L-2/T-1/CHE Date: 26/10/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **CHE 201** (Material and Energy Balance)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer **Q. No. 1** and any **TWO** from the rest.

**Question No. 1 is compulsory.**

A data booklet containing relevant data is provided.

1. (a) Explain the terms: dew point temperature and bubble point temperature with appropriate equations. **(6)**

   (b) Write short notes on standard heat of reaction and standard heat of formation. **(4)**

   (c) Explain the lever rule with appropriate diagram. **(5)**

   (d) Write a short note on differential and integral balance of a transient system. **(6)**

   (e) What is heating value of a fuel? How will you calculate lower heating value of a fuel from the higher heating value and vice-versa? **(5)**

   (f) Define the terms design variables and state variables. **(5)**

   (g) In the context of psychrometric chart, define dry bulb temperature and wet bulb temperature. **(4)**

2. (a) A fuel gas containing 95 mole% methane and the balance ethane is burned completely with 25% excess air. The stack gas leaves the furnace at 900°C and is cooled to 450°C in a heat exchanger in which heat lost by cooling gases is used to produce steam from liquid water for heating, power generation, or process applications. **(18)**

   (i) Taking as a basis of calculation 100 mol of the fuel gas fed to the furnace, calculate the amount of heat (kJ) that must be transferred from the gas in the waste heat boiler to accomplish the indicated cooling.

   (ii) How much saturated steam at 50 bar can be produced from boiler feed water at 40°C for the same basis of calculation?

   (Assume all the heat transferred from the gas goes into the steam production)

(b) Ethyl alcohol can be bacterially oxidized to acetic acid in the following two-step fermentation sequence: **(17)**

$$2\,C_2H_5OH + O_2 \rightarrow 2\,CH_3CHO + 2\,H_2O$$
$$2\,CH_3CHO + O_2 \rightarrow 2\,CH_3COOH$$

Contd .......... P/2

**CHE 201**

**Contd... Q. No. 2(b)**

An aqueous solution containing ethyl alcohol in water is fermented to produce dilute acetic acid. The feed solution and air are fed at a temperature $T_o$. The product solution contains ethanol, acetaldehyde ($CH_3CHO$), acetic acid, and water. All liquid and gaseous effluents are at temperature $T$. The variables involved in the process are $n_f$ (mol feed solution), $x_{ef}$ (mol ethanol/mol feed solution), $n_{air}$ (mol air fed), $P_{xs}$ (percent excess air), $n_e$, $n_{ah}$, $n_{aa}$, $n_w$ (gram-moles of enthanol, acetaldehyde, acetic acid, and water, respectively, in the product mixture), $n_{ox}$, $n_n$ (gram-mole of oxygen and nitrogen, respectively, emerging from the reactor), $T_o$, $T$, and $Q$ (kJ heat transferred). Perform a degrees of freedom analysis for the process and specify the design variables that must be known to solve the problem completely.

3. Wet solids pass through a continuous dryer. Hot dry air enters the dryer at a rate of 400 kg/min and picks up the water that evaporates from the solids. Humid air leaves the dryer at 50°C containing 2.44 wt% water vapor and passes through a condenser in which it is cooled to 10°C. The pressure is constant at 1 atm throughout the system. **(35)**

   (i) At what rate (kg/min) is water evaporating in the dryer?

   (ii) Use the psychrometric chart to estimate the we-bulb temperature, relative humidity, dew point, and specific enthalpy of the air leaving the dryer.

   (iii) Use the psychrometric chart to estimate the absolute humidity and specific enthalpy of the air leaving the condenser.

   (iv) Use the results of parts (b) and (c) to calculate the rate of condensation of water (kg/min) and the rate at which heat must be transferred from the condenser (kW).

   (v) If the dryer operates adiabatically, what can you conclude about the temperature of the entering air? Briefly explain your reasoning. What additional information would you need to calculate this temperature?

4. (a) Liquid methyl ethyl ketone (MEK) is introduced into a vessel containing air. The system temperature is increased to 55°C, and the vessel contents reach equilibrium with some MEK remaining in the liquid state. The equilibrium pressure is 1200 mm Hg. **(17)**

   (i) use the Gibbs phase rule to determine how many degrees of freedom exist for the system at equilibrium. State the meaning of your result in your own words.

   (ii) Mixtures of MEK vapor and air that contain between 1.8 mole% MEK and 11.5 mole% MEK can ignite and burn explosively if exposed to a flame or spark. Determine whether or not the given vessel constitutes an explosion hazard.

Contd .......... P/3

**CHE 201**

**Contd... Q. No. 4**

(b) An ammonia solution at a high pressure is flash-vaporized at a rate of 200 $lb_m/h$. The solution contains 0.70 $lb_m$ $NH_3/lb$, and its enthalpy relative to $H_2O$ (1, 32°F) and $NH_3$ (1, –40°F) is –50 $Btu/lb_m$. Liquid and gas streams emerge from the unit at 1 atm and 80°F. Use Figure for Q. no. 4(b) to determine the mass flow rates and ammonia mass fractions of the vapor and the liquid product streams and the rate (Btu/h) at which heat must be transferred to the vaporizer. **(18)**

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

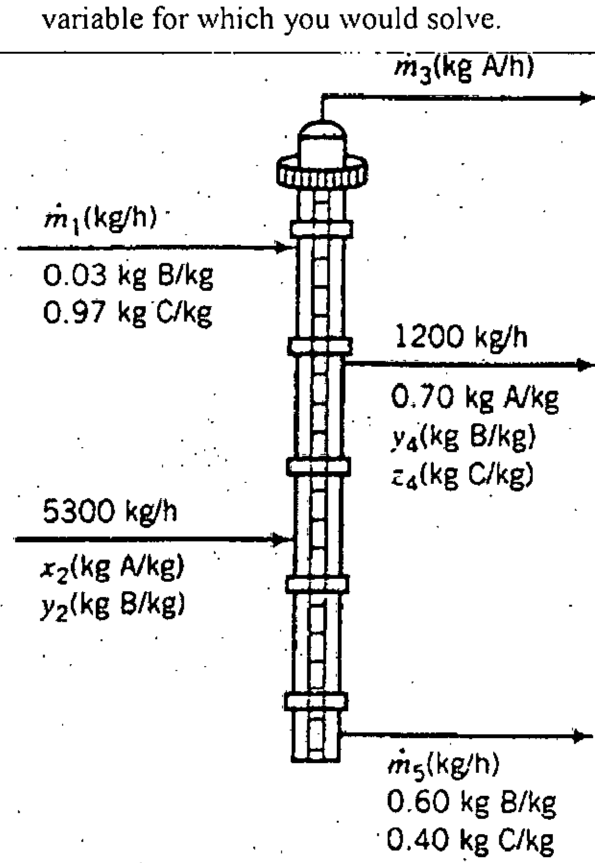
5. A distillation column is a process unit in which a feed mixture is separated by multiple partial vaporizations and condensations to form two or more product streams. The overhead product stream is rich in the most volatile components of the feed mixture (the ones that vaporize most readily), and the bottom product stream is rich in the least volatile components. **(17)**

The following flowchart (Figure 1) shows a distillation column with two feed streams and three product streams.

(i) How many independent material balances may be written for this system?

(ii) How many of the unknown flow rates and/or mole fractions must be specified before the others may be calculated? Briefly explain your answer.

(iii) Suppose values are given for $\dot{m}_1$ and $x_2$. Given a series of equations, each involving only a single unknown, for the remaining variables. Circle the variable for which you would solve.

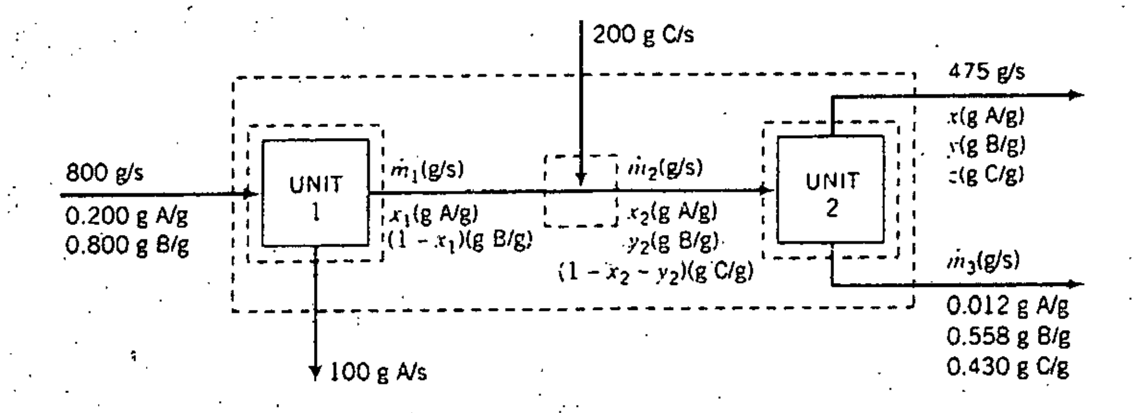



(Figure 1)

**CHE 201**

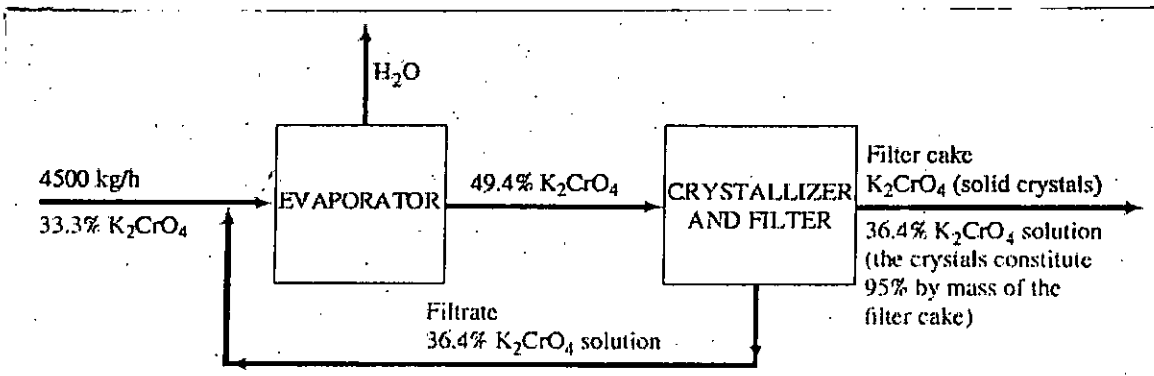
**Contd... Q. No. 2(b)**

(b) Following is a labeled flowchart (Figure 2) for a steady-state two-point process, with boundaries shown to denote subsystems about which balances can be taken. State the maximum number of balances that can be written for each subsystem and the order in which you would write balances to determine the unknown process variables. **(18)**




(Figure 2)

6. The flowchart (Figure 3) of a steady-state process to recover crystalline potassium chromate ($K_2CrO_4$) from an aqueous solution of this salt is shown below. **(35)**




Forty-five hundred kilograms per hour of a solution that is one-third $K_2CrO_4$ by mass is joined by a recycle stream containing 36.4% $K_2CrO_4$, and the combined stream is fed to an evaporator. The concentrated stream leaving the evaporator contains 49.4% $K_2CrO_4$; this stream is fed into a crystallizer in which it is cooled (causing crystals of $K_2CrO_4$ to come out of solution) and then filtered. The wet filter cake consists of $K_2CrO_4$ crystals and solution that contains 36.4% $K_2CrO_4$ by mass. The crystals account for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% $K_2CrO_4$, is the recycle stream.

(i) Calculate the rate of evaporation, the rate of production of crystalline $K_2CrO_4$, the feed rates that the evaporator and the crystallizer must be designed to handle, and the recycle ratio (mass of recycle)/(mass of fresh feed).

(ii) Suppose that the filtrate were discarded instead of being recycled. Calculate the production rate of crystals. What are the benefits and costs of the recycling?

Contd .......... P/5

**CHE 201**

7. (a) The standard heat of the reaction **(20)**

$$CaC_2(s)+5H_2O(l)\rightarrow CaO(s)+2CO_2(g)+5H_2(g) \text{ is } \Delta H_r^\circ = +69.36 \text{ kJ}$$

(i) Is the reaction exothermic or endothermic at 25°C? Would you have to heat or cool the reactor to keep the temperature constant? What would the temperature do if the reactor ran adiabatically? What can you infer about the energy required to break the molecular bonds of the reactants and that released when the product bonds form?

(ii) Calculate $\Delta U_r^\circ$ for this reaction. Briefly explain the physical significance of your calculated value.

(iii) Suppose you charge 150.0 g of $CaC_2$ and liquid water into a rigid container at 25°C, heat the container until the calcium carbide reacts completely, and cool the products back down to 25°C, condensing essentially all the unconsumed water. Write and simplify the energy balance equation for this closed constant-volume system and use it to determine the net amount of heat (kJ) that must be transferred to or from the reactor (state which).

(b) The water level in a municipal reservoir has been decreasing steadily during a dry spell, and there is concern that the drought could continue for another 60 days. The local water company estimates that the consumption rate in the city is approximately $10^7$ L/day. The city authority estimates that rainfall and stream drainage into the reservoir coupled with evaporation from the reservoir should yield a net water input rate of $10^6\exp(-t/100)$ L/day, where 't' is the time in days from the beginning of the drought, at which time the reservoir contained an estimated $10^9$ liters of water. **(15)**

(i) Write a differential balance on the water in the reservoir.

(ii) Integrate the balance to calculate the reservoir volume at the end of the 60 days of continued drought.

8. n-Butane is converted to isobutane in a continuous isomerization reactor that operates isothermally at 149°C. The feed to the reactor contains 93 mole% n-butane, 5% isobutene, and 2% HCl at 149°C, and a 40% conversion of n-butane is achieved. **(35)**

(a) Taking a basis of 1 mol of feed gas, calculate the moles of each component of the feed and product mixtures and the extent of reaction, $\xi$ (mol).

(b) Calculate the standard heat of the isomerization reaction (kJ). Then, taking the feed and product species at 25°C as references, prepare an inlet-outlet enthalpy table and calculate and fill in the component amounts (mol) and specific enthalpies (kJ/mol).

(c) Calculate the amount of heat transfer (kJ) to or from the reactor (state which it is). Then determine the required heat transfer rate (kW) for a reactor feed of 325 mol/h.

(d) Use your calculated results to estimate the heat of the isomerization reaction at 149°C, $\Delta\hat{H}_r(149°C)$ (kJ/mol).

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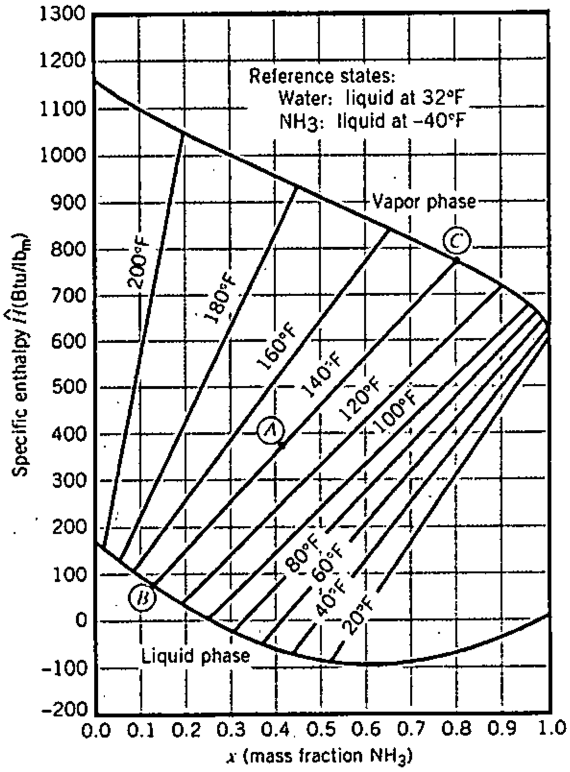


**Figure 8.5-2** Enthalpy–concentration diagram for the ammonia–water system at 1 atm. (From G. G. Brown et al., *Unit Operations*, ©1950, Figure 551. Reprinted by permission of John Wiley & Sons.)

**Figure for Q. no. 4(b)**

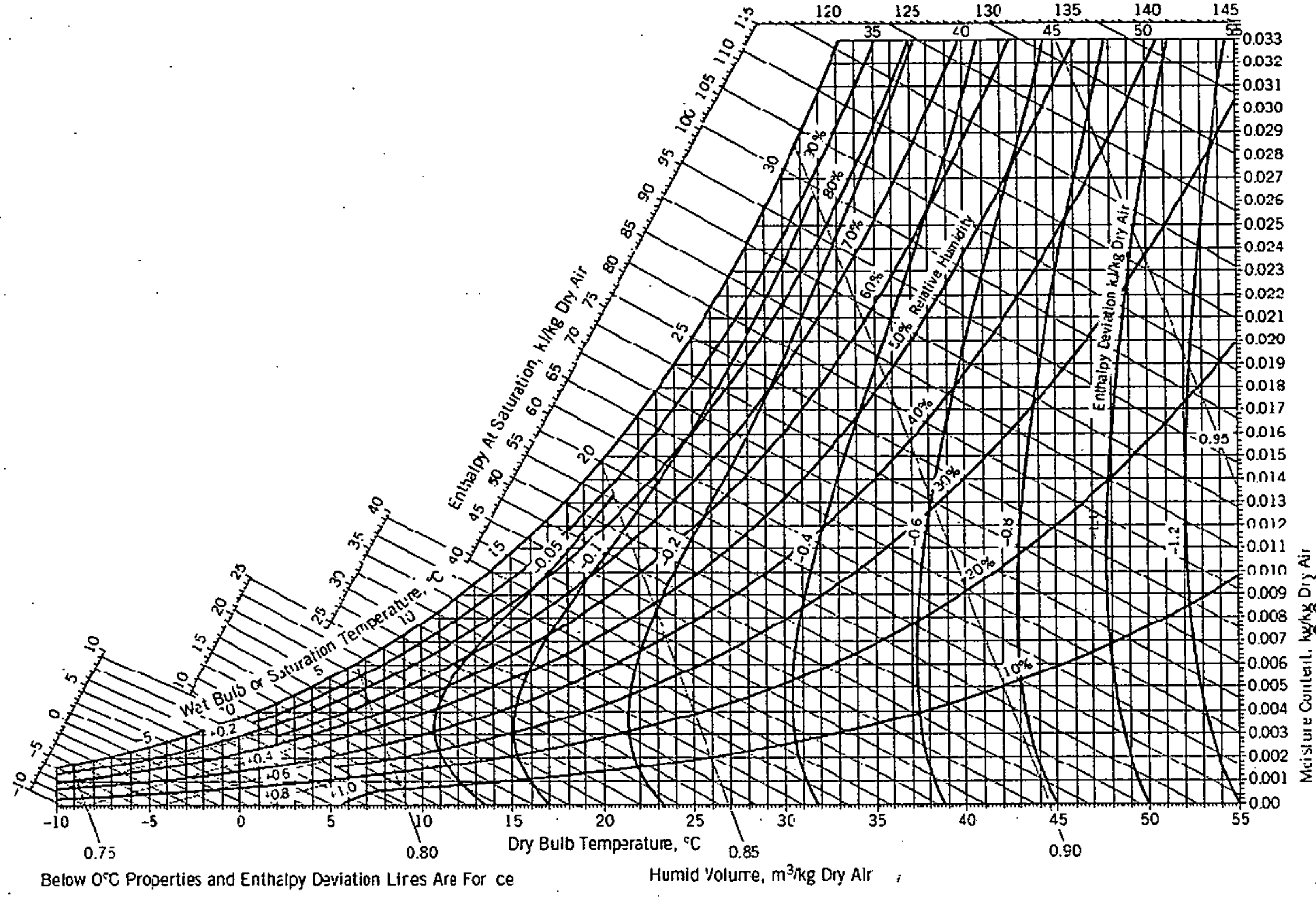


Figure 8.4-1 Psychrometric chart—SI units. Reference states: $H_2O$ (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

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CHE 201

L-2/T-1/CHE  Date: 03/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **CHE 203** (Chemical Engineering Thermodynamics I)

Full Marks: 210  Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) Briefly explain the concepts of internal energy, enthalpy, state function, equilibrium, and reversible process. **(15)**

   (b) Draw and state they key features of P-V and P-T diagram for a pure substance. **(12)**

   (c) Make a comparison between Van der Walls and Virial equation of state. **(8)**

2. (a) Derive the general expression for work done in a polytropic process. **(10)**

   (b) Write the background observations that lead to the discovery of "entropy". **(10)**

   (c) A site evaluated for a wind farm is observed to have steady winds at a speed of 8.5 m/s. Determine the wind energy (i) per unit mass, (ii) for a mass of 10 kg, and (iii) for a flow rate of 1154 kg/s for air. **(15)**

3. (a) Write short notes on **(5×4)**

   (i) The phase rule

   (ii) Carnot heat engine

   (iii) Heat pump

   (iv) Energy has quality as well as quantity

   (b) A gas in its ideal-gas state undergoes the following sequence of mechanically reversible processes in a closed system: **(15)**

   (i) From an initial state of 70°C and 1 bar, it is compressed adiabatically to 150°C.

   (ii) It is then cooled from 150 to 70°C at constant pressure.

   (iii) Finally, it expands isothermally to its original state.

   Calculate W, Q, $\Delta U^{ig}$, and $\Delta H^{ig}$ for each of the three processes and for the entire cycle. Take $C_V^{ig} = 12.471$ and $C_p^{ig} = 20.785$ $J.mol^{-1}.k^{-1}$.

4. (a) How does reversible work differ from useful work? Explain with examples. **(10)**

   (b) What is the second-law efficiency? How does it differ from the first-law efficiency? **(10)**

Contd .......... P/2

**CHE 203**

**Contd... Q. No. 4**

(c) Liquid methane is commonly used in various cryogenic applications. The critical temperature of methane is 191 K (or-82°C), and thus methane must be maintained below 191 K to keep it in liquid phase. The properties of liquid methane at various temperatures and pressures are given in the following table. Determine the entropy change of liquid methane as it undergoes a process from 110 K and 1 MPa to 120 K and 5 MPa (i) using tabulated properties and (ii) approximating liquid methane as an incompressible substance. What is the error involved in the latter case? **(15)**

**Table:** Properties of liquid methane

| Temp., $T$, K | Pressure, $P$, MPa | Density, $\rho$, kg/m³ | Enthalpy, $h$, kJ/kg | Entropy, $s$, kJ/kg · K | Specific heat, $c_p$, kJ/kg · K |
|---|---|---|---|---|---|
| 110 | 0.5 | 425.3 | 208.3 | 4.878 | 3.476 |
| | 1.0 | 425.8 | 209.0 | 4.875 | 3.471 |
| | 2.0 | 426.6 | 210.5 | 4.867 | 3.460 |
| | 5.0 | 429.1 | 215.0 | 4.844 | 3.432 |
| 120 | 0.5 | 410.4 | 243.4 | 5.185 | 3.551 |
| | 1.0 | 411.0 | 244.1 | 5.180 | 3.543 |
| | 2.0 | 412.0 | 245.4 | 5.171 | 3.528 |
| | 5.0 | 415.2 | 249.6 | 5.145 | 3.486 |

**SECTION – B**

There are **FOUR** questions in this section. Answer any **THREE** questions.

Symbols have their usual meanings

5. (a) Thermodynamic properties can be expressed as a function of a pair of independent variables: **(5+5)**

$$dU = TdS - PdV \qquad dH = TdS + VdP \qquad dA = -SdT - PdV \qquad dG = -SdT + VdP$$

$$U = U(S,V) \qquad H = H(S,P) \qquad A = A(T,V) \qquad G = G(T,P)$$

One of them serves as a generating function for other properties through simple mathematics. Which one? Why? Using the differential equation for the generating function, find the expressions for other thermodynamic properties.

(b) A simplified pH diagram is given in Figure 5(b). Label the diagram properly. Explain the processes represented by the lines 1-2, 2-3 and 3-4 in the figure. Attach this figure with your answer script. **(10)**

(c) A piston/cylinder device operating in a cycle with steam as the working fluid executes the following steps: **(15)**

- ☐ Saturated-vapor steam at 300 psia is heated at constant pressure to 900°F.
- ☐ If then expands, reversibly and adiabatically, to the iniial temperature of 417.35°F.
- ☐ Finally, the steam is compressed in a mechanically reversible, isothermal process to the initial state.

Calculate the thermal efficiency of the cycle.

Contd .......... P/3

6. Exhaust gas at 400°C and 1 bar from internal-combustion engines flow at the rate of 125 mol $s^{-1}$ into a waste-heat boiler where saturated steam is generated at a pressure of 1200 kPa. Water enters the boiler at 20°C, and the exhaust gases are cooled to within 10°C of the steam temperature. The heat capacity of the exhaust gases is $\frac{C_P}{R} = 3.34 + 1.12\times10^{-3}T$. The steam flows into an adiabatic turbine and exhausts at a pressure of 25 kPa. If the turbine efficiency is 72%, **(15+5+8+7)**

   (a) What is the power output of the turbine?

   (b) What is the thermodynamic efficiency of the boiler/turbine combination?

   (c) Determine $\dot{S}_G$ for the boiler and the turbine.

   (d) Express $\dot{W}_{lost}$ (boiler) and $\dot{W}_{lost}$ (turbine) as fraction of the ideal work of the process.

7. (a) TS diagrams of Carnot and Rankine cycles are shown in Figure 7(a). With the help of these diagrams list the steps involved in each cycle. **(10)**

   (b) "Carnot cycle is not suitable for steam power plant, but Rankine cycle is." — Explain. **(10)**

   (c) For same compression ratio, the Otto engine has higher efficiency than the Diesel engine. However, in practice, Diesel engine operates at higher efficiencies than Otto engine. — Explain. **(5)**

   (d) Liquefied natural gas (LNG) is transported in very large tankers, stored as liquid in equilibrium with its vapor at approximately atmospheric pressure. If LNG is essentially pure methane, the storage temperature is about 111.4 K, the normal boiling point of methane. The enormous amount of cold liquid can in principle serve as a heat sink for an onboard heat engine. Energy discarded to the LNG serves for its vaporization. If the heat source is ambient air at 300 K, and if the efficiency of a heat engine is 60% of its Carnot value, estimate the vaporization rate in moles vaporized per kJ of power output. For methane, $\Delta H_v^{lv} = 8.206$ kJ $mol^{-1}$. **(10)**

8. (a) What are the factors one need to consider for selection of a refrigerant? **(5)**

   (b) Figure 8(b) shows timeline for refrigerants illustrating the developments in HFCs and HFOs, the continued use of R717 and the resurgence of R744. Explain this global trend with the help of your knowledge on contemporary issues and choice of refrigerants. **(10)**

   (c) Draw the process block diagrams for Linde and Claude liquefaction process. Using the diagrams compare these processes. **(20)**

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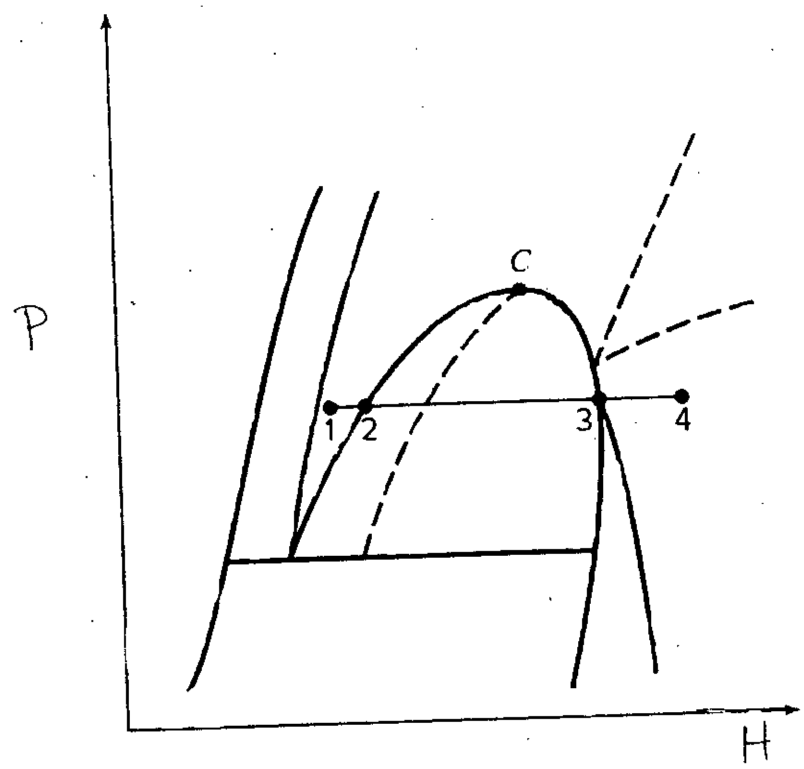


Figure 5(b)

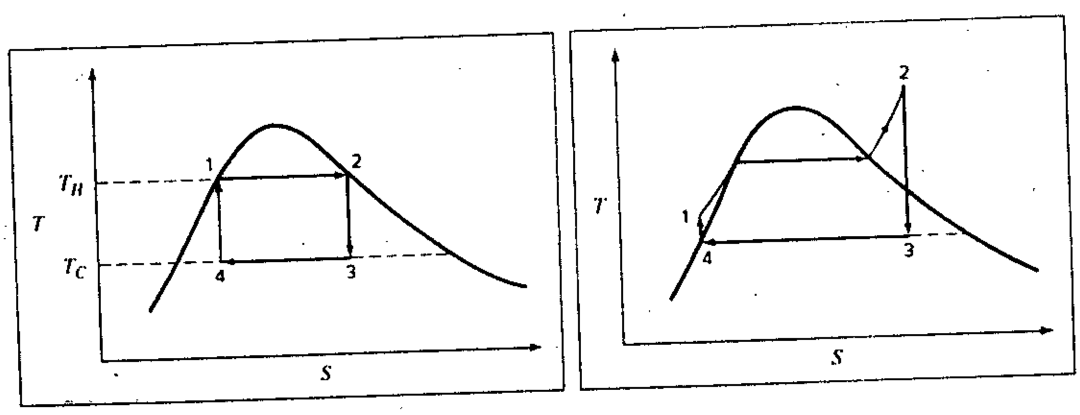


Figure 7(a)

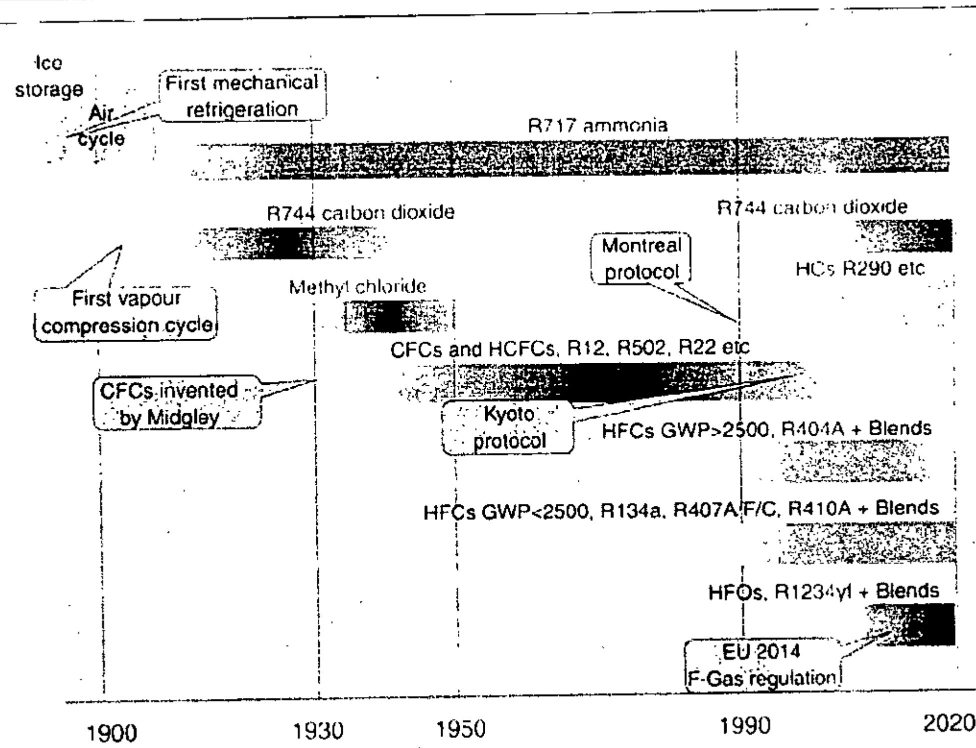


Figure 8(b)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **CHEM 235** (Physical Chemistry II)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

Symbols used here bear usual meaning. Assume reasonable value for any missing data.

1. (a) Rationalize the following: **(13×2=26)**

   (i) Equivalent conductance increases but specific conductance decreases with increasing dilution of an electrolyte solution.

   (ii) The dilution law can be used for simultaneous determination of $\Lambda^\circ$ and $K_a$ of a weak acid.

   (b) The conductivity of a solution containing 1 g of anhydrous $BaCl_2$ in 200 mL of water was found to be 0.0058 $ohm^{-1}cm^{-1}$. What are the molar conductivity and equivalent conductivity of the solution? **(9)**

   (Given: Atomic mass of $B_a$ = 137 and Cl = 35.5)

2. (a) What is ionic atmosphere? Explain how the motion of ions in ionic atmospheres is retarded by asymmetric and electrophoretic effects. **(12)**

   (b) Define ionic strength. Show that the solubility of a sparingly soluble salt increases with increasing the ionic strength of added electrolytes having no common ion. **(14)**

   (c) The solubility of $AgIO_3$ in water is $1.761\times10^{-4}$ $molL^{-1}$at 25°C. Calculate the solubility in 0.01 M $KNO_3$. **(9)**

3. (a) Define transport number. Show that the transport number of an ion is directly proportional to its migration velocity. **(12)**

   (b) What are concentration cells with transference? Consider the following cell: **(14)**

   $$H_2(g, 1\,atm)|HCl(a_1)|HCl(a_2)|H_2(g, 1\,atm)$$

   Explain the possible sources of emf of the cell and show that the transference of $Cl^-$ should appear in the emf equation.

   (c) Can a solution of 1M $CuSO_4$ be stored in a vessel made of Ni metal? Given that $E^\circ_{Ni/Ni^{2+}}$ = +0.25 V and $E^\circ_{cu|cu^{2+}}$ = –0.34 V. **(9)**

Contd .......... P/2

**CHEM 235/CHE**

4. (a) Explain the influence of ionic concentration on the emf of a cell and hence justify that the formula of mercurous chloride is $Hg_2Cl_2$ not HgCl. **(12)**

(b) Describe how ΔG, ΔH and ΔS can be determined from cell emf measurement and the temperature coefficient of the emf. **(14)**

(c) The emf of the cell **(9)**

$$Ag|AgCl(s)|KCl(aq)|Hg_2Cl_2(s)|Hg$$

is 0.455 V at 25°C and the temperature coefficient is $3.38\times10^{-4}$ volt/degree. What is the reaction taking place in the cell, and what are the values of ΔH and ΔS at 25°C?

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. (a) How would you apply the Beer-Lambert Law for quantitative estimation of metal ions in solution? What are chromophores? **(9)**

(b) Illustrate fluorescence and phosphorescence with appropriate diagrams. **(10)**

(c) Consider the vibration of a diatomic molecule. The molecule may undergo simple harmonic oscillation or anharmonic oscillation. Justify the following statements. **(16)**

(i) The diatomic molecule can never have zero vibrational energy.

(ii) The energy for an allowed vibrational transition does not depend on the vibrational quantum number (selection rule $\Delta v = \pm 1$).

(iii) Frequency of an anharmonic oscillator decreases steadily with increasing vibrational quantum number.

(iv) The vibrational transitions $v = 1$ to $v = 2$, $v = 1$ to $v = 3$, $v = 1$ to $v = 4$ etc. are not observable.

6. (a) Consider the following consecutive reaction: **(15)**

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

The rate constants $k_1$ and $k_2$ are comparable in magnitude and the rate of overall reaction depends on both constants.

(i) Identify the condition at which a reaction is consecutive.

(ii) Suggest the individual rate expressions with respect to A, B and C.

(iii) Demonstrate the reaction profile for A, B and C.

(iv) Justify the two conditions: $k_1 >> k_2$ and $k_2 >> k_1$.

(v) Estimate the *optimum time* to manufacture the intermediate B in a batch process.

(vi) Choose a common example of consecutive reaction.

(b) Why termolecular reactions are infrequent? How the reaction order can be determined by differential method? **(10)**

Contd .......... P/3

## CHEM 235/CHE

**Contd... Q. No. 6**

(c) The rate of conversion of cyclopropane to propene was measured over the range 750-900 K, and the rate constants that were found are reported below. With an appropriate Arrhenius plot, calculate the activation energy and pre-exponential factor for the reaction. **(10)**

| T/K | 750 | 800 | 850 | 900 |
|---|---|---|---|---|
| $k/(s^{-1})$ | $1.8 \times 10^{-4}$ | $2.7 \times 10^{-3}$ | $3 \times 10^{-2}$ | 0.26 |

7. (a) Illustrate the adsorption theory of catalysis. **(9)**

(b) Consider the adsorption of gas molecules on a solid surface and it follows the Langmuir isotherm: **(16)**

$A(g) + M(surface) \rightleftharpoons AM(surface)$

- (i) List the assumptions required to obtain a Langmuir isotherm.
- (ii) Construct the expression for surface coverage ($\theta$).
- (iii) Justify the effect of pressure on surface coverage with appropriate graph.
- (iv) How would you determine the volume corresponding to complete coverage?

(c) The adsorption of a gas is described by the Langmuir isotherm with K = 1.85 $kPa^{-1}$ at 25°C. Calculate the pressure at which the fractional surface coverage is (i) 0.10 (ii) 0.90. **(10)**

8. (a) Michaelis-Menten mechanism explains the enzyme catalysis reactions provided all species are in an aqueous environment. The rate of product formation is **(15)**

$$v = \frac{k_b[E]_0[S]_0}{[S]_0 + K_M}$$

- (i) Demonstrate the reaction steps in this mechanism.
- (ii) Identify the condition at which the rate of the reaction reaches its maximum.
- (iii) From Lineweaver-Burk plot, how would you determine the maximum rate?
- (iv) How the catalytic efficiency ($\eta$) can be determined? What is the significance of $\eta$?
- (v) Does this mechanism have any limitation?

(b) Explain the features of the phase diagram of sulphur. The four phases do not coexist in equilibrium. – Justify. **(10)**

(c) What are supercritical fluids? Illustrate the principle of freeze drying. **(10)**

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L-2/T-1/CHE **Date: 20/10/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **MATH 221** (Vector Analysis, Matrices and Laplace Transforms)

Full Marks: 280 Time: 3 Hours

The figures in the margin indicate full marks

Symbols indicate their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) If M and N are the middle points of AB and CD of the parallelogram ABCD, prove that DM and BN are trisected by AC and AC is trisected by them as well. **(20)**

   (b) If **a**, **b**, **c** are non-coplanar vectors then prove that the following four points are coplanar: **($16\frac{2}{3}$)**

   $$-a+4b-3c,\ 3a+2b-5c,\ -3a+8b-5c,\ -3a+2b+c$$

   (c) Give the geometrical interpretation of the scalar triple product. **(10)**

2. (a) Show that acceleration of a particle along a curve is a vector in the plane of the tangent and the normal with $\frac{dv}{dt}$ and $v^2k$ as its tangential and normal components respectively. **($21\frac{2}{3}$)**

   (b) Determine whether the vector field $\mathbf{F}(x,y,z)$ is free of sources and sinks. If it is not, locate them, for $\mathbf{F}(x,y,z)=xy\mathbf{i}-xy\mathbf{j}+y^2\mathbf{k}$. **(10)**

   (c) Show that Curl $(\mathbf{F}\times\mathbf{G}) = \mathbf{F}\,div\mathbf{G} - \mathbf{G}\,div\mathbf{F} + (\mathbf{G}.\nabla)\mathbf{F} - (\mathbf{F}.\nabla)\mathbf{G}$ **(15)**

3. (a) Find the directional derivative of $w=2x^2+3y^2+z^2$ at $(1,-1,2)$ in the direction of the line $\frac{x}{3}=\frac{y}{4}=\frac{z}{5}$. Find the maximum rate of increase of $w$ at $(1,-1,2)$. **(15)**

   (b) Show that the gradient of a scalar function $f$ is a vector along the normal to the level surface whose magnitude is the greatest rate of change of $f$. **($16\frac{2}{3}$)**

   (c) Find curl of $(\mathbf{r}f(r))$ where $f(r)$ is differentiable. **(15)**

4. (a) State and verify Green's theorem in the plane for $\int_C (2x-y^3)dx - xydy$ where $C$ is the boundary of the region enclosed by $x^2+y^2=1$ and $x^2+y^2=4$. **($26\frac{2}{3}$)**

   (b) Evaluate $\iiint_V (2x+y)dV$ where V is the closed region bounded by $z=4-x^2$, $x=0, y=0, y=2$ and $z=0$. **(20)**

Contd .......... P/2

## MATH 221

### SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Find the canonical matrix and hence find the rank of $A = \begin{bmatrix} 2 & 7 & 3 & 5 \\ 1 & 2 & 3 & 4 \\ 3 & 8 & 1 & -2 \\ 4 & 13 & 1 & -1 \end{bmatrix}$ **(16)**

(b) Using only elementary row transformation find the inverse of $A = \begin{bmatrix} 5 & -2 & -2 \\ -1 & 1 & 0 \\ -1 & 0 & 1 \end{bmatrix}$ **($14\frac{2}{3}$)**

(c) Reduce the quadratic form $q = x_1^2 + 3x_2^2 - 2x_3^2 + 2x_1x_2 + 4x_1x_3$ to the canonical form and find rank, index and signature of the form. **(16)**

6. (a) Solve the following system of linear equations by converting it to matrix form: **(20)**

$$x_1 + x_2 + x_3 + x_4 - 4 = 0$$
$$2x_1 - x_2 - x_3 + 3x_4 - 6 = 0$$
$$3x_1 + 4x_2 - 5x_3 + 6x_4 + 11 = 0$$
$$7x_1 - 5x_2 + 7x_3 + x_4 - 46 = 0$$

(b) Use Cayley-Hamilton theorem to find the inverse of A for the matrix **($16\frac{2}{3}$)**

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 1 & 3 & 6 \\ 2 & 6 & 13 \end{bmatrix}$$

(c) Find the eigenvalues and eigenvectors of the matrix $A = \begin{bmatrix} 1 & 3 & 4 \\ 3 & 5 & 6 \\ 4 & 6 & 7 \end{bmatrix}$ **(10)**

7. (a) If $L\{F(t)\} = f(s)$, then show that $L\left\{\int_0^t F(u)du\right\} = \frac{f(s)}{s}$ **(12)**

(b) Evaluate: $\int_0^\infty \frac{e^{-t}\sin^2 t}{t} dt$ **($16\frac{2}{3}$)**

(c) Prove that $L\{\cos t\, Si(t) - \sin t\, Ci(t)\} = \frac{\ln s}{s^2+1}$. **(18)**

8. (a) Evaluate: (i) $L^{-1}\left\{\frac{5s-2}{3s^2+4s+8}\right\}$ (ii) $L^{-1}\left\{\frac{1}{s^2(s^2+4)}\right\}$ using convolution theorem. **(8+8)**

(b) Evaluate: $\int_0^\infty e^{-x^2} dx$ by using Laplace transform. **(14)**

(c) Solve $Y''(t) + 2Y'(t) + 5Y(t) = e^{-t}\sin t$ , $Y(0) = 0$ , $Y'(0) = 1$ by using Laplace transform. **($16\frac{2}{3}$)**

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**L-2/T-1/CHE** **Date: 09/11/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **EEE 267** (Electrical and Electronic Technology)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** questions.

1. (a) Two balanced loads are connected to a 240 kV rms 60 Hz balanced line, as shown in Fig. for Q. 1(a). Load 1 consumes 120 kW at a power factor of 0.6 lagging, while load 2 consumes 180 kVAR at a power factor of 0.8 lagging. Assuming the *abc* sequence, determine: **(15)**

   (i) The complex, real and reactive powers consumed by the combined load
   (ii) The line currents
   (iii) The kVAR rating of the three capacitors Δ-connected in parallel with the load that will raise the power factor to 0.9 lagging.
   (iv) The capacitance of each capacitor.

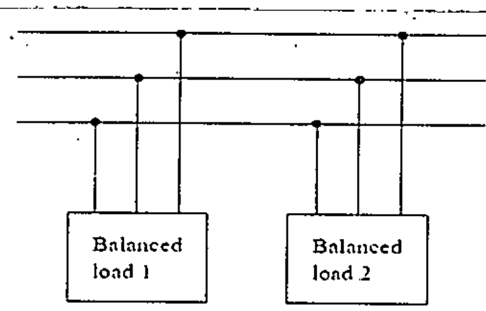


Fig. for Q. 1(a)

(b) Find the line currents in the unbalanced three-phase circuit of Fig. for Q. 1(b) and the total real power absorbed by the load. **(12)**

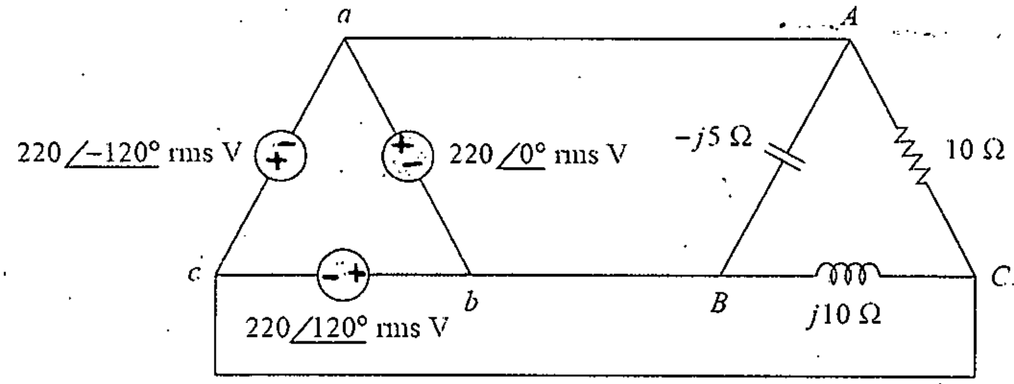


Fig. for Q. 1(b)

(c) Show that, for both Y and Δ-connected system, the total real power supplied by the 3-phase source is $3V_pI_p\cos\theta$ where, $V_p$ = Phase voltage, $I_p$ = Phase current and $\theta$ = phase difference between phase current and corresponding phase voltage. **(8)**

Contd .......... P/2

**EEE 267/CHE**

2. (a) The 6.8 V Zener diode in the circuit of Fig. for Q. 2(a) is specified to have $V_z = 6.8\,V$ at $I_z = 5\,mA$, $V_{z0} = 6.7\,V$ and $I_{ze} \approx 0.2\,mA$. The supply voltage $V^+$ is nominally 10 $V$ but can vary by $\pm 1\,V$. Find out: **(15)**

   (i) $V_0$ with no load and with $V^+$ at its nominal value.

   (ii) Line regulation

   (iii) Load regulation

   (iv) Change in $V_0$ when $R_L = 2\,k\Omega$

   (v) Change in $V_0$ when $R_L = 0.5\,k\Omega$

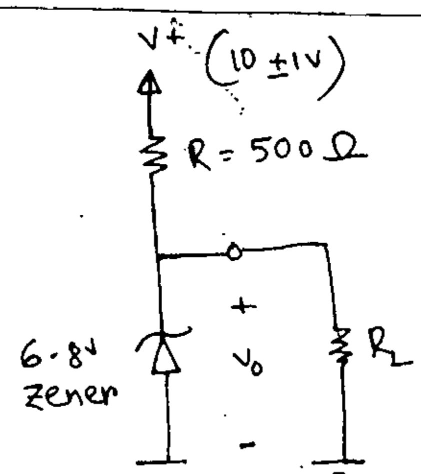


Fig. for Q. 2(a)

(b) Draw the full wave bridge rectifier arrangement. Mention the states (forward or reverse) of the diodes during the positive and negative half cycle. Draw the waveshape of the output voltage vs time for a sinusoidal input voltage. How can we make the pulsating output voltage smoother? **(12)**

(c) Assuming the diodes to be ideal, find the values of $I_1$, $I_2$ and $V$ in the circuit of Fig. for Q. 2(c). **(8)**

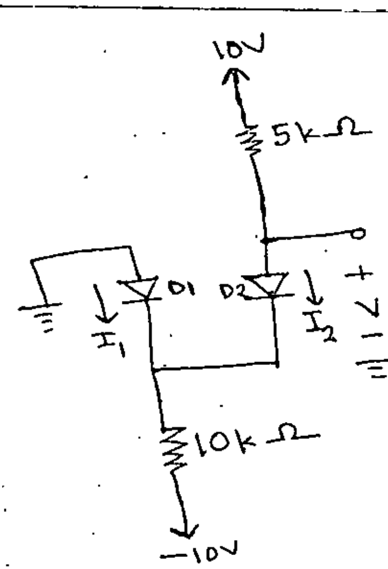


Fig. for Q. 2(c)

3. (a) Design the circuit of Fig. for Q. 3(a) so that the transistor operates in saturation with $I_D = 0.5\ mA$, $V_D = +3V$ and the current through $R_1$ and $R_2$ is 1 μA. Given the transistor has $V_t = -1\ V$ and $k'_p\left(\frac{W}{L}\right) = 1\ mA/V^2$. Neglect the channel-length modulation effect. What is the largest value that $R_3$ can have while maintaining saturation region operation? **(14)**

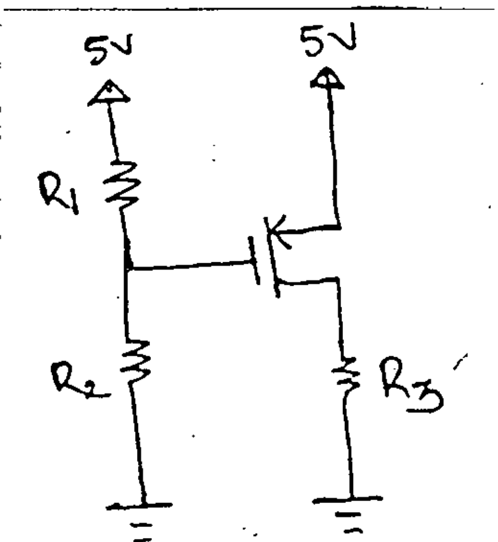


Fig. for Q. 3(a)

(b) The NMOS and PMOS transistors in the circuit of Fig. for Q. 3(b) are matched with $k'_n\left(\frac{W}{L}\right) = k'_p\left(\frac{W}{L}\right) = 1\ mA/V^2$ and $V_{tn} = -V_{tp} = 1\ V$. Assuming $\lambda = 0$ for both devices, find the drain currents $I_{DN}$ and $I_{DP}$, as well as the voltage $v_O$ for $v_{in} = 0\ V, +2.5\ V$ and $-2.5\ V$. **(16)**

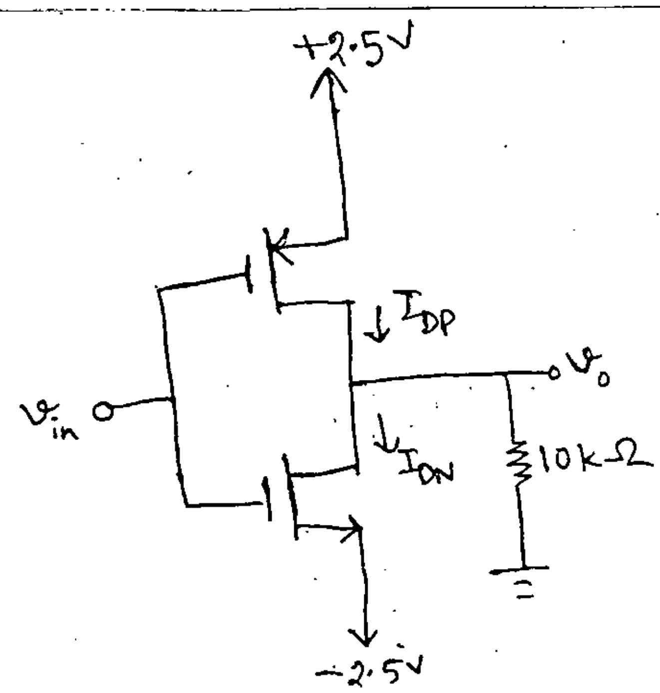


Fig. for Q. 3(b)

**EEE 267/CHE**
**Contd... Q. No. 3**

(c) Draw the clipper circuit for which the input and output graphs follow Fig. for Q. 3(c). **(5)**

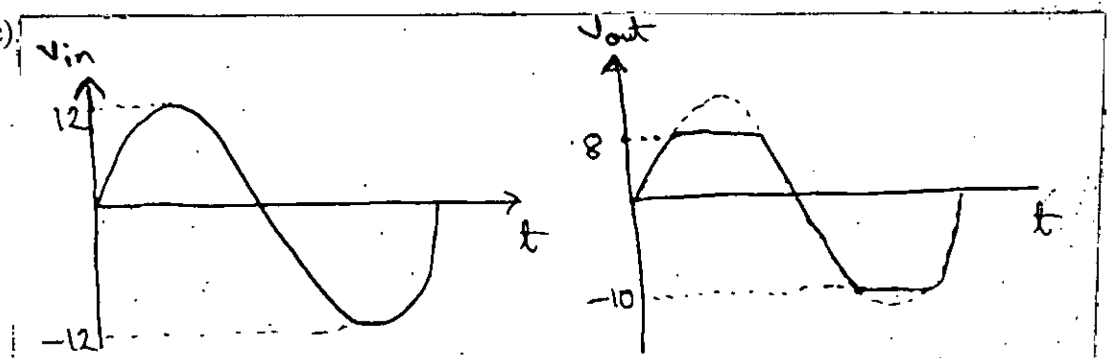


Fig. for Q. 3(c)

4. (a) Analyze the circuit of Fig. for Q. 4(a) to determine the voltages at all nodes and the current through all branches. Assume $\beta = 100$. **(15)**

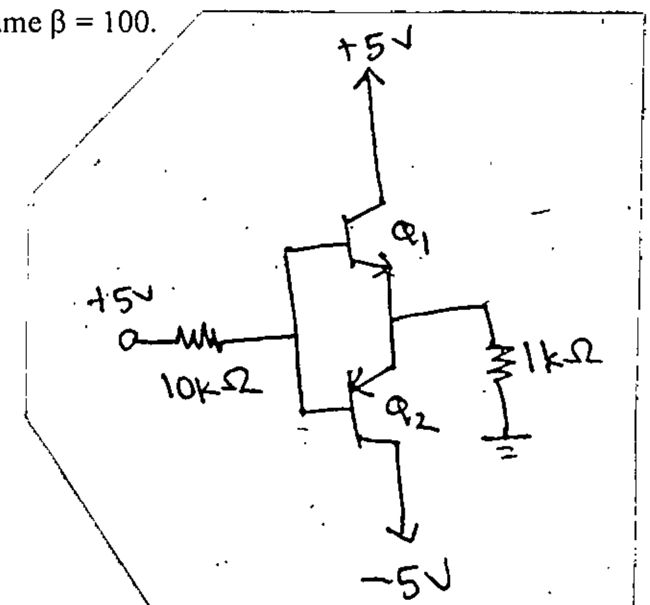


Fig. for Q. 4(a)

(b) Analyze the circuit of Fig. for Q. 4(b) to determine the voltages at all nodes and the current through all branches. Assume $\beta = 100$ for the active mode. The minimum value of $\beta$ is specified to be 30. **(15)**

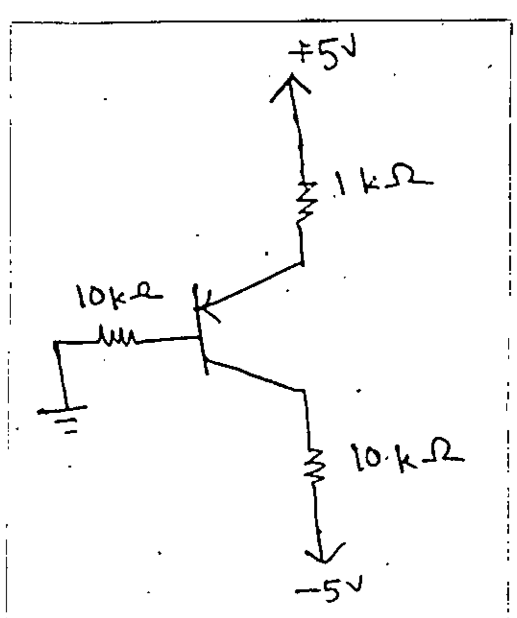


Fig. for Q. 4(b)

(c) Draw the arrangement for a non-inverting 3 *V* detector with an op-amp. **(3)**

(d) What is transducer? Give an example. **(2)**

Contd .......... P/5

## SECTION – B

There are **FOUR** questions in this section. Answer any **THREE** questions.

5. (a) Describe in detail, the effect of load change on a synchronous motor that is initially operating at a leading power factor. **(15)**

(b) A 1500 VA, 230/115-V transformer has been tested to determine its equivalent circuit. The result of the tests are shown below: **(20)**

| Open-circuit test (on primary) | Short-circuit test (on secondary) |
|---|---|
| $V_{OC} = 230\ V$ | $V_{SC} = 19.1\ V$ |
| $I_{OC} = 0.45\ A$ | $I_{SC} = 13\ A$ |
| $P_{OC} = 30\ W$ | $P_{SC} = 42.3\ W$ |

(i) Find the equivalent circuit of this transformer referred to the low-voltage side of the transformer. Also draw the equivalent circuit, using the values you have obtained.

(ii) Determine the transformer's voltage regulation at rated conditions and 0.85 PF leading. Draw the phasor diagram for this condition as well.

6. (a) A synchronous generator is driving a synchronous motor in under-excited condition. Draw separate phasor diagram for both synchronous machines in this condition. **(10)**

(b) What are the conditions and advantages for parallel operation of AC generators? **(12)**

(c) Three physically identical synchronous generators are operating in parallel. They are all rated for a full load of 100 MW at 0.8 PF lagging. The no-load frequency and slope of their frequency-power characteristics are as follows: **(13)**

Generator A    no-load frequency –61 Hz,    slope –56.27 MW/Hz
Generator B    no-load frequency –61.5 Hz,    slope –49.46 MW/Hz
Generator C    no-load frequency –60.5 Hz,    slope –65.23 MW/Hz

(i) If a total load consisting of 230 MW is being supplied by this power system, what will the system frequency be?

(ii) How much power is supplied by each of the three generators?

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7. (a) Derive the Thevenin equivalent voltage $V_{TH}$ and impedance $Z_{TH}$ of the input side of an induction motor. Also show that maximum torque of an induction motor is given by, **(17)**

$$\tau_{max} = \frac{3V_{TH}^2}{2\omega_{sync}\left[R_{TH} + \sqrt{R_{TH}^2 + (X_{TH} + X_2)^2}\right]}$$

(b) A 460-V, 25 hp, 60-Hz, four pole, wye-connected wound-rotor induction motor has the following impedances in ohms per phase referred to the stator circuit: **(18)**

$R_1 = 0.641\ \Omega$ $R_2 = 0.332\ \Omega$ $X_M = 26.3\ \Omega$

$X_1 = 1.106\ \Omega$ $X_2 = 0.464\ \Omega$

(i) What is the maximum torque of this motor? At what speed and slip does it occur?

(ii) Find the starting torque of this motor.

(iii) Draw the torque-speed characteristic of this induction motor using the values you have found in (i) and (ii).

8. (a) Derive the terminal characteristics of a shunt DC motor. Draw its terminal characteristics and explain how the shape changes due to presence of armature reaction. **(15)**

(b) A separately excited DC generator is rated at 430 V and 1800 r/min. Its magnetization curve at a speed of 1800 r/min is shown in Fig. for Q8(b). This machine has the following characteristics: **(20)**

$R_A = 0.05\ \Omega$ $V_F = 430\ V$

$R_F = 20\ \Omega$ $N_F = 1000$

$R_{adj} = 0$ to $300\ \Omega$

(i) If the variable resistance in this generator's field circuit is adjusted to 63 Ω and the generator's prime mover is driving it at 1600 r/min, what is this generator's no-load terminal voltage?

(ii) What would its voltage be if a 360-A load were connected to its terminal? Assume that the armature reaction at this load is 450 A · turns.

(iii) State the adjustment that could be made to the generator to restore its terminal voltage to the value found in part (i).

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**Contd... Q. No. 8**

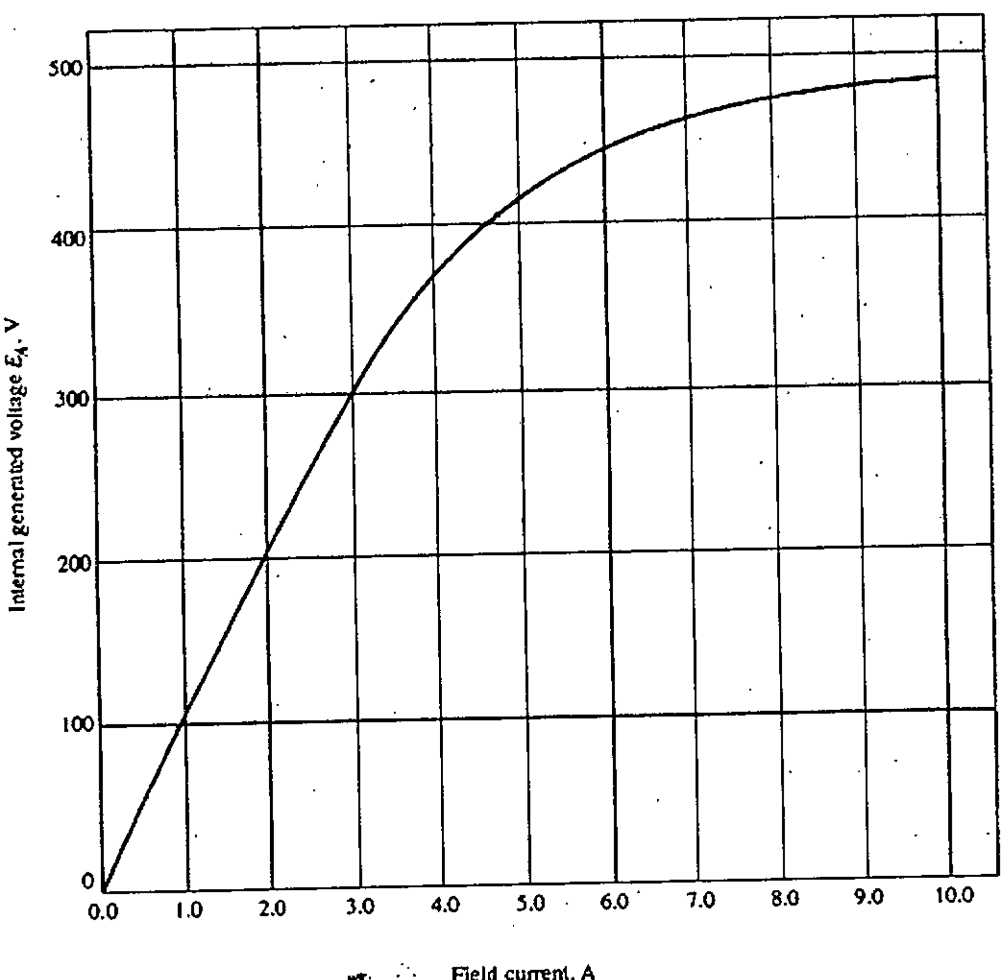


Fig. for Q8(b)

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