DYNAMICS OF MACHINES
(MECH 3105)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The engine of an aeroplane rotates in clockwise direction when seen from the tail end and the aeroplane takes turn to the left. The effect of gyroscopic couple on the aeroplane will be
(a) to dip the nose and tail
(b) to raise the nose and tail
(c) to raise the nose and dip the tail
(d) to dip the nose and raise the tail.

(ii) Two rigid bodies are said to be in dynamic equilibrium if their
(a) masses are same
(b) moment of inertias are same
(c) location of centre of mass is same
(d) all of the above.

(iii) Flywheel is used to control the
(a) mean speed
(b) maximum fluctuation of speed
(c) minimum fluctuation of speed
(d) all of these.

(iv) When the crank is at the inner dead centre, in a reciprocating steam engine, then the velocity of the piston will be
(a) minimum
(b) maximum
(c) zero
(d) none of these.

(v) A disc undergoing spin and precession must experience
(a) gyroscopic couple
(b) gravitational force
(c) centrifugal couple
(d) none of these.

(vi) In locomotives, the ratio of the connecting rod length to the crank radius is kept very large in order to
(a) minimise the effect of primary forces
(b) minimise the effect of secondary forces
(c) have perfect balancing
(d) to start the locomotive quickly.

(vii) If the rotor of motor-pump assembly is in dynamically balanced condition then they can be said to be balanced in static condition as well. This statement is
(a) true
(b) false
(c) incomplete
(d) wrong.

(viii) If the rotating mass of a rim type flywheel is distributed on another rim type flywheel whose mean radius if half the mean radius of the former, then energy stored in the same speed will be
(a) four times the first one
(b) same as the first one
(c) one fourth of the first one
(d) one and half times the first one.

(ix) Magnitude of hammer blow will increase if
(a) fraction of reciprocating mass balancing is increased
(b) fraction of reciprocating mass balancing is decreased
(c) fraction of reciprocating mass balancing remains same
(d) none of these.

(x) The balancing of a rigid rotor can be achieved by appropriately placing balancing masses in
(a) a single plane
(b) two planes
(c) three planes
(d) four planes.

Fill in the blanks with the correct word

(xi) The damping factor for critical damping is _____.

(xii) The least number of point masses to create dynamic equivalent with a distributed mass body, which is both translating and rotating, is _____.

(xiii) If the stiffness of a system is ‘k’ and mass is ‘m’ then the natural frequency of free vibration of the system is _____.

(xiv) Whirling of shaft occurs if rotational speed of shaft matches with its _____.

(xv) A shaft has two heavy rotors mounted on it. The transverse natural frequencies, considering each of the rotor separately, are 100 Hz and 200 Hz, respectively. The lowest critical speed is _____.

Group - B

2. (a) The lengths of crank and connecting rod of a horizontal reciprocating engine are 200 mm and 1 m, respectively. The crank is rotating at 400 RPM. When the crank has turned 30° from the inner dead centre, the difference of pressure between the cover end and piston end is 0.4 N/mm^2. If the mass of the reciprocating parts is 100 kg and cylinder bore is 0.4 m, then calculate,
   (i) Inertia force
   (ii) Force on piston
   (iii) Piston effort
   (iv) Thrust on the side of the cylinder walls.
   Neglect the effect of piston rod diameter and frictional resistance. *[(CO1)(Analyse/IOCQ)]*

   (b) The length of a connecting rod of an engine is 500 mm measured between centres and its mass is 18 kg. The centre of gravity is 125 mm from the crank-pin centre and the crank radius is 100 mm. Determine the dynamically equivalent system keeping one mass at the small end. The frequency of oscillations of the rod when suspended from the centre of the small end is 43 vibrations per minute. *[(CO1)(Analyse/IOCQ)]*

6 + 6 = 12

3. (a) A horizontal axle of length 100 mm and of negligible weight is supported between two bearings. A disc having mass of 5 kg with radius of gyration 60 mm is mounted centrally on the axle. The centre line of the axle, disc and the bearings lie in a horizontal plane. The disc is rotating at 720 rpm in the clockwise direction looking from the left side of bearing. The axle precesses about a vertical axis at 60 rpm in the clockwise direction looking from the top. Determine the resultant reaction at each bearing due to the disc and gyroscopic effect. *[(CO2)(Analyse/IOCQ)]*

   (b) The turning moment diagram for a multicylinder engine has been drawn to a vertical scale of 1 mm = 500 N.m and a horizontal scale of 1 mm = 5°. The areas above and below the mean torque line are -28, +380, -260, +310, -300, +242, -380, +265, and -229 mm^2. The fluctuation of speed is limited to 2% of the mean speed which is 400 rpm. The density of the rim material is 7000 kg/m^3 and width of the rim is 4 times its thickness. The hoop stress in the rim material is limited to 6 N/mm^2. Neglecting the effect of the boss and arms, determine the diameter and cross section of the flywheel rim. *[(CO1)(Apply/IOCQ)]*

5 + 7 = 12

Group - C

4. (a) Derive the magnitude of hammer blow and swaying couple occurs due to partial balancing of engines. *[(CO3)(Analyse/IOCQ)]*

   (b) The following data apply to a single cylinder reciprocating engine:
   Speed = 500 rpm
   Stroke = 150 mm
   Mass of reciprocating parts = 21 kg
   Mass of revolving parts = 15 kg at crank radius
   If the two-thirds (2/3) of reciprocating masses and all the revolving masses have to be balanced, determine
   (i) The balance mass at a radius of 150 mm, and
   (ii) The unbalanced force when the crank has moved 45° from inner dead centre. *[(CO3)(Analyse/IOCQ)]*

5 + 7 = 12

5. (a) The piston of a 60° twin V- engine have stroke of 120 mm. The connecting rods driving a common crank have a length of 200 mm. The mass of reciprocating parts per cylinder is 1 kg and the speed of crank shaft is 2500 rpm. Determine, the magnitude and direction of primary and secondary forces. *[(CO3)(Analyse/HOCQ)]*

   (b) Each crank and the connecting rod of a four crank in line engine are 200 mm and 800 mm respectively. The outer cranks are set at 1200 to each other and each has a reciprocating mass of 200 kg. The spacing between adjacent planes of cranks are 400 mm, 600 mm, 500 mm. If the engine is in complete primary balance, determine the reciprocating masses of the inner cranks and their relative angular positions. *[(CO3)(Analyze/IOCQ)]*

6 + 6 = 12

Group - D

6. (a) What do you mean by the natural frequency of vibration of a system? *[(CO4) (Understand/LOCQ)]*

   (b) Calculate the natural frequency of vibration for the system shown in Fig.1. Mass of the block is 10 kg and the stiffness of each spring is 5 kN/m.

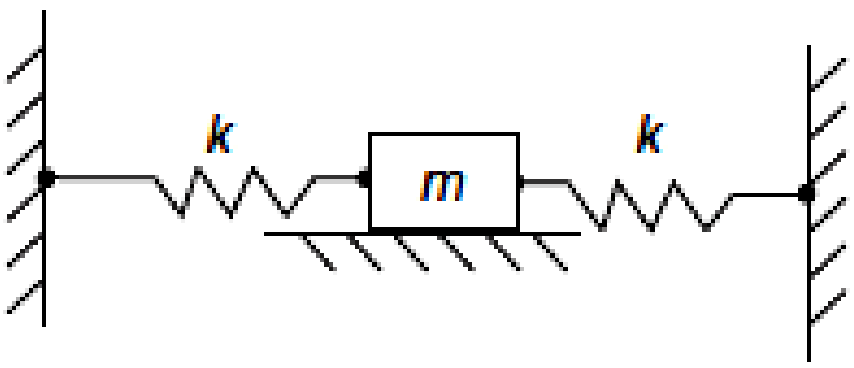

Fig.1

[(CO4)(Analyse/IOCQ)]

(c) A rigid body (can be considered as a compound pendulum) undergoing free vibration, as shown in Fig.2, takes 13 seconds to complete 10 numbers of complete oscillations. If the point of suspension of the body is at a distance of 350 mm from the centre of mass, find the radius of gyration about the axis of oscillation. Also find the radius of gyration about a parallel axis passing through the centre of mass. Assume acceleration due to gravity = 9.81 m/s^2.

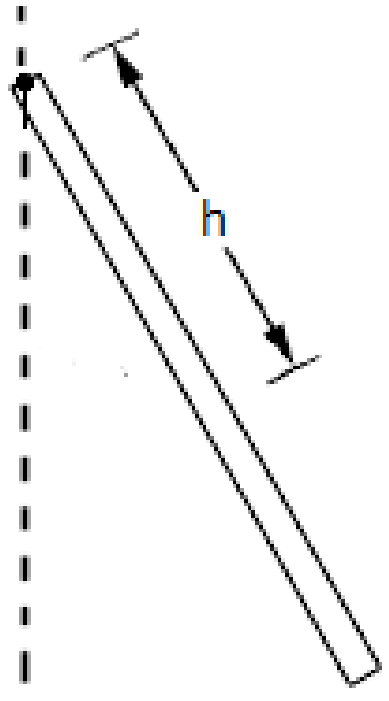

Fig. 2

[(CO4)(Analyse/IOCQ)]

2 + 4 + 6 = 12

7. (a) A mass of 5 kg hangs from a spring and makes damped oscillations. If the time of 50 complete oscillations is found to be 20 s, and the ratio of the first downward displacement to the sixth is found to be 22.5, find the logarithmic decrement and damping coefficient. *[(CO4)(Analyse/IOCQ)]*

(b) What do you understand by transmissibility? *[(CO4)(Understand/LOCQ)]*

(c) A platform is supported by springs having stiffness 25 kN/m and the system has damping factor of 0.5. A machine on the platform creates an unbalanced harmonic vibration of 770 N. If the mass of the platform with the machine is 80 kg, calculate the force transmitted to the foundation during resonance. *[(CO4)(Analyze/IOCQ)]*

6 + 2 + 4 = 12

Group - E

8. (a) A simply supported steel beam of circular cross-section having length 2.1 m carries three discs each of mass 100 kg. The diameter of the beam is 30 mm. The discs are mounted at equal distances on the shaft. Find out the fundamental natural frequency of transverse vibration using Dunkerley's method. Ignore the mass of the shaft. Consider the modulus of elasticity of steel to be 210 GPa. *[(CO5)(Analyse/IOCQ)]*

(b) What do you mean by critical speed of whirling of a shaft and how is it related to the natural frequency of transverse vibration? *[(CO5)(Understand/LOCQ)]*

(c) A steel shaft of 25 mm diameter and 1 m length is simply supported on short flexible bearings. A disc of mass 15 kg with an eccentricity of 2 mm is mounted midway on the shaft. Determine the deflection of midpoint of shaft when rotor speed is half of the critical speed. *[(CO5)(Analyze/IOCQ)]*

6 + 2 + 4 = 12

9. (a) A rod 1.2 m long and diameter of 25 mm suspended horizontally with the help of two strings as shown in the Fig.3. The lengths of strings are 500 mm and are tied at locations 250 mm away from the centre of mass on both sides. The rod undergoes an oscillation about a vertical axis passing through its centre of mass. Find out the time period of oscillation. Also find the percentage change in time period if the strings' length is halved.

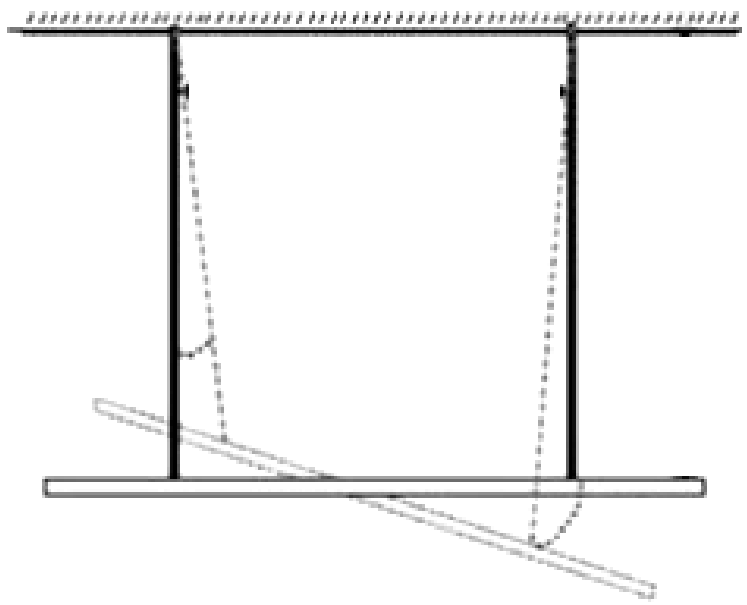

Fig.3 *[(CO5)(Analyse/IOCQ)]*

(b) For the three rotor shaft system shown in Fig.4, if MOI of rotors, J = 1.2 kgm^2 andstiffness of shaft k = 25kNm/rad, find the natural frequencies. Ignore the mass of shaft.

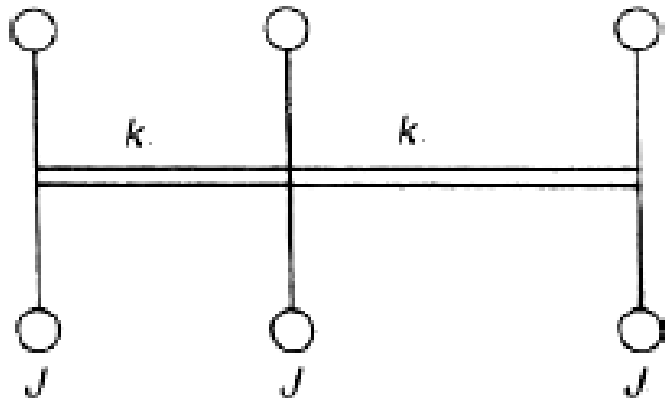

Fig.4

[(CO6) (Analyze/IOCQ)]

6 +6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	6.25	93.75	0

Course Outcome (CO):

After the completion of the course students will be able to

1. Analyze the dynamic forces, torque in mechanisms and its application to design a flywheel.
2. Explain the gyroscopic effects and analyze the stability of motion of different systems based on theeffects.
3. Examine an unbalanced system and solve the problem for balancing the same graphically andanalytically.
4. Analyze a free and forced single degree vibration system with and without damping.
5. Apply the knowledge of vibration in case of longitudinal, transverse and torsional vibrating systems
6. Describe basic idea of vibration of multi-degree of freedom system

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*