Enrolment No.

Mechanical Vibrations

LABORATORY MANUAL

B.E. SEM.VII

MECHANICAL ENGINEERING DEPARTMENT
INDUS INSTITUTE OF TECHNOLOGY & ENGINEERING
AHMEDABAD

CERTIFICATE

This is to certify that

Mr./Ms./Mrs.____

Enrolment No.____ of Class _____________________

(Divison :-___________________) has satisfactory completed the laboratory work of the

subject ____ at Indus Institute

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Date of Submission: ____________________

Concern Faculty: _______________________

Head of Department: ____________________

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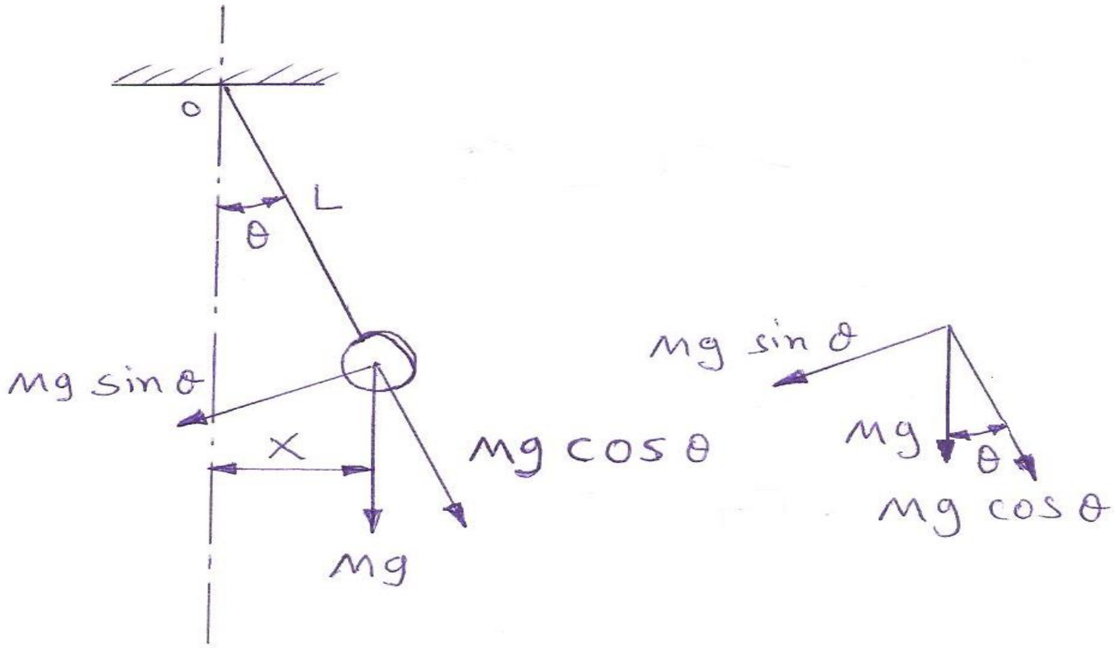
* INSTRUCTIONS *

- ✓ This laboratory manual is issued once only. This is your responsibility to preserve it in good condition up to Term work submission & Oral examination.
- ✓ Your writing should be neat and clean.
- ✓ Get checked your manual at the end of the performance of each practical.
- ✓ Practical & Tutorials that cannot be read or are not presented in a professional engineering style will not receive credit (Higher Grades).
- ✓ You have to bring every time you attend the laboratory.

EXPERIMENT NO:- 1

AIM: To study the natural frequency of Simple Pendulum. Also compare the experimental result with practical results.



OBJECTIVES:

1. To find periodic time theoretically.
2. To study and find periodic time experimentally.
3. To draw the graph of frequency versus length of string.

APPARATUS:

One string, Bob, Stop Watch.

ASSUMPTION:

- The String does not have mass.
- Air friction is neglected.
- The vibration of system is completely simple harmonic.
- The mass of bob is concentrate at geometric center.
- The displacement angle is small.

DERIVATION:

Consider bob of connected mass (*m*) is suspended at the end of string or road of negligible mass for small deflection.

$$J\frac{d^2\theta}{dt^2} = -mgX = -mgL\sin\theta \qquad (1)$$

where *m* is mass of bob, *J* is Moment of Inertia of bob about hinge point, *L* is length of string (from hinge point to center of gravity of bob).

$$mL^2\frac{d^2\theta}{dt^2} + mgL\sin\theta = 0 \qquad \therefore (J = mL^2)$$

$$L\frac{d^2\theta}{dt^2} + g\theta = 0$$

For, smaller angular displacement, $\sin\theta \approx \theta$, hence

$$f_n = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \qquad (2)$$

PROCEDURE:

- Measure the length of string.
- Knot the string with bob & knot the end of string with horizontal bar.
- Keep steady the system.
- Now simply vibrate the system.
- Note the time for 10 oscillations

GIVEN DATA: -

OBSERVATION TABLE:

Sr. No.	Mass of Bob *m* (Kg)	Length of Suspension *L* (m)	Time for 10 oscillations (Average of three observations) (s)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

CALCULATIONS:

$$Error = E = \frac{\left(f_{n(T)} - f_{n(P)} \right)}{f_{n(T)}}$$

RESULT TABLE:

Sr. No.	Length *L* (m)	$f_{n(P)}$ (Practical) (Hz)	$f_{n(T)}$ (Theoretical) (Hz)	Error *E* (%)
1.				
2.				
3.				
4.				
5.				
6.				

GRAPH :

Plot a graph of frequency (f_n) Vs Length of string

CONCLUSION:

REMEDIES:

QUESTIONS:

1. What is simple pendulum? State the application.
2. Define period of oscillation state the parameters on which it depends.
3. What is restoring force in simple pendulum?
4. What are the limitations so that the string cannot be replaced by spring?

Date:-		Sign:-		Grade:-	

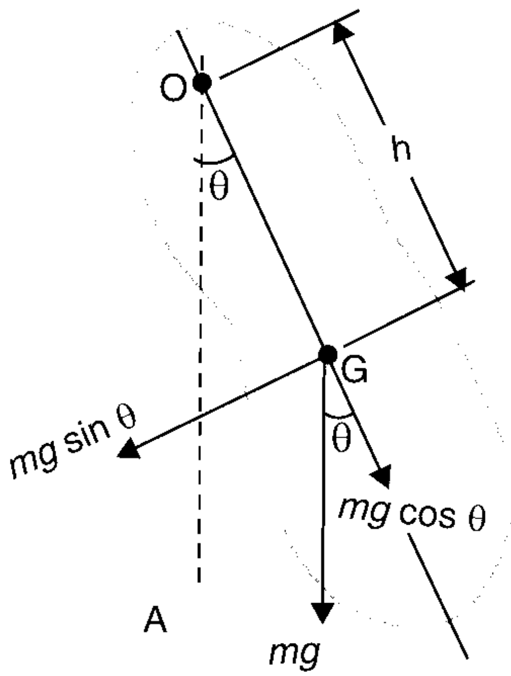
EXPERIMENT NO :- 2

AIM: To study compound pendulum system and calculate radius of gyration of unsymmetrical rod.

APPARTUS: String, weight, stop watch, scale.

ASSUMPTIONS:

- Neglect air resistance and string mass.
- Pendulum oscillates in single plane.



Compound Pendulum

PROCEDURE:

- Take the rotating mass.
- Measure the length of the same.
- Find C.O.G. of mass.
- Hang it without any external mass on fixed point.
- Give little oscillation to the mass.
- Take the readings.

DERIVATION:

$(f_u)_{pr} = \frac{\text{oscaillations}}{\text{tpr}}$

$K_{th} = \frac{1}{2\sqrt{3}}$

$(f_u)_{th} = \frac{1}{2\pi}\sqrt{\frac{gl}{L^2 + K^2}}$

GIVEN DATA:-

OBSERVATION TABLE:

Sr. No.	Mass of *m* (Kg)	Length of Suspension *L* (m)	Time for 10 oscillations (Average of three observations) (s)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

CALCULATIONS:

$$Error = E = \frac{\left(f_{n(T)} - f_{n(P)}\right)}{f_{n(T)}}$$

RESULT TABLE:

Sr. No.	Length of suspension of rod *L* (m)	$f_{n(P)}$ (Practical) (Hz)	$f_{n(T)}$ (Theoretical) (Hz)	Error *E* (%)
1.				

2.				
3.				
4.				
5.				
6.				

GRAPH :

Plot a graph of frequency (f_n) Vs Length of suspension

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO: - 3

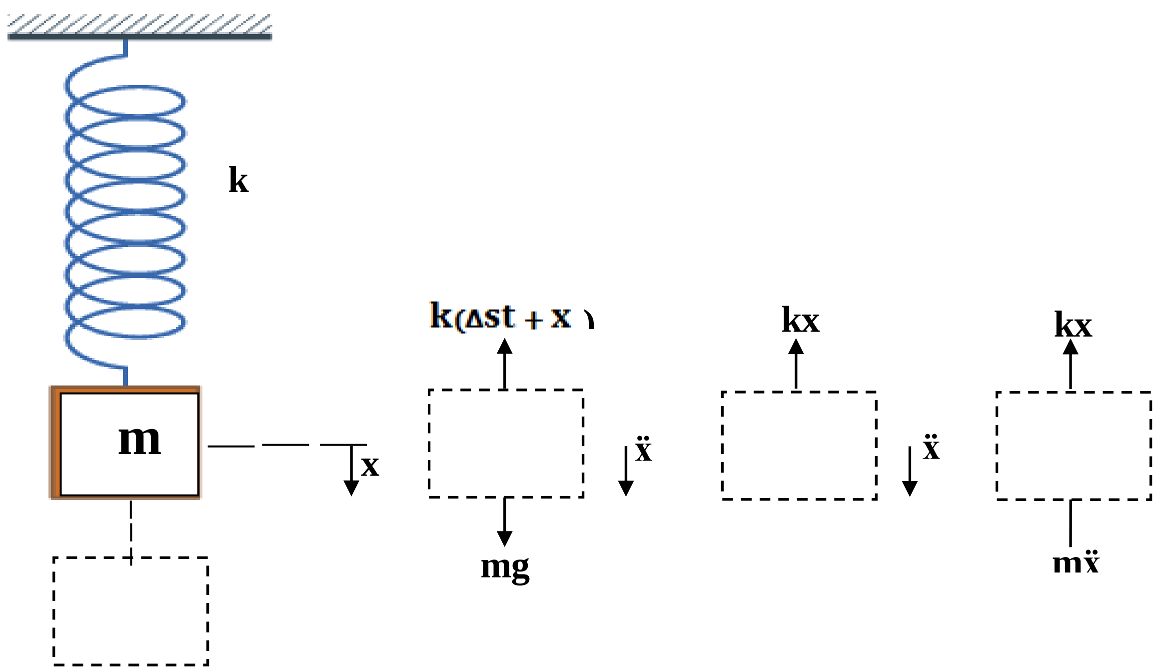
AIM: To study the natural frequency of spring-mass system.

APPARATUS:

One spring, mass, stop watch, stand.

ASSUMPTION:

- Air friction is neglected.
- The vibration of system is completely simple harmonic.
- The mass is of uniform density.
- The displacement value is small.
- The oscillations of system are in single plane.



DERIVATION :

m =value of mass

x = displacement of mass and spring

K = stiffness of spring

Δ =static deflection when mass is hanged to spring

Consider a mass M is suspended at the end of spring for small deflection.

$$(m\ddot{x}) = \sum (External\ forces)$$

$$+m\ddot{x} = +mg - K(x + \Delta)$$

$$m\ddot{x} = mg - Kx - K\Delta$$

$$But \ldots mg = K\Delta$$

$$\therefore m\ddot{x} = -Kx$$

$$\ddot{x} + \frac{K}{m} x = 0$$

$$comparing \quad with \quad \ddot{x} + \omega 2x = 0 \ we\ get$$

$$\omega = \sqrt{\frac{K}{m}}$$

$$\therefore f = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

PROCEDURE:

- Measure the value of mass.
- Suspend the assembly of spring and mass as shown in figure on stand.
- Keep steady the system.
- Now simply vibrate the system.
- Note the time for 10 oscillations

GIVEN DATA:-

OBSERVATION TABLE:

Sr. No.	Mass (Kg)	Length of Suspension *L* (m)	Time for 10 oscillations (Average of three observations) (s)
1.			
2.			
3.			
4.			
5.			
6.			

CALCULATIONS:

$$Error = E = \frac{\left(f_{n(T)} - f_{n(P)}\right)}{f_{n(T)}}$$

RESULT TABLE:

Sr. No.	Length *L* (m)	$f_{n(P)}$ (Practical) (Hz)	$f_{n(T)}$ (Theoretical) (Hz)	Error *E* (%)
1.				
2.				
3.				
4.				
5.				
6.				

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO :-4

AIM: To study about natural frequency of lateral vibration system.

APPARATUS: Rod, Masses, Stopwatch, Measuring Tape.

ASSUMPTIONS:

- Air friction is neglected.
- The vibration of system is completely simple harmonic.
- The mass is of uniform density.
- The displacement value is small.
- The oscillations of system are in single plane.

FREE BODY DIAGRAM:

DERIVATION:

According to D Alembert's principle,

$\sum$[Inertia force + External forces] = 0

$$\therefore m\ddot{x} + Kx = 0$$

$$\therefore \ddot{x} + \frac{K}{m}x = 0$$

Comparing equation with fundamental equation of simple harmonic motion, we get,

$$\omega_n{}^2 = \frac{K}{m} \qquad \textbf{OR} \qquad \omega_n = \sqrt{K/m}\text{, rad/s}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{m}}, \text{ Hz} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

At equilibrium position mg = Kδ

$$\text{So } \frac{K}{m} = \frac{g}{\delta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Substituting the equation (2) in equation (1), we get,

$$f_n = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}}, \text{ Hz}$$

PROCEDURE:

1. Measure the length of bar.
2. Attach the mass at the end of the rod.
3. Keep steady the system and note down the value of δ.
4. Now vibrate the system.
5. Note the time for oscillation.

GIVEN DATA:-

OBSERVATION TABLE:

Sr. No	Length of rod in suspension (m)	Time for 10 oscillation (sec)			Average *T*(sec)
		T_1	T_2	T_3	
1.					
2.					
3.					
4.					
5.					

CALCULATION:

δ=deflection of bar.

m= mass attached at end of bar.

$$f_{n(prac)} = \frac{10}{time \quad for \quad 10 \quad oscilation}$$

ERROR % = $\frac{f_n(th) - f_n(pr)}{f_n(th)} * 100$

RESULT TABLE:

Sr. No.	**Length *L* (m)**	$f_{n(P)}$ **(Practical) (Hz)**	$f_{n(T)}$ **(Theoretical) (Hz)**	**Error *E* (%)**
1				
2				
3				

CONCLUSION:

REMEDIES:

QUESTIONS:-

Date:-		Sign:-		Grade:-	

EXPERIMENT NO: - 5

AIM: To study about torsional vibration system

APPARATUS: round disc, shaft, measuring tape, stop watch

ASSUMPTION:

- Neglect air resistance.
- Neglect rod weight.
- Oscillation in single plane.
- Neglect the thickness of rod.

SKETCH :-

DERIVATION:

- I= mass moment of inertia
- K_t = torsional stiffness
- θ = angular displacement $I\ddot{\theta} = -K_t\theta$ (restoring torque)

$I\ddot{\theta} + K_t\theta = 0$

$\ddot{\theta} + \frac{k_t}{I}\theta = 0$

Putting, $w_n^2 = \frac{k_t}{I}$

The equation becomes, $w_n = \sqrt{\frac{k_t}{I}}$

PROCEDURE:

- First of all measure the diameter of the rod and the disc.
- Then oscillate the disc.
- Measure the time required for 10 oscillations with the help of stop watch.
- Now find out the average time required for the oscillations.
- Finally calculate the practical frequency and then compare it with theoretical frequency.

GIVEN DATA:-

OBSERVATION TABLE:

Sr. No.	Mass (Kg)	Length of Suspension *L* (m)	Time for 10 oscillations (Average of three observations) (s)
1.			
2.			
3.			
4.			
5.			
6.			

CALCULATIONS:

$$f_{th} = \frac{1}{2\pi}\sqrt{\frac{K_t}{I_p}} \text{ Hz}$$

$$K_t = \frac{G\,J}{L}$$

$$K_t = \frac{G*\pi*d^4}{32*L}$$

$$I_p = \frac{m*D^2}{8}\ \frac{kg}{m^2}$$

$$Error = E = \frac{\left(f_{n(T)} - f_{n(P)}\right)}{f_{n(T)}}$$

RESULT TABLE:

Sr. No.	**Length *L* (m)**	$f_{n(P)}$ **(Practical) (Hz)**	$f_{n(T)}$ **(Theoretical) (Hz)**	**Error *E* (%)**
1.				
2.				
3.				
4.				
5.				
6.				

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT No.:- 6

AIM: To study about free (torsional) damped vibration system.

APPARATUS: M. S. rod, Disc, Stopwatch, Drum, Measure taps.

ASSUMPTION:

- The straightness of rod.
- Oscillation in one plane.
- Neglect mass of rod.
- Neglect air resistance.
- Neglect viscosity of fluid.
- Gravitational force acting on centre of the disc

SKETCH:

DERIVATION:

PROCEDURE:

- Measure the length of string.
- Oil fill in the drum.
- After give the initial twist at small angle to the circular disc.
- Measure the depth of immersion.
- Note the time for 5 oscillations of disc.

GIVEN DATA:-

OBSERVATION TABLE:

	T_1	T_2	T_3	T_4	T_5	T_{avg}
Θ_1						
Θ_2						

CALCULATION:

GRAPH:
Length → Depth of immersion

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

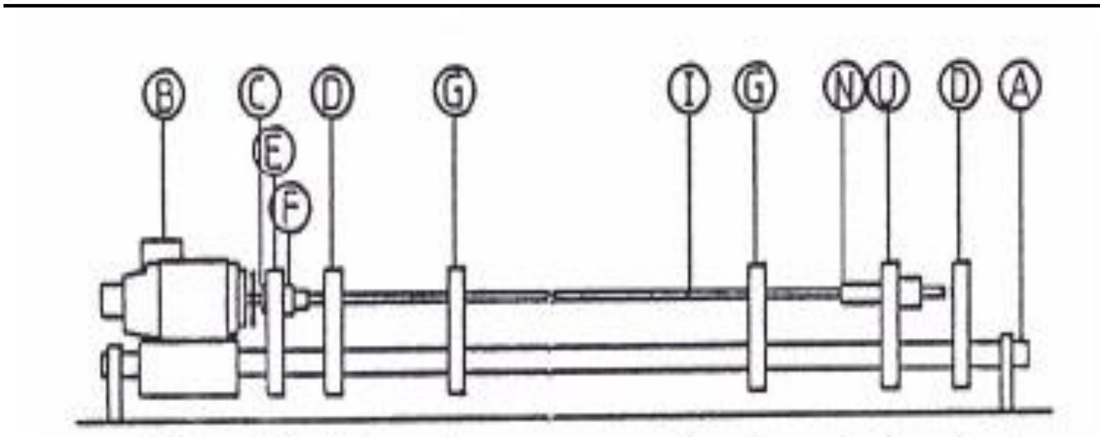
EXPERIMENT NO. - 7

AIM: To study the whirling speed of the shaft.

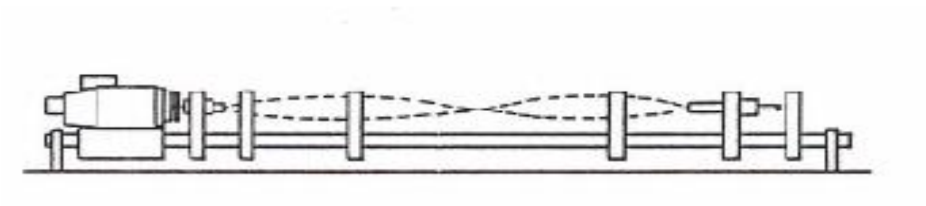
APPARTUS: AC/DC driving motor, speed controller, the caurds, shaft, Tachometer & ruler.

ASSUMPTIONS:

- Assume that shaft being of negligible weight.
- Assume that shaft has uniform cross section area.
- Neglect the air resistance.



First mode whirl.



Second mode whirl

PRCEDURE:

1. Choose the required size of the shaft.
2. Mount the two fixing ends on the frame to obtain the desired condition.
3. The shaft is fixed between two ends.
4. The motor is started.
5. Motor speed is increased slowly.
6. The amplitude of vibrations in lateral direction starts and mode shape is observed.
7. The speed is noted down so also the mode shape and mode point.
8. To observe second mode shape the speed is increased further.
9. The speed and the mode shape is noted down.
10. The procedure is followed for different shafts and different end conditions.

OBSERVATION TABLE:

Sr. No.	Speed(rpm)	Amplitude	Length of shaft

CALCULATION:

$\delta \propto \frac{PL^3}{EI}$

$\omega = \sqrt{\frac{g}{\delta}}$

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

$$m\omega^2 r = m\omega^2 c = magnitude$$

RESULT TABLE:

Sr. No.	Theoretical frequency	Practical frequency	Error (%)

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO: - 8

AIM: TO STUDY THE FORCE DAMPED VIBRATION SYSTEM.

APPRATUS: Cantilever beam, spring, motor, tachometer, recorder, damper.

ASSUMPTIONS:

1) System is one degree of freedom.
2) Resistance offered by the air to the vibration system is negligible.
3) System foundation is totally rigid.
4) Material of spring is homogenous & isentropic.

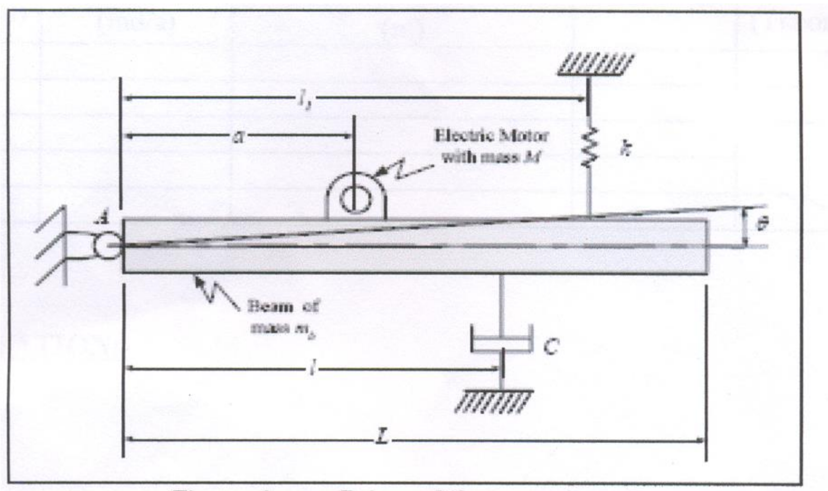


Figure 1. Setup of the experiment

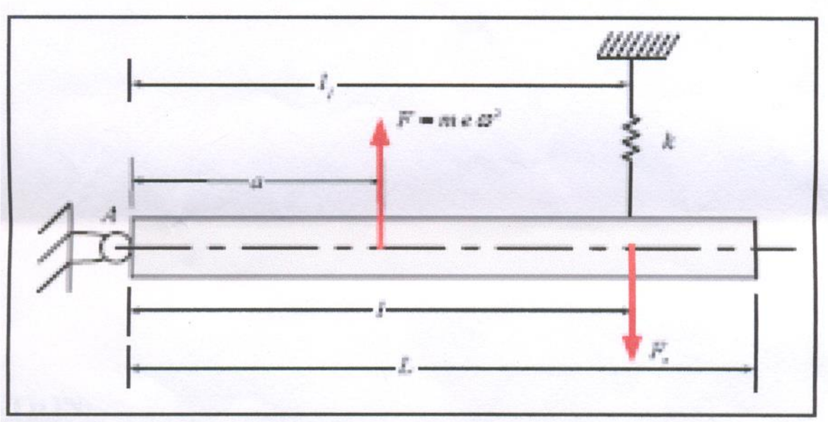


Figure 2.

THEORY:

M=Mass of the system.

m_0=Rotating unbalance mass.

e=Eccentricity of unbalanced mass.

$$F = me\omega^2$$

The cantilever beam subjected to the force at the free end, exerted by the unbalanced rotating mass. For static deflection

$$\delta = \int_0^1 \frac{\partial}{\partial P}\left[\frac{M^2 dx}{2EI}\right]$$

$$= \int_0^1 \frac{2M}{2EI}\frac{\partial M}{\partial P}dx$$

$$= \frac{1}{EI}\int_0^1 F_x x \quad dx$$

$$= \frac{F}{EI}\left[\frac{x^3}{3}\right]_0^1$$

$$\delta = \frac{Fl^3}{3EI}$$

$$\omega_n = \sqrt{\frac{g}{\delta}}$$

$$\therefore \omega_n = \sqrt{\frac{K}{M}} \Rightarrow K = m\omega^2$$

The governing equation of force vibration system subjected to force due to unbalance rotating mass is given as below.

$$M\frac{d^2x}{dt^2} + c\frac{dx}{dt} + Kx = m_o e\omega^2 \sin\omega t$$

And solution of this equation is given by

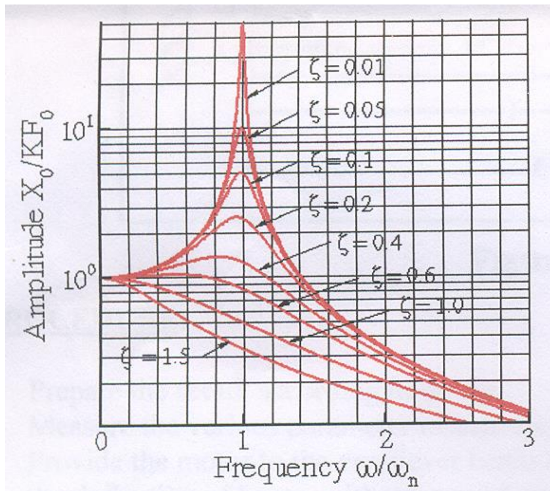
$$x = \frac{m_o e\omega^2 / K}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

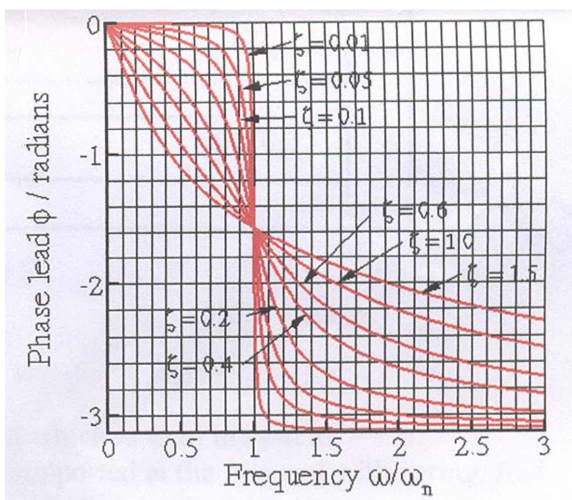
But,

$m_0 e\omega^2 / K$

$$\therefore \frac{x}{\delta} = \frac{1}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

The above term is also called as magnification factor.





By plotting the graph using the experiment observation of magnification factor v_s frequency ratio for different of damping factor get the resonance frequency practically. And verify that resonance frequency of the system is nearly natural frequency of system.

PROCEDURE:

1. Prepare the set up according to the fig.
2. Measure the various parameter of instrument which is used in system.
3. Provide the motor to the cantilever beam & supported at the free end with spring, find the deflection of beam, without providing the damper.
4. Using state deflection find the natural frequency.
5. Provide the force excitation using motor for a constant speed take the amplitude reading for different damping factor. Vary the damping factor using adjustable screw provided over the damper.
6. Take the reading for different speed & drew the graph of magnification factor v/s frequency ratio.

CONCLUSION:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO: - 9

AIM:- To study frequency of simple pendulum with considering mass of rod

APPARATUS:

1. A steel bar having no. of holes along its length
2. Steel rule
3. Stopwatch
4. Stand

ASSUMPTION:

- Air friction is neglected.
- The vibration of system is completely simple harmonic.
- Resistance at hinge neglected.
- The displacement angle is small.
- Motion is only oscillator

SKETCH:

DERIVATION:

L = length of steel bar

M = mass of pendulum

X = Amplitude

θ = Angle of deflection

J = polar moment of inertia of pendulum

d=distance from pivot to the centre of mass of pendulum

Consider a rigid steel bar of mass M which is hinge supported by the knife-edge of the stand at the hole nearest to one end of the bar.

$$I\,\ddot{\theta} = -M\,g\,d\,\sin\theta.$$

$$I\,\ddot{\theta} = -M\,g\,d\,\theta.$$

$$\omega = \sqrt{\frac{M\,g\,d}{I}}.$$

$$\omega_n \sqrt{\frac{Mgd}{M\,(k^2+l^2)}}$$

$$\omega_n = \sqrt{\frac{gd}{(k^2+l^2)}}$$

$$f_n = \frac{1}{2\Pi}\sqrt{\frac{gd}{(k^2+l^2)}}$$

PROCEDURE:

- Measure the length of the bar.
- Support the pendulum on the knife-edge at the hole nearest to one end of the bar.
- Keep steady the system.
- Now simply vibrate the system.
- Note the time for 10 oscillations

GIVEN DATA:

OBSERVATION TABLE:

Sr. No.	Length of suspension *h* (m)	Time for 10 oscillation (sec)			Average T(sec)
		T_1	T_2	T_3	
1.					
2.					
3.					
4.					

CALCULATION:

$$\omega^2 = \frac{gh}{(k^2 + l^2)}$$

RESULT TABLE:

Sr. No.	Length (m)	Mass (Kg)	f_n (practical) Hz	f_n (theoretical) Hz
1.				
2.				
3.				
4.				

GRAPH:

Plot a graph of frequency (f_n) Vs Length.

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO:- 10

AIM: To study about the frequency of the roller in the circular surface.

APPARTUS:

- Hollow circular cross section body,
- Stop watch, Scale, String,
- Circular rod of different material.

ASSUMPTIONS:

- No slip,
- Mass concentrated at the centre,
- Axis of roller in same plane as the axis of cylinder,
- Simple harmonic motion,
- Neglect air resistance,

SKETCH:

PROCEDURE:

1. First of all assure that the hollow cylinder cross section body which we use is completely half circle means radius of any point from the
2. Centre point is same.
3. Then roll the roller on the hollow cylinder with different material of
4. Roller.
5. Measure the time for different oscillation and different angle of
6. Rotation.
7. Then find the average time and find theoretical and practical
8. Frequency and error from equation.

GIVEN DATA:-

OBSERVATION TABLE:

Sr. No.	Material of the roller	Radius of Roller *r* (m)	Time (s)				Frequencies (Hz)
			T1	T2	T3	T_{avg}	
1.	Wooden						
2.	Aluminum						
3.							

CALCULATION:

P.E=mg(R-r)(1-cosθ)

K.E=½m$(R-r)^2\dot{\theta}^2$+¼m$r^2\left(\frac{R}{r}-1\right)^2\dot{\theta}^2$

Total energy method = P.E+ K.E

Differentiate this equation =

$2\cdot {}^{3}/_{4}m(R-r)^2\dot{\theta}\ddot{\theta}$+mg(R-r) sin$\theta\dot{\theta}$ =0

${}^{3}/_{2}(R-r)\ddot{\theta}+g\theta=0$

$\omega=\sqrt{\frac{2g}{3(R-r)}}\ \ {rad}/_{sec}$

$\mathcal{F}th=\frac{2\pi}{\omega}$

$\mathcal{F}pre=\frac{\text{Oscillation}}{T\ avg}$

RESULT TABLE:

Sr. No.	Material of the roller	Radius of Roller *r* (m)	$f_{n(P)}$ (Practical) (Hz)	$f_{n(T)}$ (Theoretical) (Hz)	Error *E* (%)
1.					
2.					

3.					
4.					

CONCLUSION:

REMEDIES:

QUESTIONS:

Date:-		Sign:-		Grade:-	

EXPERIMENT NO.:- 11

AIM: - To study frequency of U-tube filled with liquid.

APPARTUS: U-tube manometer, string, tape, stopwatch.

ASSUMPTION:

- Neglect air resistance.
- Human error.
- Ideal form of liquid.
- Viscosity of liquid.

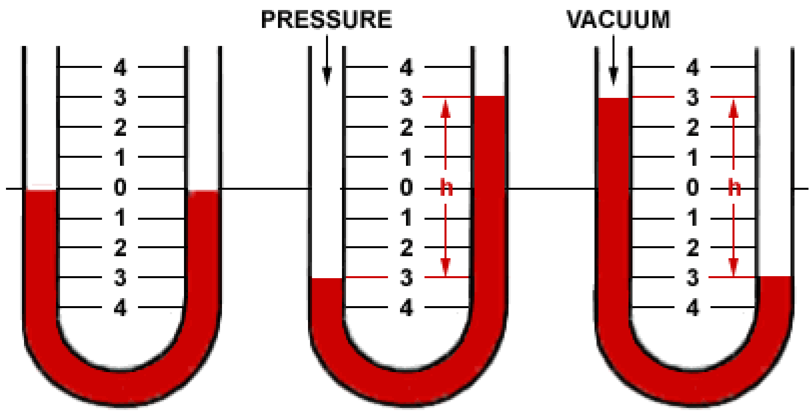


Fig. 2-1 Fig. 2-2 Fig. 2-3

DERIVATION: -

L = length of the fluid in manometer
x = distance of displacement
h = x + x = 2*x
ρ = density of fluid
A = cross-sectional area of the tube
m = mass of the fluid = ρ*A* L
m_1 = mass of displaced fluid = ρ*A*(2x)
F = m_1*g
By using Equilibrium method,
Inertia force + External force = 0

$$m\ddot{x} + F = 0$$

$$m\ddot{x} + m_1 g = 0$$

$$\rho AL\ddot{x} + \rho A(2x)g = 0$$

$$\ddot{x} + \left(\frac{2g}{L}\right)x = 0$$

By comparing equation with equation of simple harmonic motion,
We get,

$$\omega_n^{\ 2} = \frac{2g}{L}$$

$\omega_n = \sqrt{2g/L}$, rad/s

$(f_n)_{TH} = \frac{1}{2\pi}\sqrt{\frac{2g}{L}}$, Hz

$(f_n)_{PR} = oscillation/t_{avg}$, Hz

PROCEDURE: -

- Keep steady the system
- Measure length of steady fluid in manometer
- Now simply vibrate the system
- Note the time for oscillations

GIVEN DATA: -

OBSERVATION TABLE: -

L	Oscillation	t_1	t_2	t_3	t_4	t_5	t_{avg}

CALCULATION: -

RESULT TABLE: -

Sr. No.	Length (m)	Mass (Kg)	f_n (practical) Hz	f_n (theoretical) Hz
1.				
2.				
3.				

4.				

CONCLUSION: -

REMENDIES: -

QUESTIONS:

Date:-		Sign:-		Grade:-	