

# **ANNAI MATHAMMAL SHEELA ENGINEERING COLLEGE**

## **DEPARTMENT OF MECHANICAL ENGINEERING**

### **DYNAMICS OF MACHINERY III YEAR/ V SEMESTER**

#### **UNIT-I**

##### **PART-A (2 marks)**

##### **1. What are the conditions for a body to be in static and dynamic equilibrium?**

Necessary and sufficient conditions for static and dynamic equilibrium are

1. Vector sum of all forces acting on a body is zero.
2. The vector sum of the moments of all forces acting about any arbitrary point or axis is zero. First condition is the sufficient condition for static equilibrium together with second condition is necessary for dynamic equilibrium.

##### **2. Define static force analysis.**

If components of a machine accelerate, inertia is produced due to their masses. However, the magnitudes of these forces are small compared to the externally applied loads. Hence inertia effects due to masses are neglected. Such an analysis is known as static force analysis.

##### **3. Define force and applied force.**

Force is a push or pull, which acts on a body changes or tends to change, the state of rest or of uniform motion of the body. A force is completely characterized by its point of application, its magnitude and direction.

The external force acting on a system of body from outside the system are called applied force. The applied forces are classified as active and reactive force.

4. Rate of change of momentum of a body is directly proportional to Force acting on it.

##### **5. Which law helps to measure a force quantitatively?**

Newton's second law helps us to measure a force quantitatively.

##### **6. Distinguish between space diagram and free body diagram.**

A space diagram is a graphical description of the system. It generally shows the shape and size of the system, the weight, the externally applied loads, the connection and the supports of the system.

A free body diagram is a sketch of the isolated or free body which shows all the pertinent weight forces, the externally applied loads, and the reaction from its supports and connections acting upon it by the removed elements.

**7. When will the two force member is in equilibrium?**

The member under the action of two force will be in equilibrium if,

1. The two forces are of same magnitude,
2. The forces act along the same line, and
3. The forces are in opposite direction

**8. Give any three advantages of free body diagram.**

1. Free body diagram assist in seeing and understanding all aspects of problem.
2. They help in planning the approach to the problem.
3. They make mathematical relations easier to the problem.

**9. When will the three force member is in equilibrium.**

A body or member will be in equilibrium under the action of three forces if,

1. The resultant of the forces is zero, and
2. The line of action of the forces intersect at a point.

**10. Differentiate between static force analysis and dynamic force analysis.**

If components of a machine accelerate, inertia forces are produced due to their masses. If the magnitudes of these forces are small compared to the externally applied loads, they can be neglected while analyzing the mechanism. Such an analysis is known as static force analysis.

**11. What do you mean by inertia?**

The property of matter offering resistance to any change of its state of rest or of uniform motion in a straight line is known as inertia.

**12. State D'Alembert's principle.**

D'Alembert's principle states that the inertia forces and torques, and the external forces and torques acting on a body together result in statical equilibrium.

In other words, the vector sum of all external forces acting upon a system of rigid bodies is zero. The vector sum of all external moments and inertia torques acting upon a system of rigid bodies is also separately zero.

**13. How you will reduce a dynamic analysis problem into an equivalent problem of static equilibrium?**

By applying D'Alembert's principle to a dynamic analysis problem, we can reduce it into an equivalent problem of static equilibrium.

**14. What do you mean by Equivalent offset inertia force?**

Equivalent offset inertia force is the force which can replace both inertia force and inertia torque.

**15. State the principle of super position.**

The principle of super position states that for linear systems the individual responses to several disturbances or driving functions can be superposed on each other to obtain the total response of the system.

**16. Give one example each for linear and non-linear system.**

Linear system: Example: Spring system.

Non-linear system: Example: Systems with static or coulomb friction, backlash.

Principle of super position has a limitation that it cannot be applied for non-linear systems.

When the connecting rod is large the piston executes simple harmonic motion.

**18. Define Piston effort.**

Piston effort is defined as the net or effective force applied on the piston, along the line of stroke. It is also known as effective driving force (or) net load on the gudgeon pin.

**19. What do you mean by crank effort or turning moment on the crank shaft?**

It is the product of the crank-pin effort (FT) and crank pin radius (r).

**20. Define compound pendulum or torsional pendulum.**

A rigid body suspended vertically at a point and oscillating with very small amplitude under the action of gravitational force is known as compound pendulum or torsional pendulum.

**21. What are the requirements of an equivalent dynamical system?**

1. The mass of the rigid body must be equal to the sum of masses of two concentrated masses. i.e.  $m_1 + m_2 = m$

2. The centre of gravity of the two masses must coincide with the centre of gravity of the rigid body. i.e.  $m_1 l_1 = m_2 l_2$
3. The sum of mass moment of inertia of two masses about their centre of gravity is equal to the mass moment of inertia of the rigid body. i.e.  $I_1 + I_2 = (kG)^2$

## **22. What are the forces acting on the connecting rod?**

1. Inertia force of the reciprocating parts (FI) acting along the line of stroke.
2. The side thrust between the cross head and the guide bars acting at P and right angles to line of stroke.
3. Weight of the connecting rod.
4. Inertia force of the connecting rod (FC).
5. The radial force (FR) parallel to crank, and
6. The tangential force (FT) acting perpendicular to crank.

## **23. What is meant by turning moment diagram or crank effort diagram?**

It is the graphical representation of the turning moment or crank effort for various position of the crank.

In turning moment diagram, the turning moment is taken as the ordinate (Y-axis)

And crank angle as abscissa (X-axis)

## **24. Define Inertia force.**

The inertia force is an imaginary force, which when acts upon a rigid body, brings it in an equilibrium position.

Inertia force = - Accelerating force = -  $ma$

## **25. Differentiate the function of flywheel and governor.**

1. The function of flywheel is to reduce the fluctuations of speed during a cycle above and below the mean value for constant load from prime mover. The function of governor is to control the mean speed over a period for output load variations.
2. Flywheel works continuously from cycle to cycle. Governor works intermittently, i.e. only when there is change in the load.
3. Flywheel has no influence on mean speed of the prime mover. Governor has no influence over cyclic speed fluctuations.

## **26. Define Inertia Torque.**

The inertia torque is an imaginary torque, which when applied upon the rigid body, brings it in equilibrium position. It is equal to the accelerating couple in magnitude but opposite in direction.

**27. What do you understand by the fluctuations of energy and maximum fluctuation of energy?**

The variations of energy above and below the mean resisting torque line are called fluctuations of energy.

The difference between the maximum and the minimum energies is known as maximum fluctuation of energy.

**28. Define coefficient of fluctuation of energy.**

It is the ratio of maximum fluctuation of energy to the work done per cycle.

**29. What is meant by maximum fluctuation of speed?**

The difference between the maximum and minimum speeds during a cycle is called maximum fluctuation of speed.

**30. Define coefficient of fluctuation of speed.**

The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed.

**31. List out the few machines in which flywheel is used.**

1. Punching machines, 2. Shearing machines, 3. Rivetting machines, and 4. Crushing machines.

**32. What is cam dynamics?**

Cam dynamics is the study of cam follower system with considering the dynamic forces and torques developed in it.

**33. Write the importance of Balancing?**

If the moving part of a machine are not balanced completely then the inertia forces are set up which may cause excessive noise, vibration, wear and tear of the system. So balancing of machine is necessary.

### **PART-B (16 Marks)**

1. For reciprocating engine, derive the expression for (i) Velocity and acceleration of the piston  
(ii) Angular velocity and angular acceleration of the connecting rod (16)
2. In a reciprocating engine mechanism, if the crank and connecting rod are 300mm and 1m long respectively and the crank rotates at a constant speed of 200r.p.m. Determine analytically, 1. The crank angle at which the maximum velocity occurs and 2. Maximum velocity of piston. 3. Derive the relevant equations. (16)
3. (i) Deduce the expression for the inertia force in the reciprocating force neglecting the weight of the connecting rod. (8)  
(ii) A vertical petrol engine with cylinder of 150mm diameter and 200mm strokes has a connecting rod of 350mm long. The mass is 1.6kg and the engine speed is 1800 rpm. On the expansion stroke with crank angle  $30^\circ$  from TDC, the gas pressure is 750KPa. Determine the net thrust on the piston.
4. (i) Define coefficient of fluctuation of speed and coefficient of fluctuation of energy. (4)  
(ii) The radius of gyration of a fly wheel is 1meter and fluctuation of speed is not to exceed 1% of the mean speed of the flywheel. If the mass of the flywheel is 3340kg and the steam develops 150KW at 135rpm, then find 1. Maximum fluctuation of energy 2. Coefficient of fluctuation of energy (12)
5. The length of crank and connecting rod of a horizontal reciprocating engine are 100mm and 500mm respectively. The crank is rotating at 400rpm. When the crank has turned  $30^\circ$  from the IDC, find analytically 1. Velocity of piston 2. Acceleration of piston 3. Angular velocity of connecting rod 4. Angular acceleration of connecting rod. (16)

6. The length and connecting rod of a horizontal reciprocating engine are 200mm and 1meter respectively. The crank is rotating at 400rpm. When the crank has turned  $30^\circ$  from the inner dead center, the difference of pressure between cover end and piston rod is  $0.4 \text{ N/mm}^2$ . If the mass of the reciprocating parts is 100Kg and a cylinder bore is 0.4meters. Calculate (i) Inertia force (ii) Force on piston (iii) Piston effort (iv) Thrust on the side of the cylinder walls (v) Thrust in the connecting rod (vi) Crank effort. (16)

7. A horizontal gas engine running at 210rpm has a bore of 220mm and a stroke of 440mm. The connecting rod is 924mm long the reciprocating parts weight 20kg. When the crank has turned through an angle of  $30^\circ$  from IDC, the gas pressure on the cover and the crank sides are  $500 \text{ KN/m}^2$  and  $60 \text{ KN/m}^2$  respectively. Diameter of the piston rod is 40mm. Determine, 1. Turning moment on the crank shaft 2. Thrust on bearing 3. Acceleration of the flywheel which has a mass of 8kg and radius of gyration of 600mm while the power of the engine is 22KW. (16)

8. A single cylinder vertical engine has a bore of 300mm and a stroke of 400mm. The connecting rod is 1000mm long. The mass of the reciprocating parts is 140kg. On the expansion stroke with the crank at  $30^\circ$  from the top dead center, the gas pressure is  $0.7 \text{ MPa}$ . If it runs at 250rpm, determine; 1. Net force acting on the piston 2. resultant load on the gudgeon pin 3. Thrust on cylinder walls 4. The speed above which other things remaining same, gudgeon pin loads would be reversed in direction. (16)

9. A vertical double acting steam engine has a cylinder 300mm diameter and 450mm stroke and runs at 200rpm. The reciprocating parts has a mass of 225kg and the piston rod is 50mm diameter. The connecting rod is 1.2m long. When the crank has turned  $125^\circ$  from IDC the steam pressure above the piston is  $30 \text{ KN/m}^2$ . Calculate, (i) Crank-pin effort (ii) The effective turning moment on the crank shaft. (16)

10. The turning moment diagram for a petrol engine is drawn to a scale of 1mm to 6N-9-9m and the horizontal scale of 1mm to  $1^\circ$ . The turning moment repeat itself after every half revolution of the engine. The area above and below the mean torque line are 305, 710, 50,350,980 and  $275 \text{ mm}^2$ . The mass of rotating parts is 40kg at a radius of gyration of 140mm. Calculate the coefficient of fluctuation of speed if the mean speed is 1500rpm. (16)

11. The torque delivered by a two stroke engine is represented by  $T = (1000 + 300\sin 2\theta - 500\cos 2\theta)$  N-m where  $\theta$  is the angle turned by the crank from the IDC. The engine speed is 250rpm. The mass of the flywheel is 400kg and radius of gyration 400mm. Determine, (i) the power developed (ii) the total percentage fluctuation of speed (iii) the angular acceleration of flywheel when the crank has rotated through an angle of  $60^\circ$  from the IDC. (iv) the maximum angular acceleration and retardation of the flywheel. (16)

## UNIT-II

### PART-A (2 marks)

#### 1. Why balancing of dynamic forces are necessary?

If dynamic forces are not balanced, they will cause worse effects such as wear and tear on bearings and excessive vibrations on machines. It is very common in cam shafts, steam turbine rotors, engine crank shafts, and centrifugal pumps, etc.,

#### 2. Write the different types of balancing?

1. Balancing of rotating masses
  1. Static balancing
  2. Dynamic balancing
2. Balancing of reciprocating masses.

#### 3. Write the condition for complete balancing?

1. The resultant centrifugal force must be zero and
2. The resultant couple must be zero.

#### 4. Write the equation for balancing a single rotating mass by a single mass?

For balancing single rotating mass by a single rotating mass, the equation is  $m_1 r_1 = m_2 r_2$ .

#### 5. Whether grinding wheels are balanced or not? If so why?

Yes, the grinding wheels are properly balanced by inserting some low density materials. If not the required surface finish won't be attained and the vibration will cause much noise.

#### 6. Why complete balancing is not possible in reciprocating engine?

Balancing of reciprocating masses is done by introducing the balancing mass opposite to the crank. The vertical component of the dynamic force of this balancing mass gives rise to “Hammer blow”. In order to reduce the Hammer blow, a part of the reciprocating mass is balanced. Hence complete balancing is not possible in reciprocating engines.

**7. Differentiate between the unbalanced force due to a reciprocating mass and that due to revolving masses.**

1. Complete balancing of revolving mass can be possible. But fraction of reciprocating mass only balanced.
2. The unbalanced force due to reciprocating mass varies in magnitude but constant in direction. But in the case of revolving masses, the unbalanced force is constant in magnitude but varies in direction.

**8. What are the various cases of balancing of revolving masses?**

1. Balancing of single rotating mass by a single mass rotating in the same plane.
2. Balancing of single rotating mass by two masses rotating in different planes.
3. Balancing of several rotating masses in a single plane.
4. Balancing of several rotating masses in different planes.

**9. What are the effects of an unbalanced primary force along the line of stroke of two cylinder locomotive?**

1. Variation in tractive force along the line of stroke, and
2. Swaying couple.

**10. Define tractive force.**

The resultant unbalanced force due to the two cylinders along the line of stroke is known as tractive force.

**11. What is swaying couple?**

The unbalanced force acting at a distance between the lines of stroke of two cylinders, constitute a couple in the horizontal direction. This couple is known as swaying couple.

**12. What is the effect of hammer blow and what is the cause of it?**

The effect of hammer blow is to cause the variation in pressure between the wheel and the rail, such that vehicle vibrates vigorously. Hammer blow is caused due to the effect of unbalanced primary force acting perpendicular to the line of stroke.

### **13. What are in-line engines?**

Multi-cylinder engines with the cylinder centre lines in the same plane and on the same side of the centre line of the crank shaft are known as in-line engine.

### **14. What are the conditions to be satisfied for complete balance of in-line engine?**

1. The algebraic sum of the primary and secondary forces must be zero, and
2. The algebraic sum of the couples due to primary and secondary forces must be zero.

### **15. Why radial engines are preferred?**

In radial engines the connecting rods are connected to a common crank and hence the plane of rotation of the various cranks is same, therefore there are no unbalanced primary or secondary couples. Hence radial engines are preferred.

### **PART-B (16 Marks)**

1. A shaft is rotating at a uniform angular speed. Four masses  $M_1$ ,  $M_2$ , and  $M_3$  and  $M_4$  of magnitudes 300kg, 450kg, 360kg, 390kg respectively are attached rigidly to the shaft. The masses are rotating in the same plane. The corresponding radii of rotation are 200mm, 150mm, and 250mm and 300mm respectively. The angle made by these masses with horizontal are  $0^\circ$ ,  $45^\circ$ ,  $120^\circ$  and  $255^\circ$  respectively. Find, (i) the magnitude of balancing mass (ii) the position of balancing mass if its radius of rotation is 200mm. (16)
2. Four masses  $M_1$ ,  $M_2$ ,  $M_3$ , and  $M_4$  are 200kg, 300kg, 240kg and 260kg respectively. The corresponding radii of rotation are 0.2m, 0.15m, 0.25m and 0.3m respectively and the angle between successive masses  $45^\circ$ ,  $75^\circ$ , and  $135^\circ$ . Find the position and magnitude of balance mass required if its radius of rotation is 0.25m. (16)
3. The data for three rotating masses are given below:-  $M_1=4\text{kg}$   $r_1=75\text{mm}$   $\theta_1=45^\circ$   
 $M_2=3\text{kg}$   $r_2=85\text{mm}$   $\theta_2=135^\circ$   $M_3=2.5\text{kg}$   $r_3=50\text{mm}$   $\theta_3=240^\circ$  Determine the amount of counter mass at a radial distance of 65mm required for their static balance (16)

4. Four masses A, B, C, and D are completely balanced masses C and D makes angles of  $90^\circ$  and  $195^\circ$  respectively with B in the same sense. The rotating masses have the following properties:  $m_A=25\text{kg}$   $r_A=150\text{mm}$   $m_B=40\text{kg}$   $r_B=200\text{mm}$   $m_C=35\text{kg}$   $r_C=100\text{mm}$   $r_D=180\text{mm}$  Planes B and C are 250mm apart. Determine (i) the mass A and its angular position (ii) the position of planes A and D.

5. A, B, C and D are four masses carried by a rotating shaft at radii 100mm, 125mm, 200mm and 150mm respectively. The planes in which the masses revolve are spaced 600mm apart and the masses of B, C and D are 10kg, 5kg and 4kg respectively. Find the required mass A and relative angular setting of the four masses so that the shaft be in complete balance.

6. Four masses A, B, C and D revolves at equal radii and equally spaced along a shaft. The mass B is 7kg and the radii of C and D make angles of  $90^\circ$  and  $240^\circ$  respectively with the radius of B. Find the magnitude of masses A, C and D and angular position of A. So that the system may be completely balanced. (16)

7. A shaft carries four rotating masses A, B, C and D which are completely balanced. The masses B, C and D are 50kg, 80kg and 70kg respectively. The masses C and D make angles of  $90^\circ$  and  $195^\circ$  respectively with mass B in the same sense. The masses A, B, C and D are concentrated at radii 75mm, 100mm, 50mm and 90mm respectively. The plane of rotation of masses B and C are 250mm apart. Determine (i) the magnitude of mass A and its angular position (ii) the position of planes A and D. (16)

8. A four cylinder vertical engine has cranks 150mm long. The plane of rotation of the first, second and fourth cranks are 400mm, 200mm and 200mm respectively from that of the third crank and their reciprocating masses are 50kg, 60kg and 50kg respectively. Find the mass of the reciprocating parts for the third cylinder and relative angular position of the cranks in order that the engine may be in complete balance. (16)

9. A four cylinder vertical engine has cranks 300mm long. The plane of rotation of the first, third and fourth cranks are 750mm, 1050mm and 1650mm respectively from that of the second crank and their reciprocating masses are 10kg, 40kg and 250kg respectively. Find the mass of the reciprocating parts for the second cylinder and

relative angular position of the cranks in order that the engine may be in complete balance. (16)

10. Derive the following expression of effects of partial balancing in two cylinder locomotive engine (i) Variation of attractive force (ii) Swaying couple (iii) Hammer blow (16)



## UNIT-III

### **PART-A (2 marks)**

#### **1. What are the causes of vibration?**

The causes of vibration are unbalanced forces, elastic nature of the system, self excitations, winds and earthquakes.

#### **2. Define Period and cycle of vibration.**

Period is the time interval after which the motion is repeated itself. Cycle is defined as the motion completed during one time period.

#### **3. Define frequency of vibration.**

It is the number of cycles described in one second. Its unit is Hz.

#### **4. How will you classify vibration?**

1. Free vibrations

a) Longitudinal vibration,

b) Transverse vibration, and c) Torsional vibration.

2. Forced vibrations, and

3. Damped vibration.

#### **5. What is meant by free vibration and forced vibrations?**

When no external force acts on the body, after giving it an initial displacement, then the body is said to be under free or natural vibration.

When the body vibrates under the influence of external force, then the body is said to be under forced vibrations.

#### **6. What do you meant by damping and damped vibration?**

The resistance against the vibration is called damping.

When there is a reduction in amplitude over every cycle of vibration, then the motion is said to be damped vibration.

**7. Define resonance.**

When the frequency of external force is equal to the natural frequency of a vibrating body, the amplitude of vibration becomes excessively large. This phenomenon is known as resonance.

**8. What do you mean by a degree of freedom or movability?**

The number of independent coordinates required to completely define the motion of a system is known as degree of freedom of the system.

**09. Define steady state and transient vibrations.**

In ideal systems, the free vibration continues indefinitely as there is no damping. Such vibration is termed as steady state vibrations.

In real systems, the amplitude of vibration decays continuously because of natural damping and vanishes finally. Such vibration in real system is called transient vibration.

**10. What is equivalent spring stiffness?**

Equivalent spring stiffness is the measure of overall spring stiffness of any system having more than one spring connected in series or parallel.

**11. List out the various methods of finding the natural frequency of free longitudinal vibrations.**

1. Energy method, 2. Equilibrium method and 3. Rayleigh's method.

**12. What is the principle of Rayleigh's method of finding natural frequency of vibrations?**

The principle of Rayleigh's method is "the maximum kinetic energy at the mean position is equal to the maximum potential energy or (strain energy) at the extreme position.

**13. Distinguish between critical damping and large damping.**

If system is critically damped, the mass moves back very quickly to its equilibrium position within no time. Whereas in large damping, the mass moves slowly to the equilibrium position.

**14. When do you say a vibrating system is under damped?**

The equation of motion of a free damped vibration is given by  $m \frac{d^2x}{dt^2} + c \frac{dx}{dt} + s = 0$ . If  $(s/m) > (c/2m)^2$ , then radical becomes negative. The two roots  $k_1$  and  $k_2$  are known as complex conjugate. Then the vibrating system is known as under damping.

**15. Define critical or whirling or whipping speed of a shaft.**

The speed at which resonance occurs is called critical speed of the shaft. In other words, the speed at which the shaft runs so that the additional deflection of the shaft from the axis of rotation becomes infinite is known as critical speed.

**16. What are the factors that affect the critical speed of a shaft?**

The critical speed essentially depends on

- a) The eccentricity of the C.G. of the rotating masses from the axis of rotation of the shaft,
- b) Diameter of the disc, c) span of the shaft, and
- d) Type of supports connections at its ends.

**17. What are the causes of critical speed?**

- 1. Eccentric mountings,
- 2. Bending due to self weight, and
- 3. Non-uniform distribution of rotor material.

**18. Define damping ratio.**

It is defined as the ratio of actual damping coefficient to the critical damping coefficient.

**19. Define logarithmic decrement.**

Logarithmic decrement is defined as the natural logarithm of the amplitude reduction factor. The amplitude reduction factor is the ratio of any two successive amplitudes on the same side of the mean position.

**20. What is meant by dynamic magnifier or magnification factor?**

It is the ratio of maximum displacement of the forced vibration to the deflection due to the static force.

**21. What is meant by transmissibility?**

When a machine is supported by a spring, the spring transmits the force applied on the machine to the fixed support or foundation. This is called as transmissibility.

**22. Define transmissibility ratio or isolation factor.**

The ratio of force transmitted to the force applied is known as transmissibility ratio.

**23. Briefly explain elastic suspension.**

When machine components are suspended from elastic members, the vibration force produced by the machine components will not be transmitted to the foundation. This is called as elastic suspension.

**PART-B (16 Marks)**

1. Derive an expression for the natural frequency of the free longitudinal vibration by (i) Equilibrium method (ii) Energy method (iii) Rayleigh's method (16)

2. In a single degree of damped vibration system a suspended mass of 8kg makes 30 oscillations in 18 seconds. The amplitude decreases in 18 seconds. The amplitude decreases to 0.25 of the initial value after 5 oscillations. Determine (i) the spring stiffness (ii) logarithmic decrement (iii) damping factor (iv) Damping coefficient. (16)

3. Determine equation of motion when a liquid column vibrating in a 'U'tube by (i) Newton's method (ii) Energy method and hence find its natural frequency. (16)

4. (i) Deduce the expression for the free longitudinal vibration in terms of spring stiffness, its inertia effect and suspended mass. (8) (ii) A spring mass system has spring stiffness 's' N/m and has a mass of 'm' kg. It has the natural frequency of vibration as 12 Hz. An extra 2kg mass is coupled to 'm' and natural frequency reduces by 2 Hz. Find the value of 's' and 'm'. (8)

5. A vibrating system consists of a mass of 8kg, spring of stiffness 5.6 N/m and dashpot of damping coefficient of 40 N/m/s. Find, (i) Critical damping coefficient (ii) the

damping factor (iii)the natural frequency of damped vibration (iv)the logarithmic decrement(v)the ratio of two consecutive amplitude (vi)the number of cycle after which the original amplitude is reduced to 20 percent.

6. An instrument vibrates with a frequency of 1Hz when there is no damping. When the damping is provided, the frequency of damped vibration was observed to be 0.9Hz. Find, (i) damping factor

(ii) Logarithmic decrement. (16)

7. Find the equation of motion for the spring mass-dashpot system for the cases when (i)  $\zeta = 2$  (ii)  $\zeta = 1$  and (iii)  $\zeta = 0.3$ . The mass 'm' is displaced by a distance of 30mm and releases and torsional vibrations.(16)

8. Between a solid mass of 0kg and the floor are kept two slabs of isolates, natural rubber and felt, in series. The natural rubber slab has a stiffness of 3000N/m and equivalent viscous damping coefficient of 100 N-sec/m. The felt has a stiffness of 12000N/m and equivalent viscous damping coefficient of 330Nsec/ m. Determine undamped and the damped natural frequencies of the system in vertical direction. (16)

9. (i) A cantilever shaft 50mm diameter and 300mm long has a disc of mass 100kg at its free end. The young's modulus for the shaft material is 200GN/m<sup>2</sup>.SDetermine the frequency of longitudinal and transverse vibration of the shaft. (10) (ii)Explain the sketches different cases of damped vibrations. (6)

10. The barrel of a large gun recoils against a spring on firing. At the end of the firing, a dashpot is engaged that allows the barrel to return to its original position in minimum time without oscillation. Gun barrel mass is 400kg and initial velocity of recoils 1m.Determine spring stiffness and critical damping coefficient of dashpot. (16)

11. A steel shaft 100mm in diameter is loaded and support in shaft bearing 0.4m apart. The shaft carries three loads: first mass 12kg at the centre, second mass 10kg at a distance 0.12m from the left bearing and third mass of 7kg at a distance 0.09m from the right bearing. Find the value of the critical speed by using Dunker ley's method.  $E=2 \times 10^{11} \text{N/m}^2$  (16)

## UNIT-IV

### **PART-A (2 marks)**

#### **1. Specify the importance of vibration isolation?**

When an unbalanced machine is installed on the foundation, it produces vibration in the foundation. So, in order to prevent these vibrations or to minimize the transmission of forces to the foundation, vibration isolation is important.

#### **2. What are the methods of isolating the vibration?**

1. High speed engines/machines mounted on foundation and supports cause vibrations of excessive amplitude because of the unbalanced forces. It can be minimized providing spring-damper, etc.
2. The materials used for vibration isolation are rubber, felt cork, etc. These are placed between the foundation and vibrating body.

#### **3. Define torsional vibration.**

When the particles of a shaft or disc move in a circle about the axis of the shaft, then the vibrations are known as torsional vibrations.

#### **4. Differentiate between transverse and torsional vibration.**

1. In transverse vibrations, the particles of the shaft move approximately perpendicular to the axis of the shaft. But in torsional vibrations, the particles of the shaft move in a circle about the axis of the shaft.
2. Due to transverse vibrations, tensile and compressive stresses are induced. Due to torsional vibrations, torsional shear stresses are induced in the shaft.

### **5. Define node in torsional vibration.**

Node is the point or the section of the shaft at which amplitude of the torsional vibration is zero. At nodes, the shaft remains unaffected by the vibration.

### **6. Define torsional equivalent shaft.**

A shaft having variable diameter for different lengths can be theoretically replaced by an equivalent shaft of uniform diameter such that they have the same total angle of twist when equal opposing torques are applied at their ends. Such a theoretically replaced shaft is known as torsionally equivalent shaft.

### **7. What are the conditions to be satisfied for an equivalent system to that of geared system in torsional vibrations?**

1. The kinetic energy of the equivalent system must be equal to the kinetic energy of the original system.
2. The strain energy of the equivalent system must be equal to the strain energy of the original system.

### **PART-B (16 Marks)**

1. A mass of 50kg is supported by an elastic structure of total stiffness 20KN/m. The damping ratio of the system is 0.2. A simple harmonic disturbing force acts on the mass and at any time 't seconds, the force is  $60\sin 10t$  Newton's. Find amplitude of the vibration and phase angle caused by the damping. (16)

2. A mass of 50kg is supported by an elastic structure of total stiffness 20KN/m. The damping ratio of the system is 0.25. A simple harmonic disturbing force acts on the mass and at any time 't seconds, the force is  $75\cos 12t$  Newton's. Find amplitude of the vibration and phase angle caused by the damping. (16)

3. A mass of 10kg is suspended from one end of a helical spring, the other end being fixed. The stiffness of the spring is 10N/mm. The viscous damping causes the amplitude to decrease to one-tenth of the initial value in four complete oscillations. If a periodic force of  $150\cos 50t$  N is applied at the mass in the vertical direction. Find the amplitude of the forced vibrations? What is its value of resonance? (16)

4. A harmonic exciting force of 25N is acting on a machine part which is having a mass of 2Kg and vibrating in viscous medium. The exciting force causes resonant amplitude of 12.5mm with a period of 0.2sec. (16)

5. A body having a mass of 15kg is suspended from a spring which deflects 12mm under the weight of the mass. Determine the frequency of the free vibrations. What is the viscous damping force needed to make the motion a periodic at a speed of 1mm/s? If, when damped to this extent a disturbing force having a maximum value of 100N and vibrating at 6Hz is made to act on the body, determine the amplitude of the ultimate motion. (16)

6. A single cylinder vertical petrol engine of total mass of 200kg is mounted upon a steel chassis frame. The vertical static deflection of the frame is 2.4mm due to the weight of the engine. The mass of the reciprocating parts is 18kg and stroke of piston 160mm with S.H.M. If dashpot of damping coefficient of 1N/mm/s used to dampen the vibrations, calculate all steady state

(i) Amplitude of vibrations at 500rpm engine speed. (ii) The speed of the driving shaft at which resonance will occur. (16)

7. A vertical single stage air compressor having a mass of 500kg is mounted on spring having stiffness of  $1.96 \times 10^5$  N/m and dashpot with damping factor of 0.2m. The rotating parts are completely balanced and the equivalent reciprocating parts weight 20kg. The stroke is 0.2m. Determine the dynamic amplitude of vertical motion of the excitation force if the compressor is operate at 200rpm. (16)

8. A machine 100kg has a 20kg rotor with 0.5mm eccentricity. The mounting spring have  $s = 85 \times 10^3$ . The operating speed is 600rpm and the unit is constrained to move vertically. Find (i) Dynamic amplitude of machine (ii) the force transmitted to the support. (16)

9. A single cylinder engine has an out of balance force of 500N at an engine speed of 30rpm. The total mass of engine is 150kg and its carried on a set of total stiffness 300N/cm. (i) Find the amplitude of steady motion of the mass and maximum oscillating force transmitted to the foundation. (ii) If a viscous damping is interposed between the mass and the foundation the damping force 1000N at 1m/s of velocity,

find the amplitude of force damped oscillation of the mass and its angle of lag with disturbing force. (16)

10. An industrial machine weighting 445kg is supported on a spring with a statical deflection of 0.5cm.If the machine has rotating imbalance of 25kg-cm.Determine the force transmitted at 1200rpm and the dynamic amplitude at the speed. (16)

11. The mass of an electric motor is 120kg and it runs at 1500rpm.The armature mass is 35kg and its centra gravity lies 0.5mm from axis of rotation. The motor is mounted on five springs of negligible damping. So that the force transmitted is one-eleventh of the impressed force. Assume that the mass of the motor is equally distributed among the five springs. Determine (i) the stiffness of the spring (ii) the dynamic force transmitted to the base at the operating speed. (iii) Natural frequency of system. (16)

12. Find the stiffness of each spring when a refrigerator unit having a mass of 30kg is to be support by three springs. The force transmitted to the supporting structure is only 10% of the impressed force. The refrigerator unit operates at 420rpm.

## UNIT-V

### **PART-A (2 marks)**

#### **1. Explain the function of Governor?**

The function of a governor is to maintain the speed of an engine within specified limits whenever there is a variation of load. Governors control the throttle valve and hence the fuels supply to cater the load variation in engines.

#### **2. What is the principle of inertia governors?**

In inertia governors, the balls are so arranged that the inertia forces caused by an angular acceleration or retardation of the shaft tend to alter their positions.

#### **3. What is equilibrium speed?**

The speed at which the governor balls arms, sleeve, etc., are in complete equilibrium and there is no upward or downward movement of the sleeve on the spindle is known as equilibrium speed.

#### **4. Explain controlling force?**

An equal and opposite force to the centrifugal force acting radially inwards (i.e.centripetal force) is termed as controlling force of a governor.

**5. Explain the governor effort?**

The mean force acting on the sleeve for a given percentage change of speed for lift of the sleeve is known as the governor effort.

**6. Define power of a governor?**

The power of a governor is the work done at the sleeve for a given percentage change of speed. It is the product of the mean value of the effort and the distance through which the sleeve moves.

**7. Explain sensitiveness of governors?**

The sensitiveness is defined as the ratio of the mean speed to the difference between the maximum and minimum speeds.

**8. What is meant by hunting?**

The phenomenon of continuous fluctuation of the engine speed above and below the mean speed is termed as hunting. This occurs in over sensitive governors.

**9. Explain the term stability of the governor?**

A governor is said to be stable if there is only one radius of rotation for all equilibrium speeds of the balls within the working range. If the equilibrium speed increases the radius of governor ball must also increase.

**10. Explain isochronism.**

A governor with zero range of speed is known as an isochronous governor.

**11. Give the application of gyroscopic principle.**

It is used a) in instrument or toy known as gyroscope, b) in ships in order to minimize the rolling and pitching effects of waves, and c) in aeroplanes, monorail cars, gyrocompasses, etc.

**12. Define steering, pitching and rolling.**

Steering is the turning of a complete ship in a curve towards left or right, while it moves forward.

Pitching is the movement of a complete ship up and down in a vertical plane about transverse axis.

Rolling is the movement of a ship in a linear fashion.

**13. Explain gyroscopic couple?**

If a body having moment of inertia  $I$  and rotating about its own axis at  $\omega$  rad/sec is also caused to turn at  $\omega_p$  rad/sec about an axis perpendicular to axis of spin, then it experiences a gyroscopic couple of magnitude  $(\omega \omega_p)$  in an axis which is perpendicular to both the axis of spin and axis of precession.

**14. Define the term system.**

A system is an assembly of components and linkages designed to fulfill some particular function.

**15. Define transfer function.**

A transfer function is the ratio of output from the block and input to the block.

**16. What is meant by lag in response?**

In any control system, there is a delay in response due to some inherent cause and it becomes difficult to measure the input and output simultaneously.

**PART-B (16 Marks)**

1. A porter governor has equal arms each 250mm long and pivoted on the axis of rotation. Each ball has a mass of 5kg and mass of the central load on the sleeve is 25kg. The radius of rotation of the ball is 150mm when governor is at maximum speed. Find the maximum and minimum speed and range of speed of the governor. (16)
2. The length of the upper and lower arms of a porter governor are 200mm and 250mm respectively. Both the arms are pivoted on the axis of rotation. The central load is 150N, the weight of the each ball is 20N and the friction of the sleeve together with the resistance of the operating gear is equivalent to a force of 30N at the sleeve. If the limiting inclinations of the upper arms to the vertical are  $30^\circ$  and  $40^\circ$  taking friction in to account. Find the range of speed of the governor. (16)
3. Calculate the range of speed of a porter governor which has equal arms of each 200mm long and pivoted on the axis of rotation. The mass of each ball is 4kg and the central load of the sleeve is 20kg. The radius of rotation of the ball is 100mm when the governor being to lift and 130mm when the governor is at maximum speed. (16)

4. A Hartnell governor having a central sleeve spring and two right angled bell crank lever operates between 290rpm and 310rpm for a sleeve lift of 15mm. The sleeve and ball arms are 80mm and 120mm respectively. The levers are pivoted at 120mm from the governor axis and mass of the ball is 2.5kg. The ball arms are parallel at lowest equilibrium speed. Determine (i) load on the spring at maximum and minimum speeds and (ii) Stiffness of the spring. (16)

5. A governor of Hartwell type has equal balls of mass 3kg, set initially at a radius of 200mm. The arms of the bell-crank lever are 110mm vertically and 150mm horizontally. Find (i) the initial compressive force on the spring at a radius of 200mm at 240rpm and (ii) the stiffness of the spring required to permit a sleeve movement of 4mm on a fluctuation of 7.5 percent in the engine speed.

6. The controlling force in a spring controlled governor is 1500N when radius of rotation is 200mm and 887.5N when radius of rotation is 130mm. The mass of each ball is 8kg. If the controlling force curve is a straight line, then find (i) Controlling force at 150mm radius of rotation (ii) Speed of the governor at 150mm radius. (iii) Increase in initial tension so that governor is isochronous.

(iv) Isochronous speed. (16)

7. In a spring controlled governor, the controlling force curve is a straight line. When the balls are 400mm apart, the controlling force is 1200N and when 200mm apart, the controlling force is 450N. Determine the speed at which the governor runs when the balls are 250mm apart. When initial tension on the spring would be required for isochronism and what would be the speed. Take mass of each ball to be 10kg. (16)

8. Calculate the minimum speed of a Porter governor, which has equal arms each of 200mm and are provided on the axis of rotation. The mass of each ball is 4kg and the central mass on the sleeve is 20kg. The extension arms of the lower links are each 60mm long and parallel to the axis when the minimum radius of the ball is 100mm. of load. (16)

9. (i) Explain the effect of Gyroscopic couple on a Naval ship during pitching. (8) (ii) Explain the effect of Gyroscopic couple on a Aero plane. (8)

10. Each paddle wheel of a steamer has a mass of 1600kg and a radius of gyration of 1.2meters. The steamer turns to port in a circle of 160meters radius at 24Km/hr. The

speed of the paddle is 90rpm. Find the magnitude and effect of the gyroscopic couple acting on the steamer. (16)

11. The rotor of a turbine yacht rotates at 1200rpm clockwise when viewed from stern. The rotor has a mass of 750 kg and radius of gyration of 250mm. Find the maximum gyroscopic couple transmitted to the hull when yacht pitches with a maximum angular velocity of 1 rad/s. What is the effect of this couple? (16)

12. The turbine rotor of a ship has a mass of 20 tones and a radius of gyration 0.75. Its speed is 2000rpm. The ship pitches  $6^\circ$  above and below the horizontal position. One complete oscillation takes 18 seconds and the motion is simple harmonic. Determine (i) the maximum couple tending to shear the holding down bolt of the turbine (ii) The maximum angular acceleration of the ship during pitching (iii) The direction in which the bow will tend to turn while, if the rotation of the rotor is clockwise when looking from rear. (16)