPERIMENTAL STUDY OF SPEED RATIO OF COMPOUND GEAR TRAIN

***Ex. no: 13***

***Date:***

### AIM

To conduct the experimental study of speed ratio of an compound gear train

### APPARATUS REQUIRED

- Compound gear train
- Digital speed indicator
- Speed transformer

### FORMULA USED

1. Total reduction speed (N)

$$N = \frac{N_1 - N_2}{N_1} \times 100\ \%$$

Where,

$N_1$ = Input speed in rpm

$N_2$ = Output speed in rpm

2. Speed ratio = $N_1/N_2$

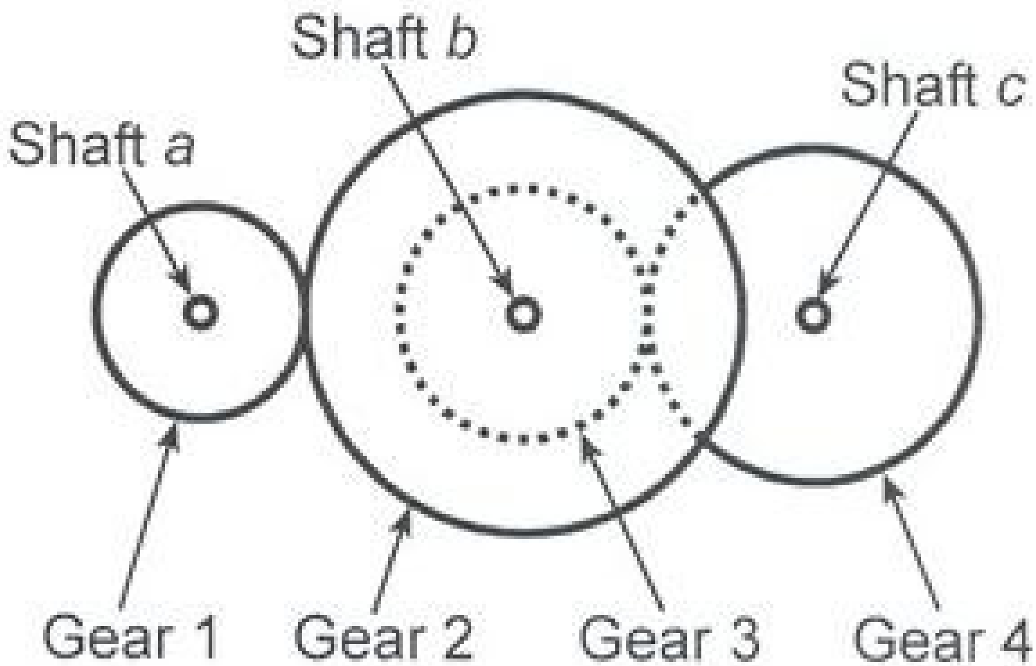
### PROCEDURE

1. Connect the main chord to the 230 V, 50 Hz power supply
2. Connect the sensor 1 and sensor 2 to the respective sensor sockets provided on the front panel of electronic speed control system.
3. Connect the motor cable to the terminal socket
4. Initially keep variable speed control knob is closed position
5. Switch on the instrument
6. Adjust the speed by tuning the knob and tabulate the readings and calculate.

### GRAPH

Input speed vs Output speed

**DIAGRAM**




`

Compound gear train

**TABULATION**

| S. No | Input speed ($N_1$) in rpm | Output speed ($N_2$) in rpm | Total reduction in speed "N" | Speed Ratio $N_1/N_2$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

**RESULT**

Thus the speed ratio of an compound gear reducer is carried out and the graph is plotted.

## EXPERIMENTAL STUDY OF SPEED RATIO OF AN EPICYCLIC GEAR TRAIN

***Ex. no: 14***

***Date:***

**AIM**

To conduct the experimental study of speed ratio of an epicyclic gear train

**APPARATUS REQUIRED**

- Epicyclic gear train
- Digital speed indicator
- Speed transformer

**FORMULA USED**

1. Total reduction speed (N)

$$N = \frac{N_1 - N_2}{N_1} \times 100\ \%$$

Where,

$N_1$ = Input speed in rpm

$N_2$ = Output speed in rpm

2. Speed ratio = $N_1/N_2$

**PROCEDURE**

1. Connect the main chord to the 230 V, 50 Hz power supply
2. Connect the sensor 1 and sensor 2 to the respective sensor sockets provided on the front panel of electronic speed control system.
3. Connect the motor cable to the terminal socket
4. Initially keep variable speed control knob is closed position
5. Switch on the instrument
6. Adjust the speed by tuning the knob and tabulate the readings and calculate.

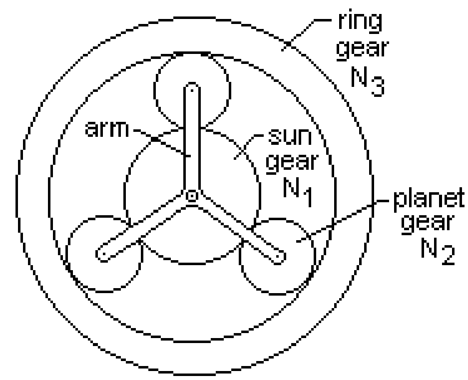
**GRAPH**

Input speed vs Output speed

**TABULATION**

| S. No | Input speed ($N_1$) in rpm | Output speed ($N_2$) in rpm | Total reduction in speed "N" | Speed Ratio $N_1/N_2$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

**DIAGRAM**




Sun-and-Planet Epicyclic Train

**RESULT**

Thus the speed ratio of an epicyclic gear reducer is carried out and the graph is plotted.

## BALANCING OF RECIPROCATING MASSES

***Ex. no: 15***

***Date:***

### AIM

To determine the balancing speed and maximum amplitude frequency of the reciprocating masses

### APPARATUS REQUIRED

1. Reciprocating pump
2. Weights
3. Steel rule

### FORMULA

1. Angular velocity ($\omega$)

$$\omega = \frac{2\pi N}{60}\ rad/sec$$

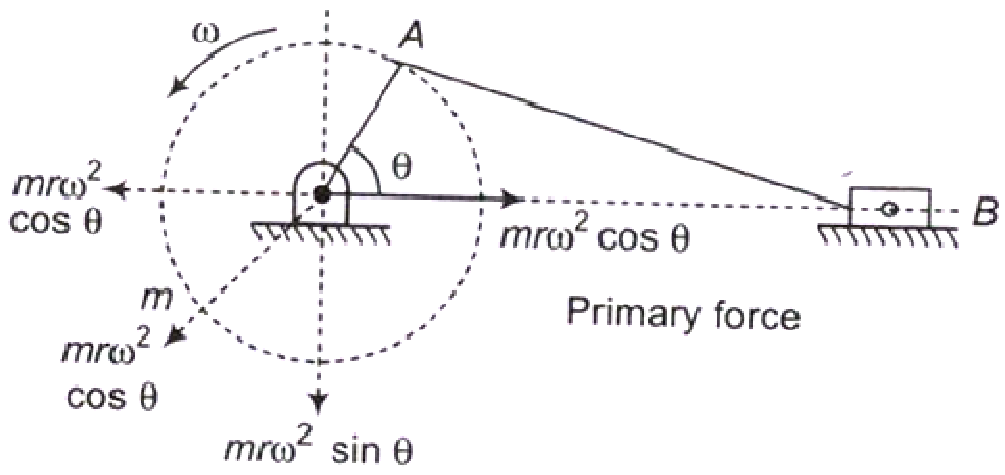
2. Frequency of amplitude (f)

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}}$$

### PROCEDURE

1. Fix the unbalanced masses as per the given conditions, radius, angular position and plane of masses
2. Find out the balancing masses and angular positions using force polygon and couple polygon
3. Fix the balancing masses (calculated masses) at the respective radii and angular position
4. Run the system at certain speeds and check that the balancing is done effectively
5. If the rotor system rotates smoothly, without considerable vibrations means the system is dynamically balanced.

**DIAGRAM**




Balancing of reciprocating mass

**TABULATION**

| S. No | Crank speed (N) in rpm | Mass (kg) | | | Angular velocity ($\omega$) In rad/sec | Maximum amplitude (m) | Frequency of amplitude $F_n$ (Hz) |
|---|---|---|---|---|---|---|---|
| | | $m_1$ | $m_2$ | $B = m_1 + m_2$ | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

**RESULT**

The given reciprocating system has been dynamically balanced.

## BALANCING OF ROTATING MASSES

***Ex. no: 16***

***Date:***

### AIM

To balance the given rotor system dynamically with the aid of the force polygon and the couple polygon

### APPARATUS REQUIRED

- Rotor system
- Weight
- Steel rule

### FORMULA

1. Centrifugal force = $m \times r$ (N)
2. Couple = $m \times r \times l$ (Nm)

### PROCEDURE

1. Fix the unbalanced masses as per the given conditions, radius, angular position and plane of masses
2. Find out the balancing masses and angular positions using force polygon and couple polygon
3. Fix the balancing masses (calculated masses) at the respective radii and angular position
4. Run the system at certain speeds and check that the balancing is done effectively
5. If the rotor system rotates smoothly, without considerable vibrations means the system is dynamically balanced.

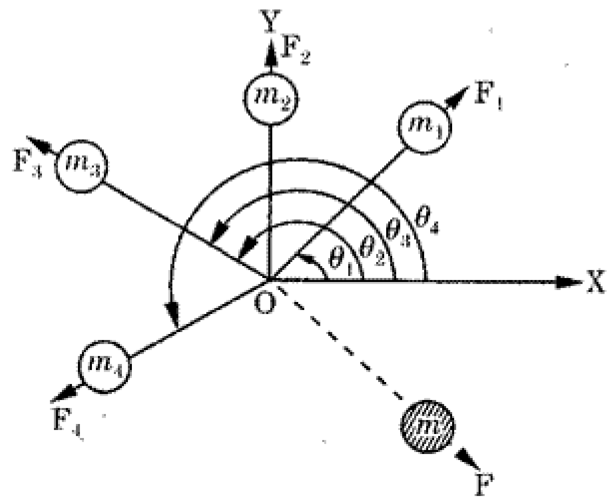
### DIAGRAM

1. Plane of mass
2. Angular position of the masses
3. Force polygon

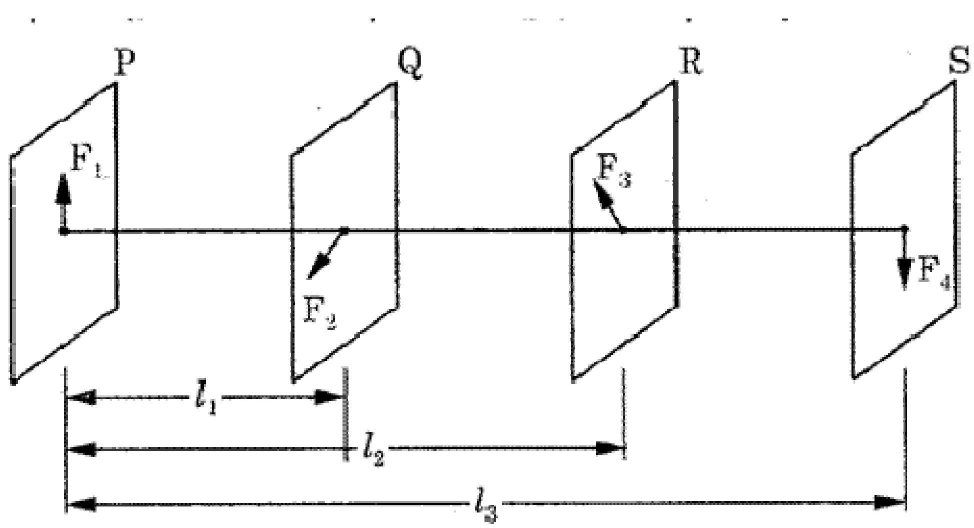
**TABULATION**

| S. No | Planes of mass | Mass ‘m’ Kg | Radius ‘r’ m | Centrifugal force N | Distance from reference plane ‘l’ (m) | Couple |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

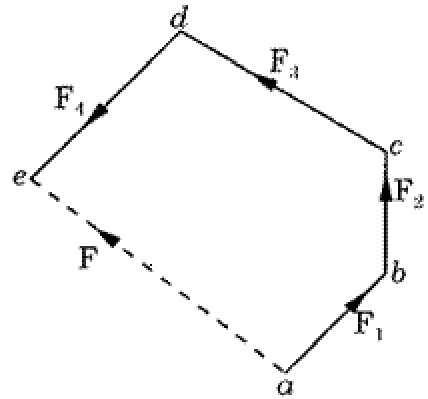
**DIAGRAM**



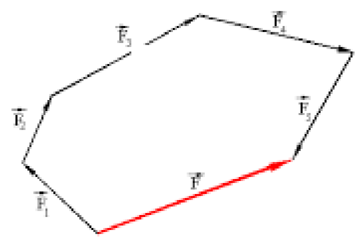

Angular position of the masses




Plane of mass




Force polygon



Couple polygon

**RESULT**

The given rotor system has been dynamically balanced with the aid of force polygon and couple polygon.

# STUDY THE PROFILE AND JUMP PHENOMENON OF CAM

***Ex. no: 17***

***Date:***

## AIM

To study the profile of given cam using cam analysis system and to draw the displacement diagram for the follower and the cam profile. Also to study the jump speed characteristics of the cam follower mechanism

## APPARATUS REQUIRED

Cam analysis system & dial gauge

## DESCRIPTION

A cam is a machine element such as a cylinder or any other solid with surface of contact so designed as to give a predetermined motion to another element called the follower. A cam is a rotating body importing oscillating motor to the follower. All cam mechanisms are composed of at least there links viz.

1. Cam
2. Follower
3. Frame which guides follower cam

## GRAPH

Displacement diagram and also the cam profile is drawn using a polar graph chart. The velocity vs acceleration curve is drawn.

## PROCEDURE

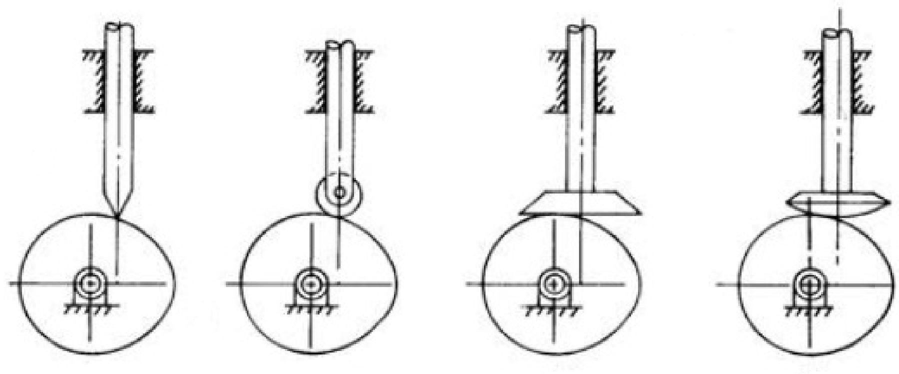
Cam analysis system consists of cam roller, follower, pull load and guide of pull rod.

1. Set the cam at $0^0$ and note down the projected length of the pull rod.
2. Rotate the cam through $10^0$ and note down the projected length of the pull rod above the guide
3. Note down the corresponding displacement of the follower

## JUMP SPEED

1. The cam is run at gradually increasing speeds, and the speed at which the follower jumps off is observed
2. This jump speed is observed for different loads on the follower.

**DIAGRAM**



Cam and follower

**TABULATION**

| S. No | Description | Forward stroke | | Dwell | Return stroke | | Dwell |
|---|---|---|---|---|---|---|---|
| | | Start | End | | Start | End | |
| 1 | Angle in degree | | | | | | |
| 2 | Followed lift in 'mm' | | | | | | |

**RESULT**

Thus the profile of cam is drawn and the jump phenomenon is studied.

## SINGLE ROTOR SYSTEM

***Ex. no: 18***

***Date:***

**AIM**

To determine the natural frequency of a steel shaft by applying free torsional vibration in a single rotor system

**APPARATUS REQUIRED**

- Shaft
- Rotor
- Stop watch

**FORMULA USED**

1. Natural frequency

$$F_n = \frac{No.of\ oscillation}{Time\ taken}.\ \text{Hz}$$

2. Polar moment of inertia of shaft

$$I = \frac{\pi d^4}{32} \quad \text{m}^4$$

3. Torsional stiffness of a shaft for flywheel length (l)

$$q_1 = \frac{C \times I}{l_1} : q_2 = \frac{C \times I}{l_2}$$

Where,

C = Rigidity of shaft modulus = $84*10^9$ N/m$^2$

4. Total torsional stiffness

$$q = q_1 + q_2.\ \text{N/m}$$

5. Mass moment of flywheel of rotor, I = mK$^2$

K = radius of gyration = 0.5 m

6. Natural frequency of torsional vibration

$$F_n = \frac{1}{2\pi}\sqrt{\frac{q}{I}}.\ \text{Hz}$$

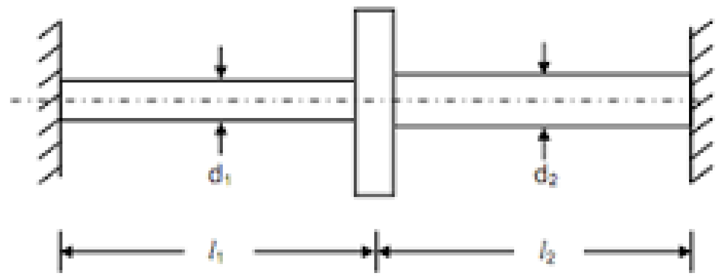
**PROCEDURE**

1. The given shaft is fixed as both ends
2. A rotor of known mass is attached to the center of shaft
3. The rotor is allowed to vibration for the particular number of oscillation in the time taken is noted down
4. Experiment is repeated for vice versa of readings
5. Thus the natural frequency of single rotor system can be calculated.

**TABULATION**

| S. No | Experimental value | | | Theoretical value of stiffness (N/m) | | Natural frequency ($F_n$) Hz | Torsional stiffness (q) N/m |
|---|---|---|---|---|---|---|---|
| | No of oscillation (n) | Time taken for n oscillation (sec) | Natural frequency (Hz) | Torsional stiffness for length ($q_1$) | Torsional stiffness for length ($q_2$) | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

**DIAGRAM**




Single rotor system

**RESULT**

Thus the natural frequency of a steel shaft in a single rotor system is determined.