

# **DYNAMICS OF MACHINERY**

## **TUTORIAL - 2 (01/09/06)**

**Do not use any book as far as possible.**

**Time yourself and indicate the time required for solving each of the problems.**

**The solutions must be submitted on full scape paper, if you wish to get them corrected.**

**Only the first few who submit will have their papers checked. (100 Marks - 180 mins)**

**Units Covered : Forced Vibrations – Vibration Measurement**

**Two Degrees of Freedom – Critical Speed of Shafts.**

### **For Private Circulation Only**

Q1a. : Derive a relationship for magnification factor and plot a graph of it versus frequency ratio for different values of damping factor.

(8 Marks)

Q1b. : A machine of mass 100 kg is mounted on springs of stiffness 1200 kN/m with an assumed damping factor of 0.2. A piston within this machine has a mass of 8 kg and a stroke of 100 mm and runs at 2000 rpm. Assuming the motion of the piston to be harmonic, find :

- The amplitude of the machine
- Its phase angle with respect to the exciting force
- Transmissibility
- Force transmitted to the foundation
- Phase angle of transmitted force with respect to the exciting force.

(10 Marks)

Q2a. : The body of a 600 kg vehicle is connected to the wheels through a suspension system that is modeled as a spring of stiffness  $5 \times 10^5$  N/m in parallel with a viscous damper of damping coefficient of 3000 Ns/m. The wheels are assumed rigid and follow the road contour, which is approximated by a sine wave of amplitude 0.01 m and wave length of 2.5 m. If the vehicle travels at a constant speed of 55 m/s, what is the acceleration amplitude of the vehicle ? What is the critical speed of vehicle ?

(8 Marks)

Q2b. A single cylinder engine has an an out of balance force of 500 N at an engine speed of 300 rpm. The complete mass of the engine is 150 kg and it is carried on a spring of stiffness 300 N/cm. Find the amplitude of motion of mass and the force transmitted to the foundation. If a viscous damper is placed having damping force of 1000 N at 1 m/s velocity, find the amplitude of the forced damped oscillation and its angle of lag with disturbing force.

(8 marks)

Q3a. Discuss the principles and method of vibration frequency measurement.

(4 Marks)

Q3b. A vibrometer has a period of free vibration of 4 seconds. It is attached to a machine with a vertical harmonic frequency of 2 Hz. If the vibrometer mass has an amplitude of 3 mm relative to the frame, find the amplitude of vibration

(4 Marks)

Q3c. A seismic instrument is used to find the magnitude of vibration of a machine tool structure. It gives a reading of relative displacement of  $0.4 \mu\text{m}$ . The natural frequency of the seismic instrument is 4 Hz. The machine tool structure is subjected to a kinematic excitation at a frequency of 2 Hz. Find the magnitude of acceleration of the vibrating machine tool structure. Assume that the damping of the seismic instrument is negligible.

(8 Marks)

Q4a : Determine the natural frequency of the system shown in Fig. I. Hence find the natural frequency if :

$$\begin{aligned} m_1 &= 20 \text{ kg} \\ m_2 &= 5 \text{ kg} \\ K_1 &= 9600 \text{ N/m} \\ K_2 &= 1980 \text{ N/m} \end{aligned}$$

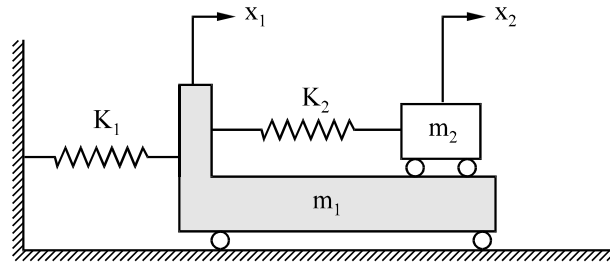


Fig. I

(9 Marks)

Q4b. Determine the natural frequencies of the system show in Fig. II. Assume that the cord does not slip over the cylinder.

$$\begin{aligned} m &= 5 \text{ kg} \\ M &= 10 \text{ kg} \\ K_1 &= 50 \text{ N/m} \\ K_2 &= 80 \text{ N/m} \end{aligned}$$

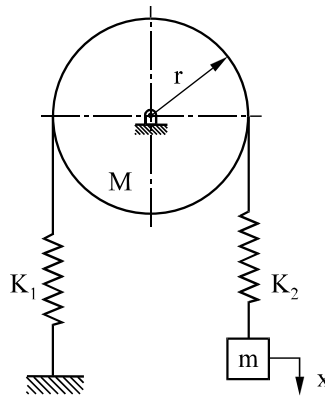


Fig. II

(9 Marks)

Q5a. A stepped shaft AB has diameters of 95 mm (at end A), 60 mm and 50 mm (at end B). The corresponding lengths of these diameter sections are 600 mm, 500 mm and 400 mm. If the mass moment of inertias at ends A and B are  $650 \text{ kgm}^2$  and  $215 \text{ kgm}^2$  respectively, determine the natural frequency of the system and the position of the node on the given shaft. Take  $G = 80 \text{ GPa}$  (8 Marks)

Q5b. A reciprocating I.C. engine is coupled to a centrifugal pump through gearing. The shaft from flywheel to the gear is 60 mm diameter and 950 mm length. Shaft from the pinion to the pump is 40 mm diameter and 300 mm length. Pinion has 25 teeth and gear has 100 teeth. Assume  $G = 84 \text{ GN/m}^2$ .

$$\begin{aligned} \text{Moment of inertia of flywheel} &= 800 \text{ kg m}^2 \\ \text{Moment of inertia of gear wheel} &= 15 \text{ kg m}^2 \\ \text{Moment of inertia of pinion} &= 4 \text{ kg m}^2 \\ \text{Moment of inertia of pump} &= 17 \text{ kg m}^2 \end{aligned}$$

Determine the natural frequency of the system.

(8 Marks)

Q6 a. Derive a relationship for analysis of critical speed of a shaft carrying a single rotor and having damping. Also plot the frequency response curve for the same and comment on the results.

(8 Marks)

Q6 b. A shaft of 10 mm diameter, rotates in a sleeve bearing with a span of 1 m and carries a disc of mass 10 kg midway between the two bearings. The mass center of the disc is 0.2 mm out of center. If the stress is not to exceed  $150 \text{ MN/m}^2$ , determine the range of speed within which it is unsafe to run the shaft. The Young's modulus of the material of the shaft is  $200 \text{ GN/m}^2$ . Also determine the critical speed of the shaft.

(8 Marks)