Code No: RR320804 **Set No. 1**

III B.Tech II Semester Regular Examinations, Apr/May 2006
MATHEMATICAL METHODS FOR CHEMICAL ENGINEERING
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. A tank contains $100ft^3$ of fresh water, $2ft^3$ of brine, having a concentration of 1 pcf of salt, is run into the tank per minute, and the mixture, kept uniform by mixing, runs out at the rate of $1ft^3/min$. What will be the exit brine concentration when the tank contains $150ft^3$ of brine? [16]

2. Discuss about the flow process from the Eulerian point of view. [16]

3. Form the partial differential equations by eliminating the arbitrary functions.
   (a) $z = y^2 + 2f(1/x + logy)$
   (b) $z = f_1(y + 2x) + f_2(y - 3x)$. [8+8]

4. (a) Find the maximum and minimum distances form origin to the curve $5x^2 + 6xy + 5y^2 - 8 = 0$
   (b) The temperature T at any point (x,y,z) in space is $T = 400xyz^2$. Find the highest temperature on the surface of the unit sphere $x^2 + y^2 + z^2 = 1$ [8+8]

5. (a) Explain in detail the concept of unit vector.
   (b) Find a unit vector parallel to the sum of the vectors $R_1 = 2i + 4j - 5k$ and $R_2 = i + 2j + 3k$. [6+10]

6. (a) Explain the concept of line integral. Define circulation of a vector.
   (b) Evaluate the line integral $\int_c F\,dr$ where $F = 3xyi + y^2j$ and the space curve c is the Curve in the xy- plane $y = 2x^2$ from (0, 0) to (1, 2). [6+10]

7. The diffusivity D for a binary perfect-gas mixture is to be obtained experimentally by measuring the rate of interdiffusion of two gases originally confined in the two ends of a hollow cylinder. A thin diaphragm separating the gases divides the cylinder into two sections of equal volume. The diaphragm is suddenly removed and the gases allowed to diffuse for a measured time. The diaphragm is then replaced, and the gas in one-half the cylinder is well mixed and analyzed. It is assumed that convection effects are not important. Pure gas A is originally confined in one-half the cylinder and pure gas B in the other half, and the pressure and temperature of the system are kept uniform and constant. Derive the expression which permits the calculation of the diffusivity from the experimental data. [16]

8. Assume that two chemical species, A and B, are in a solvent feed stream entering a liquid-phase reactor that is maintained at a constant temperature. Two species react irreversibly to form a third species, P. Find the reactor concentration of each species as a function of time. [16]

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1. Two similar vertical cylindrical tanks 6 ft in diameter and 10 ft high are placed side by side with their bottoms at the same level. They are connected at the bottom by a tube 2 ft long and 0.4 in ID. Tank A is full of oil, and tank B is empty. Tank A has an outlet at the bottom, consisting of a short tube 1 ft long and 0.4 in inner diameter. Both this outlet tube and the connected tube between the tanks are horizontal. Both tubes are opened simultaneously. What is the maximum oil level reached in tank B? Assume streamline or Viscous flow to occur in the small connecting and outlet tubes. [16]

2. The data on the thermal decomposition of N_2O_5 at constant volume at 55^0C.

Time, min	Total pressure mm Hg	Time, min	Total pressure mm Hg
0	331.2	14	589.4
3	424.5	16	604.0
4	449.0	18	616.3
6	491.8	22	634.0
8	524.8	26	646.0
10	551.3	Infinite	673.7

The reaction is $2N_2O_5 \rightarrow 2N_2O_4 + O_2$

but the tetroxide dissociates to form NO_2, with which it is in constant equilibrium. The main reaction has been shown to be not reversible and the N_2O_5 has been shown to exist as such, and not as a polymer. Making due allowance for the equilibrium between N_2O_4 and NO_2, determine the order of the reaction (test two possibilities) by plotting the data in such way as to obtain a straight line for the correct mechanism. [16]

3. If the three thermodynamic variables P, V, and T are connected by a relation (P,V,T) = 0 show that :
$\left(\partial p/\partial T\right)_V \left(\partial T/\partial V\right)_P \left(\partial V/\partial P\right)_T = -1$ [16]

4. (a) Find the maximum and minimum distances form origin to the curve $5x^2 + 6xy + 5y^2 - 8 = 0$
   (b) The temperature T at any point (x,y,z) in space is $T = 400xyz^2$. Find the highest temperature on the surface of the unit sphere $x^2 + y^2 + z^2 = 1$ [8+8]

5. If A = i - 2j + k, B = 2i - 4j + 6k, Verify that $\nabla(A.B) = A.\nabla B + B.\nabla A + AX(\nabla XB) + BX(\nabla XA)$. [16]

6. (a) Explain the concept of line integral. Define circulation of a vector.

(b) Evaluate the line integral $\int_c F\,dr$ where $F = 3xyi + y^2j$ and the space curve c is the Curve in the xy- plane $y = 2x^2$ from (0, 0) to (1, 2). [6+10]

7. Imagine a slab which extends indefinitely in the x direction and so arranged that heat flows in the x direction only. At time t = 0, suppose that the temperature distribution inside the slab is given by T = f(x). Now expose the slab face at x = 0 to a constant-temperature medium at T_1. The heat-transfer coefficient between the medium and the slab surface is constant at a value h. The temperature variation of the physical properties of the material forming the slab may be neglected. Determine the temperature distribution within the slab. [16]

8. Solve the following differential equations using the laplace transform method.

   (a) $\frac{d^2x}{dt^2} + \left(\frac{a}{mk}\right)\frac{dx}{dt} + \frac{k}{m}x = 0$. Where a, k and m are the constants and x(0) = $x^1(0) = 0$

   (b) Prove that $L\left(\frac{d^2f}{dt^2}\right) = s^2f(s) - sf(0) - \left(\frac{df}{dt}\right)_{t=0}$. [8+8]

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1. (a) Write about the formulation of differential equation of physical problem.
   (b) Discuss a flow process in which a precipitation is being carried out by mixing two streams A and B to form a third stream C in which the precipitate is carried away. [6+10]

2. A container is maintained at a constant temperature of 800^0F and is fed with a pure gas A at a steady react of 1 lb mole/min, the product gas steam is with drawn from the container at the rate a necessary to keep the total pressure constant at a value of 3 atm. The container contents are vigorously agitated, and the gas mixture is always well mixed. The following irreversible second order gas-phase reaction occurs in the container $2A \rightarrow B$
   At a temperature of 800^0F, the reaction-rate constant for the reaction has the numerical value of $1,000 ft^3/lbmole/min$. Both A and B are perfect gases. Because of their low temperature, no reaction occurs in the lines leading to and from the vessel. If, under steady-state conditions, the product stream is to contain $33\frac{1}{3}$ mole % B, how large in cubic feet should be the volume of the reaction container? [16]

3. (a) If the kinetic energy $K = \omega v^2/2g$. find approximately the change in the kinetic energy as w changes from 49 to 49.5 and v changes form 1600 to 1590.
   (b) Find the possible percentage error in computing the resistance r from the formula $1/r = 1/r_1 + 1/r_2$ if r_1 and r_2 are both in error by 2%. [6+10]

4. P is a function of both x and y as given by $P = Ax + B\frac{xy-a}{y} + \frac{c}{(xy)^{-1/2}}$
   where A, B, and C are constants. Obtain expressions for the values of x and y corresponding to maximum or minimum values of P. [16]

5. (a) Explain in detail the concept of unit vector.
   (b) Find a unit vector parallel to the sum of the vectors $R_1 = 2i + 4j - 5k$ and $R_2 = i + 2j + 3k$. [6+10]

6. (a) Explain the concept of line integral. Define circulation of a vector.
   (b) Evaluate the line integral $\int_c F\,dr$ where $F = 3xyi + y^2j$ and the space curve c is the Curve in the xy- plane $y = 2x^2$ from (0, 0) to (1, 2). [6+10]

7. A solid sphere of radius R is placed in an incompressible, inviscid fluid of infinite extent. The flow was initially uniform and parallel to the z axis, flowing with a speed V_0 in the negative z direction. It is desired to determine the velocity of the fluid after the sphere is placed in the flow and steady-state has been achieved.[16]

8. Invert the following Laplace transforms
   (a) $\frac{s-1}{s(s+2)}$
   (b) $\frac{1}{(s^2+4)(s^2+1)}$
   (c) $\frac{sA+B}{(s+i\omega)(s-i\omega)}$. [4+6+6]

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1. The calculations in the design of rectifying columns assume perfect mixing on each plate and that the composition of the liquid leaving the plate is the same as that of the liquid at every point on the plate. These conditions do not exist on the plates in any real column. Determine the effect of actual concentration gradients on the rectification of a binary mixture. [16]

2. In a chemical reaction in which two substances A and B initially of amount a and b respectively are connected, the velocity of transformation $\frac{dx}{dt}$ at any time t is known to be equal to the product (a - x) (b - x) of the amounts of the substances then remaining untransformed. Find t in terms of x if a = 0.7, b = 0.6 and x = 0.3 when t = 300 seconds. [16]

3. (a) For the case of a cylinder, discuss the conditions for one dimensional heat conduction in a radial direction.
   (b) A hollow cylinder $a \leq r \leq b$ has its boundary surface at r = a and r = b maintained at uniform temperatures T_1 and T_2 respectively. The thermal conductivity varies with temperature in the form $K = K_0(1+bT)$. Determine a relation for the heat flow through the cylinder per unit length of the cylinder. [6+10]

4. (a) Find the minimum value of $x^2 + y^2 + z^2$ given that
      i. $xyz = a^3$
      ii. $Ax + bx = cz = P$
   (b) Given $x + y + z = a$. Find the maximum value of $x^m y^n z^p$. [8+8]

5. (a) Show that the points -6i + 3j + 2k, 3i - 2j + 4k, 5i + 7j + 3k and -13i + 17j - k are coplanar.
   (b) Find a unit vector normal to the plane of A = 3i - 2j + 4k and B = i + j - 2k. [8+8]

6. (a) Explain the concept of line integral. Define circulation of a vector.
   (b) Evaluate the line integral $\int_c F\,dr$ where $F = 3xyi + y^2 j$ and the space curve c is the Curve in the xy- plane $y = 2x^2$ from (0, 0) to (1, 2). [6+10]

7. Determine the equation relating the steady-state temperature of position in an isotropic rectangular parallelepiped are $0 \leqq x \leqq L$, $0 \leqq y \leqq D$, $0 \leqq z \leqq H$. Five sides are maintained at the temperature T_0, and the remaining face (corresponding to z = H) is maintained at the temperature T_1. [16]

8. Find the Laplace inverse transform following functions.

   (a) $\frac{s}{s^2-2s+5}$

   (b) $\frac{k_p}{s(\tau_p s+1)^2}$ $Where\, k_p\, and\, \tau_p\, are\, constants.$

   (c) $\frac{k_c}{(s+1)(5s+1)\left(\frac{s}{2}+1\right)}$ $where\, k_c\, is\, constant.$ [4+6+6]

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