CHEMICAL ENGINEERING

ONE MARKS QUESTIONS (1-20)

1. Match the following, where x is the spatial coordinate and t is time.

Group I
A. Wave equation
B. Heat equation

Group II
1. $\frac{\partial c}{\partial t} = \alpha \frac{\partial c}{\partial x}$
2. $\frac{\partial c}{\partial t} = \alpha^2 \frac{\partial^2 c}{\partial x^2}$
3. $\frac{\partial^2 c}{\partial t^2} = \alpha^2 \frac{\partial c}{\partial x}$
4. $\frac{\partial^2 c}{\partial t^2} = \alpha^2 \frac{\partial^2 c}{\partial x^2}$

	A	B
a.	4	2
b.	2	4
c.	3	1
d.	1	3

2. Two bags contain ten coins each, and the coins in each bag are numbered from 1 to 10. One coin is drawn at random from each bag. The probability that one of the coins has value 1,2,3 or 4, while the other has value 7,8,9 or 10, is

a. 2/5
b. 4/25
c. 8/25
d. 16/25

3. Given $i = \sqrt{-1}$, the ratio

$$\frac{(1+2i)}{(i-2)}$$

is given by

a. 1
b. –1
c. i
d. $-i$

4. A distillation column at a pilot plant is sealed up by 3 times for industrial use at steady state. After scaling up

a. the number of theoretical trays increases by 3 times
b. the minimum reflux ratio is increased by three times
c. the feed flow rate and product flow rates are increased by three times
d. the feed composition end product compositions are increased by three times

5. A process flow sheet analysis results in the degrees of freedom having a value of –2. Which one of the following steps must be next carried out?

a. Identify and add two new independent equations from process model
b. Remove two equations that have been wrongly assumed to be independent
c. Assign values to two variables in the process
d. Assign value to one variable and remove one equation that was wrongly assumed to be independent

6. In van der Waals equation of state, what are the criteria applied at the critical point to determine the parameters 'a' and 'b'?

a. $\left(\frac{\partial P}{\partial V}\right)_T = 0 \quad \left(\frac{\partial^2 P}{\partial V^2}\right)_T = 0$

b. $\left(\frac{\partial V}{\partial P}\right)_T = 0 \quad \left(\frac{\partial^2 V}{\partial P^2}\right)_T = 0$

c. $\left(\frac{\partial P}{\partial T}\right)_V = 0 \quad \left(\frac{\partial^2 P}{\partial T^2}\right)_V = 0$

d. $\left(\frac{\partial V}{\partial T}\right)_P = 0 \quad \left(\frac{\partial^2 V}{\partial T^2}\right)_P = 0$

7. Which one of the following statements is TRUE?

a. Heat can be fully converted into work
b. Work cannot be fully converted into heat
c. The efficiency of a heat engine increases as the temperature of the heat source is increased while keeping the temperature of the heat sink fixed.
d. A cyclic process can be devised whose sole effect is to transfer heat from a lower temperature to a higher temperature

8. The unit step response of a first order system with time constant τ and steady state gain K_p is given by

a. $K_p(1 - e^{-t/\tau})$
b. $K_p(1 + e^{t/\tau})$

c. $K_p(1-e^{-2t/\tau})$
d. $K_p e^{-t/\tau}/\tau$

9. An example of an open-loop second order under damped system is
a. liquid level in a tank
b. U-tube manometer
c. thermocouple in a thermo-well
d. two non-interacting first order systems in series

10. The control valve characteristic is selected such that the product of process gain and the valve gain
a. is a linearly increasing function of the manipulated variable
b. is a linearly decreasing function of the manipulated variable
c. remains constant as the value of the manipulated variable changes
d. is an exponentially increasing function of the manipulated variable

11. Cascade control comes under the control configuration which uses
a. one measurement and one manipulated variable
b. more than one measurement and one manipulated variable
c. one measurement and more than one manipulated variable
d. more than one measurement and more than one manipulated variable

12. Match the following types of fluid (in group I) with their respective constitutive relations (in group II), where τ is the stress and $\dot{\gamma}$ is the strain rate.

Group I
A. Psedoplastic
B. Bingham plastic

Group II
1. $\tau = \mu \dot{\gamma}$
2. $\tau = \tau_0 + K\dot{\gamma}$
3. $\tau = K|\dot{\gamma}|^n;\ n < 1$
4. $\tau = K|\dot{\gamma}|^n;\ n > 1$

	A	B
a.	1	4
b.	4	1
c.	2	3
d.	3	2

13. The thermal boundary layer is significantly thicker than the hydrodynamic boundary layer for
a. Newtonian liquids
b. polymeric liquids
c. liquid metals
d. gases

14. An electrically heated element is submerged in a pool of water at its saturation temperature. As the temperature of the element increases, the maximum heat transfer coefficient is observed
a. in the free convection regime
b. between the nucleate boiling and partial nucleate boiling mixed with unstable film boiling regimes
c. in the incipient nucleate boiling regime
d. in the stable film boiling regime without significant radiation effects

15. Baffles are used in heat exchangers in order to
a. increase the tube side fluid's heat transfer coefficient
b. promote vibration in the heat exchanger
c. promote cross flow and turbulence in the shell side Fluid
d. to prevent shell expansion due to thermal effects.

16. In film type condensation of liquid along a vertical tube, the thickness of the condensate layer increases towards the bottom. This implies that the local heat transfer coefficient
a. increases from top to bottom
b. decreases from top to bottom
c. remains constant from top to bottom
d. first increases and then decreases from top to bottom

17. The critical speed of the ball mill of radius R, which contains balls of radius r, is proportional to
a. $(R-r)^{-0.5}$
b. $(R-r)^{-1}$
c. $(R-r)$
d. $(R-r)^{2}$

18. If the frequency of the stirrer in a mixing tank is increased by a factor of 2 while all other parameters are kept constant, by what factor is the power requirement increased at high Reynolds number?
a. 4
b. 8
c. 16
d. 32

19. In a tray column, separating a binary mixture, with non-ideal stages, ONE of the following statements is TRUE.
   a. Point efficiency can exceed 100%
   b. Murphree efficiency cannot exceed 100%
   c. Murphree efficiency can exceed 100%
   d. Both Murphree and point efficiencies can exceed 100%

20. The ratio of the diffusion coefficient in a gas to that in a liquid is of the order of
   a. 10^5
   b. 10^{-5}
   c. 10^{-2}
   d. 10^2

21. For turbulent flow past a flat plate, when no form drag is present, the friction factor f and the Chilton-Colburn factor j_D air related as
   a. f and j_D cannot be related
   b. f is equal to j_D
   c. f is greater than J_D
   d. f is less than J_D

22. Which of the following is NOT employed in the commercial production of linear polyvinyl chloride ?
   a. Emulsion polymerization
   b. Suspension polymerization
   c. Addition polymerization
   d. Condensation polymerization

23. Which of the following is a detergent?
   a. Benzene hexachloride
   b. Cellulose nitrate
   c. Polyvinyl chloride
   d. Alkyl benzene sulfonate

24. The chief raw material for the commercial production of methanol is
   a. Synthesis gas
   b. Formaldehyde
   c. Acetic acid
   d. Ethanol

25. For the reaction $2R + S \rightarrow T$, the rates of formation, r_R, r_S and r_T of the substances R, S and T respectively, are related by
   a. $2r_R = r_S = r_T$
   b. $2r_R = r_S = -r_T$
   c. $r_R = 2r_S = 2r_T$
   d. $r_R = 2r_S = -2r_T$

26. For the liquid phase reaction $A \rightarrow P$, in a series of experiments in a batch reactor, the half-life $t_{1/2}$ was found to be inversely proportional to the square root of the initial concentration of A. The order of the reaction is
   a. 3/2
   b. 1
   c. +1/2
   d. −1/2

27. Which is the correct statement from the following statements on the Arrhenius model of the rate constant $k = -Ae^{-E/RT}$?
   a. A is always dimensionless.
   b. For two reactions 1 and 2, if $A_1 = A_2$ and $E_1 > E_2$, then $k_1(T) > k_2(T)$
   c. For a given reaction, the % change of k with respect to temperature is higher at lower temperatures.
   d. The % change of k with respect to temperature is higher for higher A.

28. For a solid processing plant, the delivered equipment cost is Rs. 10 lakhs. Using Lang multiplication method, the total capital investment, in lakhs of rupees, is
   a. 46
   b. 57
   c. 100
   d. 200

29. The cost of a drum dryer is Rs. 10 lakhs. The cost of a drum dryer with double the surface area in lakhs of rupees is
   a. 2×10
   b. $3^{0.6} \times 10$
   c. $5^{0.6} \times 10$
   d. $2^{0.6} \times 10$

30. The cost of a distillation column in the year 2000 is x rupees. What is the cost of the column in rupees in the year 2010 given the cost indices for the years 2000 and 2010 are 480 and 520 respectively?
   a. $(520/480)^2 x$
   b. $(480/520) x$
   c. $(520/480) x$
   d. $(520/480)^{0.6} x$

TWO MARKS QUESTIONS (21-60)

31. How many solutions does the following system of equations have?

$$4x + 2y + z = 7$$
$$x + 3y + z = 3$$
$$3x + 4y + 2z = 2$$

   a. 0
   b. 1
   c. 2
   d. ∞

32. The matrix A is given by,

$$A = \begin{pmatrix} 1 & 4 \\ a & 2 \end{pmatrix}$$

The eigenvalues of the matrix A are real and non-negative for the condition

a. $(-1/16) \le a \le (1/16)$
b. $(-1/2) \le a \le (1/2)$
c. $(-1/2) \le a \le (1/16)$
d. $(-1/16) \le a \le (1/2)$

33. The divergence of a vector field A is always equal to zero, if the vector field A can be expressed as

a. the gradient of any scalar field ϕ
b. the divergence of any scalar field ϕ
c. the divergence of any vector field B
d. the curl of any vector field B

34. In the limit $x \to 0$, what is the limiting value of the function F(x) given below?

$$F(x) = \frac{1 - \cos(2x)}{x^2}$$

a. 0
b. 1
c. 2
d. ∞

35. If $z = x + iy$ is a complex number, where $i = \sqrt{-1}$ then which of the following is an analytic function of z?

a. $x^2 + y^2$
b. $2ixy$
c. $x^2 + y^2 - 2ixy$
d. $x^2 - y^2 + 2ixy$

36. What condition is to be satisfied so that the solution of the differential equation

is of the form $y = (C_1 + C_2 x)\, e^{[illegible]}$, where C_1 and C_2 are constants of integration?

a. $a^2 = b$
b. $b^2 = a$
c. $a^2 = 4b$
d. $b^2 = 4a$

37. In the domain $-\infty < x < \infty$, the function $y(x) = x^3 e^{-x}$ has

a. no maximum and no minimum
b. one maximum and no minimum
c. no maximum and one minimum
d. one maximum and one minimum

38. If f(x) is the solution of the equation

$$\frac{dy}{dx} + 2xy + 2x = 0$$

and g(x) is the solution of the equation

$$\frac{dy}{dx} + 2xy - 2x = 0,$$

and the constant of integration in f(x) is equal to that in g(x), then which of the following is true?

a. $g(x) = f(x) + 2$
b. $g(x) = f(x) + 1$
c. $g(x) = f(x) - 1$
d. $g(x) = f(x) - 2$

39. If the constants A_n are suitably chosen so as to satisfy the initial conditions, and n is an integer, which of the following is a valid solution for the unsteady one-dimensional diffusion equation, $\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2}$ in the domain $0 \le x \le L$ with boundary conditions $c = 0$ at $x = 0$ and $c = 0$ at $x = L$?

a. $\sum_n A_n \sin\left(\frac{n\pi x}{L}\right) e^{\left(\frac{Dn^2\pi^2 t}{L^2}\right)}$

b. $\sum_n A_n \cos\left(\frac{n\pi x}{L}\right) e^{\left(\frac{Dn^2\pi^2 t}{L^2}\right)}$

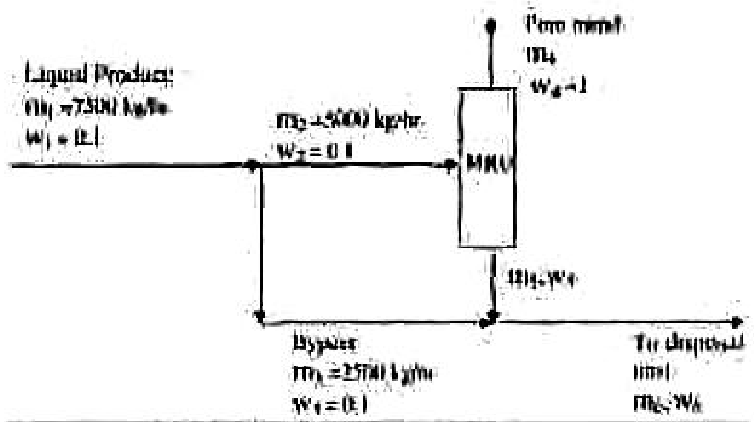
c. $\sum_n A_n \sin\left(\frac{n\pi x}{L}\right) e^{-\left(\frac{Dn^2\pi^2 t}{L^2}\right)}$

d. $\sum_n A_n \cos\left(\frac{n\pi x}{L}\right) e^{-\left(\frac{Dn^2\pi^2 t}{L^2}\right)}$

40. The function f(x) satisfies the equation $f(x) = 0$ at $x = x_e$. The Newton-Raphson iterative method converges to the solution in one step, regardless of the initial guess, is

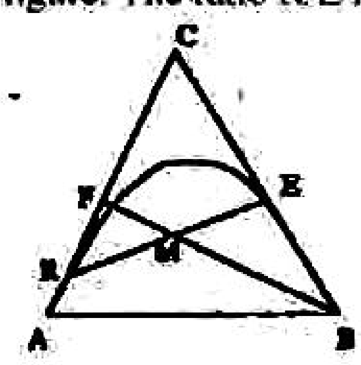
a. f(x) is a linear function of x
b. f(x) is a quadratic function of x
c. f(x) is a cubic function of x
d. f(x) is an exponential function of x

41. A metal recovery unit (MRU) of intake capacity 5000 kg/hr treats a liquid product from a plant and recovers 90% of the metal in the pure form. The unrecovered metal and associated liquid are sent to a disposal unit along with the untreated product from the plant (See figure below). Find the flow rate (m_6) and the weight fraction of the metal (w_6). The liquid product flow rate is 7500 kg/hr of composition 0.1 (wt fraction). Assume steady state



a. $m_6 = 7500$ kg/hr, $w_6 = 0.0$
b. $m_6 = 7050$ kg/hr, $w_6 = 0.04255$
c. $m_6 = 4500$ kg/hr, $w_6 = 0.1712$
d. $m_6 = 5600$ kg/hr, $w_6 = 0.0314$

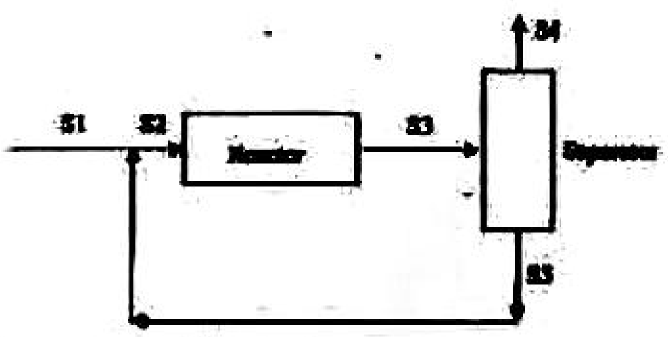
42. In the triangular diagram represented below for a batch separation process a stream F, is mixed with a solvent B to produce products R and E. Substance A is the carrier liquid and C is the solute to be extracted. The amounts of B and E are 1 kg and 1.20 kg respectively. The length FM is 3.1 and length FB is 8.5 units on the figure. The ratio R/E is estimated to be



Note: Figure not to scale

a. 1.285
b. 2
c. 0.751
d. 2.5

43. A feed stream (S1) at 100 kg/hr and containing only A mixes with recycle stream S5 before entering the reactor (see figure below), where the reaction A → B takes place. The operation is at steady state. The stream S3 leaving the reactor is separated, without either phase or composition change, into two streams S4 and S5. If the mass fraction of B in S4 is 0.95 and total flow rate of S5 is 10 kg/hr, then the ratio of flow rates of streams (S3/S5), and the flow rate of A in S3 are, respectively,



a. 11 and 110 kg/hr
b. 24 and 240 kg/hr
c. 11 and 5.5 kg/hr
d. 70 and 330 kg/hr

44. A Carnot heat engine cycle is working with an ideal gas. The work performed by the gas during the adiabatic expansion and compression steps, W_1 and W_2 respectively, are related as
a. $|W_1| > |W_2|$
b. $|W_1| < |W_1|$
c. $W_1 = W_2$
d. $W_1 = -W_2$

45. The van Laar activity coefficient model for a binary mixture is given by the form
Given $\gamma_1 = 1.40$, $\gamma_2 = 1.25$, $x_1 = 0.25$, $x_2 = 0.75$, determine the constants A^* and B^*.
a. $A^* = 0.5$, $B^* = 0.3$
b. $A^* = 3$, $B^* = 0.5$
c. $A^* = 0.333$, $B^* = 0.2$
d. $A^* = 2$, $B^* = 0.333$

46. Match the process variables (Group-I) given below with the measuring devices (Group-II)
Group-I
A. High Temperature
B. Flow
C. Composition
Group-II
1. Orifice meter
2. Chromatograph
3. Radiation Pyrometer
4. Bi-metallic Thermometer

	A	B	C
a.	1	2	3
b.	1	3	2
c.	3	1	2
d.	4	2	1

47. Given the characteristic equation below, select the number of roots which will be located to the right of the imaginary axis
$s^4 + 5s^3 - s^2 - 17s + 12 = 0$
a. One
b. Two
c. Three
d. zero

48. Given the process transfer function $G_P = 4/(\tau s + 1)^2$ and the disturbance transfer function $G_d = 2/(\tau s + 1)$, select the correct transfer function for the Feed Forward Controller for perfect disturbance rejection.
a. $-2(\tau s + 1)$
b. -1
c. $-0.5(\tau s + 1)$
d. $-(\tau s + 1)^2$

49. Given the process transfer function $G_P = 20/(s - 2)$, and controller transfer function $G_c = K_c$, and assuming the transfer functions of all other elements in the control loop are unity, select the range of K_c for which the closed loop response will be stable.
a. $K_c < 1/10$
b. $K_c < 1/100$
c. $1/100 < K_c < 1/10$
d. $K_c > 1/10$

50. The value of ultimate period of oscillation P is 3 minutes, and that of the ultimate controller gain K_{cu} is 2. Select the correct set of tuning parameters (controller gain K, the derivative time constant τ_D in minutes, and the integral time constant τ_I in minutes) for a PID controller using Ziegler-Nichols controller settings.
a. $K_c = 1.1$; $\tau_I = 2.1$; $\tau_D = 1.31$
b. $K_c = 1.5$; $\tau_I = 1.8$; $\tau_D = 0.51$
c. $K_c = 15$; $\tau_I = 1.8$; $\tau_D = 0.51$
d. $K_c = 1.2$; $\tau_I = 1.5$; $\tau_D = 0.38$

51. A dam of width 50 m is used to hold water in a reservoir. If the water height is 10 m from the bottom of the dam, what is the total force F acting on the dam due to the water? Assume $g = 10\ m/s^2$, and the fluid density is $1000\ kg/m^3$.
a. $F = 12.5 \times 10^6$ N
b. $F = 25 \times 10^6$ N
c. $F = 50 \times 10^6$ N
d. $F = 5 \times 10^6$ N

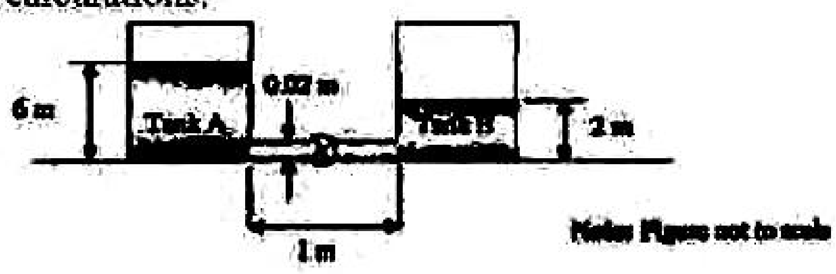
52. The relation between the stress τ and the strain rate (du_x / dy) for the rapid flow of a granular material is given by

$$\tau = B\left(\frac{du_x}{dy}\right)^2$$

where B is a constant. If M, L and T are the mass, length and time dimension respectively, what is the dimension of the constant B ?
a. $M L^{-1} T^{-1}$
b. $M L^{-1} T^{-2}$
c. $M T^{-1}$
d. $M L^{-1}$

Common Data for Questions (53 & 54)

Two tanks, A and B, of cross sectional area $1 m^2$ each, contain a fluid of density $1000\ kg/m^3$ and viscosity 1 kg/(m s). The tanks are connected by a pipe of diameter 0.02 m and length 1 m, and a check valve, at the bottom. Assume that the flow is laminar, and there is no friction in the check valve. In the initial state, the height of the fluid in the tank A is 6 m, and the height of the fluid in tank B is 2 m (as shown in the figure below). The check valve is opened, and the fluid flows from tank A to tank B till the levels in the two tanks are equal in the final state. Assume $g = 10\ m/s^2$ in the calculations.



53. What is the average fluid velocity in the pipe as soon as the valve is opened?
a. 0.25 m/s
b. 0.5 m/s
c. 1 m/s
d. 2 m/s

54. What is the total energy loss between the initial and final states due to the fluid flow?
a. 2×10^4 J
b. 16×10^4 J
c. 8×10^4 J
d. 4×10^4 J

55. A centrifuge of diameter 0.2 m in a pilot plant rotates at a speed of 50 Hz in order to achieve effective separation. If this centrifuge is scaled up to a diameter of 1 m in the chemical plant, and the same separation factor is to be achieved, what is the rotational speed of the scaled up centrifuge?
a. 15 Hz
b. 22.36 Hz
c. 30 Hz
d. 44.72 Hz

56. What is the terminal velocity in m/s, calculated from Stokes law, for a particle of diameter 0.1×10^{-3} m, density 2800

kg/m^3 settling in water of density 1000 kg/m^3 and viscosity 10^{-3} kg/(m s)? (Assume g = 10 m/s^2)

a. 2×10^{-2}
b. 4×10^{-3}
c. 10^{-2}
d. 8×10^{-3}

57. A black body at a higher temperature T_H transfers energy by radiation to a black body at a lower temperature T_L. Initially, T_H = 1850°C, T_L = 500°C, and the net rate of energy transfer is 25W. After some time, when T_H = 1500°C and T_L = 750°C, what is the net rate of energy transfer?

a. 8.73 W
b. 9.60 W
c. 13.89 W
d. 11.01 W

58. A circular tube of outer diameter 5 cm and inner diameter 4 cm is used to convey hot fluid. The inner surface of the wall of the tube is at a temperature of 80°C, while the outer surface of the wall of the tube is at 25°C. What is the rate of heat transport across the tube wall per meter length of the tube at steady state, if the thermal conductivity of the tube wall is 10 W/(m K)?

a. 13823 W/m
b. 15487 W/m
c. 17279 W/m
d. 27646 W/m

59. Consider the flow of a gas with density 1 kWm3, viscosity 1.5×10^{-5} kW(m s), specific heat C_p = 846 J/(kg K) and thermal conductivity k = 0.01665 W/(m K), in a pipe of diameter D = 0.01 m and length L = 1 m, and assume the viscosity does not change with temperature. The Nusselt number for a pipe with (L/D) ratio greater than 10 and Reynolds number greater than 20000 is given by

$$Nu = 0.026\, Re^{0.8}\, Pr^{1/3}$$

while the Nusselt number for a laminar flow fir Reynolds number less than 2100 and (Re Pr D/L) < 10 is

$$Nu = 1.86\, [Re\, Pr\, (D/L)]^{1/3}$$

If the gas flows through the pipe with an average velocity of 0.1 m/s, the heat transfer coefficient is

a. 0.68 W/(m^2 K)
b. 1.14 W/(m^2 K)
c. 2.47 W/(m^2 K)
d. 24.7 W/(m^2 K)

60. A semi-infinite slab occupying the region x = 0 and x = ∞ is at an initial temperature T_0. At time t = 0, the surface of the slab at x = 0 is brought into con-tact with a heat bath at a temperature T_H. The temperature T(x, t) of the slab rises according to the equation

$$\frac{T_H - T(x,t)}{T_H - T_0} = \frac{2}{\sqrt{\pi}} \int_0^{x/\sqrt{4\alpha t}} e^{-\eta^2}\, d\eta$$

where x is position and t is time. The heat flux at the surface x = 0 is proportional to

a. $t^{-1/2}$
b. $t^{1/2}$
c. t
d. $t^{3/2}$

61. A countercurrent flow double pipe heat exchanger is used to heat water flowing at 1 kg/s from 40°C to 80°C. Oil is used for heating and its temperature changes from 100°C to 70°C. The overall heat transfer coefficient is 300 W/(m^2 °C).

If it is replaced by a 1-2 shell and tube heat exchanger with countercurrent flow configuration with water flowing in shell and oil flowing in the tube, what is the excess area required with respect to the double pipe heat exchanger? The correction factor, F_t for LMTD (log mean temperature difference) based on the above double pipe heat exchanger is 0.5. The heat transfer coefficient remains unchanged, and the same inlet and outlet conditions are maintained.

$C_{p,\,water}$=4180 J/kg °C, $C_{p,\,oil}$ =2000 J/kg°C.

a. 0 m^2
b. −20.15 m^2
c. 22.6 m^2
d. 9.69 m^2

62. For a two-phase feed, where 80% of the feed is vaporized under column conditions, the feed line slope in the McCabe-Thiele method for distillation column design, is

a. −1/4
b. +1/4
c. +4
d. −4

63. A liquid mixture of benzene and toluene is in equilibrium with its vapour at 101 kPa and 373 K. The vapor pressures of benzene and toluene at 373 K respectively are 156 and 63 kPa respectively. Assuming that the system obeys Raoult's law, the

mole fraction of benzene in the liquid phase is

a. 0.65
b. 0.41
c. 0.065
d. 0.04

64. Two solid discs of benzoic acid (molecular weight = 122) of equal dimensions are spinning separately in large volumes of water and air at 300 K. The mass transfer coefficients for benzoic acid in water and air are 0.9×10^{-5} and 0.47×10^{-2} m/s respectively. The solubility of benzoic acid in water is 3 kg/m^3 and the equilibrium vapor pressure of benzoic acid in air is 0.04 kPa. Then the disc

a. dissolves faster in air than in water
b. dissolves faster in water than in air
c. dissolves at the same rate in both air and water
d. does not dissolve either in water or in air

65. Match the variation of mass transfer coefficient given by the theory in Group I with the appropriate variation in Group II

Group I
A. Film Theory
B. Penetration theory
C. Boundary layer theory

Group II
1. $\propto D_{AB}$
2. $\propto D_{AB}^{2/3}$
3. $\propto D_{AB}^{1/2}$

	A	B	C
a.	1	2	3
b.	2	1	3
c.	1	3	2
d.	3	2	1

66. A filter cake is dried with air at wet and dry bulb temperatures of 300 and 323 K respectively. The heat transfer coefficient is 11 W/(m^2 K) and the latent heat of vapourisation of water is 2500 kJ/kg. Mass transfer does not limit the process. Select the drying rate during the constant rate period. Neglect conduction through the solid and radiation effects.

a. 1.32×10^{-2} kg m^{-2} s^{-1}
b. 0.71×10^{-2} kg m^{-2} s^{-1}
c. 4.53×10^{-2} kg m^{-2} s^{-1}
d. 0.10×10^{-3} kg m^{-2} s^{-1}

67. The rate expression for the reaction of A is given by

$$-r_A = \frac{k_1 c_A^2}{1 + k_2 c_A^{1/2}}$$

The units of k_1 and k_2 are, respectively,

a. (mol^{-1} m^3 s^{-1}), (mol$^{-1/2}$ m$^{3/2}$)
b. (mol^{-1} m^3 s^{-1}), (mol$^{1/2}$ m$^{-3/2}$)
c. (mol m^{-3} s^{-1}), (mol$^{1/2}$ m$^{3/2}$ s^{-1})
d. (mol^{-1} m^3 s^{-1}), (mol$^{-1/2}$ m$^{3/2}$ s$^{-1/2}$)

68. The first order liquid phase reaction A→P is to be carried out isothermally in the following ideal reactor configurations

A. A 1 m^3 CSTR followed by a 1 m^3 PFR.
B. A 2 m^3 CSTR
C. A 1 m^3 PFR followed by a 1 m^3 CSTR.
D. A 1 m^3 CSTR followed by a 1 m^3 CSTR.

The overall exit conversions, X, for the above configurations P, Q, R and S, assuming identical inlet conditions and temperature, are related as

a. $X_P > X_R > X_S > X_Q$
b. $X_P = X_R > X_S > X_Q$
c. $X_P = X_S = X_Q = X_R$
d. $X_Q > X_P > X_R > X_S$

69. The gas phase reaction A → B + C is carried out in an ideal PFR achieving 40% conversion of A. The feed has 70 mol% A and 30 mol% inerts. The inlet temperature is 300 K and the outlet temperature is 400 K. The ratio of the outlet to inlet molar concentration of A (assuming ideal gas mixture and uniform pressure) is

a. 0.60
b. 0.30
c. 0.47
d. 0.35

70. Match the items in Group I with those in Group II

Group I
A. Porous catalyst
B. Parallel reactions
C. Non-ideal tubular reactor
D. Gas-solid non-catalytic reaction

Group II
1. Selectivity
2. Shrinking core model
3. Thiele modulus
4. Dispersion number

	A	B	C	D
a.	3	1	4	2
b.	1	3	2	4
c.	1	4	2	3
d.	3	4	1	2

71. The rate of the liquid phase reversible reaction $A \Leftrightarrow 2B$ in (kmol m^{-3} min^{-1}) at 298K, is

$-r_A = 0.02c_A - 0.01c_B$

where the concentrations c_A and c_B are expressed in (kmol m^{-3}). What is the maximum limiting conversion of A achievable in an isothermal CSTR at 298 K, assuming pure A is fed at the inlet?

a. 1
b. 2/3
c. 1/2
d. 1/3

72. The original value of an equipment is Rs. 10000/-. The salvage value is Rs. 500/- at the end of its useful life period of 5 years. What is the asset value in rupees after two years by textbook declining balance method?

a. 3025/-
b. 4010/-
c. 5020/-
d. 6050/-

73. The depreciable fixed cost is Rs. 100 lakhs. The average profit per year is Rs. 15 lakhs. The average depreciation cost per year is Rs. 10 lakhs. What is the payout period in years, if there is no interest charge?

a. 8
b. 4
c. 10
d. 20

74. Fluid flows in an annulus of inner diameter 0.8 m and outer diameter 1 m. Heat is transferred to the fluid from inner tube surface of the annulus. What is the equivalent diameter for heat transfer in m?

a. 0.45
b. 0.20
c. 1.64
d. 0.90

75. What is the actual power required to drive a reciprocating air compressor which has to compress 34 m^3 of air per minute from 1.013×10^5 N/m² to 4.052×10^5 N/m² ? Assume that $PV^{1.25}$ is constant, where P is the pressure and V is the volume, and the efficiency of the compressor is 85%.

a. 107.9 kW
b. 200 kW
c. 82.6 kW
d. 91.7 kW

76. A separation column for vapour-liquid contact processes 200 kmol/hr of vapour. The flooding velocity is 3 m/s. If the column operates at 85% of flooding velocity and the downcomer area is 10% of the total cross sectional area, what is the diameter of the column.? Average density of vapour = 2 kg/m³ and its molecular weight = 44.

a. 0.82 m
b. 0.72 m
c. 0.78 m
d. 1 m

77. Match the raw materials in Group II with the products in Group I

Group I
A. Nylon – 66
B. Terylene

Group II
1. Chlorodifluro methane
2. Dimethyl terephthalate and ethylene glycol
3. Acetylene and hydrogen cyanide
4. Hexamethylene diamine and adipic acid

	A	B
a.	3	4
b.	4	3
c.	4	2
d.	1	2

78. Match the product in Group I with the catalyst used for its production in Group II

Group I
A. Nitric acid
B. Formaldehyde

Group II
1. Silver oxide
2. Raney nickel
3. Activated carbon
4. Platinum- Rhodium

	A	B
a.	1	2
b.	2	3
c.	3	4
d.	4	1

79. Match the product in Group I with the raw material in Group II

Group I
A. Caustic soda
B. Soda ash

Group II
1. Ammonia and sulfuric acid
2. Sodium carbonate and slaked lime
3. Salt and limestone

4. Salt and sulfuric acid

	A	B
a.	2	3
b.	1	2
c.	3	4
d.	4	1

80. Match the feed in Group I with the process in Group II

Group I
A. Gas oil
B. Residual crude

Group II
1. Acetylene production
2. Ethylene production
3. Coking
4. Cracking

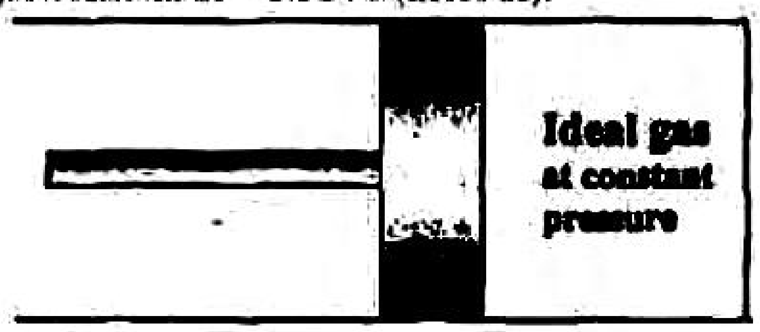
	A	B
a.	3	4
b.	4	3
c.	2	3
d.	1	4

Statement for Linked Answer Question (81.1 to 81.2)

A frictionless cylinder piston assembly contains an ideal gas. Initially pressure (P_1) = 100 kPa, temperature (T_1) = 500 K and volume (V_1) = 700 × 10^{-6} m^3. This system is supplied with 100 J of heat and pressure is maintained constant at 100 kPa. The enthalpy variation is given by

$$h(J/mol) = 30000 + 50\,T$$

where T is the temperature in K, and the universal gas constant R = 8.314 J/(mole K).



81.

81.1 The final volume of the gas (V_2) in m^3 is
a. 700 × 10^{-6}
b. 866.32 × 10^{-6}
c. 934.29 × 10^{-6}
d. 1000.23 × 10^{-6}

81.2 The change in internal energy of the gas in J is
a. 0
b. 100
c. 23.43
d. 83.37

Statement for Linked Answer Question (82.1 and 82.2)

A balloon of mass 0.01 kg is charged with hydrogen to a pressure of 102 kPa and released from the ground level. During its rise the hydrogen is permitted to escape from the balloon in order to maintain a constant differential pressure of 2 kPa under which condition the diameter of the balloon remains at 0.4 m. As this balloon rises it is assumed that the temperature in and around the balloon remains constant at 273 K. Further, the inertia of the balloon and the air resistance due to the rising balloon may be neglected.

Assume that the density of air at 273 K is 1.2733 kg/m^3, the average molecular weight of air is 28.9, the atmospheric pressure is 100 kPa and the acceleration due to gravity is 10 m/s^2.

82.

82.1 Select the correct value of the upward thrust (in N) expressed in terms of the outside pressure P which is expressed in Pa.
a. 10.06 × 10^{-7} P − 0.0122
b. 3.97 × 10^{-6} P − 0.1006
c. 15.03 × 10^{-7} P − 0.0534
d. 8.08 × 10^{-6} P − 0.1362

82.2 Select the value of the outside pressure P in Pa for which there will be no force on the balloon?
a. 25340
b. 35530
c. 12130
d. 16860

Statement for Linked Answer Question (83.1 and 83.2)

A liquid of mass 7 kg and specific heat 4 kJ/(kg °C) is contained in a cylindrical heater of diameter 0.15 m and height 0.40 m. The cylindrical surface of the heater is exposed to air at 25°C while the end caps are insulated, so that heat transfer takes place only through the cylindrical surface.

The thickness of the wall of the heater = 2 mm
The wall thermal conductivity = 10 W/(m K),
The heat transfer coefficient in the liquid = 100 W/(m^2 K)
The heat transfer coefficient in air = 10 W/(m^2 K)

The liquid is initially maintained at a temperature of 75°C. At time t = 0, the heater is switched off, and the temperature of the liquid in the heater decreases due to heat loss across the cylindrical surface.

83.

83.1 What is the overall heat transfer coefficient in $W/(m^2 K)$?

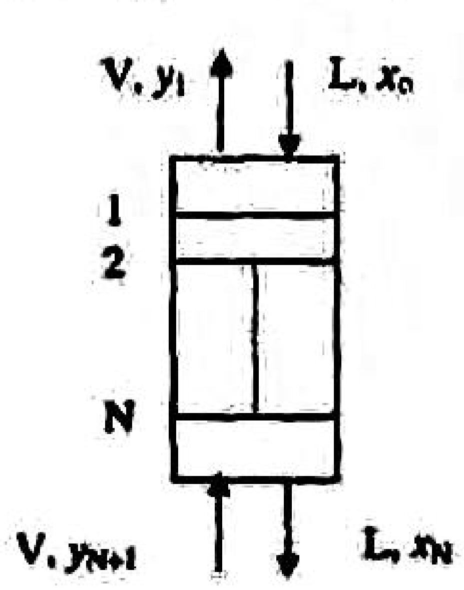
a. 1
b. 4.04
c. 9.07
d. 10

83.2 What is the time required for the temperature of the liquid to reduce to 50°C after the heater is switched off, assuming lumped system analysis is valid?

a. 7.874×10^3 s
b. 11.346×10^3 s
c. 16.828×10^3 s
d. 23.213×10^3 s

Statement for Linked Answer Question (84.1 to 84.2)

A binary gas mixture of a solute and a carrier gas is treated in a countercurrent gas absorption column, containing ideal trays, using a solvent. The compositions y and x (see figure below) are the mole fractions of the solute in the gas and liquid respectively. Also, V and L are the molar flow rates of the gas and liquid respectively. Assume that the carrier gas is insoluble in the solvent and that the vapour pressure of the solvent is very low at the given conditions of the column. Further, the gas and liquid streams are sufficiently dilute that L and V may be assumed to be constant throughout the column. The equilibrium relation is given by $y^* = m x$, where m is a positive constant.



84.

84.1 For any value of m, the change in liquid composition across a tray is independent of the tray location if

a. L/V = 1
b. m L/V = 1
c. m / (LV) = 1
d. L/(mV) = 1

84.2 Under the correct condition corresponding to part (a), the number of ideal trays in the column is given by

a. $N = \dfrac{x_0 - x_N}{x_0 - (y_{N+1}/m)}$

b. $N = \dfrac{x_0 - (y_{N+1}/m)}{x_0 - x_N}$

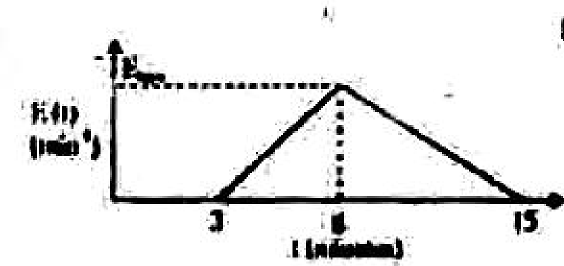
c. $N = \dfrac{x_N - x_0}{(y_{N+1}/m) - x_N}$

d. $N = \dfrac{(y_{N+1}/m) - x_0}{x_N - x_0}$

Statement for Linked Answer Question (85.1 to 85.2)

The residence time distribution E(t) (as shown below) of a reactor is zero until 3 minutes and then increases linearly to a maximum value E_{max} at 8 minutes after which it decreases linearly back to Zero a 15 minutes.

Note: Figure not to scale



85.

85.1 What is the value of E_{max} ?

a. 1/6
b. 1/8
c. 1/4
d. 1/3

85.2 What is the value of the mean residence time in minutes?

a. 5.7
b. 8
c. 8.7
d. 12