

III B.Tech II Semester Supplementary Examinations, Apr/May 2008  
**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) 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. It has been proposed that in the chlorination of methane the chlorine attacks the methane and its substituted chlorine deviation in a statistical fashion. Every molecule is assumed to have an equal chance of undergoing collision with a chlorine molecule, and the probability that such a collision results in reaction is proportional to the number of hydrogen atoms remaining on the carbon atom. Assume that the above postulated mechanism is corrects. If chlorine is added to a system originally containing pure methane, determine the fraction of methane converted to each of the four possible chlorination products,  $(CH_3Cl, CH_2Cl_2, CHCl_3, CCl_4)$  as a function of the total fraction of methane corrected. [16]
  
3. If the HP required to propel a stream varies as the cube of the velocity and square of the length, prove that a 3% increase in velocity and 4% increase in length will require an increase of about 17% in HP. [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. (a) Find the moment of force  $F = 2i + 2j + k$  acting at the point (1,-2,1) about z-axis.  
 (b) Gravitational force with components (5,-4, 2) acts on a body represented by a point P which is at a distance 3 unit from the origin. If the moment of the force about origin has components (12, 8,-14). Find the coordinates of P. [8+8]
  
6. Consider the two dimensional motion of an ideal fluid of constant density.
  - (a) Show that the stream function  $\psi$  defined by  $(\partial\psi/\partial x) = -V_y$   $(\partial\psi/\partial y) = V_x$  Satisfies momentum and continuity equations if  $\nabla^2\psi = 0$ . Is it necessary that the flow is irrotational?
  - (b) Show that the line  $\psi = \text{constant}$  is a stream line.

- (c) Show that the lines of constant  $\emptyset$  are normal to lines of constant  $\psi$ . [6+6+4]
7. Suppose that a slab (extending indefinitely in the y and z directions) at an initial temperature  $T_1$  has its two faces suddenly cooled to  $T_0$ . What is the relation between temperature, time after quenching, and position within the slab? [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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1. A tank contains 1000 gallons of brine in which 4000 lb of salt are dissolved. Fresh water runs into the tank at the rate of 8 gallons / minute and the mixture kept uniform by stirring, runs out at the same rate. How long will it be before only 200 lb of salt is left in the tank? [16]
2. In an experimental study of the specification of methyl acetate by sodium hydroxide, it is found that 25 percent of the ester is converted to alcohol in 12 min when the initial concentration of both ester and caustic are 0.01M. What conversion of ester would be obtained in 1 hr. if the initial ester and caustic are 0.01M? What conversion of ester would be obtained in 1 hr. if the initial ester concentration were 0.025 M and the initial caustic concentration 0.015M? [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 maximum and minimum distances from 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) Find the moment of force  $F = 2i + 2j + k$  acting at the point  $(1, -2, 1)$  about z-axis.  
 (b) Gravitational force with components  $(5, -4, 2)$  acts on a body represented by a point P which is at a distance 3 unit from the origin. If the moment of the force about origin has components  $(12, 8, -14)$ . Find the coordinates of P. [8+8]
6. (a) Obtain the expressions for  $\nabla \cdot \vec{F}$ ,  $\nabla \times \vec{F}$  and  $\nabla^2 f$  in spherical polar coordinates from the corresponding expressions in orthogonal curvilinear coordinates.  
 (b) Express  $zi - 2xj + yk$  in cylindrical coordinates. [8+8]
7. Determine the equation relating the steady-state temperature of position in an isotropic rectangular parallelepiped are  $0 \leq x \leq L$ ,  $0 \leq y \leq D$ ,  $0 \leq z \leq H$ . 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. Solve the following differential equations using the laplace transform method.

(a)  $\frac{d^2y}{dt^2} + 4y = 3$  Where  $y(0) = y'(0) = 1$

(b)  $\frac{dC_A(t)}{dt} + \left(\frac{1}{\tau} + K\right) C_A(t) = \frac{1}{\tau} C_{A0}(\tau)$

Where K and  $\tau$  are the constants and  $C_A(0) = 0$  and  $C_{A0}$  and  $C_A$  are the input and output concentrations respectively. [8+8]

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1. A tank contains  $100ft^3$  of fresh water,  $2ft^3$  of brine, having a concentration of 1 pc 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. In an experimental study of the specification of methyl acetate by sodium hydroxide, it is found that 25 percent of the ester is converted to alcohol in 12 min when the initial concentration of both ester and caustic are 0.01M. What conversion of ester would be obtained in 1 hr. if the initial ester and caustic are 0.01M? What conversion of ester would be obtain in 1 hr. if the initial ester concentration were 0.025 M and the initial caustic concentration 0.015M? [16]
3. If the HP required to propel a stream varies as the cube of the velocity and square of the length, prove that a 3% increase in velocity and 4% increase in length will require an increase of about 17% in HP. [16]
4. Discuss the maxima and minima of
  - (a)  $x^3y^3(1-x-y)$
  - (b)  $2(x^2-y^2) - x^4 + y^4$  [8+8]
5. (a) Define a vector. Distinguish between vectors and scalars by giving examples.  
 (b) Explain the laws of vector addition and subtraction. [8+8]
6. (a) Evaluate  $\int \int_S \bar{F} \cdot \hat{n} ds$  where  $\bar{F} = yzi + zxj + xyk$  and S is that part of the surface of the sphere  $x^2 + y^2 + z^2 = 1$  which lies in the first octant.  
 (b) Show that:  $\bar{F} = (y^2 \cos x + z^3)i + (2y \sin x - 4)j + (3xz^2 + 2)k$  is a conservative field. Find the work done in moving a particle in this field from  $(0,1,-1)$  to  $(\frac{\pi}{2}, -1, 2)$ . [8+8]
7. A solid cylinder of infinite length and radius R has an initial temperature distribution  $T = f(r)$ , where r is the local radius. The surface at  $r=R$  is suddenly brought to and maintained at the temperature  $T_1$ . Determine the interior temperature as a function of time. Compute the temperature distribution if  $T = f(r) = T_o = 70^\circ F$ ,  $T_1 = 1500^\circ F$ ,  $R = 2$  ft, and the solid is steel. [16]
8. Solve the following differential equations using the laplace transform method.
  - (a)  $\frac{d^2y}{dt^2} + 4y = 3$  Where  $y(0) = y'(0) = 1$

(b)  $\frac{dC_A(t)}{dt} + \left(\frac{1}{\tau} + K\right) C_A(t) = \frac{1}{\tau} C_{A0}(\tau)$

Where K and  $\tau$  are the constants and  $C_A(0) = 0$  and  $C_{A0}$  and  $C_A$  are the input and output concentrations respectively. [8+8]

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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. Discuss about the rate equations for Homogeneous chemical reactions. [16]
3. Derive an expression for the heat flow rate through a hollow sphere of ID  $d_1$  and OD  $d_2$  whose internal and external surfaces are maintained at temperatures  $T_1$  and  $T_2$  respectively. The thermal conductivity varies linearly with temperature from  $K_1$  at  $T_1$  to  $K_2$  at  $T_2$ . [16]
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) Find a unit vector parallel to the plane containing the vector  $\mathbf{i} + \mathbf{j} - 2\mathbf{k}$  and  $3\mathbf{i} - 2\mathbf{j} + \mathbf{k}$  but parallel to  $2\mathbf{i} + 2\mathbf{j} - \mathbf{k}$ .  
 (b) Prove that  $[\overline{ABC}] (\bar{a}x\bar{b}) = \begin{vmatrix} \bar{A}.\bar{a} & \bar{A}.\bar{b} & \bar{A}.\bar{c} \\ \bar{B}.\bar{a} & \bar{B}.\bar{b} & \bar{B}.\bar{c} \\ \bar{C}.\bar{a} & \bar{C}.\bar{b} & \bar{C}.\bar{c} \end{vmatrix}$  [8+8]
6. (a) Explain the concept of surface integral. Write the divergence theorem  
 (b) If velocity vector is  $\mathbf{F} = y\mathbf{i} + z\mathbf{j} + xz\mathbf{k} (ft/s)$ , show that the flux of water through the parabolic cylinder  $y = x^2$ ,  $0 \leq x \leq 3$ ,  $0 \leq z \leq 2$  is  $69(ft^3/s)$ . Use the concept of Surface integral. [8+8]
7. An infinitely wide flat plate is maintained at a constant temperature  $T_o$ . The plate is immersed in an infinitely wide and thick stream of constant-density fluid originally at temperature  $T_1$ . If the origin of coordinates is taken at the leading edge of the plate, a rough approximation to the true velocity distribution is  $V_x = \beta y$  ( $\beta$  is a constant)  $V_y = 0$   $V_z = 0$ . Turbulent heat transfer is assumed negligible, and molecular transport of heat is assumed important only in the y direction. The thermal conductivity of the fluid,

k, is assumed constant. Determine the temperature distribution within the fluid and the heat-transfer coefficient between the fluid and the plate. [16]

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

(a)  $\frac{d^2y}{dt^2} + 4y = 3$  Where  $y(0) = y'(0) = 1$

(b)  $\frac{dC_A(t)}{dt} + \left(\frac{1}{\tau} + K\right) C_A(t) = \frac{1}{\tau} C_{A0}(\tau)$

Where K and  $\tau$  are the constants and  $C_A(0) = 0$  and  $C_{A0}$  and  $C_A$  are the input and output concentrations respectively. [8+8]

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