L-1/T-1/CHE

Date : 25/03/2023

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CHE 101** (Elementary Principles of Chemical Engineering)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

A Data Booklet (ChE 101/201) containing relevant data to be supplied.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) A mixture of 75 mole% methane and 25 mole% hydrogen is burned with 25% excess air. Fractional conversions of 90% of the methane and 85% of the hydrogen are achieved; of the methane that reacts, 95% reacts to form CO_2 and the balance reacts to form CO. The hot combustion product gas passes through a boiler in which heat transferred form the gas converts boiler feedwater into steam. Calculate the concentration of CO (ppm) in the stack gas. **(15)**

(b) A water pipe is connected to a double-U manometer at a location where the local atmospheric pressure is 14.2 psia. See Figure 1: Fig for Q. 1(b). Determine the absolute pressure at the center of the water pipe. **(20)**

[g = 32.2 ft/s^2; Specific wt. of water = 62.4 lb_f/ft^3]

Assume all the fluids are at 20°C.

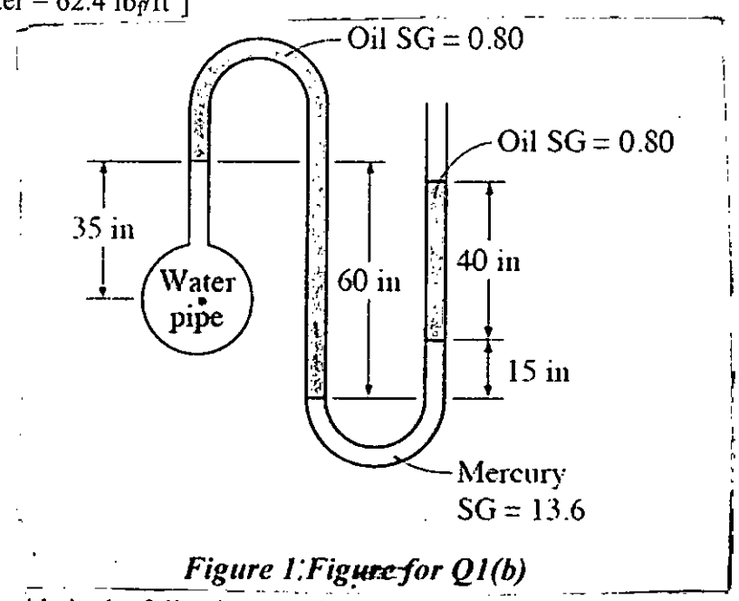

Figure 1: Figure for Q1(b)

2. (a) Ammonia is oxidized to nitric oxide in the following reaction:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

(i) If ammonia is feed to a continuous reactor at a rate of 100.0 kmol NH_3/h, what oxygen feed rate (kmol/h) would correspond to 40.0% excess O_2? **(5)**

(ii) If 50.0 kg of ammonia and 100.0 kg of oxygen are fed to a batch reactor, determine the limiting reactant, the percentage by which the other reactant is in excess, and the extent of reaction and mass of NO produced (kg) if the reaction proceeds to completion. **(10)**

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Contd ... Q. No. 2

(b) The analysis of a coal indicates 70 wt% C, 22% H, 2% S, and the balance nonocombustible ash. The coal is burned at a rate of 3,500 kg/h, and the feed rate of air to the furnace is 45 kmol/min. All of the ash and 8% of the carbon in the fuel leave the furnace as a molten slag; the remainder of the carbon leaves in the stack gas as CO and CO_2; the hydrogen in the coal is oxidized to water, and the sulfur emerges as SO_2. The selectivity of CO_2 to CO production is 9:1.

(i) Calculate the percent excess air fed to the reactor. **(4)**

(ii) Calculate the mole fractions of the gaseous pollutants—CO and SO_2—in the stack gas. **(8)**

(iii) Calculate the rate of formation of sulfuric acid (kg/h) if all the emitted SO_2 is converted in the indicated manner. **(4)**

(iv) What is the environmental implication of releasing SO_2 in the environment? **(4)**

3. Methanol is produced by reacting carbon monoxide and hydrogen. A fresh feed stream containing CO and H_2 joins a recycle stream and the combined stream is fed to a reactor. The reactor outlet stream flows at a rate of 350 mol/min and contains 10.6 wt% H_2, 64.0 wt% CO, and 25.4 wt% CH_3OH. This stream enters a cooler in which most of the methanol is condensed. The liquid methanol condensate is withdrawn as a product, and the gas stream leaving the condenser—which contains CO, H_2, and 0.40 mole% uncondensed CH_3OH vaopr—is the recycle stream that combines with the fresh feed.

(i) Draw the label the flowchart, perform a degree-of-freedom analysis, and write the equations you would use to calculate (a) the molar flow rates of CO and H_2 in the fresh feed, (b) the production rate of liquid methanol, and (c) the single-pass and overall conversions of carbon monoxide. In each equation (or pair of simultaneous equations), circle the variable(s) for which you would solve. **(15)**

(ii) Calculate the quantities specified in Part (a). **(12)**

(iii) Calculate the molar flow rates of CO and H_2 in the fresh feed needed to produce 1 ton per hour of Methanol. **(8)**

4. An evaporation-crystallization process is used to obtain solid potassium sulfate from an aqueous solution of this salt. The fresh feed to the process contains 19.6 wt% K_2SO_4. The wet filter cake consists of solid K_2SO_4 crystals and a 40.0 wt% K_2SO_4 solution, in a ratio 10 kg crystals/kg solution. The filtrate, also a 40.0% solution, is recycled to join the fresh feed. Of the water fed to the evaporator, 45.0% is evaporated. The evaporator has a maximum capacity of 175 kg water evaporated/s.

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(i) Assume the process is operating at maximum capacity. Draw and label a flowchart and do the degree-of-freedom analysis for the overall system, the recycle-fresh feed mixing point, the evaporator, and the crystallizer. Then write in an efficient order the equations you would solve to determine all unknown stream variables. In each equation (or pair of simultaneous equations), circle the variable(s) for which you would solve. **(15)**

(ii) Calculate the maximum production rate of solid K_2SO_4, the rate at which fresh feed must be supplied to achieve this production rate, and the ratio kg recycle/kg fresh feed. **(12)**

(iii) Calculate the composition and feed rate of the stream entering the crystallizer if the process is scaled to 75% of its maximum capacity. **(8)**

SECTION – B

There are **FOUR** questions in this section. **Question No. 5 is COMPULSORY and carries 45 Marks.** Answer **Q. No. 5** and any **TWO** from the rest.

5. **COMPULSORY.**

(a) Write down the general energy balance equation and simplify it with justification for each of the following cases. **(12)**

(i) A liquid stream flows through a heat exchanger in which it is heated from 25 °C to 80 °C. The inlet and outlet pipes have the same diameter, and there is no change in elevation between these points.

(ii) Water passes through the sluice gate of a dam and falls on a turbine rotor, which turns a shaft connected to a generator. The fluid velocity on both sides of the dam is negligible, and the water undergoes insignificant pressure and temperature changes between the inlet and outlet.

(iii) Natural gas is pumped through a cross-country pipeline. The pipe inlet is 200 m higher than the outlet, the pipe diameter is constant, and the pump is located near the midpoint of the pipeline. Energy dissipated by friction in the line is transferred as heat through the wall.

(b) One kg water from its ice state at –10 °C and 10 bar pressure is brought to its vapor state at 300 °C and 20 bar pressure. The specific heat of ice can be assumed as half of that of the liquid water. Perform the following: **(15)**

(i) Draw clearly a hypothetical process path for accomplishing the task.

(ii) How much heat must be added at each step of the hypothetical process path?

(iii) What is the total heat required to accomplish the entire process?

(iv) What observations/comments can be made from the above calculations?

Make and list necessary assumptions as required.

Contd P/4

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Contd ... Q. No. 5

(c) In 2022, a large industrial complex used 10 GWh (Giga Watt-hour) electricity, 1000 MMSCF (Million Standard Cubic Feet) natural gas and 1 million ton of coal. Assume, the heating value of natural gas is 1000 Btu/SCF and heating value of coal is 10000 Btu/lbm. What was the total amount of energy (Btu) used by the industrial complex? If the average cost of energy is 2 taka per 1000 Btu, how much money the company paid as its energy bill in 2022? **(8)**

(d) Perform the following calculations and write the final results using the rules of significant figures **(10)**

(a) 3.20×5.678 (b) $-0.02+2.00+300$

(c) $200.2/(0.020*5.40)$ (d) $3564.25+45.510+0.455$

(e) $200 - 80$

6. A natural gas at 20 °C containing 90 mole% methane and the balance ethane is burned with 20.0% excess air. The stack gas, which contains no unburned hydrocarbons or carbon monoxide, leaves the furnace at 900 °C and 1.2 atm and passes through a heat exchanger. The air on its way to the furnace also passes through the heat exchanger, entering it at 20°C and leaving it at 300°C. **(30)**

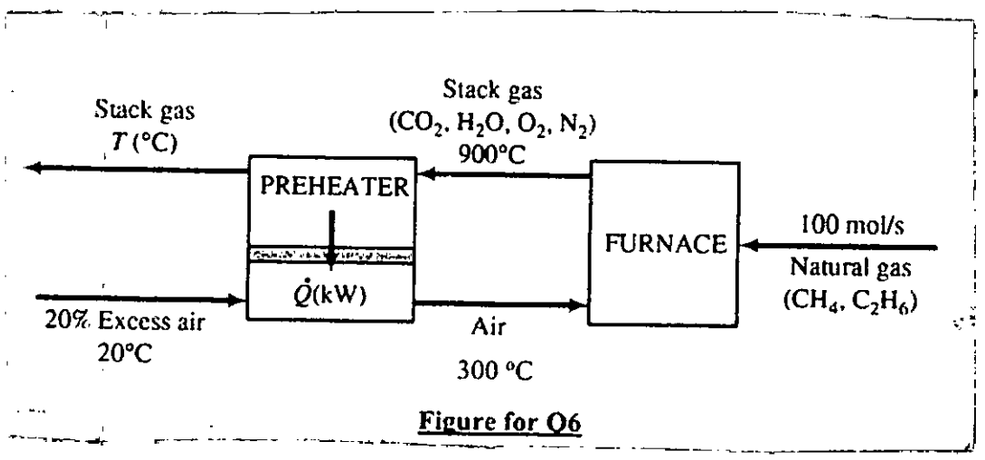

Figure for Q6

Taking as a basis 100 mol/s of the natural gas fed to the furnace, calculate the required molar flow rate of air, the molar flow rate and composition of the stack gas, the required rate of heat transfer (*kW*) in the preheater, and the temperature at which the stack gas leaves the preheater. Make reasonable assumptions (if required).

7. (a) An equimolar liquid mixture of benzenes (B) and toluene (T) at 15 °C is fed continuously to a vessel in which the mixture is heated to 60 °C. The liquid product is 35.0 mole% B, and the vapor product is 70 mole% B. How much heat must be transferred to the mixture per 100 mole of feed? **(20)**

(b) A liquid mixture of 30 wt% acetone and 70 wt% 2-methyl-1-pentanol ($C_6H_{14}O$) is cooled from 50 °C to 20 °C. Calculate the associated specific enthalpy change in J/g. Use Koop's rule to estimate heat capacity, if required. **(10)**

Contd P/5

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8. (a) Mr. Nakib Choudhury, your next-door neighbour, surprised his wife (Mrs. Della Choudhury) last January by having a hot tub installed in their back yard while she was away on a business trip. It surprised her, all right, but instead of being pleased she was horrified. "Have you lost your mind, Nakib?" she sputtered. "It will cost a fortune to keep this thing hot." "Don't be silly, Della," he replied. "It can't cost more than pennies a day, even in the dead of winter." "No way—and when did you become such as expert, anyway?" They argued for a while and then, remembering your chemical engineering educational background, came to ask you to settle it for them. You asked a few questions, made several observations, converted everything to metric units, and arrived at the following data, all corresponding to an average outside air temperature of about 15 °C. **(15)**

- The tub holds 1250 liters of water.
- Nakib normally keeps the tub water temperature at 30 °C, raises it to 40 °C when he plans to use it, keeps it at 40 °C for about hour, and drops it back to 30 °C when he is finished.
- During heating, it takes about three hours for the water temperature to rise from 30 °C to 40 °C. When the heat is shut off, it takes eight hours for the water temperature to drop back to 30 °C.
- Electricity cost 10 Taka per kilowatt-hour (kWh).

Taking the heat capacity of the tub contents to be that of pure liquid water and neglecting evaporation, answer the following questions.

(i) What is the average rate of heat loss (kW) from the tub water to the outside air? (Hint: Consider the period when the tub water temperature is dropping from 40 °C to 30 °C and calculate the heat loss.)

(ii) At what average rate (kW) does the tub heater deliver energy to the water when raising the water temperature during 3 hrs? (Account for water heating and heat loss to the surroundings estimated in part (i)).

(iii) What is the total quantity of electricity (kWh) that the heater must deliver during the heating period (3 hrs) and the use period (1hr)? [Use the result of part (i) and (ii) when performing the calculation].

(iv) Consider a day in which the tub is used once. Use the results of part (iii) to estimate the total daily cost (Taka) of running the tub? Do you think, Nakib was right in this claim?

(b) Superheated steam at 400°C and 1 bar (absolute) is to be fed to heat exchanger. It is produced by mixing an a available stream of saturated steam at 1 bar discharged from a turbine at a rate of 1000 kg/h with a second stream of superheated steam at 500°C and 1 bar. The mixing may be considered adiabatic. Calculate the amount of superheated steam at 400°C produced and the required volumetric flow rate of the 500 °C steam. **(15)**

[Hint: Use combined material and energy balance].

L-1/T-1/CHE Date : 02/04/2023

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **CHEM 111** (Inorganic Chemistry)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Draw orbital energy level diagram of (i) a single system (ii) a typical multi-electron system. Explain the reasons that account for the differences in these orbital energy level diagram patterns. **(15)**

   (b) Calculate the shortest wavelength of the electromagnetic radiation emitted by the hydrogen atom in undergoing a transition from the n = 6 level. **(10)**

   (c) How does de Broglie's hypothesis account for the fact that the energies of the electron in a hydrogen atom are quantized? **(10)**

2. (a) Calculate Z_{eff} for: (i) a 4p electron of Ag (Z = 47) (ii) 3d electron of Xe (Z = 54) (iii) 5d electron of Tungsten (Z = 74). **(15)**

   (b) What is a radial distribution function? Draw this function for the 1s, 2s, 2p, 3s, 3p and 3d orbitals in a hydrogen atom. **(10)**

   (c) Within any period, values of first ionization energy tend to increase with atomic number, except for small drops at the group IIIA and VIA elements. Explain. **(10)**

3. (a) Draw Lewis structure with resonance hybrid if applicable and predict the geometry of the following compounds using VSEPR model: **(15)**

   PCl_4^+, IF_5, CH_3CH_2OH, NO_3^-, H_3COCH_3

   (b) Using Valence Bond Theory, show and discuss the formation of $H_2C = CH_2$ molecule. What is the geometry of this molecule? Draw the orbital overlap diagram associated with formation of this molecule. **(15)**

   (c) In the trigonal bipyramidal arrangement, why does a lone pair occupy an equatorial position rather than an axial position? **(5)**

4. (a) Explain the followings: **(15)**

   (i) Dipole moment of NH_3 is larger than that of NF_3

   (ii) H-C-H bond angle in chloromethane is larger than the tetrahedral angle

   (iii) It is possible for a nonpolar molecule to have bond dipole moments

   (b) Draw and explain the potential energy curve for the bond formation in H_2. **(10)**

   (c) Why does transition elements form colored compounds? Explain. **(10)**

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SECTION – B

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

5. (a) Identify the factors that affect the strength of an acid. Why acetic acid is stronger than ethanol? **(10)**

   (b) Use 'Linear Combination of Atomic Orbitals' to demonstrate molecular orbital formation. Compare between bonding and antibonding molecular orbitals. **(10)**

   (c) How does Drago's EC approach account for reactivity by including both electrostatic and covalent factors? Calculate the enthalpy of adduct formation predicted by Drago's EC equation for the reactions of I_2 with diethyl ether and diethyl sulfide (for Et_2S, C_B = 7/40 kcal/mol and E_B = 0.399 kcal/mol). **(10)**

   (d) Draw a diagram that illustrates how atomic p orbitals can form both σ and π molecular orbitals. **(5)**

6. (a) Prepare a molecular orbital energy level diagram for the cyanide ion. Using frontier molecular orbital theory explain the reaction of CN^- with H^+. **(10)**

   (b) For the following reactions, explain the stability of the products using HSAB theory (i) $HgI + LiF \rightleftharpoons HgF + LiI$ (ii) $KI + I_2 \rightleftharpoons K^+ + I_3^-$. **(10)**

   (c) Predict the bond order, bond distance, and number of unpaired electrons for O_2^{2-}, C_2^{2-} and N_2^{2-} using MOT. **(10)**

   (d) Explain coordination complex formation according to Lweis acid base theory. **(5)**

7. (a) Classify different types of Ligands. **(10)**

   (b) What are primary and secondary valency in coordination complexes according to Warner's theory? Discuss structure isomerism in coordination complexes. **(10)**

   (c) Sketch structures of all possible stereo isomers of $M(B\text{-}B)_2A_2$ and $M(B\text{-}B)_3$ type coordination compounds. **(10)**

   (d) Based on the HSAB, what happens when AgF and LiI are placed together into water? **(5)**

8. (a) $[Fe(CN)_6]^{3-}$ is diamagnetic but $[FeF_6]^{3-}$ is paramagnetic – explain the bonding of these coordination complexes using appropriate hybridization. **(10)**

   (b) Describe how the crystal field splitting energy and crystal field stabilization energy will influence the color and magnetism of coordination complexes of octahedral, tetrahedral and square planar complexes. **(10)**

   (c) Explain the influence of pi donor and pi acceptor ligand on crystal field splitting energy. **(10)**

   (d) Give chemical names and the number of ions in aqueous solution for the following compounds: (i) $[Cu(NH_3)_4]^{2+}$ (ii) $[PtCl_4]^{2-}$ and (iii) $[Mn(CN)_6]^{4-}$. **(5)**

L-1/T-1/CHE Date : 09/04/2023

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **EEE 155** (Electrical Engineering Fundamentals)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

The symbols have their usual meaning.

Assume reasonable values for any missing data.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) The node equation of a parallel RLC circuit is given by **(10)**

$$\frac{dv}{dt} + 50v + 100\int vdt = 110\cos(377t - 10°)V$$

Determine the node voltage v(t). Assume that the value of the integral at $t = -\infty$ is zero.

(b) Analytically prove that "*For maximum average power transfer the load impedance must be equal to the complex conjugate of the Thevenin impedance*". **(10)**

(c) For the RL circuit shown in Fig. for Q. 1(c) calculate the amount of phase shift produced at 2 KHz between input voltage V_i and output voltage V_o. **(15)**

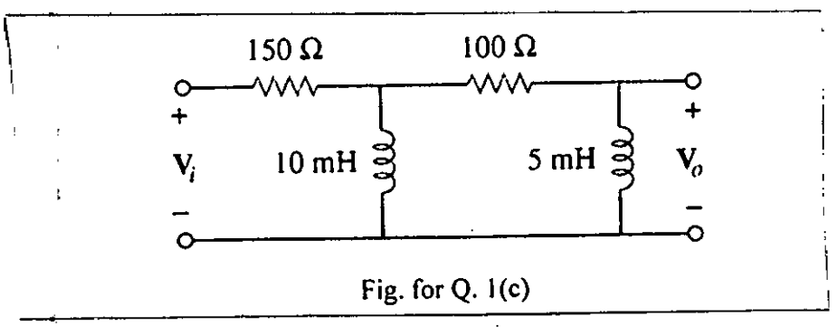

Fig. for Q. 1(c)

2. (a) The load resistance R_L in Fig, for Q. 2(a) is to be adjusted to absorb the maximum average power from the circuit. Calculate the value of R_L and the maximum average power. **(17)**

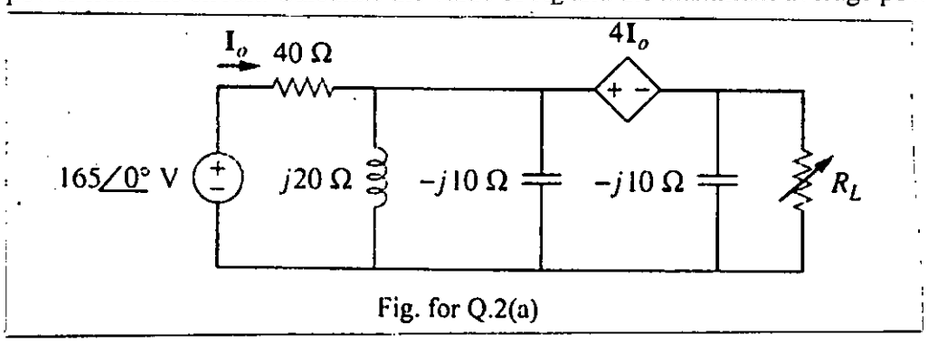

Fig. for Q.2(a)

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(b) Determine the current i_0 in the circuit shown in Fig. for Q. 2(b). **(18)**

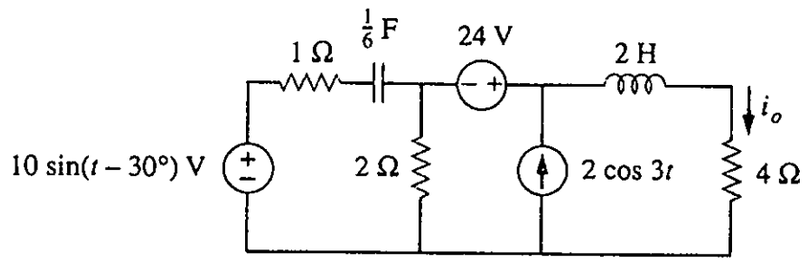

Fig. for Q.2(b)

3. (a) For the circuit shown in Fig. for Q. 3(a), find the phasor currents $\mathbf{I}_1$, $\mathbf{I}_2$, $\mathbf{I}_3$, and $\mathbf{I}_x$ using mesh analysis. **(17)**

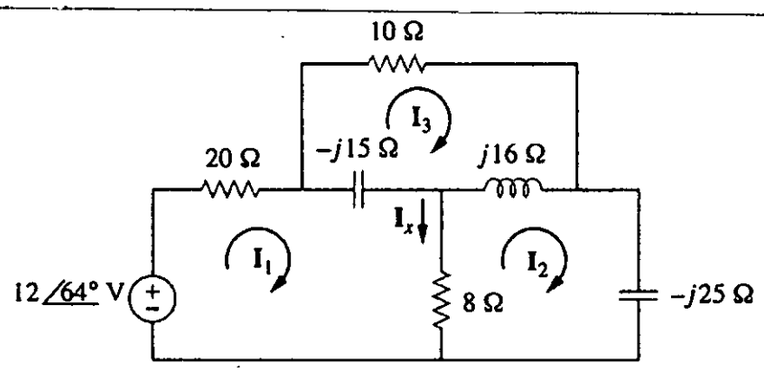

Fig. for Q.3(b) (a)

(b) For the circuit shown in Fig. for Q. 3(b), find V_s. Determine the overall power factor of the circuit and the total complex power supplied by the source. **(18)**

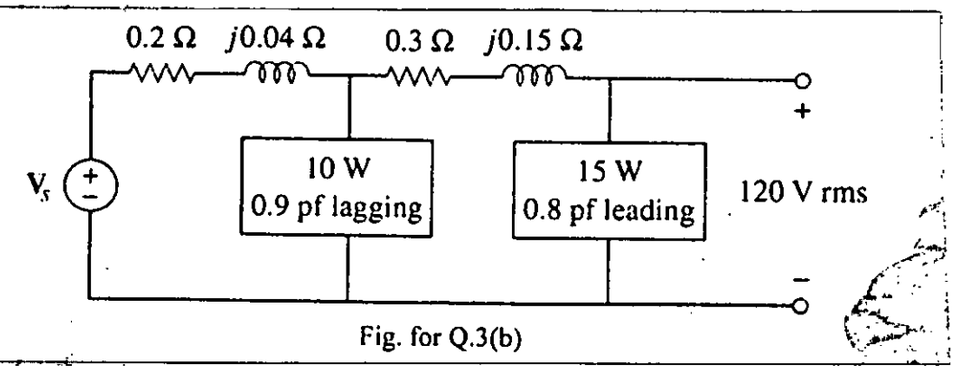

Fig. for Q.3(b)

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4. (a) Find the phasor currents $\mathbf{I}_1$ and $\mathbf{I}_2$ in the circuit shown in Fig. for Q. 4(a). Determine the power consumed by the passive elements in the circuit. **(20)**

   (b) For the magnetically coupled circuit shown in Fig. for Q. 4(b), determine the energy stored in the magnetically coupled coils. Establish an upper limit for the mutual inductance M in terms of the self-inductances L_1 and L_2. **(15)**

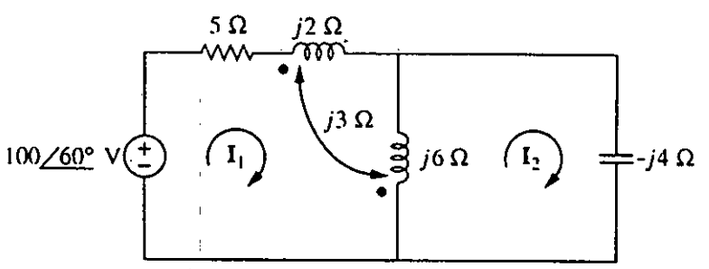

Fig. for Q.4(a)

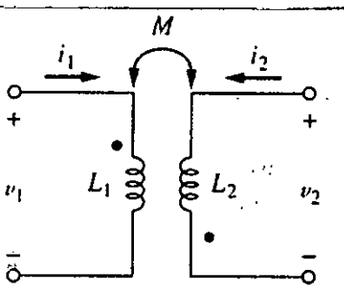

Fig. for Q.4(b)

SECTION – B

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

5. (a) Find v_c, i_L and the energy stored in the capacitor and the inductor in th circuit of Fig. for Q. No. 5(a) under DC conditions. **(10)**

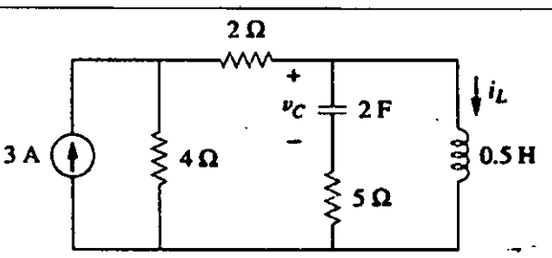

Fig. for Q. No. 5(a)

(b) Fig. for Q. No. 5(b) shows the current through and the voltage across an element. (i) Sketch the power delivered to the element for t > 0, (ii) Find the total energy absorbed by the element for the period of 0 < t < 4s. **(10)**

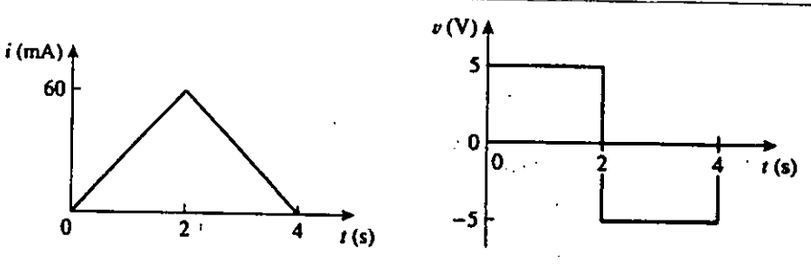

Fig. for Q. No. 5(b)

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Contd ... Q. No. 5

(c) Find the equivalent resistance R_{ab} in the circuit of Fig. for Q. No. 5(c). **(15)**

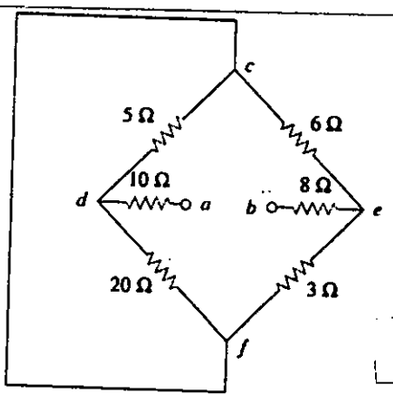

Fig. for Q. No. 5(c)

6. (a) Solve for the current **i** in the circuit of Fig. for Q. No. 6(a) using Thevenin's Theorem. Also, show the Norton's equivalent of the same circuit. **(15)**

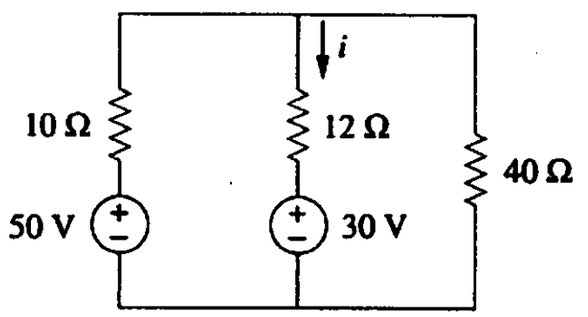

Fig. for Q. No. 6(a)

(b) Determine V in the circuit of Fig. for Q. No. 6(b). **(20)**

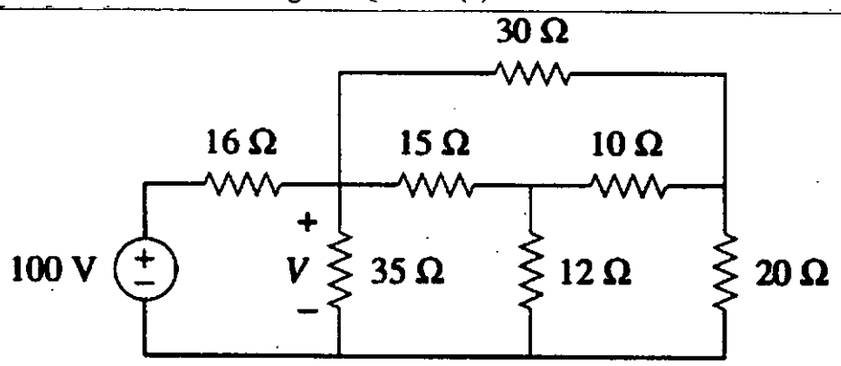

Fig. for Q. No. 6(b)

7. (a) Use the superposition principle to find i_0 and v_0 in the circuit of Fig. for Q. No. 7(a). **(15)**

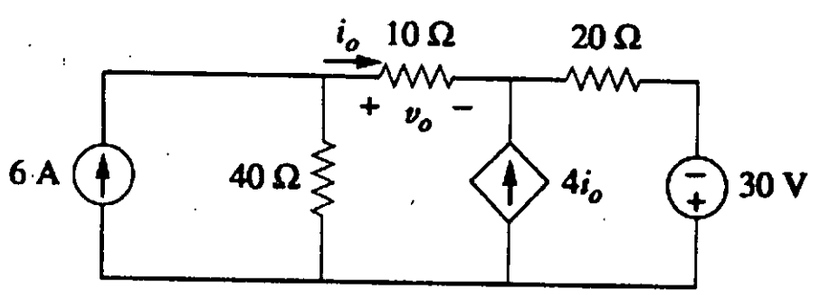

Fig. for Q. No. 7(a)

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Contd ... Q. No. 7

(b) For the circuit in Fig. for Q. No. 7(b), (i) obtain the Thevenin equivalent at terminals a-b, (ii) calculate the current in $R_L = 8\Omega$, (iii) find R_L for maximum power delivered to R_L, (iv) determine that maximum power. **(20)**

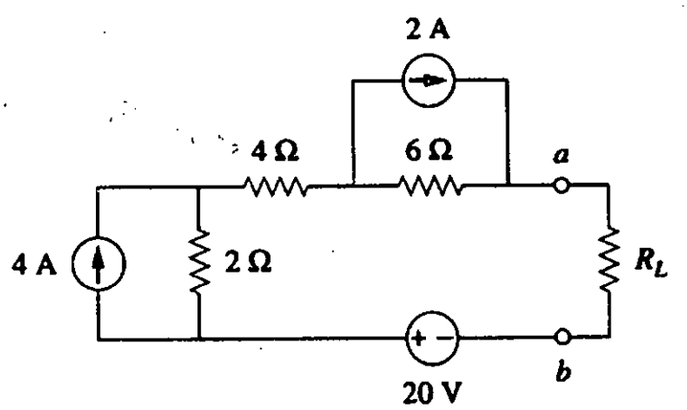

Fig. for Q. No. 7(b)

8. (a) For the circuit in Fig. for Q. No. 8(a), find v_1, v_2, and v_3 using nodal analysis. **(15)**

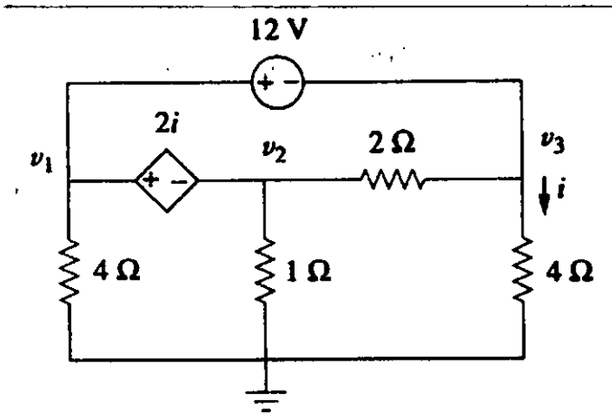

Fig. for Q. No. 8(a)

(b) Use mesh analysis to obtain i_0 in the circuit of Fig. for Q. No. 8(b). **(20)**

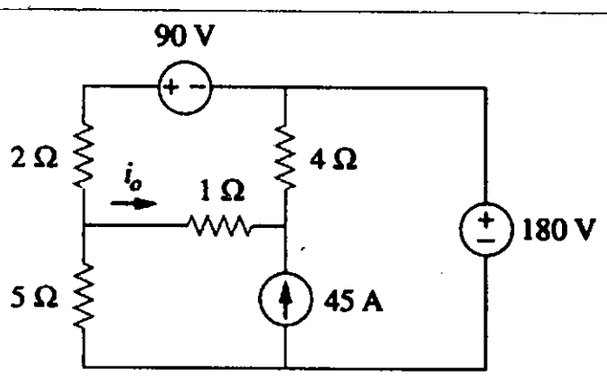

Fig. for Q. No. 8(b)

L-1/T-1/CHE **Date : 29/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **MATH 125** (Differential Calculus and Coordinate Geometry)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Evaluate $\lim_{x\to 0} \tan^{-1}\left(a/x^2\right)$. **(10)**

(b) Check the continuity and differentiability of the function at $x = 1$. Plot the graph. **(15)**

$$f(x)=\begin{cases}1+x & \text{for } x<0\\ 1 & \text{for } 0\le x\le 1\\ 2x^2+4x+5 & \text{for } x>1\end{cases}$$

(c) Sand is being poured on the ground and forms a pile which has always the shape of a right circular cone whose height is equal to the radius of the base. If sand is falling at the rate of 1.54 m^2/s, how fast if the height of the pile increasing when the height is 0.7 m? **(10)**

2. (a) If $f(x) = \tan x$, then find the value of $f^n(0) - {}^nc_2 f^{n-2}(0) + {}^nc_4 f^{n-4}(0) - \ldots$ **(15)**

(b) A bank is robbed at Mohakhali, Dhaka at 1:00 pm. The Dhaka Metropolitan Police (DMP) know that the robbers will head for either Padma Bridge or Gazipur at no more than 200 kmh. Where should they locate their roadblocks at 1:15 pm? **(10)**

(c) Expand $x^{1/2}$ in Maclaurin's infinite series. Justify your answer. **(10)**

3. (a) If $x^2 + y^2 + z^2 - 2xyz = 1$, calculate $\left(\frac{dx}{\sqrt{1-x^2}} + \frac{dy}{\sqrt{1-y^2}} + \frac{dz}{\sqrt{1-z^2}}\right)$. **(15)**

(b) Define homogeneous function with example. Write the statement of Euler's theorem on homogeneous function and prove it. **(10)**

(c) Find at what points on the curve $y = 2x^3 - 15x^2 + 34x - 20$ the tangents are parallel to $y + 2x = 0$. **(10)**

Contd P/2

MATH 125/CHE

4. (a) Find the pedal equation of the hyperbola $r^2 \cos 2\theta = a^2$. **(10)**

   (b) A cylindrical tin can, closed at both ends and of a given capacity, has to be constructed. Find the relation between height and diameter for which the amount of tin required will be a minimum. **(15)**

   (c) Find the values of p and q so that $\lim_{x \to 0} \dfrac{x + px\cos x - q \sin x}{x^3} = 1$. **(10)**

SECTION – B

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

5. Evaluate the following:

   (a) $\int e^{2x} \sin 3x \cos x \, dx$. **(11)**

   (b) $\int \sin^2 x \cos^2 x \, dx$. **(12)**

   (c) $\int \dfrac{x^3}{(x-a)(x-b)(x-c)} dx$. **(12)**

6. (a) Find the reduction formula for $\int \sec^n x \, dx$ and hence evaluate the integral $\int 5\sec^5 x \, dx$ using this formula. **(12)**

   (b) Evaluate $\lim_{n \to \infty} \left(\dfrac{1^2}{n^3 + 1^3} + \dfrac{2^2}{n^3 + 2^3} + \dfrac{3^2}{n^3 + 3^3} + \ldots + \dfrac{1}{2n} \right)$. **(11)**

   (c) Prove that, $\beta(m, n) = \dfrac{\Gamma m \, \Gamma n}{\Gamma(m+n)}$. **(12)**

7. (a) Evaluate $\int_1^5 \dfrac{dx}{(x-3)^{2/3}}$. **(11)**

   (b) Evaluate $\int_0^\infty x^5 e^{-2x^2} \, dx$. **(12)**

   (c) Find the exact arc length of the polar curve $r = 2(1 + \cos\theta)$ from 0 to 2π. **(12)**

8. (a) Find the area of the region that lies inside the circle $r = 3 \sin\theta$ and outside the centroid $r = 1 + \sin\theta$. **(12)**

   (b) Find the area of the surface that is generated by revolving the portion of the curve $y = \sqrt[3]{x}$ between $y = 1$ and $y = 8$ about the x-axis. **(11)**

   (c) Find the volume of a pyramid whose base is a square with side L and whose height is h. **(12)**

L-1/T-1/CHE Date : 03/05/2023

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-1 B. Sc. Engineering Examinations 2021-2022

Sub : **PHY 127** (Physical Optics, Waves and Oscillations and Modern Physics)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) A U-tube open at both ends is filled with an incompressible fluid of density ρ. The cross sectional area A of the tube is uniform and the total length of the fluid in the tube is L (=2l), see figure 1(a). A piston is used to depress the height of the liquid column on one side by a distance x, (raising the other side by the same distance) and then is quickly removed; its up and down motion in the two limbs of the tube is simple harmonic. Find an expression for total energy of the oscillation and hence derive the differential equation of motion. What is the angular frequency of the ensuring simple harmonic motion? Neglect any resistive forces at the walls of the U-tube. **(25)**

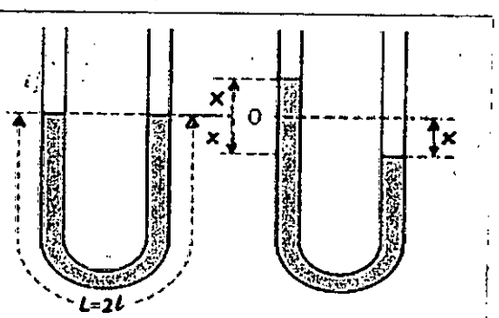

Figure for question no. 1(a)

(b) A vertical U-tube of uniform cross-section contains water up to a height of l = 30 cm (see figure 1(a)). If the water in one limb is depressed and ten released, its up and down motion in the two limbs of the tube is simple harmonic. Calculate its time period. **(10)**

2. (a) What are Lissajous' figures? On what factors does it depend? Explain how these figures are useful in the laboratory? **(8)**

(b) Derive a general expression for the resultant vibration of a particle simultaneously acted upon by two initially perpendicular simple harmonic vibrations having same period but different phase and amplitude. Hence find out the condition for circle and straight line. **(20)**

Contd P/2

PHY 127/CHE

Contd ... Q. No. 2

(c) A massless spring of force constant 340 N/m is cut into halves. (i) What is the spring constant of each half? (ii) The two halves, suspended separately, support a block of mass M (see figure 2(c)). The system vibrate at a frequency of 2.80 Hz. Find the value of mass M. **(7)**

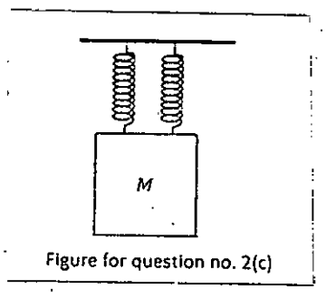

Figure for question no. 2(c)

3. (a) What are reverberation and reverberation time? Discuss the acoustic requirement of a good auditorium. **(8)**

(b) Define energy density and energy current of a plane progressive wave. Obtain expressions for them. **(20)**

(c) What are phase velocity and group velocity? Find the relation between them. When does the group velocity become equal to the phase velocity? **(7)**

4. (a) What are the differences between interference and diffraction of light? Mention some areas of applications of diffraction of light. **(8)**

(b) Consider a plane wavefront of monochromatic light incident on a circular aperture. Briefly describe the Fraunhofer diffraction pattern due this circular aperture. Show that the radius of Airy's Disc is given by $x = \frac{f\lambda}{d}$, where the terms have their usual meaning. **(17)**

(c) Diffraction pattern of a single slit of width 0.6 cm is formed by a lens of focal length 42 cm. Calculate the distance between the first dark and next bright fringe from the central fringe. Give $\lambda = 5893$ Å. **(10)**

SECTION – B

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

5. (a) Draw the schematic sketch of Fresnel's biprism and Fresnel's double mirror interference experimental setup. What are the advantages of these compared to Young's double slit experiment? **(10)**

Contd P/3

PHY 127/CHE

Contd ... Q. No. 5

(b) Consider that a ray of monochromatic light is incident on the upper surface of a transparent film of uniform thickness t and index of refraction μ. Describe the interference phenomenon observed in the thin film for the refracted light. Show that the total optical path difference between two consecutive reflected wave is $\Delta = 2\mu t \cos r + \frac{\lambda}{2}$. **(18)**

(c) A soap film of refractive index 1.33 shows a strong first-order reflection of yellow light whose wavelength is 600 nm (in vacuum). Assuming normal incidence of light find the thickness of the soap film. **(7)**

6. (a) Define diffraction of light. Mention the differences between Fresnel and Fraunhofer diffraction of light. **(9)**

(b) Consider that a parallel beam of monochromatic light is incident upon a narrow slit and diffraction patterns are observed on a screen. Describe the Fraunhofer diffraction due to this narrow slit and hence find the condition of central maximum, and secondary maxima. **(18)**

(c) In Fraunhofer diffraction due to a narrow slit, a screen is placed at 3 m away from the lens to obtain the pattern. If the slit width is 0.25 mm and the first minima lie 6 mm on either side of the central maximum, find the wavelength of light. **(8)**

7. (a) What do you mean by simultaneity? With a suitable example, show that simultaneity is a relative concept. **(8)**

(b) Obtain Lorentz space-time transformation formula and hence obtain expressions for length contraction and time dilation. **(19)**

(c) A clock in a spaceship emits signals at intervals of 3 second as observed by an astronaut in the spaceship. If the spaceship travels with a speed of 3×10^7 ms^{-1}, what is the interval between successive signals as seen by an observer at the control centre on the ground? **(8)**

8. (a) In an experiment on photoelectric effect for measuring the energy and photocurrent, what happens if : (i) the frequency of light is changed, target material and intensity of light being kept constant, (ii) the intensity of light is changed, target material and frequency of light being kept constant. **(12)**

(b) What is nuclear fission? Describe briefly the various components of a nuclear reactor. **(15)**

(c) It takes 4.2 eV to remove one of the least tightly bound electrons from a metal surface. When ultra-violet photons of a single frequency strike a metal, electrons with kinetic energies from zero to 2.6 eV are ejected. What are the energy and wavelength of the incident photons? **(8)**
