M.TECH. AUTUMN (I SEMESTER) EXAMINATION
(MECHANICAL ENGINEERING)
(MACHINE DESIGN/ THERMAL SCIENCES)
ADVANCED ENGINEERING MATHEMATICS
AM-632N
Credits: 04

Maximum marks: 60

Duration: Two Hours

Answer all the questions.

1(a) Solve the system of equations

\[ y' = yz + x, \]
\[ z' = xz + y, \]

for \( y(0.1), z(0.1) \) using fourth order Runge-Kutta method by taking \( h = 0.1 \). Initial values are \( x = 0, y = 1, z = -1 \).

1(b) An experiment on the life of a cutting tool at different cutting speed gave the values:

Speed \( v \) ft/min; \ 350 \ 400 \ 500 \ 600

Life \( T \) in min; \ 61 \ 26 \ 7 \ 2.6

It is known that \( v \) and \( T \) satisfy the relationship \( v = aT^b \). Using the method of least squares, find the best value of \( a \) and \( b \).

OR

1(b') Solve the partial differential equation \( \nabla^2 u = -10(x^2 + y^2 + 10) \) over the square with sides \( x = 0 = y, x = 3 = y \), with \( u = 0 \) on the boundary and mesh length = 1.

Give only three iterations.

2(a) With the aid of the resolvent kernel, find the solution of the integral equation

\[ \phi(x) = e^{x^2} + \int_0^x e^{x^2 - \xi^2} \phi(\xi) \, d\xi \]

2(b) Define degenerate kernel and solve the Fredholm integral equation with the method of degenerate kernel

\[ \phi(x) = 2x - \pi + 4 \int_0^\pi \sin^2 x \phi(\xi) \, d\xi \]
2(b') Find the eigenvalues and eigenfunctions of the homogeneous integral equation
\[ \phi(x) = \lambda \int_{-1}^{1} (5xt^3 + 4x^2 t + 3xt) \phi(t) dt \]

3 (a) Show that the transformation \( w = \frac{i - z}{1 + z} \) transforms the unit circle onto the real axis of the \( w \)-plane and the interior of the circle into the upper half of the \( w \)-plane.

OR

3(a') State Schwartz Christoffel Transformation. Show that
\[ w = f(z) = \frac{2bi}{\pi} \left( \sin^{-1} \sqrt{z} + \sqrt{z(1 - z)} \right) \]
maps the upper half of the \( z \)-plane onto the indicated region in the \( w \)-plane.

3(b) Find the bilinear transformation which maps \( z = 1, \ i, -1 \) respectively onto \( w = i, 0, -i \).
For this transformation find the image of \( |z| \leq 1 \).

4 (a) State Quotient law of tensors. A quantity \( A_{(p,q)} \) is such that in the coordinate system \( x^i \), \( A_{(p,q)} B^q = C_p \) where \( B^q \) is an arbitrary tensor and \( C_p \) is a tensor. Prove that \( A_{(p,q)} \) is a covariant tensor of order two.

(OR)

4(a') Find the metric tensor and the expression for the line element in cylindrical coordinates. Also determine its conjugate metric tensor

4(b) Show the following:
   (a) The contraction of the outer product of the two tensors \( A^i \) and \( B_m \) is invariant
   (b) The symmetric tensor of the second order has only \( \frac{n(n+1)}{2} \) different component.
Q.01 Generate MRP reports as per the format given below for the following data:

Item Identification: 786, Bearing

Lead Time: 01 week

Available inventory: 100 units (at the beginning of week 1)
Lot size: L4L
Safety Stock: 0
Allocated: 0

<table>
<thead>
<tr>
<th>Periods (week)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
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</table>

Product structure

Format of the report:

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td></td>
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<td>Available inventory</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Planned order receipts</td>
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<td></td>
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<tr>
<td>Planned order releases</td>
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Q.02 Answer any three of the following [3*5=15]

a) Describe Delphi technique. What are its main benefits and drawbacks?

b) What are some of the main advantages of Job specialization from management perspective? From a worker's perspective?

c) What is a balanced production line? Explain.

d) What is the difference between forward and backward scheduling? Which one is better and why?

Q.03 WorldStar Appliances Ltd. is based at New Delhi and manufactures the Blue Line range of mixer/grinders for household use. It sources the outer bodies of the mixers, electric wires, electrical plugs, etc. from external suppliers. The company is ISO9001 certified and has a huge market share in the northern parts of the country. The assembly line of this factory has a number of tasks to be performed according to the precedence requirements given as under [3,4,4,4]

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<tr>
<th>Task</th>
<th>Precedence requirements</th>
<th>Task Time (min)</th>
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<td>-</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>A, C</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>D</td>
<td>4</td>
</tr>
<tr>
<td>F</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>B, E, F</td>
<td>3</td>
</tr>
<tr>
<td>H</td>
<td>G</td>
<td>2</td>
</tr>
</tbody>
</table>

Completed...
Calculate the following:

a) The bottleneck operation and minimum cycle time.
b) Theoretical minimum number of stations required for assigning the tasks
c) Assign various tasks to stations (Use Longest operation time rule)
d) Compute the efficiency of the line

Q.04 A local chocolate distributor at a city deals with a popular brand “XYZ”. The normal lead time taken by the supplier XYZ is 10 days. The normal consumption of inventory during lead time is 500 units per day. There are 10 inventory cycles per year. Table below shows the consumption pattern of “XYZ” during lead time (from past 100 observations). The carrying cost is Rs 1 per unit per year. The stock out cost is Rs 2 per unit short. Find the optimal level of safety stock for “XYZ”.

<table>
<thead>
<tr>
<th>Consumption during lead time (units)</th>
<th>Probability</th>
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<tr>
<td>1000</td>
<td>0.01</td>
</tr>
<tr>
<td>2000</td>
<td>0.03</td>
</tr>
<tr>
<td>3000</td>
<td>0.07</td>
</tr>
<tr>
<td>4000</td>
<td>0.14</td>
</tr>
<tr>
<td>5000</td>
<td>0.61</td>
</tr>
<tr>
<td>6000</td>
<td>0.04</td>
</tr>
<tr>
<td>7000</td>
<td>0.07</td>
</tr>
<tr>
<td>8000</td>
<td>0.03</td>
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</table>

Q.05 For an item the following information is given: ordering cost=Rs 50 per order, carrying cost per week=0.5%, unit cost price=Rs 20.

<table>
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<th>Week</th>
<th>Net requirement</th>
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<tr>
<td>2</td>
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<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
<td>110</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
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</tbody>
</table>

Compute the order size using any one of the methods: (a) EOQ (b) POQ (c) LTC

Q.06 A personal computer assembling company’s marketing department has given the demand forecast as shown in table below for its PCs throughout the country in the coming 6 months from January to June.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand (units)</td>
<td>1000</td>
<td>3000</td>
<td>1000</td>
<td>5000</td>
<td>7000</td>
<td>2000</td>
</tr>
<tr>
<td>No of working days</td>
<td>24</td>
<td>25</td>
<td>20</td>
<td>22</td>
<td>20</td>
<td>24</td>
</tr>
</tbody>
</table>

Every worker assembles 2 computers a day. The overtime cost is Rs 3 per day per unit in excess of the maximum capacity of the factory i.e. 200 units. Find the total cost involved in any one of the following plans

(a) Level output rate plan
(b) Chase demand plan

-------------------------------------------xxxxxxx-----------------------------------

contd... 3
## Normal Distribution Tables

Tables of the Normal Distribution

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<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
<th>0.05</th>
<th>0.06</th>
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2017-18
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (I/P)
METAL CUTTING ANALYSIS
ME-625

Maximum Marks: 60
Credits: 04
Duration: Two Hours

Answer any four questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. Question                                                                                         M.M.
1.(a) Die for making cylindrical powder compact of 9mm diameter and 35mm height is required. Write down the machining processes involved in making the die sequentially. Suggest the die material and cutting tool materials for the processes used in making the die. [06]
1.(b) Assume that in orthogonal cutting, the rake angle is $10^\circ$. Plot the shear plane angle and cutting ratio as a function of the friction coefficient (varies from 0 to 1) and explain it. [09]
2.(a) Sketch and define the different rake angles in oblique cutting. [09]
2.(b) Describe working principle of tool – workpiece thermocouple for measuring tool-chip contact temperature. [06]
3.(a) It was stated that it is possible for the $n$ value in the Taylor tool-life equation to be negative. Explain. [06]
3.(b) Taking carbide as an example and using, determine how much the feed should be changed in order to keep the mean temperature constant when the cutting speed is tripled. The value of constants for carbide is: $a=0.2$ and $b=0.125$. [06]
3.(c) Explain machinability. [03]
4.(a) In a slab milling operation determine the expressions for maximum chip thickness and average chip thickness. [06]
4.(b) Describe the functions of a coolant in metal cutting operations. Explain Merchant’s theory of application of cutting fluid. [09]
5.(a) What are different factors that affect the surface quality in machining operations? Explain any one method for assessment of surface roughness. [09]
5.(b) A turning tool has a sharp nose, side cutting edge angle $= 60^\circ$ and end-cutting edge angle of $15^\circ$. What should be the feed rate in order to obtain a theoretical centre-line average roughness of $5\mu m$? [06]
6.(a) Discuss the important technological parameters that affect honing process. [09]
6.(b) Determine the optimum cutting speed and optimum tool life on the basis of minimum cost. [06]
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.          Question                                                                                      M.M.
1.(a)          Draw Venn diagram to represent the following situations involving three events A, B, and C, which are part of a sample space of events but do not include the whole sample space: (i) Three pairs of events (A and B, A and C, and B and C) may occur together, but all three events may not occur together, (ii) A and B are mutually exclusive, A and C are not, also B and C are not mutually exclusive, and (iii) A and B are mutually exclusive, B and C are also mutually exclusive, but A and C are not. [03]

1.(b)          Consider the following data representing the number of students enrolled in twenty universities during the academic session 2016-17 and answer the following questions: (i) Develop a frequency distribution with five classes of uniform width and represent the distribution with a suitable graphic, and (ii) Determine the mean and variance of this distribution.
5561, 4923, 3862, 4187, 3534, 3144, 4506, 2717, 4784, 6874, 5071, 3527, 5424, 4745, 4310, 2796, 3098, 5034, 6505, 6707. [06]

1.(c)          Two suppliers S1 and S2 supply a machine part to a manufacturer of a machine tool. S1 supplies 70% of the requirements and the rest is supplied by S2. Historically, 95% of the S1’s supplies are good, whereas, S2’s supply is acceptable 90% of the time. One day, a machine breaks owing to a defective part supplied by either of the two suppliers. Given the information that the part is defective, what is the probability that the part was supplied by (a) S1, (b) S2? [06]

2.(a)          An automobile manufacturer is concerned about a possible recall of their best-selling four-door sedan. If there were a recall, there is 0.25 probability that a defect is in the brake system, 0.18 in the transmission, 0.17 in the fuel system, and 0.40 in some other part. What is the probability that the defect is the brakes or the fueling system if the probability of defects in both systems simultaneously is 0.15. Also determine the probability that there are no defects in either the brakes or the fueling system. [03]

contd...
2.(b) From a box containing 4 dimes and 2 nickels, 3 coins are selected at random without replacement. Find the mean and variance of the random variable \( T \) representing the total amount of the three coins. (1 dime = 10 cents and 1 nickel = 5 cents)

2.(c) Write a brief note on applications of Gamma and Exponential distributions.

OR

2'.(a) A manufacturer knows that on the average 20% of the electric toasters which he makes will require repairs within 1 year after they are sold. When 20 toasters are randomly selected, find appropriate numbers \( x \) and \( y \) such that the probability that (i) at least \( x \) of them will require repairs is less than 0.5, and (ii) at least \( y \) of them will not require repairs is greater than 0.8

2'.(b) Consider a car batteries manufacturer who produces a very large number of batteries (N) on a continuous basis. It is important that the process produces batteries having a mean life of 30 months. The quality control department of the company, therefore, draws 50 samples, each of size 5, from the production line and examines the battery life. Explain the concept of sampling distribution choosing arbitrarily the mean life (in months) of each of the 50 samples.

2'.(c) The average life of a certain type of small motor is 10 years with a standard deviation of 2 years. The manufacturer replaces free all motors that fail while under warranty. If he is willing to replace only 3% of the motors that fail, how long a guarantee should he offer? Assume that the lifetime of a motor follows a normal distribution.

3.(a) The manufacturer of a patent medicine claimed that it was 90% effective in relieving an allergy for a period of 8 hrs. In a sample of 200 people who had the allergy, the medicine provided relief for 160 people.

(i) Determine whether the manufacturer's claim is legitimate by using 0.01 as the level of significance.

(ii) Find the p-value of the test.

3.(b) Test the hypothesis under the condition, \( \mu_1 = \mu_2 = \mu_3 \) at the 0.05 level of significance for the data of table given below on absorption of moisture by various types of cement aggregates.

<table>
<thead>
<tr>
<th>Aggregate-1</th>
<th>Aggregate-2</th>
<th>Aggregate-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Contd......3.
3.(b') A study was made on the amount of converted sugar in a certain process at various temperatures. The data were coded and recorded as follows:

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Converted Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>8.1</td>
</tr>
<tr>
<td>1.1</td>
<td>7.8</td>
</tr>
<tr>
<td>1.2</td>
<td>8.5</td>
</tr>
<tr>
<td>1.3</td>
<td>9.8</td>
</tr>
<tr>
<td>1.4</td>
<td>9.5</td>
</tr>
<tr>
<td>1.5</td>
<td>8.9</td>
</tr>
<tr>
<td>1.6</td>
<td>8.6</td>
</tr>
<tr>
<td>1.7</td>
<td>10.2</td>
</tr>
<tr>
<td>1.8</td>
<td>9.3</td>
</tr>
<tr>
<td>1.9</td>
<td>9.2</td>
</tr>
<tr>
<td>2.0</td>
<td>10.5</td>
</tr>
</tbody>
</table>

(i) Fit a parabola to these data by the method of least-square.
(ii) Estimate the mean amount of converted sugar produced when the coded temperature is 1.75.

4.(a) On a commuter train, the conductor wishes to see whether the passengers enter the train at random. He observes the first 25 people, with the following sequence of males (M) and females (F).

```
FFFMFFFFFFMFMMFFFMFFM
```

Test for randomness at $\alpha = 0.05$.

4.(b) An electrical firm manufactures light bulbs that have a length of life that is approximately normally distributed with a standard deviation of 40 hours. If a sample of 30 bulbs has an average life of 780 hours, find a 96% confidence interval for the population mean of all bulbs produced by this firm.
1. (a) Explain briefly the different applications of a measurement system. (6)

1. (b) What methods can be used for dynamic compensation in a measurement system? (6)

2. What factors are to be considered for designing a system for reliability? Explain them. (12)

OR

2'. (a) Explain the working principle of capacitive sensing element. (6)

2'. (b) Briefly explain the working of a variable reluctance tachogenerator, used for measuring angular velocity. (6)

3. Represent the system shown in Fig. 1 in state space where the output is $x_3(t)$. (12)

4. (a) A system is represented by the state and output equations that follow. Without solving the state equation, find the characteristic equation and the poles of the system. (6)

$$\begin{bmatrix} 0 & 2 & 3 \\ 0 & 6 & 5 \\ 1 & 4 & 2 \end{bmatrix} \dot{x} + \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} u(t)$$

$$y = \begin{bmatrix} 1 & 2 & 0 \end{bmatrix} x$$

4. (b) Using Mason's rule, find the transfer function, $T(s) = \frac{Y(s)}{R(s)}$, for the system represented by Fig. 2. (6)
4'.(a) Consider the translational mechanical system shown in Fig. 3. A 1N force, \( f(t) \), is applied at \( t = 0 \). If \( f_y = 1 \text{N-m} \), find \( K \) and \( M \) such that the response is characterized by a 4-second settling time and a 1-second peak time. Also, what is the resulting percent overshoot?

4'.(b) Consider the rotational mechanical system shown in Fig. 4. Represent the system as a signal-flow graph. Represent the system in state space if the output is \( \theta_2(t) \).

5.(a) Given the unity feedback system of Fig. 5, with

\[
G(s) = \frac{84}{s(s^7 + 5s^6 + 12s^5 + 25s^4 + 45s^3 + 50s^2 + 82s + 60)}
\]

tell how many poles of the closed-loop transfer function lie in the right half-plane, in the left half-plane, and on the \( j\omega \)-axis.

5.(b) For the unity feedback system shown in Fig. 5, where

\[
G(s) = \frac{60(s + 3)(s + 4)(s + 8)}{s^2(s + 6)(s + 17)}
\]

Find the steady-state error if the input is \( 80t^2u(t) \).
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. | Question | M.M.
--- | --- | ---
1(a) | A steel beam is pinned at supports A and B, as shown in Fig. 1(a), where the support B is on rollers and free to move horizontally. The ends of the beam are loaded with 5 kN loads, find the maximum bending stress at the mid-span of the beam and also the angle subtended by the cross sections at A and B in the deformed beam. | [06]

![Fig. 1(a)](image)

1(b) | A ring with a rectangular section is subjected to diametral compression, as shown in Fig. 1(b) Determine the change in horizontal and vertical diameter. | [09]

![Fig. 1(b)](image)

OR

contd... 2.
1(b') Derive the Winkler-Bach formula for bending of curved beams. Also derive the expression for \( r_o \) (radius of curvature of neutral surface) for a beam with circular section.

2(a) Determine equations for the maximum deflection and maximum radial stress for a circular plate, radius \( R \), subjected to a distributed pressure of the form \( q = K/r \). Assume simply supported edge conditions.

2(b) A solid circular steel plate 5 mm thick, 120 mm outside diameter, is clamped at its outer edge and loaded by a ring of loads at \( r = 20 \text{ mm} \). The total load on the plate is 10 kN. Calculate the central deflection of the plate.

3(a) What is meant by transformation of stresses. Derive the mathematical expression for transformation of stresses from one set of coordinate axes to another set of axes in a three dimensional state of stress.

3(b) The strain tensor at point in a stressed body of steel is given below.

\[
\varepsilon_{ij} = \begin{bmatrix}
0.001 & 0 & 0.002 \\
0 & -0.003 & 0.0003 \\
-0.002 & 0.003 & 0
\end{bmatrix}
\]

Determine the stress tensor \( \sigma_{ij} \).

E and G for the material are 207 GPa and 80 GPa respectively.

OR

3(b') What is the significance of Mohr's circle in three dimensional state of stress. Describe the procedure of drawing Mohr's circle. What are the data that can be extracted from 3D Mohr's circle.

4(a) A solid prismatic bar of general section is subjected to a twisting moment at the ends. Derive the equations in terms of the warping function which may be satisfied within the boundary i.e. in the region \( R \) and on the boundary \( S \) of the cross section of the bar.

OR

4(a') A solid bar of elliptical section is subjected to a twisting moment \( 'T' \). Derive the equation of torsion, angle of twist per unit length and shear stresses for the bar.

4(b) A hollow thin wall torsion member has two compartment with cross sectional dimensions shown in the following figure. The material is an aluminium alloy for
which $G = 26.0$ GPa. Determine the torque and unit angle of twist if maximum shear stress at locations away from stress concentrations is 40 MPa.
M.TECH. (I SEMESTER) EXAMINATION
MACHINE DESIGN
ADVANCE DESIGN OF MECHANICAL SYSTEM
ME-633

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer all the questions.
All questions carry equal marks
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. Question M.M.
(a) Explain, what do you understand by design of mechanical systems. Illustrate with suitable examples. What are different design considerations? [5]
(b) What is Pugsley’s factor of safety? Also, give its values involving different designing characteristics. [5]
(c) A material has yield strength of 700 MPa. Compute and compare factor of safety from the maximum distortion energy theory and maximum shear stress theory for ductile materials. The state of stress is given as $\sigma_1 = 420$ MPa, $\sigma_2 = 0$, $\sigma_3 = -180$ MPa [5]

2(a)
(i) Explain, what are thermal stresses? How thermal stress may increase or decrease the critical stress? [4]
(ii) Describe, in brief, thermal fatigue and thermal shocks. How it can be minimized? [4]

OR

2(a') Describe cumulative damage, illustrating with suitable example. Obtain the expression for the total damage. What is life factor? [8]

2(b) A spindle of 10mm in diameter ground at a fillet where $K_f = 2.0$, has been designed for a life of 20,000 cycles under bending stresses fluctuating between 15000 N/m² and 65000 N/m². Minimum strength values are $S_u = 140000$ N/m², $S_y = 110000$ N/m² and $S_{e'} = 70000$ N/m². Determine the life and safety factors based on a conservative estimate of finite life.
3(a) Explain the following:

(i) Various types of crack modes, showing loads and opening pattern. [3]
(ii) Stress intensity factor. [1]
(iii) Fracture toughness. [1]

3(b) A plate 100 mm wide, 200 mm long, and 12 mm thick is loaded in tension in the direction of load. The plate contains a crack as shown in figure 1 with crack length 15 mm. The material is steel with $K_{tc} = 80 \text{MPa}\sqrt{m}$, and $S_y = 1.1 \text{GPa}$. Determine the maximum possible load that can be applied before the plate

(i) yields

(ii) has uncontrollable crack growth.

![Diagram](image)

**Figure 1.** Stress intensity correction factor for plate loaded in longitudinal tension with a crack at the edge; for the solid curve there are no constraints to bending; for dashed curve bending constraints are added.

OR

[3]
3(b') An edge crack, detected on a large plate is of length 3.1 mm under a constant amplitude cyclic load having $\sigma_{\text{max}} = 310 \text{ MPa}$ and $\sigma_{\text{min}} = 172 \text{ MPa}$. If the plate is made of ferrite-pearlite steel and $K_{\text{lc}} = 165 \text{ MPa}\sqrt{\text{mm}}$, determine

(i) propagation life up to failure.
(ii) propagation life if the crack length "a" is not allowed to exceed 25 mm.

4(a) The lives of Nimonic 90 turbine blades tested under varying conditions of stress and temperature are set out in the table below.

<table>
<thead>
<tr>
<th>Stress (M N/m$^2$)</th>
<th>Temperature (°C)</th>
<th>Life (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>750</td>
<td>3000</td>
</tr>
<tr>
<td>180</td>
<td>800</td>
<td>500</td>
</tr>
<tr>
<td>300</td>
<td>700</td>
<td>5235</td>
</tr>
<tr>
<td>350</td>
<td>650</td>
<td>23820</td>
</tr>
</tbody>
</table>

Uses the information given to produce a master curve based upon the Larson-Miller parameter, and thus calculate the expected life of a blade when subjected to a stress of 250 M N/m$^2$ and a temperature of 750 °C.

4(b) Explain the following:

(i) Short time Vs long time creep behaviour.
(ii) Creep behaviour of materials at constant stress.

OR

4(b') The secondary creep rate in many metals can be represented by the equation:

$$\varepsilon^o = \beta \sigma^n.$$  

A steel bolt clamping two rigid plates together is held at a temperature of 1000 °C. If $n$ is 3.0 and $\varepsilon^o = 0.7 \times 10^{-8} \text{h}^{-1}$, at 28 M N/m$^2$, calculate the stress remaining in the bolt after 9000 h, if the bolt is initially tightened to a stress of 70 M N/m$^2$. 

_________________
1 (a) Two identical circular cylinders, of radius r and mass m each, are connected by a springs, as shown in Figure 1. Determine the natural frequencies of oscillation of the system. Assume small amplitude vibrations.

OR

(a') A simplified spring-mass vibration pickup is used to measure the vertical acceleration of a train which has vertical frequency of 10 rad/sec. The mass weighs 17.2 N and modulus of the spring is 175 N/cm. The amplitude of the relative motion of the mass is 1.27 mm as recorded by the instrument. Find the maximum vertical acceleration of the train. What is the amplitude of vibration of the train?

1 (b) Using Lagrange's equation derive the governing equations of motion of multi DOF systems shown in Figure 2.

2 Derive an expression for transverse vibration of a uniform beam of length 'l' and cross sectional area 'A' subjected to a transverse force F(x, t) per unit length. Consider the effects of rotary inertia and shear deformation.

3 Explain the following:

(i) Subharmonic and superharmonic oscillations
(ii) Sources of nonlinearity in a vibration problem.
(iii) Jump phenomenon
(iv) Phase plane, trajectory, singular point and phase velocity

4 Using Lindstedt’s Perturbation method, find the solution of Van der Pals equation with two term approximation.

OR

4 The equation of motion for the forced vibration of a single degree of freedom nonlinear system can be expressed as:

\[ \ddot{x} + c\dot{x} + k_1x + k_2x^3 = a_1\cos\omega t - a_2\sin\omega t \]

Derive the conditions for the existence of subharmonics of order three for the system.
Find the trajectories of the system governed by the equations

\[ \dot{x} = x - 2y, \quad \dot{y} = 4x - 5y \]

OR

Derive the non-linear equation of motion of spring-mass system shown in Figure 3.

Figure 1

Figure 2

Figure 3
2017-18
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL (ALL BRANCHES)
ADVANCED NUMERICAL METHODS
ME640

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. Question M.M.
1(a) What is meant by the terms; (i) Machine epsilon (ii) Overflow (iii) Underflow, in the context of floating point number representations [06]
1(b) The expression: \( x^y + y^x - xy \), is to be evaluated in a computer program. If \( x^*, y^* \) are the computer representation of the values of \( x, y \), develop an expression for the absolute error bound for the expression in terms of \( \delta(x^*) \) and \( \delta(y^*) \). [06]

2. Consider the assignment statements in MATLAB: [12]
\[
\begin{align*}
\text{>> A} &= [1 10 -5;3 2 5;3 2 -4]; \\
\text{>> B} &= [-2;1;1;6]; \\
\text{>> x} &= A(1:2,1:2); \\
\text{>> y} &= B(1:2)
\end{align*}
\]
Obtain the output of the following MATLAB commands:
(i) size(A) (ii) z = x\(y\) (iii) \( C = A \times \text{eye}(3,3) \) (iv) \( x(:,1) .* y \) (v) \( y^* \times x(:,1) \) (vi) \( x^* y \)

3. Consider replacing the function \( f(x) = \sin(\pi x^2) \) over the interval \([0, 1]\) by an interpolating polynomial of degree 3 such that the interpolating errors are minimized. By choosing the sample points appropriately, obtain the interpolating polynomial. For obtaining Chebyshev points over the interval \([a, b]\), the following relation can be used:
\[
x_k = \frac{a + b}{2} + \frac{b-a}{2} \cos\left(\frac{(2k - 1)\pi}{(2n)}\right), \quad k=1, 2, \ldots, n
\]
OR
\[
\text{cond} = 2.
\]
3'(a) Show that three non-collinear data points are necessary for a linear polynomial interpolation for a function of two independent variables.

3'(b) Consider the problem of mapping a quadrilateral having vertices \((x_i, y_i), i=1, 2, 3, 4\) in the \(x-y\) plane onto a rectangle in the \(\xi-\eta\) plane as shown in figure shown below. The mapping is to be expressed as \(x = \sum_{i}^{4} x_i N_i(\xi, \eta)\) and \(y = \sum_{i}^{4} y_i N_i(\xi, \eta)\).

Using 2D Lagrange interpolation, obtain the expressions for the mapping functions \(N_i(\xi, \eta)\).

4(a) With the help of neat sketches explain the difference between a simple root and a non-simple root. For a non-simple root with multiplicity \(q\) where \(q\) is even, can bracketing methods be employed? Give reasons. Now, consider the following set of equations

\[ f(x) = x^3 + 3x^2 - 9x + 5 \]

Determine whether \(f(x)\) has a simple root or not? If yes then what is the multiplicity of the roots. Determine the roots using

4(b) Consider the equation \(f(x) = 8x^3 + x - 2 = 0\). Show that the equation has a simple root in the interval \([0, 1]\). Using Secant method, find the root accurate up to 2nd place of decimal.

OR

Contd......3
4'(a) Solve the following system of equations using contraction mapping method
\[
\begin{align*}
    x_1 &= \frac{1}{10} \left[ 1 - x_2 - \sin (x_1 + x_2) \right] \\
    x_2 &= \frac{1}{10} \left[ x_1 - x_2 + \cos (x_1 - x_2) \right]
\end{align*}
\]
for \( x_1 \in [-1,1] \) and \( x_2 \in [-1,1] \).

4'(b) Use the method of undetermined coefficients to develop a 3-point Newton-Cotes integration formula given as,
\[
\int_{-1}^{+1} f(x) \, dx = \sum_{k=1}^{3} W_k f(x_k)
\]
Apply the formula to estimate the integral \( \int_{-1}^{+1} \frac{e^{-x}}{x^2} \, dx \).

5(a) Consider the linear system \( Ax = b \), where the coefficient matrix \( A \) and right hand vector \( b \) are given as,
\[
A = \begin{bmatrix} 2 & 1 & 1 \\ 1 & 3 & 2 \\ 1 & 2 & 2 \end{bmatrix}, \quad b = \begin{bmatrix} 4 \\ 6 \\ 5 \end{bmatrix}
\]
Using LU-Decomposition direct method (Dolittle’s reduction), solve the system of equations. What is the basic advantage of the method over Gauss Elimination method?

5(b) Show that the relative error in a computed solution of a linear system \( Ax = b \) is bounded by, \( \|A\| \|A^{-1}\| \|e\|/\|b\| \). What is an ill-conditioned linear system of equations?

OR

contd .... 4.

Derive the conditions for the existence of subharmonics of order three for the system.
5'(a) Construct a equivalent finite difference equation for the equation given below:
\[ \frac{\partial T}{\partial t} = x \frac{\partial^2 T}{\partial x^2} \]
and comment on the convergence characteristics of fully explicit, fully implicit and Crank Nicholson time integration schemes by performing consistency and Von-Neuman Stability analysis. Consider space differencing to be central.

5'(b) Design an implicit compact scheme for finding first order derivative up to sixth order accuracy on a non-uniform stencil as shown below. Derive the equations for free parameters as functions \( \alpha, \beta \) and \( h_k \).

Here, \( h_k = |x_{i+k} - x_i| \) also \( h_1 \neq h_2 \neq h_3 \)

Best of luck
Maximum Marks: 60  
Credits: 04  
Duration: TWO Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.
Use of Thermodynamic Tables is allowed

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>For the Van der Waal's gas equation of state, show that the Joule Thomson coefficient is given as: [ \mu_J = \frac{v}{C_p} \left( \frac{2a(v - b)^2 - RTv^2b}{RTv^3 - 2a(v - b)^2} \right) ]</td>
<td>[6]</td>
</tr>
<tr>
<td>1(b)</td>
<td>Propane is compressed isothermally by a piston-cylinder device from 100°C and 1 MPa to 4 MPa. Using the generalized charts, determine the work done per unit mass of propane. (For propane, critical-point properties are 370 K and 4.26 MPa)</td>
<td>[6]</td>
</tr>
<tr>
<td>2(a)</td>
<td>Derive the van't Hoff equation to show the temperature dependency of equilibrium reaction constant ( (K_p) ). What is the significance of this equation?</td>
<td>[5]</td>
</tr>
<tr>
<td>2(b)</td>
<td>A gas mixture consists of O(_2) and N(_2). The ratio of the mole numbers of N(_2) to O(_2) is 3:1. This mixture is heated during a steady-flow process from 180 to 210 K at a constant pressure of 8 MPa. Determine the heat transfer during this process per mole of the mixture, using Kay's rule.</td>
<td>[7]</td>
</tr>
<tr>
<td>3(a)</td>
<td>Derive an expression for entropy generation for a control volume involving multiple streams.</td>
<td>[04]</td>
</tr>
</tbody>
</table>
| 3(b)  | Superheated steam at 600 °C and 9 MPa enters a turbine with an isentropic efficiency of 0.8. During the adiabatic expansion process with 0.1 MPa exit pressure and atmospheric conditions as 1 bar and 30 °C, calculate for a unit rate of steam flow:  
(a) Exergy of incoming steam  
(b) Exergy of outgoing steam  
(c) Work output of turbine  
(d) Irreversibility in the process | [08] |

OR

contd...2
3'(a) Derive an expression for second law efficiency for a heat exchanger operating on two streams of incompressible fluids. (simplify in terms of temperature only) [04]

3'(b) In a heat exchanger (HE) operating at steady flow, 0.3 kg/s of oil is cooled from 150 to 60 °C using a water stream entering the heat exchanger at 30 °C. The effectiveness of the HE is to be compared when operating in the parallel and counter-flow mode. The cooling water exits at 50 °C in parallel-flow and at 70 °C in counter-flow setting. Assume no heat interaction with the environment and negligible pressure drop in the hot and cold streams. If the specific heats for water and oil are 4.18 and 2.1 kJ/kg K respectively, calculate
   (a) Mass flow rate of water  (b) Second law efficiency  (c) Rate of irreversibility [08]

4 Describe the working of a piezoelectric system. Taking entropy as a function of stress ($\sigma$), electric field ($E$) and temperature ($T$), derive the following relation for a piezoelectric system:

$$ Tds = c_{\sigma,E} \frac{\partial \epsilon}{\partial T} \, d\sigma + T \frac{\partial \phi}{\partial T} \, dE $$

where $\epsilon$ and $\phi$ represent the strain and polarization respectively. [12]

OR

4' Characterize the engineering materials in terms of magnetization properties. For a magnetic system with magnetic field ($H$), flux density ($B$), magnetization per unit volume ($M$) and permeability of free space ($\mu_0$) show that the specific heat at constant magnetic field is given as:

$$ C_H = \left( \frac{\partial U}{\partial T} \right)_H - \mu_0 V H \left( \frac{\partial M}{\partial T} \right)_H $$

5(a) Write a note on microscopic interpretation of entropy. [04]

5(b) Write a note on the degeneracy of energy levels. Derive the general Maxwell-Boltzmann distribution law as:

$$ N_i^* = \alpha g_i e^{-\beta \epsilon_i} $$

OR

5(b') Compare Maxwell Boltzmann, Fermi-Dirac and Bose Einstein statistics when four particles are distributed among two energy levels. Three particles are at energy level $\epsilon_1$ having degeneracy $g_1 = 3$ and one particle is at energy level $\epsilon_2$ having degeneracy $g_2 = 1$. Also, show their arrangement for the three cases. [08]

***** ***** ****
Q.No. | Question | M.M.
--- | --- | ---
1 | A plane wall of thickness L is initially at temperature of $T_1$. At time $t = 0$ a uniform heat flux of strength $q''$ is applied to the surface at $x = L$. The surface at $x = 0$ is maintained at temperature $T_1$. Formulate the problem in appropriate nondimensional variables. Using separation of variables and the partial solutions procedure, determine the temperature distribution in the wall as a function of position and time. | 15 |

OR

1' | A plane wall of thickness L is initially at temperature of $T_1$. The wall is maintained at $T = T_1$ at $x=0$ and the surface at $x = L$ is instantaneously brought to $T = T_2$ at $t = 0$. Formulate the problem in appropriate nondimensional variables. Using separation of variables and the partial solutions procedure, determine the temperature distribution in the wall as a function of position and time. | 15 |

2(a) | Explain Ablation heat transfer. Derive an equation for the coefficient of heat transfer for the ablation of a spherical shape body. | 7.5 |

2(b) | In the section illustrated in Figure 1 the surface 1-4-7 is insulated. The convection heat transfer coefficient at surface 1-2-3 is 28 W/m$^2$·°C. The thermal conductivity of the solid material is 5.2 W/m·°C. Using the numerical technique, compute the temperatures at nodes 1, 2, 4, and 5. | 7.5 |

---

Figure 1

$T_\infty = 0°C$

$h = 28 \text{ W/m}^2 \cdot °C$

$T_7 = T_8 = T_9 = 38°C$

$T_3 = T_6 = 10°C$
3(a) Determine the shape factor $F_{dA_1-A_2}$ from direct integration between the differential area $dA_1$ and finite area $A_2$ of diameter as shown in Figure 2.

3(b) Draw the radiation network for the radiation system consisting of two transmitting layers between two planes (Figure 3).

4 A 5-m-square room has a ceiling maintained at 28°C and a floor maintained at 20°C. The connecting walls are 4 m high and perfectly insulated. Emissivity of the ceiling is 0.62 and that of the floor is 0.75. Calculate the heat transfer from ceiling to floor, and the temperature of the connecting walls.

OR

4' Two long concentric cylinders have diameters of 4 and 8 cm, respectively. The inside cylinder is at 800°C and the outer cylinder is at 100°C. The inside and outside emissivities are 0.8 and 0.4, respectively. Calculate the percent reduction in heat transfer if a cylindrical radiation shield having a diameter of 6 cm and emissivity of 0.3 is placed between the two cylinders.
Q.No. 1(a) Mention the advantages of determining the adiabatic flame temperature (AFT) using Guldér’s method. Show the effects of ambient pressure, temperature and equivalence ratio on AFT with the help of a suitable diagram. [06]

1(b) 0.464 kg of methane leaks into a (12’ x 14’ x 8’) room at 20°C and 1 atm (101325 Pa). After sometime, the fuel gas and air get well mixed. Predict whether the mixture is flammable? [06]

2 Determine the laminar flame speed for a stoichiometric C₂H₅OH (ethanol)-air mixture at \( P_\infty = 1 \text{ atm} \) (101325 Pa) and \( T_\infty = 300 \text{ K} \), using Spalding’s approach with single step global kinetic scheme. The pre-exponential factor \( A = 1.5 \times 10^{12} (\text{g mol/cm}^3)^{1/m} \cdot 1/\text{s} \).

\[ E_g / R_g = 15098 \text{ K} \], \( m = 0.15 \), \( n = 1.6 \). The average reaction rate \( \bar{m}_r \) (kg/s.m²) is calculated with respect to the second half of the flame thickness, that is at an average temperature of \( 1/2 \left[ 1/2(T_r + T_\infty) + T_r \right] \). \( T_r \) is the adiabatic flame temperature (2155 K) of the stoichiometric reaction between fuel and air (\( \nu = 8.9530 \)). Thermal diffusivity of air, \( \alpha_{ar} = 5.912 \times 10^{-5} \text{ m}^2/\text{s} \) and mixture density \( \rho_{m} = 0.21601 \text{ kg/m}^3 \). The following reaction rate expression can be used: \( d[C_2H_5OH] / dt = -A \exp(-E_g / R_g T)[C_2H_5OH]^n [O_2]^m \).

OR

2' Differentiate between deflagration and detonation. Show that mach number \( M > 1 \) in the strong detonation region, \( M < 1 \) in the strong deflagration region and no solution for the imaginary region. Determine the detonation velocity for a stoichiometric acetylene (C₂H₂)-air mixture at 1 atmosphere, 298K neglecting dissociation. The \( C_{p_{R}} \) of reactants can be taken as 1.057 kJ/kgK. Assume the temperature of products \( (T_p) \) as 3500K and \( P_2 \gg P_1 \). Verify whether the assumptions of \( T_p \) and \( P_2 \gg P_1 \) are correct.

The expressions for detonation velocity \( V_d \) and \( T_2 \) are respectively:

\[ V_d = \{2(\gamma_2 + 1)\gamma_2 R_p \left[ \frac{C_{p_{2}} T_1 / C_{p_{2}} + q / C_{p_{2}}}{} \right] \}^{1/2} \]

\[ T_2 = 2 \gamma_2^2 / \gamma_2 + 1 \left[ C_{p_{2}} T_1 / C_{p_{2}} + q / C_{p_{2}} \right] \]

where symbols have their usual meaning. (Take \( MW_1 = 28.63 \text{ kg/kmol} \), \( MW_2 = 28.79 \text{ kg/kmol} \), \( C_{p_{CO_2}}, C_{p_{N_2}}, C_{p_{O_2}} \) (kJ/kmolK) respectively as: 62.718, 57.076, 37.302 and heat addition \( q = 3398.5 \text{ kJ/kg} \).)
3(a) Briefly discuss the significance of mixture fraction and conserved scalar approach in reacting flows. List the major assumptions of unsteady, multicomponent Shvab-Zeldovich energy equation and mention its application.

(b) A heavy duty naturally aspirated diesel engine is being evaluated on a dynamometer test stand. Operating at an air-fuel ratio of 21:1 with a fuel flowrate of $4.89 \times 10^3$ kg/s, the engine produces 80 kW of brake power. The multicomponent fuel has the equivalent formula $C_{12}H_{22}$. The unburned hydrocarbon concentration measured in the exhaust stream is 120 ppm $C_1$ (wet basis). Determine (i) the unburned hydrocarbon concentration on a dry basis and (ii) the unburned hydrocarbon emission index (g/kg) for the engine. Assume that the hydrogen-carbon ratio of the unburned $C_1$ equivalent is the same as the original fuel molecule.

4 Explain the two-film model of a burning spherical carbon particle with respect to species mass fractions and temperature profiles. Compare this model with the spherically symmetric, steady state, droplet combustion model. Draw temperature profiles for a spherically symmetric, fully transient, droplet combustion model.

5 (a) Write down expressions for second law efficiencies of (i) steady flow, constant pressure combustion chamber (gas turbine engine type), (ii) internal combustion engine and (iii) combustion products exiting from a steady flow combustor at 1 atmosphere and 298 K.

(b) Briefly discuss the methods for estimating boiling point, latent heat of vaporization and liquid density of hydrocarbon fuels at high pressure.

OR

5'(a) A spherically symmetric, 50 $\mu m$ n-octane droplet burns steadily in air at $P_a = 0.1$ MPa and $T_a = 300$ K. Calculate the transfer number $B_t$, burning constant $k_b$ and flame standoff ratio $F/D$. Consider following correlations: $Cp_{\nu} = (0.363 + 0.000467T_{av})(5.0 - 0.001\rho_f)$, $K_{\nu} = K_{\nu}(1000T_{av})^3$; symbols have their usual meaning. Assume: $AFT = 2275K$, $(A/F)_{stio} = 15.05$, heat of combustion = 44425 kJ/kg.

(b) Compare the result with that of droplet evaporation due to heat transfer only by replacing AFT with $T_a$. 

---

[06][06][07][07][05][05][08][08][04][04]
The figure given below shows a multi-evaporator, vapour compression refrigeration system working with ammonia. The refrigeration capacity of the high temperature evaporator operating at -6.7 °C is 5 TR, while it is 10 TR for the low temperature evaporator operating at -34.4 °C. The condenser pressure is 10.8 bar. Assuming saturated conditions at the exit of evaporators and condenser, ammonia vapour to behave as an ideal gas with a gas constant of 0.488 kJ/kgK and isentropic compression index \( \frac{c_p}{c_v} = 1.29 \) (a) Find the required power input to compressor in kW and compressor exit temperature in °C, (b) Find the required power input to compressors and compressors exit temperature in °C, if instead of using a single compressor, individual compressors are used for low and high temperature evaporators. Use the data given in the table:

<table>
<thead>
<tr>
<th>T, °C</th>
<th>P (kPa)</th>
<th>( h_r ) (kJ/kg)</th>
<th>( h_g ) (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-34.4</td>
<td>95.98</td>
<td>44.0</td>
<td>1417</td>
</tr>
<tr>
<td>-6.7</td>
<td>331.8</td>
<td>169.1</td>
<td>1455</td>
</tr>
<tr>
<td>27.7</td>
<td>1080.0</td>
<td>330.4</td>
<td>1485</td>
</tr>
</tbody>
</table>

OR

1'(a) A cylindrical tank 2 m long mounted with its axis horizontal is to separate liquid ammonia from ammonia vapour. The ammonia vapour bubbles through the liquid and 1.2 m³/s leaves the surface of the liquid. If the velocity of the vapour is limited to 1 m/s and the vessel is to operate with the liquid level two-thirds of the diameter from the bottom, what must the diameter of the tank be?

1'(b) A liquid subcooler receives liquid ammonia at 30°C and subcools 0.6 kg/s to 5°C. Saturated vapour leaves the subcooler for the high stage compressor at -1°C. Calculate the flow rate of ammonia that evaporates to cool the liquid.
The following data refer to a reduced ambient refrigeration system. Pressure of ram air = 1.1 bar (at 20°C), Pressure at the end of the main compressor = 3.3 bar, Main compressor efficiency = 0.8. Heat exchanger effectiveness = 0.8. The pressure at the exit of the auxiliary turbine = 0.8 bar (isentropic efficiency = 0.85), Temperature of the air leaving the cabin = 25°C, Pressure in the cabin = 1.013 bar. The flow rate of air through cabin = 1 kg/s. Cooling turbine efficiency = 0.84. Obtain the COP, tonnage and power required to operate the system.

3(a) Explain the working of a Philips refrigerator.
3(b) Explain the significance of maximum inversion temperature on the liquefaction of helium gas.
3(c) Describe the applications of Cryogenics in the following field:
   i. Space Industry
   ii. Aviation and Aerospace Industry
   iii. Medicine and Biology

4(a) Show Linde-Hampson cycle on T-S diagram when the heat exchanger is not perfect. What are its implications? Draw the schematic diagram of the system and derive expressions of Liquid yield, Work per unit mass compressed, Work per unit mass liquefied and Figure of Merit (FOM) for System.
4(b) Determine the ideal work requirement, the liquid yield, the work per unit mass compressed, the work per unit mass liquefied and the FOM for a Linde-Hampson System with nitrogen as working fluid when the system is operated between 1 atm and 200 atm at 300 K. The effectiveness of heat exchanger is 90%.
Take \( h_f = 29 \text{ J/g} \), \( s_f = 0.42 \text{ J/g-K} \).

OR

4'(a) Derive expressions of Liquid yield, Work per unit mass compressed, Work per unit mass liquefied and FOM for Pre-cooled Linde-Hampson System. Draw the schematic diagram of the system and its Temperature - Entropy plot.
4'(b) Discuss, with the help of graph, the effect of mass ratio \( (r) \) on Liquid yield, Work per unit mass compressed, Work per unit mass liquefied and FOM for a Pre-cooled Linde-Hampson System. Take at least two values of compression pressure for each graph.
Answer all questions.
Assume suitable data if missing.
Notations used have their usual meaning.

1(a) Differentiate between combined and cogeneration cycles by giving examples. [04]
1(b) In a combined gas turbine-steam turbine power plant, the exhaust gas from the open cycle gas turbine is the supply gas to the steam generator of the steam cycle at which additional fuel is burned in the gas. The pressure ratio for the gas turbine is 7.5 the air inlet temperature is 15°C and the maximum cycle temperature is 750°C. Combustion of additional fuel raises the gas temperature to 750°C and the gas leaves the steam generator at 100°C. The steam is supplied to the turbine at 50 bar, 600°C and the condenser pressure is 0.1 bar. The total power output of the plant is 200 MW. The calorific value of the fuel burned is 43.3MJ/kg. Neglecting the mass flow rate of fuel on the air flow, determine (a) the flow rates of air and steam required, (b) the power outputs of the gas turbine and steam turbine, (c) the thermal efficiency of the combined plant, (d) the air fuel ratio. [08]

2(a) Define depreciation and draw a graph between cost per kWh and load factor. [04]
2(b) Explain different energy storage methods. What is the need of energy storage? [08]

OR

2'(a) Write full forms of the terms LOCA, CANDU, LMFB, MAGNOX. What is the function of cladding in a nuclear reactor? [04]
2'(b) Explain the working of gas cooled reactor (GCR) and high temperature gas cooled reactor (HTGR). [08]

3(a) Differentiate super-charging and turbo-charging. Why are they more beneficial in a CI engine compared to an SI engine? [04]
3(b) A four-stroke CI engine of 3.5 litre capacity develops indicated power on average of 13.1 kW/m³ of free air induced per minute, while running at 3600 rpm and having a volumetric efficiency of 82 per cent, referred to free air conditions of 1,013 bar and 25°C. A blower driven mechanically from the engine is proposed to be installed for supercharging. It works through a pressure ratio of 1.75 and has an isentropic...
efficiency of 70 per cent. Assume that at the end of the intake stroke the cylinders contain a volume of charge equal to the swept volume, at the pressure and the temperature of the delivered air from the blower. Taking all mechanical efficiencies to be 80 per cent, estimate the net increase in brake power of the engine due to supercharging.

OR

3'(a) How emissions can be reduced in a gas turbine power plant and a diesel electric power plant?

3'(b) What do you mean by fluidized bed combustion (FBC)? Explain different types of FBC systems. What are their advantages?

4 Write short notes on any three of the following:
   (a) Steam turbine governing.
   (b) Advantages of high pressure boilers.
   (c) Tariff charging methods in a power plant.
   (d) Draft system in a chimney.

5 A region has maximum demand of 500 MW at a load factor of 50%. The load duration curve can be assumed to be a triangle. The utility has to meet this load by setting a generating system which is partly hydro and partly thermal. The costs are as under: Hydro plant: Rs. 7200 per kW per annum + operating expenses Rs. 0.36 per kWh. Thermal plant: Rs. 3600 per kW per annum + operating expenses Rs. 1.56 per kWh. Determine the capacity of hydro plant, capacity of thermal plant, energy generated annually by each and overall generation cost per kWh.
Q.1 Answer all the parts

(i) Why are odd-order upwind schemes preferred over even-order upwind schemes (4)

(ii) For the unsteady heat conduction equation

\[ \frac{\partial T}{\partial t} = \kappa \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) \]

show using the Von Neumann stability analysis that the viscous stability limit \( \frac{\kappa (\Delta t)}{(\Delta x)^2} + \frac{\kappa (\Delta t)}{(\Delta y)^2} < \frac{1}{2} \) holds true. (6)

(iii) Discretize a two-dimensional Poisson equation \( \nabla^2 P = Q \) using Gauss-Seidel and SOR techniques. On what factors is relaxation factor \( \omega \) dependent on? (5)

Q.2. The governing equations for two-dimensional unsteady heated equation are

\[ \frac{\partial T}{\partial t} = \alpha \nabla^2 T \]

The boundary conditions are \( \frac{\partial T}{\partial x} = 0 \) at \( x = 0, L \) and \( T = 1 \) at \( y = 0; T = 0 \) at \( y = H \). Perform the following tasks:

(i) Discretize the equations using the two-step ADI scheme. (6)

(ii) Ascertain the coefficients of Tridiagonal solver on implementation of boundary conditions (4)

(iii) Mention the steps for sequential evaluation of the algorithm implementing the ADI scheme. (5)

OR
Q.2. The non-dimensional form of 2D Euler equations in an isothermal channel are given below:

\[
\begin{align*}
\frac{\partial p}{\partial t} + \frac{\partial p u}{\partial x} + \frac{\partial p v}{\partial y} &= 0 \\
\frac{\partial p u}{\partial t} + \frac{\partial p u^2}{\partial x} + \frac{\partial p u v}{\partial y} &= -\frac{\partial p}{\partial x} \\
\frac{\partial p v}{\partial t} + \frac{\partial p u v}{\partial x} + \frac{\partial p v^2}{\partial y} &= -\frac{\partial p}{\partial y} \\
\frac{\partial p E}{\partial t} + \frac{\partial p u E}{\partial x} + \frac{\partial p v E}{\partial y} &= \gamma (\gamma - 1) M^2 \left( \frac{\partial p u}{\partial x} + \frac{\partial p v}{\partial y} \right)
\end{align*}
\]

Here \( M \) is the Mach number, \( E = T + \frac{\gamma (\gamma - 1)}{2} M^2 (u^2 + v^2) \), \( p = \frac{\rho T}{\gamma M^2} \) and the flow has translational periodicity in streamwise direction.

(i) Discretize the above equations based on flux-based scheme using mix of central-differencing and QUICK scheme with R-K integration

(ii) Mention the appropriate boundary conditions

(iii) Write a pseudo-code for implementing the above scheme

Q.3. Temperature \( T \) is being transported by means of convection and diffusion in a long, small diameter pipe. The governing equations are

\[
\frac{d(uT)}{dx} = \frac{d(k\frac{dT}{dx})}{dx}
\]

and \( \frac{dT}{dx} = 0 \). The boundary conditions are \( T = 1 \) at \( x = 0 \) and \( T_L = 0 \) at \( x = L \). Assume \( u > 0 \) for whole of the flow domain. Using five equally spaced cells in finite volume methodology,

(i) Calculate coefficients \( a_W, a_E, a_P, S_n \) and \( S_p \) for all the five nodes, if the scheme uses first-order upwinding for convective terms

(ii) Calculate coefficients \( a_W, a_E, a_P, S_n \) and \( S_p \) for all the five nodes, if the scheme uses third-order QUICK upwinding for convective terms and central-differencing for diffusion terms with mirror boundary conditions.
Q.4 We wish to solve 2D laminar, incompressible viscous flow on a backward-facing step. The governing equations are

\[
\begin{align*}
\frac{\partial u}{\partial t} + v \frac{\partial u}{\partial x} + u \frac{\partial u}{\partial y} &= -\frac{\partial p}{\partial x} + \frac{1}{Re} \nabla^2 u \\
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} &= -\frac{\partial p}{\partial y} + \frac{1}{Re} \nabla^2 v \\
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} &= 0
\end{align*}
\]

Assume appropriate inlet, outlet and farfield boundary conditions and no-slip, impenetrable wall for the step. Perform the following tasks:

(i) Write down the steps involved in discretization using Chorin's Projection technique. Assume semi-implicit discretization methodology for viscous and convective terms. (5)

(ii) Write down the appropriate boundary conditions for \(u, v\) and \(p\) (6)

(iii) Derive the Pressure Poisson equation (PPE) with appropriate boundary conditions and solve the same using SOR technique (4)

OR

Q.4' We wish to solve the 1D Euler equations

\[
\begin{align*}
\frac{\partial p}{\partial t} + \frac{\partial pu}{\partial x} &= 0 \\
\frac{\partial pu}{\partial t} + \frac{\partial (p+pu^2)}{\partial x} &= 0 \\
\frac{\partial pE}{\partial t} + \frac{\partial pu(E+p)}{\partial x} &= 0
\end{align*}
\]

where \(E = e + .5pu^2\) and \(p = (\gamma - 1)\rho c\) for Sod shock tube problem using KT scheme employing Rusanov fluxes. Perform the following tasks:

(i) Write down the slope limited left and right states of the conservative variables using linear piecewise approximation (3)

(ii) Write down the numerical fluxes at cell faces using Rusanov or Lax-Friedrich differencing. Mention the procedure used to evaluate wave speeds (5)

(iii) Draw a flowchart for sequential evaluation of the algorithm, mentioning appropriate boundary conditions (7)
2017-18  
M.TECH. (AUTUMN SEMESTER) EXAMINATION  
MECHANICAL ENGINEERING (MACHINE DESIGN)  
ROTOR DYNAMICS ME678  

Maximum Marks: 60  
Credits: 04  
Duration: Two Hours  

Answer all questions.  
Assume suitable data if missing.  
Notations used have their usual meaning.  

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Explain with the help of equations why fluid film bearings are known as 8 coefficient bearings. Derive the equations of motion for a rigid rotor mounted on fluid film bearings and also the expressions of bearing forces for the above case.</td>
<td>[15]</td>
</tr>
</tbody>
</table>
| 1'    | A disc of mass 13.6 kg and the polar mass moment of inertia 0.02 kg-m², is mounted at the mid-span of a shaft with a span length of 0.4064 m. Assume the shaft to be simply supported at bearings. The diameter of the steel shaft is 2.54 cm with E= 200 GNm². The rotor is known to have an unbalance of 0.2879 kg-cm. Determine forces exerted on bearings and their components in horizontal and vertical directions at the spin speed of 6000 rpm considering shaft as (i) rigid and (ii) flexible. Use influence coefficient method when the shaft is flexible. The expressions of influence coefficient for the above case are given as:  
\[ \alpha_{11} = \frac{l^2}{48EI}; \ \alpha_{22} = \frac{3a^2l-3a^2-l^2}{3EI}; \ \alpha_{12} = \frac{3a^2l^2-2a^2l^2-a^2l^2}{3EI}; \ \alpha_{21} = \frac{ab(b-a)}{3EI} \]  
where \( a \) and \( b \) are the distance of the disc from the left and right bearing respectively. | [15] |
| 2 (a) | Derive the equations to calculate the natural frequency and mode shapes for a simply supported shaft using Myklested method.                                                                                 | [08] |
| 2 (b) | Derive the frequency equation of overhung rotor in nonsynchronous whirl motion (non-dimensional form).                                                                                                 | [07] |
| 3. (a) | Explain the instability of rotors mounted on fluid film bearings and derive the relation                                                                                                               | [06] |

Cont'd... 2
between whirl frequency and rotational speed for the rotor to be unstable. Also, plot the Campbell type diagram for finding the instability threshold speed for oil whip.

3. (b) A rigid rotor of mass 20 kg is supported on two identical fluid film bearings with the following properties: $k_x = 2.1$ MN/m, $k_y = 1.5$ MN/m, $k_{xy} = 1.0$ MN/m, $k_{xu} = -10$ MN/m, $c_{xx} = c_{yy} = 200$ kN-s/m, $c_{yx} = c_{xy} = 150$ kN-s/m. Find the stability of the rotor.

OR

3. (b') Obtain the non dimensional form of the equations used for solving instability in flexible rotors.

4. (a) Write the characteristic frequency for the following mechanical faults along with the direction in which they are observed: (a) rotating unbalance, (b) reciprocating unbalance, (c) bent shaft, (d) misalignment, (e) mechanical looseness, (f) hysteresis, (g) loose journal bearing, (h) oil film whirl, (i) damaged hydrodynamic bearing, (j) asymmetric shaft.

4. (b) Derive the expression for balancing of flexible rotor using modal balancing theory.

OR

4. (b') A rigid rotor machine is exhibiting vibration problems caused by unbalance. The machine is symmetric about its center-line. A trial balance mass of 0.3 kg is placed at end 1 at an angle of $30^\circ$ relative to some reference position; this causes changes in vibration vectors of 50 $\mu$m at $61^\circ$ at end 1 and 42 $\mu$m at $130^\circ$ at end 2. Determine the influence coefficients for use in balancing the machine, and calculate the balance mass required at each end of the machine if the measured unbalance vibrations are $-30$ $\mu$m at $230^\circ$ at end 1 and $-70$ $\mu$m at $330^\circ$ at end 2.
Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer all the questions. Assume suitable data if missing. Notations used have their usual meaning.

Q.No. Question M.M.

1 Discuss the theory of photoelastic coatings. Also, derive the relations for stress-strain in the coating. [12]

1' Explain the reinforcing effects of birefringent coatings. Also derive the relation for the correction factor. [12]

OR

2(a) What are the important physical properties of coating materials? [06]

2(b) A polycarbonate with $K=0.14$ is used as a birefringent coating in a polariscope with a mercury green light source. If the modulus of elasticity and Poisson's ratio of the polycarbonate are $2.45$ GPa and 0.38 respectively, determine $f_0$ and $\sigma$ for the coating. [06]

3(a) Define a strain gauge. List the various types of strain gauges. [04]

3(b) The following readings of strain were obtained on a rectangular strain rosette mounted on aluminium for which $E=70$ GPa, $v=0.32$, $e_a=1200 \mu$, $e_b=470 \mu$, $e_c=670 \mu$. Determine graphically, the principal strains and $\phi$.

\[ \text{contd} \ldots \]
4 What is a Photoelastic Polariscope. List the various types of polariscope and describe a Plane Polariscope in detail including its working principle. [12]

OR

4(a) What are the basic requirements for the material of a photoelastic model used in experimental stress analysis. [06]

4(b) What are the important data obtained from photoelastic experiments. How Isoclinics and Isochromatics are interpreted? [06]

5(a) Explain the calibration method of a photoelastic tension model. [03]

5(b) A resin base brittle coating is characterised by $E_c=1.4$ GPa, $\varepsilon_{dc}=500$ $\mu$ and $V_c=0.42$. Calculate the state of stress in the coating applied on a steel cantilever if the first crack appears at a distance of 10 mm from fixed end. The free end where load is applied, is at a distance of 100 mm from the fixed end. What would be the deflection at free end to cause the cracking in the cantilever, if the cantilever is 20 mm wide and 2 mm thick? Use $E_s=200$ GPa and $V_s=0.3$. [09]