



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE : CPB22604
COURSE TITLE : SEPARATION PROCESS
PROGRAMME NAME : BACHELOR OF CHEMICAL ENGINEERING
TECHNOLOGY WITH HONOURS
DATE : 31 JANUARY 2026
TIME : 2:00PM - 5:00PM
DURATION : 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of ONE sections.
4. Section A consist of five questions. Answer FOUR (4) questions only.
5. Please write your answer on the answer booklet provided.
6. Please answer all questions in English only.
7. Refer to the attached Formula/ Appendies. ☒ Tick if applicable

THERE ARE 7 PAGES OF QUESTIONS INCLUDING THIS PAGE

SECTION A (Total: 100 marks)

Answer FOUR (4) questions.

Please use the answer booklet provided.

Question 1

Answer the following questions based on Humidification Process.

- (a) Moist air at 1 atm pressure enters an air-conditioning unit at a dry-bulb temperature of 30°C and a relative humidity of 60%. Using a standard psychrometric chart, determine the following properties of the inlet air:
- i. Wet-bulb temperature (1 marks)
 - ii. Humidity ratio (1 marks)
 - iii. Dew-point temperature (1 marks)
 - iv. Specific volume (1 marks)
 - v. Specific enthalpy (1 marks)
- (b) The air in a room is at 37.8°C and a total pressure of 101.3 kPa containing water vapor with a partial pressure is 3.59 kPa. The vapor pressure of water is 6.69 kPa. Calculate:
- i. The humidity (2 marks)
 - ii. The saturation humidity (2 marks)
 - iii. The percentage humidity (2 marks)

- iv. The percentage relative humidity
(2 marks)
- v. The humid heat
(2 marks)
- (c) Air at 1 atm pressure enters a cooling and dehumidification unit with the following initial conditions: dry bulb temperature, $T_1 = 35^\circ\text{C}$, relative humidity = 70% and mass flow rate of dry air = 1.5 kg/min. Later, the air is cooled and dehumidified to a final condition at dry bulb temperature $T_2 = 18^\circ\text{C}$ and relative humidity 90%. Using a psychrometric chart, determine:
- i. Humidity ratio at inlet and outlet
(2 marks)
- ii. Specific enthalpy at inlet and outlet
(2 marks)
- iii. Dew point temperature of inlet air
(2 marks)
- iv. Rate of heat removed in the cooling coil (kW)
(2 marks)
- v. Rate of moisture removed from the air (kg water/min)
(2 marks)

Question 2

Answer the following questions based on Drying Process.

- (a) Drying is the process of using heat to remove moisture content from a wet sample.
- i. Differentiate between batch and continuous drying.
(4 marks)
 - ii. Explain the mechanisms of moisture transportation during drying operation.
(6 marks)
- (b) An insoluble, wet, granular material is dried in a pan which dimension 0.457 m by 0.457 m and 25.4 mm deep. The material is 25.4 mm deep in the pan, and the sides and bottom are considered to be insulated. Heat transfer is by convection from an air stream flowing parallel to the surface at a velocity of 6.1 m/s. The air is at 65.6°C and has a humidity of 0.01 kg of water/kg dry air. Given the latent heat of vaporization is 2433 kJ/kg.
- i. Calculate the drying rate for the constant rate period
(10 marks)
 - ii. If the air stream flowing perpendicular to the surface of drying at the same velocity, calculate the new drying rate
(5 marks)

Question 3

Answer the following questions based on Adsorption Process.

- (a) Differentiate between physisorption and chemisorption in terms of forces involved, heat of adsorption, and reversibility.

(6 marks)

- (b) Identify two industrial applications of adsorption and explain the importance of adsorption for each application.

(4 marks)

- (c) A solution containing 0.2 g of glucose/cm³ is passed through packed bed of alumina at a flow rate of 10 cm³/s. The bed is having a diameter of 4 m and height of 14 m containing 85.0 g of alumina. The breakthrough data are shown in table.

Refer Below - Table1 : Breakthrough concentration of glucose .

Table 1: Breakthrough concentration of glucose

Concentration at outlet, C (g glucose /g alumina)	Time, t (min)
0	0
0	10
0	20
0.01	30
0.025	40
0.05	50
0.07	60
0.1	70
0.13	80
0.15	90
0.175	100
0.19	110
0.2	120
0.2	140
0.2	160
0.2	180

- i. Determine the breakpoint time when the feed concentration reduced by 99%.

(5 marks)

- ii. Calculate the fraction of total capacity used up to breakpoint and the length of unused bed (LUB).

(5 marks)

- iii. Calculate the new total length of the bed if the new breakthrough time is 40 minutes.

(5 marks)

Question 4

Answer the following questions based on Filtration Process.

- (a) A constant-pressure filtration is carried out using a plate-and-frame filter press. A slurry containing 6 wt% solids is filtered at a constant pressure drop of 60 kPa. The filtration area is 0.8 m^2 . The viscosity of the filtrate is $1.2 \times 10^{-3} \text{ Pa}\cdot\text{s}$. The specific cake resistance is $3.0 \times 10^{11} \text{ m/kg}$ and the resistance of the filter medium is equivalent to a cake resistance of $0.5 \times 10^{11} \text{ m}^{-1}$. The density of the filtrate is 1000 kg/m^3 . Calculate the time required to collect 0.30 m^3 of filtrate.

(10 marks)

- (b) A feedback control loop in the plant maintains the plate-and frame filter press operation at pressure drop of 3.0 kPa. The materials being separated are water from CaCO_3 , at 25°C , entering at a concentration of approximately 25 kg/m^3 . The filter area of the press was 0.8 m^2 . The data shown below was collected during the separation process.

Refer Below - Table2 : Separation of water- CaCO_3 mixture .

Table 2: Separation of water- CaCO_3 mixture

t (s)	300	600	900	1200	1500	1800
V (m^3)	0.19	0.31	0.41	0.49	0.56	0.63

- i. Calculate the α and R_m involve in this filtration process.
- ii. Calculate the time required to collect 1.2 m^3 of the filtrate.
- iii. After filtration, the cake is to be washed with 0.600 m^3 of water. Calculate the time of washing.

(9 marks)

(3 marks)

(3 marks)

Question 5

Answer the following questions based on Crystallization Process.

(a) Distinguish the terms as below:

i. Crystallization

(3 marks)

ii. Nucleation

(3 marks)

iii. Supersaturated solution

(3 marks)

(b) A hot solution containing 1000 kg of MgSO_4 and water having a concentration of 30 wt% MgSO_4 is cooled to 288.8 K where crystals of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ are precipitate. The solubility at 288.8 K is 24.5 wt% anhydrous MgSO_4 in the solution. Calculate the yield of crystals obtained if 5% of the total weight of solution is evaporates on cooling process.

(MW: $\text{Mg} = 24.0 \text{ g/mol}$; $\text{S} = 32.0 \text{ g/mol}$; $\text{O} = 16.0 \text{ g/mol}$; $\text{H} = 1.0 \text{ g/mol}$)

(6 marks)

(c) A feed solution of 2268 kg at 327.6 K containing 48.2 kg MgSO_4 /100 kg total water is cooled to 293.2 K where $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ crystals are removed. The solubility of the salt is 35.5 kg MgSO_4 /100 kg total water. The average heat capacity of the feed solution can be assumed as 2.93 kJ/kg.K . The heat of solution is $-13.31 \times 10^3 \text{ kJ/kg}$. (MW: $\text{Mg} = 24.0 \text{ kg/kmol}$; $\text{S} = 32.0 \text{ kg/kmol}$; $\text{O} = 16.0 \text{ kg/kmol}$; $\text{H} = 1.0 \text{ kg/kmol}$)

i. Calculate the yield of crystals obtained if no water is vaporized during process.

(5 marks)

ii. Calculate the total heat absorbed.

(5 marks)

END OF EXAMINATION PAPER

APPENDIX 1

LIST OF FORMULA

Chapter 1: Humidification Process

For air-water system;

$$MW_{\text{water}} = 18.0 \text{ g/mol}$$

$$MW_{\text{vapor}} = 28.0 \text{ g/mol}$$

Humid volume:

$$\nu_H = (2.83 \times 10^{-3} + 4.56 \times 10^{-3} H)T \quad (\text{SI unit})$$

$$\nu_H = (0.0252 + 0.0405H)T \quad (\text{English unit})$$

Humid heat:

$$C_s = 1.005 + 1.88H \quad (\text{SI unit})$$

$$C_s = 0.24 + 0.45H \quad (\text{English unit})$$

$$H = \frac{P_A}{P - P_A} \left(\frac{M_A}{M_B} \right)$$

$$H_s = \frac{M_A P_A^o}{M_B (P - P_A^o)}$$

$$H_R = \frac{P_A}{P_A^o} \times 100$$

$$H_p = \frac{H}{H_s} \times 100\%$$

Chapter 2: Drying Process

$$t_T = \frac{m_s}{A} \int_{X_2}^{X_1} \frac{dX}{R} = \frac{m_s(X_1 - X_2)}{AR_c} \longrightarrow \text{(for constant rate)}$$

$$R_c = \frac{h(T - T_w)(3600s)}{\lambda_w}$$

$$t = \int_{t_1=0}^{t_2=t} dt = \frac{m_s}{A} \int_{X_2}^{X_1} \frac{dX}{R} \longrightarrow \text{Area under curve (for falling rate)}$$

$$t = \frac{m_s(X_2 - X_1)}{A(R_2 - R_1)} \ln \frac{R_1}{R_2} \longrightarrow \text{If } R \text{ is linear function with } X$$

$$t = \frac{m_s X_c}{AR_c} \ln \frac{X_c}{X_2} \longrightarrow \text{If } R \text{ is linear function through origin}$$

Air flow to drying surface:

(i) $h = 0.0204G^{0.8} = \text{W/m}^2\cdot\text{K}$ (SI unit)
 $h = 0.0128G^{0.8} = \text{btu/h}\cdot\text{ft}^2\cdot^\circ\text{F}$ (English unit)

→ Parallel air flow

(ii) $h = 1.17G^{0.37} = \text{W/m}^2\cdot\text{K}$ (SI unit)
 $h = 0.37G^{0.37} = \text{btu/h}\cdot\text{ft}^2\cdot^\circ\text{F}$ (English unit)

→ Perpendicular air flow

(iii) $G = v_p = \text{kg/h}\cdot\text{m}^2$

→ Mass velocity

Chapter 3: Adsorption Process**Langmuir isotherm:**

$$q_e = \frac{Q_o C_e}{K_L + C_e}$$

$$\frac{1}{q_e} = \frac{K_L}{Q_o C_e} + \frac{1}{Q_o}$$

Freundlich isotherm:

$$q_e = K_F C_e^{1/n}$$

$$\log q_e = \frac{1}{n} \log C_e + \log K_F$$

$$q_e = \frac{(C_o - C_e)V}{W}$$

Batch isotherm:

$$q_F M + C_F S = qM + CS$$

Breakthrough adsorption:

$$t_T = \int_0^\infty \left(1 - \frac{C}{C_o}\right) dt$$

$$t_u = \int_0^{t_b} \left(1 - \frac{C}{C_o}\right) dt$$

$$H_{used} = \frac{t_u}{t_T} H_T$$

$$H_{unused} = \left(1 - \frac{t_u}{t_T}\right) H_T$$

$$H_{design} = H_{used} + H_{unusea}$$

$$L = u_s t_s$$

Chapter 4: Filtration Process**Constant pressure filtration:**

$$\frac{t}{V} = \left(\frac{K_c}{2} \right) V + \frac{1}{q_o}$$

$$\left(\frac{dV}{dt} \right) = \frac{1}{K_c V_f + 1/q_o} \longrightarrow \boxed{\text{Washing rate}}$$

$$c = \frac{\rho_F c_x}{1 - (m_F / m_c) c_x}$$

Cake resistance:

$$\alpha = \frac{A^2 \Delta p K_c}{c \mu} \quad (\text{SI unit})$$

$$\alpha = \frac{A^2 \Delta p g_c K_c}{c \mu} \quad (\text{English unit})$$

Filter medium resistance:

$$R_m = \frac{A \Delta p (1/q_o)}{\mu} \quad (\text{SI unit})$$

$$R_m = \frac{A \Delta p g_c (1/q_o)}{\mu} \quad (\text{English unit})$$

$$\mu_{\text{water}} = 8.937 \times 10^{-3} \text{ kg/m.s}$$

Chapter 5: Crystallization Process

$$q = (H_2 + H_v) - H_l \longrightarrow \boxed{\text{Enthalpy}}$$

$$\ln \alpha = \frac{4V_M \sigma}{vRTL} \longrightarrow \boxed{\text{Crystal size}}$$

Rate of nucleation:

$$B^o = C \exp \left[-\frac{16\pi\sigma^3 V_M^2 N_a}{3v^2 (RT)^3 (\ln \alpha)^2} \right] \longrightarrow \boxed{\text{Homogeneous solution}}$$

$$B^o = 10^{25} \exp \left[\frac{16\pi V_M^2 N_a \sigma_a^3}{3(RT)^3 v^2 s^2} \right] \longrightarrow \boxed{\text{Heterogeneous solution}}$$

B^o = number/cm³.s (Nucleation rate)

$N_a = 6.0222 \times 10^{23}$ molecules/gmol (Avogadro number)

$R = 8.314 \times 10^7$ ergs/gmol.K (Gas constant)

APPENDIX 2

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	$1 \text{ kg} = 1000 \text{ g} = 0.001 \text{ metric ton} = 2.20462 \text{ lb}_m = 35.27392 \text{ oz}$ $1 \text{ lb}_m = 16 \text{ oz} = 5 \times 10^{-4} \text{ ton} = 453.593 \text{ g} = 0.453593 \text{ kg}$
Length	$1 \text{ m} = 100 \text{ cm} = 1000 \text{ mm} = 10^6 \text{ microns } (\mu\text{m}) = 10^{10} \text{ angstroms } (\text{\AA})$ $= 39.37 \text{ in} = 3.2808 \text{ ft} = 1.0936 \text{ yd} = 0.0006214 \text{ mile}$ $1 \text{ ft} = 12 \text{ in} = 1/3 \text{ yd} = 0.3048 \text{ m} = 30.48 \text{ cm}$
Volume	$1 \text{ m}^3 = 1000 \text{ liters} = 10^6 \text{ cm}^3 = 10^6 \text{ ml}$ $= 35.3145 \text{ ft}^3 = 220.83 \text{ imperial gallons} = 264.17 \text{ gal}$ $= 1056.68 \text{ qt}$ $1 \text{ ft}^3 = 1728 \text{ in}^3 = 7.4805 \text{ gal} = 0.028317 \text{ m}^3 = 28.317 \text{ liters}$ $= 28 \text{ 317 cm}^3$
Force	$1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2 = 10^5 \text{ dynes} = 10^5 \text{ g}\cdot\text{cm}/\text{s}^2 = 0.22481 \text{ lb}_f$ $1 \text{ lb}_f = 32.174 \text{ lb}_m\cdot\text{ft}/\text{s}^2 = 4.4482 \text{ N} = 4.4482 \times 10^5 \text{ dynes}$
Pressure	$1 \text{ atm} = 1.01325 \times 10^5 \text{ N}/\text{m}^2 (\text{Pa}) = 101.325 \text{ kPa} = 1.01325 \text{ bars}$ $= 1.01325 \times 10^6 \text{ dynes}/\text{cm}^2$ $= 760 \text{ mm Hg at } 0^\circ\text{C} (\text{torr}) = 10.333 \text{ m H}_2\text{O at } 4^\circ\text{C}$ $= 14.696 \text{ lb}_f/\text{in}^2 (\text{psi}) = 33.9 \text{ ft H}_2\text{O at } 4^\circ\text{C}$ $= 29.921 \text{ in Hg at } 0^\circ\text{C}$
Energy	$1 \text{ J} = 1 \text{ N}\cdot\text{m} = 10^7 \text{ ergs} = 10^7 \text{ dyne}\cdot\text{cm}$ $= 2.778 \times 10^{-7} \text{ kW}\cdot\text{h} = 0.23901 \text{ cal}$ $= 0.7376 \text{ ft}\cdot\text{lb}_f = 9.486 \times 10^{-4} \text{ Btu}$
Power	$1 \text{ W} = 1 \text{ J}/\text{s} = 0.23901 \text{ cal}/\text{s} = 0.7376 \text{ ft}\cdot\text{lb}_f/\text{s} = 9.486 \times 10^{-4} \text{ Btu}/\text{s}$ $= 1.341 \times 10^{-3} \text{ hp}$

Conversion equations for temperature:

$$T(K) = T(^{\circ}\text{C}) + 273.15$$

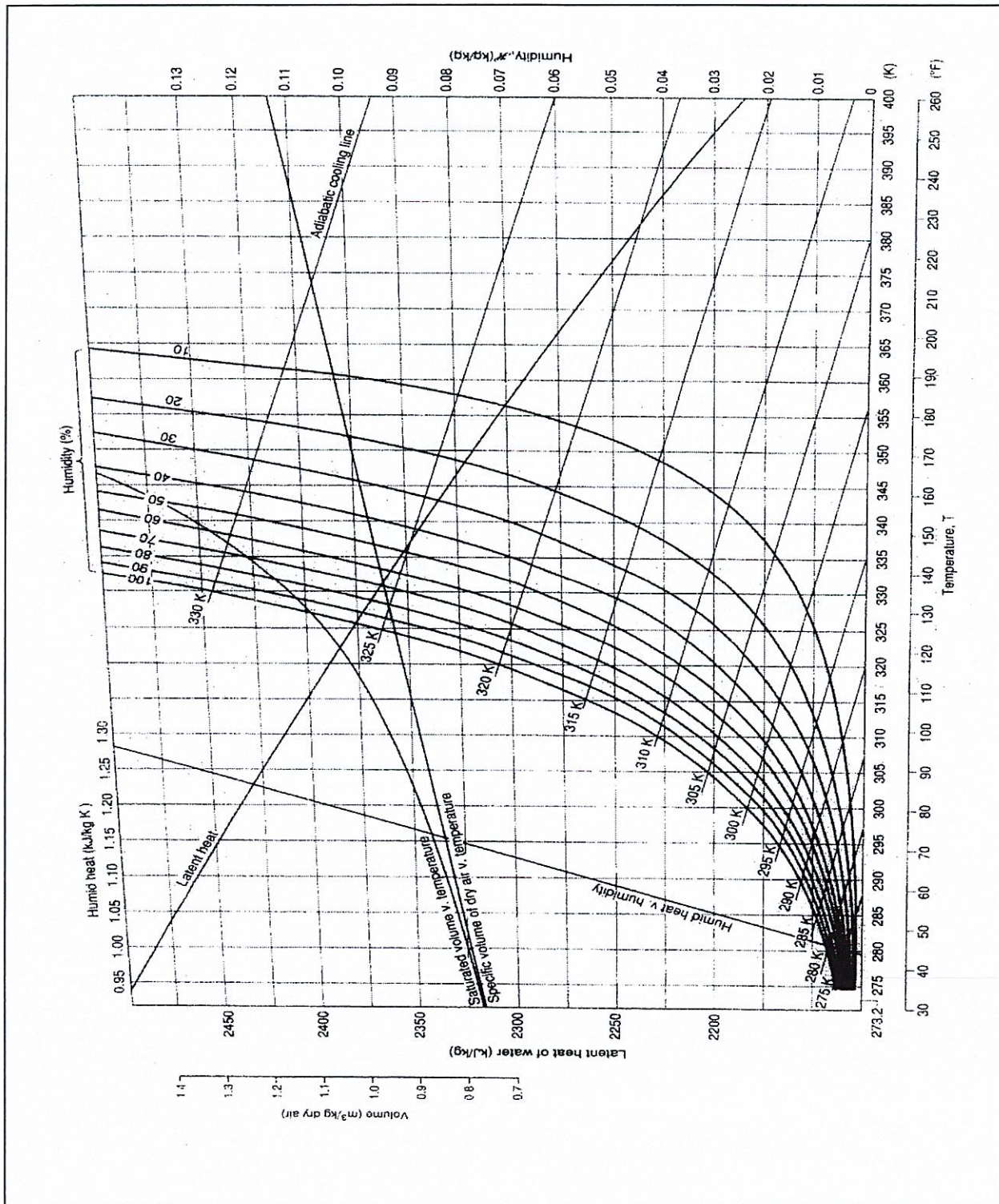
$$T(^{\circ}\text{R}) = T(^{\circ}\text{F}) + 459.67$$

$$T(^{\circ}\text{R}) = 1.8T(K)$$

$$T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32$$

APPENDIX 3

TEMPERATURE - HUMIDITY CHART (AIR-WATER SYSTEM)



APPENDIX 4

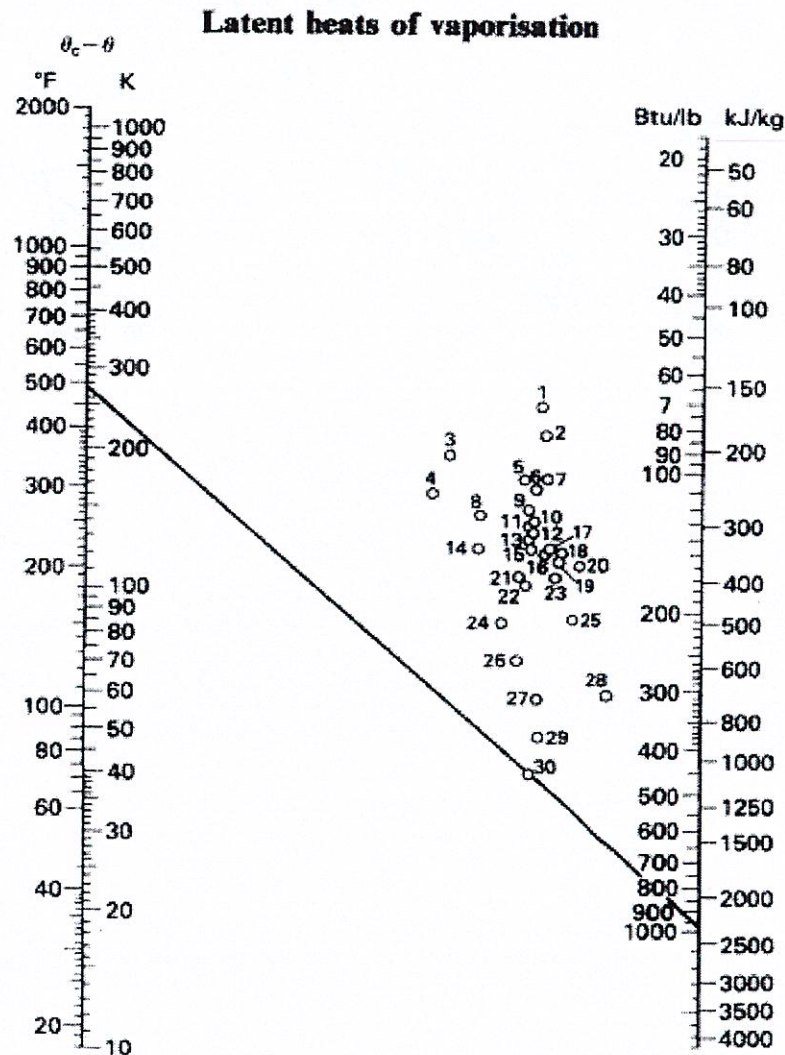
LATENT HEAT OF VAPORISATION

Table 2. Latent heats of vaporisation*

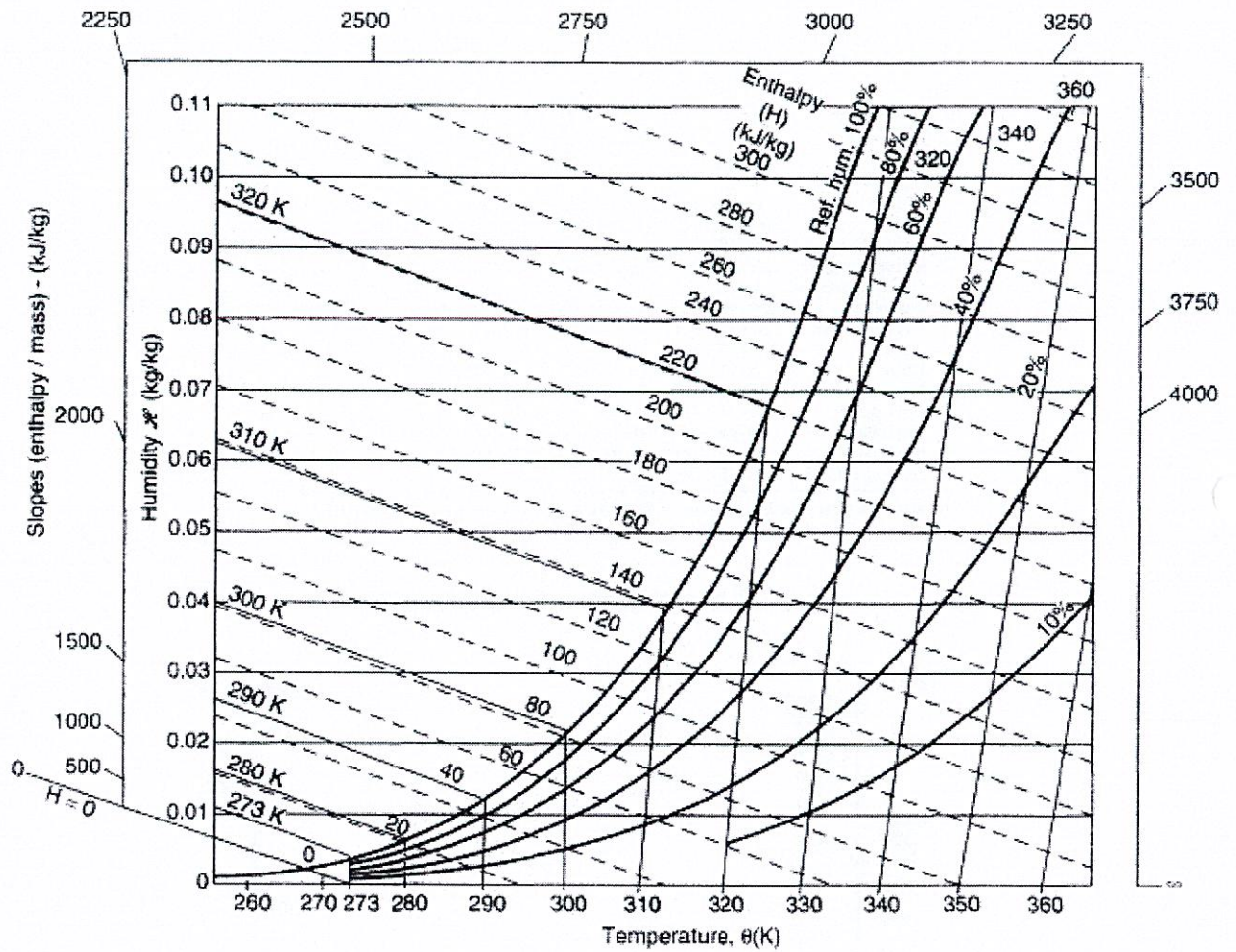
Example: For water at 373 K, $\theta_c - \theta = (647 - 373) = 274$ K, and the latent heat of vaporisation is 2257 kJ/kg

No.	Compound	Range $\theta_c - \theta$ (°F)	θ_c (°F)	Range $\theta_c - \theta$ (K)	θ_c (K)	No.	Compound	Range $\theta_c - \theta$ (°F)	θ_c (°F)	Range $\theta_c - \theta$ (K)	θ_c (K)
18	Acetic acid	180-405	610	100-225	594	2	Freon-12 (CCl_2F_2)	72-360	232	40-200	384
22	Acetone	216-378	455	120-210	508	5	Freon-21 (CHCl_2F)	126-450	354	70-250	451
29	Ammonia	90-360	271	50-200	406	6	Freon-22 (CHClF_2)	90-306	205	50-170	369
13	Benzene	18-720	552	10-00	562	1	Freon-113 ($\text{CCl}_2\text{F}-\text{CClF}_2$)	162-450	417	90-250	487
16	Butane	162-360	307	90-200	426	10	Heptane	36-540	512	20-300	540
21	Carbon dioxide	18-180	88	10-100	304	11	Hexane	90-450	455	50-225	508
4	Carbon disulphide	252-495	523	140-275	546	15	Isobutane	144-360	273	80-200	407
7	Carbon tetrachloride	54-450	541	30-250	556	27	Methanol	72-450	464	40-250	513
2	Chloroform	252-495	505	140-275	536	20	Methyl chloride	126-450	289	70-250	416
8	Dichloromethane	270-450	421	150-250	489	19	Nitrous oxide	45-270	97	25-150	309
3	Diphenyl	315-720	981	175-400	800	9	Octane	54-540	565	30-300	569
25	Ethane	45-270	90	25-150	305	12	Pentane	36-360	387	20-200	470
26	Ethyl alcohol	36-252	469	20-140	516	23	Propane	72-360	305	40-200	369
28	Ethyl alcohol	252-540	469	140-300	516	24	Propyl alcohol	36-360	507	20-200	537
17	Ethyl chloride	180-450	369	100-250	460	14	Sulphur dioxide	162-288	314	90-160	430
13	Ethyl ether	18-720	381	10-00	467	30	Water	180-900	705	100-500	647
2	Freon-11 (CCl_3F)	126-450	389	70-250	471						

*By permission from *Heat Transmission*, by W. H. McAdams, Copyright 1942, McGraw-Hill.

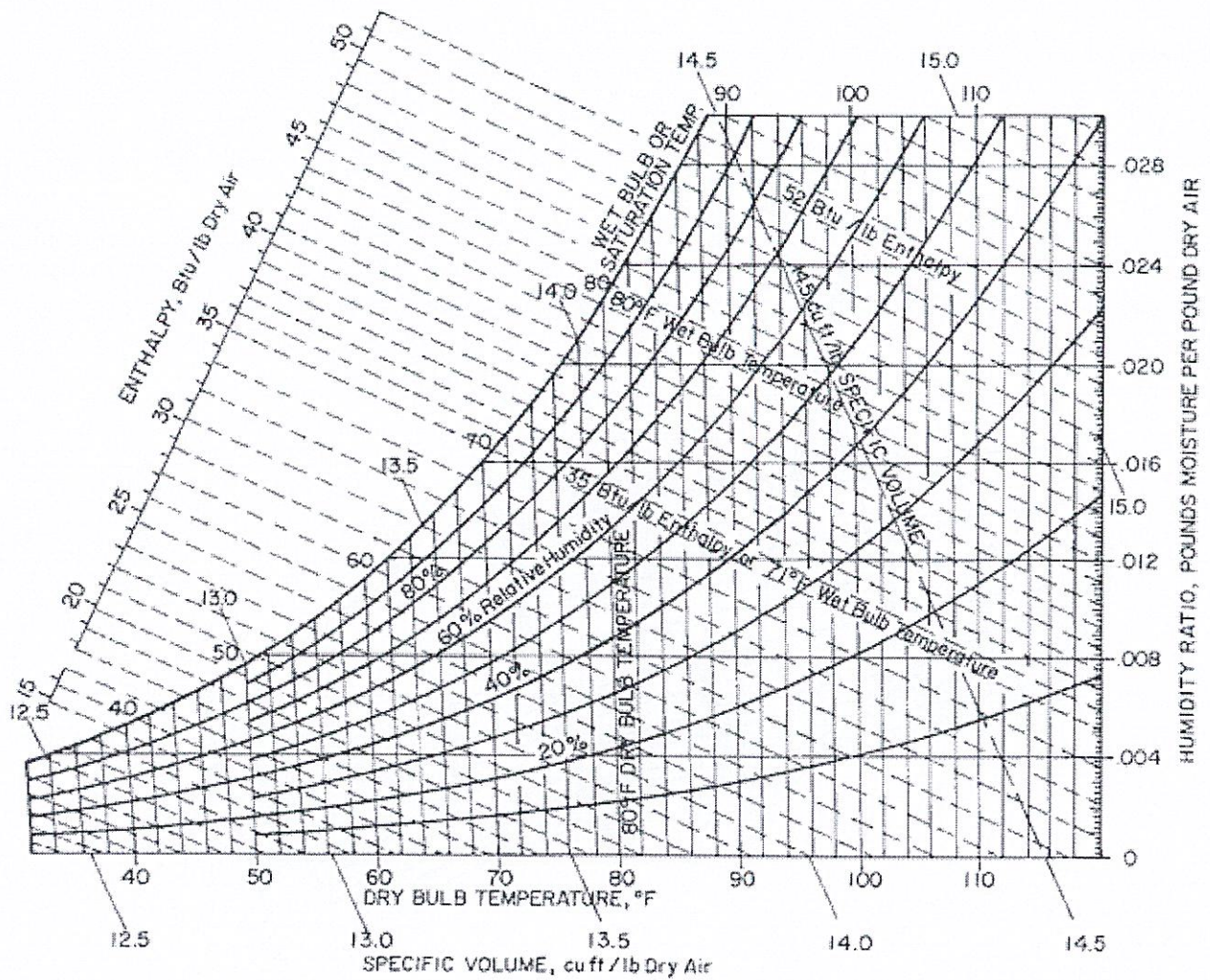


APPENDIX 5
TEMPERATURE - HUMIDITY CHART



APPENDIX 6

ENTHALPY - HUMIDITY CHART



Seat Number:

ID Number:

