2017-2018  
SECOND YEAR B.TECH. EXAMINATION  
Chemical Engineering/Petroleum Studies  
Higher Mathematics  
AM-241

Maximum Marks: 60
Answer all the questions. Assume suitable data if missing.  
Notations used have their usual meaning. Programmable calculators are not allowed.

1(a)  
(i) Write the parametric representation of the surface \( z = x^2 + y^2 \) as \( \mathbf{r} = \mathbf{r}(u,v) \) where \( u \) and \( v \) are two independent parameters.  
(ii) Given the circular helix \( \mathbf{r}(t) = \cos t \mathbf{i} + \sin t \mathbf{j} + ct \mathbf{k}, 0 \leq t \leq 2\pi \), express the position vector \( \mathbf{r}(t) \) in terms of the arc length \( s \).

OR

1(a')  
(i) Find \( \nabla \phi \) if \( \phi = r^m \) where \( m \) is a positive integer.  
(ii) Find the parametric representation of the tangent vector to the curve \( x = t^3, y = 1 + \frac{1}{t}, z = t^2 + 1 \) at \( t = 2 \).

1(b)  
Find the constants \( a, b \) and \( c \) so that the vector field \( \mathbf{v} = (x + 2y + az) \mathbf{i} + (bx - 3y - z) \mathbf{j} + (4x + cy + 2z) \mathbf{k} \) is irrotational. Also find the scalar field \( \phi \) such that \( \nabla \phi = \mathbf{v} \).

2(a)  
If \( \mathbf{A} = (3x^2 + 6y) \mathbf{i} - 14yz \mathbf{j} + 20xz^2 \mathbf{k} \), evaluate \( \int_c \mathbf{A} \cdot d\mathbf{r} \) from \((0,0,0)\) to \((1,1,1)\) along the following two paths: (i) \( x = t, y = t^2, z = t^3 \) and (ii) the straight line from \((0,0,0)\) to \((1,0,0)\), then to \((1,1,0)\), and then to \((1,1,1)\).  
Also explain whether the vector field \( \mathbf{A} \) is conservative.
2(b) Use the divergence theorem to evaluate \( \iint_S \vec{F} \cdot d\vec{S} \) where \( \vec{F} = xy^2\vec{i} + yz^2\vec{j} + x^2z\vec{k} \) and \( S \) is the surface of the hemisphere \( x^2 + y^2 + z^2 = 9 \) above the \( xy \) plane and bounded below by the plane \( z = 0 \).

OR

2(b') Evaluate \( \iint_S (y^2z\vec{i} + y^3\vec{j} + xz\vec{k}) \cdot d\vec{S} \) where \( S \) is the surface of the cube defined by \(-1 \leq x \leq 1, -1 \leq y \leq 1, \) and \( 0 \leq z \leq 2 \).

3(a) Evaluate

\[
\begin{align*}
&\text{(i)} \quad L\{f(t)\}, \text{ where } f(t) = \sin t, 0 \leq t \leq \pi \quad \text{and} \quad f(t + \pi) = f(t) \\
&\text{(ii)} \quad L^{-1}\left\{\frac{s^2}{(s^2+1)^2}\right\}
\end{align*}
\]

3(b) Solve \((D^2 - D - 2)x = 20 \sin 2t, \quad x(0) = -1, x'(0) = 2\) by Laplace transform method.

4(a) Solve the steady state two dimensional Laplace equation \( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0 \) by method of separation of variables under the following conditions: \( u(0,y) = 0, \) for \( 0 \leq y \leq b; \quad u(x,0) = 0, \) for \( 0 \leq x \leq a; \quad u(a,y) = 0, \) for \( 0 \leq y \leq b \) and \( u(x,b) = u_0 \sin \frac{\pi}{2a} x, \) for \( 0 \leq x \leq a. \) Consider \( \lambda = k^2 > 0. \)

OR

4(a') Find the steady state temperature \( u(r, \theta) \) in the semi-circular plate represented by the following boundary value problem: \( \frac{\partial^2 u}{\partial r^2} + \frac{1}{r} \frac{\partial u}{\partial r} + \frac{1}{r^2} \frac{\partial^2 u}{\partial \theta^2} = 0, \) for \( 0 < r < 2, \)
\[
\begin{align*}
&u(2, \theta) = u_0, \quad 0 < \theta < \pi; \quad u(r,0) = 0, \quad u(r,\pi) = 0, \quad 0 < r < 2.
\end{align*}
\]

(b) Find the temperature \( u(x,t) \) in a rod of length 2 if \( u(0,t) = 0 \) and \( u(2,t) = 0 \) for \( t > 0 \) and if \( u(x,0) = f(x) \) equals
\[
\begin{cases}
  x, & 0 < x < 1 \\
  0, & 1 < x < 2
\end{cases}
\]

for \( t > 0 \) and if \( u(x,0) = f(x) \) equals
\[
\begin{cases}
  x, & 0 < x < 1 \\
  0, & 1 < x < 2
\end{cases}
\]
1(a) A mixture of CH₄ and C₂H₆ has average molecular weight of 22.4. What is the composition of the mixture in mole fraction?

1(b) In the vapor-phase hydration of ethylene to ethanol, diethyl ether is obtained as byproduct

\[
\begin{align*}
C_2H_4 + H_2O &\rightarrow C_2H_5OH \\
2C_2H_4 + H_2O &\rightarrow (C_2H_5)_2O
\end{align*}
\]

The feed consisting of 60% ethylene, 37% steam, and 3% inerts on molar basis is sent to the reactor. The product gas is analysed to contain 43.89% ethylene, 14.37% ethanol, 1.80% ether, 26.35% water, and 3.59% inerts. Determine the extent of both reactions, fractional conversion of ethylene, yield of ethanol, and selectivity of ethanol production relative to ether.

OR

1'(a) Is the following equation dimensionally homogeneous?

\[
\Delta P = \frac{14L\bar{V}\mu}{D^2}
\]

where,

\[
\begin{align*}
\Delta P &= \text{Pressure drop (lb/ft}^2) \\
L &= \text{Pipe length (ft)} \\
\bar{V} &= \text{Fluid velocity (ft/s)} \\
\mu &= \text{Fluid viscosity (lb/ft} \cdot \text{s)} \\
D &= \text{Pipe diameter (ft)}
\end{align*}
\]
If so, are the units consistent? If not, what factor must be added to the right hand side of the equation to provide consistency?

1'(b) A gaseous mixture containing 20 mol% ethanol and 80 mol% carbon dioxide has a molar volume equal to \(2.0 \times 10^{-4}\) m\(^3\)/mol at 500 K. the critical parameters are; ethanol \((P_c = 6383\) kPa, \(T_c = 516.3\) K) and carbon dioxide \((P_c = 7382\) kPa, \(T_c = 304.1\) K). Using the Kay’s method, calculate the pressure of the gas.

2(a) Differentiate between the terms differential balance and integral balance. How the integral balances on semi batch and/or continuous processes can be obtained from the differential balances of these processes?

2(b) A stream containing 5.15 wt% chromium (Cr) is contained in the wastewater from a metal finishing plant. The wastewater stream is fed to a treatment unit that removes 95% of the chromium in the feed and recycles it to the plant. The residual liquid stream leaving the treatment unit is sent to a waste lagoon. The treatment unit has a maximum capacity of 4500 kg wastewater/h. The wastewater in excess of the maximum capacity of the treatment unit bypasses the unit and combines with the residual liquid leaving the unit, and the combined stream goes to the waste lagoon. Calculate the flow rate of liquid to the waste lagoon, (kg/h), and the mass fraction of Cr in this liquid, (kg Cr/kg).

OR

\(\text{cond}_{-3}\)
2 (b') The reaction \( A \rightarrow 2B + C \) takes place in a catalytic reactor. The reactor effluent is sent to a separator. The overall conversion of \( A \) is 95%. The separator has two output streams; product stream that consists of \( B, C \), and 0.5% of \( A \) entering the separator, and the recycle stream containing the remainder of \( A \) and 1% of \( B \) entering the separator. Calculate the single pass conversion of \( A \) in the reactor and molar ratio of recycle to feed.

3(a) Water flows through the system shown in Figure below, at a rate of 20 L/min. Estimate the pressure required at point 1 if friction losses are negligible.

OR

3(a') Define the term flow work related to an open system. Obtain the expression for the flow work in an open system having multiple input and output streams in terms of pressure and volumetric flowrate of the streams.

3(b) A gaseous mixture at 600 K and 1 bar consisting of methane and steam in the ratio of 1:2 by mole is sent to a reactor where the following reaction occurs.

\[
\text{CH}_4 (g) + \text{H}_2\text{O} (g) \rightarrow \text{CO} (g) + 3\text{H}_2 (g)
\]

\[
\text{CO} (g) + \text{H}_2\text{O} (g) \rightarrow \text{CO}_2 (g) + \text{H}_2 (g)
\]

The standard heats of reaction of these reactions are 206.284 kJ/mol and – 41.20 kJ/mol respectively. Methane is completely converted during the reaction and the product stream contains 17 mol% CO. Heat is supplied to the reactor so that the products reach a temperature of 1300 K. The mean heat capacities in the temperature range 298-600 K are 43.8 kJ/kmol·K for methane and 34.8 kJ/kmol·K for steam, and the mean heat capacities in the temperature range 298-1300 K are 31.8 kJ/kmol·K for CO, 29.8 kJ/kmol·K for hydrogen, 50.1 kJ/kmol·K for CO, and 31.8 kJ/kmol·K for steam, respectively. Calculate
the heat requirement for the reactor per kmol methane fed to reactor.

4(a) Water is added at varying rates to a 300-liter holding tank. When a valve in a discharge line is opened, water flows out at a rate proportional to the height and hence to the volume of water in the tank. The flow of water into the tank is slowly increased and the level rises in consequence, until at a steady input rate of 60.0 L/min the level just reaches the top but does not spill over. The input rate is then abruptly decreased to 20.0 L/min. Calculate the time in minutes required for the volume to decrease to within 1% of its steady-state value.

4(b) Air at 30 °C and 80% relative humidity is cooled to 10 °C at a constant pressure of 1 atm. Use the psychrometric chart to calculate the fraction of water that condenses and the rate at which the heat must be removed to deliver 30 m³/min of humid air at the final condition.

contd...5.
Psychrometric Chart, Ref: H2O (l, 0 °C, 1atm); Dry Air (0 °C, 1atm)
1(a) Give the rheological classification of fluids.

1(b) State and prove Pascal’s law.

1(c) Figure 1 shows a conical vessel having its outlet at A to which a U-tube manometer is connected. The reading of the manometer given in the Figure 1 is for the condition when the vessel is empty. Find the reading of the manometer when the vessel is completely filled with water.

Given: Specific gravity of mercury = 13.6

Empty Vessel

Vessel filled with water

Figure 1

OR

1'(c) A multitube manometer is employed to determine the pressure in a pipe. For the levels in the manometer as shown in Figure 2, compute the pressure in pipe.
2(a) Derive the equation of continuity in differential form for a 3-dimensional steady incompressible flow. [CO3]

OR

2'(a) Derive Bernoulli's equation for flow of an incompressible fluid. State clearly the assumptions made. Also explain why kinetic energy correction factor is required in the equation. [CO4]

2(b) Define rotational and irrotational flow. The stream function and velocity potential for a flow are given by $\Psi = 2xy, \varphi = x^2 - y^2$ Show that the conditions of continuity and irrotational flow are satisfied. [CO4]

2(c) A pipe of diameter 400 mm carries water at a velocity of 25 m/s. The pressures at the point A & B are given as 29.43 N/cm² and 22.563 N/cm² respectively while the datum head at A and B are 28 m and 30 m. Find the loss of head between A and B. [CO5]

3(a) What are the different laws on which models are designed for dynamic similarity? Give their significance and uses. [CO6]

3(b) Using Buckingham's $\pi$ theorem, show that the velocity through a circular orifice is given by $V = \sqrt{2gH \varphi \left(\frac{D}{H}, \frac{\mu}{\rho VH}\right)}$

where $H$ is the head causing flow, $D$ is the diameter of the orifice, $\mu$ is the coefficient of viscosity, $\rho$ is the mass density and $g$ is the acceleration due to gravity. [CO6]

OR

3'(b) A ship 300 m long moves in sea water whose density 1030 kg/m³. A 1:100 model of this ship is to be tested in a wind tunnel. The velocity of air in the wind tunnel around the model is 30 m/s and the resistance of the model is 60 N. Determine the velocity of ship in sea water and also the resistance of ship in sea water. The density of air is given as 1.24 kg/m³. Take kinematic viscosity of sea water and air as 0.012 stokes and 0.018 stokes respectively. [CO6]

4(a) Differentiate the following:
   i. Variable head meter and variable area meter [CO7]
   ii. Notches and weirs

OR

4'(a) Write a brief note on the choice of selection of pumps. [CO7] [04]
4(b) An orificemeter with diameter 15 cm is inserted in a pipe of 30 cm diameter. The pressure difference measured by a mercury oil differential manometer on the two sides of the orificemeter gives a reading of 50 cm of mercury. Find the rate of flow of oil of specific gravity 0.9 when the coefficient of discharge of the meter is 0.64.

4(c) Describe the working principle of a centrifugal pump. Also write the expression for head developed by a centrifugal pumps.
<table>
<thead>
<tr>
<th>Q.No</th>
<th>Questions</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>A direct-current circuit comprises two resistors, A of value 25 ohms, and B of unknown value, connected in parallel, together with a third resistor C of value 5 ohms connected in series with the parallel group. The potential difference across C is found to 90 V. If the total power in the circuit is 4320 W, Calculate (a) the value of resistor B, (b) the voltage applied to the ends of the whole circuit, (c) the current in each resistor.</td>
<td>[06]</td>
</tr>
<tr>
<td>1(b)</td>
<td>What is forced and transient response of an AC circuit? Analyse the natural response of a RC network.</td>
<td>[06]</td>
</tr>
</tbody>
</table>

**OR**

<table>
<thead>
<tr>
<th>Q.No</th>
<th>Questions</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(b')</td>
<td>For the circuit of Figure 1, find the expression for $v_c(t)$ after the switch is closed. The initial value of $V_c = 4$ volts.</td>
<td>[06]</td>
</tr>
</tbody>
</table>

![Figure 1](image_url)

*Figure 1*
2(a) A 500V, 6pole, 50Hz, 3 phase induction motor develops 20 kW inclusive of mechanical losses when running at 995rpm, the power factor being 0.87. Calculate (a) the slip (b) the rotor $I^2R$ loss (c) the total input if the stator loss is 1500W (d) line current (e) the rotor current frequency.

2(b) Explain in brief the basic principle of operation of a three phase induction motor. Draw the speed-torque characteristics of a 3 phase induction motor.

OR

2(b') Explain why synchronous motor is not self starting. Discuss any one starting method of synchronous motors.

3(a) What is the need of starter in DC motors. Explain the working of a 3-point DC shunt motor starter.

3(b) Draw current-torque, current-speed and torque-speed characteristics of DC series and DC shunt motors.

OR

3(b') Draw and briefly explain the construction of a DC motor with the help of neat diagram.

4(a) What are the different static characteristics of Measuring System. Define them. If voltmeter of range 0-150V has an error of 1%, find the percentage error when voltmeter reads 75V.

4(b) State the advantages of Electric Heating. What are the different methods for Electric Heating. Explain in detail Induction Heating with the help of suitable diagram.

OR

4(b') Write short notes on
(a) Static Energy Meters
(b) Induction furnaces

5(a) Draw the schematic diagram (Architecture) of 8085 microprocessor.

5(b) What is the function of a register? Discuss in brief different types of registers in an 8085 microprocessor.
2017-18
B.TECH. (AUTUMN SEMESTER) EXAMINATION
PETROCHEMICAL/CHEMICAL ENGINEERING
FLUID- PARTICLE OPERATIONS
PK-233/CH-214

Maximum Marks: 60
Credits: 04
Duration: Two Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.
Use of Graph paper is allowed.

Q.No. Question M.M.

1(a) Describe the following [07]
(i) Sieve analysis and its limitations.
(ii) Different flow pattern of solid mass-out from storage vessels.

1(b) Material is fed to a standard screen and separated into oversize and underrise streams. The mass flow rate of feed, overflow, and underflow are F, D, and B, respectively and the mass fraction of oversize material in feed, overflow, and underflow are X_F, X_D, and X_B. If D is the desired product then derive the expressions for recovery, rejection, and overall efficiency (E_C) of the screen. Calculate E_C if F = 15 kg/h, B = 10 kg/h, X_F = 0.47, and X_D = 0.85.

OR

1(b') The screen analysis shown in Table 1 applies to a sample of crushed quartz. The [08] density of the particles is 2650 kg/m³ and the shape factors are a = 0.8 and Φ = 0.571. Calculate:
(i) A_w (specific surface area) in mm²/g
(ii) volume-surface mean diameter (D_v)
(iii) mass mean diameter (D_m)
(iv) volume mean diameter (D_v)

Table 1

<table>
<thead>
<tr>
<th>Screen opening, D_r (mm)</th>
<th>4.699</th>
<th>3.327</th>
<th>2.362</th>
<th>1.651</th>
<th>1.168</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass fraction</td>
<td>0.574</td>
<td>0.169</td>
<td>0.152</td>
<td>0.068</td>
<td>0.057</td>
</tr>
</tbody>
</table>

contd...
2(a) Mention the name of various types of tumbling mills and discuss the difference among them.

2(b) Describe the effects of various factors on the crushing process.

OR

2(b') Write the generalized equation which can be used for various crushing laws and derive those laws from the generalized equation for different values of n (order of differential equation).

2(c) Trap rock (work index = 19.32) of nearly uniform 2-inch spheres is crushed. The differential screen-analysis of the product is given in the Table 2. The feed rate is 110 ton/h. Use the Bond's law to estimate the power necessary per ton of rock.

<table>
<thead>
<tr>
<th>Mesh</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>14</th>
<th>20</th>
<th>28</th>
<th>35</th>
<th>48</th>
<th>65</th>
<th>&lt;65</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_{50} (mm)</td>
<td>3.327</td>
<td>2.362</td>
<td>1.651</td>
<td>1.168</td>
<td>0.833</td>
<td>0.589</td>
<td>0.417</td>
<td>0.295</td>
<td>0.208</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>X_c</td>
<td>0.031</td>
<td>0.103</td>
<td>0.2</td>
<td>0.156</td>
<td>0.152</td>
<td>0.12</td>
<td>0.095</td>
<td>0.065</td>
<td>0.043</td>
</tr>
</tbody>
</table>

3(a) Explain the difference between (ANY TWO) [04]
(i) Classification and jigging
(ii) Agitation and mixing
(iii) Free settling and Hindered settling

3(b) Two miscible liquids are mixed at certain proportion using a turbine (diameter = 0.5 m) at 100 rpm. Viscosity and density of mixed liquids are 0.005 Kg/ms and 900 Kg/m³, respectively. Calculate the power consumption and blending time for a turbine of given specification (in the Table 3). Suppose, for this specific turbine, the mixing number (N_t) is found to be a function of modified power number (N_t) such that

\[ N_t = \frac{e^{-\frac{0.3N_t}{10^{12}}}}{1.5} \]

Table 3.

<table>
<thead>
<tr>
<th>Blades</th>
<th>Baffle</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
<th>S_6</th>
<th>K_1</th>
<th>K_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-flat</td>
<td>4</td>
<td>3</td>
<td>1.1</td>
<td>0.25</td>
<td>0.2</td>
<td>0.17</td>
<td>11</td>
<td>68</td>
<td>7</td>
</tr>
</tbody>
</table>

Control... 3
3(c) In Fig. 1 (settling velocity vs. time), particle A of three different sizes (solid-lines) and particle B (dashed-lines) of two different sizes are settling in a cylindrical vessel. Describe the settling behaviour of these particles shown in Fig. 1.

![Diagram of settling behavior](image)

Fig. 1

OR

3(c') In Fig. 2, a batch sedimentation process is represented through height of interface and concentration of zones. Describe the batch sedimentation process through this figure.

![Diagram of batch sedimentation](image)

Fig. 2: Height of interface and concentration of zones in batch sedimentation

4(a) Briefly explain the industrial application of packed-bed column with examples.

4(b) Explain the process of fluidization with the help of a graph between pressure drop across the bed and superficial velocity.

4(c) The ultimate filtration equation is

\[
\frac{dt}{dV} = \frac{\mu_f}{A(-\Delta P)} \left[ \frac{(\alpha V) + R_m}{A} \right]
\]

Derive the final form of the ultimate filtration equation for the filtration process at constant pressure through compressible cake.

OR

4' Describe the procedure for the "designing of batch fluidizer" in detail.