Department of Mechanical Engineering

ME6505- DYNAMICS OF MACHINES

Two Marks Question and answer

UNIT – I FORCE ANALYSIS AND FLYWHEELS

1. Distinguish between space diagram and free body diagram

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

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 externally applied loads. Hence the 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 pull or push, which acts on the body changes or tends to change the state of rest or uniform motion of the body.

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

4. Give any 3 advantages of free body diagram

- They assist in seeing and understanding all aspects of problem
- They help in planning the approach to the problem
- Theymake mathematical relations easier to the problem.

5. When will the three force member is in equilibrium.

The resultant of forces is zero.
The line of action of the forces intersect at a point.

6. When will the two force member is in equilibrium.

- The two forces are of same magnitude.
- The forces acting along same line.
- The forces are in opposite direction.

7. Differentiate static force analysis and dynamic 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 externally applied loads. Hence the inertia effects due to masses are neglected. Such an analysis is known as static force analysis.
If the inertia effect due to masses of the component is also considered it is called as dynamic force analysis.

8. Define Inertia.

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

9. State D'Alembert's principle.

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

10. What do you mean by equivalent offset inertia force?

It is the force which can replace both inertia force and inertia torque.

11. Define Inertia force.

It is an imaginary force, which when acts upon a rigid body brings it in an equilibrium position.
Inertia force = - Accelerating force = - m.a

12. Define Inertia torque.

It 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.

13. Define maximum fluctuation of speed.

The difference between maximum and minimum during a cycle is called as maximum fluctuation of speed.
E = Max energy – Min Energy.

14. List out few machines in which flywheel are used.

A) Punching Machines B) Shearing Machines C) Rivetting Machines D) Crushing Machines.

15. Why smaller fly wheels is used in multi cylinder engines.

In a multi cylinder engine, there are one or more number of power strokes per revolution of the crank shaft. So lesser energy is to be stored in the flywheel. Hence smaller flywheel is sufficient.

16. Differentiate the functions of flywheel and governor.

S. No	Flywheels	Governors
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 the prime mover.	Its function is to control the mean speed over a period for output load variations
2	It works continuously from cycle to cycle.	Its works intermittently i.e. only when there is change in the load.
3	It has no influence on mean speed of the prime mover.	It has no influence over cyclic speed Fluctuations

17. Define turning moment diagram.

It is the graphical representation of the turning moment or crank effort for various position of the crank. The turning moment is taken in Y-Axis and crank angle is taken in X-Axis for plotting the turning moment diagram.

18. Define the principle of superposition.

It 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.

19. Define turning moment.

In all reciprocating engines, force acting on piston due to expansion of charges or gases, develops a torque on crank shaft, by means of connecting rod and crank mechanism. This torque is called as turning moment or crank effort.

20. Define coefficientt of maximum fluctuation of energy.

It is the ratio between max fluctuation of energy and the work done per cycle. CE = Maximum Fluctuation of energy/Work done per cycle

21. Define coefficient of maximum fluctuation of speed.

The ratio of maximum fluctuation of speed to the mean speed is called as coefficient of maximum fluctuation of speed.
CS = N1 – N2 = 2(N1 – N2)
N (N1+N2)
N1 – Max Speed : N2 – Min Speed

22. Define crank pin effort.

The component of FQ perpendicular to crank is known as crank pin effort.

23. Define crank effort.

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

24. State the function of a flywheel.

The function of flywheel is to reduce the fluctuations of speed during a cycle above and below the mean value for constant load from the prime mover.

25. How will you 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.

UNIT – II BALANCING

1. 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 the balancing of machine is necessary.

2. 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.

3. Write the different types of balancing.

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

4. Define static balancing.

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

5. State the condition for static balancing.

The net dynamic force acting on the shaft is equal to zero. This requires that the line of action of their centrifugal forces must be same.

6. Dynamic balancing implies static balancing. Justify.

Condition for dynamic balancing are
1. The net dynamic force acting on the shaft is equal to zero. This is the condition for static balancing.
2. The net couple due to dynamic forces acting on the shaft is zer

From the above it is understood that dynamically balanced system must be initially statically balanced one.

7. Write the condition for complete balancing.

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

8. Differentiate static and dynamic balancing

S. No	Static Balancing	Dynamic Balancing
1	The dynamic forces as a result of the unbalanced masses are balanced by introducing balancing masses in the plane of rotation or diff planes The net dynamic force acting on the shaft is made zero.	The arrangement made in static balancing gives rise to a couple which tends to rock the shaft in the bearing. Dynamic balancing considers the net couple as well as net dynamic force to do complete balancing.
2	It deals with only balancing of dynamic forces.	It deals with balancing of dynamic force and balancing couple due to dynamic force.

9. The product of rotating mass and perpendicular distance between the rotating mass and reference plane is called as ----------. (Ans: Mass Moment)

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10. Write the equation for balancing a single rotating mass by a single mass.

$m_1r_1 = m_2r_2$

11. Define Dalby's method of balancing masses.

Dalby's method is used for balancing several masses rotating in different planes. In this method several forces acting on several planes are transferred to a single reference plane.

12. Write the phenomenon of transferring forces from one plane to another.

Transferring a force (F) from one plane to another plane having a distance 'l' is equivalent to transfer of same force 'F' in magnitude and direction in the reference plane is accompanied by a couple of magnitude 'Fl'.

13. 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 obtained and the vibration will cause much noise.

14.Whether your watch needles are properly balanced?

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

15.Why complete balancing is not possible in reciprocating masses?

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 hammer blow, a part of the reciprocating mass is balanced. Hence complete balancing is not possible.

16. What are the various cases of balancing revolving masses?

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

17. Why cranks of a locomotive are generally at right angles to one another?

In order to facilitate the starting of locomotive in any position the cranks of a locomotive are generally at right angles to one another.

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

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

19. Define tractive force.

The resultant unbalanced force due to the 2 cylinders along the line of stroke, is known as tractive force.

20.Define swaying couple.

The unbalanced force acting at a distance between the line of stroke of 2 cylinders constitute a couple in the horizontal direction. This couple is called as swaying couple.

21.What is the effect of hammer blow and what is the cause 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.

22. 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 crankshaft are known as in-line engine.

23. Give the reason for selecting different firing orders.

In multi cylinder engines there are several possibilities of the order in which firing takes place. To overcome the problems of vibration, fuel distribution, exhaust distribution etc. the designers select different firing orders.

24. 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.
2. The algebraic sum of the couples due to primary and secondary forces must be zero.

25. 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.

UNIT – III FREE VIBRATION

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: It is the time interval after which the motion is repeated itself.
Cycle: It 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. Unit-Hz.

4. How will you classify vibration?

A) Free vibrations
a) Longitudinal vibration b) Transverse vibration c) Torsional vibration d) Forced vibrations **e)** Damped vibrations.

5. What is free vibration?

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

6.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 vibrations.

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.

9. A cantilever beam has ---------- number of degree of freedom. (Ans: infinite).

10. Define steady state vibration.

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

11. List out methods of finding the natural frequency of free longitudinal vibration.

a) Energy method
b) Equilibrium method
c) Rayleigh's method.

12. What is the principle of Rayleigh's method of finding natural 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 postion.

13. A shaft supported in long bearing is assumed to have ---------- for solving transverse vibration problems. (Ans: Both ends fixed)

14. The damping force per unit velocity is known as ----------. (Ans: damping coefficient)

15. Define critical or whirling or whipping speed of 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 rotation masses from the axis of rotation of the shaft,
b) Diameter of the disc
c) Span (length) of the shaft
d)Type of supports connections at its ends.

17. What are the causes of critical speed?

a) Eccentric mountings.
b) Bending due to self weight
c) Non-Uniform distribution of rotor material.

18. Define vibration.

Any motion which repeats itself after as interval of time is called as vibration or oscillation.

19. Define forced vibration.

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

20. What is longitudinal vibration?

When the particles of the shaft or disc moves parallel to the axis of the shaft, then the vibrations are known as longitudinal vibrations.

21. Define transient vibration.

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.

22. Define amplitude.

The maximum displacement of a vibrating body from the mean position is amplitude.

23. What is simple harmonic motion?

The motion of a body to and fro about a fixed point is simple harmonic motion.

24. What are transverse vibrations?

When the particles of the shaft or disc move approximately perpendicular to the axis of the shaft, then the vibrations are known as transverse vibrations.

25. What are torsional vibrations?

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

UNIT – IV FORCED VIBRATION

1. A vibrating system consist of a mass of 7 kg and a spring stiffness 50 N/cm and damper of damping coefficient 0.36 Ncm-1 sec. Find the damping factor.

M= 7kg, s=50 N/cm, c= 0.36 Ncm-1 sec= 36N/m/sec ωn
= √(s/m) = √(5000/7) = 26.72 rad/sec
cc = 2m = 2x7x26.72 = 374.16 N/m/s
Damping factor = c/ cc = 0.0962.

2. What is the relationship between frequencies of undamped and damped vibrations? fd/fn =

(ωd / 2π) / (ωn / 2π) = (ωd / ωn)

3. 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.

4. Define transmissibility ratio or isolation factor

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

5. 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 elastic suspension.

6. Specify any 2 industrial applications where the transmissibility effects of vibration are important.

1. All machine tools 2. All turbo machines.

7. 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.

8. 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 by providing spring damper.
2. The materials used for vibration isolation are rubber, felt cork etc. These are placed between the foundation and vibrating body.

9. Define forced vibration.

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

10. Give some examples of forced vibration.

1. Ringing of electrical bell where the vibration is by means of electrical means.
2. The vibrations of air compressors, IC engines, machine tools and various other machinery.

11. What are the various types of external forces that cause vibration?

1. Periodic forces
2. Impulsive type forces
3. Random forces

12. Define transient vibration.

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.

13. Define magnification factor or dynamic magnifier.

The ratio of the maximum displacement(X max) to the static deflection under static force F0 (x0) is known as magnification factor.

$$X_{max} = M.F \times X0$$

14. Define frequency response curve.

A curve between the magnification factor and frequency ratio ( ) is known as frequency response curve

15. What is phase response cuϕrve?

A curve between phase angle ( ) and frequency ratio ( ) is known as phase frequency curve.

16. What are the types isolation?

1. Force isolation
2. Motion isolatioin

17. What is force isolation?

Vibrations produced in unbalanced machines should be isolated from the foundation so that the adjoining structure is not set into vibrations. This type is force isolation

18. What is motion isolation?

The unbalanced machines are isolated from their foundation so that there should not be any damage either to the machines or the foundation. This is motion isolation.

19. Define force transmissibility.

It is defined as the ratio of the force transmitted FT (to the foundation) to the force applied on the F0.

20. Define logarithmic decrement.

Logairthmic 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.

22. What is meant by harmoninc forcing?

The term harmoninc forcing refers to a spring mass system with viscous damoing, excited by a sinusoidal harmonic force.

23. What is vibration isolation?

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

UNIT – V MECHANISMS FOR CONTROL

1. Explain the function of governors.

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 variations on engines.

2. What is the principle of working of centrifugal governors?

The centrifugal governors are based on balancing of centrifugal force on the rotating balls by an equal and opposite radial force.

3. Differentiate the functions of flywheel and governor.

S. No	Flywheels	Governors
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 the prime mover.	Its function is to control the mean speed over a period for output load variations
2	It works continuously from cycle to cycle.	Its works intermittently i.e. only when there is change in the load.
3	It has no influence on mean speed of the prime mover.	It has no influence over cyclic speed Fluctuations

4. 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 position.

5. 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

6. Explain controlling force?

An equal and opposite force to the centrifugal force acting radially inwards (1.e. centripetal force) is termed as controlling force of a governor.

7. Explain governor effect?

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

8. Define power of governor.

The power of 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.

9. Explain sensitiveness of governors?

The sensitiveness is defines as the ratio of the mean speed to the difference between the maximum and minimum speeds.
Sensitiveness = N/N1 – N2 = 2(N1 + N2)/ (N1 – N2)
N1 – Max Speed : N2 – Min Speed

10. Define the coefficient of sensitiveness.

It is the ratio between range of speed and mean speed.
Coefficient of sensitiveness = Range of speed/mean Speed =
N1 – N2 /N

11. 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.

12. 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.

13. What is controlling force diagram?

When the graph is drawn between the controlling force as ordinate and radius of rotation of the balls as abscissa, the graph so obtained is called controlling force diagram.

14. What are the uses of controlling force diagram?

Controlling force diagram is used to examine the stability and sensitiveness of the governor and also shows the effect of friction on governor's performance.

15. Give the applications of gyroscopic couple.

1. In instrument or toy known as gyroscope.
2. In ships in order to minimize the rolling and pitching effects of waves.
3. In aeroplanes, monorail cars and gyro compass. Etc

16. Define steering.

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

17. Define pitching.

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

18. Why there is no effect of the gyroscopic couple acting on the body of a ship during rolling?

We know that, for the effect of gyroscopic couple to occur, the axis of procession should always be perpendicular to the axis of the 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 a body of the ship during rolling.

19. The force end of a ship is called ---------- and the rear end is known as ----------

(Ans: bow; stern or aft)

20. The left hand and the right hand sides of the ship when viewed from the stern are called ----
---------- **and** ---------- **respectively**. (Ans: port; star-board)

21. Discuss the effect of the gyroscopic couple on a 2 wheeled vehicle when taking a turn.

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

22. A disc is spinning with an angular velocity ω rad/s about the axis of spin. The couple applied to the disc causing precession will be (Ans: 1.ω. ωp)

23. Explain gyroscopic couple.

If a body having moment of inertia I and rotating about its own axis at ω rad/s is also caused to turn at ωp rad/s about an axis perpendicular to the axis of spin, then it experiences a gyroscopic couple of magnitude (1.ω. ωp) in an axis which is perpendicular to both the axis of spin and axis of precession.

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

25. The rotor of a ship rotates in clockwise direction when viewed from the stern and the ship takes a left turn. The effect of gyroscopic couple acting on will be ----------.

(Ans: to move the ship towards star-board.)

SIXTEEN MARKS QUESTION AND ANSWERS

3. A petrol engine has a stroke of 120 mm and connecting rod is 3 times the crank length. The crank rotates at 1500 rpm clockwise direction. Determine 1. Velocity and acceleration of the piston and 2. Angular velocity and angular acceleration of the connecting rod, when the piston has traveled one-fourth of its stroke from I.D.C.

(Ans. Refer Prob. No. 2.3, Page No. 2.15 Dynamics of Machines by V. JAYAKUMAR)

2. The ratio of the connecting rod length to crank length for a vertical petrol engine is 4:1. The bore/stroke is 80/100 mm and mass of the reciprocating part is 1 kg. The gas pressure on the piston is 0.7 N/mm^2 when it has moved 10 mm from TDC on its power stroke. Determine the net load on the gudgeon pin. The engine runs at 1800 rpm At what engine speed will this load be zero.

(Ans. Refer Prob. No. 2.14, Page No. 2.36 Dynamics of Machines by V. JAYAKUMAR)

3. The turning moment diagram for a four stroke gas engine may be assumed for simplicity to be represented by four triangles, the areas of which from the line of zero pressure are as follows: Expansion stroke = 3550 mm^2; Exhaust stroke = 500 mm^2; Suction stroke = 350 mm^2; and compression stroke = 1400 mm^2. each mm^2 represents 3 N-m. Assuming the resisting moment to be uniform, find the mass of the rim of a fly wheel required to keep the mean speed 200 rpm within ±2%. The mean radius of the rim may be taken as 0.75 m. Also determine the crank positions for the maximum and minimum speeds.

(Ans. Refer Prob. No. 3.11, Page No. 3.25 Dynamics of Machines by V. JAYAKUMAR)

4. The equation of the turning moment diagram for the three crank engine is given by: T(N-m) = 25000 – 7500 sin 3θ, where θ radians is the crank angle from inner dead centre. The moment of inertia of the flywheel is 400 kg-m^2 and the mean engine speed is 300 rpm. Calculate,
    1. The power of the engine, and
    2. The total fluctuation of speed of the flywheel when
        a) The resisting torque is constant, and
        b) The resisting torque is (25000 + 3600 sin θ) N-m.

(Ans. Refer Prob. No.3.16, Page No. 3.36 Dynamics of Machines by V. JAYAKUMAR)

5. A steam engine runs at 150 rpm. Its turning moment diagram gave the following area measurements in mm^2 taken in order above and below the mean torque line: 500, -250, 270, -390, 190, -340, 270, -250. The scale for the turning moment is 1 mm = 500 N-m, and for crank angle is 1 mm = 5^o. If the fluctuation of speed is not to exceed ± 1.5 % of the mean, determine a suitable diameter and cross-section of the rim of the flywheel assumed with axial dimension (i.e., width of the rim) equal to 1.5 times the radial dimension (i.e., thickness of the rim). The hoop stress is limited to 3 Mpa and the density of the material of the flywheel is 7500 kg/m^3.

(Ans. Refer Prob. No.3.19, Page No. 3.43 Dynamics of Machines by V. JAYAKUMAR)

6 Three masses are attached to a shaft as follows: 10 kg at 90 mm radius, 15 kg at 120 mm radius and 9 kg at 150 mm radius. The masses are to be arranged so that the shaft is in complete balance. Determine the angular position of masses relative to 10 kg mass. All the masses are in the same plane. (**Ans. Refer Prob. No.5.2, Page No. 5.9 Dynamics of Machines by V. JAYAKUMAR**

7. A shaft has tree eccentrics, each 75 mm diameter and 25 mm thick, machined in one piece with the shaft. The central planes of the eccentric are 60 mm apart. The distance of the centers from the axis of rotation are 12 mm,18 mm and 12 mm and their angular positions are 120^{o} apart. The density of metal is 700 kg/m^3. Find the amount of out-of-balance force and couple at 600 rpm. If the shaft is balanced by adding two masses at a radius 75 mm and at distance of 100 mm from the central plane of the middle eccentric, find the amount of the masses and their angular positions.

(Ans. Refer Prob. No.5.8, Page No. 5.21 Dynamics of Machines by V. JAYAKUMAR)

8 The cranks of a three-cylinder locomotive are set at 120^{o}. The reciprocating masses are 450 kg for the inside cylinder and 390 kg for each outside cylinder. The pitch of the cylinder is 1.2 m and the stroke of each piston 500 mm. The planes of rotation of the balance masses are 960 mm from the inside cylinder. If 40% of the reciprocating masses are to be balanced, determine

1 The magnitude and the position of the balancing masses required at a radial distance of 500 mm; and
2 The hammer blow per wheel when the axle rotates at 350 rpm.

(Ans. Refer Prob. No.6.5, Page No. 6.17 Dynamics of Machines by V. JAYAKUMAR)

9 An air compressor has four vertical cylinders 1, 2, 3 and 4 in line and the driving cranks at 90^{o} intervals reach their upper most positions in this order. The cranks are of 150 mm radius, the connecting rods 500 mm long and the cylinder centre line 400 mm apart. The mass of the reciprocating parts for each cylinder is 22.5 kg and the speed of rotation is 400 rpm. Show that there are no out-of-balance primary or secondary forces and determine the corresponding couples, indicating the position of No.1 crank for maximum values. The central plane of the machine may be taken as reference plane.

(Ans. Refer Prob. No.6.9, Page No. 6.31 Dynamics of Machines by V. JAYAKUMAR)

10. The firing order of a six cylinder, vertical, four-stroke, in-line engine is 1-4-2-6-3-5. The piston stroke is 80 mm and length of each connecting rod is 180 mm. The pitch distances between the cylinder centre lines are 80 mm, 80 mm, 120 mm, 80 mm and 80 mm respectively. The reciprocating mass per cylinder is 1.2 kg and the engine speed is 2400 rpm. Determine the out-of-balance primary and secondary forces and couples on the engine taking a plane mid-way between the cylinders 3 and 4 as the reference plane.

(Ans. Refer Prob. No.6.14, Page No. 6.41 Dynamics of Machines by V. JAYAKUMAR)

11. Determine the equivalent spring stiffness and the natural frequency of the following vibrating systems when
    a) the mass is suspended to a spring
    b) the mass is suspended at the bottom of two springs in series
    c) the mass is fixed in between two springs

    d) the mass is fixed to the mid point of a spring

(Ans. Refer Prob. No. 18.1, Page No. 598 Theory of Machines by S.S. RATTAN)

12 A vibrating system consists of a mass of 50 kg, a spring of stiffness 30 kN/m and a damper. The damping provided is only 20 % of the critical value. Determine

1 the damping factor
2 the critical damping coefficient
3 the natural frequency of damped vibrations
4 the logarithmic decrement
5 the ratio of two consecutive amplitudes.

(Ans. Refer Prob. No. 18.5, Page No. 609 Theory of Machines by S.S. RATTAN)

13 The machine mounted on springs and fitted with a dashpot has a mass of 60 kg. There are three springs, each of stiffness 12 N/mm. The amplitude of vibrations reduces from 45 to 8 mm in two complete oscillations. Assuming that the damping force varies as the velocity, determine

a. the damping coefficient,
b. the ratio of frequencies of damped and undamped vibrations, and
c. the periodic time of damped vibrations.

(Ans. Refer Prob. No. 18.8, Page No. 611 Theory of Machines by S.S. RATTAN)

14 A single cylinder vertical diesel engine has a mass of 400 kg and is mounted on a steel chassis frame. The static deflection owing to the weight of the chassis is 2.4 mm. The reciprocating masses of the engine amounts to 18 kg and the stroke of the engine is 160 mm. A dashpot with a damping coefficient 2 N/mm/s is also used to dampen the vibrations. In the steady-state of the vibrations, determine

i. the amplitude of the vibrations if the driving shaft rotates at 500 rpm.
ii. the speed of the driving shaft when the resonance occurs.

(Ans. Refer Prob. No. 18.12, Page No. 619 Theory of Machines by S.S. RATTAN)

15 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 $1/20^{th}$ of the impressed force. The machine crank shaft rotates at 800 rpm

If under actual working conditions, the damping reduces the amplitudes of successive vibrations by 30 %, find,

a. the force transmitted to the foundation at 800 rpm,
b. the force transmitted to the foundation at resonance, and
c. the amplitude of the vibrations at resonance.

(Ans. Refer Prob. No. 18.15, Page No. 624 Theory of Machines by S.S. RATTAN)

16 A shaft supported freely at the ends has a mass of 120 kg placed 250 mm from one end. Determine the frequency of the natural transverse vibrations if the length of the shaft is 700 mm, E = 200 GN/m^2 and shaft diameter is 40 mm.

(Ans. Refer Prob. No. 18.16, Page No. 626 Theory of Machines by S.S. RATTAN)

17 A shaft 40 mm diameter and 2.5 m long has a mass of 15 kg per meter length. It is simply supported at the ends and carries three masses 90 kg, 140 kg and 60 kg at 0.8 m, 1.5 m and 2 m respectively from the left support. Taking E = 200 GN/m^2, find the frequency of the transverse vibrations.

(Ans. Refer Prob. No. 18.17, Page No. 633 Theory of Machines by S.S. RATTAN)

18. The following data relate to a shaft held in long bearings.

Length of shaft	= 1.2 m
Diameter of shaft	= 14,
Mass of a rotor at mid point	= 16 kg,
Eccentricity of centre of mass of rotor from centre of rotor	= 0.4 mm
Modulus of elasticity of shaft material	= 200 GN/m^2
Permissible stress in shaft material	= 70 X 10^6 N/m^2

Determine the critical speed of the shaft and the range of speed over which it is unsafe to run the shaft. Assume the shaft to be mass less.

(Ans. Refer Prob. No. 18.20, Page No. 636 Theory of Machines by S.S. RATTAN)

19. The following data refer to the transmission gear of a motor ship:

Moment of inertia of flywheel	= 4800 kg m^2
Moment of inertia of propeller	= 3200 kg m^2
Modulus of rigidity of shaft material	= 80 X 10^9 N/m^2
Equivalent MOI per cylinder	= 400 kg m^2

Assuming the diameter of the torsionally equivalent crankshaft to be 320 mm and treating the arrangement as a three rotor system, determine the frequency of free torsional vibrations.

(Ans. Refer Prob. No. 18.27, Page No. 656 Theory of Machines by S.S. RATTAN)

20. A reciprocating IC engine is coupled to a centrifugal pump through a pair of gears. The shaft from the flywheel of the engine to the gear wheel has a 48 mm diameter and is 800 mm long. The shaft from the pinion to the pump has a 32 mm diameter and is 280 mm long. Pump speed is four times the engine speed. Moments of inertia of flywheel, gear-wheel, pinion and pump impeller are 1000 kg m^2, 14 kg m^2, 5 kg m^2 and 18 kg m^2 respectively. Find the natural frequency of the torsional oscillation of the system. G = 80 G N/m^2.

(Ans. Refer Prob. No. 18.28, Page No. 660 Theory of Machines by S.S. RATTAN)

21. Each arm of a Porter governor is 250 mm long. The upper and lower arms are pivoted to links of 40 mm and 50 mm respectively from the axis of rotation. Each ball has a mass of 5 kg and the sleeve mass is 50 kg. The force of friction on the sleeve of the mechanism is 40 N. Determine the range of speed of the governor for extreme radii of rotation of 125 mm and 150 mm.

(Ans. Refer Prob. No. 16.3, Page No. 540 Theory of Machines by S.S. RATTAN)

22. The mass of each ball of a Proell governor is 7.5 kg and the load on the sleeve is 80 kg. Each of the arms is 300 mm long. The upper arms are pivoted on the axis of rotation whereas the lower arms are pivoted to links of 40 mm from the axis of rotation. The extensions of the lower arms to which the balls are attached are 100 mm long and are parallel to the governor axis at the minimum radius. Determine the equilibrium speeds corresponding to extreme radii of 180 mm and 240 mm/

(Ans. Refer Prob. No. 16.4, Page No. 543 Theory of Machines by S.S. RATTAN)

23. In a spring loaded Hartnell type of governor, the mass of each ball is 4 kg and the lift of the sleeve is 40 mm. The governor begins to float at 200 rpm when the radius of the ball path is 90 mm. The mean working speed of the governor is 16 times the range of speed when friction is neglected. The lengths of the ball and roller arms of the bell-crank lever are 100 mm and 80 mm respectively. The pivot centre and the axis of governor are 115 mm apart. Determine the initial compression of the spring, taking into account the obliquity of arms.

    Assuming the friction at the sleeve to be equivalent to a force of 15 N, determine the total alteration in speed before the sleeve begins to move from the mid- position

(Ans. Refer Prob. No. 16.6, Page No. 548 Theory of Machines by S.S. RATTAN)

24. The controlling force curve of a spring controlled governor is a straight line. The weight of each governor ball is 40 N and the extreme radii of rotation are 120 mm and 180 mm. If the values of the controlling force at the above radii be respectively 200 N and 360 N and the friction of the mechanism is equivalent to 2 N at each ball. Find a) the extreme equilibrium speeds of the governor, b) the equilibrium speed and the coefficient of insensitiveness at a radius of 150 mm.

(Ans. Refer Prob. No.10.32, Page No. 10.68 Dynamics of Machines by V. JAYAKUMAR)

25. In a Porter governor, each arm is 200 mm long and is pivoted at the axis of rotation. The mass of each ball is 5 kg and the load on the sleeve is 30 kg. The extreme radii of rotation are 80 mm and 140 mm. Plot a graph of the controlling force vs. radius of rotation and set off a speed scale along the ordinate corresponding to a radius of 160 mm.

(Ans. Refer Prob. No. 16.10, Page No. 563 Theory of Machines by S.S. RATTAN)