COMPOUND PENDULUM

AIM:
01. To determine the radius of gyration ‘k’ of given compound pendulum.
02. To verify the relation

\[
T = 2\pi \sqrt{\frac{2}{K + (OG)^2}} \frac{1}{g (OG)}
\]

Where, \( T \) = Periodic time sec.
\( K \) = Radius of gyration about C.G. of rod from support.
\( OG \) = Distance of the C.G. of rod from support.
\( L \) = Length of suspended pendulum cm.

DESCRIPTION OF THE SET UP: (Refer Fig.2.)

The compound pendulum consists of steel bar. The bar supported in the hole by the knife-edge.

PROCEDURE
01. Support the rod on knife-edge.
02. Note the length of suspended pendulum and determine OG.
03. Allow the bar to oscillate and determined T by knowing time for says 10 oscillations.
04. Repeat the experiment with second pendulum.
05. Complete the observation table given below.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>L (Cm)</th>
<th>OG</th>
<th>No. Of Osc n</th>
<th>Time 1 for N, osc, sec.</th>
<th>T (Expt) 1/n</th>
<th>K Experimental</th>
<th>K Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATIONS.

01. Find ‘k’ experimental from the relation

\[
T = 2\pi \sqrt{\frac{2}{K + (OG)^2}} \frac{1}{g (OG)}
\]
Where, $T =$ Periodic time.

\[ T = \frac{t}{n} \]

$T =$ Time for n osc.

$n =$ No. of osc.

Substituting for $OG$ and $T$ in the above formula.

\[
\text{Fins } \kappa (\text{exp}) = \sqrt[3]{\frac{L}{2}}
\]

\[
\text{K theoretical} = \sqrt[3]{\frac{L}{2}}
\]

Compare value of $\kappa$ obtained Theo. And expt.

Note: $OG =$ For Pendulum.

RESULT:

The radius of gyration ($\kappa$) is determined
BI-FILLER SUSPENSION

AIM: To determine the radius of gyration of given bar by using Bi-Filer suspension.

DESCRIPTION OF SET UP: (Refer Fig. 3.)

A uniform rectangular section bar is suspended from the pendulum support frame by two parallel cords. Top ends of the cords attached to hooks fitted at the top. Other ends are secured the Bi-filer bar. It is possible to change the length of the cord.

The suspension may also be used to determine the radius of gyration of any body. In this case the body under investigation is bolted to the center. Radius of gyration of the combined bar and body is then determined.

PROCEDURE

01. Suspend the bar from hook. The suspension length of each cord must be the same.
02. Allow the bar to oscillate about the vertical axis passing through the center and measure the periodic time T by knowing the time for say 10 oscillations.
03. Repeat the experiment by mounting the weights at equal distance from the center.
04. Complete the observation table given below.

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>L cms.</th>
<th>a cms</th>
<th>T secs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

CALCULATIONS
For Bi-Filer suspension.

\[ T = 2\pi \frac{K}{a} \sqrt{\frac{L}{g}} \]

Where, \(2a = \text{distance between two wires cms.}\)
\(K = \text{Radius of gyration of bi-filer suspension.}\)

Find \(k\) experimental by using above formula.

\[ K_{\text{theoretical}} = \frac{L}{2 \sqrt[3]{3}} \]

RESULT: The radius of gyration of bar is determined by using bi-filler suspensio
LONGITUDINAL VIBRATIONS OF HELICAL SPRING

AIM: To supply the longitudinal vibrations of helical spring and to determine the frequency or period of vibration (oscillation) theoretically and actually by experiment.

DESCRIPTION OF APPARATUS: (refer Fig.4)

One end of open coil spring is fixed to the screw, which engages with screwed hand wheel. The screw can be adjusted vertically in any convenient position and then clamped to upper beam by means of lock nuts. Lower end of the spring is attached to the platform carrying the weights. Thus the design of the system incorporates vertical positioning of the unit to suit the convenience.

PROCEDURE

01. Fix one end of the helical spring to the upper screw.
02. Determine free length.
03. Put some weight to platform and note down the deflection.
04. Stretch the spring through some dist and release.
05. Count the time required (in sec.) for some say 10, 20 oscillations.
06. Determine the actual period.
07. Repeat the procedure for different weights.

OBSERVATIONS

01. Length of spring:
02. Mean dia of spring:
03. Wire dia:

OBSERVATION TABLE NO.1 (For finding km.)

<table>
<thead>
<tr>
<th>Obs. No.</th>
<th>Wt. Attached Kg. w</th>
<th>Deflections of Spring cm. (g)</th>
<th>K = w/d</th>
<th>Km. (MEAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
OBSERVATION TABLE NO.2

<table>
<thead>
<tr>
<th>Obs. No.</th>
<th>Wt. Attached Kg.</th>
<th>No. Of osc n</th>
<th>Time required for n osc.</th>
<th>Periodic time &amp; t expt. = t/n</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

CALCULATIONS

01. Find km. (mean stiffness) of the spring as follows.

\[ K_m = \frac{K_1 + K_2 + K_3}{n} \ldots \text{kg/cm} \]

Where, \( k_1 = \frac{W_1}{G_1} \), \( K_2 = \frac{w_2}{g^2} \), \( K_3 = \frac{w_3}{g^3} \)

\( N = \text{number of readings} \).

02. Find \( T \) theoretical by using relation.

\[ T = \text{theoretical} = 2\pi \sqrt{\frac{w}{K_m \times g}} \]

03. Check with experimental value \( T \) expt. = \( \frac{t}{n} \)

Hence, \( f \) theoretical = \( \frac{1}{T \text{ (theo)}} \) cps.

And \( f \) theoretical = \( \frac{1}{T \text{ (expt)}} \) cps.

RESULT: The frequency or period of vibration is determined by using longitudinal of helical spring
SINGLE ROTOR SHAFT SYSTEM

AIM: To determine the Torsional vibration (undamped) of single Rotor shaft System.

DESCRIPTION OF SET UP: -

Fig. No. 7 shows the general arrangement for carrying out the experiments. One end of the shaft is gripped in the chuck & heavy flywheel free to rotate in ball bearing is fixed at the other end of the shaft.

The bracket with fixed end of shaft can be clamped at any convenient position along lower beam. Thus length of the shaft can be varied during the experiments. Specially designed chucks are used for clamping ends of the shaft. The ball bearing support to the flywheel provides negligible damping during experiment. The bearing housing is fixed to side member of mainframe.

PROCEDURE: -

(1) Fix the bracket at convenient position along the lower beam.
(2) Grip one end of the shaft at the bracket by of chuck.
(3) Fix the rotor on the other end of the shaft.
(4) Twist the rotor through some angle & release.
(5) Note down the time required for 10,20 oscillations.
(6) Repeat the procedure for different length of shaft.
(7) Make the following observations: -

a) Shaft dia = 3 m.m.
b) Dia of Disc = 225 m.m.
c) Wt. Of the Disc = 4.135kg.
d) Modulus of rigidity for shaft

\[ G = \frac{E}{2(1+v)} \]

\[ G = 0.8 \times 10^6 \text{ kg/sq.cm.} \]

OBSERVATION TABLE: -

<table>
<thead>
<tr>
<th>Cbs</th>
<th>Length of shaft</th>
<th>No. of osc n</th>
<th>Time for n osc Sec</th>
<th>Periodic Time ( T = \frac{n}{N} ) (expt).</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
SPECIMEN CALCULATION: -

(1) Determination of Torsional stiffness $K_t$.

$$K = \frac{G}{L} I_p, \quad L = \text{Length of shaft}$$

$$T = \frac{4\pi}{\pi d}, \quad \frac{\pi d}{32} = \frac{d}{32}, \quad d = \text{Shaft dia}$$

(2) Determine $T$ theoretical

$$= 2\pi \sqrt{\frac{I}{K_t}}, \quad \text{Where}$$

$$I = \text{M.I. of disc} = \frac{w}{g} \times \frac{D}{8}$$

(3) Determine $T$ experimental

$$\text{Time for } n \text{ osc} = \frac{2}{\text{No. of osc. } N} = \text{sec.}$$

Result:-

<table>
<thead>
<tr>
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</table>

CALCULATIONS

$$F_{\text{Theo}} = \frac{1}{T_{\text{Theo}}} \quad \quad \quad F_{\text{Exp.}} = \frac{1}{T_{\text{Exp.}}}$$

RESULT: The torsional vibration is determined by using single rotor system.
TWO ROTOR SYSTEM

AIM: To study the free vibrations of two rotor system and to determine the natural frequency of vibration theoretically and experimentally.

DESCRIPTION OF SET UP:

Fig. No. 9 shows the general arrangement for carrying out the experiment. Two discs having different mass moment of inertia are clamped one at each end of shaft by means of collect and chucks. Mass moment of inertia of any disc can be changed by attached the cross lever weights. Both discs are free to oscillate in the ball bearings. This provides negligible damping during experiment.

PROCEDURE:

1) Fix two discs to the shaft and fit the shaft in bearings.
2) Deflect the discs in opposite direction by hand and release.
3) Note down time required for particular number of oscillations.
4) Fit the cross arm to one of the disc say b and again note down time.
5) Repeat the procedure with different equal masses. Attached to the ends of cross arm and note down the time.

OBSERVATION: -

(1) Dia of Disc A = 190 m.m.
(2) Dia of Disc B = 225 m.m.
(3) Wt. Of Disc A = kg.
(5) Wt. Of arm = 0.191 kg.
(6) Length of the cross arm = 155
(7) Dia of shaft = 3 m.m.
(8) Length of shaft between rotors = L =

OBSERVATION TABLE

<table>
<thead>
<tr>
<th>Obs No.</th>
<th>I A</th>
<th>I B</th>
<th>No. of oscillations.</th>
<th>Time required for n osc.</th>
<th>T expt. t = n secs.</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>
SPECIMEN CALCULATIONS
1) Find $k$ of shaft as follows

$$K = \frac{G I p_0}{t L}$$

Where, $G$ = modulus of rigidity of shaft

$$= 0.8 \times 10^2 \text{ kg/cm.}$$

$$I = \frac{P}{32}$$

Let – $I_A$ = M.I. of disc, A,

$I_B$ = M.I. of disc, B,

(With wts. on cross arm.)

$d$ = shaft dia.

$L$ = Length of the shaft.

Then $I = \frac{W}{a g} \times \frac{D}{a 8} + \frac{W}{b g} \times \frac{D}{b 8} + \frac{2 w_1}{g} \times \frac{R}{8}$

(Neglecting effect of cross arm)

Where $W_1$ = Wt. Attached to the cross arm.

$R$ = Radius of Fixation of Wt. on the arm.

$$T_{\text{theoretical}} = 2\pi \sqrt{\frac{I_A}{a} \times \frac{I_B}{b}} \frac{K}{(I_A + I_B)}$$

$$T_{\text{experimental}} = \frac{\text{Time for n osc}}{=} \text{sec.}$$
RESULT: The natural frequency of vibration is determined by using two rotor system.
VIBRATION OF EQUIVALENT SPRING MASS SYSTEM (undamped)

AIM: To determine the undamped free vibration of equivalent spring mass system.

DESCRIPTION OF SET UP

The arrangement is show in Fig.5. It is designed to study free forced damped and undamped vibrations. It consists of M.S. rectangular beam supported at one end by a trunnion pivoted in ball bearing. The bearing housing is fixed to the supported by the lower end of helical spring. Upper end of spring is attached to the screw.

The exciter unit can be mounted at any position along the beam. Additional know weights may be added to the weight platform under side the exciter.

PROCEDURE

01. Support one end of the beam in the slot of trunion and clamp it by means of screw.
02. Attach the other end of beam to the lower end of spring.
03. Adjust the screw to which the spring is attached such that beam is horizontal in the above position.
04. Weight the exciter assembly along with discs and bearing and weight platform.
05. Clamp the assembly at any convenient position.
06. Measure the distance L1 of the assembly from pivot. Allow system to vibrate freely.
07. Measure the time for any 10 osc and find the periodic time and natural frequency of vibrations.
08. Repeat the experiment by varying L1 and by putting different weights on the platform.

NOTE: It is necessary to clamp slotted weights to the platform by means of nut, so that weights do not fall during vibrations.

OBSERVATION TABLE

<table>
<thead>
<tr>
<th>Wt</th>
<th>L_1</th>
<th>No. Of osc n</th>
<th>Time required for N osc.</th>
<th>Periodic Time &amp; T Expt, =t/n</th>
<th>Natural Freq. in Fn (expt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CALCULATION

\[ T \text{ (Theoretical)} = 2\pi \sqrt{\frac{\text{me}}{K}} \]

Where, \( \text{me} = \) Equivalent mass at the spring.

\[ = M \left(\frac{2}{L} \left(1 + \frac{1}{L}\right)\right) \]

\( K = \) Stiffness of the spring in kg/cms,
\( W + W \)
\( M = \frac{W + M}{G} \)

Where,
\( W = \) Weight attached on exciter assembly
\( G = 981 \text{ cm/sec}. \)
\( W = \) Weight of exciter assembly along with weight platform in kg.
\( L_1 = \) Distance of w from pivot in cms.
\( L = \) Distance of spring from pivot
\( = \) Length of beam in cms.
\( M = \) Mass of exciter assembly along with wt. Platform.

RESULT: The undamped free vibration of equivalent spring mass system is determined.
AIM : To determine the Forced Vibrations of Equivalent Spring Mass System.

DESCRIPTION OF THE SET UP

The arrangement is as shown in the Fig.6. It is similar to that described for Expt.No.5. The exciter unit is coupled to D.C. Variable Speed Motor. Speed of the motor can be varied with the dimmer stat provide on the control panel. Speed of rotation can be known from the speed indicator on the control panel. It is necessary to connect the damper unit to the exciter. Amplitude record of vibration is to be obtained on the Strip Chart Recorder.

PROCEDURE

02. Arrange the set-up described for Expt. No5.
03. Start the motor and allow the system to vibrate.
03. Wait for 1 to 2 minutes for the amplitude to build the particular forcing frequency.
04. Adjust the position of strip chart recorder. Take the record of amplitude Vs. Time on strip chart by starting recording motor. Press the recorder platform on the pen gently. Pen should be wet with ink. Avoid excessive pressure to get good record.
05. Take record by changing forcing frequencies.
06. Repeat the experiment for different damping. Damping can be changed by adjusting the holes on the piston of the damper.
07. Plot the graph of amplitude vs. frequency for each damping conditions.

OBSERVATION TABLE

Set 1 with little damping

<table>
<thead>
<tr>
<th>Forcing Frequency cp.s.</th>
<th>Amplitude mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prepare similar observation tables for various damping conditions.

CALCULATIONS

Plot the graph of amplitude vs. frequency for each setting

RESULT: The forced vibration of equivalent spring mass system is determined.
AIM: To determine the forced lateral vibrations of the beam for different damping.

DISCRIPTION OF THE SET UP: -
Fig. 11 shows the general set up. Slightly heavy rectangular section bar than used for expt. No. 10 is supported at ends in tunnion fittings. Exciter unit with the weight platform can be clamped at any convenient position along the beam. Exciter unit is connected to the damper, which provides the necessary damping. Speed of Strip-chart recorder is 33 mm/sec.

PROCEDURE: -
1. Arrange the set-up as shown in Fig. 11.
2. Connect the exciter to D.C. Motor through Flexible shaft.
3. Start the Motor & allow the system to vibrate.
4. Wait for 3-4 minutes for amplitude to build up for particular forcing frequency.
5. Adjust the position of Strip-chart recorder. Take the recorded of amplitude vs. time on strip-chart recorder by starting recorder motor.
6. Take record by changing forcing frequency.
7. Repeat the experiment for different damping.
8. Plot graph of amplitude vs. frequency for each damping.

OBSERVATION TABLE: Set –1 (With little damping.)

<table>
<thead>
<tr>
<th>Forcing frequency</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prepare similar observation tables for medium and heavy damping.

RESULT: The lateral vibration of beam is determined.
EX NO:1: TRANSVERSE VIBRATION - I

Aim: To find the natural frequency of transverse vibration of the cantilever beam.

Apparatus required: Displacement measuring system (strain gauge) and Weights

Description:
Strain gauge is bound on the beam in the form of a bridge. One end of the beam is fixed and the other end is hanging free for keeping the weights to find the natural frequency while applying the load on the beam. This displacement causes strain gauge bridge to give the output in milli-volts. Reading of the digital indicator will be in mm.

Formulae used:
1. Natural frequency = \( \frac{1}{2\pi} \sqrt{\frac{g}{\delta}} \) Hz
   where \( g \) = acceleration due to gravity in m/s\(^2\) and \( \delta \) = deflection in m.

2. Theoretical deflection \( \delta = \frac{Wl^3}{3EI} \)
   Where, \( W \) = applied load in Newton, \( L \) = length of the beam in mm
   \( E \) = young’s modules of material in N/mm\(^2\), \( I \) = moment of inertia in mm\(^4\) = bh\(^3\)/12

3. Experimental stiffness = \( \frac{W}{\delta} \) N-mm and Theoretical stiffness = \( \frac{W}{\delta} = \frac{3EI}{l^3} \) N/mm

Procedure:
1. Connect the sensors to instrument using connection cable.
2. Plug the main cord to 230v/ 50hz supply
3. Switch on the instrument
4. Keep the switch in the read position and turn the potentiometer till displays reads “0”
5. Keep the switch at cal position and turn the potentiometer till display reads 5
6. Keep the switch again in read position and ensure at the display shows “0”
7. Apply the load gradually in grams
8. Read the deflection in mm

Graph:
Draw the characteristics curves of load vs displacement, natural frequency
Draw the characteristics curves of displacement vs natural frequency

Result:
Observation: Cantilever beam dimensions: Length=30cm, Breadth=6.5cm and Height=0.4cm

Tabulation:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Applied mass m (kg)</th>
<th>Deflection ( \delta ) (mm)</th>
<th>Theoretical deflection ( \delta_T ) (mm)</th>
<th>Experimental Stiffness k (N/mm)</th>
<th>Theoretical Stiffness k (N/mm)</th>
<th>Natural frequency ( f_n ) (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
CAM ANALYSIS APPARATUS

AIM:
To determine the speed at which cam jump occur for various spring loading condition.

DESCRIPTION:
Cams are used in machines to move a component in a prescribed path e. g. textile machine tools, I. C. engines, printing machines etc. Cam is a mechanical member for transmitting desired motion to follower by direct contact. Various types of cams and followers are used in practice like wedge, radial or cylindrical cams and reciprocating or oscillating followers with flat face, mushroom face or roller. The apparatus provides study of three types of cams and followers with dial gauge, follower displacement diagrams can be plotted and by rotating the cam, ‘jump’ phenomenon can be observed.

SPECIFICATIONS : -
1) Cams - Eccentric, tangent & circular arc cam one each.
2) Followers - Flat faced, Mushroom , and Roller followers one each.
3) Push rod assembly with spring and dead weights.
4) Variable speed motor to drive the cams.
5) Angular scale and dial gauge - 1 each.

EXPERIMENTAL PROCEDURE : -
1) Fit the required cam over the cam shaft and required follower to the push rod.
2) Set angular scale at required position.
3) Adjust the weight seat and dial gauge.
4) Rotate the cam by hand and note down the dial - gauge reading at every 30° intervals.
5) Remove the dial gauge. Switch ‘ON’ the power supply. Slowly increase the motor speed.
6) At particular speed a peculiar striking sound is heard. This speed is called ‘Jump Speed’. At this speed, follower does not follow the exact path guided by cam contour. Note down this speed. Use of this cam-follower system beyond this speed is useless, because desired follower motion is not obtained.

7) Repeat the procedure for different dead weight and spring tension configurations at different cam - follower configurations.

**OBSERVATIONS :**

<table>
<thead>
<tr>
<th>Cam Angle</th>
<th>Follower displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr No.</td>
<td>mm</td>
</tr>
<tr>
<td>1. 0</td>
<td></td>
</tr>
<tr>
<td>2. 30</td>
<td></td>
</tr>
<tr>
<td>3. 60</td>
<td></td>
</tr>
<tr>
<td>4. 90</td>
<td></td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>12. 360</td>
<td></td>
</tr>
</tbody>
</table>

**RESULT:** Thus the speed is determined by the cam jump occur.
WHIRLING OF SHAFT

INTRODUCTION:
In rotating machinery, if speed rotation is nearer to natural frequency of system, then the amplitude of vibration will be very high. The phenomenon is called whirling of shafts and the speed at which whirling occurs is called whirling speed or critical speed. In any machinery, it is to be ensured that the machinery is not running near the critical speed. Consider a single rotor system having mass ‘m’ at centre. If ‘q’ is lateral stiffness of shaft is N/m If e is eccentricity of mass and y is deflection.

\[
\text{If } e \text{ is eccentricity of mass and } y \text{ is deflection. Then Centrifugal force } = m \omega^2 (y + e) \\
\text{Retaining force } = q \times y \\
\text{Equating } \\
m \omega^2 (y + e) = q \times y \\
\omega^2 (y + e) = \frac{q}{m} \times y = \omega_n^2 \times y \\
\text{where } \omega_n = \sqrt{\frac{q}{m}} \\
y = \frac{\omega^2 e}{\omega_n^2 - \omega^2} = \frac{e}{\left(\frac{\omega_n}{\omega}\right)^2 - 1} \quad \text{for } \omega_n > 1 \\
\quad = \frac{e}{1 - \left(\frac{\omega_n}{\omega}\right)^2} \quad \text{for } \omega_n < 1 \\
\text{y is maximum at } \omega = \omega_n.
\]

AIM:
To determine the critical(whirling) speed of the given rotor.

EXPERIMENTAL SETUP:
This consists of a shaft y diameter ‘d’ and central mass ‘m’. The shaft is supported on two bearings and distance between bearings can be adjusted. The shaft is driven by a variable speed motor with speed indicator. The whole arrangement is mounted on a bed.

SPECIFICATION:
Shaft diameter = 8 mm
Maximum Shaft length(between centre) = 750 mm.
Rotor diameter = 110 mm
Rotor thickness = 14 mm.
Rotor weight (m) = 1 kg.

EXPERIMENTATION:
1. Initially set the bearing block at last hole so that it will be maximum centre distance between pedestals as mm.
2. Calculate lateral stiffness of shaft considering thus as both end fixed beam
   \[ q = \frac{192EI}{L^3} \times 1000 \text{ N/m} \]
   \[ E = 2 \times 10^5 \text{ N/mm}^2, \quad I = \frac{\pi}{64} d^4 \text{ mm}^4, \quad L = 750 \text{ mm}. \]
   \[ \omega_n = \sqrt{\frac{q}{m}} \]
   \[ N_c = \omega_n \times \frac{60}{2\pi} \]
3. Calculate critical speed of shaft
4. Run the shaft and gradually increase speed.
5. Note the critical speed by observing amplitude of rotor.
6. Increase the speed and ensure that amplitude decreases.
7. **CAUTION: DO NOT RUN THE SHAFT LONGER TIME AT CRITICAL SPEED.**
8. Do this for centre distance variance of 25 mm, 50 mm…… (pitch of the hole was 25 mm)

**TABULATION:**

<table>
<thead>
<tr>
<th>L (length of shaft between centre)</th>
<th>( N_c ) (rpm) (calculated)</th>
<th>( N_c ) (rpm) (observed)</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

**RESULT:**

Thus the critical speed of given rotor is determined.
**WATT GOVERNOR**

Aim: To determine the force of watt governor

**DIMENSIONS:**

a) Length of each link: \( L = 125 \text{mm} = 0.125 \text{m} \)
b) Initial height of governor: \( H_0 = 96 \text{mm} = 0.105 \text{m} \)
c) Initial radius of rotation: \( r = 0.120 \text{m} \)
d) Weight of each ball assembly: \( 0.520 \text{ kg or 0.6 Kg} \)

Go on increasing the speed gradually and take the readings or speed of rotation ‘N’ and corresponding sleeve displacement ‘X’ radius of rotation ‘r’ at any position could be found as follows:-

i) Find height \( = h = h_0 - x/2 \)

ii) Find \( \alpha \) by using \( \cos \alpha = h / l \) \( \alpha = \cos^{-1} (h/L) \) in Degrees

iii) Then \( r = 50 + L \sin \alpha \)

Angular Velocity ‘\( \omega \)’ = \( 2\pi N/60 \text{ rad/sec} \)

**PROCEDURE:**

**WATT GOVERNOR:**

1. The governor setup is connected to the power supply.

2. The set up is started at minimum speed using a speed controller.

3. The speed at which the governor just starts to lift is the minimum Equilibrium speed.

4. The speed is gradually increased and the speed corresponding to the Maximum height of the governor is the maximum equilibrium speed.

**OBSERVATION TABLE:**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Speed in RPM</th>
<th>Sleeve displacement</th>
<th>Height</th>
<th>( \cos \alpha = h / l )</th>
<th>Radius of rotation</th>
<th>Force ( F = \frac{w}{g} \omega^2 x )</th>
</tr>
</thead>
</table>

Following graphs may than be plotted to study governor characteristics
1) Force v/s radius of rotation.
Speed v/s Sleeve displacement
Result: The controlling force of a watt governor are determined
PORTER GOVERNOR

Aim: To determine the controlling force of porter Governor
Apparatus: Universal Governor Apparatus, Tachometer

Procedure:

1. Arrange the setup as a proell governor. This can be done by removing the upper sleeve on the vertical spindle of the governor and using proper linkages provided.
2. Increase the spindle speed slowly and gradually.
3. Note the speed and sleeve Vs sleeve displacement.
4. Plot the graph of speed Vs governor height.
5. Plot the graph of speed Vs governor height.
6. Plot the governor characteristic after doing the necessary calculations.

Precautions:

1. Increase the speed gradually.
2. Take the sleeve displacement when the pointer is steady.
3. Ensure that the load on sleeve does not hit the upper sleeve of the governor.
4. Bring dimmer at zero position then switch off the unit.

Observation and calculation:

Dimensions
a) Length of each link - L = 0.125 m.
b) Initial height of Governor – ho = 0.105 m.
c) Initial radius of rotation – ro = 0.120 m.
d) Weight of each ball - W = 0.6 kgs.
e) Weight of Sleeve weight = 0.5 kgs.

Radius of rotation ‘r’ at any position could be found as follows
a) Find height h = ho – X/2 mtr. ho = 0.10 m
b) Find “ a “ by using a = Cos –1 (h/L) in Degrees
c) Then r = 0.05 + L Sin a mtr.
   d) Angular Velocity ‘w’ = 2p N/60 rad/sec

<table>
<thead>
<tr>
<th>SL.No.</th>
<th>Speed N rpm</th>
<th>Sleeve Depth(X)m</th>
<th>Height (‘h’)m</th>
<th>Radius of Rotation (r) m</th>
<th>Force ‘F’ = (W/g)*r^2r</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>
Graph: 1. Force Vs Radius of rotation
2. Speed Vs Sleeve Displacement

Result: The controlling force of a porter governor is determined
PROELL GOVERNOR

Aim: To determine the controlling force of Proell Governor
Apparatus: Universal Governor Apparatus, Tachometer

Procedure:

1. Arrange the setup as a proell governor. This can be done by removing the upper sleeve on the vertical spindle of the governor and using proper linkages provided.
2. Increase the spindle slowly and gradually.
3. Note the speed and sleeve displacement.
4. Plot the graph of speed Vs sleeve displacement.
5. Plot the graph of speed Vs governor height.
6. Plot the governor characteristic after doing the necessary calculations.

Precautions:

1. Increase the speed gradually.
2. Take the sleeve displacement when the pointer is steady.
3. Ensure that the load on sleeve does not hit the upper sleeve of the governor.
4. Bring dimmer at zero position then switch off the unit.

Observation and calculation:

Length of each link L= 0.125mt
Initial height of the governor h_o = 0.100mt
Initial rad of rotation r_o =0.127mt
Weight of ball assembly W1=7.4N
Wt of sleeve W2 = 9.81 N
Total wt of assembly W=W1+W2
Extension of length BG= 0.075m

Dimensions
a) Length of each link - L = 0.125 m.
b) Initial height of Governor – ho= 0.100 m.
c) Initial radius of rotation – ro = 0.127 m.
d) Weight of ball - W = 0.6 kgs.
e) Extension of length BG = 0.075 m.

Observation table:

<table>
<thead>
<tr>
<th>SL.No.</th>
<th>Speed N rpm</th>
<th>Sleeve Depth(X)m</th>
<th>Height (‘h’)m</th>
<th>Radius of Rotation (r) m</th>
<th>Force ‘F’ = (W/g) * ( \frac{r^2}{r} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
GRAPH:  
1. Force Vs radius of rotation.
2. Speed Vs sleeve displacement.

Result: The controlling force of a proell governor is determined.
INTRODUCTION:

It is a basic equipment used for analyzing the concept of statically and dynamically balancing of rotating masses.
BASIC SETUP:

The equipment consists of rigid frame of ‘T’ shape. We may call this as supporting frame. Three nuts are provided on it to hold the equipment on horizontal level by tightening screws. The main frame consists of four steel flat is also provided with the equipment. This is the basic and important part to the experiment. This frame consists of horizontal shaft mounted between two bearings. A pulley allows with a hock and a pointer is provided on this pulley. A graduated scale of 360° is provided on this side of mainframe. Six rotating weights with marking of number letters having different holes are provided.

PROCEDURE:

1. Clamp the main frame on the supporting frame by a nut and bolt.
2. Clamp rotating weight having mark as 1/a on the main shaft by allen key provided with the machine.
3. Ensure that the weight is firmly clamped. It should move along with the shaft only. While doing this, care should be taken to have the pointer at 0°.
4. Now attach two weight pans by a light flexible string to the hook provided on the pulley. Let this string pass through the groom provided on pulley.
5. Now add steel balls in any one of the weight pans and ensure that both the weight pans are in horizontal level.
6. Add the weights until the rotating weight falls freely. At this time pointer shows 90° + 10°. Count down the steel balls.
7. Continue this procedure for all other five weights. Record these weights in a table.

<table>
<thead>
<tr>
<th>Wt. No.</th>
<th>No. of steel balls (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

To determine static balancing:
1. Select any four rotating weights at random. Select any random distance between.
2. Find the couple of all the forces (weights) with respect to any one of the forces. The general idea of this couple binding will be as under.

```
4             2         3        5
  a           b        c
```

Tabulate the results as per following:

<table>
<thead>
<tr>
<th>Weight No.</th>
<th>N</th>
<th>Distance w.r.t Weight (d)</th>
<th>Couple = N x d</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Now draw couple polygon. Here we will obtain the angle between weight no.2 & 3.
4. Force polygon is also drawn by taking a suitable scale for WR values with angle of force 4 as 0.
5. Angles of forces 2 & 3 are as found in couple polygon. Here we will find out the angle of force 6
6. Now tabulate the angles of each force.

<table>
<thead>
<tr>
<th>Force</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

7. Attach these weights as per these angles on the shaft with the use of weight setting gauges and scale provided on the main frame. For tightening the shaft at required angle, the knob may be used. Ensure that the weight is attached at right angle to the weight setting gauge and it is exactly at the distance taken for calculating couple.
8. Remove weight setting gauge and knob. Rotate the pulley by hand. It should stop at any position.
Dynamic balancing:
1. Remove the mainframe from supporting frame. Attach hook and chain to the mainframe at the given tapings.
2. Lift the mainframe and attach it to the supporting frame by chain and stud. Tighten the nut. Now the frame will be in hanging position. Adjust its level by using chain and nut arrangement.
3. Put a belt on the motor pulley and pulley provided on shaft. Use small diameter of the pulley to put belt on it.
4. Now start the motor and observe the performer. We can say that the rotating masses are perfectly dynamically balanced when there exists zero vibration to the frame.

LIMITATIONS:
1. Care is taken to minimize friction between the shaft and mainframe; however zero friction is not possible in actual practice.
2. By selecting any four weight rather that the above we can find the same static and dynamically balancing of rotary weights.

ACCELEROMETER – VIBRATION TABLE

Mechanical Vibration in something which usually people like to avoid if they can expect in some places where artificial vibrations are purposely generated to speed up pressure. This mechanical vibration, if not within limits may caused damage to the materials, components or structure associated with it. Under some circumstances such as in transport, on machine floors, where the vibration is inevitable, the components associated have to withstand these vibration. If such vibrations can be artificially generated on the components,
their stability reliability etc., at the end of the test can be studied. One such device to generate artificial vibration is called ‘VIBRATION EXCITER’

DESCRIPTION

Vibration exciter is an electrodynamics type of device. It consists of a powerful magnet placed central surrounding which is suspended the exciter coil. This assembly is enclosed by a high permeability magnetic circuit for optimum performance and enough design care has been observed to the leakage magnetic flux at the top of the Vibration table.

When an electrical current is passed through the Exciter coil a magnetic field is created around the coil, these field interacts with the field due to the central permanent magnet and this results in the upward or downward movement of the suspended coil depending upon the direction of current flow in the coil. If an alternating current is injected in the coil, it moves up and down continuously. Thus controlling the frequency of the coil current, the frequency of vibration is controlled. By controlling the amount of current, the amplitude of vibration is controlled.

POWER AMPLIFIER is the control unit for the Exciter. This unit consists of a tunable sine wave oscillator, a power amplifier to inject current in to exciter coil and protection circuits.

The Power amplifier uses all silicon transistors for stable and trouble free operation. Adequate heat sinking is provided for the power transistor to operate at a comfortable temperature even when the amplifier is delivering full power for an extend period of operation.

CONTROLS FOR SOLID STATE POWER AMPLIFIER & OSCILLATOR.

POWER ON : DPDT Switch supplies 230 V AC Mains to instrument.

FREQUENCY : Single turn potentiometer is to fine adjust the Frequency 0 – 1000 Hz.

C /S : Analog meter is to observed frequency. Rang 0- 1000 Hz (Scale reading Multiply by 10)

POWER CHORD : 5 Amps 3 pin 3 core cable is to interconnect the 230 V Mains & Instrument.

FUSE : 2 Amps fuse protect the instrument from any short circuit orOver load.

CAUTION : DO NOT REMOVE THE FUSE CAP WHILE POWER CHORD IS CONNECTED TO 230 v A.C. MAINS.
VIBRATION SET UP:

AIM:
Study of acceleration by using Accelerometer and acceleration Indicator

APPARATUS REQUIRED:
Oscillator power amplifier, vibration exciter. Accelerometer Indicator in “G” type of vibration pick up- Accelerometer.

PROCEDURE
1) Connect power amplifier o/p to the vibration exciter.
2) Place the accelerometer pick up on the vibration exciter spindle.
3) Connect vibration pick up cable to the accelerometer sensor socket.

BLOCK DIAGRAM OF VIBRATION SET UP

- Accelerometer Sensor
- Power Amplifier
- Vibration Exciter
- Accelerometer Indicator

<table>
<thead>
<tr>
<th>SL NO</th>
<th>FREQUENCY in Hz</th>
<th>Acceleration “G”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
**BIFILAR SUSPENSION**

**Aim:** To determine the radius of gyration and the moment of Inertia of a given rectangular plate.

**Apparatus required:** Main frame, bifilar plate, weights, stopwatch, thread

**Formula used:**
- Time period $T = t/N$
- Natural frequency $f_n = 1/T$ hz
- Radius of gyration $k = (Tb/2\pi)\sqrt{(g/L)}$ (mm)
  
  Where, $b =$ distance of string from centre of gravity, $T =$ time period
  
  $L =$ length of the string, $N =$ number of oscillations
  
  $t =$ time taken for $N$ oscillations

**Procedure:**
1. Select the bifilar plate
2. With the help of chuck tighten the string at the top.
3. Adjust the length of string to desired value.
4. Give a small horizontal displacement about vertical axis.
5. Start the stopwatch and note down the time required for ‘$N$’ oscillation.
6. Repeat the experiment by adding weights and also by changing the length of the strings.
7. Do the model calculation

**Graph:**
A graph is plotted between weights added and radius of gyration

**Calculations:**

**Result:**

**Observation:**
- Type of suspension = bifilar suspension
- Number of oscillation $n = 10$
- $b = 10.15$ cm $d = 4.5$ cm $b_1 = 21.5$ cm

**Tabulation:**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Weight added m (kg)</th>
<th>Length of string L (m)</th>
<th>Time taken for N osc. T sec</th>
<th>Natural frequency fn (Hz)</th>
<th>Radius of gyration k (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
TRIFILAR SUSPENSION

Aim: To determine the radius of gyration of the circular plate and hence its Mass Moment of Inertia.

Apparatus required: Main frame, chucks 6 mm diameter, circular plate, strings, stop watch.

Procedure:
1. Hang the plate from chucks with 3 strings of equal lengths at equal angular intervals (120° each)
2. Give the plate a small twist about its polar axis
3. Measure the time taken, for 5 or 10 oscillations.
4. Repeat the experiment by changing the lengths of strings and adding weights.

Formulae used:
Time period, \( T = \frac{t}{N} \), Natural frequency, \( f_n = \frac{1}{T} \text{ Hz} \)
Radius of gyration, \( K = \left( \frac{bT}{2\pi} \right) \sqrt{(g/l)} \text{ m.} \)
Where \( b \)-distance of a string from center of gravity of the plate,
\( l \)- Length of string from chuck to plate surface.
Moment of inertia of the plate only, \( I_p = \left( \frac{R^2 \times W_1}{4\pi^2 f_n^2 \times l} \right) \)
Moment of inertia with weight added, \( I_t = \frac{R^2 \times (W_1 + W)}{4\pi^2 f_n^2 \times l} \)
Where, \( R \)- Radius of the circular plate and \( W_1 \)-Weight of the circular plate = \( m_1 \)g in N \( m_1 = 3.5 \text{ kg} \)
\( W \)- Weight of the added masses = \( mg \) in N
Moment of inertia of weight, \( I_w = I_t - I_p \)

Result: The radius of gyration of the plate and moment of inertia of the weights were determined and tabulated.

Graphs:
- Weight added vs radius of gyration
- Weight added vs moment of inertia

Observations:
Type of suspension:...................., No. of oscillations ....................
Radius of circular plate, \( R = \ldots \text{m} \), mass of the plate, \( m_1 = \ldots \text{kg} \)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Length of string, ( l, \text{ m} )</th>
<th>Added mass, ( m, \text{ kg} )</th>
<th>Time for ( N ) oscillations, ( t, \text{ sec} )</th>
<th>Time period, ( T, \text{ sec} )</th>
<th>Radius of gyration, ( k, \text{ m} )</th>
<th>Natural frequency, ( f_n, \text{ Hz} )</th>
<th>Moment of inertia of weight, ( I_w, \text{ kgm} )</th>
</tr>
</thead>
<tbody>
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</table>