1(a) State the penetration theory of mass transfer along with the assumptions. Also, write down the expression for the liquid phase mass transfer coefficients according to this theory.

OR

1(a') Derive the following relationship between individual overall and two phase mass transfer coefficients.

\[ \frac{1}{K_y} = \frac{1}{k_y} + \frac{m^\prime}{k_y k_z} \]

where the symbols have their usual meaning. Also deduce from this relationship that under what circumstances the operation will be gas phase controlling.

1(b) A liquid is evaporated from the surface of a cylinder, radius \( r_0 \), into a stagnant film of gas surrounding the cylinder. The ends of cylinder are sealed for mass transfer. Outer radius of the gas film is \( r_s \). The partial pressure of liquid at the outer surface of the film and the surface of the cylinder are \( p_{a0} \) and \( p_{ao} \) respectively. Derive an expression for the mass transfer rate at the surface of the cylinder.

OR

1(b') An open beaker, 0.06 m in height, is filled with liquid benzene at 25 °C to within 0.005 m of the top. A gentle breeze of dry air at 25 °C and 1 atm is blown by a fan across the mouth of the beaker so that evaporated benzene is carried away by convection after it transfers through a stagnant air layer in the beaker. The vapor pressure of benzene at 25 °C is 0.131 atm. The mutual diffusion coefficient for
benzene in air at 25 °C and 1 atm is 9.05 × 10⁻⁶ m²/s. Compute
(i) Initial rate of evaporation of benzene as molar flux in kmol/m²-s
(ii) The time in hours for the benzene level to drop 0.02 m from the initial level if
the specific gravity of liquid benzene is 0.874. Neglect the accumulation of
benzene and air in the stagnant layer as it increases in height.

2(a) Make freehand sketch of operating diagram showing the operating lines for the two
absorbers and the equilibrium curve for the scheme shown in the figure given below.
Also mark the concentrations on the diagram.

2 (b) Solute A is to be stripped from a liquid stream by contacting with a pure gas. The
liquid enters the tower at an A-free rate of 2.5 kmol/s and contains 30 mol% A. The
gas enters the colurum counter-currently at a rate equals to 1.5 times the minimum.
Determine the number of theoretical stages required to reduce the concentration of A
in the exiting liquid to 1.0 mol%. The distribution of A in the gas and liquid is
expressed by \( y_A = 0.4 x_A \).

OR

2(b’) A gas stream from a chemical reactor containing 25 mol% ammonia and the rest inert
gas at 303 K temperature and 101.3 kPa pressure is fed to an absorption tower at the
rate of 181.4 kmol/h. It is desired to reduce its ammonia content to 2 mol% by
contacting with water containing 0.005 mol fraction of ammonia. What minimum
water rate is required? The equilibrium data for ammonia-water system at 303 K and

Contd... 3
101.3 kPa is given below:

<table>
<thead>
<tr>
<th>X</th>
<th>0.013</th>
<th>0.017</th>
<th>0.021</th>
<th>0.026</th>
<th>0.032</th>
<th>0.042</th>
<th>0.053</th>
<th>0.080</th>
<th>0.106</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>0.015</td>
<td>0.021</td>
<td>0.026</td>
<td>0.033</td>
<td>0.041</td>
<td>0.056</td>
<td>0.072</td>
<td>0.117</td>
<td>0.170</td>
<td>0.307</td>
<td>0.520</td>
</tr>
</tbody>
</table>

3(a) Define the following terms in the humidification operation

(i) Absolute humidity
(ii) Relative saturation
(iii) Dew point

OR

3(a') What is Lewis relation? Show that the systems following the Lewis relation have the wet bulb temperature and adiabatic saturation temperature identical.

3(b) A mixture of nitrogen and acetone vapor at 800 mmHg total pressure, 25 °C, has a percentage saturation of 80%. Calculate the partial pressure of acetone in the mixture and dew point of the vapor-gas mixture. The vapor pressure of acetone in mmHg at any temperature in °C is given by

\[
\log p^* = 7.02447 - \frac{1161.0}{t + 224}
\]

4(a) Define the following types of the moistures used in the drying operation and show them on an equilibrium diagram

(i) Equilibrium and free moisture
(ii) Bound and unbound moisture

4(b) What do you mean by constant drying condition? Briefly discuss the effect of the varying drying condition with respect to the gas velocity, gas temperature, gas humidity, and thickness of drying solid on the rate of drying in constant rate period.
Answer all the questions.

1(a) Classify methods for production of caustic soda. Explain the electrolytic process for its production along with the reactions and flow sheet.

1(b) Describe the production of phosphoric acid. What are the major problems encountered in its production? Suggest some ways to resolve them.

OR

1(b') What are the raw materials required for the production of phosphorous? Describe a process for the production of elemental phosphorous with a neat flow sheet.

2(a) What is the major difference in the production of superphosphate and triple superphosphate? Explain the production method of triple superphosphate with the help of a neat flow sheet.

OR

2(a') Give a detailed description for the production of sodium tri phosphate along with a neat flowsheet.

2(b) Classify processes for urea production. Elaborate one of these processes in terms of reactions involved and flow sheet.

OR

2(b') Name some common insecticides and pesticides. Describe in detail the production of DDT along with a neat flow sheet.

3(a) Give a detailed classification of cements with special reference to their composition and uses.

3(b) Name various constituents of glass along with their applications.

3 (c) Explain the manufacturing process of Portland cement with a neat flow sheet.

4(a) List some requirements essential for surface coatings. Briefly explain the main constituents of paints along with specific examples.

4(b) Differentiate between a Dye and a Pigment. How many types of dyes are generally used in industry and what are their uses?

4(c) What are the constituents of a common industrial starch? Name some starch derivatives along with their structure. Explain the production of one of them with a neat flow sheet.
2013-14
B.TECH. (WINTER SEMESTER) EXAMINATION
CHEMICAL ENGINEERING
CHEMICAL PROCESS INDUSTRIES-II
CH-321

Maximum Marks: 60
Credits: 04
Duration: Three Hours

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

Q.No. | Question | M.M.
--- | --- | ---
1(a) | What are the important properties of ethylene oxide (EO)? What is its specification as per BIS? | [03]
OR
1'(a) | List different industrial applications of Aniline. | [03]
1(b) | Mention the steps involved in the indirect hydration process in the manufacture of Ethanol | [04]
OR
1'(b) | Mention the important properties and uses of Acetic acid | [04]
1(c) | Explain the manufacturing process of Aniline with the help of process flow diagram along with chemical reactions and process conditions. | [08]
OR
1'(c) | List different processes available for the production of Acetaldehyde. Explain direct oxidation of Ethylene with the help of flow diagram along with chemical reactions and process conditions | [08]
2(a) | Explain briefly the manufacturing process of low density Polyethylene [LDPE] with the help of process flow diagram along with important process conditions. | [07]
2(b) | Differentiate between any two of the following:
   a) Sulfite and Sulfate Pulping
   b) Natural and Synthetic Fibres
   c) Natural and Synthetic Rubber
   d) Thermo setting and thermo plastics | [08]
3(a) | Briefly explain about the production of linear Alkyl Benzene Sulfonate [LABS] used in the manufacture of synthetic detergent. | [10]
OR

3'(a) Explain the production of Glycerine with the help of a process flow diagram. What are the industrial applications of Glycerine? [10]

3 (b) What are the steps involved in the hydrogenation of oil to manufacture vanaspati? [05]

OR

3' (b) Mention different steps involved in the continuous hydrolysis of oil in soap manufacture? [05]

4(a) What are different methods for the classification of crude oil? Explain them briefly. [06]

4(b) Explain briefly about different petroleum products from refinery. [09]
2013-14
B.TECH. (WINTER SEMESTER) EXAMINATION
CHEMICAL ENGINEERING
CHEMICAL PROCESS INDUSTRIES - I
CH 321N (Backlog)

Maximum Marks: 60
Credits: 03
Duration: Three Hours

Answer all the questions.
Notations used have their usual meaning.

Q.No. Question M.M.
1(a) Describe the characteristics of Indian phosphate rock? Discuss the production of [08] 
H₃PO₄ with the help of a process flow sheet, chemical reactions involved, and pertinent engineering problems. What are it's industrial applications?

OR

1(a') Discuss the manufacturing process of H₂SO₄ from a useful source of Sulphur giving the process flow sheet, reaction conditions, grades of concentration, catalyst, and kinetics. What are the pertinent engineering problems? [08]

1(b) What are various production methods of Caustic Soda? Discuss the modern method of manufacturing NaOH in India. Also describe the important engineering problems of this industry with possible solution. [07]

OR

1(b') Compare the merits and demerits of manufacturing processes of Soda ash. Discuss with the help of a neat process flow sheet, the production steps, important variables affecting the process efficiency, and major engineering problems related to this industry. [07]

2(a) Enlist the various sources of feed stock of hydrogen for manufacturing ammonia. Discuss Urea production by the latest technology, giving a neat process flow sheet contd...
producer of Urea in India.

2(b) What do you understand by Bio fertilizer? Discuss one of the methods of manufacturing bio fertilizer along with it's agricultural applications.

OR

2'(a) Explain precisely the merits of Di ammonium phosphate,(DAP) over Urea. Discuss the manufacturing process of DAP in details with the help of a process flow diagram and their related engineering problems. Is triple super phosphate is better than DAP? If yes, then why?

2'(b) What are critical air and water pollutants from fertilizer industries? Discuss the air emission and effluents guide lines for a nitrogenous fertilizer plants.

3(a) Provide a list of important constituents of Cement? Discuss the manufacturing scheme of Portland cement furnishing a neat flow sheet, engineering problems of cement industries in India and suggest their possible remedies.

3(b) Discuss briefly the chemical composition and applications of glass and ceramic materials which are generally used in chemical industries.

4(a) Starch industry in India is very strong. Is it technology or economics which makes it so? Explain the manufacturing scheme of Starch with the help of a neat flow sheet, pertinent engineering problems and reaction conditions. Also explain the significance of modified Starch and it's derivatives in Indian market.

4(b) Clearly differentiate between paints and dyes. Also explain their compositions and applications in chemical industries.
1(a) Show that for a fluid under simple shear, velocity gradient is the measure of rate of shearing strain.

1(b) A cylindrical rod of radius $kR$ moves with velocity $v_0$ along the axis of cylindrical cavity of radius $R$ as shown below. The pressure at both ends of the cavity is same so that the fluid moves through the annular region solely because of the rod motion.

Derive the expression for velocity distribution and mass flow rate through the narrow annular region. Write the important assumptions made in the derivation and also show the balances pictorially on the elemental volume.

OR

1(b') Glycerine at $26^\circ C$ is flowing through a horizontal tube 1 ft long and with 0.1 inch inside diameter. For a pressure drop of $2.76 \times 10^6$ dyne/cm$^2$, the volumetric flow rate $Q$, is $0.00398$ ft$^3$/min. The density of Glycerine at $26^\circ C$ is $1.261$ g/cm$^3$. From the flow data
find the viscosity of Glycerine in centipoise and PaS. Check whether the flow is laminar and also find the entrance length. Derive the expression used.

1(c) Distinguish between the operators $\partial / \partial t$, $d/dt$, $D/Dt$ and write their significance. [02]

2(a) A spherical vessel of radius $R_1$ meters is insulated from outside such that the outside surface of the insulated vessel has the radius $R_0$. The temperature of the inside and outside surface of the insulation are $T_1$ and $T_0$ respectively. The ambient temperature is $T_a$, the convective heat transfer coefficient outside the insulation is $h_a$ and the thermal conductivity of the insulating material is $k$. Determine the outer radius of the insulation for which the rate of heat transfer will be maximum.

Derive the expression used and state the assumptions made.

2(b) A layer of pulverized cork of 0.15m thick is used as a layer of insulation thickness in a flat wall. The temperature on a cold side of the cork is 5°C and that on the warm side is 83°C. The area of the wall is 2.25m². The thermal conductivity of the cork is 0.12 W/m²K at 0°C and is 0.18 W/m²K and 94°C. What is the rate of heat flow through the wall in Watts? Assume that the thermal conductivity varies linearly with the temperature as $k=a+bt$. Derive the expression used.

OR

2' A sphere of fissionable material with radius $R^F$ is surrounded by a spherical shell of aluminium cladding with outer radius $R^C$ as shown in figure. Inside the fuel element fission fragments are produced that have very high kinetic energy. Collision between these fragments and the atoms of the fissionable material provide major source of thermal energy. The thermal energy produced from nuclear fission is $S_n$(cal/cm³ s), it approximated by the expression:

$$S_n = S_{no} \left[ 1 + b(r/R^F)^2 \right]$$

Where, $S_{no}$ is the volume rate of heat production at the centre of the sphere and 'b' is a dimensionless positive constant. Derive the expressions for the temperature profiles in the sphere of fissionable material and the aluminium cladding.

Contd... 3
3(a) A reaction is taking place at the catalytic surface as shown in figure below:

$$3A \rightarrow B$$

The reaction is not instantaneous at the catalytic surface, $z = \delta$. Assume that the rate at which 'A' disappears at the catalyst-coated surface is proportional to the concentration of 'A'in the fluid at the interface. That is,

$$N_{A2} = k_1 C_A$$

Where, $k_1$ is the rate constant for the pseudo-first order surface reaction.

i. Obtain the concentration profile for component 'A' in the above reaction.

ii. Determine the molar flux of 'A' and write down the significance of the equation obtained.

3(b) A gas mixture at a total pressure of $1.5 \times 10^5$ Pa and 295K contains 20 mol% $H_2$, 40 mol% $O_2$ and 40 mol% $H_2O$. The absolute velocities of each species are -10 m/s, -2 m/s and 12 m/s respectively, all in the direction of $z$-axis. Determine:

i. The mass average velocity, $\bar{v}$ and the molar average velocity, $\bar{V}$

ii. The fluxes $\bar{N}_A$, $\bar{J}_A$, $\bar{n}_A$, and $\bar{j}_A$

4(a) A spherical tank of radius $R$ and its drainpipe of length $L$ and diameter $D$ are completely filled with a heavy oil (shown below). At time $t=0$, the valve at the bottom of the drainpipe...
is opened. How long will it take to drain the tank? There is an air vent at the very top of the spherical tank. Ignore the amount of oil that clings to the inner surface of the tank and assume that the flow in the drain pipe is laminar.

OR

4(a') Derive the relation of friction factor and Reynolds's number for the turbulent flow in smooth tubes using 1/7th Power Law velocity distribution.

4(b) Fluid is flowing at a steady state through a pipe bend as shown in figure. Turbulent flow is assumed and the frictional forces are considered negligible. The volumetric flow rate of the liquid, the pressure $p_2$ at point 2 and pressure $p_1$ at point 1 are known. Also, the diameters of the pipe at both ends are known. Derive the equations to calculate the forces on the pipe bend. Assume that the density $\rho$ is constant.
Q.No. Question

1(b) Design a Shell and Tube heat Exchanger to cool methanol from a condenser from 105° C to 45° C. Flow-rate of methanol 200,000 kg/hr. Brackish water will be used as a coolant, with a temperature rise from 25° C to 35° C.

Tubes Specification: 20 mm o.d, 16 mm i.d, 4.88 m long, cupro-nickel with thermal conductivity of 50 w/m° C.

Assume suitable bundle diametrical clearance.

Use Triangular Pitch

<table>
<thead>
<tr>
<th>Properties</th>
<th>Methanol</th>
<th>Brackish Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Capacity</td>
<td>2.84 kJ/kg° C</td>
<td>4.2 kJ/kg° C</td>
</tr>
<tr>
<td>Density</td>
<td>750 kg/m³</td>
<td>995 kg/m³</td>
</tr>
<tr>
<td>Viscosity</td>
<td>0.34 mNs/m²</td>
<td>0.8 mNs/m²</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>0.19 W/m° C</td>
<td>0.59 W/m° C</td>
</tr>
<tr>
<td>Fouling Coefficient</td>
<td>5000 Wm⁻²°C⁻¹</td>
<td>3000 Wm⁻²°C⁻¹</td>
</tr>
</tbody>
</table>

2(a) Estimate the heat transfer coefficient for steam condensing on the outside and on the inside, of a 25 mm o.d, 21 mm i.d, vertical tubes 3.66 m long. The steam...
condensate is 0.0015kg/s per tube and condensation takes place at 3 bar. The steam will flow down the tubes.

Physical Properties, from Steam Tables:
Saturation Temperature = 133.5 °C
Liquid Density ($\rho_L$) = 931 kg/m$^3$
Vapor Density ($\rho_v$) = 1.65 kg/m$^3$
$k_L$ = 0.688 W/m°C
$\mu_L$ = 0.21 mNs/m$^2$
$Pr_c$ = 1.27

2(b) The process fluid o-dichlorobenzene is vaporised in the tubes of a forced convection reboiler. Estimate the local heat transfer coefficient at a point where 5 percent of liquid has been vaporised. The liquid velocity at the tube inlet is 2m/s and the operating pressure is 0.3 bar. The tube side diameter is 16mm and the local wall temperature is estimated to be 120°C.

Physical Properties:
Boiling Point 136 °C
$\rho_L$ = 1170 kg/m$^3$
$\rho_v$ = 1.31 kg/m$^3$
$\mu_L$ = 0.45 mNs/m$^2$
$\mu_v$ = 0.01 mNs/m$^2$
$k_L$ = 0.11 W/m°C
$C_{pl}$ = 1.25 kJ/kg °C
$P_c$ = 41 bar

OR

2 (b) Design a vaporiser to vaporise 8000kg/hr n-butane at 5.84 bar. The minimum temperature of the feed (winter conditions) will be 0 °C. Steam is available at 1.7 bar. Physical properties of n-butane at 5.84 bar:
Boiling point = 56.1 °C
Latent heat = 326 kJ/kg °C
Critical Pressure, $P_c = 38$ bar
Steam saturation temperature at 1.7 bar $= 115.2 \, ^oC$
U-Tubes: 25 mm i.d., 30 mm o.d., 4.8 m long
Use Square pitch arrangement.

3(a) Acetone is being absorbed by water in a packed tower having a cross-sectional area of 0.186 m$^2$ at 293k and 1 atm. The inlet air contains 2.6 mol % acetone and outlet 0.5 %. The gas flow is 13.65 kg mol inert air/h. The pure water inlet flow is 45.36 kg mol water/h. Film coefficients for the given flows in the tower are $k'y_a = 3.78 \times 10^{-2}$ kg mol/s.m$^3$.mol frac and $k'x_a = 6.16 \times 10^{-2}$ kg mol/s.m$^3$.mol frac. Calculate the tower height using $k'y_a$. Equilibrium line $y = 1.186x$.

OR

3(a) An enriching tower is fed 100 kg mol/hr of a saturated vapour feed containing 40 mol % benzene (A) and 60 mol % toluene (B) at 1 atm. The distillate is to contain 90 mol % benzene and bottoms are to contain 2 mol % benzene. Use reflux ratio of 1.3 times of minimum Reflux ratio. Calculate the kg mol/hr distillate D and bottoms W and their compositions. Also calculate the number of theoretical plates required.

3(b) A tray tower is to be designed to absorb SO$_2$ from an air stream by using pure water at 293K. The entering gas contains 25 mol % SO$_2$ and that leaving 4 mol % at a total pressure of 101.32 kPa. The inert air flow rate is 200 kg water/h.m$^2$.

Assuming an overall tray efficiency of 25%, how many theoretical trays and actual trays are needed? Assume that the tower operates at 293 K.

| Equilibrium mol fraction data |  
|-------------------------------|------------------|
| $x_A$                         | $y_A$            |
| 1.00                          | 1.00             |
| 0.780                         | 0.900            |
| 0.581                         | 0.777            |
| 0.411                         | 0.632            |
| 0.258                         | 0.456            |
4(a) A hot solution of Ba(NO₃)₂ from an evaporator contains 30.6 kg Ba(NO₃)₂/100 kg H₂O and goes to a crystallizer, where the solution is cooled and Ba(NO₃)₂ crystallizes. On cooling, 10% of the original water present evaporates. For a solution of 100 kg total, calculate the following:

(a) The yield of crystals if the solution is cooled to 290K, where the solubility is 8.6 kg Ba(NO₃)₂/100 kg total water.

(b) The yield if cooled instead to 283K, where the solubility is 7.0 kg Ba(NO₃)₂/100 kg total water.

4(b) Make a preliminary design for a vertical separator a mixture of steam and water; flow rates: steam 4000 kg/hr, water 2000 kg/hr; operating pressure 4 bar.

OR

4(b) Design a horizontal separator to separate 20,000 kg/hr of liquid, density 962.0 kg/m³, from 12,500 kg/hr.
2013-14
B.TECH. (VI SEMESTER) EXAMINATION
(Chemical Engineering)
Bioprocess Engineering
CH-335

Maximum Marks: 60 Credits: 04 Duration: Three Hours

Answer all the questions.
All parts of a question should be answered in a proper sequence.
Notations used have their usual meaning.

Q.No. Question M.M.
1(a) Discuss the merits and demerits of a Biochemical reaction with suitable examples. [04]
1(b) Explain the experimental procedure to measure the bacterial growth with the help of experimental set-up. How does it differ with yeast and fungi? Explain it clearly. [06]
1(c) Show that the lactic acid bacteria can behave like growth associated and non-growth associated. [05]

OR

1'(a) Define and discuss with the help of a neat diagram, two important phases of a typical batch growth curve of an industrial bioprocess. [07]
1'(b) Explain Deindoerfer's classification of bioproducts with suitable examples. [08]

2(a) Derive Michaelis-Menten equation for an enzyme catalysed reaction. Discuss the competitive effect of inhibition on it and compare the rate equation with above equation. How will you calculate experimentally the value of $K_m$ used in the equation. [10]

OR

2'(a) An enzyme has non-competitive effect on substrate. Derive the rate equation of product formation for such reaction. [10]
2(b) Differentiate the free and immobilised cells. Discuss one important method of cell Immobilisation. [5]
3(a) Define clearly the following with suitable reasons:
   i) Bubble aeration  ii) Power number, and  iii) Sterilization of Medium

3(b) Enumerate the basic functions of a bioreactor. Explain clearly the merits and
demerits of various bioreactors used in bioprocess industries.

3(c) Write down the mathematical equations to calculate the concentration of cell, x and
substrate, s respectively for a bioprocess. Discuss their significance for industrial
production.

4(a) Discuss the manufacturing scheme of lactic acid giving raw material, process flow
diagram, and purification of the product

4(b) Explain the consumption pattern of Citric acid for various industries.

4(c) What are optimum process conditions of sugar concentration, temperature, and
pH to produce ethanol from molasses. Also discuss the mechanism of ethanol
formation. What do you anticipate about the future of alcohol industry in the
coming years.
A cylindrical storage tank with flat bottom and self-supported conical roof is required to store benzene. The tank has height of 20 m and diameter as 12 m. The tank has to be installed at Aligarh. The tank remains full upto 85% of its capacity throughout the year and emptied twice a year. The tank is fabricated from IS: 1570 grade C15Mn75 quality steel. As per IS 1730: 1971, the plate has a width of 1.7 m. Calculate

a) Annual filling loss

b) Optimum shell thickness

OR

A cylindrical storage tank with flat bottom and self-supported conical roof having a capacity 1000 m³ is required to store caustic soda. The combined annual cost of fabricated bottom and roof per unit area is equal to the annual cost of fabricated shell per unit area. The cost of tank foundation per unit area and the cost of land that is under the tank area directly chargeable to tank together is 80% of the annual cost of fabricated shell per unit area. The tank is made of IS: 2002-1962 grade 2A quality steel and all joints are spot radiographed. The dimensions of structural steel is 1800 X 6300 mm. Find the number of courses and thickness of each course.
2 A vacuum crystallizer 2.6 m in diameter is to be fabricated from low alloy steel of grade IS: 2041 – 1962 – Mn2 and has an apex angle of 60° at the bottom and a standard dished head at top. Length of the crystallizer from the junction of the cone with the shell to the point of tangency of top closure is 6mm. Calculate
   (i) Shell thickness using factor B method
   (ii) Thickness of standard dished head

OR

2* A fractionating tower has 8 m length and 6 m outside diameter. The tower contains removable trays with a tray spacing of 1m. The tower is operated under vacuum at a temperature of 50° C. The tower is fabricated from IS: 2002 – 1962 grade 2B quality steel. Determine the shell thickness with and without stiffeners. The stiffeners are located at tray spacing.

3 A thick walled pressure vessel is to be designed to withstand an internal pressure of 20,000 psi. The inside diameter of the vessel is 1.5m and outside diameter as 3.0 m. Determine the maximum induced stress according to maximum principal stress theory, the maximum shear stress theory, the maximum strain theory and strain energy theory. Factor of safety = 1.5

4 Design a ring type flange with a plain face for a heat exchanger with following specification
   Design pressure = 150 psi
   Design temperature = 200° C
   Flange material = carbon steel ( IS : 2002 – 1962 grade I)
   Gasket material = asbestos
   Boiling material = hot rolled carbon steel having permissible stress upto 200° C, 5.45 Kgf/mm² , Do = 0.6m, Di = 0.5m
Q. No. Question
1(a) Dilute A diffuses through a stagnant liquid film onto a plane solid surface consisting of B, reacts there to produce R which diffuses back into the mainstream, according to the rate given below.

$$-r_A'' = k_1 C_A / (1 + k_2 C_A)$$

Develop the overall rate expression for L/S reaction accounting for both the mass transfer and the reaction steps.

1(b) Hydrogen sulphide is removed from coal gas by passing the gas through a moving bed of iron oxide particles. In the coal gas environment (consider uniform), the solids are converted from Fe$_2$O$_3$ to FeS by the shrinking core model (SCM), reaction control, $\tau = 1$ hr. Find the fractional conversion of iron oxide to iron sulphide, if the RTD of solids in the reactor is approximated by

$$E(t) = \delta(t - t_0), \quad t_0 = 45 \text{ min.}$$

OR

1(b) Comment on the role of Hatta Number in fluid-fluid reactions. What factors must be considered in selecting a suitable gas-liquid contactor?
The following data for hydrogenation of i-octene to form i-octane were obtained using a differential reactor operated at 200°C:

<table>
<thead>
<tr>
<th>Run</th>
<th>Rate (mol/g.h)</th>
<th>Partial Pressure (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td>1</td>
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<td>1</td>
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<td>0.0127</td>
<td>0.6</td>
</tr>
<tr>
<td>12</td>
<td>0.0566</td>
<td>5</td>
</tr>
</tbody>
</table>

(i) Develop a rate law, and evaluate all the rate parameters.

(ii) Suggest a mechanism consistent with the experimental data.

3(a) The rate law for the hydrogenation (H) of ethylene (E) to form ethane (A) over a cobalt-molybdenum catalyst is

\[-r_e' = \frac{(k_E E H)}{(1 + K_E P_E)}\]

Suggest and name the mechanism and rate-limiting step consistent with the rate law.

**OR**

3(a') Gas oil is being catalytically cracked in a screw type conveyor moving-bed reactor by a 2nd order rate law. The catalyst is decaying by a 1st order kinetics. Pure feed enters in the reactor at a flow rate of $F_{A_0}$ mole/dm$^3$. Total weight of the catalyst at any time in the MBR is $W$ kg and it is passing down the reactor at a velocity of $U_S$ kg/min. Derive an equation for the conversion of the gas oil in the MBR in terms of Damköhler number ($D_{\alpha_2}$) and dimensionless decay time, $\lambda$.

*contd...*
A → Products

\[ X = D_{a2} (1 - \exp(-\lambda)) / (\lambda + D_{a2} (1 - \exp(-\lambda))) \]

3(b) The following kinetic data are obtained in an experimental Carberry type basket reactor using 100 gram of catalyst in the paddles and at different flow rates from run to run:

\[
\begin{align*}
A &\rightarrow R & \Gamma_{Ao}, \text{ mol/min} & 0.14 & 0.42 & 1.67 & 2.5 & 1.25 \\
C_{Ao} = 10 \text{ mol/m}^3 & & C_{A}, \text{ mol/m}^3 & 8 & 6 & 4 & 2 & 1
\end{align*}
\]

Determine the amount of catalyst needed in a mixed flow reactor for 90% conversion of 1000 mol A/min of a \(C_{Ao} = 10 \text{ mol/m}^3\) feed.

4(a) Write the performance equation for a batch biological reactor using the Michaelis-Menten rate equation for the microbial conversion of substrate A (initial concentration \(C_{Ao}\) into product in presence of enzyme E (total enzyme concentration \(C_{E0}\)). How can one extract Michaelis constant \(C_M\) and reaction rate constant, \(k\) using Lineweaver plot?

4(b) The second-order decomposition reaction

\[ A \rightarrow B + 2C \]

is carried out in a tubular reactor packed with catalyst pellets 0.4 cm in diameter. The reaction is internal-diffusion-limited. Pure A enters the reactor at a superficial velocity of 3 m/s, a temperature of 250°C, and a pressure of 500 kPa. Experiments carried out on smaller pellets where surface reaction is limiting yielded a specific reaction rate of 0.05 m^6/mol.g cat.s. Calculate the length of bed necessary to achieve 80% conversion.

**Additional information:**

- Effective diffusivity: \(2.66 \times 10^{-8} \text{ m}^2/\text{s}\)
- Bed porosity: 0.4
- Pellet density: \(2 \times 10^6 \text{ g/m}^3\)
- Internal surface area: \(400 \text{ m}^2/\text{g}\)
A spherical mono-dispersed solid particle is dissolving in an excess liquid solvent. The rate of dissolution is first order in the solvent concentration, C. Show that the following conversion-time relationships hold.

<table>
<thead>
<tr>
<th>Rate-Limiting Regime</th>
<th>Conversion Time relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface reaction</td>
<td>(1 - (1 - X)^{1/3} = \alpha t / D_i)</td>
</tr>
<tr>
<td>Mass transfer</td>
<td>(D_i / 2D^* [1 - (1 - X)^{2/3}] = \alpha t / D_i)</td>
</tr>
<tr>
<td>Mixed</td>
<td>([1 - (1 - X)^{1/3}] + D_i / 2D^* [1 - (1 - X)^{2/3}] = \alpha t / D_i)</td>
</tr>
</tbody>
</table>

Pharmacokinetic analysis of the dissolution process has given the following diameter-time relationship:

\[D_i - D + (1/2 D^*) [D_i^2 - D^2] = \alpha t\]

Where

\[k_c = 2 D_e / D, \quad D^* = 2 D_e / k_r, \quad \alpha = 2 k_r C_A / \rho\]
Q No. | Question | M.M.  
---|---|---  
1(a) | A new piece of materials handling equipment costs Rs. 20,000 and is expected to save Rs. 7500 the first year of operation. Maintenance and operating cost increases are expected to reduce the net saving by Rs. 500 per year for each additional year of operation until the equipment is worn out at the end of 8 years. Determine the net present worth of the equipment at an interest rate of 12 percent. | [5]  
1(b) | A 50-kilowatt gas turbine has an investment cost of $40,000. It costs another $14,000 for shipping, insurance, site preparation, fuel lines and fuel storage tanks. The operation and maintenance expense for this turbine is $450 per year. Additionally, the hourly fuel expense for running the turbine is $7.50 per hour, and the turbine is expected to operate 3,000 hours each year. The cost of dismantling and disposing of the turbine at the end of 8 year life is $8000. If the interest rate is 15% per year, what is the annual equivalent life cycle cost of the gas turbine? | [5]  
1(c) | State the law of supply and demand? | [2]  
--- | --- | ---  
OR | |  
F'(a) | Assets A1 and A2 have the capability of satisfactorily performing a required function. Asset A2 has an initial cost of $3200 and an expected salvage value of $400 at the end of its 5 year service life. Asset A1 costs $900 less initially, with an economic life of 10 years, has no salvage value, and its annual operating cost exceed those of A2 by $250. When the required rate of return is 15%, state which alternative is preferred when comparison is by present worth method. | [7]  
F'(b) | Differentiate between GDP and GNP. | [2]  
F'(c) | Explain Elasticity of demand, by giving suitable examples. | [3]  
2(a) | At the end of one-half of its expected economic life, a 4-year old machine has a book value of $5800 from its original cost of $9200. Estimated operating costs for next year will amount to $6000. An equipment dealer will allow $3600 if the machine is traded in now and $2800 if it is traded in 1 year later. The dealer proposes the purchase of a new machine to perform the same function; it will cost | [6]  
...  
2(b) | |
$14,000 installed. This machine will have an estimated operating cost of $4500 per year and a salvage value of $3000 at the end of 4 years. Is it profitable to replace the existing machine now if the minimum return on investments is 15% before taxes?

2(b) A materials testing machine was purchased for $20,000 and was to be used for 8 years with an expected salvage value of $2000. Calculate depreciation charge for year 4 and book value at end of year 3 by using double declining balance method.

2(c) What are the causes and consequences of inflation?

3(a) Is there any difference between managerial roles and managerial skills? Giving suitable examples, explain various managerial skills.

OR

3(a') What are the four basic activities of management? Explain using suitable examples.

3(b) What are the three areas of ethics which may be of special concern for managers?

OR

3(b') What are the arguments for and against social responsibility?

3(c) Discuss the role of information in a manager's job. What are the various characteristics of useful information?

OR

3(c') Explain the differences between three common methods of group decision making: Interacting groups, Delphi groups and Nominal groups.

4(a) What do you understand by organizational planning? Differentiate among strategic, tactical and operational plans.

4(b) What is the difference between chain of command and span of control?

4(c) How is the leadership different from management? Does an organization need both managers and leaders?

OR

4'(a) What are the various levels of control system in an organization? Explain the four fundamental steps for any control process.

4'(b) What is the importance of employee motivation? Explain the difference between human relation approach and human resource approach.
4(c) What is the concept of job specialization? Compare the benefits and limitations of job specialization.

5(a) Explain exponential smoothing method of demand forecasting.
A company has experienced irregular and usually increasing demand for disposable kits. The demand for September was 300 units and for October were 350 units. Using 200 units as September forecast and a smoothing coefficient of 0.7 calculate the forecast for the months of October and November.

5(b) A television manufacturer requires 24,000 two-centimetre-long pieces of wire every month for assembly. Ordering costs are estimated at $42, and cost of carrying is 25 percent of unit price, which is $0.08. Assuming delivery is instantaneous; find the reorder point and economic order quantity.

5(c) Explain the difference between macroeconomics and microeconomics in the context of financial management.