1. (a) Use Runge-Kutta method of order 4 to find the values of \( V(1.1) \) and \( W(1.1) \), given:
\[
\frac{dv}{du} = uvw, \quad V(t) = \frac{1}{3} \\
\frac{dw}{du} = \frac{uv}{w}, \quad W(t) = 1.
\]
Choose \( h = 0.1 \).
(b) Apply Euler’s method to find the value of \( x \) and \( y \) at \( t = 0.5 \), given
\[
\frac{dx}{dt} = y - t, \quad \frac{dy}{dt} = x + t, \quad x(0) = 1 = y(0).
\]
Take \( h = 0.1 \).

2. (a) Given \( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0, \quad 0 \leq x, y \leq 4 \)
Boundary conditions:
\[
u = 0 \text{ at } x = 0, \quad u = 8 + 2y \text{ at } x = 4 \]
\[
u = \frac{1}{2} x^2 \text{ at } y = 0, \quad u = x^2 \text{ at } y = 4.
\]
With \( h = 1 = K \), use two iterations of Gauss-Seidel method to find the values at internal mesh points.
(b) Consider \( \frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}, \quad 0 \leq x \leq 1 \).
Initial conditions: \( u(x, 0) = \sin \pi x \)
Boundary conditions: \( u(0, t) = 0 = u(1, t), \ t > 0 \).
Solve it up to two time levels by using Crank-Nicolson Scheme for \( h = 0.2 \) and \( K = 0.02 \).

Contd.....2
3. (a) Solve numerically the wave equation

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

with boundary conditions \( u(0, t) = u(1, t) = 0, \ t > 0 \)

and initial conditions \( u(x, 0) = x - x^2, \ \frac{\partial u}{\partial t} (x, 0) = 0, \ 0 \leq x \leq 1 \) for \( h = \frac{1}{4} \)

and \( K = 0.025 \), upto two time levels.

(b) Define Rayleigh quotient and hence obtain the estimates of the lowest and the largest eigen values of the matrix.

\[ A = \begin{bmatrix} 3 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 3 \end{bmatrix} \]

4. (a) Find the Fourier transform of

\[ f(x) = \begin{cases} 1 - x^2, & |z| \leq 1 \\ 0, & |x| > 1 \end{cases} \]

(b) Find finite Fourier sine and cosine transform of

\[ f(x) = x^2, \quad 0 < x < 4. \]

(c) State the result for \( \Im(f'(x)) \) and \( \Im(f'^n(x)) \). Hence find \( \Im(xe^{-x^2}) \), \( \Im \) stands for the Fourier transform.

SECTION – B

5. (a) Let \( S = \{(1, 2, 1)’, (1, 1, –1)’, (4, 5, –2)’\} \). Determine which of the following vectors are in the span of \( S \): (i) \((1, 1, 0)’\) (ii) \((2, –1, –8)’\) (iii) \((0, 0, 0)’\).

(b) Generate an orthonormal basis from the basis:

\( \{(1, 2, 3)’, (2, 1’, 3)’, (4, 3, 6)’\} \).

6. (a) Verify that the eigen vectors of a real matrix \( A \) are orthogonal to the complex conjugate of \( A’ \) for distinct eigen values, where

\[ A = \begin{bmatrix} 4 & -20 & -10 \\ -2 & 10 & 4 \\ 6 & -30 & -13 \end{bmatrix} \]

Contd…..3
(b) Determine whether \((A + 2I)u = b\) is consistent or inconsistent for

\[
A = \begin{bmatrix}
2 & 2 & -6 \\
2 & -1 & -3 \\
-2 & -1 & 1
\end{bmatrix}, \quad b = (2, 1, -1)'.
\]

7. A CSTR sustains the series reaction (isothermal)

\[
A \xrightarrow{2s^{-1}} B \xrightarrow{3s^{-1}} C
\]

The dynamic equations governing the system are

\[
\frac{d}{dt} C_A = \frac{1}{\tau_{\text{res}}} \left( C_{A\text{f}} - C_A \right) - K_1 C_A
\]

\[
\frac{d}{dt} C_B = \frac{1}{\tau_{\text{res}}} \left( C_{B\text{f}} - C_B \right) - K_2 C_B
\]

\[
\frac{d}{dt} C_C = \frac{1}{\tau_{\text{res}}} \left( C_{C\text{f}} - C_C \right) - K_2 C_B.
\]

The feed to the reactor is pure \(A\) at a concentration of 1 g mol/cc. The initial concentrations of \(A, B, C\) are 1, 0, 1 g mol/cc, and the residence time is \(4s^{-1}\).

Determine the evolution of concentrations of \(A, B, C\) is the CSTR to the steady state.
Note: (i) Attempt all questions
       (ii) Assume missing data suitably
       (iii) The notations have their usual meaning.

1 (a) Briefly explain the significance of chemistry in environmental engineering. (2)

(b) Using half reactions, write complete balanced oxidation reduction equations for the following:
    (i) Oxidation of $S_2O_3^{2-}$ to $SO_4^{2-}$ and reduction of $Cl_2$ to $Cl^-$ (4)
    (ii) Oxidation of $CH_3COO^-$ to $CO_2$ and reduction of $SO_4^{2-}$ to $H_2S$

(c) Briefly explain the significance of concentration diagrams in environmental engineering. (2)

(d) Define activity of an ion and its effect on equilibrium. Write the formula used for determining
    the ionic strength and activity. (4)

OR

1' (a) Briefly explain the procedure adopted for the determination of hydroxide, bicarbonate
      and carbonate forms of alkalinities. (5)

(b) Write down proton balance for the following solutions
    0.1 M NaHCO$_3$
    0.1 M H$_2$CO$_3$
    0.1 M HPO$_4$ (3)

(c) With the help of concentration diagrams and proton balance find the pH of 0.01 M solution of
    sodium carbonate. (4)

2. (a) Derive equation required for the construction of logarithmic concentration diagram for 0.1 M
      CH$_3$COOH solution. (7)

(b) With the help of equations determine the pH of 0.05 M CH$_3$COOH solution. (5)

OR

2' (a) Describe in detail the procedure adopted for the determination of sulphates ions. (8)

(b) Derive the expression for the determination of buffer index. (4)

3. (a) Calculate the pH of a buffer solution prepared by adding 8.5 g of KH$_2$PO$_4$ and 43.5 g of
      K$_2$HPO$_4$ under the following conditions:
    (i) Initially (6)
    (ii) after adding 0.001 m of HCL
    (iii) after adding 0.001 m of NaOH

(b) Briefly explain the different types of pesticides found in the environment. (6)

4. (a) Briefly explain why solubility concepts are important in the removal of pollutants (2)

contd...
(b) From a logarithmic concentration diagram, estimate the minimum pH to which a water or wastewater need to be raised to effect the precipitation as metallic hydroxide of all but $10^{-4}$ mol/l of Cd$^{2+}$. Take $K_{sp}$ of Cd(OH)$_2$ as $2 \times 10^{-14}$ at 25$^\circ$ C and the values of formation constants as Log $K_1 = 6.08$, Log $K_2 = 2.62$, Log $K_3 = -0.32$ and Log $K_4 = 0.04$.

5 (a) Describe briefly the significance of water stabilization.
(b) Draw the structures of different phenolic compounds found in industrial wastewaters and briefly write about their biodegradability.
(c) Write down the various equations involved in lime soda process of water softening. Briefly explain why excess lime is added. Also discuss the significance of recarbonation.
1(a) What are the different contexts in which the term "model" is used? Explain all of them in detail and also cite the relevant examples. (08)

1(b) Describe in detail the different types of mathematical models that are commonly used in Chemical Engineering along with their pertinent examples. (07)

OR

1(b') Discuss the transport phenomena models which are classified on the basis of their detail level and the domain of application. Also, mention their respective examples. (07)

2. A solid slab occupying the space between \( y = -b \) and \( y = +b \) is initially at temperature \( T_0 \). At time \( t = 0 \), the surfaces at \( y = \pm b \) are suddenly raised to temperature \( T_f \) and maintained there. Develop the mathematical model describing the transient temperature profile existing in the slab, assuming that the thermal conductivity of the slab is constant. Also, obtain the solution (temperature profile) of the obtained model equation. (15)

3. Derive the model equations of a multi-component conventional staged distillation column operating under steady state. Also, describe the simulation strategy which is normally adopted in solving the derived model equations. (15)

OR

3'. Obtain the model equation along with the corresponding boundary conditions for the steady state absorption of a gaseous component \( A \) into a laminar film of liquid \( B \) falling over a vertical plate. Also, solve the developed model equation assuming that the contact time between gaseous component \( A \) and liquid \( B \) is short. (15)

4. Develop the mathematical models for any two of the following systems. Also mention the relevant assumptions and associated conditions.
   (i) Packed bed adsorber
   (ii) Triple effect evaporator operating under steady state and with forward feed arrangement (boiling point rise may be neglected)
   (ii) Double pipe heat exchanger operating under steady state (the hot fluid is flowing in the inner pipe and flowing in counter-current direction to that of the cold fluid). (15)
2012 – 2013
M. TECH. AUTUMN (I SEMESTER) EXAMINATION
(PETROLEUM PROCESSING & PETRO-CHEMICAL ENGINEERING)
FLUID FLOW AND HEAT TRANSFER
(PK – 601)

Maximum Marks : 60 Duration : Three Hours

"Students governed by the old ordinances will be examined out of 75 marks and their obtained marks shall be proportionately raised."

Note: All questions carry equal marks. Answer any FOUR questions.

1. (a) Derive the modified Navier-Stokes equations in rectangular co-ordinate system and use them for calculating average velocity for a fluid flowing with a stream velocity \( U_s \), in one direction, between two large parallel plates separated by a distance 'b'. The fluid is in steady state and the plates are stagnant.

\[ \text{Direction} \]

(b) Explain the term total derivative and substantial derivative.

2. (a) A large plate of thickness 'L' has a uniform temperature distribution "2T₀" initially. The temperature at both surfaces is suddenly changed to "T₀" and held constant thereafter. Derive a relationship for the temperature as a function of time, distance and thermal properties. Neglect edge effects.

(b) Define sub cooled and saturated boiling.

3. Derive the steady state one dimensional energy equation for a variable cross sectional fin. State the assumptions clearly. Employ the equation developed for calculating the temperature distribution and the effectiveness for a triangular fin.

4. (a) A mixture of gas and liquid flows through a pipe of internal diameter of 0.01m at a steady state flow rate of 1.0 kg/s. The dynamic viscosities of gas and liquid are \( 1.2 \times 10^{-6} \) and \( 2.0 \times 10^{-4} \) Ns/m² respectively. The mt. fraction of the gas is 0.15. Calculate the pressure gradient in the pipe using Lockhart-Martinelli method.

Given 1000 cp = 1.0 Ns/m²

The two-phase correction factor, \( \phi \) can be calculated by the Chisholm equation

\[ \phi^2 = 1 + \frac{C}{X} + \frac{1}{X^2} \]

where X is the Lockhart Martinelli parameter and can be calculated from the table as given below:

Contd….2
where
\[ X = \left( \frac{1-x}{x} \right)^{0.9} \left( \frac{\rho_G}{\rho_L} \right)^{0.5} \left( \frac{\mu_L}{\mu_G} \right)^{0.2} \] when both phases are in turbulent flow
\[ X = \left( \frac{1-x}{x} \right) \left( \frac{\rho_G}{\rho_L} \right)^{0.5} \left( \frac{\mu_L}{\mu_G} \right)^{0.5} \] when both phases are in laminar flow
\[ f = \frac{16}{R_e} \] for laminar flow and \[ f = \frac{0.316}{R_e^{0.22}} \] for turbulent flow

(b) Show by a schematic diagram(s) the various flow patterns formed for a gas-liquid mixture flowing through a horizontal pipe if the gas flow rate is increased slowly.

5. (a) In a refinery, exhaust steam at low pressure is available in abundance. The exhaust steam is of limited use/or of low process value as its saturation is low. However it has been found from various estimates that the cost of the exhaust steam is \( \frac{1}{4} \) and \( \frac{1}{8} \) of the live process steam. In view of this it has been decided to use this steam by employing two heat exchanges in series to preheat the feed water to an intermediate temperature. Derive an equation to calculate the intermediate temperature so that exhaust steam is utilized optimally.

(b) Draw the sankey’s energy diagram for a commercial plant and explain its importance with reference to energy conservation.

6. (a) Explain when a heat exchanger is called as compact heat exchanger. List the various types of compact heat exchangers and describe the working principle of a fluidized heat exchanger with a schematic diagram.

(b) List the factors responsible for determining the forward and backward feed arrangement in evaporator system. Draw a schematic diagram for a mixed feed arrangement for the same.

(c) Derive an equation for the calculation of heat recovery for a counter current heat exchanger.

OR

(c') Explain the various modes of heat transfer to boiling liquid with the help of boiling curves. Why the process heat transfer equipments are not designed in the film boiling temperature range.
2012-2013
M.TECH. AUTUMN (I SEMESTER) EXAMINATION
(PETROLEUM PROCESSING AND PETROCHEMICAL ENGINEERING)
PETROLEUM PROCESSING
(PK-602)

Maximum Marks: 60
Duration: Three Hours

"Students governed by the old ordinance will be examined out of 75 marks. Their obtained marks shall be proportionately raised".

Answer any **TWO** questions from Section A and **ALL** questions from Section B

**SECTION A**

1. (a) Describe the theories of origin of petroleum.

   05

(b) Mention various physical properties of oil bearing rocks that are important for oil generation and production. Discuss any one of them in detail.

   06

(c) Discuss kerogen, types of kerogen and kerogen maturation.

   04

2. (a) Discuss the factors that influence the occurrence of petroleum.

   06

(b) Explain the process of petroleum migration and accumulation.

   04

(c) Explain the significance of Source, Reservoir and Cap rocks.

   05

3. (a) What do you understand by petroleum traps? Mention the different types of traps. Briefly describe the petroleum traps A, B and C in Figure-1.

   05

(b) Discuss, in detail, the atmospheric and vacuum distillation of crude oil, along with important tests of the products obtained from them.

   10

**SECTION B**

4. (a) Differentiate between gravity and seismic methods of oil exploration, and also name some non-explosive & environmental friendly techniques of seismic surveys.

   3+2

(b) Name different types of drill fluids and describe their functions. Why crew members put additives in drill fluids?

   5+1

**OR**

(b') What do you mean by 'Kick' and 'Trip'? Name and discuss some basic BOP equipments.

   1+5

contd... 2
(c) Differentiate between any two of the following:
(i) Jack up Rigs & Semi Submersible Rigs
(ii) Core Bit & PDC Bit
(iii) Drill Collar & Crossover Subs

5. (a) Name various steps involved in completion of well. Discuss casing & perforation in detail.
(b) Differentiate between Primary, Secondary and tertiary oil recovery. Describe the microbial & thermal methods of enhanced oil recovery.
(c) Discuss thermodynamics considerations of various reactions involved in catalytic Reforming process? Describe any one type of catalytic reforming process with the help of suitable process flow sheet.

OR

(c') Discuss the effect of various reaction parameters on reforming process and also describe the role and development of catalytic reforming catalyst on Reforming process.

Figure - 1: Petroleum Traps
"Students governed by the old ordinance will be examined out of 75 marks. Their obtained marks shall be proportionately raised."

Answer all questions.

Q1. The Liquid feed of 100 mol/h having composition in mol as (n-butane $x_A = 0.40$), n-pentane ($x_B = 0.25$), n-hexane ($x_C = 0.20$), n-heptane ($x_D = 0.15$) is fed to a distillation tower at 405.3 kPa and is to be fractionated so that 95% of the n-pentane (B) is recovered in the distillate and 95% of the n-hexane (C) in bottoms. Calculate the following:

1. Moles per hour and composition of distillate and bottoms.
2. Dew point and Bubble point
3. Minimum stages for total reflux
4. Distribution of other components in distillates and bottoms
5. Minimum Reflux Ratio using the Underwood method,

OR

Q1'. A feed of 30 mol% methanol (A), 20% ethanol (B), 15% n-propanol (C), and 35% n-butanol (D) is distilled at 101.32 kPa abs pressure to give a distillate composition containing 95.0 mol% methanol and residue composition containing 5.0% methanol and the other components as calculated. The feed is below the boiling point so that $q=1.1$. The operating reflux ratio is 2.0. The Dew point and Bubble points are 65°C and 95°C respectively. Assume that Raoult's law applies and use vapour pressure data from Table 1. Calculate the following:

1. Composition and amounts of distillates and bottoms for a feed of 100 mol/hr.
2. number of stages at total reflux.
3. Minimum reflux ratio, number of stages at $R=2.0$, and feed
Q2(a).  For the distillation column shown in Figure 1, use Tridiagonal Matrix procedure to compute $x_{ij}$ for component $C_3$ (1). Use composition independent $K$-values from the Table 2.

(b).  Explain in brief about the following:
(i)  Residue Curve Maps
(ii)  Distillation Curves Maps
(iii) Homogeneous Azeotropic Distillation

Q3(a).  An aqueous feed solution of 1000 kg/h of acetic acid-water solution containing 30.0 wt % acetic acid and is to be extracted in a countercurrent multistage process with pure isopropyl ether to reduce the acid concentration to 2.0 wt % acid in the final raffinate. Equilibrium data is given in Table 3.

1. Calculate the minimum solvent flow rate that can be used.
2. If 2500 kg/h of ether solvent is used, determine the number of theoretical stages required.

OR

(a)'  Pure water is to be used to extract acetic acid from 400 kg/h of a feed solution containing 25wt % acetic acid in isopropyl ether. Use equilibrium data from Table 3.

(a) If 400 kg/h of water is used, calculate the percent recovery in the water solution in a one-stage.

(b) If multiple three-stage system is used and 133.3 kg fresh water is used in each stage, calculate the overall percent recovery of the acid in the total outlet water.

(b).  Mention various types of equipments used for Liquid-Liquid Extraction. Explain any one commercial equipment with neat sketch.

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<tr>
<th>TABLE -1</th>
<th>Vapor pressure (mmHg)</th>
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<tr>
<td><strong>T° C</strong></td>
<td><strong>Methanol</strong></td>
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<tr>
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Table 2

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<th>3</th>
<th>4</th>
<th>5</th>
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<td>C₅(1)</td>
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<td>1.63</td>
<td>2.17</td>
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<tr>
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<td>0.71</td>
<td>0.95</td>
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<td>nC₆(4)</td>
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Table 3

<table>
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<th>Water Layer (wt%)</th>
<th>Isopropyl Ether Layer (wt%)</th>
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<td>Acetic Acid</td>
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contd...
Figure 1.
Figure 2. Equilibrium K values for light hydrocarbon systems at 405.3 kPa absolute.