# DYNAMICS OF MACHINES
# (MECH 3105)

**Time Allotted : 3 hrs** **Full Marks : 70**

***Figures out of the right margin indicate full marks.***

***Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.***

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

## Group – A
## (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Crank effort is the product of crank pin radius and _____
(a) thrust on sides (b) crankpin effort
(c) force acting along connecting rod (d) piston effort.

(ii) If mean speed of the prime mover is increased then the coefficient of fluctuation of speed will
(a) increase (b) decrease (c) remains same (d) unpredictable.

(iii) If the rotating mass of a rim type flywheel is distributed on another rim type flywheel whose mean radius is half mean radius of the former, then energy stored in the latter at 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 a half times the first one.

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

(v) Which of the following statements is correct about the balancing of a mechanical system?
(a) If it is under static balance, then there will be dynamic balance also
(b) If it is under dynamic balance, then there will be static balance also
(c) Both static as well as dynamic balance have to be achieved separately
(d) None of the mentioned.

(vi) Partial balancing in locomotives results in
(a) hammer blow (b) variation in tractive effort
(c) swaying couple (d) all of the above.

(vii) For an underdamped system, motion is
(a) exponentially decreasing (b) oscillatory
(c) non-oscillatory (d) aperiodic.

(viii) In vibration isolation system, if $\omega/\omega_n > 1$, then the phase difference between the transmitted force and the disturbing force is
(a) 0° (b) 90° (c) 180° (d) 270°.

(ix) A simple spring mass vibrating system has a natural frequency of N. If the spring stiffness is halfed and the mass is doubled, then the natural frequency will become
(a) N/2 (b) 2N (c) 4N (d) 8N.

(x) For a system having two rotors, number of natural frequency of vibration is
(a) 1 (b) 2 (c) 3 (d) 4.

## Group – B

2. (a) A horizontal engine has a piston of 50 kg. The engine has a bore of 320 mm and a stroke of 560 mm. The length of the connecting rod is 1 m. The pressure on the cover side of the piston is 1.2 MPa and on the crank side is 0.15 MPa. Ignoring the area of piston rod, calculate
(i) Net force on piston (ii) Turning moment on crankshaft.
When, the crank has rotated 50 degrees from the inner dead center at a speed of 180 RPM.
[(CO1)(Analyse/IOCQ)]

(b) In a turning moment diagram, the area above and below the mean torque line is given as follows: -30, 374, -242, 300, -310, 234, -362, 2051, -215 (in $mm^2$)
The vertical scale is 1 mm= 325 N-m and the horizontal scale is 1 mm= 3°
Mean speed of the engine is 600 rpm. Determine the moment of inertia of the flywheel if the fluctuation of speed is limited to ± 1.8 % of the mean speed. [(CO1)(Analyse/IOCQ)]

**6 + 6 = 12**

3. (a) An airplane moving at 200 km/hr takes a left turn in a path of radius 150 m. A rotor is rotating about the longitudinal axis of the airplane. The moment of inertia of the rotor about the rotary axis is 20 kg-$m^2$ and is rotating with 1000 rpm clockwise when viewed from the front. What is the gyroscopic couple and its effect on airplanes? [(CO2)(Analyse/IOCQ)]

(b) A train wheel-axle assembly (shown in the Fig.1) takes a left turn in a circular path of radius 200 m with a speed of 20 km/hr. The mass of each wheel is 340 kg and its diameter is 980 mm. The track width is 1676 mm. Ignoring the moment of inertia of the axle, find out the reaction force on each wheel due to the gyroscopic couple. [(CO2)(Analyse/IOCQ)]

***Fig.1***

**6 + 6 = 12**

## Group - C

4. A rotor has the following properties:

| Mass | Magnitude | Radius | Angle | Axial distance from 1st mass |
|---|---|---|---|---|
| 1 | 9 kg | 100 mm | 0° | |
| 2 | 7kg | 120 mm | 60° | 160 mm |
| 3 | 8 kg | 140 mm | 135° | 320 mm |
| 4 | 6 kg | 120 mm | 270° | 560 mm |

If the shaft is balanced by two counter masses located at 100 mm radii and revolving in planes midway of planes 1 and 2, and midway of 3 and 4, determine the magnitude of the masses and their respective angular positions. [(CO3)(Analyse/IOCQ)]

**12**

5. The following data refer to a four-coupled wheel locomotive with two inside cylinders as shown in Fig.2.
Pitch of cylinders = 600 mm
Reciprocating mass/cylinder = 315 kg
Revolving mass/cylinder = 260 kg
Distance between driving coupling rods = 1.6 m
Diameter of driving wheels = 1.9 m
Revolving parts for each coupling rod crank = 130 kg
Engine crank radius = 300 mm
Coupled rod crank radius = 240 mm
Distance of centre of balance mass in planes of driving wheels from axle centre = 750 mm
Angle between engine cranks = 90°

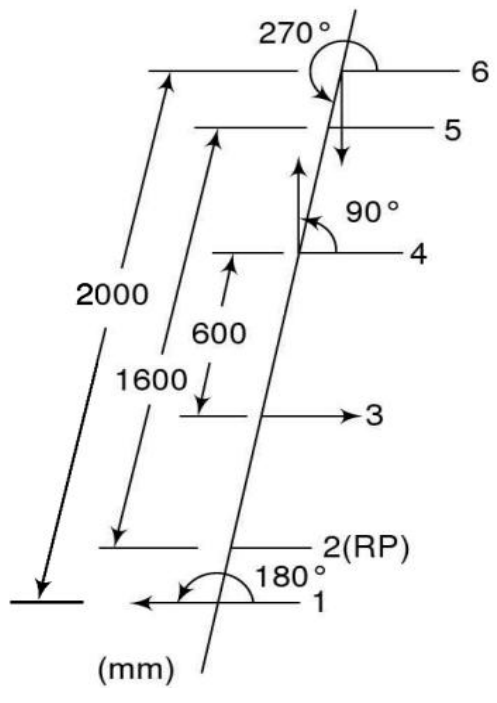


***Fig.2***

Angle between coupling rod crank with adjacent engine crank = 180°
The balanced mass required for the reciprocating parts is equally divided between each pair of coupled wheels. Determine the

(i) Magnitude and position of the balance mass required to balanced two-third of reciprocating and whole of the revolving parts.

(ii) Hammer-blow and the maximum variation of tractive force when the locomotive speed is 80 km/hr.

[(CO3)(Analyse/IOCQ)]

**12**

## Group – D

6. (a) Determine the equation of vibration and the natural frequency of vibration of the following system as shown in Fig.3. [(CO4, CO5)(Analyze/IOCQ)]

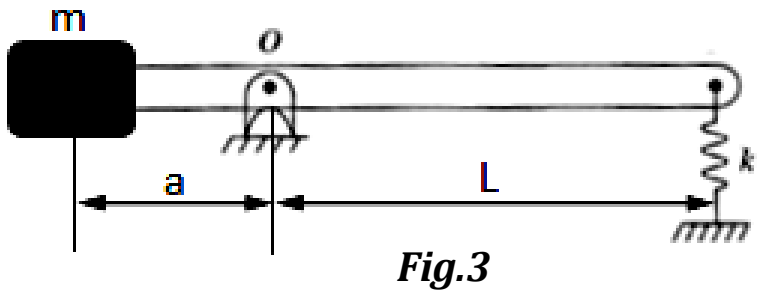


*Fig.3*

(b) Recoiling of a gun barrel weighing 300 kg after firing is 0.8 m. The stiffness of the spring is 250 N/mm.

(i) Determine initial velocity of the gun

(ii) Critical damping coefficient of the dashpot engaged at the end of recoil stroke.

[(CO4, CO5)(Analyze/IOCQ)]

**6 + 6 = 12**

7. (a) A rotor has an unbalance of 0.25 kg-m. This rotor is a part of a machine which has a total mass of 5 kg. The machine is isolated by springs and dampers. The equivalent stiffness of all the springs is 2461 N/m. If the transmissibility is to be 10% when the speed of rotor is 1000 rpm, calculate

(i) Damping factor

(ii) Force transmitted to the floor. [(CO4, CO5)(Analyze/IOCQ)]

(b) An exciting force F = 2cos3t N is acting on a 20 kg system where stiffness is 252 N/m and damping factor is 0.22. Determine the amplitude and phase of the forced vibration. [(CO4, CO5)(Analyze/IOCQ)]

**6 + 6 = 12**

## Group - E

8. (a) A shaft of 1 m long is held between long bearings. It carries a disc of weight of 15 N at the center. The eccentricity of the center of gravity of the disc from the center of the rotor is 0.3 mm. The diameter of the shaft is 15 mm. Find the critical speed of the shaft. Also find the amplitude of vibration at 2000 rpm. Take E = 200 GPa. [(CO4, CO5)(Analyze/IOCQ)]

(b) A simply supported circular cross-section beam of 800 mm span carries a load of 180 kg midway. A uniformly distributed load of 180 kg/m is also acting on the beam. The beam diameter is 25 mm. Calculate the transverse natural frequency of the beam. Take E = 200 GPa. [(CO4, CO5)(Analyze/IOCQ)]

**6 + 6 = 12**

9. (a) Find the free torsional vibration frequency of a shaft as shown in Fig.4. Mass of the disc at the free end is 200 kg and its radius of gyration about the longitudinal axis of the shaft is 200 mm. Ignore the inertia of the shaft. [(CO4, CO5)(Analyze/IOCQ)]

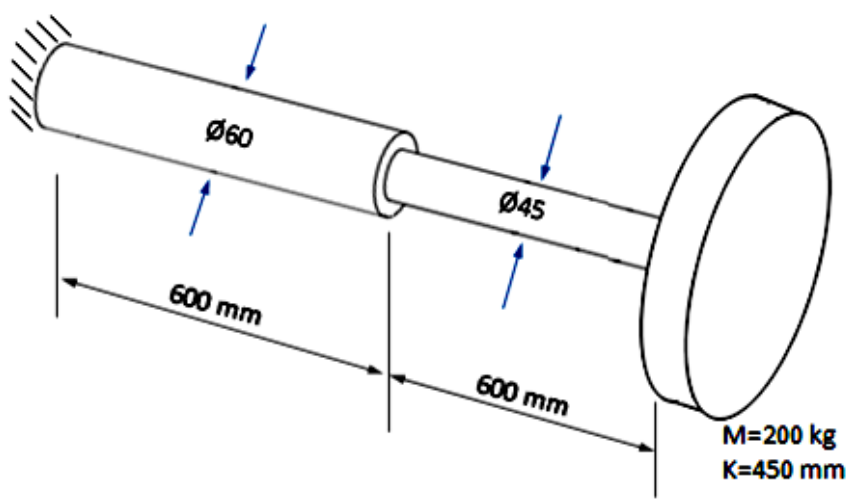


*Fig.4*

(b) Find the equations of free vibration for the following system shown in Fig.5 using Lagrange's method. $J_{cg}$ is the moment of inertia about axis perpendicular to paper and passing through centre of mass m is the mass, k is the stiffness of spring, y is the linear displacement of centre of mass and θ is the angular displacement about axis perpendicular to paper and passing through centre of mass.

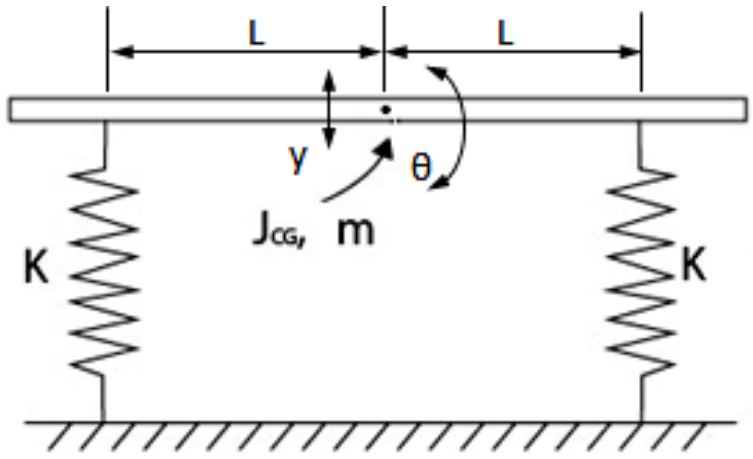


***Fig.5***

[(CO6)(Analyze/IOCQ)]
**6 + 6 = 12**

| Cognition Level | LOCQ | IOCQ | HOCQ |
|---|---|---|---|
| Percentage distribution | 0 | 100 | 0 |

**Course Outcome (CO):**

After the completion of the course, students will be able to

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