

ME6511– DYNAMICS LABORATORY

LIST OF EXPERIMENTS

1. Free Transverse Vibration – I – Determination of Natural Frequency
2. Cam Analysis – Cam Profile and Jump-speed Characteristics
3. Free Transverse Vibration – II – Determination of Natural Frequency
4. Free Vibration of Spring Mass System – Determination of Natural Frequency
5. Compound Pendulum – Determination of Radius of Gyration and Moment of Inertia
6. Bifilar Suspension – Determination of Radius of Gyration and Moment of Inertia
7. Trifilar Suspension – Determination of Radius of Gyration and Moment of Inertia
8. Whirling of Shaft – Determination of Critical Speed
9. Balancing of Rotating Masses
10. Determination of Gyroscopic Couple
11. Turn Table
12. Hartnell Governor
13. Free Vibration of Spring Mass System – Determination of Natural Frequency

Beyond the Syllabus

14. Speed Ratio of Epi-cyclic Gear Train
15. Speed Ratio of Worm and Worm Wheel

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 millivolts. Reading of the digital indicator will be in mm.

Formulae used:

1. Natural frequency = $1/2\pi\sqrt{g/\delta}$ Hz

Where g = acceleration due to gravity in m/s^2 and δ = deflection in m.

2. Theoretical deflection

$$\delta = WL^3/3EI$$

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 = W/δ N-mm and

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

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

Tabulation:

Sl. No.	Applied mass m (kg)	Deflection δ (mm)	Theoretical deflection δ_T (mm)	Experimental Stiffness k (N/mm)	Theoretical Stiffness k (N/mm)	Natural frequency f_n (Hz)

Result:

The natural frequency of transverse vibration of the cantilever beam were determined and tabulated.

EX NO:2

CAM ANALYSIS

Aim:

To study the profile of given can 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 and Dial gauge

Description:

A cam is a machine element such as a cylinder or any other solid with a 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 motion to the follower. All cam mechanisms are composed of at least three links viz: 1. Cam, 2. Follower and 3. Frame which guides follower and cam.

Specification :

Diameter of base circle = 150mm, Lift = 18mm, Diameter of cam shaft = 25mm

Diameter of follower shaft = 20 mm, Diameter of roller = 32mm, Dwell period = 180

Type of follower motion = SHM (during ascent & descent)

Procedure:

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

1. Set the cam at 0° and note down the projected length of the pull rod
2. Rotate the cam through 10° and note down the projected length of the pull rod above the guide
3. Calculate the lift by subtracting each reading with the initial reading.

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.

Graph:

Displacement diagram and also the cam profile is drawn using a polar graph chart.

The Force Vs Jump-speed curve is drawn.

Tabulation:

	1. Cam profile			2. Jump-speed.	
Sl. No.	Angle of rotation (degrees)	Lift in mm	Lift + base circle radius (mm)	Load on the Follower, F (N)	Jump-speed N (RPM)

Result:

EX NO:3

TRANSVERSE VIBRATIONS - II

Aim: To study the transverse vibrations of a simply supported beam subjected to central or offset concentrated load or uniformly distributed load.

Apparatus Required: Trunnion bearings, beams, weights.

Set-up:

Procedure:

1. Fix the beam into the slots of trunnion bearings and tighten.
2. Add the concentrated load centrally or offset, or uniformly distributed.
3. Determine the deflection of the beam for various weights added.

Formulae used:

Deflection at the center, $\delta_T = Wl^3/48EI$ for central concentrated load.

Deflection at the load point, $\delta_T = Wa^2b^2/3EI$ for offset concentrated load.

Deflection at the center, $\delta_T = 5wl^4/384EI$ for uniformly distributed load.

$I = bd^3/12$; b = width of the beam, d = depth of the beam, l = length of the beam.

Natural frequency of transverse vibrations, $f_n = 1/2\pi\sqrt{(g/\delta)}$ Hz

where g = acceleration due to gravity in m/s^2 and δ = deflection in m.

Observations: $b =$, $d =$, $l =$, $E =$

Tabular column:

Sl. No.	Mass added m , kg	Experimental Deflection δ , m	Theoretical Deflection δ_T , m	Theoretical Nat. freq. f_n , Hz	Experimental Stiffness K , N/m	Theoretical Stiffness K , N/m

Graphs:

1. Deflection Vs. load (N) from this get stiffness (graph)
2. Deflection Vs. Natural frequency
3. Load in N Vs. natural frequency

Stiffness experimental, $K = \text{load/deflection} = W/\delta = mg/\delta$ N/mm

Stiffness theoretical, $K = W/\delta_T = 48EI/l^3$ for center load,

$= 3EI/a^2b^2$ for offset load,

$= 384EI/5l^3$ for uniformly distributed load,

Diagrams: Simply Supported beam with the given load and parameter.

Result:

EX NO:4

FREE VIBRATION OF SPRING-MASS SYSTEM

Aim: To calculate the undamped natural frequency of a spring mass system

Apparatus required: Weights, Thread, Ruler, Stopwatch

Description:

The setup is designed to study the free or forced vibration of a spring mass system either damped or undamped condition. It consists of a mild steel flat firmly fixed at one end through a trunnion and in the other end suspended by a helical spring, the trunnion has got its bearings fixed to a side member of the frame and allows the pivotal motion of the flat and hence the vertical motion of a mass which can be mounted at any position along the longitudinal axes of the flat. The mass unit is also called the exciter, and its unbalanced mass can create an excitational force during the study of forced vibration experiment. The experiment consists of two freely rotating unbalanced discs. The magnitude of the mass of the exciter can be varied by adding extra weight, which can be screwed at the end of the exciter.

Formula used

Stiffness, $k = \text{load/deflection N/m}$

Experimental natural frequency, $f_{n(\text{exp})} = 1/t \text{ Hz}$

Theoretical natural frequency, $f_{n(\text{the})} = 1/2\pi\sqrt{(g/\delta)} \text{ Hz}$

Procedure

Determination of spring stiffness

1. Fix the top bracket at the side of the scale and Insert one end of the spring on the hook.
2. At the bottom of the spring fix the other plat form
3. Note down the reading corresponding to the plat form
4. Add the weight and observe the change in deflection
5. With this determine spring stiffness

Determination of natural frequency

1. Add the weight and make the spring to oscillate for 10 times
2. Note the corresponding time taken for 10 oscillations and calculate time period
3. From the time period calculate experimental natural frequency

Calculation:

Graph:

Load vs Deflection

Load vs Theoretical natural frequency

Load vs Experimental natural frequency

Tabulation:

Sl no	Weight added m (kg)	Deflection δ (mm)	Stiffness k (N/m)	Time for 10 oscillation t (sec)	Time period T (sec)	Experimental natural frequency, $f_{n(\text{exp})}$, Hz	Theoretical natural frequency $f_{n(\text{the})}$, Hz

Result:

EX NO:5**COMPOUND PENDULUM**

Aim: To determine the radius of gyration and mass moment of inertia of the given rectangular rod experimentally.

Apparatus required: 1. Vertical frame, 2. Rectangular rod, 3. Stop watch and 4. Steel rule etc

Procedure:

1. Suspend the rod through any one of the holes
2. Give a small angular displacement to the rod & note the time taken for 5 oscillations
3. Repeat the step by suspending through all the holes.

Formulae used:

Time period $T = t/N$ sec and also Experimental time period $T = 2\pi\sqrt{((K^2+L_1^2)/gL_1)}$

Where $K =$ experimental radius of gyration and $K = \sqrt{((gL_1T^2/4\pi^2)-L_1^2)}$,

$L_1 =$ distance from point of suspension to centre of gravity of rod and $L =$ total length of the rod

Theoretical radius of gyration, $K_t = L/\sqrt{12} = 0.2886L$

Natural frequency $f_n = 1/T$ (Hz) and Moment of inertia $I_m = mk^2$ kg-m²

Result:**Tabulation:**

Sl. No.	Distance L_1 (m)	Time for 5 oscillations t (sec)	Time period T (sec)	Natural frequency f_n (Hz)	Experimental radius of gyration (K_{exp})

Calculation:**Result:**

EX NO:6

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 stop watch 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:

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:

Sl. No.	Weight added m (kg)	Length of string L (m)	Time taken for N osc. T sec	Natural frequency f_n (Hz)	Radius of gyration k (mm)

Result:

EX. NO. 7

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, $T = t/N$, Natural frequency, $f_n = 1/T$ Hz

Radius of gyration, $K = (bT/2J) \sqrt{(g/l)}$ 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, $I_p = (R^2 \times W_1) / (4\pi^2 f_n^2 \times l)$

Moment of inertia with weight added, $I_t = R^2 \times (W_1 + W) / 4\pi^2 f_n^2 \times l)$

Where, R- Radius of the circular plate and W_1 -Weight of the circular plate = m_1g in N $m_1 = 3.5$ kg

W- Weight of the added masses = mg in N

Moment of inertia of weight, $I_w = I_t - I_p$

Graphs:

Weight added vs radius of gyration

Weight added vs moment of inertia

Observations:

Type of suspension:....., No. of oscillations

Radius of circular plate, $R = \dots\dots m$, mass of the plate, $m_1 = \dots\dots kg$

Sl. No.	Length of string l, m	Added, mass, m, kg	Time for N oscillations, t, sec	Time period T, sec	Radius of gyration, k, m	Natural frequency f_n , Hz	Moment of inertia of weight I_w, kgm

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

EX NO: 8

WHIRLING OF SHAFT

Aim: To determine theoretically the critical speed of the given shaft with the given end conditions

Description:

The speed at which the shaft runs so that additional deflection of the shaft from the axis of rotation becomes infinite is known as critical speed.

Normally the centre of gravity of a loaded shaft will always displace from the axis of rotation although the amount of displacement may be very small. As a result of this displacement, the centre of gravity is subjected to a centripetal acceleration as soon as the Shaft begins to rotate. The inertia force acts radially outwards and bend the shaft. The bending of shaft not only depends upon the value of eccentricity, but also depends upon the speed at which the shaft rotates.

Formula used:

$$f_n = K\sqrt{(EgI/wl^4)} \text{ and } N = f_n \times 60$$

Where, f_n = natural frequency of vibration in Hz

g = acceleration due to gravity, (9.81m/s^2), E = modulus of elasticity of the shaft

I = moment of inertia of shaft in m^4 , w = weight /unit length in N/m

l = effective length of the shaft between supports in m. and N = speed of the shaft in RPM

K = constant (2.45)

Calculation:

1. Moment of inertia
2. Weight of solid shaft
3. Natural frequency
4. Critical speed

Result:

EX NO:9

BALANCING OF ROTATING MASSES

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

Apparatus required: rotor system, weights, steel rule, etc.

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.

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

Sl. No.	Planes of mass	Mass m, kg	Radius r, m	C.Force / ω^2 mr, kg-m	Distance from Ref. Plane l, m	Couple / ω^2 mrl, kg-m ²
1	A					
2	B					
3	C					
4	D					

Diagrams:

- 1 Plane of the masses
- 2 Angular position of the masses
- 3 Force polygon
- 4 Couple polygon

EX NO:10

DETERMINATION OF GYROSCOPIC COUPLE

Aim: To determine the active and reactive gyroscopic couples and compare them.

Apparatus required: Gyroscope, tachometer, or stroboscope, variable voltage transformer, rotating disc with a light reflecting sticker for stroboscope speed measurement

Procedure:

1. The disc is made to rotate at a constant speed at a specific time using variable voltage transformer.
2. The speed of the (N) disc is measured using a tachometer or a stroboscope.
3. A weight /mass is added on the extending platform attached to the disc.
4. This causes an active gyroscopic couple and the whole assembly (rotating disc, rotor and weight platform with weight) is standing to move in a perpendicular plane to that of plane of rotating of disc. This is called gyroscopic motion.
5. The time taken (t) to traverse a specific angular displacement ($\phi = 60^\circ$) is noted.

Formula used:

Mass moment of inertia of the disc, $I = md^2 / 8$, kg-m^2 , m-mass of the disc and d-dia of the disc.

Angular velocity of the disc, $\omega = 2\pi N / 60$, rad/s, N-speed of disc in rpm

Angular velocity of precession, $\omega_p = (\phi / t) \times (\pi/180)$ rad/s

Reactive gyroscopic couple, $C_r = I \cdot \omega \cdot \omega_p$ Nm and Active gyroscopic couple, $C_a = W \times L$,

W-weight added = mg, N and L-distance between centers of weight to center plane of disc.

Sl no	Speed of disc, N, rpm	Weight added m, kg	Time taken for 60° precision t, sec	Active couple $C_a = W \times L$ Nm	Reactive couple $C_r = I \cdot \omega \cdot \omega_p$ Nm

Graph:

1. Active couple Vs. Reactive couple
2. Weight added Vs. Reactive couple

EX NO :11

TURN TABLE

Aim: To determine angular velocity, angular acceleration, mass moment of inertia and centrifugal force of reciprocating masses

Apparatus required: Turn table, masses, steel rule

Definitions: velocity, acceleration, angular velocity, angular acceleration, centrifugal force and mass moment of inertia.

Procedure:

1. Fix the mass to the sliding arm and measure the initial radius R_1
2. Make the turn table to rotate at (30-40 rpm) low speeds and measure the final radial position of the mass, R_2 and the time taken by the mass to travel from initial radial position to final position, t in seconds.
3. Repeat the steps for different amounts of masses.

Formulae used:

Initial velocity, $V_1 = 2\pi R_1 N / 60$, m/s

Final velocity, $V_2 = 2\pi R_2 N / 60$

Linear acceleration, $a = (V_2 - V_1) / t$, m/s^2

Normal acceleration, $a_n = V_2^2 / R_2$, m/s^2

Tangential acceleration, $a_t = \sqrt{(a^2 - a_n^2)}$, m/s^2

Angular acceleration, $\alpha = a_t / R_2$, rad/s^2

Angular velocity, $\omega = 2\pi N / 60$, rad/s

Centrifugal force, $F = m V_2^2 / R_2$, N

Mass moment of inertia, $I_m = m R_2^2$, $kg-m^2$

Tabulation:

Sl. No.	Mass m, kg	Initial radius R_1 , m	Final radius R_2 , m	Speed N, rpm	Initial velocity V_1 , m/s	Final velocity V_2 , m/s	Angular velocity ω , rad/s	Angular acceleration α rad/s ²	Time taken t, sec	Centrifugal force F, N	Mass Moment of Inertia I_m , $kg-m^2$

Calculations:

Result: The angular velocity, angular acceleration, centrifugal force and mass moment of inertia were determined and tabulated.

EX NO:12

HARTNELL GOVERNOR

Aim: To find the stiffness, sensitivity and effort of the spring using Hartnell governor

Apparatus required: Hartnell governor setup and Tachometer

Description:

Hartnell governor is a centrifugal type spring controlled governor where the pivot of the ball crank lever is carried by the moving sleeve. The spring is compressed between the sleeve and the cap is fixed to the end of the governor shaft. The ball crank is mounted with its bell and the vertical arm pressing against the cap.

Formula used:

$$F_{c1} = m \omega_1^2 r_1 \text{ (N) and } F_{c2} = m \omega_2^2 r_2 \text{ (N)}$$

$$\omega_1 = 2\pi N_1 / 60 \text{ rad/s and } \omega_2 = 2\pi N_2 / 60 \text{ rad/s}$$

$$S_1 = 2F_{c1} (x/y) \text{ N and } S_2 = 2F_{c2} (x/y) \text{ N}$$

$$r_2 = r - R(x/y) \text{ (mm)}$$

$$\text{Sensitivity} = (\text{maximum speed} - \text{minimum speed}) / \text{mean speed} = (N_1 - N_2) / N$$

$$\text{Effort} = (\text{spring force at maximum speed} - \text{spring force at minimum speed}) / 2$$

$$\text{Spring stiffness} = (S_1 - S_2) / R \text{ N/mm}$$

Where, m = mass of the ball is ($m = 0.18 \text{ kg}$)

ω_1 & ω_2 = angular speed of governor at maximum radius and minimum radius respectively in rad/sec

r_1 & r_2 = maximum and minimum radius of rotation

F_{c1} & F_{c2} = centrifugal forces at ω_1 and ω_2 in N

X = length of the vertical ball arm of lever in m

Y = length of the horizontal ball arm of lever in m

S_1 & S_2 = spring forces at ω_1 & ω_2 in N

Procedure:

1. Keep the speed regulation in 0 position before starting the motor.
2. Increase the regulated output gradually till the motor takes the critical speed and immediately control the speed of the governor
3. Maintain the speed for each and every graduation as required to take the direct reading

Result:

Tabular column: $X = 95 \text{ mm}$, $Y = 95 \text{ mm}$, $r_1 = r_2 = 95 \text{ mm}$

Sl. No.	Speed, N (rpm)			Sensitivity	Effort (N)	Stiffness (N/mm)
	Min	max	mean			

Calculation:

Graph:

1. Mean speed Vs. Sensitivity
2. Mean speed Vs. Effort

EX. NO: 13**EQUIVALENT SPRING MASS SYSTEM**

Aim : to determine the undamped natural frequency of an equivalent spring –mass system.

Apparatus required : Spring, trunnion, beam, extra mass, steel rule.

Procedure:

1. Attach the beam to the trunnion bracket
2. Measure the distance between pivot and spring (L_1) m
3. Mount the exciter assembly over the beam at suitable length after altering the spring at the other end (L_2) m
4. Excite the beam by a simple jerk and measure the time taken for N oscillations (t) sec
5. Repeat the experiment by changing the exciter position or mass or both.

Formulae used:

Spring stiffness, $K = \text{load/deflection} = W/\delta = mg/\delta$ N/m in (part I)

m- Mass added to spring in kg

Equivalent mass, $M_{eq} = M (L_2/L_1)$ kg, M- mass of the exciter assembly in kg

Time period, (Theoretical) $T_{the} = 2\pi \sqrt{M_{eq}/K}$ sec.

L_1 - Distance between pivot and spring, m and L_2 - Distance between pivot and exciter assembly, m

Theoretical natural frequency, $f_{n(the)} = 1/T_{the}$ Hz ,

Experimental natural frequency, $f_{n(exp)} = 1/T_{exp}$

Experimental time period, $T_{exp} = t/N$ sec.

Observations: Mass of the exciter assembly, $M = \dots\dots\dots$ kg

Sl no	Mass of exciter assembly M, (kg)	Lengths		Time for N oscillations (t) sec	Experimental time period, T_{exp} , sec	Theoretical time period, T_{the} , sec	Experimental Natural frequency, $f_{n(exp)}$	Theoretical Natural frequency, $f_{n(the)}$
		L_1 m	L_2 m					
1								
2								
3								
4								
5								

Graphs: L_2 Vs T_{exp} , T_{the}

L_2 Vs $f_{n(exp)}$, $f_{n(the)}$

Diagrams: spring-mass system, equivalent spring mass system