1. **a)** Discuss a naval ship usually subjected to what type of motions and associated gyroscopic effects.
   **b)** An aircraft makes a half circle of 100m radius towards left when flying at 400 km/hr. The engine and the propeller of the plane weigh 4.9 kN having a radius of gyration of 50 cm. The engine rotates at 3000 rpm clockwise when viewed from the rear. Find the gyroscopic couple and its effect on the aircraft.

2. **a)** What do you mean by spin, precession and gyroscopic planes?
   **b)** A turbine rotor of a ship weighs 196 kN and has a radius of gyration of 75 cm. Its speed is 2000 rpm. The ship pitches 60 above and below the mean position. A complete oscillation takes place in 20 seconds and the motion is simple harmonic. Determine: **a)** the maximum couple tending to shear the holding down bolts of the turbine. **b)** the direction in which the bow will tend to turn while rising, if the rotation of the rotor is clockwise, when looking from the aft.

3. A rear engine automobile is travelling along a track of 100 m mean radius. Each of the four road wheels has a moment of inertia of 2 kg-m² and an effective diameter of 60 cm. The rotating parts of the engine have a moment of inertia of 1 kg-m². The engine axis is parallel to the rear axle and the crank shaft rotates in the same sense as the road wheels. The gear ratio, engine to back axle, is 3:1. The vehicle weighs 14.71 kN and has its centre of gravity 50 cm above the road level. The width of the track of the vehicle is 1.5 m. Determine the limiting speed of the vehicle around the curve for all the four wheels to maintain contact with the road surface if this is not cambered.

4. **a)** Discuss Gyroscopic effects on aeroplane.
   **b)** The turbine rotor weighing 9.8 kN rotates at 2000 rpm clockwise when looking from stern. The vessel pitches with an angular velocity of 0.5 rad/s. Calculate the gyroscopic couple during the rise of bow. Assume radius of gyration of the rotor as 25.4 cm.

5. **a)** A flywheel of mass 10 kg and radius of gyration 200 mm is spinning about its axis, which is horizontal and is suspended at a point distant 150mm from the plane of rotation of the flywheel. Determine the angular velocity of precession of the flywheel. The spin speed of flywheel is 900 rpm.
   **b)** What will be the effect of the gyroscopic couple on a disc fixed at certain angle to a rotating shaft?

6. **a)** Explain the gyroscopic effect on four wheeled vehicles.
   **b)** The rotor of the turbine of a ship makes 1500 rpm clockwise when viewed from the stern. The rotor has a mass of 800 kg and its radius of gyration is 300 mm. Find the maximum gyro-couple transmitted to the hull when the ship pitches with maximum angular velocity of 1 rad/s.
7. a) What is the principle of virtual work? Explain.
   b) Derive an expression for the angular acceleration of connecting rod reciprocating engine.

8. a) How do the effects of gyroscopic couple and of centrifugal force make the rider of a two
     wheeler tilt on one side? Derive a relation for the limiting speed of the vehicle.
   b) A flywheel having a mass of 20 kg and a radius of gyration of 300mm is given a spin of 500
     rpm about its axis which is horizontal. The flywheel is suspended at a point that is 250mm from
     the plane of rotation of the flywheel. Find the rate of precession of the wheel.

---

**UNIT – 2 (FRICTION)**

1. a) Derive an expression for the efficiency of an inclined plane when a body moves down a
     plane.
   b) A conical pivot supports a load of 20 kN. The angle of cone is 1200 and intensity of
     pressure is not to exceed 0.35 MPa. The external radius is 3 times the internal radius. Find the
     diameter of the bearings surface. If $\mu =0.065$ and rpm of shaft is 120, what power in kW is
     absorbed by friction?

2. a) Derive the expression for the friction torque of a flat collar bearing by uniform wear theory.
   b) The mean diameter of a square threaded screw jack is 50 mm. The pitch of the thread is 10
     mm. The coefficient of friction is 0.15. What force must be applied at the end of a 0.7 m long
     lever which is perpendicular to the longitudinal axis of the screw to raise a load of 20 kN and to
     lower it.

3. In a screw jack, the diameter of the threaded screw is 40 mm and the pitch 8mm. The load is
   20 kN and it does not rotate with the screw but is carried on swivel head having a bearing
   diameter of 70 mm. The coefficient of friction between the swivel head and the spindle is 0.08
   and between the screw and nut 0.1. Determine the total torque required to raise the load and the
   efficiency.

4. The shaft of a collar thrust bearing rotates at 200 rpm and carries an end thrust of 10 tonnes.
   The outer and inner diameters of the bearing are 480 mm and 280 mm respectively. If the power
   lost in friction is not to exceed 8 kW, determine the coefficient of friction of the lubricant of the
   bearing.

5. a) A square threaded screw of mean diameter 30 mm and pitch of threads 5mm is used to lift a
     load of 15kN by a horizontal force applied at the circumference of the screw. Find the force
     required if the coefficient of friction between screw and nut is 0.02.
   b) What do you mean by film friction? State its laws.

6. a) Explain the difference between the coefficient of friction and angle of friction.
b) A body of weight 150 N is placed on a rough horizontal plane. If the coefficient of friction between the body and the horizontal plane is 0.4, determine the horizontal force required to just slide the body on the plane.

7. a) Explain clearly what are thick and thin film lubrications.
   b) What is meant by the expression ‘friction circle’? Deduce an expression for the radius of the friction circle in terms of radius of the journal and the angle of friction.

8. a) Describe the working of a Mitchell thrust bearing.
   b) Do you recommend the uniform pressure theory or uniform wear theory for the friction torque of a bearing? Explain.

UNIT – 3 (CLUTCHES)

1. a) Derive a relation for the frictional torque acting on a centrifugal clutch.
   b) A band and block brake having 12 blocks, each of which subtends an angle of 160 at the centre, is applied to a rotating drum of 600 mm diameter. The blocks are 75 mm thick. The two ends of the band are attached to pins on opposite sides of the fulcrum at distances of 40 mm and 150 mm. Determine the maximum braking torque, if a force of 250 N is applied to the lever at a distance of 900 mm from the fulcrum. Take $\mu = 0.3$.

2. A simple band brake is fitted on a crane having the diameter of barrel as 50 cm. The band embraces $3/4^{th}$ of the circumference of the brake drum of diameter 70 cm. The tight end of the band is attached to the fulcrum of the brake lever while the slack end of the band is attached to a pin which is 10 cm away from the fulcrum. Calculate the braking torque acting on the drum shaft if the operating force of 392.4 N is acting on the lever at a distance of 65 cm from the fulcrum. The coefficient of friction is 0.3. Instead of attaching the tight end of the band to the fulcrum of the lever, if it is attached to a pin 2 cm away from the fulcrum of the lever and on opposite side of the pin to which the slack end of the band is attached, what will be the increase of braking torque acting on the drum shaft?

3. a) What is meant by self locking and a self energized brake.
   b) A centrifugal clutch has 4 shoes which slide radially in a spider keyed to the driving shaft and make contact with internal cylindrical surface of a rim keyed to the driven shaft. When the clutch is at rest, each shoe is pulled against a stop by a spring so as to leave a radial clearance of 5 mm between the shoe and the rim. The pull exerted by the spring is then 500 N. The mass centre of shoe is 160 mm from the axis of the clutch. If the internal diameter of the rim is 400 mm, the mass of each shoe is 8 kg, the stiffness of each spring is 50 N/mm and the coefficient of friction between the shoe and the rim is 0.3. Find the power transmitted by the clutch at 500 rpm.

4. A single plate clutch both sides effective is required to transmit 27 kW at 1600 rpm. The outer diameter of the plate is limited to 30 cm, and the intensity of pressure between the plates is not to exceed 6.87 N/cm². Assuming uniform wear and a coefficient of friction of 0.3, find the required inner diameter of the plates, and the axial force necessary to engage the clutch.

5. a) Describe with a neat sketch the working of a single plate friction clutch.
b) A single plate clutch having both sides effective is required to transmit 30 kW at 1500 rpm. The outer diameter of the plate is limited to 300 mm, and the intensity of pressure between the plates is not to exceed 0.07 MPa. Assuming uniform wear and a coefficient of friction 0.35, determine the inside diameter of the plate.

6. A multiple disc clutch has six active friction surfaces. The power transmitted is 20 kW at 400 rpm. Inner and outer radii of the friction surfaces are 90 mm and 120 mm respectively. Assuming uniform wear with a coefficient of friction 0.3, find the maximum axial intensity of pressure between the discs.

7. a) With the help of a neat sketch explain the working of a block or shoe brake.
   b) In a single block brake, the drum diameter is 300 mm, the angle of contact is 90°, and the coefficient of friction between the lining and the drum is 0.30. If the operating force is 400 N, applied at the end of a lever 400 mm long, determine the torque transmitted by the brake. The distance of the fulcrum from the centre of the brake drum is 200 mm, and assume that the force of friction passes through the fulcrum.

8. a) With a neat sketch, describe a single shoe brake. What is the advantage of double shoe brake over single shoe brake?
   b) With a neat sketch, describe the principle and working of an internal expanding shoe-brake. Derive the expression for the breaking torque.

**UNIT – 4 (FLY WHEELS)**

1. A machine is coupled to a two stroke engine when produces a torque of \((800+180\sin\theta)\) N-m, where \(\theta\) is the crank angle. The mean engine speed is 400 rpm. The flywheel and the other rotating parts attached to the engine have a mass of 350 kg at a radius of gyration of 220 mm. Calculate (i) the power of the engine (ii) the total fluctuation of speed of the flywheel when resisting torque is constant and \((800+80\sin\theta)\) N-m.

2. a) Derive a relation for the turning moment at the crankshaft in terms of piston effort and the angle turned by the crank.
   b) A single cylinder, single acting, four stroke gas engine develops 20 kW at 300 rpm. The work done by the gases during the expansion stroke is three times the work done on the gases during the compression stroke, the work done during the suction and exhaust strokes being negligible. If the total fluctuation of speed is not to exceed ±2 percent of the mean speed and the turning moment diagram during compression and expansion is assumed to be triangular in shape, find the moment of inertia of the flywheel.

3. a) Differentiate between terms crank pin effort and crank effort. Derive an expression for crank pin effort in terms of piston effort.
   b) A punching press is driven by a constant torque electric motor. The press is provided with a flywheel that rotates at maximum speed of 225 rpm. The radius of gyration of the flywheel is 0.5 m. The press punches 720 holes per hour; each punching operation takes 2 seconds and requires 15 kN-m of energy. Find the power of the motor and minimum mass of the flywheel if speed of the same is not to fall below 200 rpm.
4. a) What do you understand by coefficient of fluctuation of speed and coefficient fluctuation of energy?

   b) The equation of the turning moment curve of a three crank engine is \((9000 + 1500 \sin 3 \theta)\) N-m, where \(\theta\) is the crank angle in radians. The moment of inertia of the flywheel is 1000 kg-m\(^2\) and the mean speed is 300 rpm. Calculate i) power of the engine ii) the maximum fluctuation of speed of flywheel in percentage when the resisting torque is constant and \((5000 + 600 \sin \theta)\) N-m.

5. Draw the tuning moment diagrams for the following different types of engines, neglecting the effect of inertia of the connecting rod:
   i. Single cylinder double acting steam engine
   ii. Four stroke cycle. I.C. engine

6. a) What is the function of a flywheel? How does it differ from that of a governor?

   b) In a turning moment diagram, the areas above and below the mean torque line taken in order are 4400, 1150, 1300, and 4550 mm\(^2\) respectively. The scales of the turning moment diagram are: Turning moment: 1mm = 100 N-m; Crank angle: 1mm = 10 Find the mass of the flywheel required to keep the speed between 297 and 303 rpm, if the radius of the gyration is 0.525m.

7. a) Define and explain the terms: piston effort, crank effort, thrust on the sides of cylinder walls and thrust on the crank-shaft bearing.

   b) The maximum and minimum speeds of a flywheel are 242 rpm and 238 rpm respectively. Mass of the flywheel is 2600 kg, and the radius of gyration is 1.8 m. Find the
   (i) Mean speed of the flywheel,
   (ii) Maximum fluctuation of energy, and
   (iii) Coefficient of fluctuation of speed

8. a) Differentiate between the functions of a flywheel and a governor.

   b) In a diesel generating set, is it possible to use only a flywheel or a governor? Give your answer with justification.

   c) In the design of flywheels, permissible speed variation in an important parameter. State the approximate range of permissible speed variation in percent in case of a diesel engine and a punching machine. Justify your answer.

---

**UNIT – 5 (GOVERNERS)**

1. In a spring controlled governor of the Hartung type, the length of the ball and sleeve arms are 80 mm and 120 mm respectively. The total travel of the sleeve is 25 mm. In the mid position, each spring is compressed by 50 mm and the radius of rotation of the mass centres is 140 mm. Each ball has a mass of 4 kg and the spring has a stiffness of 10 kN/m of compression. The equivalent mass of the governor gear at the sleeve is 16 kg. Neglect the moment due to the revolving masses when the arms are inclined, determine the ratio of the range of speed to the mean speed of the governor. Find also speed in the mid position.
2. a) Discuss the following with respect to governor: i) Sensitiveness ii) isochronous governors
   b) In an engine governor of the porter type, the upper and lower arms are 20 cm and 25 cm long respectively and pivoted on the axis of rotation. The central load is 147.2 N the weight of each ball is 19.6 N and friction of sleeve together with the resistance of the operating gear is equal to the weight of 24.5 N at the sleeve. If the limiting inclinations of the upper arms to the vertical are 300 and 400, find range of speeds of the governor.

3. In a spring loaded governor of the Hartnell type, the mass of each ball is 1 kg, length of vertical arm of the ball crank lever is 100 mm and that of the horizontal arm is 50 mm. The distance of fulcrum of each bell crank lever is 80 mm from the axis of rotation of the governor. The extreme radii of rotation of the balls are 75 mm and 112.5 mm. The maximum equilibrium speed is 5 percent greater than the minimum equilibrium speed which is 360 rpm. Find, neglecting obliquity of arms, initial compression of the spring and equilibrium speed corresponding to the radius of rotation of 100 mm.

4. a) Explain the terms sensitiveness, hunting and stability relating to governors?
   b) A Proell governor has all the four arms of length 25 cm. The upper and lower ends of the arms are pivoted on the axis of rotation of the governor. The extension arms of lower links are each 10 cm long and parallel to the axis when the radius of the ball path is 15 cm. The weight of each ball is 44.15 N and the central weight of 353.2 N. Determine the equilibrium speed of the governor.

5. a) Discuss the controlling force and stability of a governor and show that the stability of a governor depends on the slope of the curve connecting the controlling force (FC) and radius of rotation (r) and the value (FC/r).
   b) The length of the upper arm of a Watt governor is 400mm and its inclination to the vertical is 300. Find the percentage increase in speed, if the balls rise by 20mm.

6. a) What is the function of a governor? How does it differ from that of a flywheel?
   b) A Porter governor has two balls each of mass 3 kg and a central load of mass 15kg. The arms are all 200 mm long, pivoted on the axis. If the maximum and minimum radii of rotation of the balls are 160 mm and 120 mm respectively, find the range of the speed.

7. a) Write short note on ‘coefficient of insensitiveness’ of governors.
   b) In a Porter governor, the mass of the central load is 18 kg and the mass of each ball is 2 kg. The top arms are 250 mm while the bottom arms are each 300 mm long. The friction of the sleeve is 14 N. If the top arms make 450 with the axis of rotation in the equilibrium position, find the range of speed of the governor in that position.

8. a) Compare the functions of a flywheel and a governor.
   b) In a spring controlled governor, the radial force acting on the balls was 4500 N when the center of the balls were 200mm from axis and 7500 N when at 300mm. Assuming that the force varies directly as the radius, find the radius of the ball path when the governor runs at 270 rpm.
Also find what alteration in spring load is required in order to make the governor isochronous and the speed at which it would then run. The mass of each ball is 30 kg.

**UNIT – 6 (BALANCING)**

1. A circular disc mounted on a shaft carries three attached masses 4kg, 3kg and 2.5 kg at radial distances 75 mm, 85mm and 50 mm and at the angular positions of 450, 1350, and 2400 respectively. The angular positions are measured counterclockwise from the reference line along the x-axis. Determine the amount of the counter mass at a radial distance of 75mm required for the static balance.

2. Four masses A, B, C and D are completely balanced. Masses C and D make angles of 900 and 1950 respectively with that of mass B in the counter clockwise direction. The rotating masses have following properties: mb=25 kg, mc=40 kg, md=35 kg, ra=150mm, rb=200 mm, rc =100 mm, rd=180 mm The Planes B and C are 250 mm apart. Determine i)the mass A and its angular position with that of mass B ii) the positions of all the planes relative to plane of mass A.

3. A shaft carries four masses A, B, C and D placed in parallel planes perpendicular to the shaft axis and in this order along the shaft. The masses of B and C are 353 N and 245 N respectively and both are assumed to be concentrated at a radius of 15 cm, while the masses in planes A and D are both at a radius of 20 cm. The angle between the radii of B and C is 1000 and that between B and A is 1900, both angles being measured in the same sense. The planes containing A and B are 25 cm apart and those containing B and C are 50 cm apart. If the shaft is to be in complete dynamic balance, determine i) Masses of A and D ii) distance between the planes containing C and D iii) angular position of the mass D.

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

5. a) Why balancing of rotating parts necessary for high speed engines?
   b) Four masses A, B, C, D are attached to a shaft and revolve in the same plane. The masses are 12 kg, 10 kg, 18 kg, and 15 kg respectively and their radii of rotations are 40 mm, 50 mm, 60 mm, and 30 mm. The angular position of the masses B, C, and D are 600, 1350, and 2700 from the mass A. Find the magnitude and position of the balancing mass at a radius of 100mm.

6. a) What do you mean by static and dynamic balancing? What are the necessary conditions to achieve them?
   b) The following as shown in figure below is a system of four unbalance masses. Determine the Bearing reactions if the rotor speed is 600 r.p.m.
7. a) Why is it that the need for balancing is increasing these days?  
   b) Two weights of 8 kg and 16 kg rotate in the same plane at radii of 1.5 and 2.25m respectively. The radii of these weights are 600 apart. Find the position of the third weight of the magnitude of 12 kg in the same plane, which can produce complete dynamic balance of the system using analytical method.

8. a) Explain clearly the terms 'static balancing' and 'dynamic balancing'. State the necessary conditions to achieve them.  
   b) Four masses A, B, C, D revolve at equal radii and are equally spaced along a shaft. The mass B is 7kg and the radii of C and D make angles of 900 and 2400 respectively with the radius of B. Find the magnitude of the masses A, C, and D and the angular position of A so that the system may be completely balanced.

**UNIT – 7 (BALANCING RECIPROCATING MASSES)**

1. A four crank engine has the two outer cranks set at 1200 to each other, and their reciprocating masses are each 3290 N. The distances between the planes of rotation of adjacent cranks are 45, 75 and 60 cm. If the engine is to be in complete primary balance, find the reciprocating mass and the relative angular position for each of the inner cranks. If the length of each crank is 30 cm, the length of each connecting rod is 120 cm and the speed of rotation is 240 rpm, what is the maximum secondary unbalanced force?

2. a) Derive the condition to the limiting speed for which wheels of the locomotive are not lifted from rails.  
   b) A single cylinder oil engine has a stroke of 38 cm and the crank makes 360 rpm. The reciprocating parts weigh 670 N and revolving parts are equivalent to 800 N at crank radius. A revolving balance weight is introduced at a radius of 15 cm to balance the whole of the revolving parts and one half of the reciprocating parts. Find the balancing weight required and the residual unbalanced force on the crank shaft.

3. A two cylinder uncoupled locomotive has inside cylinders 60 cm apart. The radius of each crank is 30 cm. The cranks are at right angles. The weight of the revolving mass per cylinder is 2452.5 N and the weight of the reciprocating mass per cylinder is 2943 N. The whole of the
revolving and 2/3rd of the reciprocating masses are to be balanced and the balanced weights are placed, in the planes of rotation of the driving wheels, at radius of 80 cm. The driving wheels are 2 m in diameter and 1.5 m apart. If the speed of the engine is 80 km/hr, find the hammer blow, maximum variation of tractive effort and maximum swaying couple.

4. a) How do you balance reciprocating masses in radial engines?
   b) A three cylinder radial engine, driven by a common crank has the cylinders spaced at 1200. The stroke is 125 mm, length of the connecting rod is 225 mm and the weight of the reciprocating mass per cylinder is 19.6 N. Calculate the primary and secondary forces at crank shaft speed of 1200 rpm.

5. a) Explain the terms i. Primary disturbing force and ii. Secondary disturbing force.
   b) The two cylinder engine with cranks set at 1800 and the cylinders on the same side of the crank shaft centre line is having identical reciprocating masses, crank lengths and connecting rod lengths for each cylinder. If the crank of the first cylinder makes an angle of 300 with IDC then to what extent the engine is balanced for
   i. Primary and secondary forces  ii. Primary and secondary couples.

6. a) What do you mean by coupled locomotives and uncoupled locomotives? What is the advantage of coupled locomotives?
   b) A single cylinder horizontal engine runs at 150 rpm. The length of the stroke is 600 mm. The mass of the revolving parts assumed concentrated at the crank pin is 200 kg and mass of reciprocating parts is 160 kg. Determine the magnitude of the balancing mass required to be placed opposite to the crank at a radius of 170mm which is equivalent to all the revolving and 2/3rd of the reciprocating masses. If the crank turns 300 from the inner dead centre, find the magnitude of the unbalanced force due to the balancing mass.

7. a) Explain the procedure of Primary balancing of multi cylinder Inline-engines.
   b) A three cylinder radial engine driven by a common crank has the cylinders spaced at 1200. The stroke is 150 mm, length of the connecting rod is 190 mm and the reciprocating mass per cylinder 2.5 kg. Calculate the primary and secondary forces at crank shaft speed of 1500 rpm

8. a) What are inline-engines? How are they balanced? Is it possible to balance them completely?
   b) Three cylinders of an air compressor have their axes 1200 to one another and their connecting rods are coupled to a single crank. The stroke is 125 mm and the length of each connecting rod 230 mm. The mass of the reciprocating parts per cylinder is 3 kg. Determine the maximum primary and secondary forces acting on the frame of the compressor when running at 2300 rpm. Describe a method by which such forces may be balanced

UNIT – 8 (VIBRATIONS)

1. a) Explain the term critical speed, prove that the critical speed of a rotating shaft is the same as the natural frequency of transverse vibration.
   b) A shaft of 8 cm diameter and 80 cm length has one of its ends fixed and the other end carries a disc of weight 4800 N. The young’s modulus of elasticity for the material of the shaft is 196.2 kN/mm². Determine the frequency of longitudinal and transverse vibrations.
2. A steel shaft of 1.5 m long is 95mm in diameter for the first 0.6m of its length, 60 mm in diameter for the next 0.5 m of the length and 50 mm diameter for the remaining 0.4 m of its length. The shaft carries two flywheels at two ends, the first having a mass of 900 kg and 0.85 m radius of gyration located at the 95mm diameter end and the second having a mass of 700 kg and 0.55 m radius of gyration located at the other end. Determine the location of the node and natural frequency of free torsional vibration of the system. The modulus of rigidity of shaft is assumed as 80 GN/m².

3. a) Derive an expression for the natural frequency of free transverse vibration of simply supported beam carrying several of point loads by energy method.
   b) A shaft 40 mm diameter and 2.5 m long has a mass of 15 kg per metre 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 GPa, find the frequency of the transverse vibration.

4. A trailer has 1000 kg mass when fully loaded and 250 kg when empty. The spring of the suspension is 350 kN/m. The damping factor is 0.5 when the trailer is fully loaded. The speed is 100 km/hr. The road varies sinusoidally with a wave length of 5 m. Determine the amplitude ratio of the trailer when fully loaded and empty.

5. a) Define and explain the terms i. Vibrations, ii. Free vibrations and iii. Forced vibrations
   b) A simply supported shaft of length 1.6 m carries a mass of 120 kg placed 500 mm from one end. If E = 2 x10⁵ N/ mm² and diameter of the shaft is 50 mm, then find natural frequency of transverse vibrations.

6. a) What are the different methods of finding the natural frequency of free longitudinal vibrations? Explain any two methods.
   b) Find the frequency of transverse vibrations of a shaft which is simply supported at the ends and is of 40 mm in diameter. The length of the shaft is 5m. The shaft carries three point loads of masses 15 kg, 35 kg and 22.5 kg at 1 m, 2 m and 3.4 respectively from the left support. The young’s modulus for the material of the shaft is 2 x10⁵ N/mm². Neglect the weight of the shaft.

7. a) Discuss the expression for a natural frequency of free transverse vibrations for a simply supported shaft carrying a uniformly distributed mass of m kg per unit length.
   b) A mass hanging from a spring is observed to make one complete oscillation in 0.8 sec. and the amplitude of the fifth oscillation is half that of first. If the top of the spring be compelled to make vertical oscillation of period 4 sec. and amplitude 29 mm, find the amplitude of the motion of the mass. Damping is assumed proportional to the velocity.

8. a) What is meant by equivalent spring stiffness? How is it determined?
   b) The flywheel of an engine driving a dynamo has a mass of 180 kg and a radius of gyration of 30 mm. The shaft at the flywheel end has an effective length of 250 mm and is 50 mm diameter. The armature mass is 120 kg and its radius of gyration is 22.5 mm. The dynamo shaft
is 43 mm diameter and 200 mm effective length. Calculate the position of the node and the frequency of torsional oscillation. $G = 83 \text{kN/mm}^2$. 