



DHANALAKSHMI SRINIVASAN ENGINEERING COLLEGE
(AUTONOMOUS)

(Approved by AICTE & Affiliated to Anna University, Chennai)

Re-Accredited by NAAC with 'A' Grade

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PERAMBALUR-621212, TAMILNADU, INDIA.

Website: www.dsengg.ac.in



COURSE MATERIALS

Course Code/Name	U23MET52 / DYNAMICS OF MACHINES			
Year/Department	III / MECHANICAL ENGINEERING			
Credits Details	L: 3	T: 0	P: 0	C: 3
Total Contact Hours Required	45			

Syllabus:

UNIT I/ FORCE ANALYSIS	No. of Periods : 9
Dynamic force analysis - Inertia force and Inertia torque- D'Alembert's principle -Dynamic Analysis in reciprocating engines - Gas forces - Inertia effect of connecting rod- Bearing loads - Crank shaft torque - Turning moment diagrams -Fly Wheels - Flywheels of punching presses- Dynamics of Cam follower mechanism.	
UNIT II/ BALANCING	No. of Periods : 9
Static and dynamic balancing - Balancing of rotating masses - Balancing a single cylinder engine - Balancing of Multi-cylinder inline, V-engines - Partial balancing in engines - Balancing of linkages - Balancing machines-Field balancing of discs and rotors.	
UNIT III/ SINGLE DEGREE FREE VIBRATION	No. of Periods : 9
Basic features of vibratory systems – Degrees of freedom – single degree of freedom – Free vibration – Equations of motion – Natural frequency – Types of Damping – Damped vibration– Torsional vibration of shaft – Critical speeds of shafts – Torsional vibration – Two and three rotor torsional systems.	
UNIT IV/ FORCED VIBRATION	No. of Periods : 9
Response of one degree freedom systems to periodic forcing – Harmonic disturbances –Disturbance caused by unbalance – Support motion –transmissibility – Vibration isolation vibration measurement	
UNIT V/ MECHANISM FOR CONTROL	No. of Periods : 9
Governors – Types – Centrifugal governors – Gravity controlled and spring controlled centrifugal governors – Characteristics – Effect of friction – Controlling force curves. Gyroscopes –Gyroscopic forces and torques – Gyroscopic stabilization – Gyroscopic effects in Automobiles, ships and airplanes.	

Objective:

- ❖ To impart knowledge in dynamic analysis of simple mechanism and design of flywheel.
- ❖ To provide knowledge on balancing of rotating and reciprocating masses.
- ❖ To study the working principle of governor and gyroscope.
- ❖ To learn the concept of free and forced vibration.
- ❖ To learn the concept of transverse and torsional vibration.

Text Book:

- T1: Uicker, J.J., Pennock G.R and Shigley, J.E., "Theory of Machines and Mechanisms" 3rd Edition, Oxford University Press, 2014.
T2: 2. Rattan, S.S, "Theory of Machines", 4th Edition, Tata McGraw-Hill, 2017.

Reference Book:

- R1. Khurmi, R.S., "Theory of Machines", 14th Edition, S Chand Publications, 2005.
R2. Cleghorn. W. L, "Mechanisms of Machines", Oxford University Press, 2005
R3. Benson H. Tongue, "Principles of Vibrations", Oxford University Press, 2nd Edition, 2007
R4. Robert L. Norton, "Kinematics and Dynamics of Machinery", Tata McGraw-Hill, 2009.
R5. Ghosh. A and Mallick, A.K., "Theory of Mechanisms and Machines", Affiliated East-West Pvt.Ltd., New Delhi, 1988.
R6. John Hannah and Stephens R.C., "Mechanics of Machines", Viva Low-Prices Student Edition, 1999.
R7. William T. Thomson, Marie Dillon Dahleh, Chandramouli Padmanabhan, "Theory of Vibration with Application", 5th edition, Pearson Education, 2011
R8. V.Ramamurthi, "Mechanics of Machines", Narosa Publishing House, 2002.

Website:

- W1 : http://www.iitg.ac.in/scifac/qip/public_html/cd_cell/chapters/r_tiwari_dyn_of_mach/chapter_4_governers.pdf
W2 : http://www.iitg.ac.in/scifac/qip/public_html/cd_cell/chapters/r_tiwari_dyn_of_mach/chapter_5_gyroscope.pdf.

Online Mode of Study (if Any):

- ❖ <http://nptel.ac.in/courses/112101096/download/lecture-6.pdf>:
- ❖ https://nptel.ac.in/courses/112101096/Mod%206/Lec1/6.1_4.html
- ❖ <http://nptel.ac.in/courses/112101096/download/lecture-8.pdf>
- ❖ <http://nptel.ac.in/courses/112107088/module1/lecture2/lecture2.pdf>

Unit – I Force Analysis**PART-A****1. State D'Alembert's principle for dynamic equilibrium (Apr/May 2018)**

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.

2. State the significance of turning moment diagram(Nov/Dec 2014)

It is the graphical representation of the turning moment or crank effort for various position of the crank. In turning moment diagram, the turning moment is taken as the ordinate (Y-axis) and crank angle as abscissa (X-axis)

3. What is the need for providing a flywheel in a punching machine?(Nov/Dec 2014,2016)

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

4. What is crank 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.

5. Differentiate between static and dynamic equilibrium

Necessary and sufficient conditions for static and dynamic equilibrium are:

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

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

6. Define inertia force and Inertia torque.(May/June 2016)(Nov/Dec 2016)

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

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

7. How you will reduce a dynamic analysis problem into an equivalent problem of static equilibrium?(May/June 2014)

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

8. Define the significance of inertia force analysis.

Inertia force analysis reduces the dynamic analysis problem into an equivalent static analysis problem by determining the required torque and the direction

9. 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

10. What is the difference between piston effort, crank effort and crank-pin effort?

Piston effort is defined as the net of 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. 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 the connecting rod perpendicular to the crank is known as crank pin effort.

11. Define the terms coefficient of fluctuation of energy (Apr/May 2018)

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

$$C_E = \frac{\text{Maximum fluctuation of energy } (\Delta E)}{\text{Work done per cycle}}$$

12. Define the terms coefficient of fluctuation of speed (Nov/Dec 2018)

The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed (C_s)

$$C_s = \frac{N_1 - N_2}{N}$$

13. Explain the term maximum fluctuation of energy in flywheels

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

$E = \text{Maximum Energy} - \text{Minimum Energy}$.

14. List out the few machines in which flywheel are used. (Nov/Dec 2015)

1. Punching machines
2. Shearing machines
3. Riveting machines
4. Crushing machines

15. Why smaller flywheels are used in multi cylinder engines? (May/June 2014)

In multi cylinder engine more than one power stroke is produced per second. So the need to store energy in flywheel is lesser than single cylinder engines.

16. What is the free body diagram?

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

17. State the principle of super position.

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.

18. What is meant by maximum fluctuation of speed?

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

19. What is meant by dynamics

The branch of mechanics that is concerned with the effects of forces on the motion of a body or system of bodies, especially of forces that do not originate within the system itself.

20. Write the conditions for equivalent system? (Dec 2013)

1. The sum of their masses is equal to the total mass of the body
 $m_1 + m_2 = m$
2. The centre of gravity of the two masses coincide with that of the body
 $m_1 l_1 = m_2 l_2$
3. The sum of mass moment of inertia of the masses about their centre of gravity is equal to the mass moment inertia of the body.
 $m_1 l_1^2 + m_2 l_2^2 = m k_G^2$

21. Define crank pin effort (Nov/Dec 2018)

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

22. What is meant by ‘correction couple’?

In a dynamically equivalent system, if the two masses are placed arbitrarily, an error in torque is produced. To make the system dynamically equivalent, a couple should be applied. This couple is called correction couple.

23. Why negative loops are formed in turning moment diagrams?

During strokes other than power stroke, flywheels losses energy, negative loops are formed in turning moment diagram

24. The length of the crank and connecting rod of vertical reciprocating engine are 300mm and 1.5mm respectively. If the crank rotates at 200rpm, find the velocity if the piston at $\theta = 40^\circ$. [Nov/Dec 2015]

Solution : Velocity if the piston $V_p = \omega r \left[\sin \theta + \frac{\sin 2\theta}{2n} \right]$

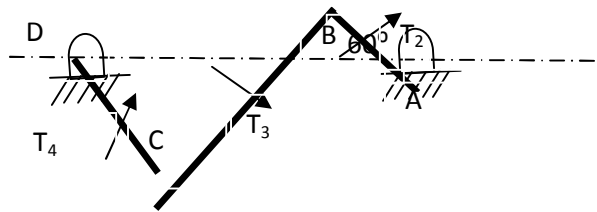
25. Differentiate between static force analysis and dynamic force analysis

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

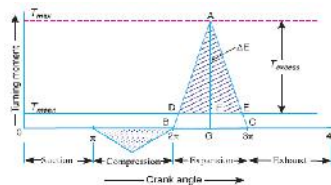
If the inertia effect due to the mass of the component is also considered, it is called dynamic force analysis.

PART-B

1. The ratio of 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 0.5 N/mm^2 when it has moved 10mm from TDC on its power stroke. Determine the net head on gudgeon pin. The engine runs at 1800 rpm. What engine speed will this load be zero? **(May/June 2016)**
2. a) Derive the equation of forces on the reciprocating part of the engine, neglecting the weight of connecting rod
b) What is turning moment diagram and draw it for 4 stroke IC engine. **(May/June 2016)**
3. The lengths of crank and connecting rod of a horizontal engine are 200mm and 1m respectively. The crank is rotating at 400 rpm. When the crank has turned through 30° from inner dead centre, the difference of pressure between cover and piston rod is 0.4 N/mm^2 . If the mass of the reciprocating parts is 100 kg and cylinder bore is 0.4m, then calculate, the inertia force, force on piston, piston effort, thrust on the sides of the cylinder walls, the thrust in the connecting rod, and the crank effort. **(Nov/Dec 2017)**
4. In a 4 link mechanism shown in figure, torques T_3 and T_4 have magnitudes of 30Nm and 20 Nm respectively. The link lengths are $AD = 800\text{mm}$, $AB = 300\text{mm}$, $BC = 700\text{mm}$ and $CD = 400\text{mm}$. For the static equilibrium of the mechanisms, determine the required input torque T_2 **(Nov/Dec 2017)**



5. An electric motor drives a punching machine. A flywheel fitted to the press has a radius of gyration of 0.5m and runs at 250 rpm. The press is capable to punch 800 holes per hour with each punching operation taking 1.5 seconds and requiring 12000 Nm of work. Determine the rating of the machine in kW and the mass of the flywheel if the speed of the flywheel does not drop below 230rpm. **(Nov/Dec 2018)**
6. 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 through 125° from the top dead center, the steam pressure is 30kN/m^2 and below the piston is 1.5 kN/m^2 . Calculate the effective turning moment on the crank shaft. **(Nov/Dec 2018)**
7. A single cylinder, single acting, four stroke gas engine develops 20 kW at 300 r.p.m. 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 per cent 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. **(Nov/Dec 2014)**



8. 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 inner dead centre. 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 centre. (iv) The maximum angular acceleration and retardation of the flywheel. **(Nov/Dec 2014)**
9. The crank and connecting rod of a vertical single cylinder gas engine running at 1800 rpm are 60 mm and 240 mm respectively. The diameter of the piston is 80 mm and mass of the reciprocating parts is 1.2 kg. At a point during power stroke, when the piston has moved 20 mm from the top dead centre, the pressure on the piston is 800 kN/m^2 . Determine the (i) Net force on the piston (ii) Thrust in the connecting rod (iii) Thrust on the sides of the cylinder walls (iv) The engine speed at which the above values are zero. **(Nov/Dec 2016)**
10. A vertical double acting steam engine develops 75 kW at 250 rpm. The maximum fluctuation of energy is 30 percent of the work done per stroke. The maximum and minimum speeds are not to vary more than 1% on either side of the mean speed. Find the mass of the flywheel required if the radius of gyration is 0.6 meters. **(May/June 2015)**
11. The lengths of crank and connecting rod of a horizontal reciprocating engine are 200 mm and 1 meter respectively. The crank is rotating at 400 rpm. When the crank has turned through 30° from the inner dead centre. The difference of pressure between cover and piston rod is 0.4 N/mm^2 . If the mass of the reciprocating parts is 100 kg and cylinder bore is 0.4 meters, then calculate: (i) inertia force, (ii) force on piston, (iii) piston effort, (iv) thrust on the sides of the cylinder walls, (v) thrust in the connecting rod, and (vi) crank effort. **(May/June 2015)**
12. The radius of gyration of a flywheel is 1 meter and the fluctuation of speed is not to exceed 1% of the mean speed of the flywheel. If the mass of the flywheel is 3340 kg and the steam engine develops 150 kW at 135 rpm, then find (i) maximum fluctuation of energy and (ii) coefficient of fluctuation of energy. **(May/June 2014)**
13. The turning moment diagram for a multicylinder has been drawn to a scale 1 mm = 600 Nm vertically and 1 mm = 3° horizontally. The intercepted areas between the output torque curve and the mean resistance line, taken in order from one end, are as follows: +52, -124, +90, -140, +85, -72 and +107 mm^2 , when the engine is running at 600 rpm. If the total fluctuation of speed is not to exceed $\pm 1.5\%$ of the mean, find the necessary mass of the flywheel of radius 0.5 m. **(Nov/Dec 2016)**
14. A multicylinder engine is to run at a speed of 600 rpm. On drawing a turning moment diagram to the scale of 1 mm = 250 Nm and 1 mm = 3° , the areas above and below the mean torque line in mm^2 are: +160, -172, +168, -191, +197, -162. The speed is to be kept within $\pm 1\%$ of mean speed of the engine. Calculate the necessary moment of inertia of the flywheel. Determine the suitable dimensions of a rectangular flywheel rim if the breadth is twice the thickness. The density of cast iron is 7250 kg/m^3 and its hoop stress is 6 MPa. Assume that the rim contributes 92% of the flywheel effect. **(Apr/May 2018)**
15. A connecting rod is suspended from a point 25 mm above the centre of small end and 650 mm above its centre of gravity, its mass being 37.5 kg. When permitted to oscillate, the time period is found to be 1.87 seconds. Find the dynamically equivalent system constituted of two masses, one of which is located at the small end center. **(Apr/May 2018)**

PART C

1. The turning moment diagram of a four stroke engine is assumed to be represented by four triangles, the areas of which from the line of zero pressure are: Suction stroke = 440 mm^2 , Compression Stroke = 1600 mm^2 , Expansion stroke = 7200 mm^2 , Exhaust stroke = 660 mm^2 . Each mm^2 of area represents 3 Nm of energy. If the resisting torque is uniform, determine the mass of the rim of a flywheel to keep the speed between 218 rpm and 222 rpm, when the mean radius of the rim is to be 1.25 m. **(Nov/Dec 2017)**

2. The crank pin circle radius of a horizontal engine is 300mm. The mass of the reciprocating parts is 250kg. When the crank has travelled 60° from IDC, the difference between the driving and the back pressure is 0.35 N/mm^2 . The connecting rod length between centres is 1.2 m and cylinder bore is 0.5m. If the engine runs at 250 rpm and if the effect of piston rod diameter is neglected, calculate : (i) Pressure on slide bars, (ii) Thrust in the connecting rod, (iii) Tangential force on the crank pin, and (iv) Turning moment on the crank shaft. (Apr/May 2018)
3. A horizontal steam engine running at 120 rpm has a bore of 250mm and a stroke of 400mm. The connecting rod is 0.6m and mass of reciprocating parts is 60kg. When the crank has turned through an angle of 45° from the inner dead center, steam pressure on the cover end side is 550 kN/m^2 and that on the crank end side is 70 kN/m^2 . Considering the diameter of the piston rod equal to 50mm, determine : (1) Turning moment on the crank shaft, (2) Thrust on the bearings, and (3) Acceleration of flywheel , if the power of the engine is 20kW, mass of the flywheel 60kg and radius of gyration 0.6m. (Apr/May 2018)

Unit – II Balancing of Masses

PART-A

1. What is meant by balancing of rotating masses?(May/June 2014)

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

2. Mention the importance of dynamic balancing? (Nov/Dec 2018)

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.

3. Write different types of balancing. (Nov/Dec 2014)

1. Balancing of rotating masses (a) Static balancing (b) dynamic balancing
2. Balancing of reciprocating masses.

4. Define static balancing. (Nov / Dec 2012)

The net dynamic force acting on the shaft is equal to zero. This requires that the line of action of three centrifugal forces must be the same. In other words, the centre of the masses of the system must lie on the axis of rotation. This is the condition for static balancing.

5. What are the conditions of dynamic balancing. (Nov/Dec 2017)

(i) The net dynamic force acting on the shaft is equal to zero. This requires that the line of action of three centrifugal forces must be the same. In other words, the centre of the masses of the system must lie on the axis of rotation. (ii) The net couple due to the dynamic forces acting on the shaft is equal to zero. In other words, the algebraic sum of the moments about any point in the plane must be zero. The above conditions together give dynamic balancing

6. State the conditions for complete balance of several masses revolving in different planes. (Nov/Dec 2014)

1. The forces in the reference plane must balance, i.e. the resultant force must be zero.
2. The couples about the reference plane must balance, i.e. the resultant couple must be zero.

7. Why complete balancing is not possible in reciprocating engine? (Nov/Dec 2016)

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 the complete balancing is not possible in reciprocating engines.

8. Why are the cranks of a locomotive engine with 2 cylinders placed at 90° to each other?

In order to facilitate the starting of locomotive in any position the cranks of a locomotive are generally at 90° to one another.

9. What do you understand by the term partial balancing? (Nov/Dec 2015)

In a reciprocating engine, the provision of a rotating counter mass results in partial balance, as one vertical component of rotating mass remains unchecked.

10. Differentiate between the unbalanced force due to a reciprocating mass and that to revolving masses. (Nov/Dec 2015)

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

11. Define Tractive force.

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

12. Define Swaying couple(Nov/Dec 2018)

The couple has swaying effect about a vertical axis, and tends to sway the engine alternately in clockwise and anticlockwise directions. Hence the couple is known as **swaying couple**.

13. Define Hammer blow (Nov / Dec 2012) (Dec 2013) (Nov/Dec 2016)

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

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

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

15. Differentiate coupled and uncoupled locomotives.

If two or more pairs of wheels are coupled together, the locomotives are of coupled type. Whereas, if there is only one pair of driving wheel, the locomotives is not possible in reciprocating engines.

16. What are the conditions to be satisfied for complete balancing of in line engine?

1. The algebraic sum of the primary forces must be equal to zero. In other words, the primary force polygon must close ; and
2. The algebraic sum of the couples about any point in the plane of the primary forces must be equal to zero. In other words, the primary couple polygon must close.

17. 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.

18. State the condition for static balancing. (Dec 2013)

The net dynamic force acting on the shaft is equal to zero or the centre of the masses of the system must lie on the axis of rotation.

19. What is meant by balancing machines?

The machines which is used to determine whether the rotating parts of a machine is completely balanced or not, to check the static and dynamic balancing of rotating parts and to which balancing is done.

20. Write any two advantages of coupling the wheels of a coupled locomotive.

1. The wheel resistance against slipping on the rails is increased.
2. The hammer blow effect is minimized.

21. Give the different types of balancing machines used in practice.

Static balancing machines , Dynamic balancing machines, Universal balancing machines

22. Write short notes on balancing linkages.

Linkages are balanced by balancing the shaking force and shaking moment. In force balancing, the total mass centre is to be made stationary.

23. What are in-line engines?

The 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 engines**.

24. What is the difference between balancing of rotating and reciprocating masses.

S.No.	Balancing of rotating masses	Balancing of reciprocating masses
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1	Unbalanced force remains constant in magnitude, but varies in direction.	Unbalanced force remains constant in direction, but varies in magnitude.
2	Complete balancing is possible.	Only partial balancing is possible

25. What you meant by primary and secondary balancing?(Nov/Dec 2017)

$$\therefore \text{Primary unbalanced force, } F_p = m \cdot \omega^2 \cdot r \cos \theta$$

$$\text{and secondary unbalanced force, } F_s = m \cdot \omega^2 \cdot r \frac{\cos 2\theta}{n}$$

PART-B

1. A shaft carries four masses in parallel planes A, B, C and D in this order along its length. The masses at B and C are 18 kg and 12.5 kg respectively, and each has an eccentricity of 60 mm. The masses at A and D have an eccentricity of 80 mm. The angle between the masses at B and C is 100° and that between the masses at B and A is 190°, both being measured in the same direction. The axial distance between the planes A and B is 100 mm and that between B and C is 200 mm. If the shaft is in complete dynamic balance, determine the magnitude of the masses at A and D ; the distance between planes A and D and the angular position of the mass at D. **(Nov/Dec 2017)**
2. The reciprocating mass per cylinder in a 60° V-twin engine is 1.5 kg. The stroke and connecting rod length are 100 mm and 250 mm respectively. If the engine runs at 1800 r.p.m., determine the maximum and minimum values of the primary and secondary forces. Also find out the crank position corresponding these values. **(Nov/Dec 2017)**
3. A twin cylinder V engine has V angle of 60° has a stroke of 120 mm and the connecting rods of length 240mm. The mass of reciprocating parts per cylinder is 2 kg. If the crank speed is 2000 rpm, determine the magnitude of the primary and secondary forces. **(Nov/Dec 2018)**
4. A shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radii 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitudes and angular positions. **(Nov/Dec 2018) (Apr/May 2018)**
5. The three cranks of a three cylinder locomotive are all on the same axle and are set at 120°. The pitch of the cylinders is 1 metre and the stroke of each piston is 0.6 m. The reciprocating masses are 300 kg for inside cylinder and 260 kg for each outside cylinder and the planes of rotation of the balance masses are 0.8 m from the inside crank. If 40% of the reciprocating parts are to be balanced, find : 1. the magnitude and the position of the balancing masses required at a radius of 0.6 m ; and 2. the hammer blow per wheel when the axle makes 6 r.p.s. **(Apr/May 2018)**
6. Four masses A, B, C and D revolve at equal radii and are equally spaced along a shaft. The mass B is 7 kg and the radii of C and D make angles of 90° and 240° 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. **(Nov / Dec 2014)**
7. The following particulars relate to an outside cylinder of uncoupled locomotive: Revolving mass per cylinder = 300kg; Reciprocating mass per cylinder = 450 kg; Length of each crank = 350 mm; Distance between wheels = 1.6 m; Distance between cylinder centers = 1.9 m; Diameter of driving wheels = 2m; Radius of balancing mass = 0.8m; angle between the cranks = 90°. If the whole of the revolving mass and 2/3 of the reciprocating masses are to be balanced in planes of driving wheels, determine; Magnitude and direction of the balance masses, speed at which the wheel will lift off the rails when the load on each driving wheel is 35 KN, and Swaying couple at speed arrived in (ii) above. **(Nov/Dec 2014)**

8. The cranks are 3 cylinder locomotive are set at 120° . 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: The magnitude and the position of the balancing masses required at a radial distance of 500 mm; and The hammer blow per wheel when the axle rotates at 350 rpm. **(Nov/Dec 2015)**
9. An inside cylinder locomotive has its cylinder centre lines 0.7 m apart and has a stroke of 0.6 m. The rotating masses per cylinder are equivalent to 150 kg at the crank pin, and the reciprocating masses per cylinder to 180 kg. The wheel centre lines are 1.5 m apart. The cranks are at right angles. The whole of the rotating and $\frac{2}{3}$ of the reciprocating masses are to be balanced by masses placed at a radius of 0.6 m. Find the magnitude and direction of the balancing masses. Find the fluctuation in rail pressure under one wheel, variation of tractive effort and the magnitude of swaying couple at a crank speed of 300 r.p.m. **(Nov/Dec 2015)**
10. A 4 cylinder engine has the two outer cranks as 120° to each other and their reciprocating masses are each 400 kg. The distance between the planes of rotation of adjacent cranks are 400mm, 700mm, 700mm and 500mm. Find the reciprocating mass and the relative angular position for each of the inner cranks, if the engine is to be in completely balance. Also find the maximum unbalanced secondary force, if the length of each crank is 350 mm, the length of each connecting rod 1.7m and the engine speed 500 rpm. **(Nov/Dec 2016)**
11. A 4 cylinder vertical engine has cranks 150 mm long. The planes of rotation of first, second and fourth cranks are 400 mm, 200 mm and 200 mm respectively from the third crank and their respective masses are 50kg, 60kg, and 50 kg respectively. Find the mass of the reciprocating mass for the third cylinder and the relative angular positions of the cranks in order that the engine may be in computer primary balance. **(Nov/Dec 2016)**
12. A 3 cylinder radial engine driven by a common crank has the cylinders spaced at 120° . The stroke is 125 mm; the length of the connecting rod is 225 mm and the reciprocating mass per cylinder 2 kg. Calculate the primary and secondary forces at crank shaft speed of 1200 rpm. **(May/June 2014)**
13. The reciprocating mass per cylinder in a 60° V-twin engine is 1.5 kg. The stroke is 100 mm for each cylinder. If the engine runs at 1800 rpm, determine the maximum and minimum values of the primary forces and find out the corresponding crank position. **(May / June 2014)**
14. 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. **(Apr/May 2015)**
15. The following data relate to a single cylinder vertical reciprocating engine; mass of the reciprocating parts = 40 kg, mass of revolving parts = 30 kg at 180 mm radius, speed = 150r.p.m. stroke 350mm. If 60 % of the reciprocating parts and all the revolving parts are to be balanced, determine (1) the balance mass required at a radius of 320 mm (2) the unbalanced force when the cranks has turned 45° from the top dead centre. **(Apr/May 2015)**

PART C

1. A four cylinder vertical engine has cranks 150mm long. The planes of rotation of the first, second and fourth cranks are 400mm, 200mm and 200mm respectively from the third crank and their reciprocating masses are 50 kg, 60kg and 50 kg respectively. Find the mass of the reciprocating parts for the third cylinder and the relative angular positions of the cranks in order that the engine may in complete primary balance. **(Nov/Dec 2018)**

2. A shaft is supported in bearings 1.8 m apart and projects 0.45 m beyond bearings at each end. The shaft carries three pulleys one at each end and one at the middle of its length. The mass of end pulleys is 48 kg and 20 kg and their centre of gravity are 15 mm and 12.5 mm respectively from the shaft axis. The centre pulley has a mass of 56 kg and its centre of gravity is 15 mm from the shaft axis. If the pulleys are arranged so as to give static balance, determine : 1. relative angular positions of the pulleys, and 2. dynamic forces produced on the bearings when the shaft rotates at 300 r.p.m.
3. A shaft has three 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 centres from the axis of rotation are 12 mm, 18 mm and 12 mm and their angular positions are 120° apart. The density of metal is 7000 kg/m³. Find the amount of out-of-balance force and couple at 600 r.p.m. If the shaft is balanced by adding two masses at a radius 75 mm and at distances of 100 mm from the central plane of the middle eccentric, find the amount of the masses and their angular positions.

Unit – III Free Vibration

PART-A

1. Define vibrations and classify it.

When elastic bodies such as a spring, a beam and a shaft are displaced from the equilibrium position by the application of external forces, and then released, they execute a vibratory motion.

Types (1) Free vibration (2) Forced Vibration (3) Damped vibration

2. Define vibration

Any motion that exactly repeats itself after an interval, of time is a periodic motion and is called vibration.

3. Vibration can have desirable effects – justify.(May/June 2014)

Though vibration is mainly known for its undesirable effects like, unwanted noise and wear, sometimes it is used to design a machine with a specific application. Vibratory conveyor and cell phones are example in support of the statement.

4. How do you classify vibration and define transient vibration? (Nov/Dec 2014,2015)

i) according to the actuating force:

- a) Free vibration
- b) Forced vibration

ii) according to energy dissipation:

- a) Undamped vibration
- b) Damped vibration

according to behavior of vibrating system:

- a) Linear vibration
- b) Non – linear vibration

according to motion of system with respect to axis:

- a) Longitudinal vibration
- b) Transverse vibration
- c) Torsional vibration

5. What is longitudinal vibration? Mention the types of stresses developed due to this.

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

In this case, the shaft is elongated and shortened alternately and thus the tensile and compressive stresses are induced alternately in the shaft

6. Define the following terms: (a) time period (b) cycle (c) frequency

1. Period of vibration or time period. It is the time interval after which the motion is repeated itself. The period of vibration is usually expressed in seconds.

2. Cycle. It is the motion completed during one time period.

3. Frequency. It is the number of cycles described in one second. In S.I. units, the frequency is expressed in hertz (briefly written as Hz) which is equal to one cycle per second.

7. Define transverse vibration and mention the type of stress developed due to this. (Nov/Dec 2018)

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**. In this case, the shaft is straight and bent alternately and bending stresses are induced in the shaft.

8. What is the principle of Raleigh's method? (Apr/May 2018)

In this method, the maximum kinetic energy at the mean position is equal to the maximum potential energy (or strain energy) at the extreme position

9. Give the equation for the natural frequency of longitudinal vibration when, (a) the mass of the shaft is negligible (b) the mass of the shaft is considered.

If Mass negligible

$$f_n = \frac{1}{t_p} = \frac{1}{2\pi} \sqrt{\frac{s}{m}} = \frac{1}{2\pi} \sqrt{\frac{g}{\delta}}$$

If Mass Consider

$$f_n = \frac{1}{2\pi} \sqrt{\frac{s}{m + \frac{m_C}{3}}}$$

10. Define critical speed/ whirling speed. (Nov / Dec 2012)(May/June 2016)

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 or whirling speed.

11. A shaft of length 0.75 m, supported freely at the ends, is carrying a body of mass 90 kg at 0.25m from one end. Find the natural frequency of transverse vibration. Assume E = 200 GN/m² and shaft diameter = 50 mm.

We know that moment of inertia of the shaft,

$$I = \frac{\pi}{64} \times d^4 = \frac{\pi}{64} (0.05)^4 \text{ m}^4$$

$$= 0.307 \times 10^{-6} \text{ m}^4$$

and static deflection at the load point

$$\delta = \frac{W a^2 b^2}{3EI} = \frac{90 \times 9.81 (0.25)^2 (0.5)^2}{3 \times 200 \times 10^9 \times 0.307 \times 10^{-6} \times 0.75} = 0.1 \times 10^{-3} \text{ m}$$

We know that natural frequency of transverse v

$$f_n = \frac{0.4985}{\sqrt{\delta}} = \frac{0.4985}{\sqrt{0.1 \times 10^{-3}}} = 49.85 \text{ Hz}$$

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

The eccentricity of the centre of gravity of the rotating masses from the axis of rotation of the shaft, diameter of the disc, span (length) of the shaft, and Type of supports connections at its ends

13. Distinguish between critical damping and large damping.

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

14. Define the term damping and damped vibration. (Nov/Dec 2017)

In vibrating systems, the effect of friction is referred to as damping. The damping provided by fluid resistance is known as viscous damping.

15. Mention any three types of damping. (Nov/Dec 2016)

Overdamping, underdamping, critical damping

16. What is meant by critical damping?

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

17. When will the maximum amplitude of vibration occur?

Irrespective of the amount of damping, the maximum amplitude of vibration occurs before the ratio r/n reaches unity or when the frequency of the forced vibration is less than that of the undamped vibration.

18. What are the various types of damping?

Viscous damping, Coulomb or dry friction damping, Solid or structural damping, and Slip or interfacial damping

19. Define - (1) Damping Co efficient (2) Damping factor (Dec 2013)

The ratio of the actual damping coefficient (c) to the critical damping coefficient (cc) is known as **damping factor or damping ratio**. Mathematically,

$$\text{Damping factor} = \frac{c}{c_c} = \frac{c}{2m\omega_n}$$

20. What is the principle of Raleigh's method?

In this method, the maximum kinetic energy at the mean position is equal to the maximum potential energy (or strain energy) at the extreme position

21. What is the limit beyond which damping is detrimental and why? (Nov/Dec 2015)

When damping factor > 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.

22. Define - (1) Amplitude reduction factor(2) Logarithmic decrement (Nov/Dec2018) (May/June 2016) (Apr/May 2018)

It 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.

23. Define node in torsional vibration. (Nov/Dec 2017)

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

24. Define – Torsionally equivalent shaft. (May/June 2014)

The shaft have variable diameter for different length. such a shaft may, theoretically be replaced by an equivalent shaft of uniform diameter.

25. Define degrees of freedom in vibrations (May/June 2016)

It is defined as the independent coordinate to move independently in the space.

PART B

1. In a damped free vibrations mass is 2kg and spring stiffness is 100 N/m. It is observed that an initial amplitude of 100mm is reduced to 1mm in 10 oscillations. Find the damping constant and the natural frequency of vibrations. **(Nov/Dec 2018)**
2. Calculate the whirling speed of a shaft 20mm diameter and 0.6m long carrying a mass of 1 kg at its mid-point. The density of the shaft material is 40 Mg/m³. Assume the shaft to be freely supported. **(Nov/Dec 2018)**
3. A machine mounted on springs and fitted with a dashpot has a mass of 60kg. There are three springs, each of stiffness 12 N/mm. The amplitude of vibrations reduces from 45 to 8mm in two complete oscillations. Assuming that the damping force varies as the velocity, determine the damping coefficient, the ratio of frequencies of damped and undamped vibrations and the periodic time of damped vibrations. **(Nov/Dec 2017)**
4. A rotor has a mass of 12 kg and is mounted midway on a 24mm diameter horizontal shaft supported at the ends by two bearings. The bearings are 1 m apart. The shaft rotates at 2400 rpm. If the centre of mass of the rotor is 0.11 mm away from the geometric centre of the rotor due to certain manufacturing defect, find the amplitude of steady state vibration and the dynamic force transmitted to the bearing. Take E as 200 G N/m². **(Nov/Dec 2017)**
5. A shaft 1.5 m long, supported in flexible bearings at the ends carries two wheels each of 50 kg mass. One wheel is situated at the centre of the shaft and the other at a distance of 375 mm from

- the centre towards left. The shaft is hollow of external diameter 75 mm and internal diameter 40 mm. The density of the shaft material is 7700 kg/m^3 and its modulus of elasticity is 200 GN/m^2 . Find the lowest whirling speed of the shaft, taking into account the mass of the shaft. **(Apr/May 2018)**
6. A coil of spring stiffness 4 N/mm supports vertically a mass of 20 kg at the free end. The motion is resisted by the oil dashpot. It is found that the amplitude at the beginning of the fourth cycle is 0.8 times the amplitude of the previous vibration. Determine the damping force per unit velocity. Also find the ratio of the frequency of damped and undamped vibrations. **(Apr/May 2018)**
 7. (a) A machine of weighs 18 kg and is supported on springs and dashpots. The total stiffness of the springs is 12 N/mm and damping is 0.2 N/mm/s the system is initially at rest and a velocity of 120 mm/s is imparted to the mass. Determine (1) the displacement and velocity of mass as a function of time (2) the displacement and velocity after 0.4s .
- (b) Describe the types of vibrations with simple sketch. **(Nov/Dec 2014)**
8. (i) Derive the expression for the natural frequency of free transverse or longitudinal vibrations by using any two methods. (ii) A shaft of 100 mm diameter and 1 m long is fixed at one end and other end carries a flywheel of mass 1 tonne . Taking young's modulus for the shaft material as 200 GN/m^2 ; find the natural frequency of longitudinal and transverse vibrations. **(May/June 2016)**
 9. A flywheel is mounted on a vertical shaft as shown in figure. The both ends of the shaft are fixed and its diameter is 50 mm . The flywheel has a mass of 500 kg . Find the natural frequency of free longitudinal and transverse vibrations. Take $E = 200\text{GN/m}^2$. **(May/June 2016)**
 10. A Steel bar 25 mm wide and 50 mm deep is freely supported at two points 1m apart and carries a mass of 200 kg in the middle of the bar. Neglecting the mass of the bar, find the frequency of free transverse vibration. If an additional mass of 200 kg is distributed uniformly over the length of the shaft, what will be the frequency of free transverse vibration? Take $E = 200 \text{ GN/m}^2$. **(Nov/Dec 2015)**
 11. A vibrating system consists of a mass of 8 kg , spring of stiffness 5.6 N/mm and a dashpot of damping coefficient of 40 N/m/s . Find (a) damping factor (b) logarithmic decrement (c) ratio of two consecutive amplitudes. **(Nov/Dec 2015)**
 12. A centrifugal pump is driven through a pair of spur wheels from an oil engine. The pump runs at 4 times the speed of the engine. The shaft from the engine flywheel to the gear is 75 mm diameter and 1.2 m long, while that from the pinion to pump is 50 mm diameter and 400 mm long. The moments of inertia are as follows: flywheel = 1000kg-m^2 ; pinion = 10kg-m^2 ; and pump impeller = 40kg-m^2 . Find the natural frequencies of torsional oscillations. Take $C = 84 \text{ GN/m}^2$. **(Nov/Dec 2014)**
 13. A steel shaft ABCD 1.5m long has flywheel at its end A and D. the mass of the flywheel A is 600kg and has a radius of gyration of 0.6m . the mass of the flywheel D is 800 kg and has a radius of gyration of 0.9m . The connecting shaft has a diameter of 50mm for the portion AB which is of 0.4m long; and has a diameter of 60mm for the portion BC which is 0.5m and has a diameter of d mm for the portion CD which is 0.6m long. Determine N 1. The diameter 'd' of the portion CD so that the node of the torsional vibration of the system will be at the centre of the length BC and 2. The natural frequency of the torsional vibration The modulus of rigidity for the shaft material is 80GN/m^2 **(May/June 2016)**
 14. The following data are given for a vibratory system with viscous damping: Mass = 2.5 kg ; spring constant = 3 N/mm and the amplitude decreases to 0.25 of the initial value after five consecutive cycles. Determine the damping coefficient of the damper in the system. **(Nov/Dec 2016)**
 15. A gun is so designed that on firing, the barrel recoils against a spring. A dashpot at the end of the recoil, allows the barrel to comeback to its initial position within the minimum time without any oscillation. The gun barrel has 500 kg mass and recoil spring of 300 N/mm . The barrel recoils 1 m on firing. Determine (i) the initial recoil velocity of the gun barrel (ii) the critical damping coefficient of the dashpot engaged at the end of recoil stroke. **(Nov/Dec 2016)**

PART C

1. A Commercial type vibration pick up has a natural frequency of 5.75 Hz and a damping factor of 0.65. What is the lowest frequency beyond which the amplitude can be measured within one percent error? (Nov/Dec 2018)
2. A shaft 30mm diameter and 1.5 m long has a mass of 16 kg per meter length. It is simply supported at the ends and carries three isolated loads 1 kN, 1.5 kN and 2 kN at 0.4m, 0.6m and 0.8 m respectively from the left support. Find the frequency of the transverse vibrations. (i) Neglecting the mass of the shaft (ii) Considering the mass of the shaft. Take the Young's modulus of the shaft material E as 200 GPa (Nov/Dec 2017)
3. A motor drives a centrifugal pump through gearing, the pump speed being one-third of motor. The shaft from the motor to the pinion is 60mm diameter and 300 mm long. The moment of inertia of rotor is 400 Kg m². The impeller shaft is 100mm diameter and 600mm long. The moment of inertia of impeller is 1500 kg m². Neglecting the inertia of gears and shaft, determine the frequency of torsional vibration of the system. The modulus of rigidity of shaft material is 80GN/m².

Unit – IV Forced Vibration

Part A

1. Define - forced vibration.

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

2. What do you meant by 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.

3. What is meant by 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 meant by damping and undamped 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 said to be damped vibration.

5. Write the governing/differential equation of forced vibration. (Nov / Dec 2012) (Nov/Dec 2016)

$$m \times \frac{d^2x}{dt^2} + c \times \frac{dx}{dt} + s \cdot x = F \cos \omega t$$

6. What do you understand by single – node frequency?

In the other set of values, one gives the position of a single node and the other is beyond the physical limits of the equation. The frequency so obtained is known as single – node frequency.

7. What do you understand by two – node frequency?

One set of values given by the quarradic equation gives the position of two nodes and the frequency thus obtained is known as two – node frequency.

8. Define - phase angle.

$$\phi = \tan^{-1} \left(\frac{c \omega}{s - m \omega^2} \right)$$

9. Define – Magnification factor or Dynamic magnifier. (Nov/Dec 2014)

It is the ratio of **maximum displacement of the forced vibration (xmax) to the deflection due to the static force F(xo)**. We have proved in the previous article that the maximum displacement or the amplitude of forced vibration,

10. Define – vibration isolation.(Nov/Dec 2015) (May/june 2016) (Nov/Dec 2016)

A little consideration will show that when an unbalanced machine is installed on the foundation, it produces vibration in the foundation. In order to prevent these vibrations or to minimise the transmission of forces to the foundation, the machines are mounted on springs and dampers or on some vibration isolating material

11. Specify the importance of vibration isolation? (May/june 2014)

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

12. Define the term isolating factor/transmissibility ratio. (Nov / Dec 2014) (May/june 2014)

The ratio of the force transmitted (FT) to the force applied (F) is known as the **isolation factor** or **transmissibility ratio** of the spring support.

13. Define damping ratio.

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

14. What is meant by harmonic forcing? (Dec 2013)

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

15. Define frequency response curve.

Frequency response curve is a curve drawn between magnification factor and frequency ratio for various values of damping factor.

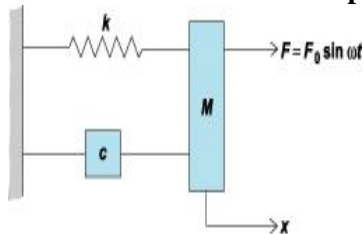
16. What are the methods of isolating the vibration?

1. High speed engines / machines mounted on foundation and supports cause vibrations of excessive amplitude because of the unbalanced forces.
2. The materials used for vibration isolation are rubber, felt cork, etc, etc. these are placed between the foundation and vibrating body.

17. What are the methods of isolating the vibration?(Nov/Dec2015)

1. High speed engines / machines mounted on foundation and supports cause vibrations of excessive amplitude because of the unbalanced forces.
2. The materials used for vibration isolation are rubber, felt cork, etc, etc. these are placed between the foundation and vibrating body.

18. To draw the Mass-spring-damper system



19. What is forced – Damped vibrations?

If in a spring mass system, damping is also provided with a dashpot means, the system is called as forced – damped vibration system.

20. Define 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 as elastic suspension.

21. When will the maximum amplitude of vibration occur? (Nov / Dec 2012)

Irrespective of the amount of damping, the maximum amplitude of vibration occurs before the ratio r/n reaches unity or when the frequency of the forced vibration is less than that of the undamped vibration.

PART-B

1. A single cylinder vertical petrol engine of total mass 200 kg is mounted upon a steel chassis frame and causes a vertical static deflection of 2.4 mm. The reciprocating parts of the engine has a mass of 18 kg and move through a vertical stroke of 160 mm with simple harmonic motion. A

- dashpot is provided whose damping resistance is directly proportional to the velocity and amounts to 1 N/mm/s. Considering that the steady state of vibration is reached ; determine : 1. the amplitude of forced vibrations, when the driving shaft of the engine rotates at 500 r.p.m., and 2. the speed of the driving shaft at which resonance will occur. **(Nov/Dec 2018)**
2. A compressor supported symmetrically on four springs has a mass of 100 kg. The mass of the reciprocating parts is 2 kg which move through a vertical stroke of 80mm with SHM. Neglecting damping, determine the combined stiffness of the springs so that the force transmitted to the foundation is 1/25 th of the impressed force. The machine crankshaft rotates at 1000 rpm. When the compressor is actually supported on springs, it is found that the damping reduces the amplitude of successive free vibrations by 25%. Find the force transmitted through the foundation at 1000 rpm, the force transmitted to the foundation at resonance and the amplitude of the vibrations at resonance. **(Nov/Dec 2018)**
 3. A 1000 kg machine is mounted on four identical springs of total spring constant K and having negligible damping. The machine is subjected to a harmonic external force of amplitude $F_0 = 490$ N and frequency of 180 rpm. Determine the amplitude of motion of the machine and the maximum force transmitted to the foundation because of the unbalance force when $K = 1.96 \times 10^6$ N/m **(Nov/Dec 2017)**
 4. The springs of an automobile trailer are compressed 0.1 m under its own weight. Find the critical speed when the trailer is travelling over a road profile approximated by a sine wave of amplitude 0.08 m and wave length of 14m. What will be the amplitude of vibration at 60 km/hr? **(Nov/Dec 2017)**
 5. A machine part of mass 2 kg vibrates in a viscous medium. Determine the damping coefficient when a harmonic exciting force of 25 N results in a resonant amplitude of 12.5 mm with a period of 0.2 second. If the system is excited by a harmonic force of frequency 4 Hz what will be the percentage increase in the amplitude of vibration when damper is removed as compared with that with damping. **(Apr/May 2018)**
 6. A single-cylinder engine of total mass 200 kg is to be mounted on an elastic support which permits vibratory movement in vertical direction only. The mass of the piston is 3.5 kg and has a vertical reciprocating motion which may be assumed simple harmonic with a stroke of 150 mm. It is desired that the maximum vibratory force transmitted through the elastic support to the foundation shall be 600 N when the engine speed is 800 r.p.m. and less than this at all higher speeds. **1.** Find the necessary stiffness of the elastic support, and the amplitude of vibration at 800 r.p.m., and **2.** If the engine speed is reduced below 800 r.p.m. at what speed will the transmitted force again becomes 600 N? **(Apr/May 2018)**
 7. (a) Derive the relation for the displacement of mass from the equilibrium position of a damped vibration system with harmonic forcing.
- (b) Define the term vibration isolation. **(Nov/Dec 2014)**
8. A vibrating system having a mass of 1.5 kg is suspended by a spring of stiffness 1200N/m and it is put to harmonic excitation of 12 N. Assuming viscous damping, Determine, (1) Resonant Frequency (2) Phase angle at resonance (3) Amplitude at resonance (4) Damped frequency; Take $c = 48$ NS/m **(Nov/Dec 2015)**
 9. A machine supported symmetrically on five springs, has a mass of 90 kg. The mass of the reciprocating parts is 3 kg which moves through a vertical stroke of 90 mm with SHM. Neglecting damping determine the combined stiffness of the springs so that force transmitted to the foundation is 1/30th of impressed force. The machine crank shaft rotates at 750 rpm. If the under actual working conditions the damping reduces the amplitude of successive vibration by 25%, find: (i) Force transmitted to the foundation at 900 rpm (ii) Force transmitted to the foundation at resonance.(iii)The amplitude of vibration at resonance**(Nov/Dec 2015)**
 10. A 75 kg machine is mounted on springs of stiffness $K = 11.76 \times 10^5$ N/m with an assumed damping factor of 0.2. A 2 kg piston within the machine has a reciprocating motion with a stroke of 0.08 m and a speed of 3000 rpm. Assuming the motion of the piston to be harmonic, determine

the amplitude of vibration of the machine and the vibratory force transmitted to the foundation. **(Nov/Dec 2014)**

11. A body of mass 70 kg is suspended from a spring which deflects 2 cm under the load. It is subjected to a damping effect adjusted to a value of 0.23 times that required for critical damping. Find the natural frequency of the un-damped and damped vibrations and ratio of successive amplitudes of damped vibrations. If the body is subjected to a periodic disturbing force of 700 N and of frequency equal to 0.78 times the natural frequency, find the amplitude of forced vibrations and the phase difference with respect to the disturbing force. **(May/June 2016)**
12. The support of a spring mass system is vibrating with amplitude of 6 mm and a frequency of 1200 cycles/min. If a mass is 95 kg and the spring has a stiffness of 1950 N/m, determine the amplitude of vibration of the mass. If a damping factor of 0.2 is included, what would be the amplitude? **(Nov/Dec 2013)**
13. A machine of mass 75 kg is mounted on springs of stiffness 1200 kN/m and with an assumed damping factor of 0.2. A piston within the machine of mass 2 kg has a reciprocating motion with a stroke of 80 mm and a speed of 3000 cycles/min. Assuming the motion to be simple harmonic, find: 1. the amplitude of motion of the machine, 2. Its phase angle with respect to the exciting force, 3. the force transmitted to the foundation, and 4. the phase angle of transmitted force with respect to the exciting force. **(May/June 2016)**.
14. The mass of an electric motor is 120 kg and it runs at 1500 r.p.m. The armature mass is 35 kg and its C.G. lies 0.5 mm from the 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 : 1. stiffness of each spring; 2. dynamic force transmitted to the base at the operating speed; and 3. natural frequency of the system. **.(Nov/Dec 2016)**
15. A single cylinder vertical petrol engine of total mass 300 kg is mounted upon a steel chassis frame and causes a vertical static deflection of 2 mm. The reciprocating parts of the engine has a mass of 20 kg and move through a vertical stroke of 150 mm with simple harmonic motion. A dashpot is provided whose damping resistance is directly proportional to the velocity and amounts to 1.5 kN per metre per second. Considering that the steady state of vibration is reached ; determine : 1. the amplitude of forced vibrations, when the driving shaft of the engine rotates at 480 r.p.m., and 2. the speed of the driving shaft at which resonance will occur. **.(Nov/Dec 2016)**

PART C

1. The mass of an electric motor is 120 kg and it runs at 1500 r.p.m. The armature mass is 35 kg and its C.G. lies 0.5 mm from the 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 : 1. stiffness of each spring; 2. dynamic force transmitted to the base at the operating speed; and 3. natural frequency of the system.
2. A mass of 10 kg is suspended from one end of a helical spring, the other end being fixed. The stiffness of the spring is 10 N/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 $150 \cos 50 t$ N is applied at the mass in the vertical direction, find the amplitude of the forced vibrations. What is its value of resonance ?
3. The time of free vibration of a mass hung from the end of a helical spring is 0.8 second. When the mass is stationary, the upper end is made to move upwards with a displacement y metre such that $y = 0.018 \sin 2 \pi t$, where t is the time in seconds measured from the beginning of the motion. Neglecting the mass of the spring and any damping effects, determine the vertical distance through which the mass is moved in the first 0.3 second.

Unit – V Mechanisms for Control

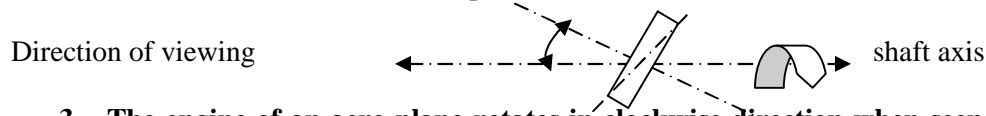
Part –A

1. Differentiate Hunting from Sensitiveness (Nov/Dec 2017)

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

2. What will be the effect of the gyroscopic couple on a disc fixed at a certain angle to a rotating shaft?

The effect of the resultant gyroscopic couple is that the shaft tends to turn in the plane of paper in anticlockwise direction as seen from top, as a result the horizontal force is exerted on the shaft bearing



3. The engine of an aero plane rotates in clockwise direction when seen from the tail and the aero plane takes a turn to the left. What will be the effect of gyroscopic couple on the aero plane? (Nov/Dec 2017)

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

4. When is a governor said to be hunt? (Nov / Dec 2012)

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.

5. How governors are classified? (Nov/Dec 2018)

1. Centrifugal Governors.
 - (a) Pendulum type : Example: Watt Governors
 - (b) Gravity controlled type : Example: Porter and Proell Governors
 - (c) Spring Controlled type : Example : Hartnell and Hartung Governors.
2. Inertia Governor

6. Define gyroscope. (Nov/Dec 2015)

A gyroscope is a spinning body which is free to move in other directions under the action of external forces.

7. What is meant by isochronous governor? (May/June 2014)

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

8. Differentiate a governor from a flywheel (Nov / Dec 2012)

Governor:

- The function of a governor is to regulate the mean speed of an engine, when there are variations in the load
- It is provided on prime movers such as engine and turbines
- It works intermittently
- It has no influence over cyclic speed fluctuation

Flywheel

- The function of a flywheel is to reduce the fluctuations of speed caused by the fluctuation of the engine turning moment during each cycle of operation
- It is provided on engine and fabricating machines
- It works continuously from cycle to cycle
- It has no influence on mean speed of the prime movers

9. What is the effect of gyroscopic couple on rolling of ship? Why? (Nov/Dec 2018)

During the rolling, the axis of rolling and that of turbine are generally same. So there is no precession of axis of spin and therefore there is no gyroscopic effect when the ship rolls.

10. Write the expression for gyroscopic couple. (Dec 2013) (Nov/Dec 2016).

Gyroscopic couple, $C = I \cdot \omega \cdot \omega_p$

I = moment of inertia of the disc

ω = Angular velocity of the engine

ω_p = Angular velocity of precession.

11. When is a governor said to be sensitive? (Nov/Dec 2014)

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

12. What is the gyroscopic effect on stability of two wheeler when it takes a turn?(Nov / Dec 2012)

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

13. What is the effect of friction on the governors?

The effect of friction on the governors is to increase the range of speed, governor effort, and power of the governor.

14. What is the function of a governor?

The function of a governor is to regulate the mean speed of an engine, when there are variations in the load

15. Define stability of a governor

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

16. 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.

17. What is meant by Hunting? (Apr/May 2018)

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

18. Define gyroscopic couple(May/June 2014)

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 in an axis which is perpendicular to both the axis of spin and axis of precession

19. Define coefficient of sensitiveness (Nov/Dec 2015)

It is the ratio between range of speed and mean speed.

$$\text{Coefficient of sensitiveness} = \frac{\text{Range of speed}}{\text{Mean speed}} = \frac{N_1 - N_2}{N}$$

20. What are the applications of gyroscopic couple?

The gyroscopic couple is usually applied through the bearings which support the shaft.

The gyroscopic principle is used in an instrument or toy known as gyroscopic.

They are installed in ships in order to minimize the rolling and pitching effects of waves.

They are used in aero planes, monorails cars, gyrocompasses etc.

21. Define pitching.

Pitching is the movement of a complete ship up and down in a vertical plane about transverse axis. The pitching of the ship is assumed to take place with SHM i.e. the motion of the axis of spin about transverse axis is simple harmonic.

22. Differentiate between centrifugal and inertia governor

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

23. Define Sensitivity of Governor.(Nov/Dec 2016)

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

24. Explain the term spin and precession. (Apr/May 2018)

spin is the axis of rotation free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum. Precession is a change in the orientation of the rotational axis of a rotating body.

25. Differentiate spring controlled and gravity controlled governors.(May/June 2016)

In gravity controlled governors there is gravity force due to weight on the sleeve or weight of sleeve itself which controls movement of the sleeve. These governors are comparatively larger in size.

In spring controlled governors, a helical spring or several springs are utilised to control the movement of sleeve or balls. These governors are comparatively smaller in size.

PART-B

1. Each arm of a Porter Governor is 250mm long. The upper and lower arms are pivoted to links of 40mm and 50mm 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 40N. Determine the range of speed of the governor for extreme radii of rotation of 125mm and 150mm. **(Nov/Dec 2017)**
2. The turbine rotor of a ship has 2.5 tonnes and rotates at 1750 rpm clockwise when viewed from the aft. The radius of gyration of the rotor is 300mm. Determine the gyroscopic couple and its effect when : (i) the ship turns right at a radius of 250 m with a speed of 22 kmph. (ii) the ship pitches with the bow rising at an angular velocity of 0.85 rad/s and (iii) the ship rolls with angular velocity of 0.15 rad/s. **(Nov/Dec 2017)**
3. Calculate the minimum and maximum speeds and the range of speed of a Porter Governor, which has equal arms each 200mm long and pivoted on the axis of rotation. The mass of each ball is 4kg and the central mass on the sleeve is 20 kg. The radius of rotation of the ball is 100mm when the governor begins to lift and 130mm when governor is at the maximum speed. **(Nov/Dec 2018)**
4. A ship propelled by a turbine rotor which has a mass of 5 tonnes and a speed of 2100 r.p.m. The rotor has a radius of gyration of 0.5 m and rotates in a clockwise direction when viewed from the stern. Find the gyroscopic effects in the following conditions: 1. The ship sails at a speed of 30 km/h and steers to the left in a curve having 60 m radius. 2. The ship pitches 6 degree above and 6 degree below the horizontal position. The bow is descending with its maximum velocity. The motion due to pitching is simple harmonic and the periodic time is 20 seconds. 3. The ship rolls and at a certain instant it has an angular velocity of 0.03 rad/s clockwise when viewed from stern. Determine also the maximum angular acceleration during pitching. Explain how the direction of motion due to gyroscopic effect is determined in each case. **(Nov/Dec 2018)**
5. The mass of the turbine rotor of a ship is 20 tonnes and has a radius of gyration of 0.60 m. Its speed is 2000 r.p.m. The ship pitches 6° above and 6° below the horizontal position. A complete oscillation takes 30 seconds and the motion is simple harmonic. Determine the following: 1. Maximum gyroscopic couple, 2. Maximum angular acceleration of the ship during pitching, and 3. The direction in which the bow will tend to turn when rising, if the rotation of the rotor is clockwise when looking from the left. **(Apr/May 2018)**
6. The arms of a Porter governor are each 250 mm long and pivoted on the governor axis. The mass of each ball is 5 kg and the mass of the central sleeve is 30 kg. The radius of rotation of the balls is 150 mm when the sleeve begins to rise and reaches a value of 200 mm for maximum speed. Determine the speed range of the governor. If the friction at the sleeve is equivalent of 20 N of load at the sleeve, determine how the speed range is modified. **(Apr/May 2018)**
7. What is the effect of gyroscopic couple on the stability of a Four wheel vehicle taking a turn? **(Nov/Dec 2014)**

8. (a) Explain the function of a proell governor with the help of a neat sketch. Derive the relationship among the various forces acting on the link.(b) What are centrifugal governors? How do they differ from inertia governors? **(Nov/Dec 2014)**
9. 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 **(May/June 2014)**
10. Find the angle of inclination with respect to the vertical for a two wheeler having the following details negotiating a turn of radius 50 m: combined mass of vehicle with rider = 250 kg; Centre of gravity with rider in vertical position = 0.6 m; Moment of inertia of flywheel = 0.3 kgm²; M.I of each road wheel = 1 kg-m²; Speed of engine is five times that of road wheels and in same direction; Vehicle speed = 90km/h; wheel diameter = 600 mm. **(May/June 2014)**
11. A hartnell governor having a central sleeve spring and two right angled bell crank levers operates between 290 rpm and 310 rpm for a sleeve lift of 15 mm.the sleeve and ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg.the ball arms are parallel at lowest equilibrium speed. Determine (i) loads on the spring at maximum and minimum speeds, and (ii) stiffness of the spring. **(Nov/Dec 2015)**
12. In a Hartnell governor the lengths of ball and sleeve arms of a bell crank lever are 120 mm and 100 mm respectively. the fulcrum of the bell crank lever is located at 140 mm from the governor axis each governor ball is 4 kg.the governor runs at 5 rps with ball arms vertical and sleeve arms horizontal the sleeve movement is found to be 10 mm (upwards) for an increase of speed of 4%.find (i) maximum speed if the total sleeve movement is limited to 20 mm (ii) the spring stiffness (iii) sensitiveness of governor (iv) required spring stiffness for isochronous at 300 rpm. **(Nov/Dec 2015)**
13. A loaded Porter governor has four links each 250 mm long, two revolving masses each of 3 kg and a central dead weight of mass 20 kg. All the links are attached to respective sleeves at radial distances of 40 mm from the axis of rotation. The masses revolve at a radius of 150 mm at minimum speed and at a radius of 200 mm at maximum speed. Determine the range of speed. **(May/June 2016).**
14. Four wheeled motor car of mass 2000 kg has a wheel base 2.5 m, track width 1.5 m and height of centre of gravity 500 mm above the ground level and lies at 1 metre from the front axle. Each wheel has an effective diameter of 0.8 m and a moment of inertia of 0.8 kg-m². The drive shaft, engine flywheel and transmission are rotating at 4 times the speed of road wheel, in a clockwise direction when viewed from the front, and is equivalent to a mass of 75 kg having a radius of gyration of 100 mm. If the car is taking a right turn of 60 m radius at 60 km/h, find the load on each wheel. **(Nov/Dec 2016).**
15. (a) A ship has a propeller of mass moment of inertia 2000 kgm². The propeller rotates at a speed of 360 rpm in clockwise sense looking from the stern. Determine gyroscopic couple and its effect when ship moves at 30km/hr and steers to the left at a radius of 200m.(b) An aircraft consists of a propeller. It consists of engine and propeller of mass moment of inertia 150kgm². The engine rotates at 3600 rpm in a sense clockwise looking from rear. The aircraft completes half circle of radius 100m towards left flying at 360 km/hr. determine the gyroscopic couple on the aircraft and state its effect. **(May/June 2016).**

PART C

1. An aeroplane makes a complete half circle of 50 metres radius, towards left, when flying at 200 km per hr. The rotary engine and the propeller of the plane has a mass of 400 kg and a radius of gyration of 0.3 m. The engine rotates at 2400 r.p.m. clockwise when viewed from the rear. Find the gyroscopic couple on the aircraft and state its effect on it.

2. In a spring loaded governor of the Hartnell type, the mass of each ball is 1kg, length of vertical arm of the bell 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 per cent greater than the minimum equilibrium speed which is 360 r.p.m. Find, neglecting obliquity of arms, initial compression of the spring and equilibrium speed corresponding to the radius of rotation of 100 mm.
3. In a spring controlled governor of the type, as shown in figure , the mass of each ball is 1.5 kg and the mass of the sleeve is 8 kg. The two arms of the bell crank lever are at right angles and their lengths are $OB = 100$ mm and $OA = 40$ mm. The distance of the fulcrum O of each bell crank lever from the axis of rotation is 50 mm and minimum radius of rotation of the governor balls is also 50 mm. The corresponding equilibrium speed is 240 r.p.m. and the sleeve is required to lift 10 mm for an increase in speed of 5 per cent. Find the stiffness and initial compression of the spring.

