Time: 3 Hours **Total Marks: 80**

N.B: 1) **Question No. 1 is *compulsory*.**
2) **Attempt any *THREE* questions out of remaining *FIVE* questions.**
3) **Assume suitable data wherever necessary.**
4) **Use of Graph paper is allowed.**
5) **Figures to the right indicate full marks.**

1. Answer of the following questions (*any Four)*. **(20)**

i) Differentiate between primary, secondary and tertiary standards.

ii) Explain roughness and waviness with suitable diagram.

iii) Define: Accuracy, Precision, Span and Range of measuring instruments.

iv) What is RTD? How does it work?

v) Define the term transfer function with its significance in control system.

vi) Write a note on *Frequency domain specifications.*

2. (A) Define the term gauge factor of a strain gauge with its significance. **(05)**

(B) Describe with neat diagrams the working of *McLeod gauge* for the pressure measurement. **(05)**

(C) Find the shaft and hole dimensions with tolerance for a **90 H8 e9 pair** with the following data: **(10)**

90 mm lies in the diameter step of **80 to 100 mm**
Upper deviation for e shaft = $\mathbf{11\ D^{0.41}}$
Tolerance unit $\mathbf{i = 0.45\ D^{1/3} + 0.001D}$ micron
Also find the type of fit produced.

3. (A) Classify control system with suitable examples. **(05)**

(B) What is difference between unilateral and bilateral tolerances? Why is unilateral tolerance preferred over bilateral tolerance? **(05)**

(C) Describe with neat diagrams the working principle of the magnetic flow meter and ultrasonic flow meter for flow measurement. **(10)**

4. (A) What is the difference between direct and indirect measuring instrument? Give one example of each type. **(05)**

(B) A system is represented by the characteristic equation **(05)**

$$P(S) = S^6+S^5+8S^4+12S^3+20S^2+16S+16 = 0,$$

Determine the stability of the system by using Routh's criterion.

(C) Define *Interferometry*. Describe with neat sketch the working principle of Laser interferometer. **(10)**

5. (A) Describe with neat sketch ***'Two Wire Method'*** in screw thread measurement. **(10)**

(B) Define desired input, modifying input and interfering input for measuring instruments with suitable examples. Also suggest the methods to minimize the effect of modifying and interfering input. **(10)**

6. (A) A unity feedback system is characterized by open loop transfer function **(10)**

$$G_{(S)} = \frac{25}{S(S+5)}$$

For a unit step input, determine a) Rise time, b) Peak time, c) Settling time d) Peak overshoot.

(B) A system is characterized by transfer function **(10)**

$$G_{(S)}\,H_{(S)} = \frac{K}{S\,(S+5)\,(S+10)}$$

Determine the stability of the system by using root locus method.

Time: 3 Hours **Marks: 80**

- ***Question No.1 is compulsory.***
- *Solve **ANY THREE** questions from the **remaining five** questions.*
- *Figure to the right indicates full marks.*
- *Assume suitable data wherever required, but justify the same.*

			Marks
Q. 1		Solve **ANY FOUR** questions from following. (Each question carries **5 marks**)	**20**
	a)	Discuss the effect of increase in temperature on thermal conductivity of materials which are conductors and insulators.	
	b)	Explain the following non dimensional numbers applied to heat transfer by convection: (i) Nusselt Number (ii) Prandtl Number (iii) Grashoff Number	
	c)	A steam pipe is insulated to reduce the heat loss. However, the measurement reveals that the rate of heat lost has increased instead of decreasing. Explain the reason for this phenomenon.	
	d)	Explain Biot number and Fourier number applied to transient heat transfer.	
	e)	Longer ignition lag in an SI engine and a shorter ignition lag in CI engine is desirable. Discuss the reason for this.	
	f)	Describe the effects of Thermal Converters and Catalytic Converters on emission reduction.	
Q. 2	**a)**	During the trial of a single-cylinder, four-stroke oil engine, having inner diameter 20 cm and stroke length 40 cm, the following results were obtained. Mean effective pressure = 6 bar Torque = 407 Nm Speed = 250 rpm Oil consumption = 4 kg/h Calorific value of fuel = 43 MJ/kg Cooling water flow rate = 4.5 kg/min Air used per kg of fuel = 30 kg Rise in cooling water temperature = 45°C Temperature of exhaust gases = 420°C Room temperature = 20°C Mean specific heat of exhaust gas = 1 kJ/kg K Specific heat of water = 4.18 kJ/kg K Calculate the ip, bp and draw up a heat balance sheet for the test in kJ/h.	**8**
	b)	A composite cylinder consists of 10 cm radius steel pipe of 25 mm thickness over which two layers of insulation 30 mm and 35 mm are laid. The conductivities are 25 W/mK, 0.25 W/mK and 0.65 W/mK for the pipe, first layer and second layer respectively. The inside is exposed to convection at 300°C with h = 65 W/m^{2}K.The outside is exposed to air at 30°C with h = 15 W/m^2 K. Determine the heat loss per metre legth of the pipe. Also calculate the interface temperatures.	**12**

Q. 3 **a)** A 6-cylinder 4-stroke C.I. engine develops 220 kW at 1500 r.pm. with brake specific fuel consumption of 0.273 kg/kWh. Determine the size of the single hole injector nozzle if the injection pressure is 160 bar and the pressure in the combustion chamber is 40 bar. The period of injection is 30° of crank angle. Specific gravity of fuel = 0.85 and orifice discharge coefficient = 0.9. **8**

b) A flat plate 1 m wide and 1.5 m long is to be maintained at 90°C in air when free stream temperature is 10 °C. Determine the velocity at which air must flow over the plate so that the rate of energy dissipation from the plate is 3.75 kW. Consider the range of convective heat transfer coefficient for laminar flow as $h < 10\ W/m^{2\,o}C$ and turbulent flow as $h > 10\ W/m^{2\,o}C$. Use the appropriate correlation from the correlations given below: **12**

$\overline{Nu} = \frac{\bar{h}L}{k} = 0.664(Re_L)^{1/2}(Pr)^{1/3}$ ..... for laminar flow

$\overline{Nu} = \frac{\bar{h}L}{k} = [0.036\ (Re_L)^{0.8} - 836](Pr)^{1/3}$ ..... for turbulent flow

Take the following properties of air at 50°C: ρ = 1.0877 kg/m^3, k = 0.02813 W/m°C, c_p = 1007.3 J/kg°C, μ = 2.029 × 10^{-5} kg/ms and Pr = 0.703.

Q. 4 **a)** A fin 5 mm thick and 45 mm long has its base on a plane plate which is maintained at 125°C. The ambient temperature is 25°C. The conductivity of fin material is 55 W/m°C and the convective heat transfer coefficient is 145 W/m^2 °C. Assuming heat loss by convection from the end of the fin determine: **8**

(i) Temperature at the end of the fin
(ii) Heat dissipated by the fin (per metre width).

b) In a certain double pipe heat exchanger hot water flows at a rate of 50000 kg/h and gets cooled from 95°C to 65°C. At the same time 50000 kg/h of cooling water at 30°C enters the heat exchanger. The flow conditions are such that overall heat transfer coefficient remains constant at 2270 W/m^2 K. Determine the heat transfer area required and the effectiveness, assuming two streams are in parallel flow. Assume for the both the streams c_p = 4.2 kJ/kg K. **12**

Q. 5 **a)** The effective temperature of a body having an area of 0.12 m^2 is 527°C. Calculate the following: **5**
(i) The total rate of energy emission,
(ii) The intensity of normal radiation

b) Explain Willan's line method for measurement of frictional power. **5**

c) Differentiate between the efficiency and effectiveness of an extended surface. **5**

d) Illustrate with suitable diagram, the temperature profile from inlet to outlet for the following: **5**
(i) Parallel flow heat exchanger
(ii) Counter flow heat exchanger
(iii) Condenser
(iv) Evaporator

Q. 6 **a)** Draw a boiling curve for water and identify the different boiling regimes. Explain each regime in brief. **5**

b) A four-stroke gas engine has a bore of 20 cm and stroke of 30 cm and runs at 300 rpm firing every cycle. If air-fuel ratio is 4:1 by volume an volumetric efficiency on NTP basis is 80%, determine the volume of gas used per minute. If the calorific value of the gas is 8 MJ/m^3 at NTP and the brake thermal efficiency is 25% determine the brake power of the engine. **5**

c) Explain the phenomenon of knocking in Spark Ignition (SI) engine. **5**

d) State and explain Fick's Law of diffusion. **5**

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TIME: 3 Hrs **Total Marks: 80**

Instructions:

i. Question No.1 is compulsory
ii. Attempt any 3 out of the remaining questions
iii. Use your judgement for unspecified data, if any but justify the assumption.
iv. Numbers to the right indicate marks.

Q1. Attempt any four of the following sub questions:

a. Compare vibrometer and accelerometer on the basis of the following parameters: mass, natural frequency, practical applicability and error estimation. (5)

b. Why does gyroscopic couple occurs. Derrive an expression for Gyroscopic couple. (5)

c. Compare under damped, critical damp and over damped in details (5)

d. What do you mean by Dynamically Equivalent systems? State the conditions for systems to be dynamically equivalent. (5)

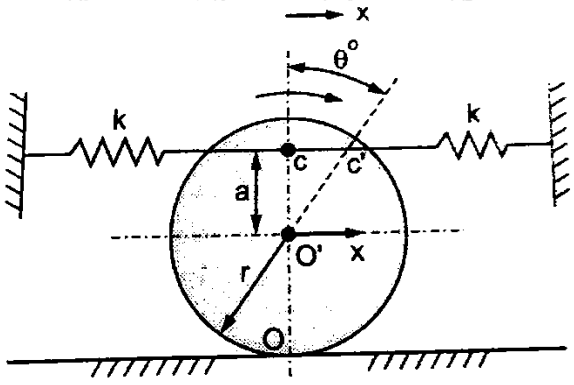
e. Explain the meaning of vibration isolation and transmissibility. List at least four vibration isolation materials. (5)

Q2.a A gun barrel having mass 560kg is designed for following data: Initial recoil velocity 36m/sec. Recoil distance on firing 1.5m Determine i) Spring constant ii)Damping coefficient iii.) Time required by barrel to return to a position of 0.12m from its initial position. (10)

Q2.b The rotor of a turbine installed in a boat with its axis along the longitudinal axis of the boat makes 1500 r.p.m. clockwise when viewed from the stern. The rotor has a mass of 750 kg and a radius of gyration of 300 mm. If at an instant, the boat pitches in the longitudinal vertical plane so that the bow rises from the horizontal plane with an angular velocity of 1 rad /s, determine the torque acting on the boat and the direction in which it tends to turn the boat at the instant. (10)

Q3.a A steam engine 200 mm bore and 300 mm stroke has a connecting rod 625 mm long. The mass of the reciprocating parts is 15 kg and the speed is 250 r.p.m.When the crank is at 30° to the inner dead centre and moving outwards, the difference in steam pressures is 840 kN/m^2. If the crank pin radius is 30 mm determine: 1. the force on the crankshaft bearing; and 2. the torque acting on the crank shaft. (10)

Q3.b Determine the natural frequency of the system shown in Fig below. Assume the Cylinder rolls on the surface without slipping. Consider the mass of cylinder as M. (10)



Q4.a A loaded governor of the Porter type has equal arms and links each 250 mm long. The mass of each ball is 2 kg and the central mass is 12 kg. When the ball radius is 150 mm, the valve is fully open and when the radius is 185 mm, the valve is closed. Find the maximum speed and the range of speed. If the maximum speed is to be increased 20% by an addition of mass to the central load, find what additional mass is required. (10)

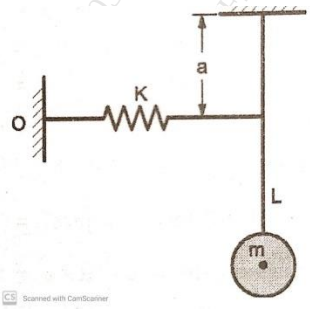
Q4.b The springs of an automobile trailer are compressed 0.1 m under its own weight. Find the critical speed when the trailer is passing over a road with a profile of sinewave whose amplitude is 80 mm and the wavelength is 14 m. Find the amplitude of vibration at a speed of 60 km/kr. (10)

Q5.a. A five cylinder in-line engine running at 750 r.p.m. has successive cranks 144° apart, the distance between the cylinder centre lines being 375 mm. The piston stroke is 225 mm and the ratio of the connecting rod to the crank is 4. Examine the engine for balance of primary and secondary forces and couples. Find the maximum values of these and the position of the central crank at which these maximum values occur. The reciprocating mass for each cylinder is 15 kg. (10)

Q5.b A machine of mass 1000 kg is acted upon by an external force of 3000 N at 1800 rpm. To reduce the effect of vibrations, isolators having static deflection of 2 mm under the machine weight and damping factor of 0.2 are used. Determine : (10)

(i) Amplitude of vibration of machine
(ii) Force transmitted to the foundation
(iii) Phase lag and
(iv) Phase angle between transmitted force and exciting force.

Q6.a Find the differential equation of motion and the natural frequency of vibration for a system shown in Fig. (7)



Q6.b Explain vibration based condition monitoring and fault diagnosis in rotating machine. (5)

Q6.c The natural frequency and the damping ratio of a vibrometer are 6 Hz and 0.22 respectively. What is the range of frequencies for the measurement error to be below 3%. (8)

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(3 hours) **Total marks: 80**

- ***Question No.1 is compulsory.***
- *Solve **ANY THREE** questions from the **remaining five questions.***
- *The figure to the right indicates full marks.*
- *Assume suitable data wherever required, but justify the same.*

Marks

Q. 1 Solve **ANY FOUR** questions from following. (Each question carries **5 marks**) **20**

i) Explain general FEM procedure.

ii) Define shape function and enlist the properties of shape functions.

iii) Explain h-method and p-method of FEM.

iv) Describe the significance of Jacobian Matrix in co-ordinate transformation.

v) Explain the principle of minimum total potential.

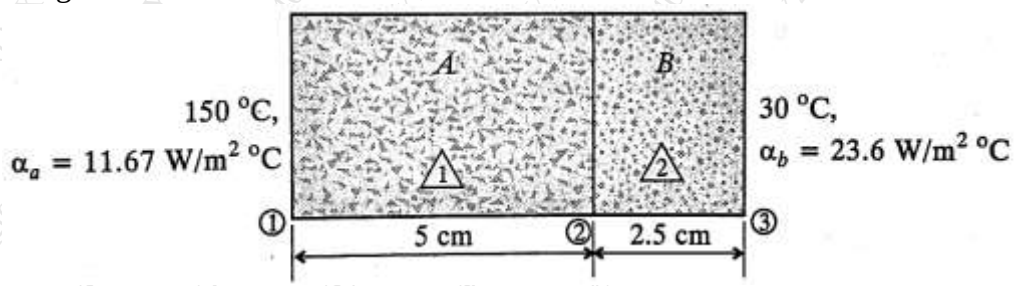
vi) Explain iso-parametric, sub-parametric and super-parametric elements.

Q. 2 a) Solve following differential equation using galerkin method **10**

$$3\frac{d^2y}{dx^2} - \frac{dy}{dx} + 8 = 0 \; ; \; 0 \le x \le 1$$

Boundary Conditions: y(0) = 1, y(1) = 2, find y(0.6)

b) Consider a plain composite wall which is made of two materials of thermal conductivity k_a = 204 W/m°C and k_b = 46 W/m°C and thickness h_a = 5 cm and h_b = 2.5 cm. Material A adjoins a hot fluid at 150°C for which heat transfer coefficient α_a = 11.67 W/m^2 °C and the material B is in contact with a cold fluid at 30°C and heat transfer coefficient α_b = 23.6 W/m^2 °C. Calculate rate of heat transfer through the wall and the temperature at the interface. The wall is 2 m high and 2.5 m wide. **10**



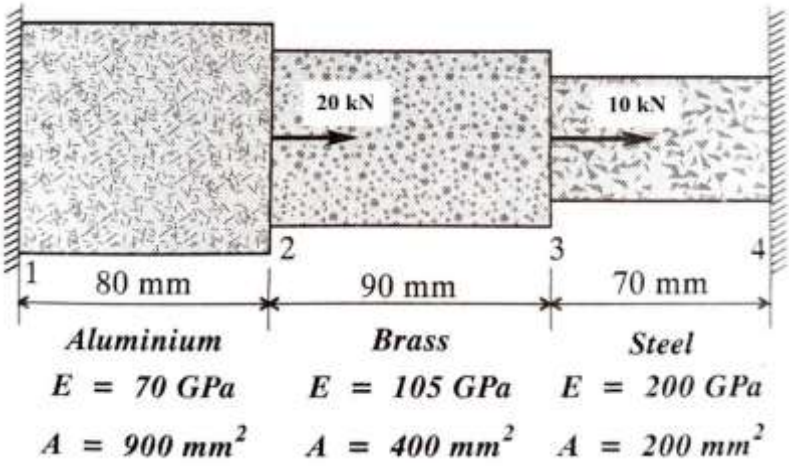
Q. 3 a) Solve the following differential equation by Rayleigh Ritz method. **10**

$$\frac{d^2y}{dx^2} - 10x^2 = 5 \; ; \qquad 0 \le x \le 1$$

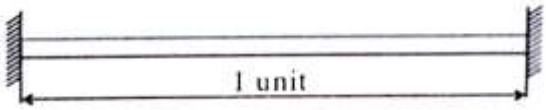
Given boundary conditions are: $y(0) = y(1) = 0$

b) Find the natural frequency of axial vibrations of a bar of uniform cross section of 50 mm^2 and length of 1 meter using consistent mass matrix. Take E = 200 GPa and density = 8000 kg/m^3. Take two linear elements. **10**

Q. 4 **a)** Determine the unknown reactions, displacement and element stresses for the stepped bar shown in the figure below. **10**

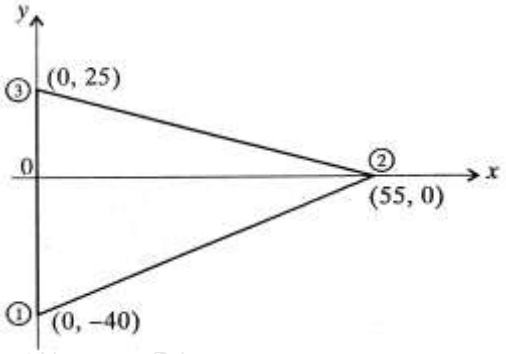


b) Determine the two natural frequencies of transverse vibration of a beam fixed at both ends as shown in figure. Use consistent mass matrix and comment on the results. Divide the whole domain into two elements of equal lengths. [Take EI = 10^6 units, ρA = 10^6 units] **10**



Q. 5 **a)** Using the concept of serendipity, derive the shape functions for eight node rectangular element in natural co-ordinate system (ξ and η). **10**

b) The nodal displacements for the CST element shown in the figure are given as: **10**
u_1 = 1 mm, u_2 = 0.5 mm, u_3 = 2 mm
v_1 = 1 mm, v_2 = 0.5 mm, v_3 = 2 mm
Evaluate the stress for the element. Take Young's Modulus (E) = 200 GPa, Poisson's Ratio (ν) = 0.3 and thickness (t) = 1 cm.



Q. 6 **a)** A CST element ABC having vertices A(10, 10), B(10, 50), C(40, 10), and nodal temperatures 50 ^{0}C, 60 ^{0}C, and 80 ^{0}C respectively. Determine shape functions and nodal temperature at (20, 20). **10**

b) The following differential equation arises in connection with heat transfer in an insulated rod. **10**

$$\frac{d}{dx}\left(-K\frac{dT}{dx}\right) = q; \qquad 0 \le x \le L$$

$$\text{BCS; } T(0) = T_0 \text{ and } \left[K\frac{dT}{dx} + \beta(T - T_\infty)\right]_{x=L} = 0$$

Where T is temperature, K is thermal conductivity and q is the heat generation. Take the following data;
L= 0.1m, K=0.1 W/m^{0}C, β= 25 W/m$^{2\,0}$C, $q = \bar{q} = 0$, T_0=50^{0}C and T_∞=5^{0}C.
Solve the problem using two linear finite elements for temperature values at x=L/2 and x=L. Derive the element matrix equation for the same.

Time: 3Hrs **Marks:80**

Note :

- **Question No.1 is compulsory.**
- Solve **ANY THREE** questions from the **remaining** five questions.
- Figure to the right indicates full marks.
- Assume suitable data wherever required, but justify the same.

Marks

Q. 1 Solve **ANY FOUR** from the following.

a) List any five engineering applications of optimization. **(5)**

b) Show the formulation of a generalized transportation problem. **(5)**

c) Explain the branch and bound technique. In this technique when is the node said to be fathomed? **(5)**

d) What do you understand by full factorial and fractional factorial design? **(5)**

e) Explain the concept of Taguchi loss function with an example. **(5)**

Q. 2 a) Solve the following Simplex problem **(10)**

Maximize $Z = 2x_1 + 5x_2$

S.T. $x_1 + 4x_2 \leq 24$

$3x_1 + x_2 \leq 21$

$x_1 + x_2 \leq 9$

$x_1, x_2 \geq 0$

b) Determine maximum and minimum values of the function **(10)**

$f(x) = 3x^4 - 4x^3 - 24x^2 + 48x + 15$

Q. 3 a) Solve using the Lagrange's multiplier method the following NLPP **(10)**

Optimize $Z = 6{x_1}^2 + 5{x_2}^2$

S. T. $x_1 + 5x_2 = 7$

$x_1, x_2 \geq 0$

b) List the non-traditional optimization techniques and explain any one in detail. **(10)**

Q. 4 a) A person has to select a house from given 3 alternatives he has with the details as given in the table. He considers 3 attributes of price, near to market and near to school with weights as 0.625, 0.125 and 0.25 respectively. Select the best alternative of house by SAW method. **(10)**

Alternative/criteria	Price (Rs lakhs)	Near Market (Km)	Near School (Km)
House 1	100	1.5	2.75
House 2	140	1.0	3.5
House 3	80	1.7	3.0

b) A sample of 100 arrivals of a customer at a retail sales depot is according to the following distribution. **(10)**

Time between arrival (mins.)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Frequency	2	6	10	25	20	14	10	7	4	2

A study of the time required to service customer by adding up the bills, receiving payments and placing packages yields the following distribution.

Service time (mins.)	0.5	1.0	1.5	2.0	2.5	3.0
Frequency	12	21	36	19	7	5

Estimate the average of customer waiting time and average of idle time of the server by simulation for the next 10 arrivals.
Use random number for arrivals: 93, 22, 53, 64, 39, 07, 10, 63, 76, 35
Use random number for service: 78, 76, 58, 54, 74, 92, 38, 70, 96, 92

Q. 5 a) Apply dynamic programming method and solve **(10)**

Maximize $Z = y_1y_2y_3$

S.T. $y_1 + y_2 + y_3 = 5$

$y_1, y_2, y_3 \geq 0$

b) Describe the procedure of AHP method step wise in detail. **(10)**

Q. 6 a) Write the dual of the following primal problem **(5)**

Maximize $Z = x_1 - x_2 + 3x_3$

S.T. $x_1 + x_2 + x_3 \leq 10$

$2x_1 - x_2 - x_3 \leq 2$

$2x_1 - 2x_2 - 3x_3 \leq 6$

$x_1, x_2, x_3 \geq 0$

b) A firm produces three products. These products are processed on three different machines. The time required to manufacture one unit of each of the three products and the daily capacity of the three machines are given in the table below. The profit per unit for product 1, 2 and 3 is Rupees 4, 3 and 6 respectively. Formulate the mathematical linear programming model that will maximize the daily profit. **(5)**

Machine	Time per unit (Minutes)			Machine Capacity (Minutes / Day)
	Product 1	Product 2	Product 3	
M1	2	3	2	440
M2	4	-	3	470
M3	2	5	-	430

c) Write a note on Design of Experiment. **(5)**

d) Determine the quadratic form of matrix $A = \begin{bmatrix} 4 & -5 & 7 \\ -5 & -6 & 8 \\ 7 & 8 & -9 \end{bmatrix}$ **(5)**

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