(Time : 3 Hours) **(Total 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.**

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

a) What is an infeasible solution, and how does it occur? How is this condition recognized in the graphical method? **(05)**

b) Explain the terms Local optimum, global optimum and saddle point. **(05)**

c) Explain Taguchi's loss function **(05)**

d) What is duality? What is the significance of dual variables in an LP model? **(05)**

e) Explain concept of Dynamic programming **(05)**

Q. 2 a) Solve the following problem by simplex method **(10)**

Maximize $Z = 6x_1 + 4x_2$

Subject to $x_1 + x_2 <= 8$

$x_1 - x_2 <= 4$

$x_1, x_2 >= 0$

b) Minimize $f(x) = 8x_1 + 4x_2 + x_1x_2 - x_1^2 - x_2^2$ **(05)**

subject to $2x_1 + 3x_2 \leq 24$

$-5x_1 + 12x_2 \leq 24$

$x2 \leq 5$

State the Kuhn–Tucker conditions for above.

c What is integer linear programming? How does the optimal solution of an integer programming problem compare with that of the linear programming problem? **(05)**

Q. 3 a) Following table shows the various alternatives of Material (M1, M2,..) for piston cyinder, and corresponding attributes as Cost (A1), tensile strength (A2), thermal conductivity (A3), and machinability index (A4) Suggest suitable material using SAW method. Assume equal weight of 0.25 for the all attributes, A1 as non-beneficial and rest all as beneficial attributes for the following case. **(10)**

No	Alternative	M1(Rs/kg)	A2 (MPa)	A3 (W/m-K)	A4
1	M1	300	110	142	100
2	M2	350	100	125	110
3	M3	375	120	100	105
4	M4	400	130	120	120
5	M5	315	125	135	115

b Determine the stationary points, minima or maxima of the following function $f(x) = 2x^6 - 6x^4 + 6x^2 + 10$ **(05)**

c Write a note on design of experiments **(05)**

Q. 4 a) A confectioner sells confectionery items. Past data of demand per week (in hundred kilograms), with probabilities, is given below: **(10)**

Demand/week :	05	10	15	20	25
Probabilities	0.36	0.31	0.19	0.09	0.05

Using the following sequence of random numbers, generate the demand for the next 10 weeks. Also find the average demand per week:
52, 90, 13, 23, 73, 34, 57, 35, 83, 94

b) A factory can manufacture 2 products A & B. The profit on one unit of A is Rs. 80 and one unit of B is Rs. 40. The maximum demand of A is 6 units per week and of B it is 8 units per week. The manufacturer has set up a goal of achieving a profit of exactly Rs. 640 per week. Show only the formulation of the problem as goal programming. **(05)**

c) Describe briefly geometric programming **(05)**

Q. 5 a) What are the various non-traditional optimization techniques? Explain any one with illustration **(10)**

b) Explain multi attribute decision making with suitable illustration. **(10)**

Q. 6 a) Write plan of experiments having 3 factors each at three levels. **(05)**

b) A company produces three types of bearings, B1, B2, and B3, on two machines, A1 and A2. The processing times of the bearings on the two machines are indicated in the following table: **(05)**

	Processing time (min) for bearing:		
Machine	B1	B2	B3
A1	10	6	12
A2	8	4	4

The times available on machines A1 and A2 per day are 1200 and 1000 minutes, respectively. The profits per unit of B1, B2, and B3 are Rs 4, Rs 2, and Rs 3, respectively. The maximum number of units the company can sell are 500, 400, and 600 for B1, B2, and B3, respectively. Formulate the problem for maximizing the profit.

c) Explain concept of robust design **(05)**

d) Discuss in brief some applications of Optimization in Engineering **(05)**

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[Time- 03 Hours] **Total Marks: 80**

N. B : (1) Question no.1 is **Compulsory**.
(2) Attempt any **THREE** from question no.2 to 6.
(3) Use illustrative diagrams wherever possible.
(4) Assume suitable data if necessary and mention it clearly.

Q.1 Answer **Any Four** questions from the following :

a) Name the various modes of heat transfer and also explain its governing laws. 5

b) Explain EURO and BHARAT Norms. 5

c) Explain the term critical radius of insulation and Derive the same for a cylinder with usual notations. 5

d) Distinguish between film and Dropwise condensation. 5

e) 16.5 kg/s of the product at 650^{0}C (C_p - 3.55 kJ/kg^{0}C) ,in a chemical plant ,are to be used to heat 20.5 kg/s of the incoming fluid from 100^{0}C (C_p - 4.2kJ/kg^{0}C).If the overall heat transfer coefficient is 0.95 W/m^2 ^{0}C and the installed heat transfer surface is 44 m^2 .Assume Counter flow arrangement. Determine : 5
i) Capacity ratio
ii) NTU
iii) Effectiveness of heat exchanger

Q.2 (a) A steam pipe of inner diameter 150 mm , outer diameter 160 mm and 1metre long having thermal conductivity 58 W/m^{0}C is covered with two layers of insulation, of thickness 30 mm and 50 mm respectively and thermal conductivities 0.18 W/m^{0}C and 0.09 W/m^{0}C respectively. The temperature of inner surface of steam pipe is 320^{0}C and that of the outer surface of the insulation layer is 40^{0}C. 12
Determine :
i) The quantity of heat lost per metre length of steam pipe
ii) Layer contact temperatures

(b) Air at 20^{0}C and 1.013 bar flows over a flat plate at 40 m/s. The plate is 1m long and is maintained at 60^{0}C.Assuming unit depth, calculate the heat transfer from the plate.Use the following relation 4

$Nu_L = (Pr)^{0.33} [0.037 (Re_L)^{0.8} - 850]$

Properties of air at 40^{0}C are : $\rho = 1.128$ kg/m^3, $k = 0.0275$ W/m^{0}C, $Cp = 1.005$ kJ/kg^{0}C, $Pr = 0.699$, $\nu = 16.96 \times 10^{-6}$ m^2/s.

(c) Define 'Heat Exchanger Effectiveness'. Draw temperature profile for Parallel flow heat exchanger, Counter flow heat exchanger. 4

Q.3 (a) Air at velocity of 2.8 m/s and at 30^{0}C flows over a flat plate along its length. The length ,width and thickness of the plate are 1m , 0.6m , 0.025m .The top surface of the plate is maintained at 90^{0}C.If the thermal conductivity of the plate material is 25W/m^{0}C.Calculate: 10
i) Heat lost by the plate
ii) Bottom temperature of the plate for the steady state condition
The thermo-physical properties of air at mean film temperature 60^{0}C are :
$\rho = 1.06$ kg/m^3, $k = 0.02894$ W/m^{0}C, $Cp = 1.005$ kJ/kg^{0}C, $Pr = 0.696$; $\nu = 18.97 \times 10^{-6}$ m^2/s.
Choose the appropriate relation from the following:
$Nu = 0.664 (Re)^{1/2} (Pr)^{1/3}$ – For Laminar flow

$Nu = 0.036 (Re)^{0.8} (Pr)^{1/3}$ – For Turbulent flow

(b) Explain the stages of combustion in C.I engine with the help of p-θ diagram. 10

Q.4 (a) A 15 mm diameter mild steel sphere (k= 42 W/m°C) is exposed to cooling airflow at 20°C resulting in the convective coefficient h= 120 W/m²°C. Determine : 10

i) Time required to cool the sphere from 550°C to 90°C
ii) Instantaneous heat transfer rate 2 minutes after the start of cooling.
iii) Total energy transferred from the sphere during the first 2 minutes.

For mild steel take: ρ= 7850 kg/m³, C_P =475 J/kg.°C, α =0.045m²/h.

(b) State and explain Fick's law diffusion mass transfer. Compare Fick's law diffusion mass transfer with Fourier's law of heat conduction. 05

(c) Define "Shape Factor" and explain its properties. 05

Q.5 (a) Cold water at 1495 kg/h enters at 25°C through a parallel flow heat exchanger to cool 605 kg/h of hot water entering at 70°C and leaving at 50°C.The overall heat transfer coefficient is 795 W/m².K. For water C_P =4180 J/kg.K. Find area of heat exchanger by LMTD and NTU methods 12

(b) Calculate the diameter of fuel orifice of 4 stroke engine which develops 25 kW per cylinder at 2500 rpm. The specific fuel consumption is 0.3 kg/kW h and fuel is injected at a pressure of 150 bar over a crank travel of 25°. The pressure in the combustion chamber is 40 bar. Coefficient of velocity is 0.875 and density of fuel is 876.2 kg/m³ 08

Q.6 (a) The following data were obtained from a test on a single cylinder ,4-stroke, oil engine: 12

Cylinder Bore	= 15 cm
Stroke	= 25 cm
Indicated mean effective pressure	= 7.355 bar
Engine speed	= 400 rpm
Brake torque	= 225Nm
Fuel consumption	= 3 kg/hr
Calorific value of fuel	= 44200 kJ/kg
Cooling water flow rate	= 4 kg/min
Cooling water temperature rise	= 42°C
Specific heat of water	= 4.2 kJ/kg.K

Find out the following:

i) Mechanical Efficiency
ii) Brake thermal efficiency
iii) Specific fuel consumption on B.P basis
iv) Draw heat balance sheet on kW basis and percentage basis

(b) With usual notations, derive the formula for rate of heat transfer for an insulated tip fin of finite length from the following differential equation 08

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0$$

(3 Hours) **Total Marks: 80**

Note:

1. **Question No. 1 is compulsory.**
2. **Attempt any THREE out of the remaining FIVE questions.**
3. **Assume suitable data if necessary.**
4. **Use of Statistical table is allowed**

Q. 1. Write short notes on **any FOUR** questions. (20)

(a) When do we use ANOVA?

(b) Confounding in experimental design.

(c) What is Random effects model?

(d) Define Noise Factor.

(e) Explain Taguchi Loss Function

Q. 2. (a) State and explain the principles of robust design. (10)

(b) What are blocking and confounding of DOE? (10)

Q. 3. (a) Write a short note on 'Analysis of an orthogonal experiment. (10)

(b) Explain Taguchi's orthogonal array design completely. (10)

Q. 4. (a) Write a short note on 'confounding in experimental design'. (10)

(b) With suitable illustrations explain how will you conduct single factor experiment (10)

Q. 5. (a) What are the advantages of the Latin square design over other designs (10)

(b) State and explain with example the principles of robust design. (10)

Q. 6. Write short notes on: (20)

(a) Explain Signal to Noise ratio.

(b) Define the Population in DOE.

(c) What is interaction effect?

(d) Independence of error

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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: (20)

a. Explain what you mean by Dynamically Equivalent systems. State the conditions for systems to be dynamically equivalent. (5)

b. What do you mean by critical speed of a shaft, derive an expression for critical frequency for an undamped shaft. (5)

c. Compare viscous and coulomb damping. Mention at least five points of difference. (5)

d. Explain the terms: Logarithmic decrement, Magnification factor. Also mention the significance of logarithmic decrement. (5)

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

Q2.a A body of mass 70 kg is suspended from a spring which deflects 2.0 cm under the load. It is subjected to a damping effect adjusted to a value 0.23 times that required for critical damping. Find the natural frequency of the undamped and damped vibrations and ratio of successive amplitudes for damped vibrations. (10)
If the body is subjected to a periodic disturbing force of 700 N and of frequency equal to 0.78 times the natural undamped frequency, find the amplitude of forced vibrations and the phase difference with respect to the disturbing force.

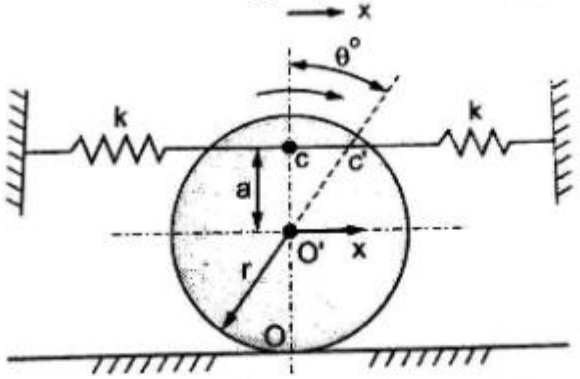
Q2.b The mass of a turbine rotor of a ship is 8 tonnes and has a radius of gyration 0.6 m. It rotates at 1800 r.p.m. clockwise when looking from the stern. Determine the gyroscopic effects in the following cases: 1. If the ship travelling at 100 km/h steers to the left in a curve of 75 m radius, 2. If the ship is pitching and the bow is descending with maximum velocity. The pitching is simple harmonic, the periodic time being 20 seconds and the total angular movement between the extreme positions is 10°, and (10)
3. If the ship is rolling and at a certain instant has an angular velocity of 0.03 rad/s clockwise when looking fromstern.

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 The disc of a torsional pendulum has a moment of inertia of 600 kg-cm^2 and is immersed in a viscous fluid. The brass shaft attached to it is of 10 cm diameter and 40 cm long. When the pendulum is vibrating, the observed amplitudes on the same side of the rest position for successive cycles are 9°, 6° and 4°. Determine (a) logarithmic decrement (b) damping torque at unit velocity, and(c) the periodic time of vibration. (10)
Assume for the brass shaft, G = 4.4 x 10^{10} N/m^2.

Q4.a In a governor of the Hartnell type, the mass of each ball is 1.5 kg and the lengths of the vertical and horizontal arms of the bell crank lever are 100 mm and 50 mm respectively. The fulcrum of the bell crank lever is at a distance of 90 mm from the axis of rotation. The maximum and minimum radii of rotation of balls are 120 mm and 80 mm and the corresponding equilibrium speeds are 325 and 300 rpm. Find the stiffness of the spring and equilibrium speed when the radius of rotation is 100mm. (10)

Q4.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)



Q5.a. 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. (10)

Q5.b A machine of mass one tonne is acted upon by an external force of 2450 N at a frequency of 1500 rpm. To reduce the effects of vibration, isolator of rubber having a static deflection of 2 mm under the machine load and an estimated damping factor 0.2 are used. Determine: (a) the force transmitted to the foundation, (b) the amplitude of vibration of machine(c) the phase lag. (10)

Q6.a A vehicle of mass 490 kg and total spring constant of its suspension system is 60 x 10^3 N/m. The profile of the road may be approximated to a line curve of amplitude 4.0 cm and wavelength of 4.0 metres. Determine :(a) the critical speed of the vehicle (8)
(b) the amplitude of the steady state motion of the mass when the vehicle is driven at critical speed and the damping factor is 0.5; and
(c) The amplitude of the steady state motion of mass when the vehicle is driven at 57 km/hr and the damping factor same as in (b).

Q6.b Show that the transmissibility ratio is 1 at a frequency ratio of 2 (5)

Q6.c A vibrometer having a natural frequency of 4 rad/sec and $\xi = 0.2$ is attached to a structure that performs a harmonic motion. If the difference between the maximum and the minimum recorded values is 8 mm, find the amplitude of motion of the vibrating structure with its frequency is 40 rad/s. (7)

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(3 Hours) **Total 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.

Q. 1 Solve **ANY FOUR** questions from the following. **20**

a) Distinguish between h and p methods of mesh refinement with necessary illustrations. **5**

b) Distinguish between plane stress and plane strain conditions. **5**

c) Describe the significance of principle of minimum potential energy. **5**

d) Explain convergence criteria in FEM. **5**

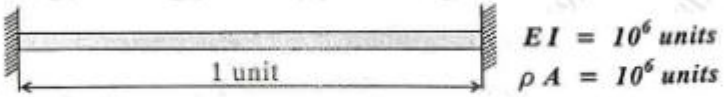
e) Explain lumped mass matrix, consistent mass matrix and HRZ lumping scheme with suitable examples. **5**

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

$$\frac{d^2u}{dx^2} - 9\,u = x^3 \quad ; \qquad 0 \le x \le 1$$

Given boundary conditions are: $u(0) = 0$ and $u(1) = 2$. Determine u (0.5).

b) Determine the two natural frequencies of transverse vibrations of a beam fixed at both ends a shown in fig. Use Consistent Mass Matrix. Take EI = 10^6 units and $\rho A = 10^6$ units. **10**

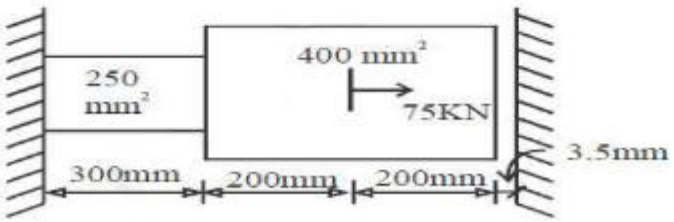


Q. 3 **a)** Solve the following differential equation by Rayleigh Ritz method. **10**

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

Given Boundary Conditions are: $y(0) = y(1) = 0$

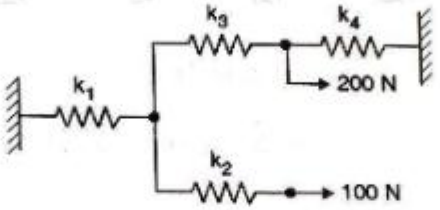
b) Determine the unknown reactions, displacement and element stresses for the stepped bar shown in the figure below (E = 200 GPa). **10**



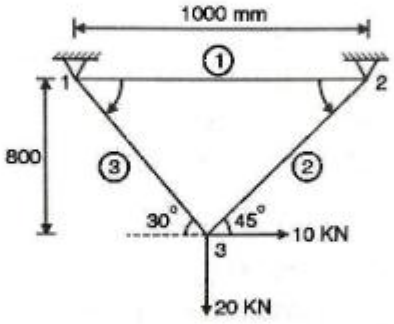
Q. 4 **a)** Find the natural frequency of axial vibrations of a bar of uniform cross section of 50 mm^2 and length of 1 meter using consistent mass matrix and compare with exact frequencies. Take E = 200 GPa and density = 7860 kg/m^3. Take two linear elements. **10**

b) The triangular element has nodal coordinates (10, 10), (40, 20) and (30, 50) for nodes 1, 2 and 3 respectively. For the point P located inside the triangle, determine x and y coordinates if the shape functions, $N_1 = 0.15$ and $N_2 = 0.25$. **10**

Q. 5 **a)** Determine the displacement at nodes by using principle of minimum potential energy approach **10**



b) Find nodal displacement, reaction forces and stresses in each element for a truss given below. Take E= 210 GPa and A = 100 mm^2. **10**



Q. 6 **a)** A steel fin of diameter 2 cm, length 10 cm and thermal conductivity 80 W/m-K is exposed to ambient air at 40^0C with a heat transfer coefficient of 100 W/m^2-K. One end of the fin is at a temperature of 540^0C and the other end is insulated. Governing DE is; **10**

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0 \qquad \theta = T - T_\infty$$

Where $m^2 = \frac{hp}{KA}$ and $\Omega = 0 \le x \le L$

P = Perimeter, A = Cross section area

h = Heat transfer coefficient

K = Thermal conductivity, and T_∞ = Ambient temperature

Take three liner elements of equal lengths and solve to get temperatures at these intermediate points.

b) Explain the procedure of Rayleigh-Ritz method based on principle of stationary total potential. **10**

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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 the following questions (*any Four*). **20**

i) Differentiate between systematic errors and random errors.

ii) How can flatness be checked with the help of an optical interferometer?

iii) Define: Reproducibility, Hysteresis, Threshold, Range and Span of measuring instruments.

iv) Illustrate the working principle of nozzle flapper for displacement measurement.

v) Explain open loop and closed loop control systems.

vi) Using Routh's criterion examine the stability of a control system whose characteristic equation is $S^5 + 2S^4 + 3S^3 + 4S^2 + 5S + 6 = 0$

2. (A) Derive an expression for "Two-wire Method" for effective diameter measurement of a screw thread **10**

(B) Calculate the limits, tolerances and allowances on a 25 mm shaft and hole pair. Designated H7/g6 to get precision fit. The fundamental tolerances is calculated by following equations: **10**

$$i = 0.4533\,D + 0.001D \text{ micron}$$

The following data is given:

a) Upper deviation of shaft = $-2.5\,D^{0.4}$
b) 25 mm falls in the diameter step of 18 - 30 mm
c) IT7 = 16i
d) IT6 = 10i
e) Wear allowance = 10% gauge tolerance

3. (A) With neat sketch, explain the constructional features and working of **10**

i) LVDT
ii) Parkinson's Gear Tester

(B) Draw the Root-Locus of the system having **10**

$$G(s)H(s) = \frac{K}{S(S+1)(S+3)(S+4)}$$

4. **(A)** 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**

(B) A system has transfer function given by **10**

$$\frac{C_{(s)}}{R_{(s)}} = \frac{\mathbf{100}}{\boldsymbol{s^2 + 15s + 100}}$$

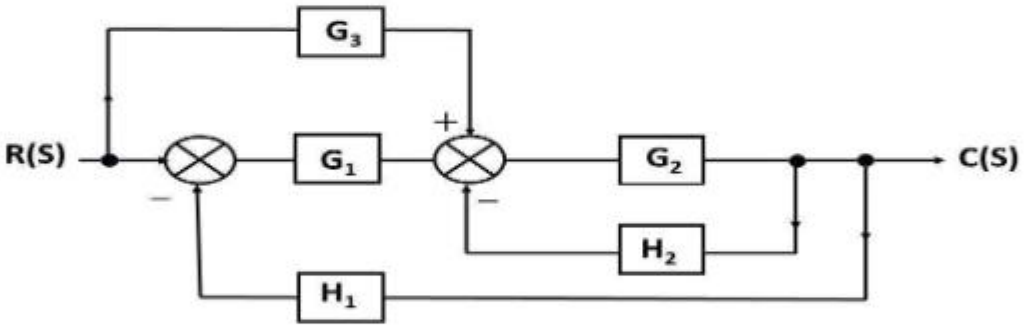
Determine, peak time, percent overshoot, settling time and rise time.

5. **(A)** With neat sketch, explain the constructional features and working of **10**

i) Ultrasonic Flow Meter

ii) Ionization Gauge

(B) Reduce the given block diagram to a its canonical form and hence obtain equivalent transfer function, $\frac{C(s)}{R(s)}$. **10**



6. Write short note on ***(any Four)*** **20**

i) Interference Fit

ii) Strain Gauge based load cell

iii) Frequency Domain Specifications

iv) Tomlinson Surface Tester

v) Static Calibration

vi) RTD

(3 Hours) **Total Marks: 80**

N.B. : **(1)** Question No. 1 is compulsory.

(2) Attempt any three questions out of remaining five questions

Q.1. (a) Find the eigen values and eigen vectors of $A = \begin{bmatrix} 0 & -2 \\ 6 & -7 \end{bmatrix}$ **(5)**

(b) A random variable X has following probability distribution **(5)**

X	1	2	3	4	5	6	7
P(X = x)	K	2K	3K	K^2	K^2+K	$2K^2$	$4K^2$

Find (i) Value of K and Mean of X
(ii) P (X < 5)
(iii) P (X > 5)

(c) Compare discrete and continuous data. **(5)**

(d) Obtain the Hessian Matrix for the function **(5)**

$$Z = 2x_1x_2 + 10x_1 + 16x_3 + 3x_1^2 - 5x_2^2 - 6x_3^2$$

Q.2. (a) Find Singular Value of Decomposition of matrix $A = \begin{bmatrix} 3 & 1 & 1 \\ -1 & 3 & 1 \end{bmatrix}$ **(10)**

(b) Two samples were drawn from two populations and the results were as given below: **(10)**

Population	A	B
Sample Size	19	13
Sample S.D	45	30

Test the hypothesis that variance of A is greater than or equal to variance of B. (for degrees of freedom 12 and 18 at 5% F = 2.34).

Q.3. (a) Represent the following data by a subdivided bar diagram. The data represents figures of production of paper in thousand tonnes for the years 2018, 2019, 2020. Also represent the data by a percentage bar diagram. **(10)**

Types	**2018**	**2019**	**2020**
Printing and Writing	25	32	35
Wrapping	18	20	30
Miscellaneous	12	15	18
Total	55	67	83

(b) What is a scatter plot and explain types of correlation in scatter plot with example. **(10)**

Q.4. (a) Find 3 yearly moving averages and represent these on a graph paper. Also represent the original time series on the graph. **(10)**

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
Sales (in lakhs)	70	79	81	86	68	99	110	105	120

(b) Find the minimizer of $f(x) = x^2 + \frac{36}{x}$ using bisection method in (1,4) within a range of 0.2 **(10)**

Q.5. (a) Minimize the function $f(x_1, x_2) = 3x_1 + 5x_2 - x_1^2 - 2x_2^2$ subject to **(10)**
$$x_1 + x_2 = 4, \quad x_1, x_2 \geq 0$$

(b) Write a short note on linear discriminant analysis techniques and principal component analysis algorithm. **(10)**

Q. 6 (a) Explain the need for exploratory data analysis. Also list and explain exploratory data analysis techniques. **(10)**

(b) Write short notes on (any two) **(10)**

i. Curse of Dimensionality.
ii. Hyperbolic functions and their graphs
iii. Non-linear dimensionality reduction -Multidimensional Scaling
iv. Supervised learning models

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