2011-2012
M.TECH. (I SEMESTER) EXAMINATION
(PETROCHEMICAL ENGINEERING)
ADVANCED MATHEMATICS
(AM - 641)

Maximum Marks: 60
Duration: Three Hours

Note: Answer five questions by selecting at least two questions from each section.

SECTION - A

1. (a) Use Runge - Kutta method of order 4 to find the values of x (0.2) and y (0.2), given
\[
\frac{dx}{dt} = xy + t, \quad x(0) = 1
\]
\[
\frac{dy}{dt} = ty + x, \quad y(0) = -1
\]
(Choose h = 0.2)

(b) Apply Modified - Euler’s method to find the value of y (0.2) for the initial value problem:
\[
y'' + 4y' + 5y = 0, \quad y(0) = 3, \quad y'(0) = -5
\]
(choose h = 0.2)

2. (a) Solve the boundary value problem
\[
y'' + 3y' - 2y = 2, \quad y(0) = 1 \text{ and } y'(1) = 0
\]
by difference method with h = 1/3.

(b) Consider
\[
\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0, \quad 0 \leq x, y \leq 3.
\]

Given u (x, y) = x + y on the boundary and h = 1, apply three iterations of Liebmann’s iterative method to find the approximate solution.

3. (a) Given:
\[
\frac{\partial f}{\partial t} = 2 \frac{\partial^2 f}{\partial x^2}, \quad 0 \leq x \leq 4, \quad t \geq 0
\]

Initial conditions: \( f(x, 0) = 10 (4 - x) \)

Boundary conditions: \( f(0, t) = f(4, t) = 0 \) for \( t \geq 0 \). Solve it up to three time levels using Crank – Nicholson scheme.

(b) Solve numerically the wave equation
\[
\frac{\partial^2 u}{\partial t^2} = 4 \frac{\partial^2 u}{\partial x^2}, \quad 0 \leq x \leq 4, \quad t \geq 0
\]

with the boundary conditions \( u(0, t) = 0 = u(4, t), \quad t \geq 0 \) and the initial conditions: \( u(x, 0) = x (4 - x), \quad \frac{\partial u}{\partial t} (x, 0) = 0 \) with \( h = 1 \), up to two time levels.

4. (a) Find the Fourier transform of
\[
f(x) = \begin{cases} a - |x|, & |x| < a \\ 0, & |x| > a \end{cases}
\]

Contd........2
(b) State the results of $\mathcal{F}[f'(x)]$ and $\mathcal{F}[xf(x)]$. Use these to calculate $\mathcal{F}[e^{-ax^2}]$, where $\mathcal{F}$ stands for the Fourier transform.

(c) State the two shifting theorems involving Fourier transforms and prove any one of them.

SECTION – B

5. (a) Define an inner product space and show that $\langle u + v, u - v \rangle = \|u\|^2 - \|v\|^2$.

(b) Differentiate between orthogonal and orthonormal basis and hence express the vector $\begin{pmatrix} 7, 3, 9 \end{pmatrix}$ in terms of the orthogonal basis $\{\begin{pmatrix} 1,1,1 \end{pmatrix}, \begin{pmatrix} 1,0,-1 \end{pmatrix}, \begin{pmatrix} 1, -2, 1 \end{pmatrix}\}$ in $\mathbb{R}^3$.

OR

(b') Generate an orthonormal set from the linearly independent set of vectors $\begin{pmatrix} 2,0,1 \end{pmatrix}, \begin{pmatrix} 2,1,3 \end{pmatrix}, \begin{pmatrix} 4,1,2 \end{pmatrix}$ in $\mathbb{R}^3$.

6. (a) Define a linear transformation. Construct a linear transformation $T : \mathbb{R}^3 \rightarrow \mathbb{R}^2$ such that $T(1,0,0) = (1,1)$, $T(0,1,0) = (1,2)$ and $T(0,0,1) = (1,3)$.

(b) Show that the eigen vectors of the given real symmetric matrix $A$ are orthogonal to each other

$$A = \begin{bmatrix} 2 & -1 & 0 \\ -1 & 3 & -1 \\ 0 & -1 & 2 \end{bmatrix}.$$  

OR

(b') Determine if $(A + 2I)u = b$ is consistent or inconsistent for

$$A = \begin{bmatrix} 2 & 2 & -6 \\ 2 & -1 & -3 \\ -2 & -1 & 1 \end{bmatrix} \& b = (1, 1, -1)'$$

7. (a) Define biorthogonality. Find the biorthogonal sets of eigenvectors for the matrix:

$$A = \begin{bmatrix} 2 & 2 \\ 1 & 3 \end{bmatrix}.$$  

(b) The reversible reaction $x_1 \rightleftharpoons x_2$ occurs isothermally in a batch reactor. The forward and reverse reactions are both first order with rate constants $1s^{-1}$ and $2s^{-1}$ respectively. The initial concentrations of $x_1, x_2$ are 2g mol/cc and 3g mol/cc. Determine the equilibrium concentration in the reactor. The evaluation of the concentrations $x_1$ and $x_2$ are given by

$$\frac{dx_1}{dt} = -x_1 + 2x_2, \quad \frac{dx_2}{dt} = x_1 - 2x_2.$$  

****
3'. A wastewater contain 50 mg/L of Zn$^{2+}$. How high must the pH be raised to precipitate all but 1 mg/L of zinc? What adverse effect might occur if pH were raised too high. Take the values of $K_{sp}$ and formation constants as follows $K_{sp} = 8 \times 10^{-18}$, $\log K_1 = 4.15$, $\log K_2 = 6.0$, $\log K_3 = 4.11$ and $\log K_4 = 1.26$.

4. (a) A buffer solution has been prepared by adding 0.2 mol/l of acetic acid and 0.1 mole/l of acetate. The pH of the buffer solution has been adjusted to 5.0 by addition of NaOH. How many mol/l of NaOH is required to inverse the pH to 5.5. 
(b) What organic compounds are likely to be present in domestic wastewater? Differentiate between starch and cellulose molecules.
(c) Briefly describe the properties of surfactants.

5. (a) Describe briefly water stabilisation. Derive the equation used for the determination of Lauglier Index.
(b) Calculate the activity coefficient and activity of each ion in a solution containing 75 mg/L Na$^+$, 25 mg/L Ca$^{2+}$, 10 mg/L Mg$^{2+}$, 125 mg/L Cl$^-$, 50 mg/L HCO$_3^-$ and 48 mg/L SO$_4^{2-}$.
2011 – 2012
M.TECH. (I SEMESTER) EXAMINATION
(CIVIL / PETRO-CHEMICAL ENGG.)
ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL CHEMISTRY
(CE-622 / PK-620)

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: (i) Answer all the questions.
(ii) Assume missing data suitably.

1. (a) Briefly explain the different units used for the expression of strength of a solution.
(b) Calculate the equivalent weight of potassium dichromate as used in the following reactions.
   (i) \( \text{Cr}_2\text{O}_7^{2-} + 2\text{Pb}^{2+} + \text{H}_2\text{O} \rightarrow 2\text{PbCrO}_4 + 2\text{H}^+ \)
   (ii) \( \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} \)
(c) Balance the following redox reactions
   (i) Oxidation of \( \text{S}_2\text{O}_3^{2-} \) to \( \text{SO}_4^{2-} \) and reduction of \( \text{Cl}_2 \) to \( \text{Cl}^- \)
   (ii) Oxidation of \( \text{C}_6\text{H}_5\text{O}_6 \) to \( \text{CO}_2 \) and reduction of \( \text{SNO}_3^- \) to \( \text{N}_2 \)

OR

1’. (a) Calculate the hydroxide, carbonate and bicarbonate alkalinity using the following titration results

<table>
<thead>
<tr>
<th>Sample pH</th>
<th>Total mL of titrant to reach end point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phenol.</td>
</tr>
<tr>
<td>11.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Take sample volume as 100 mL and strength of \( \text{H}_2\text{SO}_4 \) as N/50.

(b) Define proton balance. Illustrate with atleast two examples.

2. (a) Describe in detail the procedure used for the determination of fluoride ion.
(b) How many moles of \( \text{H}_2\text{SO}_4 \) are required to form 65 g of \( \text{CaSO}_4 \) from \( \text{CaCO}_3 \).

3. (a) Briefly describe the significance of concentration diagrams. Draw the logarithmic concentration diagrams for the following solutions.
   (i) 0.1 M \( \text{H}_2\text{CO}_3 \)
   (ii) 0.1 M \( \text{H}_3\text{PO}_4 \)

   Draw the diagrams on graph papers.

(b) What are the persistent organic pollutants found in environment? Also describe their properties.

OR
2011-2012
M.TECH. (I SEMESTER) EXAMINATION
(CHEMICAL / PETRO-CHEMICAL ENGINEERING)
PROCESS MODELING & SIMULATION – I
(CH-615 / PK-616)

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."

Answer all questions.

1. (a) Derive and discuss (by an example) the logic flow diagram for the development of mathematical model of a system. Differentiate between various modeling techniques.

(b) Discuss the structure of ASPEN PLUS process simulator and the basic computation elements in it. Explain the use of simulator for a distillation column.

2. (a) Construct a model each for lumped and distributed parameter system. Solve the model for steady state situation.

(b) Explain multiplicity of steady states with the help of a suitable example.

OR

2'. (a) Derive the state space model of a non-isothermal CSTR, used for the design of its control systems. Solve the model using analytical techniques.

(b) Consider that a first order irreversible exothermic reaction is taking place in a CSTR, fitted with cooling coils. Use Van-Heerden analysis to develop the slope criteria in general form for the stability of steady states.

3. (a) Corrigan and Beavers proposed a flow model of a real CSTR. By using stochastic approach, derive expression for its RTD functions, E(t) and F(t).

(b) Apply population balance modeling technique to describe back flow cell model. How is the back flow cell model related to axial dispersion model?
4. Write model equations and simulation algorithm for any two of the following. (08-
Give a clear description of the process along with the assumptions and boundary
conditions.

(a) Multicomponent Distillation.
(b) Jacketed Stirred Tank Heater.
(c) Fluidized bed Catalytic Cracker.
(d) Multiple Effect Evaporator.
2011 - 2012
M.TECH. (I SEMESTER) EXAMINATION
PETROLEUM PROCESSING AND PETROCHEMICAL ENGINEERING
PETROLEUM PROCESSING
(PK - 602)

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: Answer all questions.

Q1 (a) Describe Offshore Seismic Exploration method, also name some non-explosive & environmental friendly techniques of Seismic surveys.

(b) Name the different types of drill fluids. Discuss in detail the various functions performed by various drilling fluids.

OR

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

(c) Differentiate any two of the following.

(i) Core Bit & PDC Bit
(ii) Drill Collar & Crossover Subs
(iii) Jack up Rigs & Semi Submersible Rigs

Q2 (a) Name various steps involved in completion of well. Discuss cementing & perforation in detail.

(b) Describe the chemical, microbial & thermal methods of enhanced oil recovery.

(c) Discuss the thermodynamics & kinetic considerations of various reactions involved in catalytic reforming process, also discuss the effect of various reaction parameters on reforming process.

OR

(c') What are different types of catalyst used in reforming process? Describe any one type of catalytic reforming process with the help of suitable process flow sheet.
3(a) Write a note on the historical development of Indian Petroleum Industry. Explain the Modern theory for the formation of crude petroleum?

OR

(a') Give brief accounts of: i) Kerogen and Shale ii) Resins and asphaltenes iii) Heavy and extra heavy crude oils iv) Specific gravity and API gravity

(b) What are the critical parameters you will select to evaluate a crude oil? How the hydrocarbon losses can be computed by measuring the RVP?

(c) Nitrogen content and salt content of crude oils are undesirable constituents. Justify the statement.

4(a) Describe briefly various methods which are usually employed for determining the base of the crude oil. Which method do you feel convenient and superior?

OR

(a') How does TBP distillation become an important tool at the hands of the refiner to know a crude oil? Describe briefly the different sequences followed for the operation of a TBP distillation. Mention the key points which are included in its report.

(b) Explain briefly the method of operation of a multidraw vacuum distillation column. How does it differ from conventional distillation?

(c) Describe the terms: IBP and EP. What do you mean by the distillation range of a sample?

(d) What is knocking? Why is it considered a nuisance?
2011 – 2012
M.TECH. (I SEMESTER) EXAMINATION
(PETROLEUM PROCESSING & PETROCHEMICAL ENGINEERING)
DISTILLATION AND EXTRACTION
(PK – 603)

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: Answer all questions.

Q1. The Liquid feed of 100 mol/h having composition in mol as (n-15 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 92% 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.

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 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 3.0. Assume that Roults 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. Top and bottom temperatures and number of stages at total reflux.
   3. Minimum reflux ratio, number of stages at R=3.00.
Q2. For the distillation column shown in Figure 1, use Tridiagonal Matrix procedure to compute $x_{i,j}$ for components nC$_4$ (2). Use composition independent K-values from the Table 2.

Q3.(a) Write in brief the advantages and disadvantages of different types of Extraction Equipments.

(b) Explain in brief about Residue Curve Maps and Distillation Curves Maps.

(c) An inlet water solution of 100 kg/h containing 0.010 wt fraction nicotine (A) in water is stripped with kerosene stream of 200 kg/h containing 0.0005 wt fraction nicotine in a countercurrent stage tower. The water and kerosene are immiscible in each other. It is desired to reduce the concentration of the exit water to 0.0010 wt fraction nicotine. Determine the theoretical number of stages needed. The equilibrium data is given in Table 3.

Q4. An aqueous feed solution of 1000 kg/h containing 23.5 wt% acetone and 76.5 wt% water is being extracted in a countercurrent multistage extraction system using pure methyl isobutyl ketone solvent at 298-299 K. The outlet water raffinate will contain 2.5wt% acetone. Equilibrium data is given in Table 4.

1. Calculate the minimum solvent that can be used.
2. Using a solvent flow rate of 1.5 times the minimum, calculate the number of theoretical stages.

Q4'. Pure isopropyl ether of 450 kg/h is being used to extract an aqueous solution of 150 kg/h with 30 wt% acetic acid (A) by countercurrent multistage extraction. The exit acid concentration in the aqueous phase is 4.0 wt %. Calculate the number of stages required. Use equilibrium data from Table 5.
### Table 1

<table>
<thead>
<tr>
<th>T°C</th>
<th>Methanol</th>
<th>Ethanol</th>
<th>n-propanol</th>
<th>n-butanol</th>
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<td>50</td>
<td>415</td>
<td>220.0</td>
<td>88.9</td>
<td>33.7</td>
</tr>
<tr>
<td>60</td>
<td>629</td>
<td>351.5</td>
<td>148.9</td>
<td>59.2</td>
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<tr>
<td>65</td>
<td>767</td>
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<td>190.1</td>
<td>77.7</td>
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<td>70</td>
<td>929</td>
<td>542.0</td>
<td>240.6</td>
<td>99.6</td>
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<td>75</td>
<td>1119</td>
<td>665.0</td>
<td>301.9</td>
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<td>80</td>
<td>1339</td>
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<td>376.0</td>
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<td>1593</td>
<td>984.0</td>
<td>465.0</td>
<td>206.1</td>
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<td>1884</td>
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<td>571.0</td>
<td>225.9</td>
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<tr>
<td>100</td>
<td>2598</td>
<td>1706.0</td>
<td>843.0</td>
<td>387.6</td>
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### Table 2

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<th>Stage</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>C₃(1)</td>
<td>1.23</td>
<td>1.63</td>
<td>2.17</td>
<td>2.70</td>
<td>3.33</td>
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<tr>
<td>nC₄(2)</td>
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<td>0.50</td>
<td>0.71</td>
<td>0.95</td>
<td>1.25</td>
</tr>
<tr>
<td>nC₅(3)</td>
<td>0.103</td>
<td>0.166</td>
<td>0.255</td>
<td>0.36</td>
<td>0.49</td>
</tr>
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### Table 3

<table>
<thead>
<tr>
<th>weight fraction Nicotine in water solution</th>
<th>weight fraction Nicotine in Kerosene</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 0.001010</td>
<td>0.000806</td>
</tr>
<tr>
<td>2. 0.00246</td>
<td>0.001959</td>
</tr>
<tr>
<td>3. 0.00500</td>
<td>0.00454</td>
</tr>
<tr>
<td>4. 0.00746</td>
<td>0.00682</td>
</tr>
<tr>
<td>5. 0.00988</td>
<td>0.00904</td>
</tr>
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<td>6. 0.0202</td>
<td>0.0185</td>
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### Table 4

<table>
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<tr>
<th>MIK</th>
<th>Acetone</th>
<th>Water</th>
<th>Water Phase</th>
<th>MIK Phase</th>
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<td>0</td>
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<td>10.0</td>
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<td>12.5</td>
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<td>43.2</td>
<td>10.7</td>
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<td>2.20</td>
<td>0</td>
<td>97.8</td>
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### Table 5

<table>
<thead>
<tr>
<th>Water Layer (wt%)</th>
<th>Isopropyl Ether Layer (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid</td>
<td>Water</td>
</tr>
<tr>
<td>0</td>
<td>98.8</td>
</tr>
<tr>
<td>0.69</td>
<td>98.1</td>
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<td>13.30</td>
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<td>44.30</td>
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<tr>
<td>46.40</td>
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</table>
Figure 1.
Figure 2. Equilibrium K values for light hydrocarbon systems at 405.3 kPa absolute.

Figure 3. Erbar-Maddox correlation between reflux ratio and number of stages ($R_m$ based on Underwood method) [From J. H. Erbar, R. N. Maddox, Petrol. Refiner. 40 (5), 183 (1961). With permission.]