ME-756A Quiz-1

Time: 60 minutes (Write your *complete final answer* for objective questions. Don't Tick mark.) Total: 50 marks

1. Balancing of Inertia forces can be classified as the following method of vibration control **[2 marks]**
   - System Modification
   - Active Feedback Control
   - Excitation Reduction at Source
   - Energy Harvesting
   - All of the options

2. Power Spectral Density of an excitation shows the presence of several peaks starting with a base frequency f_0 and subsequently; the peaks at $2f_0$, $3f_0$ to infinity. What can be said about the nature of excitation? **[2 marks]**
   - Harmonic
   - Periodic
   - Narrow-band Random Excitation
   - Broadband Excitation
   - Impact Excitation

3. Name two applications based on beneficial effects of vibration **[2 marks]**
   - Engine Vibration and Power Transmission
   - Aircraft Sound Generation and Reciprocating Pump
   - Concrete compaction and Guided waves
   - Transmission Line Sway and Concrete Compaction
   - Non-destructive Testing and Engine Vibration

4. What is the primary concept of jet noise vibration control? **[2 marks]**
   - Smaller jet diameter can create high-frequency noise
   - Larger Jet Diameter can create large eddies
   - High shear rate exists in the flow-mixing region
   - Karman Vortices are controlled through serrated jets
   - Presence of a limited flow mixing region is exploited

5. The Strouhal number of a pipe obstructing a river flow is 0.2. The free stream flow velocity is 2m/s, and the radius of the pipe is 1m. The excitation frequency is: **[2 marks]**
   - 0.1 Hz
   - 1 Hz
   - 2 Hz
   - 0.02 Hz
   - 0.2 Hz

6. During field balancing of a rotor if one can only measure the amplitude of trial mass vibration, then how many and which of these measurements are needed to obtain the balancing angle? **[2 marks]**
   - 2, without any trial mass and trial mass at 0^0
   - 4, without trial mass, trial mass at 0^0, 90^0 and 180^0 respectively
   - 3, without trial mass and trial mass at 0^0 and 180^0 respectively
   - 5, without trial mass and trial mass at four different radial locations
   - None of these

7. Which of the following is related to the parametric excitation? **[2 marks]**

- Shock loading
- Source vibration independent of response
- Vortex induced vibration
- Mass, damping and stiffness changing with time
- None of the options

8. Serrated Jet Exit is an example of **[2 marks]**

- Vibration reduction at source
- Dynamic Vibration Absorber
- Active Control
- Vortex Induced Vibration
- Constrained Layer Damping

9. Find the Fourier series for $f(x) = \begin{cases} -1, & -3 \le x < 0 \\ 1, & 0 < x \le 3 \end{cases}$ $\quad on\ [-3,3]$. **[2+4+6 marks]**

Write separately a_0, a_k , b_k

$$a_k = \frac{1}{3}\int_{-3}^{3} f(x)\cos(\frac{k\pi x}{3})\,dx = \frac{1}{3}\int_{-3}^{0} -\cos(\frac{k\pi x}{3})\,dx + \frac{1}{3}\int_{0}^{3} \cos(\frac{k\pi x}{3})\,dx$$

$$= \frac{1}{k\pi}\left[\sin(\frac{k\pi x}{3})\right]_{-3}^{0} - \frac{1}{k\pi}\left[\sin(\frac{k\pi x}{3})\right]_{0}^{3} = 0$$ — 4

$$a_0 = \frac{1}{3}\int_{-3}^{0} -dx + \frac{1}{3}\int_{0}^{3} dx = -1 + 1 = 0$$ — 2

$$b_k = \frac{1}{3}\int_{-3}^{3} f(x)\sin(\frac{k\pi x}{3})\,dx = \frac{1}{3}\int_{-3}^{0} -\sin(\frac{k\pi x}{3})\,dx + \frac{1}{3}\int_{0}^{3} \sin(\frac{k\pi x}{3})\,dx$$

$$= \frac{1}{k\pi}\left[\cos(\frac{k\pi x}{3})\right]_{-3}^{0} - \frac{1}{k\pi}\left[\cos(\frac{k\pi x}{3})\right]_{0}^{3}$$

$$= \frac{1}{k\pi} - \frac{(-1)^k}{k\pi} - \frac{(-1)^k}{k\pi} + \frac{1}{k\pi} = \frac{2-2(-1)^k}{k\pi} \quad k = 1,2,3,...$$

$$= \frac{4}{(2k+1)\pi}, \quad k = 0,1,2,...$$ — 6

So the Fourier series is.

$$f(x) = \sum_{k=0}^{\infty} \frac{4}{(2k+1)\pi} \sin\left(\frac{(2k+1)\pi x}{3}\right)$$

10. Four holes are drilled in a uniform circular disc at a radius of 0.1 m and angles of 0°, 60°, 120°, and 180°. The weight removed at holes 1 and 2 is 100 gm each and the weight removed at holes 3 and 4 is 150 gm each. If the disc is to be balanced statically by drilling a fifth hole at a radius of 0.12 m, find the weight to be removed and the angular location of the fifth hole (assume constant ω)? **[6 marks]**

Mass removed from holes 1 and 2 is 100 grams, and from 3 and 4 is 150 grams, radius for holes 1 to 4 is 0.1 m, 5th hole at a radius of 0.12 m.

Solution:

Unbalance due to hole is proportional to (r.m)

Let m_5 = mass removed from 5th hole

r_5 = radius at which 5th hole is drilled = 0.12 m.

θ_5 = angle at which 5th hole is drilled.

$$\Sigma F_x = \sum_{i=1}^{5} r_i m_i \cos\theta_i = 0$$

$\Rightarrow$ $0.1\ (0.1)\cos 0° + 0.1\ (0.1)\cos 60° + 0.1\ (0.15)\cos 120° + 0.1\ (0.15)\cos 180° + r_5 m_5 \cos\theta_5 = 0$ 2

$\Rightarrow$ $0.01 + 0.005 - 0.0075 - 0.015 + 0.12\ m_5\cos\theta_5 = 0$

$0.12\ m_5\cos\theta_5 = 0.0075$

$$\Sigma F_y = \sum_{i=1}^{5} r_i m_i \sin\theta_i = 0$$

$\Rightarrow$ $0.1\ (0.1)\sin 0° + 0.1\ (0.1)\sin 60° + 0.1\ (0.15)\sin 120° + 0.1\ (0.15)\sin 180° + r_5 m_5 \sin\theta_5 = 0$ 2

$\Rightarrow$ $0 + 0.00866 + 0.01299 + 0 + r_5 m_5 \sin\theta_5 = 0$

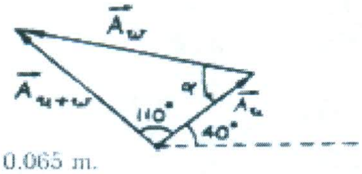
$0.12\ m_5\sin\theta_5 = -0.02165$

$$m_5 = \frac{1}{0.12}\sqrt{(0.0075)^2 + (-0.02165)^2} = 0.1909\ \text{(kg)}$$ 1

$$\theta_5 = \tan^{-1}\left(\frac{-0.02165}{0.0075}\right) = -70.8929°$$ 1

11. The amplitude and phase angle due to original unbalance in a grinding wheel operating at 1200 rpm are found to be 0.2 mm and 40° counterclockwise from the phase mark. When a trial weight of 0.2 kg is added at 65°clockwise from the phase mark and at a radial distance 0.065 m from the center of rotation, the amplitude and phase angle are observed to be 0.5 mm and 150° counterclockwise. Find the magnitude and angular position of the balancing weight if it is to be located 0.065 m radially from the center of rotation? **[6 marks]**

Amplitude of unbalance 0.2 mm,
phase angle of unbalance 40°, ↺,
trial weight M = 0.2 kg, at a radius 0.065 m.,
new amplitude of unbalance 0.5 mm.,
new phase angle 150°, ↺,
balancing weight to be located at a radial distance of 0.065 m.



Solution:

$\vec{A}_u = (0.2,\ 40°\ \text{ccw})$

$\vec{A}_{u+w} = (0.5,\ 150°\ \text{ccw})$

$A_w = [A_u^2 + A_{u+w}^2 - 2A_u A_{u+w}\cos(\phi - \theta)]^{\frac{1}{2}}$

$= (0.2^2 + 0.5^2 - 2\ (0.2)\ (0.5)\cos 110°)^{\frac{1}{2}} = 0.5987$ 2

M_0 = original unbalance $= \left(\frac{A_u}{A_w}\right) M = \left(\frac{0.2}{0.5987}\right) 0.2 = 0.06681$ kg. 2

or using sine law $\frac{\sin\alpha}{0.5} = \frac{\sin 110°}{0.5987}$

$\therefore \alpha = 51.69°$ ccw

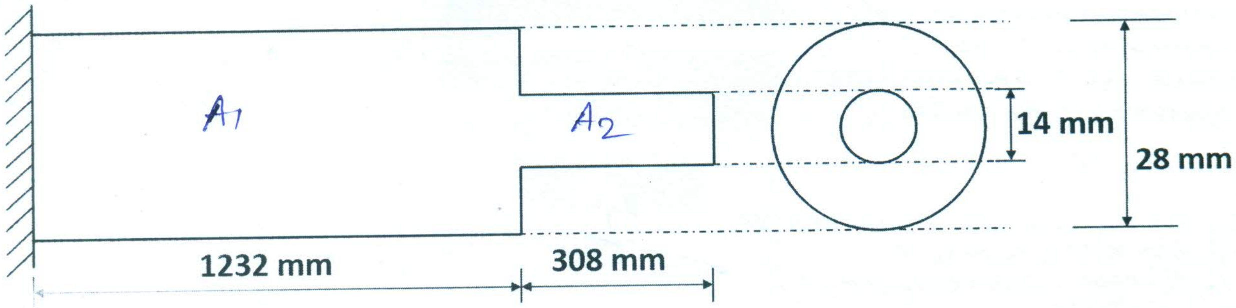
$\alpha = \cos^{-1}\left[\frac{A_u^2 + A_w^2 - A_{u+w}^2}{2A_u A_w}\right] = \cos^{-1}\left[\frac{0.2^2 + 0.5987^2 - 0.5^2}{2\ (0.2)\ (0.5987)}\right] = \cos^{-1}(0.6199)$ 2

$= 51.6912°$ ccw

Grinding wheel will be balanced if a weight of 0.06681 kg is added at 51.6912° clockwise from the position of the trial weight

12. A stepped solid circular shaft of given geometry and material property set is found to be having two major peaks in the frequency response of the system. Find out these two peak frequencies (in rad/s) considering axial and torsional excitations.

Given: Mass, M = 2 kg, Mass moment of inertia of stepped shaft, I = 10 kg-m^2, Elastic modulus, E = 200 GPa, and Shear modulus, G = 100 GPa. **[10 marks]**



$$A_1 = \frac{\pi}{4} D_1^2 = \frac{22}{4 \times 7} \times 28 \times 28 = 616\ mm^2$$ 1

$$A_2 = \frac{\pi}{4} D_2^2 = 154\ mm^2$$

$$J_1 = \text{Polar M.I} = \frac{\pi}{32} D_1^4 = 60368\ mm^4$$ 1

$$J_2 = \frac{\pi}{32} D_2^4 = 3773\ mm^4$$

For axial loading (shaft in series)

$$K_{eq} = \frac{AE}{L}$$

$$\frac{1}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{L_1}{A_1 E} + \frac{L_2}{A_2 E}$$

$$\therefore K_{eq} = \frac{10^8}{2}\ N/m$$ 2

$$\omega_1 = \sqrt{\frac{K_{eq}}{M}} = \sqrt{\frac{10^8}{2 \times 2}} = 5000 \text{ rad/s}$$ 2

For torsional loading

$$\frac{T}{J} = \frac{G\theta}{L} \Rightarrow \frac{T}{\theta} = K_T = \frac{GJ}{L}$$

$$(K_T)_{eq} = \frac{GJ}{L}$$

$$\frac{1}{(K_T)_{eq}} = \frac{L_1}{GJ_1} + \frac{L_2}{GJ_2}$$

$$(K_T)_{eq} = 10^3 \frac{N\text{-}m}{rad}$$ = Torsional eq. stiffness 2

$$\omega_2 = \sqrt{\frac{(K_T)_{eq}}{I}} = \sqrt{\frac{10^3}{10}} = 10 \text{ rad/sec.}$$ 2