L-3/T-1/CHE **Date: 25/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **CHE 301** (Heat Transfer)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section.

Answer Question 1 is compulsory and carries 35 marks. Answer any **TWO** from the rest.

1. [Compulsory] In a petroleum refinery, it is required to cool 30,000 lb/h of kerosene from 400°F to 250°F by heat exchange with 75,000 lb/h of gas oil, which is at 110°F. Available for this duty is a shell-and-tube exchanger having 156 tubes in a $21\frac{1}{4}$- in. ID shell. The tubes are 1-in. OD, 14 BWG, 16 ft long on a $1\frac{1}{4}$-in. square pitch. There is one pass on the shell side and six passes on the tube side. The baffles are 20% cut segmental type and are spaced at 5-in. intervals. Both the shell and tubes are carbon steel having k = 26 Btu/h.ft. °F. Following fluid properties are available:

Fluid Property	Kerosene	Gas oil
CP (Btu/lbm . °F)	0.6	0.5
μ (cp)	0.45	3.5
k(Btu/h . ft . °F)	0.077	0.08

(a) Draw a temperature profile along the heat exchanger length, and find the corrected log mean temperature difference. **(5)**

(b) Determine the tube side and shell side heat transfer coefficients, h_i and h_0 respectively. **(16)**

(c) Calculate the minimum required dirt factor for the exchanger. **(06)**

(d) Fill in the attached TEMA sheet and attach it to your answer script. **(08)**

2. (a) "Equivalent diameter of the annular area of a double pipe system can be different based on its application." – Explain. **(06)**

(b) "Nusselt number is also considered as dimensionless heat transfer coefficient" – explain. **(06)**

(c) For a shell and tube heat exchanger, mention few criteria to decide shell side and tube side fluid. **(06)**

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(d) A steam condenser is designed to condense 76 kg/min of steam at 83 kPa with cooling water at 10°C. The exit water temperature is not to exceed 57°C. The overall heat-transfer coefficient is 3400 W/m^2. °C, if the condenser is a double pipe hairpin of 1/2-in. OD, 16 BWG, 18 ft long, calculate the number of hairpins required to fulfill the requirement. $T_{sat} = 95.6°C$, $h_{fg} = 2.27 \times 10^6$ J/kg. **(17)**

3. (a) Derive the working equation of LMTD and state the assumptions made for the derivation. **(18)**

   (b) A steam condenser consists of a square array of 400 tubes, each 6 mm in diameter. If the tubes are exposed to saturated steam at 0.15 bar, and the tube surface temperature is maintained at 25°C, calculate the steam condensation rate per unit length of the tube for this array. Consider modified heat of vaporization for your calculation. **(17)**

4. (a) What is the critical heat flux of a pool boiling curve? List the factors that can influence the critical heat flux. **(06)**

   (b) Why does total heat transfer during film boiling consider only 75% of radiation heat transfer? Explain the reason for not considering total radiation heat transfer? **(06)**

   (c) "Natural convection heat transfer is typically lowest in the case of the horizontal orientation with hot surface facing down" – explain with schematics. **(07)**

   (d) A household oven door (0.5 m × 0.7 m) reaches an average temperature of 32° C during its operation. Estimate free convection heat loss to the room with ambient air of 22°C. If the door has an emissivity factor of 1.0, how much heat will be lost by radiation? **(16)**

SECTION – B

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

5. (a) What is bulk temperature? Why is it called 'Mixing Cup' temperature? **(7)**

   (b) Describe the thermal boundary layer formation for forced convection on an isothermal fat plate. Indicate the relative thickness of hydrodynamic and thermal boundary layers for common fluids. **(10)**

   (c) Derive the general three-dimensional heat conduction equation. From this general equation derive equations for following conditions. **(12+3+3=18)**

   (i) Steady state one dimensional heat flow with no heat generation.

   (ii) Two-dimensional heat flow without heat generation.

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6. (a) Write down Dittus-Boelter equation with its applicability ranges. **(5)**

(b) Define stanton number and Prandtl number? Explain their physical significance? What are the typical values of Prandtl number for gas and liquid metals? **(10)**

(c) Water at 60 °C enters a tube of 1-in (2.54 cm) diameter at a mean flow velocity of 2 cm/s. Calculate the exit water temperature if the tube is 3.0 m long and the wall temperature is constant at 80 °C. **(20)**

7. (a) The velocity distribution and the laminar boundary layer thickness for the fluid can be expressed by the following equations, respectively. **(18)**

$$\frac{u}{u_\infty} = \frac{3}{2}\cdot\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

$$\delta = 4.64\sqrt{\frac{\nu_x}{u_\infty}}$$

Where U_∞ is the fluid velocity outside the boundary layer and other symbols have their usual meanings.

Derive Reynolds-Colburn analogy using the above equations and state its significance in heat transfer.

(b) Air at 25 °C flows past a flat plate at 2.5 m/s. The plate measures 600 mm X 300 mm and is maintained at a uniform temperature at 95 °C. Calculate the heat loss from the plate if the air flows parallel to the 600 mm side. How this heat loss be affected if the flow of air is made parallel to the 300 mm side. Use an appropriate heat transfer equation to solve the problem. **(17)**

8. (a) Derive the equation for critical radius of insulation in a cylindrical system. What would you suggest reducing heat loss if the bare pipe radius is smaller than the critical radius of insulation? Explain your answer with a schematic of heat loss vs. radius. **(15)**

(b) Briefly state the mechanism of radiation heat transfer. **(5)**

(c) A hollow aluminum sphere with an electrical heater in the center is used in tests to determine the thermal conductivity of insulating materials. The inner and outer radii of the sphere are 0.15 and 0.18 m, respectively. The testing is done under steady-state conditions with the inner surface of the aluminum maintained at 250 °C. A spherical shell of insulation is cast on the outer surface of the sphere to a thickness of 0.12 m. The outside air temperature is 20 °C and the convection coefficient at the outer surface of the insulation is 30 W/m^2.K. If 80 W heat is dissipated during the test, what is the thermal conductivity of insulation? Conductivity of Aluminum at 250 °C is 230 W/m.K. **(15)**

Relevant film condensation for horizontal tube:

$$h_{vert} = 0.943 \left[\frac{g\rho_l(\rho_l - \rho_v)h_{fg}^* k_l^3}{\mu_l(T_{sat} - T_s)L}\right]^{1/4}$$

$$h_{horiz} = 0.729 \left[\frac{g\rho_l(\rho_l - \rho_v)\, h_{fg}^* k_l^3}{\mu_l(T_{sat} - T_s)D}\right]^{1/4}$$

$$h_{horiz,\, N tubes} = 0.729 \left[\frac{g\rho_l(\rho_l - \rho_v)\, h_{fg}^* k_l^3}{\mu_l(T_{sat} - T_s)\, ND}\right]^{1/4}$$

Properties of air at atmospheric pressure

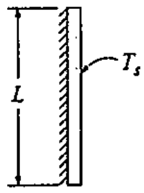
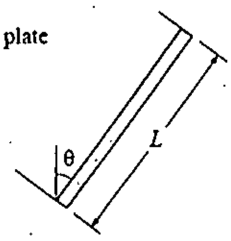
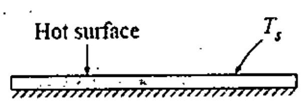
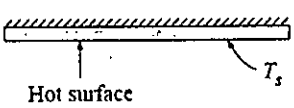
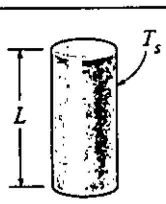
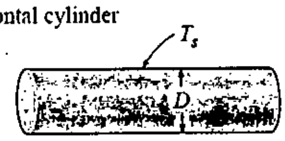
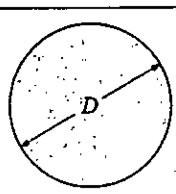
The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m^3	c_p kJ/kg·°C	$\mu \times 10^5$ kg/m·s	$\nu \times 10^6$ m^2/s	k W/m·°C	$\alpha \times 10^4$ m^2/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

Table. Water physical properties

Temperature (T)	Density (ρ)	Dynamic Viscosity (μ)	Kinematic Viscosity (v)	Specific Heat Capacity (cp)	Thermal Conductivity (k)	Prandtl Number (Pr)
^0C	kg/m^3	$x10^{-3}$ Pa.s	$x10^{-6}$ m^2/s	kJ/kg.K	W/m.K	–
0	999.84	1.792	1.792	4.219	0.561	13.47
5	999.97	1.518	1.518	4.205	0.571	11.19
10	999.70	1.306	1.306	4.195	0.580	9.45
15	999.10	1.138	1.139	4.189	0.589	8.09
20	998.21	1.002	1.003	4.185	0.598	7.00
25	997.05	0.890	0.893	4.182	0.607	6.13
30	995.65	0.797	0.801	4.180	0.616	5.41
35	994.04	0.719	0.724	4.179	0.623	4.82
40	992.22	0.653	0.658	4.179	0.631	4.33
45	990.22	0.596	0.602	4.179	0.637	3.91
50	988.05	0.547	0.553	4.180	0.644	3.55
55	985.71	0.504	0.511	4.181	0.649	3.25
60	983.21	0.466	0.474	4.183	0.654	2.98
65	980.57	0.433	0.442	4.185	0.659	2.75
70	977.78	0.404	0.413	4.188	0.663	2.55
75	974.86	0.378	0.387	4.192	0.667	2.37
80	971.80	0.354	0.365	4.196	0.670	2.22
85	968.62	0.333	0.344	4.200	0.673	2.08
90	965.32	0.314	0.326	4.205	0.675	1.96
95	961.90	0.297	0.309	4.211	0.677	1.85
100	958.43	0.282	0.294	4.217	0.679	1.75

Table: Summary of forced-convection relations

Geometry	Characteristic length L_c	Range of Ra	Nu
Vertical plate 	L	10^4–10^9 10^9–10^{13} Entire range	$Nu = 0.59Ra_L^{1/4}$ (9-19) $Nu = 0.1Ra_L^{1/3}$ (9-20) $Nu = \left\{0.825 + \frac{0.387Ra_L^{1/6}}{[1 + (0.492/Pr)^{9/16}]^{8/27}}\right\}^2$ (9-21) (complex but more accurate)
Inclined plate 	L		Use vertical plate equations for the upper surface of a cold plate and the lower surface of a hot plate Replace g by $g\cos\theta$ for $Ra < 10^9$
Horiontal plate (Surface area A and perimeter p) (a) Upper surface of a hot plate (or lower surface of a cold plate) Hot surface  (b) Lower surface of a hot plate (or upper surface of a cold plate)  Hot surface	A_s/p	10^4–10^7 10^7–10^{11} 10^5–10^{11}	$Nu = 0.54Ra_L^{1/4}$ (9-22) $Nu = 0.15Ra_L^{1/3}$ (9-23) $Nu = 0.27Ra_L^{1/4}$ (9-24)
Vertical cylinder 	L		A vertical cylinder can be treated as a vertical plate when $D \geq \frac{35L}{Gr_L^{1/4}}$
Horizontal cylinder 	D	$Ra_D \leq 10^{12}$	$Nu = \left\{0.6 + \frac{0.387Ra_D^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2$ (9-25)
Sphere 	D	$Ra_D \leq 10^{11}$ $(Pr \geq 0.7)$	$Nu = 2 + \frac{0.589Ra_D^{1/4}}{[1 + (0.469/Pr)^{9/16}]^{4/9}}$ (9-26)

TEMA Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit:		Our Reference:			
4	Item No.:	Your Reference:				
5	Date:	Rev No.:	Job No.:			
6	Size / in	Type		Connected in	parallel	series
7	Surf/unit(eff.) ft2	Shells/unit		Surf/shell (eff.)		ft2
8	PERFORMANCE OF ONE UNIT					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name					
11	Fluid quantity, Total	lb/h				
12	Vapor (In/Out)	lb/h				
13	Liquid	lb/h				
14	Noncondensable	kg/s				
15						
16	Temperature (In/Out)	F				
17	Dew / Bubble point	F				
18	Density	lb/ft3				
19	Viscosity	cp				
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	BTU/(lb*F)				
23	Thermal conductivity	BTU/(ft*h*F)				
24	Latent heat	BTU/lb				
25	Pressure	psi				
26	Velocity	ft/s				
27	Pressure drop, allow./calc.	psi				
28	Fouling resist. (min)	ft2*h*F/BTU				
29	Heat exchanged	BTU/h		MTD corrected		F
30	Transfer rate, Service		Dirty	Clean		BTU/(h*ft2*F)
31	CONSTRUCTION OF ONE SHELL				Sketch	
32			Shell Side	Tube Side		
33	Design/Test pressure	psi	/ Code	/ Code		
34	Design temperature	F				
35	Number passes per shell					
36	Corrosion allowance	in				
37	Connections	In	/	/		
38	Size/rating	Out	/	/		
39	in	Intermediate	/	/		
40	Tube No.	OD	Tks-avg in	Length ft	Pitch	in
41	Tube type		Material		Tube pattern	
42	Shell	ID	OD in	Shell cover		
43	Channel or bonnet			Channel cover		
44	Tubesheet-stationary			Tubesheet-floating		
45	Floating head cover			Impingement protection		
46	Baffle-crossing	Type	single seg	Cut(%d) hor	Spacing: c/c	in
47	Baffle-long		Seal type		Inlet	in
48	Supports-tube		U-bend	Type		
49	Bypass seal		Tube-tubesheet joint			
50	Expansion joint		Type			
51	RhoV2-Inlet nozzle	Bundle entrance		Bundle exit		lb/(ft*s2)
52	Gaskets - Shell side		Tube Side			
53	Floating head					
54	Code requirements			TEMA class		
55	Weight/Shell		Filled with water		Bundle	lb
56	Remarks					
57						
58						

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Table 5-2 | Summary of equations for flow over flat plates. Properties evaluated at $T_f = (T_w + T_\infty)/2$ unless otherwise noted.

Flow regime	Restrictions	Equation	Equation number
		Heat transfer	
Laminar, local	$T_w = \text{const}$, $Re_x < 5 \times 10^5$, $0.6 < Pr < 50$	$Nu_x = 0.332\, Pr^{1/3} Re_x^{1/2}$	(5-44)
Laminar, local	$T_w = \text{const}$, $Re_x < 5 \times 10^5$, $Re_x\, Pr > 100$	$Nu_x = \dfrac{0.3387\, Re_x^{1/2}\, Pr^{1/3}}{\left[1 + \left(\dfrac{0.0468}{Pr}\right)^{2/3}\right]^{1/4}}$	(5-51)
Laminar, local	$q_w = \text{const}$, $Re_x < 5 \times 10^5$, $0.6 < Pr < 50$	$Nu_x = 0.453\, Re_x^{1/2}\, Pr^{1/3}$	(5-48)
Laminar, local	$q_w = \text{const}$, $Re_x < 5 \times 10^5$	$Nu_x = \dfrac{0.4637\, Re_x^{1/2}\, Pr^{1/3}}{\left[1 + \left(\dfrac{0.0207}{Pr}\right)^{2/3}\right]^{1/4}}$	(5-51)
Laminar, average	$Re_L < 5 \times 10^5$, $T_w = \text{const}$	$\overline{Nu}_L = 2\, Nu_{x=L} = 0.664\, Re_L^{1/2}\, Pr^{1/3}$	(5-46)
Laminar, local	$T_w = \text{const}$, $Re_x < 5 \times 10^5$, $Pr \ll 1$ (liquid metals)	$Nu_x = 0.564 (Re_x\, Pr)^{1/2}$	
Laminar, local	$T_w = \text{const}$, starting at $x = x_0$, $Re_x < 5 \times 10^5$, $0.6 < Pr < 50$	$Nu_x = 0.332\, Pr^{1/3}\, Re_x^{1/2} \left[1 - \left(\frac{x_0}{x}\right)^{3/4}\right]^{-1/3}$	(5-43)
Turbulent, local	$T_w = \text{const}$, $5 \times 10^5 < Re_x < 10^7$	$St_x\, Pr^{2/3} = 0.0296\, Re_x^{-0.2}$	(5-81)
Turbulent, local	$T_w = \text{const}$, $10^7 < Re_x < 10^9$	$St_x\, Pr^{2/3} = 0.185 (\log Re_x)^{-2.584}$	(5-82)
Turbulent, local	$q_w = \text{const}$, $5 \times 10^5 < Re_x < 10^7$	$Nu_x = 1.04\, Nu_{x\, T_w = \text{const}}$	(5-87)
Laminar-turbulent, average	$T_w = \text{const}$, $Re_x < 10^7$, $Re_{crit} = 5 \times 10^5$	$\overline{St}\, Pr^{2/3} = 0.037\, Re_L^{-0.2} - 871\, Re_L^{-1}$	(5-84)
		$\overline{Nu}_L = Pr^{1/3} (0.037\, Re_L^{0.8} - 871)$	(5-85)
Laminar-turbulent, average	$T_w = \text{const}$, $Re_x < 10^7$, liquids, μ at T_∞, μ_w at T_w	$\overline{Nu}_L = 0.036\, Pr^{0.43} (Re_L^{0.8} - 9200) \left(\frac{\mu_\infty}{\mu_w}\right)^{1/4}$	(5-86)
High-speed flow	$T_w = \text{const}$, $q = hA(T_w - T_{aw})$; $r = (T_{aw} - T_\infty)/(T_o - T_\infty)$ = recovery factor = $Pr^{1/2}$ (laminar) = $Pr^{1/3}$ (turbulent)	Same as for low-speed flow with properties evaluated at $T^* = T_\infty + 0.5(T_w - T_\infty) + 0.22(T_{aw} - T_\infty)$	(5-124)
		Boundary-layer thickness	
Laminar	$Re_x < 5 \times 10^5$	$\frac{\delta}{x} = 5.0\, Re_x^{-1/2}$	(5-21a)
Turbulent	$Re_x < 10^7$, $\delta = 0$ at $x = 0$	$\frac{\delta}{x} = 0.381\, Re_x^{-1/5}$	(5-91)
Turbulent	$5 \times 10^5 < Re_x < 10^7$, $Re_{crit} = 5 \times 10^5$, $\delta = \delta_{lam}$ at Re_{crit}	$\frac{\delta}{x} = 0.381\, Re_x^{-1/5} - 10.256\, Re_x^{-1}$	(5-95)
		Friction coefficients	
Laminar, local	$Re_x < 5 \times 10^5$	$C_{fx} = 0.332\, Re_x^{-1/2}$	(5-54)
Turbulent, local	$5 \times 10^5 < Re_x < 10^7$	$C_{fx} = 0.0592\, Re_x^{-1/5}$	(5-77)
Turbulent, local	$10^7 < Re_x < 10^9$	$C_{fx} = 0.37 (\log Re_x)^{-2.584}$	(5-78)
Turbulent, average	$Re_{crit} < Re_x < 10^9$	$\overline{C}_f = \frac{0.455}{(\log Re_L)^{2.584}} - \frac{A}{Re_L}$; A from Table 5-1	(5-79)

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Table 6-8 | Summary of forced-convection relations. (See text for property evaluation.)

Subscripts: b = bulk temperature, f = film temperature, ∞ = free stream temperature, w = wall temperature

Geometry	Equation	Restrictions	Equation number
Tube flow	$\mathrm{Nu}_d = 0.023\,\mathrm{Re}_d^{0.8}\mathrm{Pr}^n$	Fully developed turbulent flow, $n = 0.4$ for heating, $n = 0.3$ for cooling, $0.6 < \mathrm{Pr} < 100$, $2500 < \mathrm{Re}_d < 1.25 \times 10^5$	(6-4a)
Tube flow	$\mathrm{Nu}_d = 0.0214(\mathrm{Re}_d^{0.8} - 100)\mathrm{Pr}^{0.4}$	$0.5 < \mathrm{Pr} < 1.5$, $10^4 < \mathrm{Re}_d < 5 \times 10^6$	(6-4b)
	$\mathrm{Nu}_d = 0.012(\mathrm{Re}_d^{0.87} - 280)\mathrm{Pr}^{0.4}$	$1.5 < \mathrm{Pr} < 500$, $3000 < \mathrm{Re}_d < 10^6$	(6-4c)
Tube flow	$\mathrm{Nu}_d = 0.027\,\mathrm{Re}_d^{0.8}\mathrm{Pr}^{1/3}\left(\frac{\mu}{\mu_w}\right)^{0.14}$	Fully developed turbulent flow	(6-5)
Tube flow, entrance region	$\mathrm{Nu}_d = 0.036\,\mathrm{Re}_d^{0.8}\mathrm{Pr}^{1/3}\left(\frac{d}{L}\right)^{0.055}$ See also Figures 6-5 and 6-6	Turbulent flow $10 < \frac{L}{d} < 400$	(6-6)
Tube flow	Petukov relation	Fully developed turbulent flow, $0.5 < \mathrm{Pr} < 2000$, $10^4 < \mathrm{Re}_d < 5 \times 10^6$, $0 < \frac{\mu_b}{\mu_w} < 40$	(6-7)
Tube flow	$\mathrm{Nu}_d = 3.66 + \frac{0.0668(d/L)\,\mathrm{Re}_d\mathrm{Pr}}{1 + 0.04[(d/L)\,\mathrm{Re}_d\mathrm{Pr}]^{2/3}}$	Laminar, T_w = const.	(6-9)
Tube flow	$\mathrm{Nu}_d = 1.86(\mathrm{Re}_d\mathrm{Pr})^{1/3}\left(\frac{d}{L}\right)^{1/3}\left(\frac{\mu}{\mu_w}\right)^{0.14}$	Fully developed laminar flow, T_w = const. $\mathrm{Re}_d\mathrm{Pr}\frac{d}{L} > 10$	(6-10)
Rough tubes	$\mathrm{St}_b\mathrm{Pr}_f^{2/3} = \frac{f}{8}$ or Equation (6-7)	Fully developed turbulent flow	(6-12)
Noncircular ducts	Reynolds number evaluated on basis of hydraulic diameter $D_H = \frac{4A}{P}$ A = flow cross-section area, P = wetted perimeter	Same as particular equation for tube flow	(6-14)
Flow across cylinders	$\mathrm{Nu}_f = C\,\mathrm{Re}_{df}^n\,\mathrm{Pr}^{1/3}$ C and n from Table 6-2	$0.4 < \mathrm{Re}_{df} < 400{,}000$	(6-17)
Flow across cylinders	$\mathrm{Nu}_{df} = 0.3 + \frac{0.62\,\mathrm{Re}_f^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1 + \left(\frac{0.4}{\mathrm{Pr}}\right)^{2/3}\right]^{1/4}}\left[1 + \left(\frac{\mathrm{Re}_f}{282{,}000}\right)^{5/8}\right]^{4/5}$	$10^2 < \mathrm{Re}_f < 10^7$, $\mathrm{Pe} > 0.2$	(6-21)
Flow across cylinders		See text	(6-18) to (6-20) (6-22) to (6-24)
Flow across noncircular cylinders	$\mathrm{Nu} = C\,\mathrm{Re}_{df}^n\,\mathrm{Pr}^{1/3}$ See Table 6-3 for values of C and n.		(6-17)

L-3/T-1/CHE **Date: 24/09/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **CHE 303** (Mass Transfer-I)

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.

All notations have their usual meanings.

1. (a) "The main advantage of a valve tray over other trays is it offers a better turndown ratio and is more flexible" — justify this statement. **(10)**

(b) Why flooding velocity is critical in distillation column design and how does it affect the sizing of the column? **(8)**

(c) You have designed a sieve tray column with 0.3048 m tray spacing to operate at a pressure of 1.0 atm. The value of the flow parameter is F_{lv} = 0.090 and the flooding velocity was calculated as 1.83 m/s. Unfortunately, your manager thinks that 0.3048 m tray spacing is not enough and that your reflux ratio is too low. You must redesign for a 0.6096 m tray spacing and increase L/V by 11%. Estimate the new flooding velocity. Assumptions: Ideal gas, σ, ρ_L, and ρ_G are unchanged. (see the Figure for Question no 1(c)). **(17)**

2. We have a steam stripper operating isothermally at 100°C. The entering liquid stream contains 0.0004 mole frac nitrobenzene in water at 100°C. The flow rate of entering liquid is 2 kmol/min. The entering steam is pure water at 100°C. We desire an outlet liquid mole frac of 0.00001 nitrobenzene. L/V is set at 10. At 100°C, equilibrium is $y = 28x$ (in terms of nitrobenzene mole frac). **(16+12+7=35)**

(a) Find the outlet mole fraction of the nitrobenzene in the vapor stream and the number of stages.

(b) What will happen to the purity of the outlet liquid if we increase (i) liquid flow rate, (ii) steam flow rate, and (iii) temperature of inlet gas and inlet liquid? Explain your answer with appropriate equations.

(c) Determine the height of the stripping column using a tray spacing of 1.5 feet.

3. (a) In recent years sustainability has become one of the main concerns in chemical process design. How would you select a solvent if sustainability needs to be considered in designing an extraction process? **(10)**

Contd P/2

CHE 303

Contd.... for Q. No. 3

(b) The equilibrium for extraction of acetic acid from water into 3-heptanol at 25°C is $y = 0.828x$, where y is wt frac acetic acid in 3-heptanol and x is wt frac acetic acid in water. We have a feed of 400 kg/h containing 0.005 wt frac acetic acid in water. We have a solvent containing 0.0001 wt frac acetic acid in 3-heptanol. Assume water and 3-heptanol are immiscible. **(25)**

If 200 kg/h of solvent is added to each stage of a cross-flow cascade with two stages, find the total recovery of acetic acid in the 3-heptanol solvent phase.

4. Pure isopropyl ether (C) of 450 kg/h is being used to extract an aqueous solution of 150 kg/h with 30 wt% acetic acid (A) and 70% water (B) by countercurrent multistage extraction. The equilibrium data at 20°C, 1 atm, are given in the table for Question no 4. The desired exit acetic acid concentration in the aqueous phase is 4%. **(35)**

(a) In a right-angle triangle, plot the solubility curve

(b) Locate the delta point

(c) Find the composition of the extract phase leaving the first stage.

Table for Question no 4

Water phase (mass fraction)			isopropyl ether phase (mass fraction)		
acetic acid (x_A)	Water (x_B)	isopropyl ether (x_C)	acetic acid (y_A)	Water (y_B)	isopropyl ether (y_C)
6.9e-3	0.9810	0.0120	1.8e-3	5.0e-3	0.9930
0.0141	0.9710	0.0150	3.7e-3	7.0e-3	0.9890
0.0289	0.9550	0.0160	7.9e-3	8.0e-3	0.9840
0.0642	0.9170	0.0190	0.0193	0.0100	0.9710
0.1330	0.8440	0.0230	0.0482	0.0190	0.9330
0.2550	0.7110	0.0340	0.1140	0.0390	0.8470
0.3670	0.5890	0.0440	0.2160	0.0690	0.7150
0.4430	0.4510	0.1060	0.3110	0.1080	0.5810
0.4640	0.3710	0.1650	0.3620	0.1510	0.4870

SECTION – B

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

5. (a) Do the thermal, mechanical and chemical, three equilibrium attain simultaneously for the establishment of vapor-liquid equilibrium? Justify your answer. **(7)**

(b) Make a detailed comparison between y vs. x experimental data and y vs. x data obtained from equation based no relative volatility for the same pressure and chemical system. **(8)**

Contd P/3

CHE 303

Contd.... for Q. No. 5

(c) Sketch the basic flash distillation process and rationalize the use of a heater in this process. **(5+5=10)**

(d) A mixture that is 40 mole % benzene and 60 mole % toluene is to be flashed in a flash distillation system. Feed is 100 kg moles/day. We desire a liquid product that is 30 mole % benzene. The relative volatility is 2.4. Determine (i) vapor composition, (ii) liquid flow rate. **(10)**

6. Answer the followings for column distillation:

(a) What are the purposes of reflux and boilup? **(8)**

(b) Explain the reason why a constant pressure distillation column is preferable to an isothermal distillation system. **(4)**

(c) State what CMO is, discuss shortly the necessity of CMO, and determine if CMO is valid in a given situation. **(11)**

(d) Show the flow profile, calculate the feed line slope, and compare the feed lines for the following cases: **(6+6=12)**

(i) A superheated vapor feed where 1 mole of liquid will vaporize on the feed stage for each 9 moles of feed input.

(ii) A liquid feed subcooled by 35°F. Average liquid heat capacity is 30 Btu/lb-mole-°F and $\lambda = 15000$ Btu/lb-mole.

7. Answer the followings for column distillation and advanced distillation:

(a) Find the number of stages and the best feed location for a column separating ethanol and propanol, $\alpha = 2.1$. Feed composition = 0.48, $x_D = 0.96$, $x_B = 0.04$. Constant molal overflow can be assumed, and reflux is a saturated liquid. Column has a total condenser and a partial reboiler. Pressure is 101.3 kPa. Reflux ratio and feed quality are 3 and 0.4, respectively. **(23)**

(b) With a hand-drawing, show the typical McCabe-Thiele diagram-analysis for each of the following systems/cases: **(12)**

(i) Column with one side stream

(ii) Stripping column

(iii) Column with total reflux

(iv) Column with a given Murphree stage vapor efficiency of 0.75.

Contd P/4

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8. (a) Discuss the advantages of batch distillation compared to continuous distillation. **(6)**

(b) Assuming that either batch or continuous distillation could be used, which would use less energy? Explain why. **(6)**

(c) We wish to use a distillation system with a still pot plus a column with one equilibrium stage to batch distill a mixture of methanol and water. A total condenser is used. The feed is 57 mole % methanol. We desire a final bottoms concentration of 15 mole % methanol. Pressure is 1 atm. Reflux is a saturated liquid, and L_o/D is constant at 1.85. Find W_{final}, D, and $x_{D,\,avg}$. Methanol-water equilibrium data is given below. Calculate on the basis of 1 kg mole of feed. **(23)**

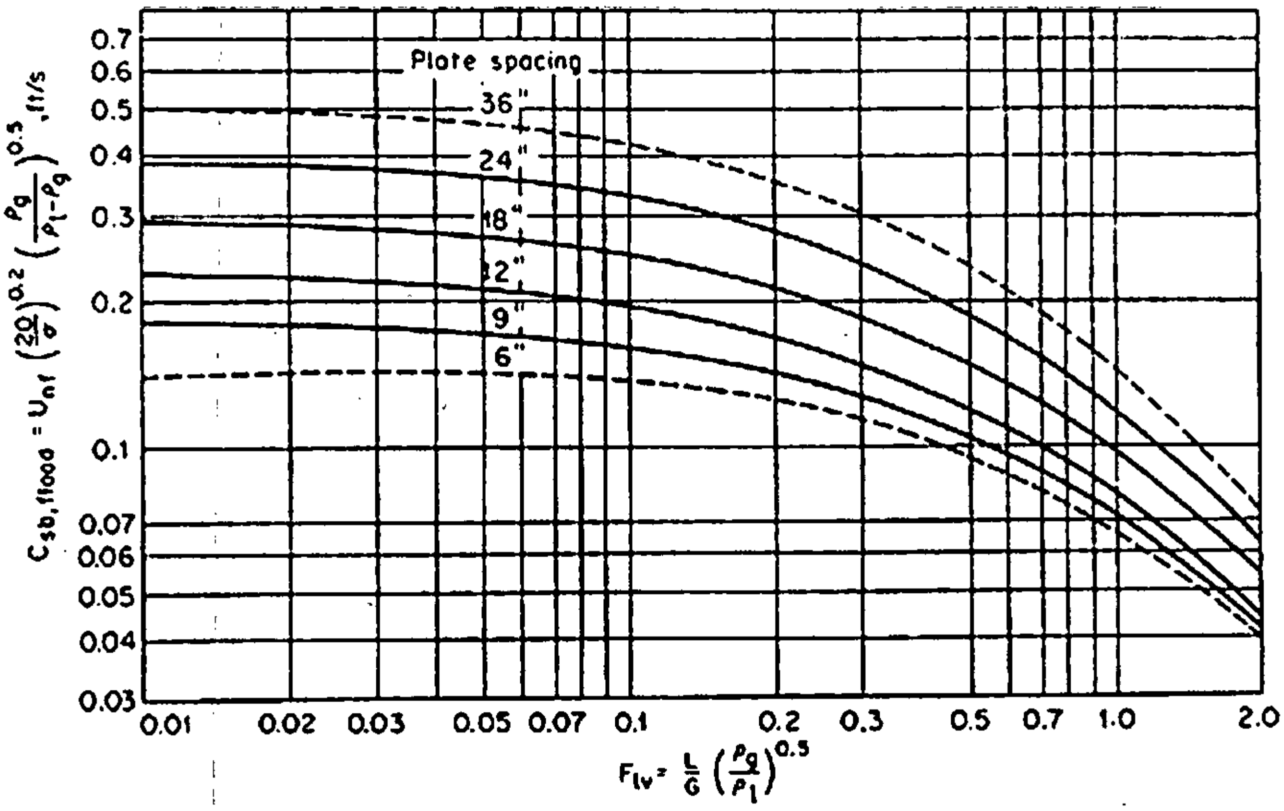
Table: VLE Data for Methanol-Water

Mole % Methanol at 1 atm

Liquid	Vapor
0	0
2.0	13.4
4.0	23.0
6.0	30.4
8.0	36.5
10.0	41.8
15.0	51.7
20.0	57.9
30.0	66.5
50.0	77.9
70.0	87.0
90.0	95.8
100.0	100.0

(Data for Q. 8(c))

Figure for Question no 1c)



$$U_{N,f} = C_{SB}\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{0.5}\left(\frac{\sigma_L}{20}\right)^{0.2}$$

$$C_{SB}(\text{ft s}^{-1}) = 0.04232 + 0.1674T_S + (0.0063 - 0.2686T_S)F_{lv} + (0.1448T_S - 0.008)F_{lv}^2$$

L-3/T-1/CHE Date : 15/10/2022

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub : **CHE 307** (Chemical Engineering Thermodynamics II)

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**.

Assume reasonable values for different parameters if necessary.

Symbols have their usual meanings.

Data booklet is to be supplied.

1. (a) Determine the mole fraction of the water vapor at the surface of a lake whose temperature is 15°C, and compare it to the mole fraction of water in the lake. Take the atmospheric pressure at lake level to be 92 kPa. **(5+3=8)**

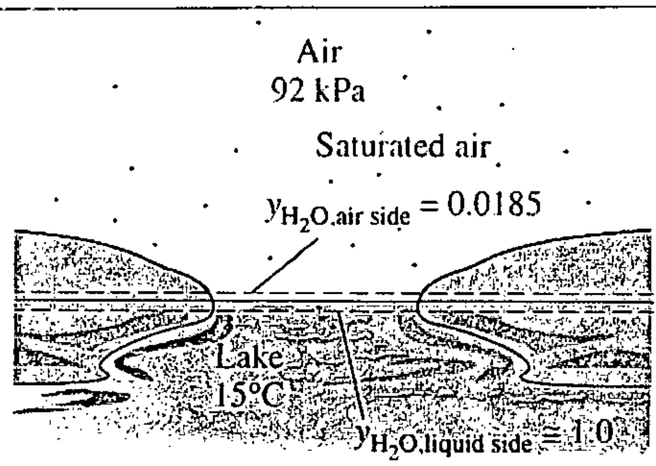


Figure for Question no. 1(a)

(b) Consider a carbonated drink in a bottle at 27°C and 115 kPa. Assuming the gas space above the liquid consists of a saturated mixture of CO_2 and water vapor and treating the drink as water, determine – **(5+10=15)**

(i) The mole fraction of the water vapor in the CO_2 gas and

(ii) The mass of dissolved CO_2 in a 300-ml drink.

(c) The following questions are based on phase Equilibrium. **(3×4=12)**

(i) Consider a tank that contains a saturated liquid-vapor mixture of water in equilibrium. Some vapor is now allowed to escape the tank at constant temperature and pressure. Will this disturb the phase equilibrium and cause some of the liquid to evaporate?

(ii) Consider a two-phase mixture of ammonia and water in equilibrium. Can this mixture exist in two phases at the same temperature but at a different pressure?

Contd P/2

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Contd ... Q. No. 1(c)

(iii) Using the solubility data of a solid in a specified liquid, explain how you would determine the mole fraction of the solid in the liquid at the interface at a specified temperature.

(iv) Using the Henry's constant for a gas dissolved in a liquid, explain how you would determine the mole fraction of the gas dissolved in the liquid at the interface at a specified temperature.

2. (a) Prepare plots of f vs. P for chloroform at 200°C for the pressure range from 0 to 40 bar. **(25)**

$$V^{sat} = V_c Z_c (1-T_r)^{0.2857} \qquad B^0 = 0.083 - 0.422/T_r^{1.6}$$

$$\phi = \exp\left[\frac{P_r}{T_r}\left(B^0 + \omega B^1\right)\right] \qquad B^1 = 0.139 - 0.172/T_r^{4.2}$$

(b) Show that – **(10)**

(i) The 'partial molar mass' of a species in solution is equal to its molar mass.

(ii) A partial specific property of a species in solution is obtained by division of the partial molar property by the molar mass of the species.

3. (a) What is the heat effect when 20 kg of LiCl(s) is added to 125 kg of an aqueous solution containing 10 wt% LiCl in an isothermal process at 25°C? You must draw the corresponding H-x diagram. **(12+3=15)**

(b) For the system ethyl ethanoate(1)/n-heptane(2) at T = 343.15 K, **(8+12=20)**

$$\ln \gamma_1 = 0.95\, x_2^2 \qquad \ln \gamma_2 = 0.95\, x_1^2$$

$$P_1^{sat} = 79.80 \text{ kPa} \qquad P_2^{sat} = 40.50 \text{ kPa}$$

Assuming the validity of Modified Raoult's law,

(i) Make a bubble point pressure (BUBL P) calculation for the given T and $x_1 = 0.05$.

(ii) What is the azeotrope composition and pressure at the T mentioned above?

4. (a) Draw a neat and clean block diagram for the calculation of dew point pressure (DEW P) applying the gamma/phi formulation. **(10)**

$$x_i = \frac{y_i \Phi_i P}{\gamma_i P_i^{sat}} \quad \text{.............................. (A)}$$

$$P = \frac{1}{\sum_i y_i \Phi_i / \gamma_i P_i^{sat}} \quad \text{...................... (B)}$$

Contd P/3

(b) A vapor mixture of nitrogen(1) and methane(2) at 200 K and 300 bar contains 40 mol% N_2. Determine the fugacity coefficients of nitrogen and methane in the mixture. The Redlich/Kwong equation of state is valid for the system. You may consider the following equations. **(25)**

$$\ln \hat{\phi}_i = \frac{b_i}{b}(Z-1) - \ln(Z-\beta) - \bar{q}_i I$$

$$Z = 1 + \beta - q\beta \frac{Z-\beta}{(Z+\epsilon\beta)(Z+\sigma\beta)}$$

$$\beta \equiv \frac{bP}{RT}$$

$$q \equiv \frac{a(T)}{bRT}$$

$$\bar{a}_i \equiv \left[\frac{\partial(na)}{\partial n_i}\right]_{T,n_j}$$

$$\bar{b}_i \equiv \left[\frac{\partial(nb)}{\partial n_i}\right]_{T,n_j}$$

$$b = \sum_i x_i b_i$$

$$a = \sum_i \sum_j x_i x_j a_{ij}$$

$$I = \frac{1}{\sigma - \epsilon} \ln\left(\frac{1+\sigma\rho b}{1+\epsilon\rho b}\right)$$

$$I = \frac{1}{\sigma - \epsilon} \ln\left(\frac{Z+\sigma\beta}{Z+\epsilon\beta}\right)$$

$$\bar{q}_i \equiv \left[\frac{\partial(nq)}{\partial n_i}\right]_{T,n_j} = q\left(1 + \frac{\bar{a}_i}{a} - \frac{\bar{b}_i}{b}\right)$$

SECTION – B

There are **FOUR** questions in this section. **Question No. 5** is **Compulsory** and contains 45 marks. Answer any **TWO** questions from the rest of 3 questions.

The symbols have their usual meanings if not explained.

5. Answer the following questions

(a) "For a reaction to be in thermodynamic equilibrium, it is assumed that the reaction has progressed for infinite time". True/False. Give reasons to your answer. **(5)**

(b) Why do we need stability criteria for any equilibrium? Explain. **(6)**

(c) Describe the operating principles of Linde process with a schematic diagram of the process. Mention the preferable scale of application for the process. **(12)**

(d) "At solid-vapor equilibrium, the fugacities of solid phase and vapor phase will be equal". Do you agree with this statement? Clarify your answer. **(5)**

(e) We have a stability criterion for a system with arbitrary number of species – **(6)**

$$dU^t + PdV^t - TdS^t \leq 0$$

This criterion is not ideal for practical applications. Why is that? Interpret.

(f) How do you express equilibrium constant for multiphase reactions? Describe with examples. **(5)**

(g) Describe the conditions shown in the figure below: **(6)**

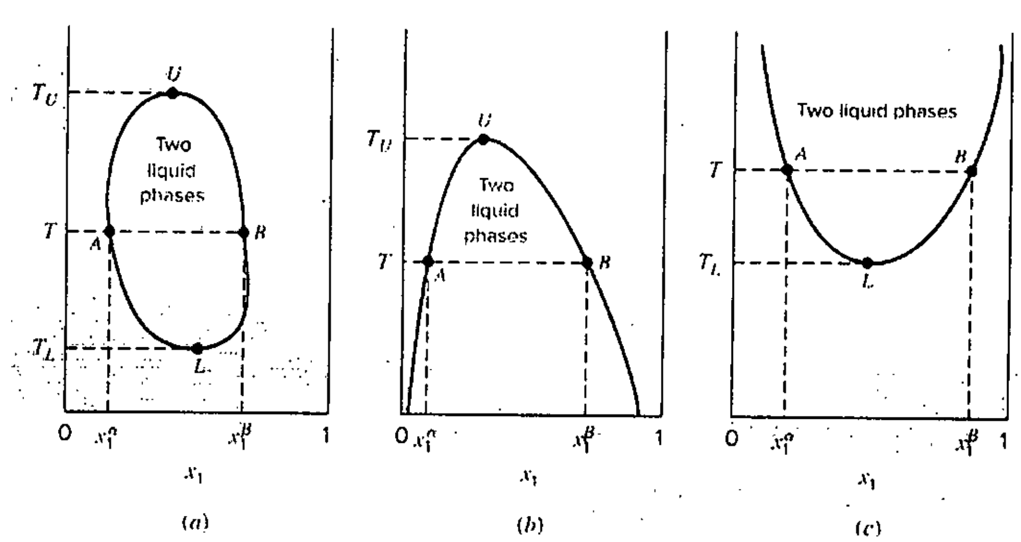


Figure 5g

CHE 307

6. (a) Draw an absorption refrigeration cycle and describe its working principle. **(16)**

(b) What is the maximum efficiency that could be reached by a hydrogen fuel cell thermodynamically? How much of it is practically achievable? **(6+2=8)**

(c) Describe the reasons behind banning some of the refrigerants. What are the possible alternatives to them? **(6)**

7. (a) Derive the stability criteria for a binary liquid-liquid mixture in equilibrium. **(18)**

(b) For an isothermal binary component vapor-liquid equilibrium, what criteria are to be met? Explain the significance of these criteria. **(12)**

8. (a) $\Delta G_{f\,i}^{0} + RT\,ln\left(\frac{y_i \phi_i P}{P^o}\right) + \sum_k \lambda_k a_{ik} = 0$, symbols have their usual meanings.

Explain the significance of the equation and its parameters. **(8)**

(b) The equilibrium compositions at 1000 K and 1 bar of a gas-phase system containing the species H_2O, CO, CO_2 and H_2 are to be determined. In the initial unreacted state, there are 2 mol CO and 4 mol of H_2O present. Value of ΔG_f^0 at 1000 K are: **(22)**

$$\Delta G_{f\,H_2O}^{0} = -192.42\ kJ/mol \qquad \Delta G_{f\,CO}^{0} = -200.24\ kJ/mol$$

$$\Delta G_{f\,CO_2}^{0} = -395.79\ kJ/mol$$

At equilibrium, H_2 is measured by gas chromatography and found to have 3 moles. With this measurement, it will be possible to estimate the equilibrium concentration of the gas components and λ_k values. Determine the values of λ_k. [Hint: See the equation in 8(a)].

Data

Saturated water—Temperature table

Temp., T °C	Sat. press., P_{sat} kPa	Specific volume, m³/kg: Sat. liquid, v_f	Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Entropy, kJ/kg·K: Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302

Saturated water—Temperature table (*Concluded*)

Temp., T °C	Sat. press., P_{sat} kPa	Specific volume, m³/kg: Sat. liquid, v_f	Specific volume, m³/kg: Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Internal energy, kJ/kg: Evap., u_{fg}	Internal energy, kJ/kg: Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Enthalpy, kJ/kg: Evap., h_{fg}	Enthalpy, kJ/kg: Sat. vapor, h_g	Entropy, kJ/kg·K: Sat. liquid, s_f	Entropy, kJ/kg·K: Evap., s_{fg}	Entropy, kJ/kg·K: Sat. vapor, s_g
205	1724.3	0.001164	0.11508	872.86	1723.5	2596.4	874.87	1920.0	2794.8	2.3776	4.0154	6.3930
210	1907.7	0.001173	0.10429	895.38	1702.9	2598.3	897.61	1899.7	2797.3	2.4245	3.9318	6.3563
215	2105.9	0.001181	0.094680	918.02	1681.9	2599.9	920.50	1878.8	2799.3	2.4712	3.8489	6.3200
220	2319.6	0.001190	0.086094	940.79	1660.5	2601.3	943.55	1857.4	2801.0	2.5176	3.7664	6.2840
225	2549.7	0.001199	0.078405	963.70	1638.6	2602.3	966.76	1835.4	2802.2	2.5639	3.6844	6.2483
230	2797.1	0.001209	0.071505	986.76	1616.1	2602.9	990.14	1812.8	2802.9	2.6100	3.6028	6.2128
235	3062.6	0.001219	0.065300	1010.0	1593.2	2603.2	1013.7	1789.5	2803.2	2.6560	3.5216	6.1775
240	3347.0	0.001229	0.059707	1033.4	1569.8	2603.1	1037.5	1765.5	2803.0	2.7018	3.4405	6.1424
245	3651.2	0.001240	0.054656	1056.9	1545.7	2602.7	1061.5	1740.8	2802.2	2.7476	3.3596	6.1072
250	3976.2	0.001252	0.050085	1080.7	1521.1	2601.8	1085.7	1715.3	2801.0	2.7933	3.2788	6.0721
255	4322.9	0.001263	0.045941	1104.7	1495.8	2600.5	1110.1	1689.0	2799.1	2.8390	3.1979	6.0369
260	4692.3	0.001276	0.042175	1128.8	1469.9	2598.7	1134.8	1661.8	2796.6	2.8847	3.1169	6.0017
265	5085.3	0.001289	0.038748	1153.3	1443.2	2596.5	1159.8	1633.7	2793.5	2.9304	3.0358	5.9662
270	5503.0	0.001303	0.035622	1177.9	1415.7	2593.7	1185.1	1604.6	2789.7	2.9762	2.9542	5.9305
275	5946.4	0.001317	0.032767	1202.9	1387.4	2590.3	1210.7	1574.5	2785.2	3.0221	2.8723	5.8944
280	6416.6	0.001333	0.030153	1228.2	1358.2	2586.4	1236.7	1543.2	2779.9	3.0681	2.7898	5.8579
285	6914.6	0.001349	0.027756	1253.7	1328.1	2581.8	1263.1	1510.7	2773.7	3.1144	2.7066	5.8210
290	7441.8	0.001366	0.025554	1279.7	1296.9	2576.5	1289.8	1476.9	2766.7	3.1608	2.6225	5.7834
295	7999.0	0.001384	0.023528	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2076	2.5374	5.7450
300	8587.9	0.001404	0.021659	1332.7	1230.9	2563.6	1344.8	1404.8	2749.6	3.2548	2.4511	5.7059
305	9209.4	0.001425	0.019932	1360.0	1195.9	2555.8	1373.1	1366.3	2739.4	3.3024	2.3633	5.6657
310	9865.0	0.001447	0.018333	1387.7	1159.3	2547.1	1402.0	1325.9	2727.9	3.3506	2.2737	5.6243
315	10,556	0.001472	0.016849	1416.1	1121.1	2537.2	1431.6	1283.4	2715.0	3.3994	2.1821	5.5816
320	11,284	0.001499	0.015470	1445.1	1080.9	2526.0	1462.0	1238.5	2700.6	3.4491	2.0881	5.5372
325	12,051	0.001528	0.014183	1475.0	1038.5	2513.4	1493.4	1191.0	2684.3	3.4998	1.9911	5.4908
330	12,858	0.001560	0.012979	1505.7	993.5	2499.2	1525.8	1140.3	2666.0	3.5516	1.8906	5.4422
335	13,707	0.001597	0.011848	1537.5	945.5	2483.0	1559.4	1086.0	2645.4	3.6050	1.7857	5.3907
340	14,601	0.001638	0.010783	1570.7	893.8	2464.5	1594.6	1027.4	2622.0	3.6602	1.6756	5.3358
345	15,541	0.001685	0.009772	1605.5	837.7	2443.2	1631.7	963.4	2595.1	3.7179	1.5585	5.2765
350	16,529	0.001741	0.008806	1642.4	775.9	2418.3	1671.2	892.7	2563.9	3.7788	1.4326	5.2114
355	17,570	0.001808	0.007872	1682.2	706.4	2388.6	1714.0	812.9	2526.9	3.8442	1.2942	5.1384
360	18,666	0.001895	0.006950	1726.2	625.7	2351.9	1761.5	720.1	2481.6	3.9165	1.1373	5.0537
365	19,822	0.002015	0.006009	1777.2	526.4	2303.6	1817.2	605.5	2422.7	4.0004	0.9489	4.9493
370	21,044	0.002217	0.004953	1844.5	385.6	2230.1	1891.2	443.1	2334.3	4.1119	0.6890	4.8009
373.95	22,064	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

Molar mass, gas constant, and critical-point properties

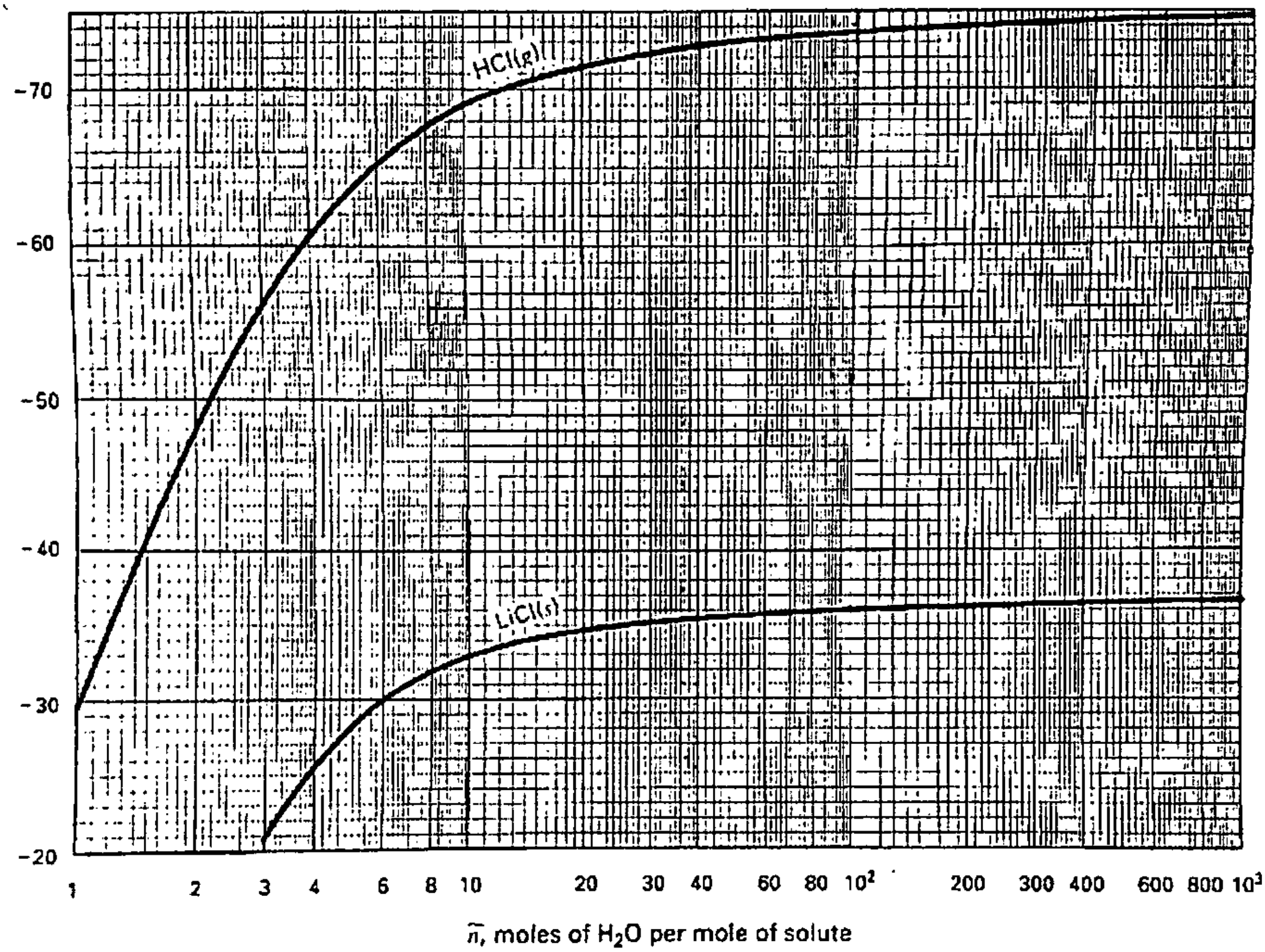
Substance	Formula	Molar mass, M kg/kmol	Gas constant, R kJ/kg·K*	Critical-point properties: Temperature, K	Pressure, MPa	Volume, m^3/kmol
Air	—	28.97	0.2870	132.5	3.77	0.0883
Ammonia	NH_3	17.03	0.4882	405.5	11.28	0.0724
Argon	Ar	39.948	0.2081	151	4.86	0.0749
Benzene	C_6H_6	78.115	0.1064	562	4.92	0.2603
Bromine	Br_2	159.808	0.0520	584	10.34	0.1355
n-Butane	C_4H_{10}	58.124	0.1430	425.2	3.80	0.2547
Carbon dioxide	CO_2	44.01	0.1889	304.2	7.39	0.0943
Carbon monoxide	CO	28.011	0.2968	133	3.50	0.0930
Carbon tetrachloride	CCl_4	153.82	0.05405	556.4	4.56	0.2759
Chlorine	Cl_2	70.906	0.1173	417	7.71	0.1242
Chloroform	$CHCl_3$	119.38	0.06964	536.6	5.47	0.2403
Dichlorodifluoromethane (R-12)	CCl_2F_2	120.91	0.06876	384.7	4.01	0.2179
Dichlorofluoromethane (R-21)	$CHCl_2F$	102.92	0.08078	451.7	5.17	0.1973
Ethane	C_2H_6	30.070	0.2765	305.5	4.48	0.1480
Ethyl alcohol	C_2H_5OH	46.07	0.1805	516	6.38	0.1673
Ethylene	C_2H_4	28.054	0.2964	282.4	5.12	0.1242
Helium	He	4.003	2.0769	5.3	0.23	0.0578
n-Hexane	C_6H_{14}	86.179	0.09647	507.9	3.03	0.3677
Hydrogen (normal)	H_2	2.016	4.1240	33.3	1.30	0.0649
Krypton	Kr	83.80	0.09921	209.4	5.50	0.0924
Methane	CH_4	16.043	0.5182	191.1	4.64	0.0993
Methyl alcohol	CH_3OH	32.042	0.2595	513.2	7.95	0.1180
Methyl chloride	CH_3Cl	50.488	0.1647	416.3	6.68	0.1430
Neon	Ne	20.183	0.4119	44.5	2.73	0.0417
Nitrogen	N_2	28.013	0.2968	126.2	3.39	0.0899
Nitrous oxide	N_2O	44.013	0.1889	309.7	7.27	0.0961
Oxygen	O_2	31.999	0.2598	154.8	5.08	0.0780
Propane	C_3H_8	44.097	0.1885	370	4.26	0.1998
Propylene	C_3H_6	42.081	0.1976	365	4.62	0.1810
Sulfur dioxide	SO_2	64.063	0.1298	430.7	7.88	0.1217
Tetrafluoroethane (R-134a)	CF_3CH_2F	102.03	0.08149	374.2	4.059	0.1993
Trichlorofluoromethane (R-11)	CCl_3F	137.37	0.06052	471.2	4.38	0.2478
Water.	H_2O	18.015	0.4615	647.1	22.06	0.0560
Xenon	Xe	131.30	0.06332	289.8	5.88	0.1186

*The unit kJ/kg·K is equivalent to kPa·m^3/kg·K. The gas constant is calculated from $R = R_u/M$, where R_u = 8.31447 kJ/kmol·K and M is the molar mass.

Source of Data: K. A. Kobe and R. E. Lynn, Jr., *Chemical Review* 52 (1953), pp. 117-236; and ASHRAE, *Handbook of Fundamentals* (Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1993), pp. 16.4 and 36.1.

Henry's constant H (in bars) for selected gases in water at low to moderate pressures (for gas i, $H = P_{i,\text{gas side}}/y_{i,\text{water side}}$) (from Mills, 1995, Table A.21, p. 874)

Solute	290 K	300 K	310 K	320 K	330 K	340 K
H_2S	440	560	700	830	980	1140
CO_2	1,280	1,710	2,170	2,720	3,220	—
O_2	38,000	45,000	52,000	57,000	61,000	65,000
H_2	67,000	72,000	75,000	76,000	77,000	76,000
CO	51,000	60,000	67,000	74,000	80,000	84,000
Air	62,000	74,000	84,000	92,000	99,000	104,000
N_2	76,000	89,000	101,000	110,000	118,000	124,000



Eq. of State	$\alpha(T_r)$	σ	ϵ	Ω	Ψ	Z_c
vdW (1873)	1	0	0	1/8	27/64	3/8
RK (1949)	$T_r^{-1/2}$	1	0	0.08664	0.42748	1/3
SRK (1972)	$\alpha_{SRK}(T_r;\omega)^\dagger$	1	0	0.08664	0.42748	1/3
PR (1976)	$\alpha_{PR}(T_r;\omega)^\ddagger$	$1+\sqrt{2}$	$1-\sqrt{2}$	0.07779	0.45724	0.30740

$$^\dagger\alpha_{SRK}(T_r;\,\omega) = \left[1 + (0.480 + 1.574\,\omega - 0.176\,\omega^2)\left(1 - T_r^{1/2}\right)\right]^2$$

$$^\ddagger\alpha_{PR}(T_r;\,\omega) = \left[1 + (0.37464 + 1.54226\,\omega - 0.26992\,\omega^2)\left(1 - T_r^{1/2}\right)\right]^2$$

L-3/T-1/CHE **Date: 29/09/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **CHE 451** (Fuels and Combustion Science)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section. **Question No. 1 is compulsory.** Answer any **TWO** Questions from the rest of **THREE** Questions.

1. Answer the following questions (**COMPULSORY**):

(a) How do you measure elemental composition of a fuel? **(3)**

(b) Between explicit and implicit methods of finite difference analysis, which one would you prefer for heat transfer calculation in a fuel particle? Give reasons behind your answer. **(5)**

(c) Describe the assumption behind the volumetric and grain/shrinking core model. Which one is more appropriate to apply on a non-porous solid fuel particle? **(4+3=7)**

(d) Identify and mention the alternative fuels to fossil resources in Bangladesh scenario. Give reasons to your answer. **(5)**

(e) How is fossil fuel formed naturally? Is it possible to produce artificial fossil like fuels from other resources? If yes, give an example. **(7)**

(f) Describe the step-by-step method to determine the reaction rate constant (k) for char conversion using graphical methods, starting from grain/shrinking model. **(9)**

(g) Explain what you understand by multiscale modelling of fuel conversion. **(4)**

(h) A combined heat and power generation plant has a combined efficiency of 65%, interpret this. **(5)**

2. (a) Hydrogen is a next generation fuel. Briefly describe two methods of generating hydrogen. What are the possibilities of using hydrogen as fuel in Bangladesh context? **(6+4=10)**

(b) Describe the merits/demerits of kinetic modelling over thermodynamic modelling during fuel conversion. **(8)**

(c) Heat transfer inside a fuel particle takes place during the combustion. True/False. Explain. **(5)**

Contd P/2

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Contd... Q. No. 2

(d) A fuel has 20% (w/w) carbon on wet basis. It has 70% (w/w) moisture and 13% (w/w) ash. The HHV of the fuel on wet basis is 4 MJ/kg. What would be the carbon content and HHV on dry ash free basis? **(7)**

3. (a) Briefly describe a process which utilize ash from combustion. **(5)**

(b) Based on elements analysis of a fuel particle the following fuel composition is available: carbon (34%), hydrogen (5%), nitrogen (3%), sulfur (1%), oxygen 42%) and ash (15%) on weight basis. Based on this information: **(4+6+10=20)**

(i) Determine the hypothetical molecular formula of the fuel (excluding ash).

(ii) How many equations are necessary to solve all the unknowns for the combustion of this fuel?

(iii) How many equilibrium relations would be necessary to determine the outlet gas concentration from the combustor? Write down the possible reactions in equilibrium to solve this problem. If you make any assumption, clarify.

(c) Why is it required to perform thermodynamic calculation for fuel particle conversion? **(5)**

4. (a) A stagnant char particle is getting heated before gasification on a fixed bed. The following represents the heating process of a char particle: **(6+14=20)**

$$\rho C_p \frac{\partial T_p}{\partial t} = \lambda \left[\frac{\partial^2 T_p}{\partial r^2} + \frac{b-1}{r} \frac{\partial T_p}{\partial r} \right]$$

As there is no reaction involved until the particle gets heated till 650 °C, this equation is valid till that temperature. The gas temperature surrounding the particle is 800 °C. The char particle is of cylindrical shape.

Make any assumption as required to derive the equation for explicit (finite difference) method to solve this fuel heat transfer problem. (Hint: b = 2)

(b) What do you understand by characteristic time for combustion process? Explain with an example. **(6)**

(c) What is the difference between devolatilization and pyrolysis? **(4)**

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SECTION – B

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

5. (a) Is a drum type boiler a super-critical boiler? -Why? What are the basic thermodynamic cycles for sub-critical and super-critical power plants with regenerative heating and preheating systems? Explain the cycles with T-S diagram. **(3+6=9)**

(b) Show the working schematic of a drum-type RH utility boiler with ECON and AH as back-end equipment and its associated energy balance diagram. **(10+5=15)**

(c) What are direct and indirect measurement of boiler efficiency? For routine check what type of boiler efficiency is performed? - Why? How do ambient environmental parameters affect the boiler efficiency? **(3+4+4=11)**

6. (a) What is IRC burner and how does it function? Draw the schematic of an IRC burner and show its velocity profile with some industrial uses. What is twin fluid atomizer for liquid fuel? -Show its functionality with necessary diagram. **(3+4+6+5=18)**

(b) How can you categorize the waste heat types based on waste heat temperature? Propose a WHR unit (that has no moving part to recover WH up to 315 °C) along with its working schematic, advantages and typical applications. **(3+6=9)**

(c) What is the dry ash free LHV of $C_{16}H_{34}$ if the HHV is 44.307 MJ/kg and the ash content and moisture content of the fuel are 2.5% and 5%, respectively? State all the assumptions clearly. **(7+1=8)**

7. (a) When are open cycle gas turbine and closed cycle gas turbine used for power generation? - Explain with their schematic diagram. **(5+5=10)**

(b) What does cogeneration mean? Draw the T-S diagram of the system shown in Figure 3(b) and find the global thermal efficiency of the CHP cycle. Consider superheated stem at 60 bar (P1) and 540° C(T1). Temperature of superheated steam at 20 bar(P2) is 360°C(T2). The stream for heating is extracted at a 50% ratio. Assume an ideal Ranking cycle with steam exit pressure at 3 bar(P3). Clearly mention the assumptions you considered. Data given: **(2+5+10=17)**

Contd P/4

CHE 451

Contd... Q. No. 7(b)

	T(°C)	Enthalpy (kJ/kg			Entropy (kJ/kg/K)	
		h_v	h_l	Δh_{vap}	s_v	s_l
Superheated steam, 60 bar	540	3517.0			6.9999	
Superheated steam, 20 bar	360	3159.3			6.9917	
Saturated steam, 20 bar	212.4	2799.5	908.8	1890.7	6.3409	2.4235
Saturated steam, 3 bar	180	2725.3	561.5	2163.8	6.9919	2.1379

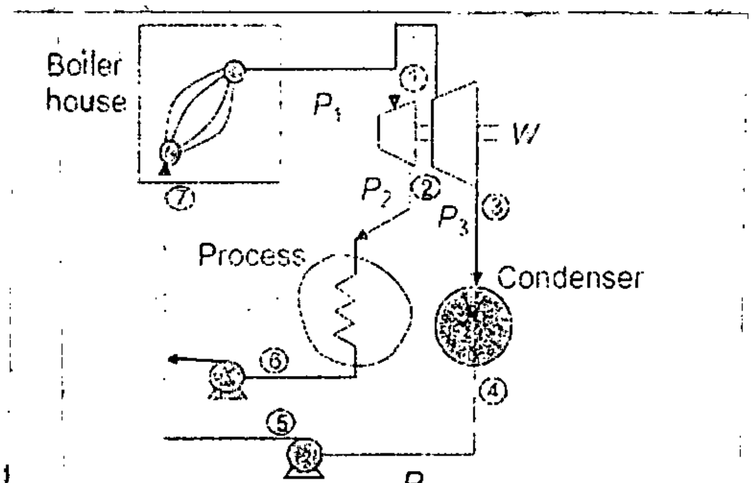

Figure: 3(b)

(c) Explain the PM separation mechanism of fabric filter. **(8)**

8. (a) Show the progression of solid fuel conversion during gasification schematically including temperature ranges and mechanisms. **(8)**

(b) Draw a typical schematic diagram of CLC process. What is the main difference between $Ni/NiAl_2O_4$ and $Cu_{0.95}Fe_{1.05}AlO_4$ as oxygen carrier in CLC process? **(4+2=6)**

(c) What is oxy-fuel combustion? -Show with diagram. Why is the size of oxy fired CFB boiler smaller than traditional CFB boiler? Show the heat recovery arrangement in oxy fired CFB boiler? -Why is the heat recovery system in oxy fired CFB like that? **(5+2+5=12)**

(d) Explain PM separation mechanism of ESP with necessary diagram. **(9)**

Formulae Sheet

Characteristic time

$$t_{conv} = \frac{\rho_p C_p d_p}{6h}$$

$$t_{rad} = \frac{\rho_p C_p d_p}{6\sigma\epsilon(T_g+T_p)(T_g^2+T_p^2)}$$

$$t_{cond} = \frac{\rho_p C_p d_p^2}{36\lambda}$$

$$t_{pyro} = \frac{1}{k_{pyro}}$$

HHV on dry basis

Sheng and Azevedo

-1.3675 + 0.3137C + 0.7009H + 0.0318O

Channiwala and Parikh

0.3491C + 1.1783H + 0.1005S – 0.1034O – 0.0151N – 0.0211A

Thermodynamics

For the reaction,

$$a \cdot A + b \cdot B \leftrightarrow r \cdot R + s \cdot S$$

- $\ln K_p = \frac{a \cdot g_A^0 + b \cdot g_B^0 - r \cdot g_R^0 - s \cdot g_S^0}{R \cdot T}$
- $\left(\frac{p_R^r \cdot p_S^s}{p_A^a \cdot p_B^b} \cdot p_0^{(a+b-r-s)} \right) = K_p$
- $\frac{[R]^r [S]^s}{[A]^a [B]^b} = K_c$

- $K_c = \frac{K_p}{(RT)^{p+s-a-b}}$

Water Gas Shift Reaction

$\ln(K_{WG}) = 1.8907[\ln(T)]^2 - 30.084[\ln(T)] + 117.942$

Methane Steam Reforming

$K_{MS} = e^b P^a$

Where

$a = -7.1635(T/1000)^5 + 53.378(T/1000)^4 - 157.83(T/1000)^3 + 230.86(T/1000)^2 - 166.32(T/1000) + 44.849$

$b = 9.5578(T/1000)^3 - 52.5(T/1000)^2 + 105.19(T/1000) - 61.45$

T in Kelvin. P in MPa.

Kinetics

- Reaction rate, dx/dt= k (Cg.T) f (x)
- $k = k_o e^{-\frac{E}{RT}}$
- $k = k_c C_g^n$
- Volumetric model: $\frac{dX}{dt} = k_v(1 - X)$
- Grain model: $\frac{dX}{dt} = k_g(1 - X)^{\frac{2}{3}}$
- Random pore model: $\frac{dX}{dt} = k_r(1 - X)\sqrt{[1 - \Psi \ln(1 - X)]}$

DAEM

$$\mathbf{x = 1 - \int_0^{\infty} \exp\left(-\int_0^t k\,dt\right) f(E)\,dE}$$

Gaussian distribution

Gaussian distribution, $f(E) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(E-\text{mean}E)^2}{2\sigma^2}}$

Standard deviation, $\sigma = \sqrt{\frac{1}{1-N}\sum_1^N (E - \text{mean}E)^2}$

Heat transfer for pyrolysis

$$\rho C_p \frac{\partial T_p}{\partial t} = \lambda \left[\frac{\partial^2 T_p}{\partial r^2} + \frac{b-1}{r} \frac{\partial T_p}{\partial r} \right] + q_{pyro} \left(-\frac{d\rho}{dt} \right)$$

b = structural parameter (3 for sphere, 2 for cylindrical shape, 1 for flat surface)

q_{pyro} = heat of pyrolysis

λ = thermal conductivity

Explicit method

- $-\frac{\partial q}{\partial x} = \rho C \frac{\partial T}{\partial t}$
- $k \frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t}$
- $\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1}^l - 2T_i^l + T_{i-1}^l}{\Delta x^2}$
- $\frac{\partial T}{\partial t} = \frac{T_i^{l+1} - T_i^l}{\Delta t}$
- $T_i^{l+1} = T_i^l + \lambda(T_{i+1}^l - 2T_i^l + T_{i-1}^l)$

where $\lambda = k\,\Delta t/(\Delta x)^2$

Implicit method

- $$k\frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t}$$
- $$\frac{\partial^2 T}{\partial x^2} \cong \frac{T_{i+1}^{l+1} - 2T_i^{l+1} + T_{i-1}^{l+1}}{(\Delta x)^2}$$
- $$\frac{\partial T}{\partial t} = \frac{T_i^{l+1} - T_i^l}{\Delta t}$$
- $$-\lambda T_{i-1}^{l+1} + (1 + 2\lambda)T_i^{l+1} - \lambda T_{i+1}^{l+1} = T_i^l$$

Calculation on a particle in fixed bed

$$-\frac{d\rho_b}{dt} = -k\rho_b$$

- $$\frac{d\rho}{dt} = v_c k\rho_b$$
- $$\lambda_1\frac{\partial T_p}{\partial r} = 0$$
- $$\lambda_1\frac{\partial T_s}{\partial r} \quad h\left(T_g - T_s\right) + \sigma\varepsilon\left(T_g^4 - T_s^4\right)$$

$$\rho = \rho_b + \rho_c$$

$$C_p = \left(\rho_b C_{p,b} + \rho_c C_{p,c}\right)/\rho$$

- $$\lambda_1 = \left(\rho_b\lambda_b + \rho_c\lambda_c\right)/\rho$$
- $$Nu = 2 + 0.6Re_D^{0.5}\, Pr_D^{1/3}$$

L-3/T-1/CHE **Date: 29/09/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **CHE 471** (Biochemistry)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

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

1. A researcher was studying the kinetic properties of β-galactosidase using an assay in which o-nitrophenol-b-galactoside (ONPG), a colorless substrate, is converted to galactose and onitrophenolate, a brightly colored, yellow compound. Upon addition of 0.25 mM substrate to a fixed amount of enzyme, o-nitrophenolate (ONP) production was monitored as a function of time by spectrophotometry at λ = 410 nm. The following data were obtained:

Time (s)	Absorbance, A_{410nm}
0	0.000
15	0.158
30	0.273
45	0.360
60	0.429
75	0.484
90	0.529
150	0.652
210	0.724
270	0.771
330	0.805
390	0.830
450	0.849
510	0.864

(a) Convert A_{410} nm to concentration of o-nitrophenolate [ONP], using extinction coefficient, E = 3.76 mM^{-1} cm^{-1} and optical length 1 cm. **(8)**

(b) Plot [ONP] versus time and explain why the curve is nearly linear initially and later approaches a plateau. **(10)**

(c) Find out the initial velocity at t = 0s, 30s, 60s, 270s, 390s, and 510s. **(9)**

Contd P/2

CHE 471
Contd... Q. No. 1

(d) Describe how K_M and V_{max} for β-galactosidase can be determined with additional experimentation. **(8)**

2. (a) For a Michaelis-Menten reaction, $k_1 = 7\times10^7\ M^{-1}\ sec^{-1}$, $k_{-1} = 10^3\ sec^{-1}$, $k_2 = 2\times10^4\ sec^{-1}$. What are the values of K_d and K_M? Does substrate binding approach equilibrium or does it behave more like a steady state system? Explain. **(10)**

   (b) An unknown compound contains only C, H, and O. Combustion of 3.50 g of this compound produced 8.24 g CO_2 and 2.25 g H_2O. Is the empirical formula of this substance consistent with its being a carbohydrate? **(13)**

   (c) How do biochemical methods determine the presence of carbohydrates? Write at least three methods and their procedures. **(12)**

3. (a) Write down the major functions of carbohydrates. Diagrammatically represent the formation of α-D Glucopyranose and β-D Glucopyranose from D-glucose. Also draw their Haworth Projection. **(15)**

   (b) Briefly explain the following: **(6)**

      i) Enantiomers
      ii) Diastereomers
      iii) Epimers
      iv) Anomers

   (c) How are the membrane lipids classified? What are the structural components of them? How does one of them manage to survive in extreme conditions like low pH or high temperatures? **(14)**

4. (a) How does glucose transport protein 4 (GLUT4) control blood sugar level after consuming a meal high in carbohydrates? **(10)**

   (b) Draw the diagram of metabolism happening in our body after food ingested. Your diagram must include glycolysis, glycogenesis, lipogenesis, ketonegesis, citric acid cycle, electron transport chain, glycogenolysis, ketolysis, gluconeogenesis and lipolysis processes. Also calculate the ATP produce in each step of cellular respiration from two moles of glucose. **(25)**

Contd P/3

SECTION – B

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

5. (a) The density range and size range of certain biological materials are shown in the table below. Will you use differential centrifugation or isopycnic centrifugation to separate from the following components of a mixture? Explain the reason for your choice: **(15)**

i) Mammalia cells and organelles

ii) DNA and RNA

Material	Density (g/cm^3)	Size range (μm)
Microbial cells	1.05-1.15	1-5
Mammalian cells	1.04-1.10	10-50
Organelles	1.10-1.6	1-2
Proteins	1.3	0.001-0.006
DNA	1.7	0.03-0.7*
RNA	2.0	0.02-0.05

*depends on cell phase.

(b) Describe briefly any two techniques for characterization of either proteins or DNA/RNA. Mention a modification to any one of your described methods so that it can detect covie-19 virus. **(14+6=20)**

6. (a) The DNA sequence is given as follows: **(5+10+10=25)**

5' ATGTGGCACAGAGAATAA'

i) If the above DNA sequence is part of the DNA coding sequence, what is the corresponding mRNA sequence?

ii) Use the codon chart and the correct reading frame to write down the correct peptide sequence in three letter code and one letter code.

iii) For the peptide obtained in part (b), draw the fully protonated structure and the titration curve. Using schematic diagrams show the net charge on the peptide at various pHs. What is the pI and the molecular weight of this peptide?

(b) Give a few examples of commonly found secondary structures in RNA strands? Explain why they are formed. **(10)**

7. (a) Describe how hydrogen bonds play a role in the following scenarios (include appropriate diagrams) **(6+6+3=15)**

i) a sucrose molecule dissolving in water

ii) stabilization of the α-helix

iii) initiation step of DNA replication

(b) (i) Calculate the pH of a buffer system that is 0.2 M benzoic acid and 0.8 M ammonium benzoate if the $pK_a = 4.2$. **(20)**

(ii) Calculate the number of grams of benzoate and benzoic acid are required to make a liter of 0.5 M buffer solution at the pH calculated in b)(i)

(MW benzoic acid, C_6H_5COOH = 122g mol^{-1}); (MW ammonium benzoate, $C_6H_5COONH_4$ = 139 g mol^{-1}).

8. (a) Describe with diagrams any FIVE factors that provide stability to proteins. **(25)**

(b) Why are the p*K*a values for the ionizable groups in glycine lower than those for simple, methyl-substituted amino and carboxyl groups? **(10)**

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mRNA Codon Chart

	U	C	A	G	
U	Phe Phe Leu Leu	Ser Ser Ser Ser	Tyr Tyr stop stop	Cys Cys stop Trp	U C A G
C	Leu Leu Leu Leu	Pro Pro Pro Pro	His His Gln Gln	Arg Arg Arg Arg	U C A G
A	Ile Ile Ile Met	Thr Thr Thr Thr	Asn Asn Lys Lys	Ser Ser Arg Arg	U C A G
G	Val Val Val Val	Ala Ala Ala Ala	Asp Asp Glu Glu	Gly Gly Gly Gly	U C A G

Amino Acid Properties

Amino acid name	Molecular weight amino acid	Molecular weight residue	pK_1	pK_2	pK_R
Alanine	89.10	71.08	2.34	9.69	
Arginine	174.20	156.18	2.17	9.04	12.48
Asparagine	132.12	114.10	2.02	8.80	
Aspartic Acid	133.11	115.09	1.88	9.60	3.65
Cysteine	121.16	103.14	1.96	10.28	8.18
Glutamic Acid	147.13	129.11	2.19	9.67	4.25
Glutamine	146.15	128.13	2.17	9.13	
Glycine	75.07	57.05	2.34	9.60	
Histidine	155.16	137.14	1.82	9.17	6.00
Hydroxyproline	131.13	113.11	1.82	9.65	
Isoleucine	131.18	113.16	2.36	9.60	
Leucine	131.18	113.16	2.36	9.60	
Lysine	146.19	128.17	2.18	8.95	10.53
Methionine	149.21	131.19	2.28	9.21	
Phenylalanine	165.19	147.17	1.83	9.13	
Proline	115.13	97.11	1.99	10.60	
Serine	105.09	87.07	2.21	9.15	
Threonine	119.12	101.10	2.09	9.10	
Tryptophan	204.23	186.21	2.83	9.39	
Tyrosine	181.19	163.17	2.20	9.11	10.07
Valine	117.15	99.13	2.32	9.62	

L-3/T-1/CHE **Date: 19/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **HUM 201** (Sociology)

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) What do you mean by human ecology and environment? Identify the major greenhouse gases. **(10)**

   (b) Describe the potential consequences of global warming. **(15)**

   (c) Briefly discuss the disposable society. **(10)**

2. (a) Define industrial revolution and capitalism. **(10)**

   (b) Write about the consequences of capitalism. **(10)**

   (c) Explain the fourth industrial revolution. Discuss the social impacts of the fourth industrial revolution. **(15)**

3. (a) Define urbanization, urbanism and over-urbanization. **(10)**

   (b) What are the underlying problems that exist in megacities? How can these problems be dealt with? **(15)**

   (c) Briefly discuss Malthusian population theory. **(10)**

4. (a) Describe the different types of mass media. **(10)**

   (b) Explain how mass media significantly influences personality development. **(10)**

   (c) Can you identify the methods via which poverty can be alleviated in Bangladesh? **(15)**

SECTION – B

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

5. (a) 'Sociological imagination is an unusual type of creative thinking for understanding social relationships' — Explain. **(15)**

   (b) Briefly discuss the functionalist theoretical perspective of sociology. **(20)**

Contd P/2

HUM 201/CHE

6. (a) What do you understand by social stratification? Explain caste system and social class system of social stratification with relevant examples. **(15)**

   (b) Discuss the different types of social mobility with suitable examples. **(10)**

   (c) Demonstrate the significance of social stratification in human society. **(10)**

7. (a) Critically describe Merton's modes of individual adaptation. **(20)**

   (b) Illustrate the factors affecting juvenile delinquency in Bangladesh. **(15)**

8. Write short notes on any THREE of the following: **(35)**

   (a) Steps of social research.

   (b) Sampling.

   (c) Functionalist perspective.

   (d) Social status.

L-3/T-1/CHE **Date: 19/10/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2020-2021

Sub: **HUM 303** (Principles of Accounting)

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. Mr. Hasan has started his computer service business on April 1st, 2019. The following transaction occurred during the month. **(35)**

April-1:	Invested cash in the business Tk. 3,00,000.
April-4:	Purchase computer terminals for Tk. 20,000 on account.
April-9:	Purchase supplies for Tk. 1,500 cash.
April-10:	Paid office rent for next two months Tk. 30,000.
April-13:	Performed computer services for Tk. 8,000 cash.
April-15:	Get bill for advertisement of current month Tk. 4,000.
April-17:	Paid dues for purchase on account on April 4.
April-20:	Provide service on credit to a customer Tk. 5,000.
April-23:	Paid utility expense for the month Tk. 2,000.
April-28:	Received Tk. 5,000 from the customer who has been previously billed on April 20.

Required:

(i) Prepare the tabular summary for the above transactions.

(ii) Prepare the Income Statement for April 30, 2019.

2. (a) The comparative Income Statement of Jacky Corporation are shown below: **(15)**

Particulars	2021	2020
Net sales	$600,000	$500,000
Cost of Goods Sold	483,000	420,000
Gross Profit	117,000	80,000
Operating Expenses	57,200	44,000
Net Income	59,800	36,000

(i) Prepare a horizontal analysis of the income statement data for Jacky Corporation using 2020 as a base and interpret the performance of the entity.

(ii) Prepare a vertical analysis of the income statement data for Jacky Corporation in columnar form for both years and interpret the performance of the entity.

Contd P/2

HUM 303/CHE

Contd... for Q. No. 2

(b) Mr. Jack opened a consulting firm on May 1, 2018. Following transactions happened for the month of May. **(20)**

May-2:	Invested Tk. 2,00,000 cash in the business.
May-5:	Purchase decorated office room for Tk. 1,50,000.
May-8:	Paid advertising expense of Tk. 7,000.
May-13:	Received Tk. 30,000 as consultancy fees.
May-19:	Billed a client for services performed on credit Tk. 8,500.
May-25:	Withdraw Tk. 5,000 for personal use.
May-27:	Received dues for services provided on account on May 19.
May-28:	Purchase supplies for office in cash Tk. 2,000.
May-30:	Paid salary to the office staff Tk. 10,000.
May-30:	Provide advertisement on account Tk. 4,000.

Required: Journalize the transactions in appropriate format for May 2018.

3. The trial balance of Tareq Electronics at January 31, 2018 is given below: **(35)**

Tareq Electronics
Trial Balance
January 31, 2018

Account Title	Debit (tk.)	Credit (tk.)
Cash	8,000	
Accounts Receivable	6,000	
Supplies	2,000	
Prepaid Insurance	3,000	
Office Equipment	15,000	
Account Payable		4,500
Unearned Service Revenue		4,000
Capital		22,600
Service Revenue		7,900
Salary Expense	4,000	
Rent Expense	1,000	
Total	39,000	39,000

Analysis reveals the following additional data:

- Supplies on hand at January 31, Tk. 750.
- Insurance policy is for a year.
- Depreciation Tk. 250 for each month.
- Unearned revenue is earned Tk. 2,800.
- Utility bill accrued at January Tk. 200.
- Salaries accrued Tk. 1,900.
- Service provided but no cash received and not recorded Tk. 1,200

Required:

(i) Prepare adjusting entries for January 31st, 2018.

(ii) Prepare adjusted trial balance as on January 31st, 2018.

Contd P/3

HUM 303/CHE

4. The following is the trial balance of Farlin Company as on December 31st, 2018. **(35)**

Farlin Company

Trial Balance

December 31st 2018

Account Title	Debit (tk.)	Credit (tk.)
Cash	5,300	
Accounts Receivable	10,800	
Supplies	1,500	
Prepaid Insurance	2,000	
Equipment	27,000	
Accumulated Depreciation- Equipment		5,600
Notes Payable		15,000
Accounts Payable		6,100
Salaries Payable		2,400
Internet Payable		600
Owner's Capital		13,000
Owners Drawings	7,000	
Service Revenue		61,000
Advertising expense	8,400	
Supplies Expense	4,000	
Depreciation Expense	5,600	
Insurance Expense	3,500	
Salaries expense	28,000	
Internet Expense	600	
Total	1,03,700	1,03,700

Other Information: Tk. 1,000 of Prepaid Insurance expired during the year.

Required:

(a) Prepare an Income Statement and Owners Equity Statement.

(b) Prepare a Balance Sheet as on 31st December 2018.

SECTION – B

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

5. Apex Creative Inc. makes high quality calculator. Sales and production data relating to the most recent year are given below: **(35)**

Sales (in unit)	2800
Selling price per unit	Tk. 265
Contribution Margin Ratio	60%
Annual Fixed Costs	Tk. 1,11,300

Management is anxious to improve the company's profit performance and has asked for several items of information.

HUM 303/CHE

Contd... for Q. No. 5

Required:

(a) Compute break-even point in units sales Taka.

(b) Assume that sales increases by Tk. 60,000 next year. If cost behavior patterns remain unchanged, by how much will the company's net income be increased?

(c) Refer to the original data. Assume that next year management wants to earn a profit of Tk. 1,82,850. How much units will have to be sold to meet this target profit?

(d) Refer to the original data. Compute margin of safety both in Taka and percentage form.

(e) Refer to the original data. The sales manager is convinced that a 15% reduction in the selling price combined with a Tk. 56,100 increase in advertisement cost would cause annual sales in units to increase by 40%. Would you recommend that the company should do as the sales manager suggests?

(f) (i) Compute degree of operating leverage at the present level of sales.

(ii) Assume that the company likes to increase its net profit by 90% next year. By what percentage would you expect sales to increase? Use degree of operating leverage (DOL) to answer.

(iii) Verify your answer by preparing income statement.

6. (a) In what situation, absorption costing method will result higher net income than variable costing method? Why? **(5)**

(b) Consider the following data relating to Stratford Manufacturing Company for the period ended on December 31, 2021. **(30)**

Cost Data:

Variable manufacturing cost:	
Direct materials	Tk. 25
Direct labor	Tk. 12
Variable manufacturing overhead	Tk. 13
Variable selling and administrative overhead	Tk. 10
Fixed costs for the period:	
Fixed manufacturing overhead	Tk. 250,000
Fixed selling and administrative overhead	Tk. 150,000

Contd P/5

HUM 303/CHE

Contd... for Q. No. 6(b)

Production and Sales Data:

Unit produced	25,000 units
Units sold	20,000 units
Unit selling price	Tk. 100

Required:

(i) Compute unit product cost under absorption costing and variable costing methods.

(ii) Prepare income statements under absorption costing and variable costing methods.

7. (a) Differentiate between direct method and reciprocal service method for cost allocation. **(5)**

(b) A manufacturing company has two service departments – Plant Maintenance and Information System and two production departments – Machining and Assembly. The relevant data for allocating service departments costs over production departments are given below: **(30)**

	Service Department		Production Department		Total
	Plant Maintenance	Information System	Machining	Assembly	
Overhead cost before allocation (Tk.)	600,000	116,000	400,000	200,000	1,316,000
Service work finished: By Plant Maintenance (Budgeted Labour Hours in %)	—	20%	30%	50%	100%
By Information System (Budgeted computer hours in %)	10%	—	80%	10%	100%

Required: Allocate service departments cost to the production departments by using

(i) Direct cost allocation method;

(ii) Reciprocal service method.

Contd P/6

8. (a) A company is going to purchase a new machine. The related information of machine is given below: **(25)**

Cost of the machine Tk. 80,000

Year	Net profit after tax (NPAT)
1	Tk. 35,000
2	12,000
3	18,000
4	10,000
5	8,000

Required:

(i) Pay Back Period

(ii) Net Present Value (NPV) at 10% cost of capital (discount rate)

(iii) Internal Rate of Return (IRR)

(iv) Profitability Index.

(b) "A variable cost is a cost that varies per unit of product. Where as a fixed cost is constant per unit of product." Do you agree? Explain with example. **(5)**

(c) Listed below are the number of costs typically found in organisations: **(5)**

(i) Advertising by a dental office;

(ii) Shipping costs in product sold;

(iii) Thread used in a garment factory;

(iv) Sugar used in soft-drink production;

(v) Boxes used for packing computer.

Required: Classify each item as variable, fixed or mixed cost.
