Maximum Marks: 60  Credit: 04  Duration: Two Hours

Note: Answer all the questions

Q.No. Questions  M.M.
1(a) Find the directional derivative of the function \( f = e^{2x-y-z} \) at \( P(1,1,1) \) in the direction of tangent to the curve \( x = e^{-t}, \ y = 2 \sin t + 1, \ z = t - \cos t \) at \( t=0 \).  [06]

1(b) Show that the vector field given by \( \overrightarrow{F} = (y\sin z - \sin x)i + (x\sin z + 2yz)j + (xy\cos z + y^2)k \) is irrotational. Find the scalar function \( \phi \) such that \( \overrightarrow{F} = \nabla \phi \).  [09]

2(a) Explain the idea behind the divergence theorem and verify it for \( \overrightarrow{F} = 4xzi - yj + yzk \) taken over the cube bounded by the planes \( x = 0, x = 1, y = 0, y = 1, z = 0, z = 1 \).  [08]

2(b) Verify Stokes theorem for function \( \overrightarrow{V} = (3x - y)i - 2yz^2k - 2y^2zk \), taken over the surface of the sphere \( x^2 + y^2 + z^2 = 16 \) above the xy-plane.  [07]

OR

2(b') Verify Greens theorem in the plane for \( \oint_C (xy + y^2)dx + x^2dy \), where \( C \) is the closed curve of the region bounded by \( y = x \) and \( y = x^2 \).  [08]

3(a) Solve any TWO

i. Determine the function \( f(t) \) whose Laplace transform is \( s \log \frac{s+1}{s+2} \).

ii. Verify initial and final value theorem for the function \( f(t) = t^2e^{-3t} \).

iii. Find the Laplace transform of the functions \( f(t) = \frac{1-e^t}{t} \) and \( g(t) = t^2\cos 2t \).

3(b) Solve by Laplace Transform Method the equations: \[ \frac{dx}{dt} - y = e^t, \quad \frac{dy}{dt} + x = \sin t \]

\[ \text{Control} \ldots 2 \]
given that \( x(0) = 1 \) and \( y(0) = 0 \).

OR

3(b') The current \( i \) and the charge \( q \) in a series circuit containing an inductance \( L \), a capacitance \( C \) and an e.m.f. \( L \) satisfy the equations

\[
L \frac{di}{dt} + \frac{q}{C} = E, \quad i = \frac{dq}{dt}.
\]

Express \( i \) and \( q \) in terms of time \( t \), given that \( L, C, E \) are constants and that the initial values of \( i \) and \( q \) are both zero.

4(a) If a string of length \( l \) is initially at rest in its equilibrium position and each of its points is given a velocity \( v \) such that

\[
v = cx \quad \text{for} \quad 0 < x \leq \frac{l}{2}
\]

\[
= c(l - x) \quad \text{for} \quad \frac{l}{2} < x \leq l,
\]

Show that the displacement at any time \( t \) is given by

\[
y = \frac{4ct^2}{\alpha n^3} \left[ \sin \frac{\pi x}{l} \sin \frac{\pi at}{l} - \frac{1}{3^3} \sin \frac{3\pi x}{l} \sin \frac{3\pi at}{l} + \ldots \right]
\]

OR

4(a') A rod of length \( l \) has its ends A and B kept at \( 0^\circ C \) and \( 100^\circ C \) respectively, until steady-state conditions prevail. If the temperature at B is reduced suddenly to \( 0^\circ C \) and kept so, while that of A is maintained, find the temperature \( u(x, t) \) at a distance \( x \) from A and at time \( t \).

4(b) Find particular solutions of the Laplace equation

\[
\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0,
\]

by the method of separation of variables.
1(a) Define average molecular weight. Calculate the average molecular weight of the mixture containing 10.0 mole% ethanol, 75.0 mole% ethyl acetate, and 15.0 mole% acetic acid. The molecular weights of ethanol, ethyl acetate, and acetic acid are 46.07 kg/kmol, 88.10 kg/kmol, and 60.05 kg/kmol respectively. [CO-1]

1(b) A gas cylinder filled with nitrogen at standard temperature and pressure has a mass of 37.289 g. The same container filled with carbon dioxide at STP has a mass of 37.440 g. When filled with an unknown gas at STP, the container mass is 37.062 g. Calculate the molecular weight of the unknown gas, and then state its probable identity. [CO-1]

OR

1'(a) The heat capacity of ammonia at a constant pressure, is, over a limited temperature range, given by the expression

\[
C_p \left( \frac{\text{Btu}}{\text{lb}_m \cdot ^\circ\text{F}} \right) = 0.487 + 2.29 \times 10^{-4} T \left( ^\circ\text{F} \right)
\]

Determine the expression for \( C_p \) in J/(kg \cdot ^\circ\text{C}) in terms of \( T \) (°C) [CO-1]

1'(b) Acrylonitrile is produced in the reaction of propylene, ammonia, and oxygen:

\[
\text{C}_3\text{H}_6 + \text{NH}_3 + \frac{3}{2}\text{O}_2 \rightarrow \text{C}_3\text{H}_3\text{N} + 3\text{H}_2\text{O}
\]

The feed contains 10.0 mole% propylene, 12.0% ammonia, and 78.0% air. A fractional conversion of 30.0% of the limiting reactant is achieved. Taking 100 mol of feed as a basis, determine which reactant is limiting, the percentage by which each of the other...
reactants is in excess, and the extent of reaction.

2(a) What do you mean by differential and integral balances? How an integral balance can be obtained from the differential balance for a semibatch/continuous process?

2(b) One thousand kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and the bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 673 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol. Calculate the mass and mole fractions of methanol and the molar flow rates of methanol and water in the bottom product stream.

OR

2(b') Ethane is burned with 50% excess air. The percentage conversion of the ethane is 90%; of the ethane burned, 25% reacts to form CO and the balance reacts to form CO₂. Calculate the molar composition of the stack gas on a dry basis and the mole ratio of water to dry stack gas.

3(a) Define shaft work and flow work. Obtain the expression for the flow work for an open system.

OR

3(a') Define formation reaction. How is the heat of formation of the species in a reaction used to calculate the heat of reaction?

3(b) Calculate the heat of vaporization of water (kJ/mol) at 50 °C and low pressure using the following information. Show clearly the process path selected for the calculation.

- Heat of vaporization of water at its normal boiling point: 40.656 kJ/mol
- Heat capacity of liquid water: 75.4×10⁻³ kJ/mol·°C
- Enthalpy of water vapor at 100 °C relative to 25 °C: 2.54 kJ/mol

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.

(a) Write the equation that relates the discharge rate, \( \dot{V}_{\text{out}} \) (L/min), to the volume of water...
in the tank, \( V \) (L), and use it to calculate the steady-state volume when the input rate is 20 L/min.

(b) Write a differential balance on the water in the tank for the period from the moment the input rate is decreased \((t = 0)\) to the attainment of steady state \((t = \infty)\).

(c) Separate variables and integrate the balance equation to derive an expression for \( V(t) \).

Calculate the time in minutes required for the volume to decrease to within 1% of its steady-state value.

4(b) On a cold winter day the temperature is 2 °C and the relative humidity is 15%. You inhale air at an average rate of 5500 mL/min and exhale a gas saturated with water at body temperature, roughly 37 °C. If the mass flow rates of the inhaled and exhaled air (excluding water) are the same, the heat capacities \( C_p \) of the water-free gases are each 1.05 J/(g·°C), and water is ingested into the body as a liquid at 22 °C, at what rate in J/day do you lose energy by breathing? Treat breathing as a continuous process (inhaled air and liquid water enter, exhaled breath exits) and neglect work done by the lungs.
Psychrometric Chart, Ref: H2O (l, 32 °F, 1atm); Air (g, 0 °F, 1atm)
2016-2017
B. TECH AUTUMN (III SEMESTER) EXAMINATION
PETROCHEMICAL ENGINEERING
REACTION KINETICS AND REACTOR DESIGN
(PK - 214)
CREDITS:04

Max Marks: 60
Duration: Two Hours

Note: Answer all questions.
All questions carry equal marks.

1. (a) The irreversible reaction, \( A + B \rightarrow AB \) has been studied kinetically and the rate of formation of product has been found to be well co-related by the following reaction mechanism

\[
\begin{align*}
\text{A} + \text{B} & \xrightarrow{k_1} \text{A} \_ \text{B}^* \\
\text{A} \_ \text{B}^* & \xrightarrow{k_2} \text{AB} + \text{B}
\end{align*}
\]

The rate of formation, \( r_{AB} = kC_B^2CA \) show that the above reaction mechanism matches well the predicted rate and find the value of \( k \).

(b) Explain the merits and demerits of the batch and flow reactors for homogenous reactions with the schematic diagrams.

(c) Explain the Arrhenius plot and show that it is the best approximation of Collision and transition state theory.

2. (a) Explain the integral and differential method of analysis of data with reference to merits and demerits.

(b) Explain the shifting order of reactions with an example. Enzyme E catalyzes the transformation of reaction A to R (product) as follows:

\[
A \xrightarrow{\text{enzyme}} R, \quad r_A = \frac{200C_A C_{B_0}}{2 + C_A}, \text{mol/lit.mine}
\]

If we introduce enzyme \((C_{B_0} = 0.001 \text{ mol/litre})\) and reactant \((C_{A_0} = 10 \text{ mol/litre})\) into a reactor (batch) and let the reaction proceed. Find the time needed for the concentration of reactant drops to 0.025 mol/lit. Note that the concentration of enzyme remains unchanged during the reaction.

OR

2'. (a) A small reaction bomb fitted with a sensitive pressure measuring device is flushed out and filled with pure dimethyl ether at 140°C and 760 mm of Hg, a temperature low enough that the reaction does not proceed to any appreciable extent. The temperature is raised rapidly to 504°C and reaction is carried out isothermally at 504°C in a constant volume reactor. The stoichiometry of the reaction is as follows:

\[
(\text{CH}_3)_2\text{O} \xrightarrow{k} \text{CH}_4 + \text{H}_2 + \text{CO}
\]

Determine the rate equation in units of moles, liters and minutes which will satisfactorily fit the data

<table>
<thead>
<tr>
<th>Time, sec</th>
<th>390</th>
<th>1195</th>
<th>3155</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure increase (mm of Hg)</td>
<td>96</td>
<td>250</td>
<td>476</td>
</tr>
</tbody>
</table>
2' (b) Explain the autocatalytic reaction with the help of $x_A$ vs $t$ and $(-r_A)$ vs $C_A$ graphs.

3. (a) Define the fractional change in volume $\mu \in \varepsilon_A$. Find the fractional change $\varepsilon_A$, in volume for the following gas phase reaction:

$$A + 3B \rightarrow 6R$$

If the feed consists of A (C_{AO} = 100 moles/liter), B (200 moles/liter) and inert, I (100 moles/liter).

(b) The homogenous gas phase reaction of phosphine,

$$4\text{PH}_3(g) \rightarrow P_4(g) + 6\text{H}_2$$

proceeds at 600°C with the first order rate

$$-r_{\text{PH}_3} = (10/\text{hr})C_{\text{PH}_3}$$

What size of plug flow reactor operating at 640°C and 460 kPa can produce 80% conversion of a feed consisting of 40 mole of pure phosphine per hour. Drive the equation used.

Given: $R = 8.314 \text{ Pa.m}^3/\text{mol.k}$

OR

3' (a) Pure gaseous reactant A (C_{AO} = 100 moles/liter) is fed at a steady rate into a mixed flow reactor ($v = 1.0$ liter) where it dimerizes $2\text{A} \rightarrow \text{R}$. For a gas feed rate of, $v_O = 30.0$ liter/hr, the C_{M} obtained is 85.7 millimol/liter. Find the order of reaction if the rate constant, $k$ is 0.36 liter/hr, millimol.

3' (b) The reactor set up shown in the following figure consists of the three plug flow reactors in two parallel branches D&E. What fraction of the feed should go to the branch D if the same conversion is maintained in each branch.

3'. (c) Three reactors i.e. two mixed flow Reactors of 40 liters and 100 liters capacity and one plug flow reactor of 20 liters capacity are to be arranged in series. Arrange them in series for $n > 1$.

3'. (d) For an auto catalytic reaction, $A + R \rightarrow R + R$, if the $x_{\text{AI}}$ (final conversion) is as follows, suggest the best reactor/Reactor System.

Contd....3
For the competing aqueous reactions

\[ A + B \xrightarrow{k_1} R \text{ desired, } \quad \frac{dC_R}{dt} = 1.0 C_A^{1.5} C_B^{0.3} \text{ mol/lit.min} \]

\[ A + B \xrightarrow{k_2} R \text{ undesired, } \quad \frac{dC_S}{dt} = 1.0 C_A^{0.5} C_B^{1.8} \text{ mol/lit.min} \]

For 80% conversion of A, find the concentration of R in the product stream from a plug flow reactor. Equal flow rates of A and B streams are fed to reactor and each stream has a concentration of 10 mol/liter of reactant.

(b) Under the appropriate conditions, A decomposes as follows

\[ A \xrightarrow{k_{1}} R \xrightarrow{k_{3}} S \]

R is to be produced from 100 liter/hr of feed in which \( C_{AO} = 1.0 \text{ mol/liter, } C_{RO} = 0 \) & \( C_{SO} = 0 \). What size plug flow reactor will maximize the yield of R and \( C_{R_{\text{max}}} \) in the effluent stream?

OR

4'. (a) For the parallel decomposition of first order or reactant A,

\[ \begin{align*}
\text{A} & \xrightarrow{k_1} \text{R} \\
& \quad \quad k_1 = 10 \ e^{3500/T} \\
\text{A} & \xrightarrow{k_2} \text{S} \\
& \quad \quad k_2 = 10^8 \ e^{8500/T}
\end{align*} \]

occurring in a mixed flow reactors with space time of 1.0hr\(^{-1}\). Find the temperature which maximizes the production of R. Feed in pure A (\( C_{AO} = 1.0 \text{ mol/liter} \)). Drive the equation used.

4'. (b) The successive reactions, \( A \xrightarrow{k_{1}} R \xrightarrow{k_{2}} S \), have been carried out in a beaker.

These reactions proceed only in the presence of light and stop at the instant the light is switched off. Consider the following two ways of treating a beaker containing pure A. First the contents are irradiated all at once time, second a very small stream is continuously withdrawn from the beaker, irradiated and returned to the beaker. The rate of absorption of radiation energy is same in two cases. Is the distribution of R & S different in two beakers? Justify your answer qualitatively for all values of rate constants.

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B.TECH. (AUTUMN SEMESTER) EXAMINATION
Petrochemical Engineering
Chemistry of Hydrocarbons
COURSE CODE: PK 231

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer all the questions. Assume suitable data if missing. Notations used have their usual meaning.

Q.No. Question M.M.
1 i. Englers's theory or Modern theory—Which one you feel the best to explain the origin of petroleum. Why?
   ii. What is the role of OPEC in deciding the prices of crude oil in the International market. Why the prices of crude oil in the International market are still low?
   iii. Why petroleum is considered so important for various industrial activities? List the name of any three important oilfields and petroleum refineries each

OR

1' Explain the following:
   i) Sweet and sour natural gas ii) Porphyrins iii) Heavy, extra heavy crude oils and Tar sands. iv) Specific and API gravity of crude oils

[3+3+6+3]

2(a) Give detailed classification of sulphur and nitrogen compounds present in the crude oil along with their adverse effects.
   Name two oxygen compounds present in crude oil along with their structures.

[10]

2(b) What do you mean by Simulated distillation? What are its advantages over TBP distillation? How does flash vaporization technique work?

[05]

OR

contd... 2
2'(b) What is the importance and significance of \( K_{\text{UOP}} \)? How is it calculated? Comment on the quality of Mumbai High and N. Gujarat crude oils.

3(a) Explain the method of operation of a multidraw vacuum distillation column with the help of a neat sketch. How does it differ from conventional distillation? Give the different products of crude oil distillation along with their carbon number, boiling ranges and uses. Why stripping is important?

3 (b) What do you mean by Octane number and Cetane number? How do the Motor and Research methods differ from each other?

OR

How pour point, cloud point and CFPP differ from each other? Why is an upper limit for aromatic content prescribed for ATF?

OR

Write on the types of naphtha produced in Indian refineries. What do you mean by Petrochemical grade naphtha?

4(a). Discuss the name of important feed stocks which are employed for the production of petrochemicals. List the name of various primary and secondary petrochemicals. Why ethylene and propylene are considered as building blocks for the petrochemical Industry?

(b) Write short notes on any two of the following:

i. reaction mechanism and application of thermal cracking reactions.

OR

i. reaction mechanism of alkylation reactions

OR

i. Importance of nitration reactions along with the mechanism
Maximum Marks: 60
Credits: 04
Duration: Two Hours

Answer all the questions.

1(a) Define the following terms.
    i) Streamline  ii) Pathline  iii) Streak line  iv) Time line [CO-1] [04]

1(b) A tank 18 ft deep and 7 ft wide is layered with 8 ft of oil, 6 ft of water, and 4 ft of mercury. As shown in figure-1, Compute the total hydrostatic force. [CO-2] [05]

Figure-1

OR

1(b') The pressure difference between two pipes is measured by a double-fluid manometer. For given fluid heights and specific gravities, as shown in figure-2 Calculate pressure difference between two ends of pipes. Take $\rho_w=1000 \text{ Kg/m}^3$ [CO-2] [05]

1(c) Define and explain Continuum hypothesis in detail. Explain the axioms of rheology. [CO-1] [06]

2(a) Explain Eulerian and Lagrangian approaches to the study of fluid motion. [CO-5] [03]

2(b) Derive differential linear momentum balance equation and simplify it to obtain Navier-Stokes equation [CO-3] [12]

contd...
2(b') Derive integral energy balance equation and simplify it to obtain Bernoulli Equation. [CO-4] [12]

3(a) Write five dimensionless numbers with their significance. [CO-6] [05]

3(a') Define Buckingham Pi theorem and Rayleigh Method [CO-6] [05]

3(b) Define the geometric, kinematics and dynamic similarity of model and prototype. [CO-6] [03]

3(c) Use a dimensional analysis to obtain an expression that allows the calculation of the power of a stirrer as a function of the variables that could affect it. It is known from experimental studies, that the stirring power depends on the diameter of the stirrer (D), its rotation velocity (N), the viscosity (η) and density (ρ) of the fluid being stirred, and the gravity acceleration (g) [CO-6] [07]

3(c') When a fluid circulates through a pipe, mechanical energy losses occur due to friction with the pipe walls' mechanical energy losses by mass unit of the fluid (Eₚ), depending on the characteristics of the pipe (internal diameter, roughness, and length) and on the properties of the circulation fluid (density and viscosity), as well as on the circulation velocity (v). Use Buckingham’s method to deduce an expression that allows calculation of Eₚ as a function of the mentioned variables. [CO-6] [07]

4(a) Describe the working principle of a centrifugal pump and positive displacement pump. Write the expression for head developed by a centrifugal pump. [CO-7] [06]

4(b) Write brief notes on valves and fittings used in chemical industry. [CO-7] [05]

4(b') Write brief notes on Pumping Equipment for Liquids and gases. [CO-7] [05]

4(c) Water is pumped at a rate of 36 m³/hr from a tank 2m below the pump to an overhead pressurized vessel 10m above the pump. The pressure values at the point of suction from the bottom tank and at the discharge point to the overhead vessel are 120 kPa and 240 kPa, respectively. All pipes in the system have the same diameter. Take acceleration due to gravity, g = 10 m/s² and ρₚ = 1000 Kg/m³. Neglecting frictional losses, what is the power (in kW) required to deliver the fluid? [CO-7] [04]

------------------------------------------------------------------------------------------
Question
1(a) Differentiate between differential-analysis and cumulative-analysis in the sieving of solid particles. Which analysis, differential or cumulative, does not depend on the type of screen-series selected for sieving of a particular mixture of particles and explain why?

1(b) What do you understand by “effectiveness of screen” in sieving process? A table salt is being fed to a vibration screen at a rate of 150 kg/h. The desired product is \(-30/+20\) mesh fraction. The differential sieve-analysis is given in the Table 1. During the operation, it was observed that the average proportion of oversize (from 30-mesh screen): oversize (20-mesh screen): undersize (from 20-mesh screen) is 2:1.5:1. Calculate the effectiveness of the screen.

<table>
<thead>
<tr>
<th>Mesh</th>
<th>(-85 + 60)</th>
<th>(-60 + 40)</th>
<th>(-40 + 30)</th>
<th>(-30 + 20)</th>
<th>(-20 + 15)</th>
<th>(-15 + 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed (mass fraction)</td>
<td>0.097</td>
<td>0.186</td>
<td>0.258</td>
<td>0.281</td>
<td>0.091</td>
<td>0.087</td>
</tr>
<tr>
<td>Oversize (from 30-mesh)</td>
<td>0.066</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oversize (from 20-mesh)</td>
<td>0.526</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undersize (from 20-mesh)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3490</td>
</tr>
</tbody>
</table>

OR
1(b’) Trap rock 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 100 ton/h. If actual
power required for crushing is 300 kW and of this 20 kW needed to operate empty mill, then calculate the crushing efficiency of the operation (specific gravity of trap rock = 2.87, sphericity of product particles = 0.6).

<table>
<thead>
<tr>
<th>Mesh</th>
<th>Dₚi (mm)</th>
<th>Mass fraction, Xᵢ</th>
<th>Xᵢ/Dₚi</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/6</td>
<td>4.013</td>
<td>0.031</td>
<td>0.00772</td>
</tr>
<tr>
<td>6/8</td>
<td>2.845</td>
<td>0.103</td>
<td>0.03622</td>
</tr>
<tr>
<td>8/10</td>
<td>2.007</td>
<td>0.2</td>
<td>0.09965</td>
</tr>
<tr>
<td>10/14</td>
<td>1.409</td>
<td>0.186</td>
<td>0.13201</td>
</tr>
<tr>
<td>14/20</td>
<td>1.001</td>
<td>0.152</td>
<td>0.15185</td>
</tr>
<tr>
<td>20/28</td>
<td>0.711</td>
<td>0.12</td>
<td>0.16878</td>
</tr>
<tr>
<td>28/35</td>
<td>0.503</td>
<td>0.095</td>
<td>0.18887</td>
</tr>
<tr>
<td>35/48</td>
<td>0.356</td>
<td>0.065</td>
<td>0.18258</td>
</tr>
<tr>
<td>48/65</td>
<td>0.252</td>
<td>0.043</td>
<td>0.17063</td>
</tr>
<tr>
<td>-65</td>
<td></td>
<td></td>
<td>0.005</td>
</tr>
</tbody>
</table>

1(c) Explain Rittinger’s law and its assumptions.

2(a) Derive the expression for ‘critical speed’ of the ball mill using spherical steel balls. In a ball mill of diameter 2000 mm, 100 mm diameter steel balls are being used for grinding. Presently, for the material being ground, the mill is run at 15 rpm. At what speed will the mill have to be run if the 100 mm balls are replaced by 50 mm balls, all the other conditions remaining the same?

2(b) Explain the working of “hammer mills with classification” with proper sketch.

OR

2(b') Explain the working of Apron conveyors and how it is different from Belt conveyors.

2(c) From the Figure 1, identify (with proper reasoning) the different flow patterns observed during the solid mass-flow out from bins.

Figure 1.

(i) 
(ii) 
(iii)
3(a) Calculate the maximum velocity at which silica particles of 0.04 mm diameter (sp. gravity = 2.65) fall through still water (viscosity = 0.001 kg/ms) that fills a 50 mm ID glass cylinder, if
(i) the slurry is so dilute that free settling prevails [Hint: Wall effect].
(ii) the mass ratio of water and silica is 2.0 [Hint: Hindered settling].

3(b) Discuss the effect of wetting agent, solid concentrations of feed and height of the sedimentation tank (for identical slurries) on the sedimentation rate in the batch sedimentation process.

3(c) Explain the working of Spitzkasten with proper sketch.

OR

3' Using dimensionless analysis, proof that the expression for power (P) required to derive the mechanical-agitator for liquid-liquid mixing is (i) $P = K_L n^2 D_a^3 \mu_f$ for laminar case and (ii) $P = K_T n^3 D_a^5 \rho_f$ for turbulent case. [$K_L$, $K_T$ = constants; $n$ = stirring speed; $D_a$ = Diameter of agitator; $\mu_f$ = viscosity of liquid; $\rho_f$ = density of liquid]

4(a) The ultimate filtration equation is

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

A leaf filter with $1.0 \text{ m}^2$ of filtering surface operated at a constant pressure of 1.8 bar gave the following results:

<table>
<thead>
<tr>
<th>Filtrate volume (m$^3$)</th>
<th>3.99</th>
<th>6.09</th>
<th>7.65</th>
<th>9.63</th>
<th>11.33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (sec)</td>
<td>600</td>
<td>1200</td>
<td>1800</td>
<td>2700</td>
<td>3600</td>
</tr>
</tbody>
</table>

The original slurry contained 10 wt% of solid CaCO$_3$ (sp. gravity = 2.72) in water and the cake formed is essentially incompressible. Determine the time required to wash the cake formed at the end of 70 minutes of filtering at the same pressure using 3.0 m$^3$ of wash water. [Hint: Case of constant pressure on an incompressible sludge]

4(b) Differentiate between particulate-fluidization and aggregative-fluidization.

OR

4(b') Write the standard form of Ergun's equation and discuss the various limitations of Ergun's equation.

4(c) Explain the importance of filter aids in the filtration process.