1. (a) Solve the following system of equations by Gauss-Seidel method, using three iterations:

\[ \begin{align*}
1.2x + 2.1y + 4.2z - 9.9 &= 0 \\
5.3x + 6.1y + 4.7z - 21.6 &= 0 \\
9.2x + 8.3y + z - 15.2 &= 0.
\end{align*} \]

(b) Derive Newton-Raphson's iteration formula for finding the cube root of a positive number \( N \). Hence find \( \sqrt[3]{12} \). [07]

OR

(b') Find a real root of the equation \( 2x = \cos x + 3 \) correct to three decimal places by using iteration method. [07]

2. (a) Prove the following identities:

(i) \( \delta^2 E = \Delta^2 \)  
(ii) \( \Delta V = \nabla \Delta = \delta^2 \)

where symbols have their usual meanings. [4+4]

OR

(a') Evaluate \( \int_0^1 \frac{dx}{1+x} \) by

(i) Simpson's rule  
(ii) Trapezoidal rule

after dividing the range into eight equal parts. Hence approximate \( \log_e 2 \). Compare the result with the exact value. [08]

(b) Find the interpolating polynomial for the following data:

<table>
<thead>
<tr>
<th>( x )</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f(x) )</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>147</td>
</tr>
</tbody>
</table>

by using Lagrange's formula. [07]

3. (a) Solve the boundary value problem \( \frac{d^2 y}{dx^2} = y + x, y(0) = 0, y(1) = 0, h = \frac{1}{4} \) by finite difference method. [07]
(b) Using modified Euler's method, determine the value of \( y \) at \( x = 0.1 \) correct to four decimal places, given that \( \frac{dy}{dx} = x^2 + y, y(0) = 1 \). Take \( h = 0.05 \).

OR

(b') Given \( \frac{dy}{dx} = 1 + y^2 \), where \( y = 0 \) when \( x = 0 \). Find \( y(0.2) \) and \( y(0.4) \) by using Runge-Kutta fourth order method. Take \( h = 0.2 \).

4. (a) Use graphical method to find the maximum value of \( z = 2x + 3y \) subject to the constraints:
\[
x + y \leq 30,\; y \geq 3,\; 0 \leq y \leq 12,\; x - y \geq 0 \quad \text{and} \quad 0 \leq x \leq 20.
\]

(b) Using Simplex method, minimize \( z = x_1 - 3x_2 + 3x_3 \)
Subject to
\[
3x_1 - x_2 + 2x_3 \leq 7,\; 2x_1 + 4x_2 \geq -12,\; -4x_1 + 3x_2 + 8x_3 \leq 10,\; x_1,\; x_2,\; x_3 \geq 0.
\]
Describe vacancy and self-interstitial crystalline defects with line diagram.

What do you understand by the following indices: (hkl), [hkl], {hkl} and <hkl>?

Determine the Miller indices for the plane shown in the Fig. 1 and Fig. 2.

If lattice constant of copper unit cell (FCC) is 3.61 Å. Compute the density of atoms per unit length along the directions <110> and <111>.

Find theoretical density of Aluminium (FCC) having lattice parameter, \(a = 4.05 \text{ Å}\), Atomic weight of Aluminium is 26.98 g/mol. (Avogadro no. = 6.023 \times 10^{23} \text{ g/mol}).

Compute planar density in simple cube (SC) on <100> plane.

State briefly why it is necessary to study crystal structures of metals?

Draw unit cells for face-centered cubic, body-centered cubic, and hexagonal close-packed crystal structures.

Construct a (011) plane within a cubic unit cell.

1'(b) Explain Bragg's law. Bragg angle corresponding to a reflection for which \((h^2 + k^2 + l^2) = 8\) is found to be 17.03° at first order diffraction. Determine the lattice parameter of the crystal. X-rays of wavelength 0.071 nm are used. Also

\[\text{contd...}\]
determine the Miller Indices of the family of reflecting planes.

2(a) What is phase diagram? Give classification. Differentiate between (i) eutectic and eutectoid (ii) peritectic and peritectoid reaction.

OR

2'(a) Why heat treatment is done on metals and alloys. Explain Carburizing and Cyaniding with a line diagram.

2(b) What is solidus, liquidus and solvus. A binary tin-lead phase diagram is shown in Fig. 3. At point A for a 40 wt% Sn- 60 wt% Pb alloy at 220°C, determine (i) the phase(s) present, (ii) phase compositions and (iii) relative amount of each phase.

![Phase Diagram](image)

Fig 3

Composition, wt% Sn

0 100 200 300
C₀ 0 100 183°C 220°C 300°C
L (liquid) α + β

3(a) Explain briefly (i) diffusion and give its types (ii) activation energy (iii) Fick's law

3(b) What is precipitation hardening? Explain how it is done by giving an example with supporting line diagram.

4(a) Why is it necessary to study the mechanical properties of materials? Define Resilience, Proof Resilience and Toughness with corresponding curve.

4(b) Why do the blades of gas turbine creep? What are the different stages in the creep curve? Write some creep resistant materials.

OR

4'(b) What is true-stress strain curve? Deduce the relations for true stress and strain. Compute true stress and true strain for the corresponding conventional stress of 98.9 MPa and conventional strain of 0.35 mm/mm. Consider constant volume concept.

5(c) Define corrosion. Give types of corrosion. Discuss laws of corrosion with examples.

5(b) Describe the methods used to resist corrosion in (i) Boiler (ii) Steel ornaments (iii) Underground petroleum pipeline (draw line diagram)
Maximum Marks: 60

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)        Define the terms; kinematic joint, kinematic chain, mechanism and kinematic inversion.              [04]
1(b)        Discuss the Gruebler’s mobility criterion related to mechanisms. For the backhoe mechanism shown in Figure 1, mark all the links as (1, 2, 3,...), joints as (R,P,...) and determine the mobility of the mechanism. [08]

Fig. 1

OR

1′(a)        With the help of neat sketches discuss various types of kinematic joints with their symbols and designation. [05]
1′(b)        Show the inversions of a slider crank chain and explain briefly the working of Withworth’s quick return mechanism or Gnome Engine. [07]
2(a)        Figure 2, shows a mechanism that tips the bed of a dump truck. Determine the required speed of the hydraulic cylinder in order to tip the truck at a rate of 5 rad/min. [06]

contd...2
2(b) Figure 3, illustrates a self-locking brace for a platform used on shipping docks. For this mechanism draw the kinematic diagram and locate all the instantaneous centres.

3(a) With the help of neat sketches discuss in brief various types of gears and gear trains.

3(b) A planetary gear train is illustrated in Figure 4. The carrier (link 2) serves as the input to the train. The sun (gear 1) is the fixed gear and has 30 teeth. The planet gear (gear 3) has 35 teeth. The ring gear serves as the output from the train and has 100 teeth. Determine the rotational speed of all members of this gear train when the input shaft rotates at 1200 rpm clockwise.

3'(a) Discuss briefly interference in spur gears with involute profile teeth and derive the condition to avoid interference.

3'(b) A planetary gear train is shown in Figure 5. The carrier (link 2) serves as the input to the train. The sun (gear 1) is fixed and has a 1.25-in. pitch diameter with a diametral pitch of 16. Gear 3 has 42 teeth and gear 4 has 21 teeth. Gear 5 has 32 teeth and is
keyed to the same shaft as gear 4. Gear 5 mates with the ring gear (gear 6), which serves as the output from the train and has 144 teeth. Determine the rotational velocity of all members of this gear train when the input shaft rotates at 680 rpm clockwise.

Fig. 5

4(a) Write different theories of failure and briefly describe any two of them. Draw the comparison diagram of different failure theories.

4(b) A spherical pressure vessel, with a 500 mm inner diameter is welded from steel plates. The welded joints are sufficiently strong and do not weaken the vessel. The plates are made from cold drawn steel 20C8 (S_{ut} = 440 \text{ N/mm}^2 \text{ and } S_{yt} = 242 \text{ N/mm}^2). The vessel is subjected to internal pressure which varies from 0 to 6 \text{ N/mm}^2. The expected reliability is 50% and the factor of safety is 3.5. The vessel is expected to withstand infinite number of stress cycles. Calculate the thickness of the plates using modified Goodman diagram.

OR

4'(a) A machine component is subjected to a flexural stress which fluctuates between +300\text{MN/m}^2 and -150\text{MN/m}^2. Determine the value of minimum ultimate strength according to (i) Gerber relation; (ii) Goodman relation; and (iii) Soderberg relation. Take yield strength = 0.55 of Ultimate strength; Endurance strength = 0.5 of Ultimate strength; and factor of safety = 2.

4'(b) A forged steel bar 50 mm in diameter is subjected to a reversed bending stress of 250 \text{N/mm}^2. The bar is made of steel 40C8 (S_{ut} = 600 \text{ N/mm}^2). Calculate the life of the bar for reliability of 90%.

cont'd...
5(a) A steel plate subjected to a force of 5 kN and fixed to a channel by means of three identical bolts as shown in Figure 6. The bolts are made from plain carbon steel 45C8 ($S_t = 380$ N/mm$^2$) and factor of safety is 3. Specify the size of bolts.

5(b) Write short note on riveted joints and power screws

![Figure 6](image)

Table 1: Size factor

<table>
<thead>
<tr>
<th>$K_b$</th>
<th>d ≤ 7.6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0.85</td>
<td>7.6 ≤ d ≤ 50 mm</td>
</tr>
<tr>
<td>0.75</td>
<td>d ≥ 50 mm</td>
</tr>
</tbody>
</table>

Table 2: Size factor

<table>
<thead>
<tr>
<th>Reliability %</th>
<th>$K_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>90</td>
<td>0.897</td>
</tr>
<tr>
<td>99.99</td>
<td>0.702</td>
</tr>
</tbody>
</table>

Table 3: Design dimensions for Bolts and nuts

<table>
<thead>
<tr>
<th>Designation</th>
<th>Pitch mm</th>
<th>Major or Nominal Diameter Nut and Bolt mm</th>
<th>Effective or Pitch Diameter Nut and Bolt (d_e) mm</th>
<th>Minor or Core Diameter (d_c) mm</th>
<th>Depth of Thread (b) mm</th>
<th>Tensile Area (A) mm$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16</td>
<td>2</td>
<td>16.000</td>
<td>14.701</td>
<td>13.546</td>
<td>1.227</td>
<td>157</td>
</tr>
<tr>
<td>M18</td>
<td>2.5</td>
<td>18.000</td>
<td>16.376</td>
<td>14.933</td>
<td>1.534</td>
<td>192</td>
</tr>
<tr>
<td>M20</td>
<td>2.5</td>
<td>20.000</td>
<td>18.376</td>
<td>16.933</td>
<td>1.534</td>
<td>245</td>
</tr>
<tr>
<td>M22</td>
<td>2.5</td>
<td>22.000</td>
<td>20.376</td>
<td>18.933</td>
<td>1.534</td>
<td>303</td>
</tr>
</tbody>
</table>