Answer all questions:

Q. 1 (a) Solve the system of differential equations
\[ \frac{dy}{dx} = xz + 1, \quad \frac{dz}{dx} = -xy \quad \text{for} \quad x = 0.3 \]
using fourth order Runge-Kutta method taking \( h = 0.3 \). Initial values are \( x = 0; \ y = 0; \ z = 1 \).

OR

(a') Evaluate the pivotal values of the equation
\[ 16 \frac{d^2u}{dx^2} = \frac{d^2u}{dt^2} \]
taking \( h = 1 \) and upto one half of the period of vibration,
given that \( u(0,t) = u(5,t) = 0 \)
\( u(x,0) = x^2(5-x) \) and \( u_t(x,0) = 0 \).

(b) Using the principle of least square method, fit a second degree parabola to the following data:

<table>
<thead>
<tr>
<th>x</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>1</td>
<td>1.8</td>
<td>1.3</td>
<td>2.5</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Q. 2(a) Show that the function \( \varnothing(x) = xe^{-x} \) is a solution of the integral equation
\[ \varnothing(x) = e^x \sin x + 2 \int_0^x \cos(x-t) \varnothing(t) \, dt . \]

OR

(a') Transform the boundary value problem:
\[ \frac{d^2y}{dx^2} + y = x , \quad y(0) = 0 , \quad y'(1) = 0 \]
to a Fredholm integral equation, constructing Green’s function.

(b) Find the integral equation corresponding to the differential equation
\[ y'' + (1 + x^2)y = \cos x , \quad y(0) = 0 , \quad y'(0) = 2 . \]

Q. 3 (a) Define conformal mapping and find the transformation of the strip \( 1 < x < 2 \)
under the mapping \( w = \frac{1}{z} \).
(b) Determine the linear fractional transformation that sends the points $z = 0, -i, 2i$ into the points $w = 5i, \infty, -\frac{1}{3}$ respectively. Also find the fixed points of this transformation.

(c) Define bilinear transformation and find the image of $x^2 + y^2 - 4y + 2 = 0$ under the mapping $w = \frac{z-i}{iz-1}$

OR

(c') Show that the transformation $w = \frac{z+1}{z}$ maps the circle $r = c$ into the ellipse $u = \left(c + \frac{1}{c}\right)\cos \theta, v = \left(c - \frac{1}{c}\right)\sin \theta$. Discuss the case when $c = 1$.

Q.4 (a) Show that the contravariant and covariant tensors are invariant under Cartesian coordinate system.

(b) Define symmetric and skew-symmetric tensors. If $A_i$ are the components of covariant tensor, show that $B_{ij} = A_i(A_j - A_jA_i$ are the components of the skew-symmetric covariant tensor of rank two.

OR

(b') A covariant tensor has components $xy, 2y - z^2, xz$ in rectangular coordinates. Find its covariant components in spherical coordinates.
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (INDUSTRIAL & PRODUCTION)
ME621: OPERATIONS MANAGEMENT

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Assume data suitably, if required.
Notations used have their usual meaning.

M.M.

1(a) Discuss the common components of demand that are taken into considerations in a forecasting system for operations.

OR

1(a') Distinguish the statistical methodology of casual methods of forecasting from time series methods

1(b) The enrolment at a higher education center is more in the first semester than in the second semester. Given the following past data, forecast student enrolment in semester 1 and semester 2 of the upcoming year (2017)

<table>
<thead>
<tr>
<th>Semester</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>

Use the ratio seasonality model with
\[ \alpha = \gamma = 0.1, S_{semester1,2016} = 75, I_{semester1,2016} = \frac{4}{3} \text{ and } I_{semester2,2015} = \frac{2}{3} \]

2(a) Consider a shop which produces three items. The items are produced in lots. The demand rate for each item is constant and is assumed to be deterministic. No back orders are allowed. The pertinent data for the items is given in the following table

<table>
<thead>
<tr>
<th>Item</th>
<th>Item-1</th>
<th>Item-2</th>
<th>Item-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Cost (Rs.)</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Setup Cost (Rs.)</td>
<td>50</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Cost per Unit (Rs.)</td>
<td>6</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Yearly Demand</td>
<td>10000</td>
<td>12000</td>
<td>7500</td>
</tr>
</tbody>
</table>

Determine approximately the Economic Order Quantities when the total monetary value of average inventory levels of these items is Rs. 1000.

OR
2(a') Derive expression for Economic Production Quantity (EPQ). List all the assumptions made and hence solve the following problem.

A company has to supply 10,000 bearings per day to an automobile manufacturer. When a production run starts, the output achieved is 25000 bearings per day. The cost of holding a bearing in stock for one year is Rs 2 and the setup cost of a production run is Rs 1800. Find EPQ and the frequency of production runs.

2(b) What are the characteristics of unpaced production systems? Explain optimum and critical bowl limits.

3 A manufacturing plant produces products X and Y for which the demand, safety stock and product structure level is shown in the following Table and Figures.

<table>
<thead>
<tr>
<th>Item</th>
<th>Safety Stock</th>
<th>Week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>X</td>
<td>50</td>
<td>300</td>
</tr>
<tr>
<td>Y</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

The on hand inventories for various product items are: X=100, Y=30, A=70, B=0, C=200 and D=800. The lot sizes are, for A=250 and D=1000 units (or multiples of it, both for A and B). While all other items are specified on lot for lot (L4L) basis (quantities are same as requirements). The only schedules receipt is 250 units of X due in period 2. Determine the order quantities and release dates for all requirements.

OR

Contd...
A company needs to develop an aggregate production plan for the six months from January through June. The following information is available.

**DEMAND & WORKING DAYS**

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Forecast</td>
<td>500</td>
<td>600</td>
<td>650</td>
<td>800</td>
<td>900</td>
<td>800</td>
<td>4250</td>
</tr>
<tr>
<td>Number of working days</td>
<td>22</td>
<td>19</td>
<td>21</td>
<td>21</td>
<td>22</td>
<td>20</td>
<td>125</td>
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</tbody>
</table>

**COSTS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Rs 100/unit</td>
</tr>
<tr>
<td>Inventory holding cost</td>
<td>Rs 10/unit/month</td>
</tr>
<tr>
<td>Cost of Stock out</td>
<td>Rs 20/unit/month</td>
</tr>
<tr>
<td>Cost of Subcontracting</td>
<td>Rs 100/unit</td>
</tr>
<tr>
<td>Hiring and Training cost</td>
<td>Rs 50/worker</td>
</tr>
<tr>
<td>Layoff cost</td>
<td>Rs 100/worker</td>
</tr>
<tr>
<td>Labour hours required</td>
<td>4/unit</td>
</tr>
<tr>
<td>Straight time cost (first eight hours each day)</td>
<td>Rs 12.50/hour</td>
</tr>
<tr>
<td>Overtime cost</td>
<td>Rs 18.75/hour</td>
</tr>
</tbody>
</table>

**INVENTORY**

<table>
<thead>
<tr>
<th>Inventory</th>
<th>200 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Stock required</td>
<td>Nil</td>
</tr>
</tbody>
</table>

What is the cost of each of the following production strategies?

(a) Produce exactly to meet demand (level production); vary workforce (assuming starting workforce equal to first month’s requirements).

(b) Constant workforce; vary inventory and allow shortages only (assuming starting workforce of 10).

(c) Constant workforce of 10; use subcontracting.

4(a) Explain OPTIZ system of coding and classification.  [05]

4(b) Explain the steps required for preparing a process plan.  [05]

4(c) Explain the pond drain system of production planning and control.  [05]
Normal Distribution Tables

Tables of the Normal Distribution

Probability Content from $-\infty$ to $Z$

<table>
<thead>
<tr>
<th>Z</th>
<th>0.00</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
<th>0.05</th>
<th>0.06</th>
<th>0.07</th>
<th>0.08</th>
<th>0.09</th>
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<tbody>
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<td>0.5000</td>
<td>0.5040</td>
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<td>0.5160</td>
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<tr>
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</table>
2016-17
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (I/P)
METAL CUTTING ANALYSIS
ME-625

Maximum Marks: 60

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

Q.No. Question

1. (a) Select the correct answer (s) from the given four possible answers:
   i. The value of chip reduction coefficient, $\zeta$ does not depend upon
      a. cutting velocity   b. depth of cut   c. cutting tool material   d. tool rake angle
   ii. The most commonly used abrasive is
        a. silicon carbide   b. aluminum oxide   c. diamonds   d. cubic boron nitride
   iii. Coolant retention is affected by the grinding wheel’s:
        a. hardness   b. bond type   c. grain size   d. porosity
   iv. A cutting tool can never have its
        a. rake angle – positive   b. rake angle – negative
           c. clearance angle – positive   d. clearance angle – negative
   v. Normal rake and side rake of a turning tool will be same if its
      a. $\phi = 0^\circ$ & $\lambda = 0^\circ$   b. $\phi = 90^\circ$ & $\lambda = 0^\circ$   c. $\phi = 90^\circ$ & $\lambda = 90^\circ$   d. $\phi = 0^\circ$ and $\lambda = 90^\circ$
   vi. In oblique cutting chips are in form of:
        a. Long curl   b. Flat spiral   c. Discontinuous   d. Short & thick

1. (b) What should be the aims and objectives in manufacturing of any product? Justify “Machining is a value addition process”.

2. (a) It has been stated that it is generally undesirable to allow temperatures to rise excessively in machining operations. Explain why.
2. (b) Show that the distance \( l \) in slab milling is approximately equal to \( \sqrt{Dd} \) for situations where \( D >> d \). Where \( D \) and \( d \) are the cutter diameter and depth of cut, respectively.

3. Determine the power required at the cutting point in a turning process in which the following data is noted:
   - Cutting force component parallel to cutting velocity, \( F_h = 1450 \text{ N} \)
   - Cutting force component parallel to feed motion, \( F_f = 450 \text{ N} \)
   - Cutting force component in the radial direction, \( F_r = 160 \text{ N} \)
   - Work piece diameter = 50mm; Cutting rpm = 318;
   - Feed = 0.1mm/rev; Depth of cut = 4mm

   If 85% of the heat produced is retained by the chip, determine the rise in temperature.

4. (a) Describe moving thermocouple technique for measurement of cutting temp. Give a neat sketch of the same.

4. (b) Explain hot machining. In what circumstances is it useful and why. Write down the different techniques of hot machining.

5. (a) How does the geometry of cutting tool affect the machinability?

5. (b) Write the benefits of controlled contact machining.

6. (a) Discuss the important technological parameters that affect lapping process. Why is high velocity desired in grinding?

6. (b) Determine the optimum cutting speed and optimum tool life on the basis of minimum cost.
Answer all questions.

Q1. (a) Explain the difference with a suitable example between “mutually exclusive” and “statistically independent” events. (6)

(b) A certain federal agency employs three consulting firms (A, B, and C) and assigns 40 percent, 35 percent, and 25 percent consultancies to them respectively. From past experience it is known that the probabilities of cost overruns for the firms are 0.05, 0.03, and 0.15 respectively. Suppose a cost overrun is experienced by the agency, what is the probability that the consulting firm involved is company C? (9)

OR

Q1'.(a) A town has two fire engines operating independently. The probability that a specific engine is available when needed is 0.96. What is the probability that at least one fire engine is available when needed? Also find the probability that neither is available when needed? (6)

(b) Of 10 computer chips, 4 are defective. Show all possible outcomes on a tree diagram to determine the probability of having only one defective out of 3 chips randomly selected without replacement. What is the said probability? (9)

Q2. (a) The mean and standard deviation of a normally distributed population are 78.3 kgs and 5.6 kgs, respectively, and m samples of size 64 are collected from the population. Determine how the variance of the sampling distribution of mean will change if the sample size is increased from 64 to 196? (6)

(b) The lifetime of the picture tubes of colour TV is normally distributed with a mean of 8 years and standard deviation of 2 years. If the company guarantees the picture tube for 4 years, what percentage of the TVs sold will have to be replaced? If the company is willing to replace the picture tubes up to only 1% of the TVs sold, what guarantee period should the company offer? Draw the required normal curves. (9)

Q3. (a) Test the hypothesis that the average content of the containers of a particular lubricant is 10 liters if the contents of a random sample of 10 containers measure 10.2, 9.7, 10.1, 10.3, 10.1, 9.8, 9.9, 10.4, 10.3, and 9.8 liters. Use a 0.01 level of significance and assume that the distribution of contents is normal. (6)

(b) Researchers want to test a new anti-anxiety medication. They split the participants into three conditions (0 mg, 50 mg and 100 mg) and ask them to rate their anxiety level on a
scale of 1-5. Refer to the following and determine are there any differences between the three conditions? Use $\alpha = 0.05$? (9)

<table>
<thead>
<tr>
<th>0 mg</th>
<th>50 mg</th>
<th>100 mg</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>

OR

(b') A bank manager claims that the median number of customers per day is no more than 750. A teller doubts the accuracy of the claim. The numbers of bank customers per day for 16 randomly selected days are noted as below. Can the teller reject the bank manager claim at $\alpha = 0.05$? (9)

<table>
<thead>
<tr>
<th>775</th>
<th>765</th>
<th>801</th>
<th>742</th>
<th>754</th>
<th>753</th>
<th>739</th>
<th>751</th>
</tr>
</thead>
<tbody>
<tr>
<td>745</td>
<td>750</td>
<td>775</td>
<td>769</td>
<td>756</td>
<td>760</td>
<td>782</td>
<td>789</td>
</tr>
</tbody>
</table>

Q4. The following are measurements of the air velocity and evaporation coefficient of burning fuel droplets in an impulse engine.

<table>
<thead>
<tr>
<th>Air Velocity (cm/s)</th>
<th>Evaporation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.18</td>
</tr>
<tr>
<td>60</td>
<td>0.37</td>
</tr>
<tr>
<td>100</td>
<td>0.35</td>
</tr>
<tr>
<td>140</td>
<td>0.78</td>
</tr>
<tr>
<td>180</td>
<td>0.56</td>
</tr>
<tr>
<td>220</td>
<td>0.56</td>
</tr>
<tr>
<td>260</td>
<td>0.75</td>
</tr>
<tr>
<td>300</td>
<td>1.18</td>
</tr>
<tr>
<td>340</td>
<td>1.36</td>
</tr>
<tr>
<td>380</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Fit a second order polynomial to these data by the method of least square and use it to estimate the evaporation coefficient of a droplet when the air velocity is 190 cm/s. (15)
Assume suitable data if missing.  
Notations used have their usual meaning.

Q.No.  

1. Find the transfer function of a second order element and also find the response of the 1st order element to a sine function. (12)  

2. (a) Explain the correlation coefficient ‘r’ and find its expression. (04)  
2. (b) Explain the working principle of a piezoelectric sensing element. (03)  
2. (c) Briefly explain the working of a piezoelectric tri-axial accelerometer. (05)  

OR  

2.(b') Explain the working principle of an inductive sensing element. (03)  
2.(c') Briefly explain the working of a Linear Variable Differential Transformer. (05)  

3. (a) Explain the following:  
   (a) Model reduction  (b) Unmodelled dynamics (4)  
3. (b) Obtain the closed loop response of a second order system  
\[ \dot{x} = \begin{bmatrix} 0 & 1 \\ -4 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0.1 \end{bmatrix} u; \quad y = \begin{bmatrix} 0 & 1 \end{bmatrix} x, \]  
where \( x \) is the state vector and \( u \) is the control input through feedback. Design a suitable feedback control system for the above dynamical system to obtain 0.3% active damping. (08)  

4. Discuss the necessity of an state estimator / state observer in the design of optimal control system. For the system,  
\[ \dot{x} = Ax + Bu; \quad y = Cx, \]  
Assuming the control law is governed by \( u = G\hat{x}, \) where \( \hat{x} \) is the estimated state vector, derive the expression for the closed loop response of the system. (12)  

OR  

4'. Consider the optimal control problem with the following cost function (12)
\[ j = \int_{0}^{t} \left( y^2 + ru^2 \right) dt \quad \text{subject to} \quad x = \begin{bmatrix} 0 & 1 \\ 0 & -10 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \]

\[ y = \begin{bmatrix} 1 & 0 \end{bmatrix} x; \quad x(0) = x_0 \]

Where \( r \) is the positive definite parameter and \( u \) is the control input. The linear dynamics are both controllable and observable. Determine optimal feedback control and optimal cost. Note:

\[ y^2 = y^T y = x^T Q x, \quad \text{where} \quad Q = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \]

5. Explain feedback linearization of Single-Input-Single-Output (SISO) and Multi-Input-Multi-Output (MIMO) systems.

OR

5' (a). Consider the system

\[ \dot{x}_1 = \sin x_2 + (x_2 + 1)x_3 \]
\[ \dot{x}_2 = x_1^5 + x_3 \]
\[ \dot{x}_3 = x_1^2 + u \]

\[ y = x_1 \]

Design a tracking controller for the above system.

5'(b). A Simulink model is given ahead. Represent the system in the form of equation. What will be the frequency and damping ratio for the system.
2016-17
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (MACHINE DESIGN)
ADVANCED MECHANICS OF SOLIDS
ME 631

Maximum Marks: 60 Credits: 04 Duration: Two Hours

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

Q.No. Question M.M.
1(a) Determine the principal stresses and their axes for the state of stress characterized by the following stress matrix. [07]

\[
\sigma_{ij} = \begin{bmatrix}
18 & 0 & 24 \\
0 & -50 & 0 \\
24 & 0 & 32 \\
\end{bmatrix}
\text{in MPa}
\]

1(b) For the following strain components at a point in a steel machine element, determine the stress components.

\[
\varepsilon_x = 600 \times 10^{-6}, \quad \varepsilon_y = 900 \times 10^{-6}, \quad \varepsilon_z = 600 \times 10^{-6}, \\
\gamma_{xy} = 1200X10^{-6}, \quad \gamma_{yz} = 1750X10^{-6}, \quad \gamma_{xz} = 900X10^{-6}
\]
Also find out the invariants of strain tensor.
The values of E and ν for the steel are 200 GPa and 0.3, respectively.

OR
1(b') What are the Octahedral stresses? Derive the mathematical expression of Octahedral normal stress and Octahedral shear stress in a three dimensional state of stress. [08]

2(a) A thin walled tube of variable thickness is subjected to a twisting moment 'T'. Derive the Bredt-Batho equation of torsion and angle of twist per unit length for the said tube. [08]

OR
2(a') A thin solid bar of rectangular section is subjected to a twisting moment 'T'. Derive the equation of torsion and angle of twist per unit length for the thin solid bar. [08]
2(b) A thin tubular bar shown below is subjected to a torque \( T = 113 \text{ kNm} \). The dimensions are as indicated. Determine the shear stresses in the walls.

Given: \( a = 12.7 \text{ cm}, t_1 = 0.06 \text{ cm}, t_2 = 0.08 \text{ cm}, t_3 = 0.06 \text{ cm}, t_4 = 0.10 \text{ cm}, t_5 = 0.13 \text{ cm} \).

3(a) Derive the expression of radius of curvature of Neutral axis \( (r_o) \) for a curved beam with rectangular cross-section. Also, find the maximum tensile stress across the section AA of the member loaded as shown in figure.

3(b) A ring with a rectangular section is subjected to diametral compression, as shown in figure below. Determine the bending moment and stress at point A of the inner radius across a section \( \theta \), \( r_1 \) and \( r_2 \) are the inner and external radii respectively.
Answer any five questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. | Question                                                                                                                                                                                                                                                                                                                                 | M.M.
-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------
1(a) | What is Von-Mises theory of failure? Derive its expression for a general state of stress. Also, show that under combined state of stress system, maximum shear stress theory predicts 15% less yield stress than the maximum distortion energy theory.                                                                                           | [6]  
1(b) | A lever is subjected to a downward force, \( F = 1.8 \text{ KN} \) as shown in Fig (1). The solid round bar has a uniform diameter of 25 mm. The lengths are given as \( L = 225 \text{ mm} \) and \( a = 175 \text{ mm} \). The round bar is made of steel with yield strength, \( S_y = 1020 \text{ MPa} \) based on static loading. Find (i) Critical stresses in the bar. (ii) Factor of safety using distortion energy theory. (iii) As a check on (ii), find the factor of safety from max. shear stress theory. | [6]  
2(a) | Why theories of failure are applied? What are Von-Mises and Tresca’s theories of failure, applied to fatigue loading?                                                                                                                                                                                                                       | [6]  
2(b) | A 5 cm diameter shaft is made from carbon steel having ultimate tensile strength of 630 N/mm\(^2\) and yield strength of 510 N/mm\(^2\) is subjected to a torque which fluctuates between 2000 N-m and -800 N-m. Using Sodenberg criterion, calculate the factor of safety.                                                                                     | [6]  
3(a) | Illustrate with neat figure, how fatigue strength of a specimen is determined using Roger Moore’s machine.                                                                                                                                                                                                                                    | [5]  
3(b) | A spindle of 10 mm 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/m\(^2\)                                                                                                                                                     | [7]  

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Cont'd on next page.
and 65000 N/m². There is an added predicted alternating stresses of ± 65000 N/m² for a total of 1000 cycles and of ± 25000 N/m² for a total of 5000 cycles. Minimum strength values are $S_u = 140000$ N/m², $S_y = 110000$ N/m² and $S_e = 70000$ N/m².

Determine the damage and life factors and factor of safety based on a conservative estimate of finite life. The values of surface, size and reliability factors are given as 1, 0.9 and 1 respectively.

4(a) What are thermal stresses? How temperature affects the mechanical properties of different engineering material. Support your answer with neat illustrated diagrams. Also, discuss, how materials should be selected for the design purpose?

4(b) Idealized charts of creep test at several stresses for a material at 950° F are given in Fig (2) and Fig (3). And, log-log Strain rate vs Stress curve for the same material at the same temperature is shown in Fig (4). Determine the limiting stress for a part to be subjected to 950° F and at constant load, if the creep is limited to 1% in 100000 hours.

The values of constants, $\beta$ and $m$, can be found out from Fig (2) and Fig (3) or it can also be found out by interpolation, using the Fig (4).

5(a) What do you understand by stress relaxation? Deduce the expression for the stress relaxation.

5(b) Describe, in brief, thermal fatigue and thermal shocks. How it can be minimized?

5(c) A chemical reaction chamber working at a temperature of 500 °C uses steel bolts to tighten the two halves of the chamber. The test on bolt materials at this temperature resulted into strain rates of $3 \times 10^{-18}$/ hr and $2 \times 10^{-18}$/ hr at 30 MPa and 25 MPa stress levels respectively. If the bolts are tightened to a stress of 61 MPa initially, calculate in what time the stress will be reduced to half this value. Assume that the two halves of the chamber are made of same material and the flanges are very rigid. Take $E$ (at 500 °C) = $17 \times 10^4$ MPa.

6(a) What are three modes of crack displacement? Which crack displacement mode is encountered in majority of engineering situations?

6(b) A wide mild steel plate is subjected to uniform tensile load causing a stress of 10 MPa. The fracture toughness of mild steel is given as 13 k N / mm². Calculate the critical crack length in the centre of the plate which when reached, the plate
would fracture.

7(a) Explain, how plastic deformation around close vicinity of a crack tip influences crack growth rate in fatigue and increases the life of the component. Give suitable equations of modified stress intensity factor and crack growth rate.

7(b) A square cross-section beam specimen carries a fatigue crack in one of its faces. It is supported over a span of eight times its depth. The load is slowly applied in the middle of the span opposite to the crack until the crack becomes unstable, when the load is recorded as 6 KN and the crack length is measured as 12.5 mm. If each side of the cross-section of the beam is 25 mm, calculate the fracture toughness of the material of the beam. If the yield strength of this material is 900 MPa, calculate the size of the plastic deformation and modified fracture toughness.

The following equation of the calibration factor, $\gamma$, may be used

$$\gamma = 1.96 - 2.75 \left( \frac{a}{W} \right) + 13.66 \left( \frac{a}{W} \right)^2 - 23.29 \left( \frac{a}{W} \right)^3 + 25.22 \left( \frac{a}{W} \right)^4$$
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)  
One of the tail rotor blades of a helicopter has an unbalanced mass of \( m = 0.5 \text{ kg} \) at a distance of \( e = 0.15 \text{ m} \) from the axis of rotation, as shown in Figure 1. The tail section has a length of 4 m, a mass of 240 kg, a flexural stiffness \((EI)\) of 2.5 MN-m², and a damping ratio of 0.15. The mass of the tail rotor blades, including their drive system, is 20 kg. Determine the forced response of the tail section when the blades rotate at 1500 rpm.

OR

(a') Figure 2 shows a metal block supported on two identical cylindrical rollers rotating in opposite directions at the same angular speed. When the centre of gravity of the block is initially displaced by a distance \( "x" \), the block will be set into simple harmonic motion. If the frequency of motion of the block is found to be \( \omega \), determine the coefficient of friction between the block and the rollers.

1 (b) Derive the governing equations of motion of multi DOF systems shown in Figure 3, using Lagrange's Equation.

2 Derive an expression for transverse vibration of a beam subjected to a transverse force \( F(x, t) \) per unit length together with an axial force \( P(x, t) \). Assume the beam to be uniform and neglect rotary inertia.

contd... 2.
3. Explain the following:
   (i) Various sources of nonlinearity in a vibration problem.
   (ii) Jump phenomenon
   (iii) Phase plane, trajectory, singular point and phase velocity

4. Using Ritz method find out the relation between frequency and amplitude for the nonlinear system given by equation \( m\ddot{x} + x - \frac{x^3}{6} = 0 \). Also verify the result using Harmonic Balance method.

OR

4'. Find the equilibrium position and plot the trajectories in the neighborhood of equilibrium position for the following equation of motion.
\[ \ddot{x} + 0.1(x^2 - 1)\dot{x} + x = 0 \]

5. Find the exact solution of nonlinear pendulum equation \( \dot{\theta} + \omega_0^2 (\theta - \theta_0^3/6) = 0 \) with \( \dot{\theta} = 0 \) when \( \theta = \theta_0 \), where \( \theta_0 \) is the maximum angular displacement.

OR

5'. Using two term approximation in Lindstedt's Perturbation method, find the solution of Duffing's oscillator assuming the spring to be that of hardening type.

---

Figure 1
Figure 2

Figure 3

Rigid bar, mass = 2m
Answer all the 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(a)</td>
<td>What is meant by the terms; (i) Machine epsilon (ii) Overflow (iii) Underflow, in the context of floating-point number representation. Obtain expressions for absolute and relative error bounds for addition of two floats.</td>
<td>[06]</td>
</tr>
<tr>
<td>1(b)</td>
<td>Determine the binary representation of 34.015625. Also express the real number in normal form. If 32-bit storage (s = 23, e = 8) is employed, determine whether the number can be stored in computer without any error or not.</td>
<td>[06]</td>
</tr>
<tr>
<td>2(a)</td>
<td>Consider the following assignment statements in sequence in MATLAB:</td>
<td>[06]</td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; A= [1 7 -3; 2 1 5; 3 8 -4];</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; B=[-1; 3; -6];</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; C=[A B];</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; A(3,:)=[ ];</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; A(:,3)=[ ];</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; x=A;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;&gt; y=B(2:3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obtain the output of the following MATLAB commands:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(i) size(C) (ii) det(A) (iii) x(:,2).* y (iv) y* x(1,:);</td>
<td></td>
</tr>
<tr>
<td>2(b)</td>
<td>Write MATLAB commands for the following tasks:</td>
<td>[06]</td>
</tr>
<tr>
<td></td>
<td>(i) Obtain the eigenvalues and eigenvectors of the square matrix</td>
<td></td>
</tr>
</tbody>
</table>
(ii) Plot the functions \( f(x) = 1 - x^2 \), \( g(x) = \sin(\pi x) \) using 9 equally spaced points over the interval \([0, 2]\) on the same axes.

3 (i) 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:

\[
x_k = \frac{a + b}{2} + \frac{b - a}{2} \cos\left(\frac{(2k - 1)\pi}{2n}\right), \quad k = 1, 2, \ldots, n
\]

(ii) Obtain the maximum value of \( f(x) \) from the interpolating polynomial and compare with the exact value.

3' In an experiment related to heat transfer, temperatures were recorded on the surface of a square 1 m \( \times \) 1 m metal plate placing thermocouples at uniformly placed 16x16 points. After sometime, some damaged thermocouples were replaced. Due to demonetisation only half of thermocouples were bought. Now, 9x9 sample points are to be used. Construct an algorithm to interpolate values at new sample points.

4(a) Calculate Condition number of the Van De Mande Matrix given below

\[
A = \begin{bmatrix}
1 & 2 & 4 \\
1 & 3 & 9 \\
1 & 5 & 25
\end{bmatrix}
\]

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

4(a)' Consider a function \( f(x) \) sampled discretely over uniformly spaced points with a spacing 'h'. Obtain a second order forward difference formula for the second
4(b) Use the method of undetermined coefficients to develop a 4-point Newton-Cotes integration formula given as,

\[ \int_{-1}^{1} f(x) dx = \sum_{i=1}^{4} W_i f(x_i) \]

Apply the formula to estimate the integral \( \int_{0}^{\pi} \frac{\cos x}{x} \, dx \).

5 Answer any one of the following.

(a) Construct a equivalent finite difference equation for conduction equation governing the variation of temperature in a slab of unit thickness and apply Von-Neuman Stability analysis for fully explicit, fully implicit and Crank Nicholson time integration. Space differencing to be central.

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

(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 of \( \alpha, \beta \) and \( h_i \).

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

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Best of luck
2016-17
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (THERMAL SCIENCES)
ADVANCED THERMODYNAMICS
ME 641

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

Q.No. Question
1(a) For the Van der Waal’s gas equation of state, show that
\[ ds = C_v \frac{dT}{T} - \frac{R}{(v-b)} dv \]  [6]

1(b) A rigid tank contains 2 kmol of N₂ and 6 kmol of CO₂ gases at 300 K and 15 MPa. Estimate the volume of the tank on the basis of Kay’s rule.  [6]

2(a) Derive the van’t Hoff equation to show the temperature dependency of equilibrium reaction constant (K_p).  [5]

2(b) Estimate the enthalpy of reaction (h_rx) of CO₂ to form CO and O₂ at 2200 °C using K_p data. (CO₂ ⇌ CO + 1/2O₂)  [7]

3(a) Derive an expression for exergy balance on a unit mass basis for a single stream steady flow process. Consider heat input, work output and neglect KE and PE terms.  [04]

3(b) A piston–cylinder device initially contains 2 L of air at 100 kPa and 25 °C. Air is now compressed to a final state of 600 kPa and 150 °C. The useful work input is 1.2 kJ. Assuming the surroundings are at 100 kPa and 25 °C, determine (a) the exergy of the air at these conditions, (b) the minimum work that must be supplied to accomplish this compression process, and (c) the second-law efficiency of this process. (Take R = 0.287 kJ/kg.K, c_p = 1.009 kJ/kg.K and c_v = 0.722 kJ/kg.K at average temperature).  [08]

OR

3'(a) Steam is throttled from 9 MPa and 500 °C to a pressure of 7 MPa. Determine the decrease in exergy of the steam during this process. Assume the surroundings to be at 25 °C.  [04]
Steam enters an adiabatic turbine at 6 MPa, 600 °C, and 80 m/s and leaves at 50 kPa, 100 °C, and 140 m/s. If the power output of the turbine is 5 MW, determine (a) the reversible power output and (b) the second-law efficiency of the turbine. Assume the surroundings to be at 25 °C.

4 Derive Maxwell’s relations for an elastic system.

OR

4' For a magnetic system with magnetic field \( \mathcal{H} \), flux density \( \mathbf{B} \), magnetisation per unit volume \( \mathcal{M} \) and permeability of free space \( \mu_0 \) show that:

\[
Tds = C_H dT + \mu_0 V \left( \frac{\partial \mathcal{M}}{\partial T} \right) \mathcal{H} d\mathcal{H}
\]

5(a) Write a note on microscopic interpretation of heat and work.

5(b) Write a note on the salient features of Fermi-Dirac statistics and derive the following relation:

\[
N_n = \frac{\alpha g_1 e^{-\beta e_1}}{1 + \alpha e^{-\beta e_1}}
\]

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 \( e_1 \) having degeneracy \( g_1 = 3 \) and one particle is at energy level \( e_2 \) having degeneracy \( g_2 = 1 \). Also, show their arrangement for the three cases.

Table 1

| Temp., K | \( H_2 \) mol | 2H | \( O_2 \) mol | 2O | \( N_2 \) mol | 2N | \( H_2O \) mol | 2H + \( 1/2O_2 \) | \( H_2O \) mol | 2H + OH | \( CO_2 \) mol | CO + \( 1/2O_2 \) | \( 1/2H_2 \) + \( 1/2O_2 \) mol | NO |
|----------|---------------|----|---------------|----|-------------|----|---------------|----------------|-------------|-----------|-------------|----------------|----------------|-----------------|-----|
| 2800     | -5.002        | -5.826  | -25.117       | -3.612        | -3.763        | -1.894            | -2.372         |
1 A square, 2-D rod is exposed to identical convection conditions on the left and right faces. The bottom surface is insulated, and the top surface receives a nonuniform heat flux given by

\[ q''(x) = q_0 \exp \left(-a^2 (x - L/2)^2 \right) \]

in which \( q_0 \) and \( a \) are constants. Formulate the problem for the temperature distribution in appropriate dimensionless form, and derive a solution using the separation of variables method.

OR

1' Consider a square region of width = height = \( L \). The surface at \( y = 0 \) is maintained at \( T_1 \), and convection occurs at the \( y = L \) surface, characterized by \( h \) and \( T_{\infty} \). The surface at \( x = 0 \) is adiabatic, and a uniform heat flux of \( q_0 \) is applied at \( x = L \). A uniform heat generation, of strength \( q \) occurs within the region. Formulate the problem for the temperature distribution in appropriate dimensionless form, and
derive a solution using the separation of variables method.

2(a) Derive equation for the temperature at node T_{mn} for transient heat conduction using finite difference method. Show how to select time and distance increments for 2D and 3D.

2(b) Calculate the efficiency of a plate fin of length L=1.524 \times 10^{-2} m and thickness t=0.254 \times 10^{-2} m. The fin material being Aluminium (k=207.64 W/m.°C) has the heat transfer coefficient, h=283.9 W/m².°C.

3(a) Draw the radiation network and analyse the radiation system consisting of an absorbing and transmitting media.

3(b) Two large parallel plates are maintained at 400 and 600 °C, respectively, and have surface emissivities of 0.6. A radiation shield having ε=0.1 is placed equidistant between the two heated plates. Calculate the radiant heat transfer through the plate shield arrangement per m² of surface area.

4 Two parallel planes 90 by 60 cm are separated by a distance of 60 cm. One plane is maintained at a temperature of 800 K and has an emissivity of 0.6. The other plane is insulated. The planes are placed in a large room that is maintained at 290 K. Calculate the temperature of the insulated plane and the energy lost by the heated plane.

OR

4' An annular space is filled with a gas whose emissivity and transmissivity are 0.3 and 0.7, respectively. The inside and outside diameters of the annular space are 30 and 60 cm, and the emissivities of the surface are 0.5 and 0.3, respectively. The inside surface is maintained at 760°C, while the outside surface is maintained at 370 °C. Calculate the net heat transfer per unit length from the hot surface to the cooler surface. What is the temperature of the gas? Neglect convection heat transfer.
3(b') Determine the shear stress distribution in a channel section of a cantilever beam subjected to a load F, as shown in figure below. Also, locate the shear centre of the section.

4(a) Fill in the following blanks:

(i) For a central concentrated load, the maximum deflection in the freely supported edge condition is \( \) times that for clamped edges.

(ii) For uniformly loaded circular plate, the maximum deflection with freely supported edges is \( \) times that for the clamped-edge condition.

(iii) With \( \), the maximum deflection for a central concentrated load is four times that for the equivalent uniformly distributed load and the maximum stresses are \( \).

(iv) With \( \), the maximum deflection for a central concentrated load is 2.5 times that for the equivalent uniformly distributed load.

4(b) A circular flat plate of diameter 120 mm and thickness 10 mm is constructed from steel with \( E = 208 \) GN/m² and \( v = 0.3 \). The plate is subjected to a uniform pressure of 5MN/m² on one side only. If the plate is clamped at the edges determine:

(i) the maximum deflection;

(ii) the position and magnitude of the maximum radial stress.

What percentage change in the results will be obtained if the edge conditions are changed such that the plate can be assumed to be freely supported?
2016-17
M.TECH. (AUTUMN SEMESTER) EXAMINATION
THERMAL SCIENCES
COMBUSTION ENGINEERING
ME 644

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.  Answer any three questions from Section ‘A’ and two questions from Section ‘B’. M.M.

SECTION ‘A’

1. A mixture of CH₄(g) and O₂ held in a rigid vessel at 100 bar and 308 K is ignited and burns completely. Write down the procedure in detail with appropriate relations for determining (i) the final pressure, (ii) heat transfer to the surroundings and (iii) mass of the reactants. Assume gaseous water in the products of combustion. (No derivation is required).

2. Ethene C₂H₄(g) (with a lower heating value) and 400% theoretical air enter an adiabatic, steady flow combustion chamber at $P=200$ kPa and $25^\circ$C. The combustion products leave at $P=200$ kPa and 1000 K. The surroundings are at $T_0=298$ K, $P_0=100$ kPa. Calculate (i) the entropy of the products $S_{prod}$, (ii) If $S_{max} = 11235.605$ kJ/K, determine the irreversibility '$I$' of the process. Where entropy of a species '$i$' is: $S_i = n_i[x_i^0 - R_i \ln(x_i P/P_0)]$, ($x_i^0$ is the absolute entropy, $x_i$ is the species mole fraction, other symbols have their usual meaning), (iii) briefly discuss the procedure for finding out the $W_{rev}$.

3. Find the amount of NO produced in primary zone of gas turbine using the Zeldovich mechanism: $d[NO]/dt = 2k_f[O][N_2]$, $k_f = 1.8 \times 10^{11} \exp(-33870/T)$. Assume ideal gas behaviour; O, O₂ and N₂ at equilibrium values and no reverse reactions. Following...

contd ... 2...
information is provided.

\( \phi, t, T, P, x_{O}, x_{O_{2}}, x_{N_{2}}, x_{NO}, Fuel: \)

1,7ms, 2300 K, 14 atm, 7.93x10^{-3}, 3.62x10^{-3}, 0.7295, 2.09x10^{-3}, decane (C_{10}H_{22})

4 Differentiate between explosion, deflagration and detonation with examples. Explain the Rankine-Hugoniot curve (\( P \) versus \( 1/\rho \)) with respect to the regions of possible solutions. Verify that Mach number \( M>1 \) in the strong detonation region, \( M<1 \) in the strong deflagration region and no solution for the imaginary region.

**SECTION 'B'**

5(a) What is \( d^2 \)-law of droplet combustion. Draw \( d^2 \) versus time plot for (i) steady state droplet combustion, (ii) steady state combustion with convection, (iii) droplet heating and (iv) droplet heating with thermal expansion.

(b) Draw and explain the variation of temperature and species concentration profiles for a spherically symmetric droplet combustion model with and without droplet heating.

6 A 100 \( \mu \)m diameter, spherically symmetric, liquid ethanol (C\(_2\)H\(_5\)OH) droplet burns steadily in stagnant air at 0.1 MPa and 300 K. Assuming adiabatic flame temperature as 2000 K. Calculate (i) burning constant and (ii) mass burning rate. Take: \( T_{f} = 351 \) K, \( K_{g} = 0.01368 \) W/mK, \( C_{p_g} = 1.427 \) kJ/kgK, Heat of combustion = 26811 kJ/kg, \( \rho_{f} = 783 \) kg/m\(^3\), \( h_{fg} = 841.56 \) kJ/kg, \( v = 10.45 \), (iii) mention the methods for obtaining boiling point, latent heat of vaporization, specific heat and diffusion coefficient at high pressures.

7(a) In a natural gas (methane) fired, stationary gas turbine engine, NO is measured as 20 ppm (by volume) in the exhaust with an oxygen concentration of 13% (by volume). No after treatment (SNCR or SCR) is used. Estimate: (i) the NO concentration corrected to 3% oxygen, (ii) NOx emission index in grams of NOx per kg of fuel burned.

(b) Write down the reaction steps in which CO is converted to CO\(_2\), assuming hydrogen containing species (H\(_2\)O and H\(_2\)) are present. Identify the primary reaction in the reaction scheme.
2016-17
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (THERMAL SCIENCES)
REFRIGERATION AND CRYOGENICS
(ME 662)

Maximum Marks: 60  Credits: 04  Duration: Two Hours

Assume suitable data if missing.
Notations used have their usual meaning.
Answer any two questions from Section A and two from Section B.

Q.No.  Section A  M.M.

1(a)  An aircraft is flying at a speed of 1000 km/h at a height where the surrounding air pressure and temperature are 0.35 bar and -15°C. Calculate the limiting temperature to which air can be cooled after compression.

1(b)  A reduced ambient cycle is used in the above aircraft refrigeration system. The pressure ratio of the jet compressor is 3. Effectiveness of the air cooler is 0.75. Determine DART and COP of the cycle.

2  A two-stage R 22 plant with flash inter-cooler for food freezing has two 45 mm bore and 40 mm stroke compressors as follows:
LP Compressor:
- No. of cylinders = 6
- RPM = 1000
- Volumetric efficiency = 75%
HP Compressor:
- No. of cylinders = 4
- RPM = 800
- Volumetric efficiency = 69%
Find the refrigerating capacity of the plant when operating at a condenser temperature of 40°C and an evaporator temperature of -40°C. Also find the inter-stage pressure.

3(a)  What do you mean by Refrigerant recovery, Recycling and Reclamation? Explain.

3(b)  Discuss the refrigerants in use after the year 2000 highlighting their environmental impact and other properties.

Contd...
Section B

4(a) Derive expressions of Liquid yield, Work requirement and Figure of Merit (FOM) for Dual–Pressure Linde–Hampson System. Draw the schematic diagram of the system and its Temperature - Entropy plot. [8]

4(b) Find the fraction of liquefaction, the work of liquefaction and the FOM in a Dual–Pressure Linde–Hampson System operating with nitrogen. The inlet stream is at 1 atm, 300 K. The pressure delivered by the first compressor is 50 atm. The pressure delivered by the second compressor is 200 atm. Liquid nitrogen is removed at 1 atm. The intermediate-pressure-stream flow rate ratio, i = 0.8. Assume a 5 K temperature difference of approach for the heat exchanger. Take $h_f = 35$ J/g, $s_f = 0.5$ J/g-K. [7]

5(a) Derive expressions of Liquid yield, Work requirement and FOM for Kapitza System. Draw the schematic diagram of the system and its Temperature - Entropy plot. [8]

5(b) Find the fraction of liquefaction, the work of liquefaction and the FOM in a Kapitza System operating with nitrogen. The pressure delivered by the compressor is 20 atm and the fraction of total flow that passes through the expander (x) is 0.4. Feed is available at 1 atm and 300 K. Liquid nitrogen is removed at 1 atm. The expander is 75% efficient. Assume temperature at inlet to expander = 275 K. Take $h_{ea} = 270$ J/g, $s_{ea} = 3.42$ J/g-K, $h_f = 35$ J/g, $s_f = 0.5$ J/g-K. [7]

6(a) Derive expressions of Liquid yield, Work requirement and FOM for Collin’s System. Draw the schematic diagram of the system and its Temperature - Entropy plot. [8]

6(b) Find the fraction of liquefaction, the work of liquefaction and the FOM for the liquefaction of helium using the Collin’s method. Helium is available at 300 K and 1 atm. The compressor provides a pressure of 14 atm. Helium is removed at 1 atm. Assume isentropic efficiency of the expanders to be 0.75. Let ratios of the gas sent through the expanders to be $x_1 = 0.5$ and $x_2 = 0.25$. The first expander operates between point 3 (14 atm, 60 K) and point $e_1$ (1 atm). The second expander operates between point 5 (14 atm, 15 K) and point $e_2$ (1 atm). Take $h_{e1} = 123.75$ J/g, $s_{e1} = 17.5$ J/g-K, $h_{e2} = 38.5$ J/g, $s_{e2} = 9.25$ J/g-K, $h_f = 9.5$ J/g, $s_f = 3.45$ J/g-K. [7]
M.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (THERMAL)
THERMAL POWER PLANT ENGINEERING
ME667

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer any two questions from section A and two questions from section B.
Assume suitable data if missing. Use of tables and charts is allowed.
Notations used have their usual meaning.

Q. No.  Question                                                                                       M.M.

Section A

1  Design and analyse a Boiling water reactor (BWR). Find expression for heat generated in BWR.     [15]

2  In a cogeneration binary cycle, superheated steam enters the turbine with a mass flow rate of 5 kg/s at 40 bar, 440°C and expands isentropically to 1.5 bar. Half of the flow is extracted at 1.5 bar and used for industrial process heating. The remaining steam passes through a heat exchanger which serves as the boiler of the R-12 cycle and the condenser for the steam cycle. The condensate leaves the heat exchanger as saturated liquid at 1 bar, where it is combined with the return flow from the industrial process at 60°C and 1 bar, before being pumped isentropically to the steam generator. Refrigerant R-12 cycle is an ideal Rankine cycle with refrigerant entering the turbine at 16 bar, 100°C and saturated liquid leaves the condenser at 9 bar. Determine (a) the rate of heat transfer in the steam generator, (b) the net power output of the binary cycle, (c) the rate of heat transfer to the industrial process.   [15]

3(a) Discuss the need for energy storage. Explain working of Pumped Hydro.                              [08]

3(b) Discuss the working of FBC (Fluidized bed combustion) based power plant. Draw different arrangements using FBC in combined mode type of power plant. [07]
Section B

4. A surface type steam condenser is designed to condense 300 tonnes of steam per hour at 0.04 bar pressure and 0.9 dry. The cooling water inlet and outlet temperatures are 15°C and 25°C respectively. The overall heat transfer coefficient in the condenser is 3 kJ/m²K. The condenser has two water passes and tubes used are of inner diameter as 17.6 mm and outer diameter as 20 mm. Determine the number of tubes used in one pass and length of each tube if the water speed in the condenser tube is limited to 2.5 m/s.

5. Discuss the working of Steam injected gas turbine cycle (STIG) based power plant. How can its thermal efficiency be improved.

6. A diesel engine is fitted with a turbocharger which comprises a radial compressor driven by a radial exhaust gas turbine. The air is drawn into the compressor at a pressure of 0.97 bar and a temperature of 30°C and is delivered to the engine at a pressure of 2.1 bar. The engine operates on an air-fuel ratio of 18 and the exhaust leaves the engine at 580°C and 1.9 bar. The turbine exhausts at 1.06 bar. The isentropic efficiencies of the compressor and turbine are 0.75 and 0.85 respectively. Determine (a) the temperature of air leaving the compressor, (b) the temperature of gases leaving the turbine and (c) the mechanical power loss in the turbocharger as a percentage of the power generated in the turbine.
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.1 Show that

(i) for the unsteady heat conduction equation

\[ \frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2} \]

the viscous stability limit \( \frac{\alpha \Delta t}{(\Delta x)^2} < \frac{1}{2} \) holds true. \( \text{(8)} \)

(ii) the usage of first-order upwinding in Burger's equation

\[ \frac{\partial \omega}{\partial t} + u \frac{\partial \omega}{\partial x} = \nu \frac{\partial^2 \omega}{\partial x^2} \]

leads to generation of artificial viscosity given by \( \nu_e = 1/2(u \Delta x(1 - c)) \) where \( c = \frac{u \Delta t}{\Delta x} \) for \( u > 0 \). \( \text{(7)} \)

Q.2. The governing equations for unsteady heat diffusion 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 for the two-step ADI scheme \( \text{(7)} \)

(ii) Mention the steps for sequential evaluation of the algorithm and write down a pseudo-code implementing the ADI scheme. \( \text{(8)} \)

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

\[
\frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} = 0
\]

\[
\frac{\partial \rho u}{\partial t} + \frac{\partial \rho u^2}{\partial x} + \frac{\partial \rho uv}{\partial y} = -\frac{\partial p}{\partial x}
\]

\[
\frac{\partial \rho v}{\partial t} + \frac{\partial \rho vu}{\partial x} + \frac{\partial \rho v^2}{\partial y} = -\frac{\partial p}{\partial y}
\]

\[
\frac{\partial \rho E}{\partial t} + \frac{\partial \rho u E}{\partial x} + \frac{\partial \rho v E}{\partial y} = \gamma (\gamma - 1) M^2 \left( \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} \right)
\]

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

(i) Discretize the above equations using McCormack's predictor-corrector scheme stating also the boundary conditions.

(ii) Draw a flowchart for evaluation of the algorithm using 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

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

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 the coefficients \( a_W, a_E, A_P, S_u \) and \( S_p \) for all the five nodes, if the scheme uses first-order upwinding for convective terms.

(ii) Calculate coefficients \( a_W, a_E, A_P, S_u \) and \( S_p \) for all the five nodes, if the scheme uses second-order QUICK upwinding for convective terms and central differencing for diffusion terms.

contd...
Q.4 We wish to solve 2D laminar, incompressible viscous flow in a channel. The governing equations are

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

Assume periodic flow in streamwise direction and no-slip, impenetrable walls in y-direction. 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.

(ii) Derive the Pressure Poisson equation (PFE) with appropriate boundary conditions and write a pseudo-code for solving the same using SOR technique

OR

Q.4’ We wish to solve 2D laminar, incompressible viscous flow in a lid-driven cavity. The governing equations are

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

The boundary conditions are \( u = v = 0 \) at \( x = 0, L \) and \( u = v = 0 \) at \( y = 0 \); \( u = U, v = 0 \) at \( y = H \). Perform the following tasks:

(i) Write down the steps, involving pressure-correction Poisson equations with boundary conditions, if SMAC pressure-correction scheme is used to solve the above equations. Assume implicit discretization for viscous and explicit discretization for convective terms.

(ii) Write down the steps involved in the sequential algorithm
**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>Derive the equations of motion for a Jeffcott rotor model with offset disc.</td>
<td>[12]</td>
</tr>
<tr>
<td>1'</td>
<td>A disc of mass 13.6 kg and the polar mass moment of inertia 0.02 kgm², 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 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. The diameter of the steel shaft is 2.54 cm with $E= 200$ GNm².</td>
<td>[12]</td>
</tr>
<tr>
<td>2 (a)</td>
<td>What effect does gyroscopic couple cause on the critical speed of overhung rotor in synchronous whirl motion? Also, plot the effect of disc inertia on critical speed of a simple overhung rotor in synchronous whirl motion.</td>
<td>[05]</td>
</tr>
<tr>
<td>2 (b)</td>
<td>Briefly derive the frequency equation of overhung rotor in nonsynchronous whirl motion (dimensional form).</td>
<td>[07]</td>
</tr>
<tr>
<td>3. (a)</td>
<td>Plot the Campbell diagram for finding the instability threshold speed for oil whip.</td>
<td>[04]</td>
</tr>
<tr>
<td>3. (b)</td>
<td>Explain the cause of instability of rotor mounted on fluid film bearings.</td>
<td>[08]</td>
</tr>
<tr>
<td>4. (a)</td>
<td>Classify the rotors for the purpose of balancing.</td>
<td>[03]</td>
</tr>
<tr>
<td>4. (b)</td>
<td>A short rotor or flywheel has to be balanced. Observations of the vibration at one of the bearings are made in four runs as follows: (i) Run 1; rotor “as is”: amplitude 6.0</td>
<td>[09]</td>
</tr>
</tbody>
</table>

*Contd...*
μm, (ii) Run 2; with 5gm. at 0 deg.: amplitude 5.0 μm, (iii) Run 3; with 5 gm. at 180 deg.: amplitude 10.0 μm, and (iv) Run 4; with 5gm. at 90 deg.: amplitude 10.5 μm.

Find the weight and location of the correction factor. Take the trial and balancing masses at the same radius.

OR

4. (b') Derive the expression for balancing of flexible rotor using modal balancing theory. [09]

5. Derive the equations to calculate the natural frequency and mode shapes for a simply supported shaft using Myklested method. [12]

OR

5.' Derive the equations to calculate the natural frequency and mode shapes for a cantilevered shaft using Myklested method. [12]
### Question Paper

**M.TECH. (AUTUMN SEMESTER) EXAMINATION**  
MECHANICAL ENGINEERING  
Experimental Stress Analysis (ME679/ME634)

<table>
<thead>
<tr>
<th>Maximum Marks: 60</th>
<th>Credits: 04</th>
<th>Duration: Two Hours</th>
</tr>
</thead>
</table>

*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 (a)</td>
<td>Explain in brief the importance of Experimental Methods and their scope.</td>
<td>(06)</td>
</tr>
<tr>
<td>1 (b)</td>
<td>What is meant by Birefringence? How Birefringence can be employed in the determination of stresses in a system. Also describe briefly the procedure for preparing two-dimensional models from pre-machined templates.</td>
<td>(06)</td>
</tr>
<tr>
<td>2 (a)</td>
<td>State and explain Brewster’s stress optic law used in Photoelasticity and state the significance of each term involved.</td>
<td>(06)</td>
</tr>
<tr>
<td>2 (b)</td>
<td>What is a polariscope? Explain the construction and working of a circular polariscope, along with the scope of the equipment.</td>
<td>(06)</td>
</tr>
</tbody>
</table>

**OR**

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (b')</td>
<td>What are Birefringent coatings? Sketch and explain the construction and working of a reflection polariscope.</td>
<td>(06)</td>
</tr>
<tr>
<td>3 (a)</td>
<td>Discuss scattered light techniques in photoelasticity with the help of neat sketches.</td>
<td>(06)</td>
</tr>
<tr>
<td>3 (b)</td>
<td>What are Moiré Fringes? How the Moiré effect can be used in strain measurements?</td>
<td>(06)</td>
</tr>
</tbody>
</table>

**OR**

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
</table>
| 3' (a)| Differentiate between any three of the following:  
a) Plane and Circular polarized light  
b) Polariser and Analyser  
c) Isoclinic and Isochromatic  
d) Relative and absolute phase difference                                                                                           | (06) |
| 3' (b)| What is meant by Holography? How recording and reconstruction of the image of an object is done using a hologram.                                                                                         | (06) |

*Conf... 2*
4. (a) Derive the expressions for coating stresses in brittle coating

**OR**

4. (a') Discuss the crack patterns which can be obtained under various combinations of stresses. Illustrate the answer by giving sketches.

4. (b) Determine the stresses in a brittle coating applied to a component made of aluminium for which $E^* = 70$ GPa, $\nu^* = 0.33$. When the specimen stresses are $\sigma^*_{xx} = 70$ MPa and $\sigma^*_{yy} = 25$ MPa and $\nu^* = 0.36$ and $E^* = 0.7$ GPa.

5. (a) What are the various types of strain gauges? Explain any two in details.

**OR**

5. (a') What do you understand by a strain rosette? What are the different types of strain rosette configurations?

5. (b) A delta rosette yields the following strain readings:

$$\varepsilon_a = -845 \mu \varepsilon, \ \varepsilon_b = 1220 \mu \varepsilon \text{ and } \varepsilon_c = 710 \mu \varepsilon$$

Calculate the max. principal strain direction, the principal stresses and the max. shear stress $E = 200$ GPa, $\nu = 0.285$