GATE question papers: Chemical Engineering 2008 (CH)

Q. 1 – Q – 20 carry one mark each

1. Which ONE of the following is NOT an integrating factor for the differential equation $xdy - ydx = 0$?

(A) $\frac{1}{x^2}$ (B) $\frac{1}{y^2}$ (C) $\frac{1}{xy}$ (D) $\frac{1}{(x+y)}$

2. Which ONE of the following is NOT a solution of the differential equation $\frac{d^2y}{dx^2} + y = 1$?

(A) y = 1 (B) y = 1 + cos x
(C) y = 1 + sin x (D) y = 2 + sin x + cos x

3. The limit of is $\frac{\sin x}{x}$ as $\to \infty$ is

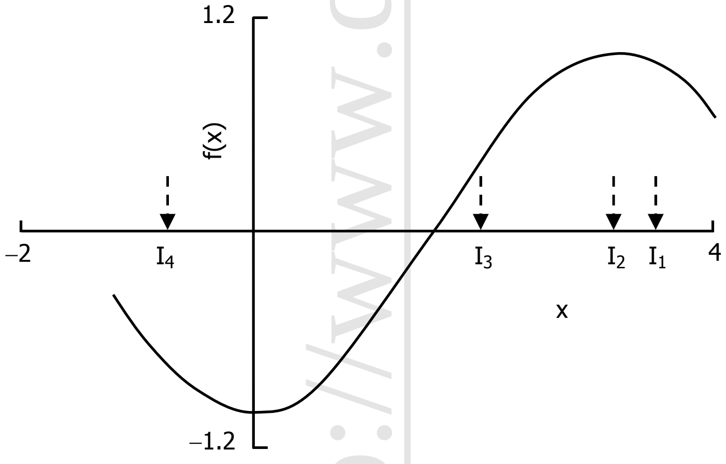
(A) -1 (B) 0 (C) 1 (D) ∞

4. The unit normal vector to the surface of the sphere $x^2 + y^2 + z^2 = 1$ at the point $\left(\frac{1}{\sqrt{2}},0,\frac{1}{\sqrt{2}}\right)$ is ($\hat{i},\hat{j},\hat{k}$ are unit normal vectors in the Cartesian coordinate system)

(A) $\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}$ (B) $\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{k}$

(C) $\frac{1}{\sqrt{2}}\hat{j} + \frac{1}{\sqrt{2}}\hat{k}$ (D) $\frac{1}{\sqrt{3}}\hat{i} + \frac{1}{\sqrt{3}}\hat{j} + \frac{1}{\sqrt{3}}\hat{k}$

5. A nonlinear function f(x) is defined in the interval $-1.2 < x < 4$ as illustrated in the figure below. The equation f(x) = 0 is solved for x within this interval by using the Newton – Raphson iterative scheme. Among the initial guesses (I_1, I_2, $I_3$and I_4), the guess that is likely to lead to he root most rapidly is



(A) I_1 (B) I_2 (C) I_3 (D) I_4

6. For a Carnot refrigerator operating between 40°C and 25°C, the coefficient of performance is

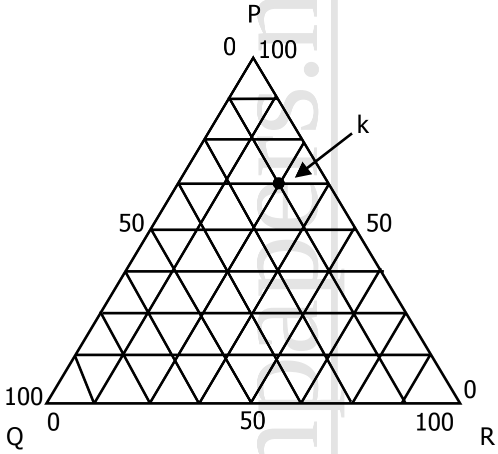
(A) 1 (B) 1.67 (C) 19.88 (D) 39.74

7. The work done by one mole of a van der Waals fluid undergoing reversible isothermal expansion from initial volume V_i to final volume V_f is

(A) $RT\ln\left(\frac{V_f}{V_i}\right)$ (B) $RT\ln\left(\frac{V_f - b}{V_i - b}\right)$

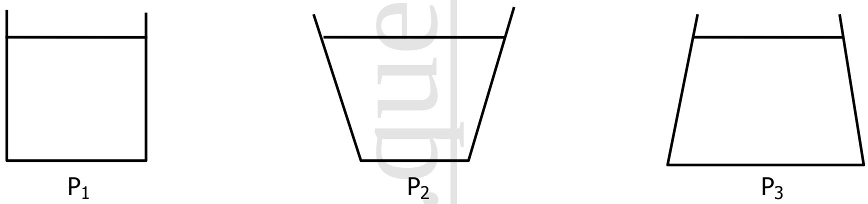
(C) $RT\ln\left(\frac{V_f - b}{V_i - b}\right) - a\left(\frac{1}{V_f} - \frac{1}{V_i}\right)$ (D) $RT\ln\left(\frac{V_f - b}{V_i - b}\right) + a\left(\frac{1}{V_f} - \frac{1}{V_i}\right)$

8. For a system containing species P, Q and R, composition at point k on the ternary plot is



(A) 62.5% P, 12.5% Q, 25% R (B) 25% P, 62.5% Q, 12.5% R
(C) 12.5% P, 62.5% Q, 25% R (D) 12.5% P, 25% Q, 62.5% R

9. Three containers are filled with water up to the same height as shown. The pressures at the bottom of the containers are denoted as P_1, P_2 and P_3. Which ONE of the following relationships is true?



(A) $P_3 > P_1 > P_2$ (B) $P_2 > P_1 > P_3$
(C) $P_1 > P_2 = P_3$ (D) $P_1 = P_2 = P_3$

10. Losses for flow through valves and fittings are expressed in terms of
(A) drag coefficient (B) equivalent length of a straight pipe
(C) shape factor (D) roughness factor.

11. To determine the performance of a compressor, a standardized test is performed. In the testing process, when the compressor is under operation, "shut off' term signifies
(A) maximum flow (B) zero flow,
(C) steady flow, (D) intermittent flow

12. Given a pipe of diameter D, the entrance length necessary; to achieve fully developed laminar flow is proportional to (N_{Re} is Reynolds number).

(A) $D\,N_{Re}$ (B) $\frac{D}{N_{RE}}$ (C) DN_{Re}^2 (D) $\frac{D}{N_{Re}^2}$

13. For laminar flow conditions, the relationship between the pressure drop (ΔP_c) across an incompressible filter cake and the specific surface area (S_o) of the particles being filtered in given by ONE of the following:

(A) ΔP_c is proportional to S_o
(B) ΔP_c is proportional to $1/S_o$
(C) ΔP_c is proportional to S_o^2
(D) ΔP_c is proportional to $1/S_o^2$

14. The power required for size reduction in crushing is

(A) proportional to $\frac{1}{\text{Surfaceenergyofthematerial}}$
(B) proportional to $\sqrt{\frac{1}{\text{surfaceenergyofthematerial}}}$
(C) proportional to Surface energy of the material
(D) independent of the Surface energy of the material

15. Transient three-dimensional heat conduction is governed by ONE of the following differential equations (α – thermal diffusivity, k – thermal conductivity and ψ – volumetric rate of heat generation).

(A) $\frac{1}{\alpha}\frac{\partial T}{\partial t} = \nabla T + \Psi k$
(B) $\frac{1}{\alpha}\frac{\partial T}{\partial t} = \nabla T + \frac{\Psi}{k}$
(C) $\frac{1}{\alpha}\frac{\partial T}{\partial t} = \nabla^2 T + \Psi k$
(D) $\frac{1}{\alpha}\frac{\partial T}{\partial t} = \nabla^2 T + \frac{\Psi}{k}$

16. In a countercurrent gas absorber, both the operating and equilibrium relations are linear. The inlet liquid composition and the exit gas composition are maintained constant. In order to increase the absorption factor

(A) the liquid flow rate should decrease
(B) the gas flow rate should increase
(C) the slope of the equilibrium line should increase
(D) the slope of the equilibrium line should decrease

17. A species (A) reacts on a solid catalyst to produce R and S as follows:

1) $A \rightarrow R \qquad r_R = k_1 C_A^2$
2) $A \rightarrow S \qquad r_S = k_2 C_A^2$

Assume film resistance to mass transfer is negligible. The ratio of instantaneous fractional yield of R in the presence of pore diffusion to that in the absence of pore diffusion is

(A) 1
(B) >1
(C) <1
(D) Zero

18. For the case of single lump-sum capital expenditure of Rs. 10 crores which generates a constant annual cash flow of Rs. 2 crores in each subsequent year, the payback period (in years), if the scrap value of the capital outlay is zero is

(A) 10
(B) 20
(C) 1
(D) 5

19. The relation between capital rate of return ratio (CRR), net present value (NPV) and maximum cumulative expenditure (MCE) is

(A) $CRR = \frac{NPV}{MCE}$
(B) $CRR = \frac{MCE}{NPV}$
(C) $CRR = NPV \times MCE$
(D) $CRR = \frac{MCE}{(NPV + MCE)}$

20. Which ONE of the following is NOT a major constituent of crude oil?

(A) Paraffins
(B) Olefins
(C) Naphthenes
(D) Aromatics

Q. 21 to Q. 75 carry two marks each.

21. Which ONE of the following transformations {u = f(y)} reduces $\frac{dy}{dx} + Ay^3 + By = 0$ to a linear differential equation? (A and B are positive constants)

(A) $u = y^{-3}$ (B) $u = y^{-2}$
(C) $u = y^{-1}$ (D) $u = y^{2}$

22. The Laplace transform of the function f (t) = t sin t is

(A) $\frac{2s}{(s^2+1)^2}$ (B) $\frac{1}{s^2(s^2+1)}$ (C) $\frac{1}{s^2} + \frac{1}{(s^2+1)}$ (D) $\frac{1}{(s^2-1)+1}$

23. The value of the surface integral $\oint\!\!\oint_s (x\hat{i} + y\hat{j}).\hat{n}dA$ evaluated over the surface of a cube having sides of length a is ($\hat{n}$ is unit normal vector).

(A) 0 (B) a^3 (C) $2\ a^3$ (D) $3\ a^3$

24. The first four terms of the Taylor series expansion of Cos x about the point x = 0 are

(A) $1 + x + \frac{X^2}{2!} + \frac{X^3}{3!}$ (B) $1 - x - \frac{X^2}{2!} - \frac{X^3}{3!}$

(C) $1 - \frac{x^2}{2!} + \frac{X^4}{4!} + \frac{X^6}{6!}$ (D) $x - \frac{X^3}{3!} + \frac{X^5}{5!} - \frac{x^7}{7!}$

25. If $A = \begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix}$, then the eigenvalues of A^3 are

(A) 5, 4 (B) 3, -1 (C) 9, -1 (D) 27, -1

26. An analytic function w (z) is defined as w = u + iv, where i = √ -1 and z = x + iy. If the real part is given by $u = \frac{y}{x^2+y^2}$, w (z) is

(A) $\frac{1}{z}$ (B) $\frac{1}{z^2}$ (C) $\frac{i}{z}$ (D) $\frac{i}{iz}$

27. The normal distribution is given by

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right), -\infty < x < \infty$$

The points of inflexion to the normal curve are

(A) x = - σ, + σ (B) x = μ + σ , μ – σ
(C) x = μ + 2σ , μ – 2σ (D) x = μ + 3σ , μ – 3σ

28. Using Simpson's 1/3 rule and FOUR equally spaced intervals (n = 4), estimate the value of the integral $\int_0^{\frac{\pi}{4}} \frac{\sin x}{\cos^3 x} dx$

(A) 0.3887 (B) 0.4384 (C) 0.5016 (D) 0.5527

29. The following differential equation is to be solved numerically by the Euler's explicit method. $\frac{dy}{dx} = x^2 y - 1.2y$ with y(0) = 1;
A step size of 0.1 is used. The solution for y at x = 0.1 is

(A) 0.880 (B) 0.905 (C) 1.000 (D) 1.100

30. The Poisson distribution is given by $P(r)=\frac{m^r}{r!}\exp(-m)$. The first moment about the origin for the distribution is

(A) 0 (B) m (C) 1/m (D) m^2

31. Air (79 mole % nitrogen and 21 mole % oxygen) is passed over a catalyst at high temperature. Oxygen completely reacts with nitrogen as shown below,

$$0.5\ N_{2\,(g)} + 0.5\ O_{2\,(g)} \rightarrow NO_{(g)}$$
$$0.5\ N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{2(g)}$$

The molar ratio of NO to NO_2 in the product stream is 2:1. The fractional conversion of nitrogen is

(A) 0.13 (B) 0.20 (C) 0.27 (D) 0.40

32. A 35 wt% Na_2SO_4 solution in water, initially at 50°C, is fed to a crystallizer at 20°C. The product stream contains hydrated crystals $Na_2SO_4.10H_2O$ in equilibrium with a 20 wt% Na_2SO_4 solution. The molecular weights of Na_2SO_4 and $Na_2SO_4.10H_2O$ are 142 and 322, respectively. The feed rate of the 35% solution required to produce 500 kg/hr of hydrated crystals is

(A) 403 kg/ha (B) 603 kg/hr (C) 803 kg/hr (D) 1103 kg/hr

33. 600 kg/hr of saturated steam at 1 bar (enthalpy 2675.4 kJ/kg) is mixed adiabatically with superheated steam at 450°C and 1 bar (enthalpy 3382.4 kJ/kg). The product is superheated steam at 350°C and 1 bar (enthalpy 3175.6 kJ/kg). The flow rate of the product is

(A) 711 kg/hr (B) 1111 kg/hr (C) 1451 kg/hr (D) 2051 kg/hr

34. Carbon black is produced by decomposition of methane:

$$CH_{4\,(g)} \rightarrow C_{(s)} + 2H_{2\,(g)}$$

The single pass conversion of methane is 60%. If fresh feed is pure methane and 25% of the methane exiting the reactor is recycled, then the molar ratio of fresh feed stream to recycle stream is

(A) 0.9 (B) 9 (C) 10 (D) 90

35. The molar volume (v) of a binary mixture, of species 1 and 2 having mole fractions x_1 and x_2 respectively is given by

$$v = 220\ x_1 + 180\ x_2 + x_1\ x_2\ (90\ x_1 + 50\ x_2).$$

The partial molar volume of species 2 at $x_2 = 0.3$ is

(A) 183.06 (B) 212.34 (C) 229.54 (D) 256.26

36. The standard Gibbs free energy change and enthalpy change at 25°C for the liquid phase reaction

$$CH_3COOH_{(1)} + C_2H_5OH_{(1)} \rightarrow CH_2COOC_2H_{5\,(1)} + H_2O_{(1)},$$

are given as ΔG°_{298} = - 4650 J/mol and ΔH°_{298} = - 3640 J/mol. If the solution is ideal and enthalpy change is assumed to be constant, the equilibrium constant at 95°C is

(A) 0.65 (B) 4.94 (C) 6.54 (D) 8.65

37. A cylindrical vessel with hemispherical ends is filled with water as shown in the figure. The head space is pressurized to a gauge pressure of 40 kN/m^2. The vertical forces F (in kN) tending to lift the top dome and the absolute pressure P (in kN/m^2) at the bottom of the vessel are (g = 9.8 m/s^2, density of water = 1000 kg/m^3)

(A) F = 83.6; P = 64.5

(B) F = 83.6; P = 165.8

(C) F = 125.7; P = 64.5

(D) F = 125.7; P = 165.8

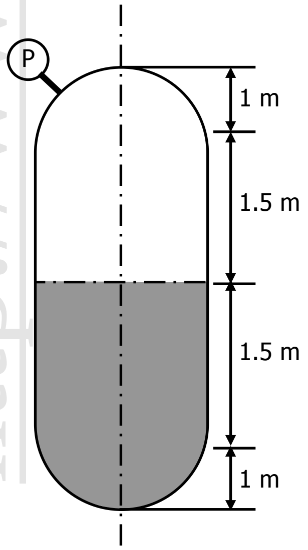


Figure not to scale

38. A pump draws oil (specific gravity 0.8) from a storage tank and discharges it to an overhead tank. The mechanical energy delivered by the pump to the fluid is 50 J/kg. The velocities at the suction and the discharge points of the pump are 1 m/s and 7 m/s, respectively. Neglecting friction losses and assuming kinetic energy correction factor to be unity, the pressure developed by the pump (in kN/m^2) is

(A) 19.2 (B) 20.8 (C) 40 (D) 80

39. Match the following:

Group 1	**Group 2**
(P) Euler number	(1) Viscous force / Inertial force
(Q) Froude number	(2) Pressure force / Inertial force
(R) Weber number	(3) Inertial force / Gravitational force
	(4) Inertial force / Surface tension force

(A) P-1, Q-2, R-3 (B) P-2, Q-3, R-4 (C) P-3, Q-2, R-1 (D) P-4, Q-3, R-2

40. A steady flow field of an incompressible fluid is given by $\vec{V} = (Ax + By)\hat{i} - Ay\hat{j}$, where A = 1 s^{-1}, B = 1 s^{-1}, and x, y are in meters. The magnitude of the acceleration (in m/s^2) of a fluid particle at (1, 2) is

(A) 1 (B) $\sqrt{2}$ (C) $\sqrt{5}$ (D) $\sqrt{10}$

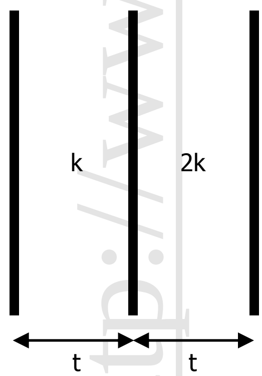
41. Two identically sized spherical particles A and B having densities ρ_A and ρ_B, respectively, are settling in a fluid of density ρ. Assuming free settling under turbulent flow conditions, the ratio of the terminal settling velocity of particle A to that of particle B is given by

(A) $\sqrt{\dfrac{(\rho_A - \rho)}{\rho_B - \rho}}$ (B) $\sqrt{\dfrac{(\rho_B - \rho)}{\rho_A - \rho}}$ (C) $\dfrac{(\rho_A - \rho)}{\rho_B - \rho}$ (D) $\dfrac{(\rho_B - \rho)}{\rho_A - \rho}$

42. Consider the scale-up of a cylindrical baffled vessel configured to have the standard geometry (i.e. Height = Diameter). In order to maintain an equal rate of mass transfer under turbulent conditions for a Newtonian fluid, the ratio of the agitator speeds should be
(Given N_1, D_1 are agitator speed and vessel diameter before scale-up; N_2, D_2 agitator speed and vessel diameter after scale-up)

(A) $\dfrac{N_1}{N_2} = \dfrac{D_1}{D_2}$ (B) $\dfrac{N_1}{N_2} = \dfrac{D_2}{D_1}$ (C) $\dfrac{N_1}{N_2} = \left(\dfrac{D_1}{D_2}\right)^{\frac{2}{3}}$ (D) $\dfrac{N_1}{N_2} = \left(\dfrac{D_2}{D_1}\right)^{\frac{2}{3}}$

43. Two plates of equal thickness (t) and cross-sectional area, are joined together to form a composite as shown in the figure. If the thermal conductivities of the plates are k and 2k then, the effective thermal conductivity of the composite is



(A) 3k/2 (B) 4k/3 (C) 3k/4 (D) 2k/3

44. A metallic ball (ρ = 2700 kg/m^3 and Cp = 0.9 kJ/kg °C) of diameter 7.5 cm is allowed to cool in air at 25°C. When the temperature of the ball is 125°C, it is found to cool at the rate of 4°C per minute. If thermal gradients inside the ball are neglected, the heat transfer coefficient (in W/m^2 °C) is

(A) 2.034 (B) 20.34 (C) 81.36 (D) 203.4

45. Hot liquid is flowing at a velocity of 2 m/s through a metallic pipe having an inner diameter of 3.5 cm and length 20 m. The temperature at the inlet of the pipe is 90°C. Following data is given for liquid at 90°C.

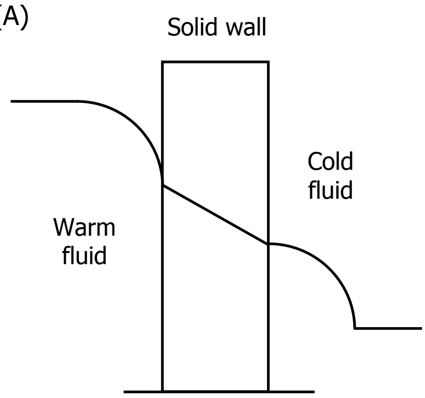
Density = 950 kg/m^3;
Specific heat = 4.23 kJ/kg °C
Viscosity = 2.55 x 10^{-4} kg/m.s;
Thermal conductivity = 0.685 W/m °C

The heat transfer coefficient (in W/m^2 °C) inside the tube is

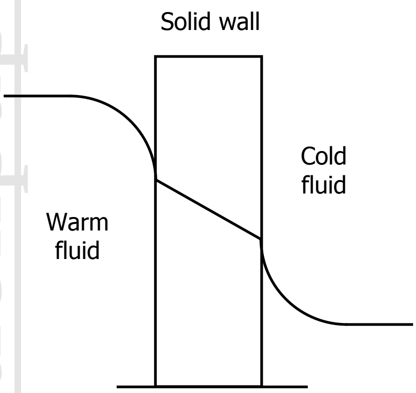
(A) 222.22 (B) 111.11 (C) 22.22 (D) 11.11

46. The temperature profile for heat transfer from one fluid to another separated by a solid wall is

(A)



(B)



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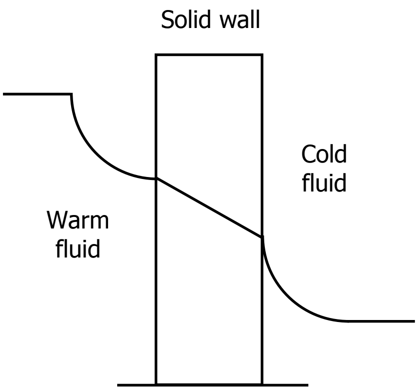
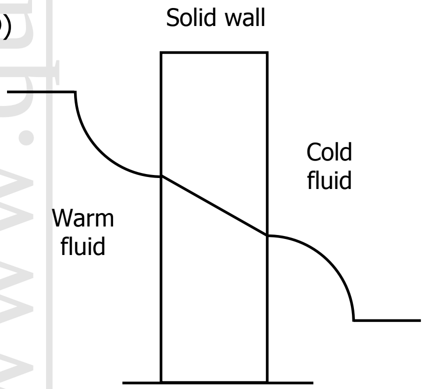


(D)

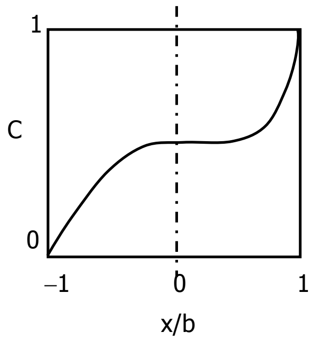


47. A rectangular slab of thickness 2b along the x axis and extending to infinity along the other direction is initially at concentration C_{AO}. At time t=0, both surfaces of the slab(x=+b) have their concentrations increased to C_{AW} and maintained at that value. Solute A diffuses into the solid. The dimensionless concentration C is defined as

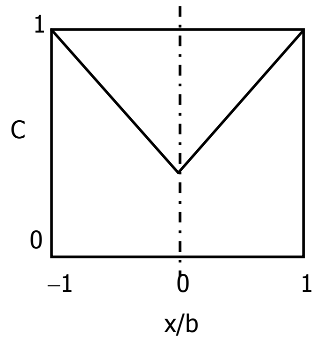
$$C = \frac{C_A - C_{AO}}{C_{AW} - C_{AO}}$$

The diffusivity of A inside the solid is assumed constant. At a certain time instant, which ONE of the following is the correct representation of the concentration profile?

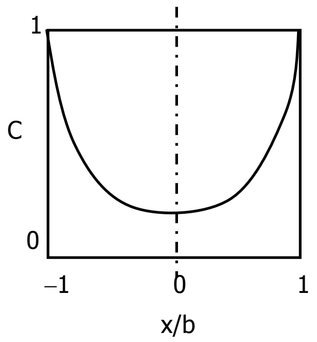
(A)



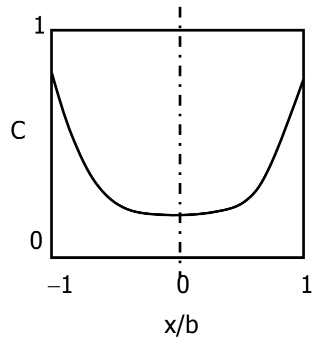
(B)



(C)



(D)



48. In a binary mixture containing components A and B, the relative volatility of A with respect to B is 2.5 when mole fractions are used. The molecular weights of A and B are 78 and 92 respectively. If the compositions are however expressed in mass fractions the relative volatility will then be

(A) 1.18 (B) 2.12 (C) 2.5 (D) 2.95

49. An ideal flash vaporization is carried out with a binary mixture at constant temperature and pressure. A process upset leads to an increase in the mole fraction of the heavy component in the feed. The flash vessel continuous to operate at the previous temperature and pressure and still produces liquid and vapor. After steady state is re-established,

(A) the amount of vapor produced will increase
(B) the amount of liquid produced will decrease
(C) The new equilibrium compositions of the vapor and liquid products will be different,
(D) The new equilibrium compositions of the vapor and liquid products will remain as they were before the upset occurred.

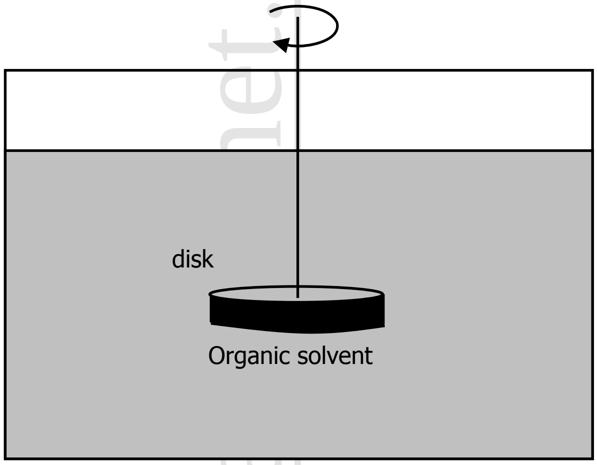
50. A batch distillation operation is carried out to separate a feed containing 100 moles of a binary mixture of A and B. The mole fraction of A in the feed is 0.7. The distillation progresses until the mole fraction of A in the residue decreases to 0.6. The equilibrium cure in this composition range may be linearized to $y^* = 0.7353\ x + 0.3088$. Here x and y are the mole fractions of the more volatile component A in the liquid and vapor phases respectively. The number of moles of residue is

(A) 73.53 (B) 4l8.02 (C) 40 (D) 30.24

51. A packed tower containing Berl saddles is operated with a gas-liquid system in the countercurrent mode. Keeping the gas flow rate constant, if the liquid flow rate is continuously increased,

(A) the void fraction available for the gas to flow will decrease beyond the loading point
(B) the gas pressure drop will decrease,
(C) liquid will continue to flow freely down the tower beyond the loading point,
(D) the entrainment of liquid in the gas will considerably decrease near the flooding point.

52. A sparingly soluble solute in the form of a circular disk is dissolved in an organic solvent s shown in the figure. The area available for mass transfer from the disk is A and the volume of the initially pure organic solvent is V. The disk is rotated along the horizontal plane at a fixed rpm to produce a uniform concentration of the dissolving solute in the liquid.
The convective mass transfer coefficient under these conditions is k_c. The equilibrium concentration of the solute in the solvent is C*. The time required for the concentration to reach 1% of the saturation value is given by



(A) $\exp\left(-\frac{k_c A}{V} t\right) = 0.99$ (B) $\exp\left(-\frac{k_c A}{V} t\right) = 0.01$

(C) $\frac{V}{Ak_c} \exp(-0.99) = t$ (D) $\frac{V}{Ak_c} \exp(0.01) = t$

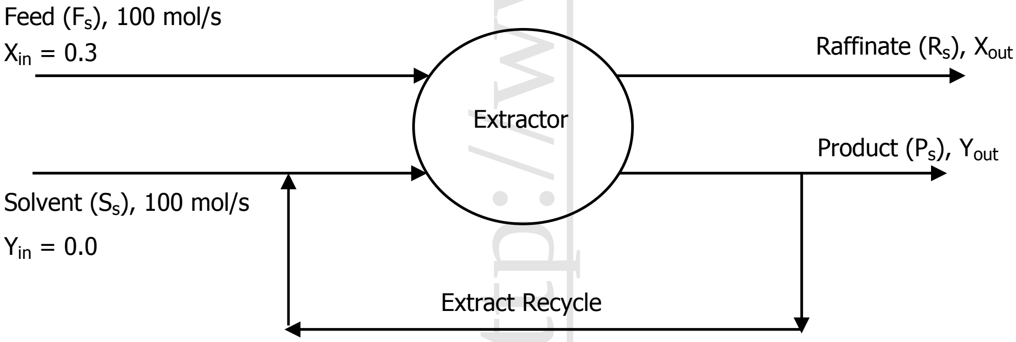
53. Air concentrated with solute P is brought in contact with water. At steady state, the bulk concentrations of P in air and water are 0.3 and 0.02 respectively. The equilibrium equation relating the interface compositions is

$$y_{p,i} = 0.25x_{p,i}$$

Assume that the mass transfer coefficients F_G and F_L are identical. The gas phase mole fraction of P at the interface ($y_{P,i}$) is

(A) 0.0663 (B) 0.075 (C) 0.16 (D) 0.3

54. A feed (F) containing a solute is contacted with a solvent (S) in an ideal stage as shown in the diagram below. Only the solute transfers into the solvent. The flow rates of all the streams are shown on a solute free basis and indicated by the subscript S. The compositions of the streams are expressed on a mole ratio basis. The extract leaving the contactor is divided into two equal parts, one part collected as the product (P) and the other stream is recycled to join the solvent. The equilibrium relationship is Y* = 2X.
The product flow rate (Ps) and composition (Y_{out}) are



(A) P_S = 50 mol/s, Y_{out} = 0.3 (B) P_S = 100 mol/s, Y_{out} = 0.2
(C) P_S = 200 mol/s, Y_{out} = 0.1 (D) P_S = 100 mol/s, Y_{out} = 0.4

55. The gas phase reaction A + 3 B → 2 C is conducted in a PFR at constant temperature and pressure. The PFR achieves a conversion of 20% of A. The feed is a mixture of A, B and an inert I. It is found that the concentration of A remains the same throughout the reactor.
Which ONE of the following ratios of inlet molar rate ($F_{A,\,in}$: $F_{B,\,in}$: $F_{I,\,in}$) is consistent with this observation? Assume the reaction mixture is an ideal gas mixture.

(A) 2: 3: 0 (B) 2: 2: 1
(C) 3: 2: 1 (D) 1: 2: 1

56. The elementary liquid phase series parallel reaction scheme

$$A \rightarrow B \rightarrow C$$
$$A \rightarrow R$$

Is to be carried out in an isothermal CSTR. The rate laws are given by

$$r_R = k' C_A$$
$$r_B = k\, C_A - kC_B$$

Feed is pure A. The space time of the CSTR which results in the maximum exit concentration of B is given by

(A) $\dfrac{1}{\sqrt{kk'}}$ (B) $\dfrac{1}{\sqrt{k'(k+k')}}$ (C) $\dfrac{1}{(k+k')}$ (D) $\dfrac{1}{\sqrt{k(k+k')}}$

57. The liquid phase reaction A → Products is governed by the kinetics

$$-r_A = k\, C_A^{1/2}$$

If the reaction undergoes 75% conversion of A in 10 minutes in an isothermal batch reactor, the time (in minutes) for complete conversion of A is

(A) 40/3 (B) 20 (C) 30 (D) ∞

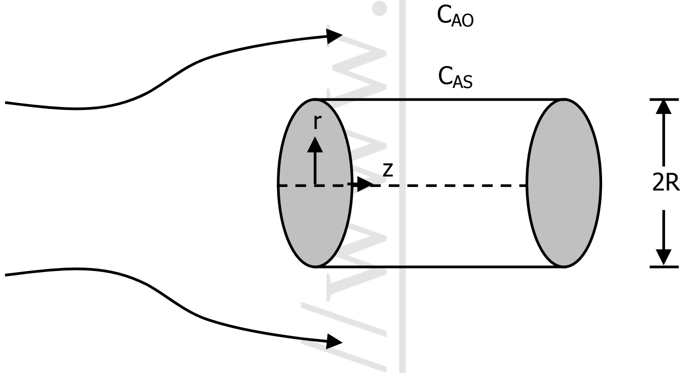
58. The homogeneous reaction A + B → C is conducted in an adiabatic CSTR at 800 K so as to achieve a 30% conversion of A. The relevant specific heats and enthalpy change of reaction are given by

$C_{P,\,A}$ = 100 J / (mol K), $C_{P,\,C}$ = 150 J / (mol K),
$C_{P,\,B}$ = 50 J / (mol K), Δh^{rxn} = -100 kJ / mol,

If the feed, a mixture of A and B, is available at 550 K, the mole fraction of A in the feed that is consistent with the above data is

(A) 5/7 (B) ¼ (C) 1/2 (D) 2/7

59. The irreversible zero order reaction A → B takes place in a porous cylindrical catalyst that is sealed at both ends as shown in the figure. Assume dilute concentration and neglect any variations in the axial direction.



The steady state concentration profile is $\dfrac{C_A}{C_{AS}} = 1 + \dfrac{\phi_0^2}{4}\left[\left(\dfrac{r}{R}\right)^2 - 1\right]$

where ϕ_o is the Thiele modulus. For ϕ_o = 4, the range of r where C_A = 0 is

(A) $0 < r < \dfrac{R}{4}$ (B) $0 < r < \dfrac{R}{2}$ (C) $0 < r < \sqrt{\dfrac{3}{4}}R$ (D) $0 \le r \le R$

60. The unit impulse response of a first order process is given by $2e^{-0.5t}$. The gain and time constant of the process are, respectively,
(A) 4 and 2 (B) 2 and 2 (C) 2 and 0.5 (D) 1 and 0.5

61. A unit step input is given to a process that is represented by the transfer function $\frac{(s+2)}{(s+5)}$. The initial value ($t = 0^+$) of the response of the process to the step input is
(A) 0 (B) 2/5 (C) 1 (D) ∞

62. A tank of volume 0.25 m^3 and height 1 m has water flowing in at 0.05 m^3/min. The outlet flow rate is governed by the relation

$$F_{out} = 0.1\,h,$$

where h is the height of the water in the tank in m and F_{out} is the outlet flow rate in m^3/min. The inlet flow rate changes suddenly from its nominal value of 0.05 m^3/min to 0.15 m^3/min and remains there. The time (in minutes) at which the tank will begin to overflow is given by
(A) 0.28 (B) 1.01 (C) 1.73 (D) ∞

63. Which ONE of the following transfer functions corresponds to an inverse response process with a positive gain?
(A) $\frac{1}{2s+1} - \frac{2}{3s+1}$ (B) $\frac{2}{s+1} - \frac{5}{s+10}$
(C) $\frac{3(0.5s-1)}{(2s+1)(s+1)}$ (D) $\frac{5}{s+1} - \frac{3}{2s+1}$

64. Match the following

Group 1	**Group 2**
(P) Temperature	(1) Hot wire anemometry
(Q) Pressure	(2) Strain Gauge
(R) Flow	(3) Chromatographic analyzer
	(4) Pyrometer.

(A) P-1, Q-2, R-3 (B) P-4, Q-1, R-3 (C) P-1, Q-2, R-4 (D) P-4, Q-2, R-1

65. Match the following

Group 1	**Group 2**
(P) Ziegler Nichols	(1) Process Reaction Curve
(Q) Under damped response	(2) Decay ratio3210210
(R) Feed forward control	(3) Frequency 0r1esponse
	(4) Distribution measurement.

(A) P-3, Q-2, R-4 (B) P-1, Q-2, R-3 (C) P-3, Q-4, R-2 (D) P-1, Q-4, R-2

66. A reactor has been installed at a cost of Rs. 50,000 and is expected to have a working life of 10 years with a scrap value of Rs. 10,000. The capitalized cost (in Rs.) of the reactor based on an annual compound interest rate of 5% is
(A) 1, 13, 600 (B) 42, 000 (C) 52, 500 (D) 10, 500

67. In a shell and tube heat exchanger, if the shell length is L_S, the baffle spacing is L_B and the thickness of baffle is t_b, the number of baffles on the shell side, N_B, is
(A) $\frac{L_S}{L_B + t_b}$ (B) $\frac{L_S}{L_B + t_b} - 1$
(C) $\frac{L_S}{L_B + t_b} + 1$ (D) $\frac{L_S}{L_B + t_b} + 2$

68. Match the unit processes in Group 1 with the industries in Group 2

Group 1	**Group 2**
(P) Saponification	(1) Petroleum refining
(Q) Calcination	(2) Synthetic fibres
(R) Alkylation	(3) Cement
	(4) Soaps and Detergents

(A) P-1, Q-3, R-4 (B) P-2, Q-3, R-4 (C) P-4, Q-2, R-1 (D) P-4, Q-3, R-1

69. Which ONE of the following process sequences is used in the production of synthesis gas?
(A) Desulphurization → Steam reforming→ Hot K_2CO_3 cycle
(B) Steam reforming → Desulphurization → Hot K_2CO_3 cycle
(C) Hot K_2CO_3 cycle → Steam reforming→ Desulphurization
(D) Hot K_2CO_3 cycle → Desulphurization→ Steam reforming

70. Which ONE of the following process sequences is used in the sugar industry?
(A) Ca_2HPO_4/Lime Treatment → Crystallization → Crushing
(B) Ca_2HPO_4/Lime Treatment → Multiple stage evaporation -→ Crystallization
(C) Crushing -→ Crystallization-→ Ca_2HPO_4/Lime Treatment
(D) Multiple stage evaporation -→ Crystallization -→ Ca_2HPO_4/Lime Treatment

Common Data Questions

Common Data for Questions 71, 72 and 73:

Methane and steam are fed to a reactor in molar ratio 1: 2. The following reactions take place,

$$CH_{4\,(g)} + 2H_2O_{(g)} \rightarrow CO_{2\,(g)} + 4H_{2\,(g)}$$
$$CH_{4\,(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2\,(g)}$$

where CO_2 is the desired product, CO is the undesired product and H_2 is a byproduct. The exit stream has the following composition

Species	CH_4	H_2O	CO_2	H_2	CO
Mole %	4.35	10.88	15.21	67.39	2.17

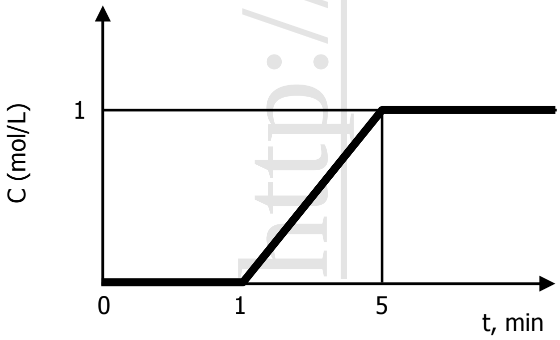
71. The selectivity for desired product relative to undesired product is
(A) 2.3 (B) 3.5 (C) 7 (D) 8

72. The fractional yield of CO_2 is
(where fractional yield is defined as the ratio of moles of the desired product formed to the moles that would have been formed if there were no side reactions and the limiting reactant had reacted completely)
(A) 0.7 (B) 0.88 (C) 1 (D) 3.5

73. The fractional conversion of methane is
(A) 0.4 (B) 0.5 (C) 0.7 (D) 0.8

Common Data for Questions 74 and 75:

A liquid is flowing through a reactor at a constant flow rate. A step input of tracer at a molar flow rate of 1 mol/min is given to the reactor at time t =0. The time variation of the concentration (C) of the tracer at the exit of the reactor is as shown in the figure:



74. The volumetric flow rate of the liquid through the reactor (in L/min) is
(A) 1 (B) 2 (C) 1.5 (D) 4

75. The mean residence time of the fluid in the reactor (in minutes) is
(A) 1 (B) 2 (C) 3 (D) 4

Linked Answer Questions: Q.76 to Q.85 carry two marks each
Statement for Linked Answer Questions 76 and 77:

A binary mixture containing species 1 and 2 forms an azeotrope at 105.4°C and 1.013 bar. The liquid phase mole fraction of component 1 (x_1) of this azeotrope is 0.62. At 105.4°C, the pure component vapor pressures for species 1 and 2 are 0.878 bar and 0.665 bar, respectively. Assume that the vapour phase is an ideal gas mixture. The van Laar constants, A and B, are given by the expressions:

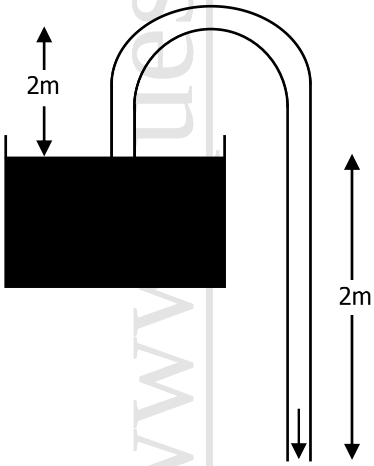
$$A = \left[1 + \frac{x_2 \ln\gamma_2}{x_1 \ln\gamma_1}\right]^2 \ln\gamma_1, \qquad B = \left[1 + \frac{x_1 \ln\gamma_1}{x_2 \ln\gamma_2}\right]^2 \ln\gamma_2$$

76. The activity coefficients (γ_1, γ_2) under these conditions are
(A) (0.88, 0.66) (B) (1.15, 1.52),
(C) (1.52, 1.15) (D) (1.52, 0.88)

77. The van Laar constants (A, B) are
(A) (0.92, 0.87) (B) (1.00, 1.21) (C) (1.12, 1.00) (D) (1.52, 1.15)

Statement for Linked Answer Questions 78 and 79:

A siphon tube having a diameter of 2 cm draws water from a large open reservoir and discharges into the open atmosphere as shown in the figure. Assume incompressible fluid and neglect frictional losses. ($g = 9.8\ m/s^2$)



78. The velocity (in m/s) at the discharge point is
(A) 9.9 (B) 11.7 (C) 98 (D) 136.9

79. The volumetric flow rate (in L/s) of water at the discharge is
(A) 3.11 (B) 3.67 (C) 30.77 (D) 42.99

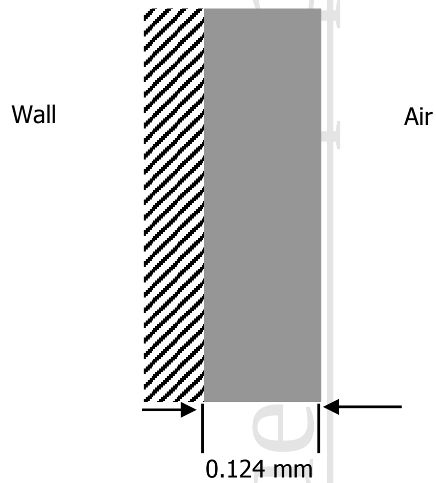
Statement for Linked Answer Questions 80 and 81:
The liquid phase reaction A→ Products is to be carried out at constant temperature in a CSTR followed by a PFR in series. The overall conversion of A achieved by the reactor system (CSTR + PFR) is 95%. The CSTR has a volume of 75 liters. Pure A is fed to the CSTR at a concentration C_{AO} = 2 mol/liter and a volumetric flow rate of 4 liters/min. The kinetics of the reaction is given by

$$-r_A = 0.1C_A^2 \frac{\text{mol}}{\text{liter.min}}$$

80. The conversion achieved by the CSTR is
(A) 40% (B) 50% (C) 60% (D) 80%

81. The volume of the PFR required (in liters) is
(A) 380 (B) 350 (C) 75 (D) 35

Statement for Linked Answer Questions 82 and 83:
A thin liquid film flows at steady state along a vertical surface as shown in the figure. The average velocity of the liquid film is 0.05 m/s. The viscosity of the liquid is 1 cP and its density is 1000 kg/m^3. The initially pure liquid absorbs a sparingly soluble gas from air as it flows down. The length of the wall is 2 m and its width is 0.5 m. The solubility of the gas in the liquid is 3.4 x $10^{-2\ zz}$ol/m^3 and isothermal conditions may be assumed.



82. If the exit average concentration in the liquid is measured to be 1.4 x 10^{-2} kmol/m^3, the total mass transfer rate (in kmol/s) of the sparingly soluble gas into the liquid is
(A) 0.133 x 10^{-4} (B) 0.434 x 10^{-7} (C) 3.4 x 10^{-2} (D) 17 x 10^{-2}

83. The mass transfer coefficient $k_{c,\,avg}$ (in m/s), averaged along the length of the vertical surface is
(A) 2.94 x 10^{-6} (B) 2.27 x 10^{-6} (C) 1.94 x 10^{-6} (D) 1.65 x 10^{-6}

Statement for Linked Answer Questions 84 and 85:
The cross-over frequency associated with a feedback loop employing a proportional controller to control the process represented by the transfer function

$$G_p(s) = \frac{2e^{-s}}{(\tau s+1)^2}, \text{ (units of time is minutes)}$$

is found to be 0.6 rad/min. Assume that the measurement and valve transfer functions are unity.

84. The time constant, τ (in minutes) is
(A) 1.14 (B) 1.92 (C) 3.223 (D) 5.39

85. If the control loop is to operate at a gain margin of 2.0, the gain of the proportional controller must equal
(A) 0.85 (B) 2.87 (C) 3.39 (D) 11.50

END OF THE QUESTION PAPER