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Beyond Knowledge

Question Bank

DYNAMICS OF MACHINES

Department of Mechanical Engineering

DYNAMICS OF MACHINES

UNIT -1 - FORCE ANALYSIS

1. What is free body diagram?

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

2. Define static force analysis.

If components of a accelerate, inertia is produced due to their masses. However, the magnitude of these forces is 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. Differentiate between static & dynamic equilibrium.

Necessary and sufficient conditions for static and dynamic equilibrium are:

1. Vector sum of all the forces acting on a body is zero.
2. The vector sum of all the moments of all the forces acting about any arbitrary point or axis is zero.

First conditions are sufficient conditions for static equilibrium together with second condition is necessary for dynamic equilibrium.

4. Define applied and constraint force.

The external force acting on a system of body from outside the system is called applied force. The constraint forces are the forces existing internally within the body.

5. 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 magnitude of these forces are small compared to the externally applied loads, they can be neglected while analysis the mechanism. Such an analysis is known as static force analysis.

6. 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 = $-m.a$

7. 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.

8. State principle of superposition.

The principle of superposition 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.

9. 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.

10. Define crank effort and crank pin effort.

Crank effort is the net effort applied at the crank pin perpendicular to the crank, which gives the required turning moment on the crank shaft.

The component of force acting along connecting rod perpendicular to the crank is known as crank-pin effort.

11. 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 and crank angle as abscissa.

12. Explain the term maximum fluctuation of energy in flywheels.

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

Maximum fluctuation=maximum energy-minimum energy.

13. Define coefficient of fluctuation of energy.

It is the ratio of maximum fluctuation of energy to the work done per cycle.
 $C_e = \text{maximum fluctuation of energy} / \text{work done per cycle}.$

14. Define coefficient of fluctuation of speed.

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

$$C_s = (N_1 - N_2) / N$$

Where,

$N_1 = \text{maximum speed}$

N_2 =minimum speed

N =mean speed= $(N_1+N_2)/2$.

15. Define coefficient of steadiness.

The reciprocal of the fluctuation of speed is known as coefficient of steadiness. $M=1/C_s =N/ (N_1-N_2)$.

16. Flywheels are needed in forging and pressing operation?

In both forging and pressing operation, flywheels are required to control the variations in speed during each cycle of an engine.

17. What is cam dynamics?

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

18. Define unbalance and spring surge.

Unbalance: A disc cam produces unbalance because its mass is not symmetrical with the axis of rotation.

Spring surge: Spring surge means vibration of the retaining spring.

19. Define windup. What is the remedy for camshaft windup?

Twisting effect produced in the camshaft during the raise of heavy load follower is called as windup.

Camshaft windup can be prevented to a large extent by mounting the flywheel as close as possible to the cam.

20. What are the effect and causes of windup?

The effect of windup will produce follower jump or float or impact.

Causes of windup are:

- When heavy loads are moved by the follower,
- When the follower moves at a high speed, and
- When the shaft is flexible.

UNIT - 2 – BALANCING

1) What is meant by balancing of rotating masses?

The process of providing the second mass in order to counteract the effect of the centrifugal force of the unbalanced first mass is called balancing of rotating masses

2) Why rotating masses are to be dynamically balanced?

If the rotating masses are not dynamically balanced, the unbalanced dynamic force will cause worse effect such as wear and tear on bearing and excessive vibrations on the machines. It is very common in cam shafts, steam turbine rotors, engine crank shafts, and centrifugal pumps, etc.

3) Define static balancing?

A system of rotating mass is said to be static balance if the combined mass centre of the system lies on the axis of rotation.

4) Define dynamic balancing?

A system of rotating masses is in dynamic balance when there doesn't exist any resultant centrifugal force as well as resultant couple.

5) State the conditions for static and dynamic balancing?

- 1) The net dynamic force acting on the shaft is zero. This is called as conditions for static balancing.
- 2) The net couple due to dynamic force acting on the shaft is zero.

6) State the conditions for complete balance of several masses revolving in different planes of a shaft?

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

7) 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 give 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 engine.

8) Can a single cylinder engine be fully balanced? Why?

No. A single cylinder engine can't be fully balanced. Because the unbalanced forces due to reciprocating masses remains constant in magnitude (because of variation in Θ).

9) Differentiate between the unbalanced force caused due to rotating and reciprocating masses?

1. Complete balancing of revolving mass can be possible. But fraction of reciprocating masses only balanced
2. The unbalanced force due to reciprocating masses 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.

10) Why are the crank of a locomotive, with two cylinders, placed in 90° to each other?

In order to facilitate the starting of locomotive in any position (i.e., in order to have uniformity in turning moment) the cranks of a locomotive are generally at 90° to one another.

11) List the effect of partial balancing of locomotives?

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

12) Define swaying couple?

The unbalanced force acting at a distance between the line of stroke of two cylinder, constitute a couple in horizontal direction. This couple is called as swaying couple

13) Define hammer blow with respect to locomotives?

The maximum magnitude of the unbalanced force along the perpendicular to the line of stroke is known as hammer blow.

14) What are the effect of hammer blow and swaying couple?

1. The effect of hammer blow is to cause the variation in pressure between the wheel and the rail, such that vehicle vibrates vigorously.
2. The effect of swaying couple is to make the leading wheels sway from side to side.

15) what for the balancing machines are used?

- i. Determine whether the rotating parts of a machine is completely balanced or not;
- ii. Check the static and dynamic balancing of rotating parts; and
- iii. Determine the extent to which the balancing is done (in case of unbalanced system).

17) What are different types of balancing machines?

1. Static balancing machines,
2. Dynamic balancing machines, and
3. Universal balancing machines.

18) Define tractive force?

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

19) Unbalanced effects of shafts in high speed machines are to be closely looked into – Why?

The dynamic forces of centrifugal forces or a result of unbalanced masses are a function the angular velocity of rotation.

20. 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.

21. Write different types of balancing?

- a) Balancing of rotating masses
 - Static balancing
 - Dynamic balancing
- b) Balancing of reciprocating masses.

22. State the conditions for complete balance of several masses revolving in different planes of a shaft?

- (a) The resultant centrifugal force must be zero, and
- (b) The resultant couple must be zero.

23. 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.

24. Whether your watch needles are properly balanced or not?

Yes, my watch needles are properly balanced by providing some extra projection (mass) in the opposite direction.

25. Why is only a part of the unbalanced force due to reciprocating masses balanced by revolving mass? (Or) 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.

26. Can a single cylinder engine be fully balanced? Why?

- No. A single cylinder engine cannot be fully balanced.
- Because the unbalanced forces due to reciprocating masses remains constant in direction but varies in magnitude.

27. Differentiate between the unbalanced force caused due to rotating and reciprocating masses?

- Complete balancing of revolving mass can be possible. But fraction of reciprocating mass only balanced.
- 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.

28. Why are the cranks of a locomotive, with two cylinders, placed 90° to each other?

In order to facilitate the starting of locomotive in any position (i.e., in order to have uniformity in turning moment) the cranks of a locomotive are generally at 90° to one another.

UNIT – III – SINGLE DEGREE FREE VIBRATION

1. What are the different types of vibrations?

- Free vibrations,
- Forced vibrations, and
- Damped vibration

2. State different methods of finding natural frequency of a system?

- Equilibrium (or Newton’s) method,

- Energy method, and
- Rayleigh method.

3. What is meant by free vibration and forced vibrations?

Free or natural 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 vibrations.

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

4. What do you mean by damping and damped vibration?

Damping: The resistance against the vibration is called damping.

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

5. 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.

6. What are the various types of damping?

- (a) Viscous damping
- (b) coulomb or dry friction damping
- (c) Solid or structural damping, and
- (d) slip or interfacial damping.

7. What is the limit beyond which damping is detrimental and why?

When damping factor $\xi > 1$, the aperiodic motion is resulted. That is, aperiodic motion means the system cannot vibrate due to over damping. Once the system is disturbed, it will take infinite time to come back to equilibrium position.

8. When do you say a vibration system in under-damped?

The equation of motion of a free damped vibration is given by

$$\frac{d^2x}{dt^2} + \frac{c}{m} \frac{dx}{dt} + \frac{s}{m} x = 0$$

$$\text{if } \frac{s}{m} > \left(\frac{c}{2m}\right)^2,$$

, then radical becomes negative. The two roots k_1 and k_2 are known as complex conjugate. Then the vibration system is known as under-damping.

9. What is meant by critical damping?

The system is said to be critically damped when the damping factor $\zeta = 1$. If the system is critically damped, the mass moves back very quickly to its equilibrium position within no time.

10. Explain the Dunkerley's method used in natural transverse vibration?

The natural frequency of transverse vibration for a shaft carrying a number of point loads and uniformly distributed load is obtained by Dunkerley's formula. Dunkerley's formula:

$$\frac{1}{f_n^2} = \frac{1}{(f_{n1})^2} + \frac{1}{(f_{n2})^2} + \frac{1}{(f_{n3})^2} + \dots + \frac{1}{(f_{nm})^2}$$

$f_{n1}, f_{n2}, f_{n3}, \dots, f_{nm}$, etc. = Natural frequency of transverse vibration at each point loads, and

f_{nm} = Natural frequency of transverse vibration of the UDL.

11. 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.

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

The critical speed essentially depends on:

- The eccentricity of the C.G of the rotating masses from the axis of rotation of the shaft,
- Diameter of the disc,
- Span of the shaft, and
- Type of supports connections at its ends.

13. Critical speed of shaft is the same as the natural frequency of transverse vibration. Justify?

We know that critical or whirling speed, $\omega_w = \omega_n$

$$\omega_w = \omega_n = \sqrt{\frac{s}{m}} = \sqrt{\frac{g}{\delta}} \text{ Hz}$$

If N_c is the critical speed in rps, then

$$2\pi N_c = \sqrt{\frac{g}{\delta}} \Rightarrow N_c = \frac{1}{2\pi} \sqrt{\frac{g}{\delta}} = \frac{0.4985}{\sqrt{\delta}} \text{ rps}$$

Hence proved.

14. What are the causes of critical speed? (Or) Why is critical speed encountered?

The critical speed may occur due to one or more of the following reasons:

- Eccentric mountings like gears, flywheels, pulleys, etc.,
- Bending of the shaft due to self-weight,
- Non-uniform distribution of rotor material, etc.

15. 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.

16. Differentiate between transverse and torsional vibration?

- 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.
- Due to transverse vibrations, tensile and compressive stresses are induced.
- Due to torsional vibrations, torsional shear stresses are induced in the shaft.

17. Define torsional equivalent shaft?

A shaft having 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 torsion ally equivalent shaft.

18. State natural frequency of torsional vibration of a simple system?

Natural frequency of torsional vibration, $f_n = \frac{1}{2\pi} \sqrt{\frac{CJ}{I}}$

Where C = Rigidity modulus of shaft,

I = Mass M.I. of rotor,

J = polar M.I of shaft, and

l = Length of shaft from rotor.

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

Two conditions are:

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

20. What is meant by degrees of freedom in a vibrating system?

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

UNIT – IV – FORCED VIBRATIONS

1. Define damping ratio or damping factor?

It is defined as the ratio of actual damping coefficient (c) to the critical damping coefficient (C_c)

Mathematically, Damping ratio, $\zeta = \frac{c}{c_c} = \frac{c}{2m\omega_n}$

2. 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.

3. Give the equation for damping factor ζ and damped frequency ω_d ?

$$(i) \text{ Damping factor, } \zeta = \frac{c}{c_c} = \frac{c}{2m\omega_n}$$

$$(ii) \text{ Damped frequency, } \omega_d = f_d = \sqrt{1 - \zeta^2} \times \omega_n$$

Where c = Damping coefficient,

c_c = Critical damping coefficient, and

ω_n = Natural or Undamped frequency.

4. What is meant by harmonic forcing?

The term harmonic refers to a spring-mass system with viscous damping, excited by a sinusoidal harmonic force. $F = F_0 \sin \omega t$

5. What is the relationship between frequencies of undamped and damped vibrations?

$$\frac{f_d}{f_n} = \frac{\left(\frac{\omega_d}{2\pi}\right)}{\left(\frac{\omega_n}{2\pi}\right)} = \frac{\omega_d}{\omega_n} = \sqrt{1 - \zeta^2}$$

6. What is meant by dynamic magnifier or magnification factor? What are the factors on which it depends?

- It is the ratio of maximum displacement of the forced vibration (x_{max}) to the deflection due to the static force F (x_0)

$$D = \frac{x_{max}}{x_0} = \frac{1}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\zeta \frac{\omega}{\omega_n}\right]^2}} = \frac{1}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

It depends on: (i) the ratio of circular frequencies ($\frac{\omega}{\omega_n}$), and

(ii) the damping factor (ζ)

7. Define 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 transmissibility.

8. Define transmissibility ratio or isolation factor?

The ratio of force transmitted (F_T) to the force applied (F) is known as transmissibility ratio

$$\varepsilon = \frac{F_T}{F_0} = \frac{\sqrt{1 + (2\zeta r)^2}}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

Where $r = \text{Frequency ratio} = \left(\frac{\omega}{\omega_n}\right)$

9. Briefly explain elastic suspension?

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

10. Specify any two industrial application where the transmissibility effects of vibration are important?

- (a) All machine tools (b) All turbo machines.

11. What is vibration isolation?

The term vibration isolation refers to the prevention or minimisation of vibrations and their transmission due to the unbalanced machines.

12. 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.

13. What are the methods of isolating the vibration?

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

14. Give Examples of forced vibrations.

- Ringing of electrical bell
- The vibrations of air compressors, internal combustion engines, machine tools and various other machinery.

15. What are the types of external excitation?

- Periodic forces
- Impulsive forces and
- Random forces.

16. Give the governing equation of damped forced vibrations.

$$\frac{d^2x}{dt^2} + \frac{c}{m} \frac{dx}{dt} + \frac{s}{m} x = \left(\frac{F_0}{m} \right) \sin \omega t$$

17. What are isolating materials?

- Rubber
- Felt
- Cork
- Metallic Springs

18. Define vibration isolation.

The process of reducing the vibrations of machines and hence reducing the transmitted force to the foundation using vibration isolating materials is called vibration isolation.

19. What are the types of isolation?

- Isolation of force
- Isolation of motion.

20. Define Amplitude Transmissibility.

Amplitude transmissibility is defined as the ratio of absolute amplitude of the mass (x_{max}) to the base excitation amplitude(y).

UNIT – V - MECHANISM FOR CONTROL

1. What is 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 fuel supply to cater the load variation on engines.

2. How governors are classified?

- (a). Centrifugal governors.
 - Pendulum type: Example: Watt governor.
 - Gravity controlled type: Example: Porter and Proell governors.
 - Spring controlled type: Example: Hartnell and Hartung governors.
- (b). Inertia governors.

3. Differentiate between governor and flywheel?

SL NO	Governor	Flywheel
1	The function of a governor is to regulate the mean speed of an engine, when there are variations in the load.	The function of a flywheel is to reduce the fluctuations of speed caused by the engine turning moment during each cycle of operation.
2	It is provided on, prime movers such as engines and turbines.	It is provided on engine and fabricating machines viz., rolling mills, punching machines, shear machines, presses, etc.
3	It works intermittently, i.e., only when there is change in load.	It works continuously from cycle to cycle.
4	It has no influence over cyclic speed fluctuation	It has no influence on mean speed of the prime mover

4. What do you mean by 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.

5. 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. Power = Mean effort x Lift of sleeve.

6. What is meant by sensitiveness of a governor?

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

· A governor is said to be sensitive, when it really responds to a small change of speed.

7. Define coefficient of sensitiveness?

It is the ratio between range of speed and mean speed

$$\text{coefficient of sensitiveness} = \frac{N_1 - N_2}{N}$$

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 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. What is meant by isochronous condition in governors?

A governor with zero range of speed is known as an isochronous governor. Actually the isochronism is the stage of infinite sensitivity. i.e., when the equilibrium speed is constant for all radii of rotation of rotation of the balls within the working range, the governor is said to be in isochronism.

11. Can a Porter governor be isochronous?

For a Porter governor, Maximum speed (N_1) and minimum speed N_2 are given by

$$(N_1)^2 = m + \frac{m}{2}(1+q) \times \frac{895}{h_1}$$

$$(N_2)^2 = m + \frac{m}{2}(1+q) \times \frac{895}{h_2}$$

For isochronism, range of speed = ∞

$$\text{i.e., } N_1 - N_2 = 0 \Rightarrow h_1 = h_2$$

which is highly impossible. Hence Porter governor cannot be isochronous.

12. Give the application of gyroscopic principle?

It is used:

- In instrument or troy known as gyroscope,
- In ships in order to minimize the rolling and pitching effects of waves, and
- In aeroplane, monorail cars, gyrocompasses, etc.

13. What is gyroscopic torque?

Whenever a rotating body changes its axis of rotation, a torque is applied on the rotating body. This torque is known as gyroscopic torque.

14. 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.

15. What is the effect of gyroscopic couple on rolling of ship? Why?

We know that, for the effect of gyroscopic couple to occur, the axis of precession should always be perpendicular to the axis of spin. In case of rolling of a ship, the axis of precession is always parallel to the axis of spin for all positions. Hence there is no effect of the gyroscopic couple acting on the body of the ship during rolling.

16. The left hand and the right hand sides of the ship when viewed from the stern are called _____ and _____ respectively?

Ans: port ; star-board.

17. Discuss the effect of the gyroscopic couple on a two wheeled vehicle when taking a turn?

The gyroscopic couple will act over the vehicle outwards. The tendency of this couple is to overturn the vehicle in outward direction.

18. The engine of an aeroplane rotates in clockwise direction when seen from the tail end and the aeroplane takes a turn to the left. What will be the effect of the gyroscopic couple on the aeroplane?

The effect of gyroscopic couple will be to raise the nose and dip the tail.

19. Define gyroscopic couple?

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

20. Write the expression for gyroscopic couple?

$$\text{Gyroscopic couple, } C = I \cdot \omega \cdot \omega_p$$

Where I = Moment of inertia of the disc,
 ω = Angular velocity of the engine, and
 ω_p = Angular velocity of precession.

PART-B&C Questions**UNIT I - FORCE ANALYSIS**

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
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.
3. (i) Deduce the expression for the inertia force in the reciprocating force neglecting the weight of the connecting rod.
 (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° 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.
 (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.

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° 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.

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° from the inner dead center, the difference of pressure between cover end and piston rod is 0.4 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.

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° from IDC, the gas pressure on the cover and the crank sides are 500 KN/m^2 and 60 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.

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° from the top dead center, the gas pressure is 0.7 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.

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° from IDC the steam pressure above the piston is 30 KN/m^2 . Calculate,

- (i) Crank-pin effort
- (ii) The effective turning moment on the crank shaft.

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° . 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 275mm². 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.

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 θ 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° from the IDC.
- (iv) The maximum angular acceleration and retardation of the flywheel.

UNIT II BALANCING

1. A shaft is rotating at a uniform angular speed. Four masses M₁, M₂, and M₃ and M₄ 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, 250mm and 300mm respectively. The angle made by these masses with horizontal are 0° , 45° , 120° and 255° respectively. Find, (i) the magnitude of balancing mass (ii) the position of balancing mass if its radius of rotation is 200mm.

2. Four masses M₁, M₂, M₃, and M₄ 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° , 75° , and 135° . Find the position and magnitude of balance mass required if its radius of rotation is 0.25m.

3. The data for three rotating masses are given below:-

M₁=4kg r₁=75mm $\theta_1=45^\circ$ M₂=3kg r₂=85mm $\theta_2=135^\circ$ M₃=2.5kg r₃=50mm $\theta_3=240^\circ$ Determine the amount of counter mass at a radial distance of 65mm required for their static balance

4. Four masses A, B, C, and D are completely balanced masses C and D makes angles of 90° and 195° 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 revolve 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° and 240° 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.

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° and 195° 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 (16) apart. Determine (i) the magnitude of mass A and its angular position (ii) the position of planes A and D.

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.

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.

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

UNIT III SINGLE DEGREE FREE VIBRATION

1. Derive an expression for the natural frequency of the free longitudinal vibration by (i) Equilibrium method (ii) Energy method (iii) Rayleigh's method
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.
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.
4. (i) Deduce the expression for the free longitudinal vibration in terms of spring stiffness, its inertia effect and suspended mass.
(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 12Hz. An extra 2kg mass is coupled to 'm' and natural frequency reduces by 2Hz. Find the value of 's' and 'm'.
5. A vibrating system consists of a mass of 8kg, spring of stiffness 5.6N/m and dashpot of damping coefficient of 40N/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.
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 released
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 Nsec/m. The felt has a stiffness of 12000N/m and equivalent viscous damping coefficient of 330N-sec/m. Determine undamped and the damped natural frequencies of the system in vertical direction.

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/m². Determine the frequency of longitudinal and transverse vibration of the shaft.

(ii) Explain the sketches different cases of damped vibrations.

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

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 Dunkerley's method. $E=2 \times 10^{11} \text{N/m}^2$

UNIT IV FORCED VIBRATION

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 $60 \sin 10t$ newtons. Find amplitude of the vibration and phase angle caused by the damping.

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 $75 \cos 12t$ newtons. Find amplitude of the vibration and phase angle caused by the damping.

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?

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

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.
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 damped the vibrations, calculate at steady state (i) Amplitude of vibrations at 500rpm engine speed. (ii) The speed of the driving shaft at which resonance will occurs.
7. A vertical single stage air compressor having a mass of 500kg is mounted on spring having stiffness of $1.96 \times 10^5 \text{ N/m}$ and dashpot with damping factor of 0.2. 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.
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.
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.
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.
11. The mass of an electric motor is 120kg and it runs at 1500rpm. The armature mass is 35kg and its centre 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.

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 MECHANISM FOR CONTROL

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.

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° and 40° taking friction in to account. Find the range of speed of the governor.

3. Calculate the rage 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.

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 repectively. The levers are pivoted at 120mm from the governoraxis 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.

5. A governor of hartnell 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.

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 isochronisms and what would be the speed. Take mass of each ball to be 10kg.

8. Calculate the minimum speed of a proell 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.

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

10. Each paddle wheel of a steamer have 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.

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?

12. The turbine rotor of a ship has a mass of 20 tonnes and a radius of gyration 0.75. Its speed is 2000rpm. The ship pitches 6° 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.

Previous year university Question papers

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2010

Fifth Semester

Mechanical Engineering

ME 2302 — DYNAMICS OF MACHINERY

(Regulation 2008)

Time : Three hours Maximum : 100 Marks

Answer ALL questions

PART A — (10 × 2 = 20 Marks)

1. Distinguish between crank effort and piston effort.
2. Define co-efficient of fluctuation of energy.
3. When is a system said to be completely balanced?
4. Name the efforts caused by the unbalanced primary force acting along the line of stroke due to partial balancing of locomotives.
5. Name the types of motion exhibited by critically damped or over damped vibrating systems.
6. Define logarithmic decrement.
7. Define transmissible.
8. When does resonance take place in a system?
9. When is a governor said to be Isochronous?
10. When is a governor said to be stable?

PART B — (5 × 16 = 80 Marks)

11. (a) The lengths of crank and connecting rod of horizontal steam engine are 300 mm and 1.2 m respectively. When the crank has moved 30° from the inner dead center, the acceleration of piston is 35 m/s^2 . The average frictional resistance to the motion of piston is equivalent to a force of 550 N and net effective steam pressure on piston is 500 kN/m^2 . The diameter of piston is 0.3 m and mass of reciprocating parts is 160 kg. Determine (i) Reaction on the cross-head guides; (ii) Thrust on the crankshaft bearings; and (iii) Torque on the crank shaft.

Or

(b) The torque delivered by two-stroke engine is represented by $T = (1000 + 300 \sin 2\theta - 500 \cos 2\theta) \text{ N.m}$ Where θ is the angle turned by the crank from the inner-dead center. The engine speed is 250 rpm. The mass of the flywheel is 400 kg and radius of gyration 400 mm. 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° from the inner-dead center; and (iv) the maximum angular acceleration and retardation of the flywheel. [Marks 16]

12. (a) A shaft carries four rotating masses A, B, C and D in this order along its axis. The mass of B, C and D are 30 kg, 50 kg and 40 kg respectively. The planes containing B and C are 30 cm apart. The angular spacing of the planes containing C and D are 90° and 210° respectively relative to B measured in the same sense. If the shaft and masses are to be in complete dynamic balance, find (i) the mass and the angular position of mass A; and (ii) the position of planes A and D.

Or

(b) The firing order in a 6 cylinder vertical four stroke engine in-line engine is 1-4-2-6-3-5. The piston stroke is 100 mm and the length of each connecting rod is 200 mm. The pitch distances between the cylinder center lines are 100 mm, 100 mm, 150 mm, 100 mm, and 100 mm respectively. The reciprocating mass per cylinder is 1 kg and the engine runs at 3000 rpm. Determine the out-of-balance primary and secondary forces and couples on this engine, taking a plane midway between the cylinder 3 and 4 as the reference plane.

13. (a) Determine: (i) the critical damping co-efficient, (ii) the damping factor, (iii) the natural frequency of damped vibrations, (iv) the logarithmic decrement and (v) the ratio of two consecutive amplitudes of a vibrating system which consists of a mass of 25 kg, a spring of stiffness 15 kN/m and a damper. The damping provided is only 15% of the critical value.

Or

(b) A shaft of length 1.25 m is 75 mm in diameter for the first 275 mm of length, 125 mm in diameter for the next 500 mm length, 87.5 mm in diameter for the next 375 mm length and 175 mm in diameter for the remaining 100 mm of its length. The shaft carries two rotors at two ends. The mass moment of inertia of the first rotor is 75 kgm^2 whereas of the second rotor is 50 kgm^2 . Find the frequency of natural torsional vibrations of the system. The modulus of the rigidity of the shaft material may be taken as 80 GN/m^2 .

14. (a) A body having a mass of 15 kg is suspended from a spring which deflects 12 mm under 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 1 mm/s? If, when damped to this extent, disturbing force having a maximum value of 100 N and vibrating at 6 Hz is made to act on the body, determine the amplitude of the ultimate motion.

Or

(b) A machine supported symmetrically on four springs has a mass of 80 kg. The mass of the reciprocating parts is 2.2 kg which move through a vertical stroke of 100 mm with simple harmonic motion. Neglecting damping, determine the combined stiffness of the springs so that the force transmitted to the foundation is 1/20th of the impressed force. The machine crankshaft rotates at 800 rpm. If, under actual working conditions, the damping reduces the amplitudes of successive vibrations by 30%, find: (i) the force transmitted to the foundation at 800 rpm, and (ii) the force transmitted to the foundation at resonance.

15. (a) The turbine rotor of a ship has a mass of 2.2 tonnes and rotates at 1800 rpm clockwise when viewed from the aft. The radius of gyration of the rotor is 320 mm. Determine the gyroscopic couple and its effect when (i) The ship turns right at a radius

of 250 m with a speed of 25 km/h., (ii) The ship pitches with the bow rising at an angular velocity of 0.8 rad/s., and (iii) The ship rolls at an angular velocity of 0.1 rad/s.

Or

(b) The following particulars refer to a pro-ell governor with open arms: Length of all arms = 200 mm, distance of pivot of arms from the axis of rotation = 40 mm, length of extension of lower arms to which each ball is attached = 100 mm, mass of each ball = 6 kg and mass of the central load = 150 kg. If the radius of rotation of the balls is 180 mm when the arms are inclined at an angle of 40° to the axis of rotation, find the equilibrium speed for the above configuration.

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