GATE Chemical Engineering

Sample Paper – 3

Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Chemical Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Take $R = 8.314$ J/mol·K and $g = 9.81$ m/s^2 unless stated otherwise.

Process Calculations & Thermodynamics

Q1. A gas mixture is made up of 4 kmol of nitrogen and 1 kmol of oxygen. The mole fraction of oxygen in the mixture is: **[1 mark]**

(A) 0.25

(B) 0.20

(C) 0.80

(D) 0.50

Q2. Methane is burnt completely in oxygen following $\mathrm{CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O}$. If 8 kg of methane (molar mass 16) is burnt completely, the mass of carbon dioxide (molar mass 44) produced is: **[1 mark]**

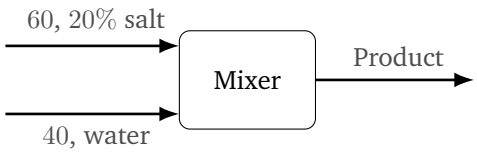
(A) 44 kg

(B) 11 kg

(C) 22 kg

(D) 8 kg

Q3. In the steady mixing operation shown, a stream of 60 kg/h containing 20% salt by mass is blended with 40 kg/h of pure water. The mass fraction of salt in the combined product stream is: **[1 mark]**



(A) 0.20

(B) 0.08

(C) 0.24

(D) 0.12

Q4. A closed system is compressed adiabatically (no heat crosses the boundary). During the process 250 J of work is done *on* the system by the surroundings. Using the first law $\Delta U = Q - W$ with W the work done *by* the system, the change in internal energy of the system is: **[1 mark]**

(A) $+250$ J

(B) -250 J

(C) 0 J

(D) $+500$ J

Q5. One mole of an ideal gas expands isothermally and reversibly at 300 K until its volume doubles. For such a process the entropy change of the

gas is $\Delta S = R\ln(V_2/V_1)$. Taking $R = 8.314$ J/mol·K, the value of ΔS is nearest to: **[1 mark]**

(A) 8.31 J/K

(B) 5.76 J/K

(C) 2.88 J/K

(D) 11.5 J/K

Q6. For an ideal gas the molar heat capacities obey Mayer's relation $C_p - C_v = R$. If the molar heat capacity at constant volume is $C_v = 20.8$ J/mol·K, then, with $R = 8.314$ J/mol·K, the molar heat capacity at constant pressure C_p is nearest to: **[1 mark]**

(A) 20.8 J/mol·K

(B) 12.5 J/mol·K

(C) 29.1 J/mol·K

(D) 8.31 J/mol·K

Q7. A gas-phase reaction has a thermodynamic equilibrium constant $K = 10$ at 300 K. Using $\Delta G^\circ = -RT\ln K$ with $R = 8.314$ J/mol·K, the standard Gibbs free energy change of the reaction is nearest to: **[1 mark]**

(A) $+5.74$ kJ/mol

(B) 0 kJ/mol

(C) -2.49 kJ/mol

(D) -5.74 kJ/mol

Q8. For a binary system that follows the constant relative-volatility relation, the equilibrium vapour composition is $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$. For a relative volatility $\alpha = 3$ and a liquid mole fraction $x = 0.25$, the equilibrium vapour mole fraction y is: **[1 mark]**

(A) 0.50

(B) 0.25

(C) 0.75

(D) 0.375

Q9. A pure substance is held at its triple point, where the solid, liquid and vapour phases coexist. Applying the Gibbs phase rule $F = C - P + 2$, the number of degrees of freedom of the system is: **[1 mark]**

(A) 0

(B) 1

(C) 2

(D) 3

Q10. A reversible Carnot refrigerator operates between a cold space at 250 K and a warm surroundings at 300 K. Its coefficient of performance is $\text{COP} = \dfrac{T_C}{T_H - T_C}$. The value of the COP is: **[1 mark]**

(A) 6.0

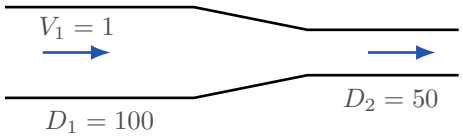
(B) 1.2

(C) 0.83

(D) 5.0

Fluid Mechanics & Mechanical Operations

Q11. Water flows steadily through the contracting pipe shown, whose diameter reduces from $D_1 = 100$ mm to $D_2 = 50$ mm. The mean velocity at the larger section is $V_1 = 1$ m/s. Using continuity $A_1 V_1 = A_2 V_2$, the mean velocity V_2 at the smaller section is: **[1 mark]**



(A) 2 m/s

(B) 4 m/s

(C) 0.25 m/s

(D) 8 m/s

Q12. A stream of water of density 1000 kg/m^3 moves with a mean velocity of 3 m/s. The dynamic pressure of the stream, $q = \frac{1}{2}\rho V^2$, is: **[1 mark]**

(A) 3.0 kPa

(B) 9.0 kPa

(C) 4.5 kPa

(D) 1.5 kPa

Q13. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 20 mm at a mean velocity of 0.05 m/s. The Reynolds number of the flow, $Re = \rho V D/\mu$, is: **[1 mark]**

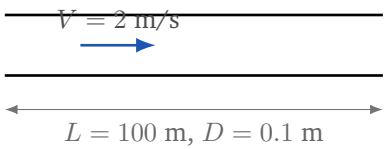
(A) 500

(B) 1000

(C) 2000

(D) 100

Q14. Water flows through the horizontal pipe shown, of length $L = 100$ m and diameter $D = 0.1$ m, at a mean velocity $V = 2$ m/s. The Darcy friction factor is $f = 0.02$. Using the Darcy–Weisbach equation $h_f = f\dfrac{L}{D}\dfrac{V^2}{2g}$ with $g = 9.81$ m/s^2, the head loss due to friction is nearest to: **[1 mark]**



(A) 2.04 m

(B) 8.16 m

(C) 4.08 m

(D) 20.4 m

Q15. A solid body of volume 0.002 m^3 is fully submerged in water of density 1000 kg/m^3. Taking $g = 9.81$ m/s^2, the buoyant (upward) force exerted by the water on the body, $F_B = \rho\, g\, V$, is: **[1 mark]**

(A) 9.81 N

(B) 19.62 N

(C) 2.0 N

(D) 39.24 N

Q16. Two solid spheres of the *same* material settle under gravity in the same liquid in the Stokes (creeping-flow) regime, in which $v_t \propto d^2$. If the second sphere has twice the diameter of the first, the ratio of the terminal settling velocity of the larger sphere to that of the smaller sphere is: **[1 mark]**

(A) 2

(B) 8

(C) 0.25

(D) 4

Q17. In the jaw crusher shown, lumps of feed of characteristic size 60 mm are crushed to a product of characteristic size 15 mm. The size-reduction ratio of the crusher, defined as feed size divided by product size, is: **[1 mark]**

(A) 45

(B) 75

(C) 0.25

(D) 4

Q18. Which law of size reduction states that the energy required per unit mass of feed is proportional to $\ln(d_1/d_2)$, i.e. to the logarithm of the size-reduction ratio, and is therefore best suited to coarse crushing? [1 mark]

(A) Rittinger's law

(B) Kick's law

(C) Bond's law

(D) Stokes' law

Q19. A ball mill of internal diameter 0.9 m (ball diameter negligible) is operated at 70% of its critical speed. Using the critical-speed relation $n_c = 42.3/\sqrt{D}$ rpm, with D in metres, the operating speed of the mill is nearest to: [1 mark]

(A) 44.6 rpm

(B) 22.3 rpm

(C) 31.2 rpm

(D) 62.3 rpm

Q20. Steady one-dimensional conduction occurs through a plane wall of thermal conductivity $k = 0.4$ W/m·K, cross-sectional area $A = 2$ m^2 and thickness $L = 0.2$ m. The conductive thermal resistance of the wall, $R = L/(kA)$, is: [1 mark]

(A) 1.0 K/W

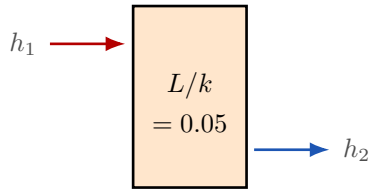
(B) 0.5 K/W

(C) 0.1 K/W

(D) 0.25 K/W

Heat Transfer

Q21. Heat flows steadily through the plane wall shown, which is exposed to a fluid on each face. The inside film coefficient is $h_1 = 10$ W/m^2·K, the outside film coefficient is $h_2 = 10$ W/m^2·K, and the wall has $L/k = 0.05$ m^2·K/W. Using $\frac{1}{U} = \frac{1}{h_1} + \frac{L}{k} + \frac{1}{h_2}$, the overall heat-transfer coefficient U is: **[2 marks]**



(A) 4 W/m^2·K

(B) 0.25 W/m^2·K

(C) 10 W/m^2·K

(D) 2 W/m^2·K

Q22. A metal sphere is suddenly plunged into a stirred fluid. The convective coefficient is $h = 100$ W/m^2·K, the sphere's characteristic length is $L_c = 0.01$ m and its thermal conductivity is $k = 50$ W/m·K. The Biot number, Bi $= hL_c/k$, is: **[2 marks]**

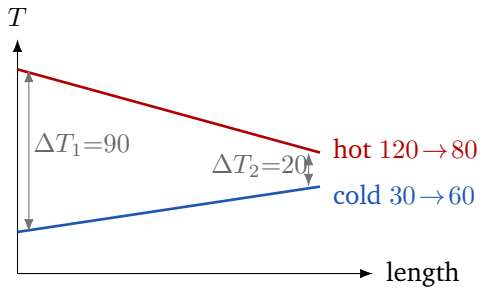
(A) 2.0

(B) 0.2

(C) 0.5

(D) 0.02

Q23. In the parallel-flow (co-current) double-pipe exchanger whose temperature profile is sketched, a hot fluid is cooled from 120 °C to 80 °C while a cold fluid is heated from 30 °C to 60 °C. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



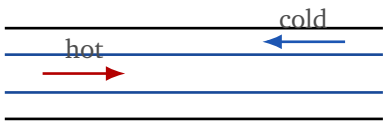
(A) 46.5 °C

(B) 55.0 °C

(C) 40.0 °C

(D) 70.0 °C

Q24. The balanced counter-flow exchanger shown has equal heat-capacity rates, so the capacity ratio is $C_r = C_{\min}/C_{\max} = 1$. Its number of transfer units is NTU $= 1$. For a counter-flow exchanger with $C_r = 1$ the effectiveness is $\varepsilon = \dfrac{\text{NTU}}{1 + \text{NTU}}$. The value of the effectiveness is: **[2 marks]**



Counter-flow, $C_r = 1$, NTU $= 1$

(A) 0.5

(B) 1.0

(C) 0.63

(D) 0.25

Q25. A liquid has thermal conductivity $k = 0.6$ W/m·K, density $\rho = 1000$ kg/m^3 and specific heat $c_p = 4200$ J/kg·K. Its thermal diffusivity, $\alpha = \dfrac{k}{\rho\, c_p}$, is nearest to: **[2 marks]**

(A) 6.0×10^{-4} m^2/s

(B) 1.43×10^{-4} m^2/s

(C) 4.2×10^{-3} m^2/s

(D) 1.43×10^{-7} m^2/s

Q26. A grey surface at a temperature of 400 K has an emissivity of $\varepsilon = 0.8$. Taking the Stefan–Boltzmann constant as $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the total emissive power of the surface, $E = \varepsilon\,\sigma\,T^4$, is nearest to: **[2 marks]**

(A) 1814 W/m^2

(B) 1451 W/m^2

(C) 2903 W/m^2

(D) 1161 W/m^2

Q27. An evaporator transfers a heat duty of $Q = 200$ kW across a heating area of $A = 10$ m^2 with an overall temperature driving force of $\Delta T = 20$ K. Using $Q = U A \Delta T$, the overall heat-transfer coefficient U is: **[2 marks]**

(A) 1000 W/m^2·K

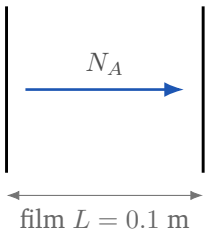
(B) 500 W/m^2·K

(C) 2000 W/m^2·K

(D) 100 W/m^2·K

Mass Transfer & Separation Processes

Q28. Component A diffuses through the stagnant film shown, of thickness $L = 0.1$ m, with a diffusivity $D = 1 \times 10^{-5}$ m^2/s. A convective mass-transfer coefficient of $k_c = 1 \times 10^{-2}$ m/s applies at the surface. The Sherwood number, $\mathrm{Sh} = \dfrac{k_c L}{D}$, is: **[2 marks]**



(A) 10

(B) 1000

(C) 100

(D) 1

Q29. For the diffusion of a solute in a liquid, the momentum and mass diffusivities are compared through the Schmidt number $\mathrm{Sc} = \dfrac{\mu}{\rho\, D}$. Taking $\mu = 1 \times 10^{-3}$ Pa·s, $\rho = 1000$ kg/m^3 and $D = 2 \times 10^{-9}$ m^2/s, the Schmidt number is: **[2 marks]**

(A) 1000

(B) 500

(C) 250

(D) 2000

Q30. A dilute gas is in equilibrium with a liquid according to Henry's law $p = H\,x$, where the Henry constant is $H = 50$ kPa per unit mole fraction. For a liquid-phase mole fraction of $x = 0.02$, the equilibrium partial pressure of the solute in the gas is: **[2 marks]**

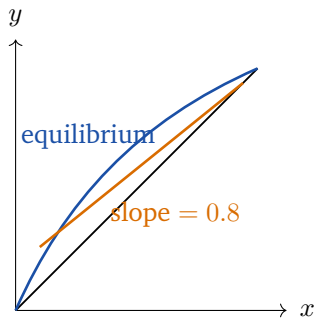
(A) 2.5 kPa

(B) 1.0 kPa

(C) 0.5 kPa

(D) 25 kPa

Q31. In the McCabe–Thiele diagram shown, the rectifying-section operating line has a measured slope of 0.8. Since this slope equals $\dfrac{R}{R+1}$, where R is the reflux ratio, the value of the reflux ratio R is: **[2 marks]**



(A) 0.8

(B) 1.25

(C) 4

(D) 5

Q32. A continuous distillation column separates a feed of 100 mol/h containing a light-key mole fraction $x_F = 0.5$ into a distillate of $x_D = 0.9$ and a bottoms of $x_W = 0.1$. Using overall and component material balances, the molar flow rate of the distillate D is: **[2 marks]**

(A) 40 mol/h

(B) 50 mol/h

(C) 60 mol/h

(D) 90 mol/h

Q33. In a stripping column the gas rate is $G = 50$ mol/h, the liquid rate is $L = 200$ mol/h and the equilibrium slope is $m = 2$. The stripping factor, defined as $S = \dfrac{mG}{L}$, is: **[2 marks]**

(A) 2.0

(B) 1.0

(C) 0.5

(D) 4.0

Q34. A packed absorption tower has a total packing height of $Z = 4$ m, and for the required separation the height of a transfer unit is HTU $= 0.8$ m. Using $Z = \text{HTU} \times \text{NTU}$, the number of transfer units achieved by the packing is: **[2 marks]**

(A) 5

(B) 3.2

(C) 4

(D) 0.8

Q35. In the single-stage liquid–liquid extraction shown, a solute distributes between the extract (y) and the raffinate (x) with a distribution coefficient $K_D = y/x = 4$. If the raffinate leaves with a solute mole fraction $x = 0.05$, the equilibrium extract mole fraction y is: **[2 marks]**

(A) 0.20

(B) 0.05

(C) 0.80

(D) 0.0125

Q36. A wet solid has a total moisture content of 0.30 kg water per kg dry solid, and its equilibrium moisture content under the drying conditions is 0.05 kg water per kg dry solid. The free moisture content of the solid, which is the moisture available for removal, is: **[2 marks]**

(A) 0.35 kg/kg

(B) 0.30 kg/kg

(C) 0.05 kg/kg

(D) 0.25 kg/kg

Reaction Engineering, Process Control & Plant Economics

Q37. A liquid-phase reaction is second order in the single reactant A, with a rate constant $k = 0.5$ L/mol·min and an initial concentration $C_{A0} = 2$ mol/L. For a second-order reaction the half-life is $t_{1/2} = \dfrac{1}{k\,C_{A0}}$. The half-life of the reactant is: **[2 marks]**

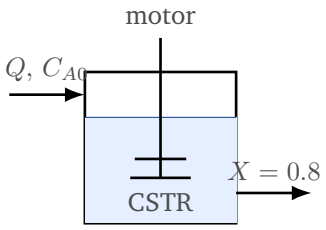
(A) 2 min

(B) 1 min

(C) 0.5 min

(D) 4 min

Q38. A first-order liquid-phase reaction ($-r_A = kC_A$, $k = 0.2$ min^{-1}) is run in the ideal CSTR shown to a conversion of $X = 0.8$, with a feed volumetric flow rate of $Q = 10$ L/min. Using $\tau = \dfrac{X}{k(1-X)}$ and $V = \tau Q$, the required reactor volume is: **[2 marks]**



(A) 20 L

(B) 100 L

(C) 50 L

(D) 200 L

Q39. A zero-order liquid-phase reaction ($-r_A = k = 0.1$ mol/L·min) is carried out in an ideal plug-flow reactor with an inlet concentration $C_{A0} = 2$ mol/L. For a zero-order reaction $\tau = \dfrac{C_{A0}\,X}{k}$. The space time required to reach a conversion of $X = 0.5$ is: **[2 marks]**

(A) 20 min

(B) 5 min

(C) 10 min

(D) 2 min

Q40. For a reaction of the form $-r_A = k\,C_A^n$, it is observed that when the concentration of A is doubled the reaction rate becomes four times as large (all else fixed). The order of the reaction with respect to A, obtained from $2^n = 4$, is: **[2 marks]**

(A) 2

(B) 1

(C) 0.5

(D) 4

Q41. An ideal CSTR of working volume $V = 50$ L is fed by a liquid stream at a constant volumetric flow rate of $Q = 25$ L/min. The space velocity of the reactor, defined as SV $= Q/V$, is: **[2 marks]**

(A) 0.5 min^{-1}

(B) 2.0 min^{-1}

(C) 5.0 min^{-1}

(D) 0.2 min^{-1}

Q42. A first-order reaction occurs in a slab-shaped porous catalyst of half-thickness $L = 1 \times 10^{-3}$ m. The rate constant is $k = 4 \times 10^{-3}$ s^{-1} and the effective diffusivity is $D_e = 1 \times 10^{-9}$ m^2/s. The Thiele modulus, $\phi = L\sqrt{k/D_e}$, is: **[2 marks]**

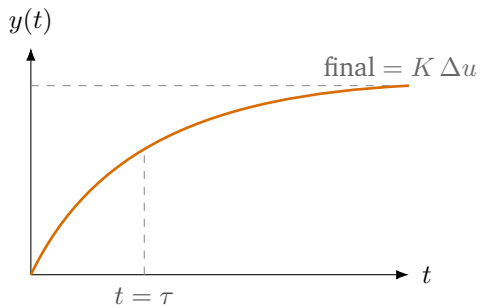
(A) 0.5

(B) 4

(C) 2

(D) 1

Q43. A first-order process has a time constant $\tau = 4$ min and a steady-state gain $K = 5$. It is subjected to a step change of magnitude 2 in its input. The response follows $y(t) = K\,\Delta u\,(1 - e^{-t/\tau})$, as sketched. The ultimate (final, $t \to \infty$) change in the output is: **[2 marks]**



(A) 10

(B) 5

(C) 2

(D) 20

Q44. A closed-loop control system behaves as an underdamped second-order system with an undamped natural frequency $\omega_n = 2$ rad/s and a damping ratio $\zeta = 0.5$. The damped natural frequency, $\omega_d = \omega_n\sqrt{1-\zeta^2}$, is nearest to: **[2 marks]**

(A) 2.0 rad/s

(B) 1.0 rad/s

(C) 1.73 rad/s

(D) 0.87 rad/s

Q45. In a feedback control loop, a sustained (steady-state) offset remains when only proportional action is used. Which single controller mode, when added, drives the steady-state offset to zero for a step change in set point or load? **[2 marks]**

(A) Proportional action

(B) Integral action

(C) Derivative action

(D) On–off (two-position) action

Q46. A process plant requires an initial fixed-capital investment of Rs. $5{,}00{,}000$ and is expected to generate a uniform net annual cash flow of Rs. $1{,}25{,}000$. The simple payback period, defined as investment divided by annual cash flow, is: **[2 marks]**

(A) 5 years

(B) 4 years

(C) 2.5 years

(D) 8 years

Detailed Solutions

Q1.

Solution

Concept – mole fraction is the moles of a component divided by the total moles: $y_{O_2} = \dfrac{n_{O_2}}{n_{N_2} + n_{O_2}}$.

Step 1 – list the amounts: $n_{N_2} = 4$ kmol, $n_{O_2} = 1$ kmol.

Step 2 – find the total moles: $n_{\text{total}} = 4 + 1$

$n_{\text{total}} = 5$ kmol

Step 3 – form the mole fraction of oxygen: $y_{O_2} = \dfrac{1}{5}$

Step 4 – evaluate: $y_{O_2} = 0.20$

Final Answer: $y_{O_2} = 0.20 \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – use the stoichiometry of the combustion reaction: $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$, so 1 mole of methane yields 1 mole of carbon dioxide.

Step 1 – find the moles of methane burnt: $n_{CH_4} = \dfrac{8 \text{ kg}}{16 \text{ kg/kmol}} = 0.5$ kmol

Step 2 – apply the $1:1$ mole ratio of CH_4 to CO_2: $n_{CO_2} = n_{CH_4} = 0.5$ kmol

Step 3 – convert the carbon-dioxide moles to mass: $m_{CO_2} = n_{CO_2} \times M_{CO_2} = 0.5 \times 44$

$m_{CO_2} = 22$ kg

Final Answer: $m_{CO_2} = 22$ kg $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – the salt is conserved; its mass fraction in the product is the salt mass divided by the total product mass: $w_{\text{salt}} = \dfrac{\text{salt in}}{\text{total product}}$.

Step 1 – salt entering with the first stream: $m_{\text{salt}} = 60 \times 0.20 = 12$ kg/h

Step 2 – total mass of the product stream (overall balance): $m_{\text{total}} = 60 + 40 =$

100 kg/h

Step 3 – form the salt mass fraction in the product: $w_{\text{salt}} = \dfrac{12}{100}$

Step 4 – evaluate: $w_{\text{salt}} = 0.12$

Final Answer: $w_{\text{salt}} = 0.12 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – first law for a closed system: $\Delta U = Q - W$, with Q the heat added to the system and W the work done *by* the system.

Step 1 – assign the heat term: The process is adiabatic, so $Q = 0$.

Step 2 – assign the work term: Work is done *on* the system, so the work done *by* the system is negative: $W = -250$ J.

Step 3 – substitute into the first law: $\Delta U = 0 - (-250)$

Step 4 – evaluate: $\Delta U = +250$ J

Final Answer: $\Delta U = +250$ J $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – entropy change of an ideal gas in an isothermal reversible expansion: $\Delta S = R \ln\left(\dfrac{V_2}{V_1}\right)$.

Step 1 – list the data: $R = 8.314$ J/mol·K, and the volume doubles so $\dfrac{V_2}{V_1} = 2$.

Step 2 – take the logarithm of the volume ratio: $\ln 2 = 0.6931$

Step 3 – multiply by R: $\Delta S = 8.314 \times 0.6931$

Step 4 – evaluate: $\Delta S = 5.763$ J/K ≈ 5.76 J/K

Final Answer: $\Delta S \approx 5.76$ J/K $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – Mayer's relation between the molar heat capacities of an ideal gas: $C_p - C_v = R$, so $C_p = C_v + R$.

Step 1 – list the data: $C_v = 20.8$ J/mol·K, $R = 8.314$ J/mol·K.

Step 2 – add R to C_v: $C_p = 20.8 + 8.314$

Step 3 – evaluate: $C_p = 29.114$ J/mol·K ≈ 29.1 J/mol·K

Final Answer: $C_p \approx 29.1$ J/mol·K $\Rightarrow$ C

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – relation between standard Gibbs energy and the equilibrium constant: $\Delta G^\circ = -RT \ln K$.

Step 1 – list the data: $R = 8.314$ J/mol·K, $T = 300$ K, $K = 10$.

Step 2 – take the logarithm of the equilibrium constant: $\ln 10 = 2.3026$

Step 3 – form the product RT: $RT = 8.314 \times 300 = 2494.2$ J/mol

Step 4 – multiply by the logarithm and apply the minus sign: $\Delta G^\circ = -2494.2 \times 2.3026$

$\Delta G^\circ = -5743$ J/mol

Step 5 – express in kilojoules: $\Delta G^\circ \approx -5.74$ kJ/mol

Final Answer: $\Delta G^\circ \approx -5.74$ kJ/mol $\Rightarrow$ D

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – equilibrium vapour composition from constant relative volatility: $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$.

Step 1 – list the data: $\alpha = 3$, $x = 0.25$.

Step 2 – evaluate the numerator: $\alpha x = 3 \times 0.25 = 0.75$

Step 3 – evaluate the denominator: $1 + (\alpha - 1)x = 1 + (2)(0.25) = 1 + 0.5 = 1.5$

Step 4 – divide: $y = \dfrac{0.75}{1.5}$

Step 5 – evaluate: $y = 0.50$

Final Answer: $y = 0.50 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – Gibbs phase rule: $F = C - P + 2$, where C is the number of components and P the number of phases in equilibrium.

Step 1 – identify the components: A pure substance has $C = 1$.

Step 2 – identify the phases at the triple point: Solid, liquid and vapour coexist, so $P = 3$.

Step 3 – substitute into the phase rule: $F = 1 - 3 + 2$

Step 4 – evaluate: $F = 0$

Interpretation: zero degrees of freedom means the triple point is fixed (invariant); neither temperature nor pressure may be varied while all three phases persist.

Final Answer: $F = 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept – coefficient of performance of a Carnot refrigerator: $\text{COP} = \dfrac{T_C}{T_H - T_C}$, with temperatures in kelvin.

Step 1 – list the temperatures: $T_C = 250$ K, $T_H = 300$ K.

Step 2 – find the temperature difference: $T_H - T_C = 300 - 250 = 50$ K

Step 3 – form the ratio: $\text{COP} = \dfrac{250}{50}$

Step 4 – evaluate: $\text{COP} = 5.0$

Final Answer: $\text{COP} = 5.0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – continuity for an incompressible fluid: $A_1V_1 = A_2V_2$, and since $A \propto D^2$, this gives $V_2 = V_1\left(\frac{D_1}{D_2}\right)^2$.

Step 1 – list the data: $D_1 = 100$ mm, $D_2 = 50$ mm, $V_1 = 1$ m/s.

Step 2 – form the diameter ratio: $\frac{D_1}{D_2} = \frac{100}{50} = 2$

Step 3 – square the ratio: $\left(\frac{D_1}{D_2}\right)^2 = 2^2 = 4$

Step 4 – multiply by the inlet velocity: $V_2 = 1 \times 4$

$V_2 = 4$ m/s

Final Answer: $V_2 = 4$ m/s $\Rightarrow$ B

Answer: (B) Go Back to Q11

Q12.

Solution

Concept – dynamic pressure of a moving fluid: $q = \frac{1}{2}\rho V^2$.

Step 1 – list the data: $\rho = 1000$ kg/m^3, $V = 3$ m/s.

Step 2 – square the velocity: $V^2 = 3^2 = 9$ m^2/s^2

Step 3 – substitute: $q = 0.5 \times 1000 \times 9$

Step 4 – multiply stepwise: $0.5 \times 1000 = 500$

$500 \times 9 = 4500$ Pa

Step 5 – express in kilopascals: $q = 4.5$ kPa

Final Answer: $q = 4.5$ kPa $\Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – Reynolds number for pipe flow: $Re = \frac{\rho V D}{\mu}$.

Step 1 – list the data in SI units: $\rho = 1000$ kg/m^3, $V = 0.05$ m/s, $D = 20$ mm $= 0.02$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – evaluate the numerator: $\rho V D = 1000 \times 0.05 \times 0.02$

$= 1.0$

Step 3 – divide by the viscosity: $Re = \dfrac{1.0}{1 \times 10^{-3}}$

Step 4 – evaluate: $Re = 1000$

Note: $Re = 1000 < 2300$, so the flow is laminar.

Final Answer: $Re = 1000 \Rightarrow$ B

Answer: (B) Go Back to Q13

Q14.

Solution

Concept – Darcy–Weisbach head loss: $h_f = f \dfrac{L}{D} \dfrac{V^2}{2g}$.

Step 1 – list the data: $f = 0.02$, $L = 100$ m, $D = 0.1$ m, $V = 2$ m/s, $g = 9.81$ m/s^2.

Step 2 – evaluate the length-to-diameter ratio: $\dfrac{L}{D} = \dfrac{100}{0.1} = 1000$

Step 3 – evaluate the velocity-head term: $\dfrac{V^2}{2g} = \dfrac{2^2}{2 \times 9.81} = \dfrac{4}{19.62} = 0.2039$ m

Step 4 – multiply the three factors: $h_f = 0.02 \times 1000 \times 0.2039$

Step 5 – multiply stepwise: $0.02 \times 1000 = 20$

$20 \times 0.2039 = 4.077$ m

Step 6 – round: $h_f \approx 4.08$ m

Final Answer: $h_f \approx 4.08$ m $\Rightarrow$ C

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – Archimedes' principle for a fully submerged body: $F_B = \rho g V$, where V is the volume of liquid displaced.

Step 1 – list the data: $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $V = 0.002$ m^3.

Step 2 – multiply the density and gravity: $\rho g = 1000 \times 9.81 = 9810$ N/m^3

Step 3 – multiply by the volume: $F_B = 9810 \times 0.002$

Step 4 – evaluate: $F_B = 19.62$ N

Final Answer: $F_B = 19.62$ N $\Rightarrow$ B

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – in the Stokes regime the terminal velocity scales with the square of the diameter: $v_t \propto d^2$ (same particle density and fluid).

Step 1 – write the ratio of the two terminal velocities: $\dfrac{v_{t,2}}{v_{t,1}} = \left(\dfrac{d_2}{d_1}\right)^2$

Step 2 – insert the diameter ratio: $\dfrac{d_2}{d_1} = 2$

Step 3 – square it: $\dfrac{v_{t,2}}{v_{t,1}} = 2^2$

Step 4 – evaluate: $\dfrac{v_{t,2}}{v_{t,1}} = 4$

Why option A is wrong: 2 is the diameter ratio itself; the velocity depends on the *square* of the diameter, so the ratio is 4.

Final Answer: ratio $= 4 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – size-reduction ratio of a crusher: reduction ratio $= \dfrac{\text{feed size}}{\text{product size}}$.

Step 1 – read the sizes from the diagram: Feed size $= 60$ mm, product size $= 15$ mm.

Step 2 – form the ratio: reduction ratio $= \dfrac{60}{15}$

Step 3 – evaluate: reduction ratio $= 4$

Final Answer: reduction ratio $= 4 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q17

Q18.

Solution

Concept – the three classic size-reduction laws differ in what the energy is proportional to: Rittinger → new surface; Bond → crack length; Kick → size ratio.

Step 1 – recall Kick's statement: Energy per unit mass is proportional to $\ln(d_1/d_2)$, i.e. to the logarithm of the size-reduction ratio.

Step 2 – match it to the application: Because the energy depends only on the size ratio, Kick's law is best suited to coarse crushing, where the ratio (not the new surface) dominates.

Why the other options are wrong:

- Rittinger's law: energy $\propto \left(\frac{1}{d_2} - \frac{1}{d_1}\right)$, suited to fine grinding.
- Bond's law: energy $\propto \left(\frac{1}{\sqrt{d_2}} - \frac{1}{\sqrt{d_1}}\right)$, used for intermediate crushing.
- Stokes' law: a settling law, not a size-reduction law.

Final Answer: Kick's law $\Rightarrow$ B

Answer: (B) Go Back to Q18

Q19.

Solution

Concept – operating speed as a fraction of the critical speed of a ball mill: $n_c = \dfrac{42.3}{\sqrt{D}}$ rpm, then $n_{\text{op}} = 0.70\, n_c$.

Step 1 – list the data: $D = 0.9$ m, operating fraction $= 0.70$.

Step 2 – take the square root of the diameter: $\sqrt{0.9} = 0.9487$

Step 3 – compute the critical speed: $n_c = \dfrac{42.3}{0.9487} = 44.59$ rpm

Step 4 – take 70% of the critical speed: $n_{\text{op}} = 0.70 \times 44.59$

Step 5 – evaluate: $n_{\text{op}} = 31.2$ rpm

Final Answer: $n_{\text{op}} \approx 31.2$ rpm $\Rightarrow$ C

Answer: (C) Go Back to Q19

Q20.

Solution

Concept – conductive thermal resistance of a plane wall: $R = \dfrac{L}{k\,A}$.

Step 1 – list the data: $L = 0.2$ m, $k = 0.4$ W/m·K, $A = 2$ m^2.

Step 2 – evaluate the denominator: $k\,A = 0.4 \times 2 = 0.8$ W/K

Step 3 – divide the thickness by the denominator: $R = \dfrac{0.2}{0.8}$

Step 4 – evaluate: $R = 0.25$ K/W

Final Answer: $R = 0.25$ K/W $\Rightarrow$ D

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – for convection–conduction–convection in series the resistances add per unit area: $\dfrac{1}{U} = \dfrac{1}{h_1} + \dfrac{L}{k} + \dfrac{1}{h_2}$.

Step 1 – list the three resistances (per unit area): $\dfrac{1}{h_1} = \dfrac{1}{10} = 0.1$, $\dfrac{L}{k} = 0.05$, $\dfrac{1}{h_2} = \dfrac{1}{10} = 0.1$.

Step 2 – add the resistances: $\dfrac{1}{U} = 0.1 + 0.05 + 0.1$

$\dfrac{1}{U} = 0.25$ m^2·K/W

Step 3 – invert to obtain the overall coefficient: $U = \dfrac{1}{0.25}$

Step 4 – evaluate: $U = 4$ W/m^2·K

Final Answer: $U = 4$ W/m^2·K $\Rightarrow$ A

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – the Biot number compares internal conduction resistance with surface convection resistance: $\mathrm{Bi} = \dfrac{h\,L_c}{k}$.

Step 1 – list the data: $h = 100$ W/m^2·K, $L_c = 0.01$ m, $k = 50$ W/m·K.

Step 2 – evaluate the numerator: $h\,L_c = 100 \times 0.01 = 1.0$ W/m·K

Step 3 – divide by the conductivity: $\text{Bi} = \dfrac{1.0}{50}$

Step 4 – evaluate: $\text{Bi} = 0.02$

Note: $\text{Bi} = 0.02 < 0.1$, so the lumped-capacitance approximation is valid.

Final Answer: $\text{Bi} = 0.02 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – log-mean temperature difference: $\text{LMTD} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$.

Step 1 – temperature difference at the inlet end (both fluids enter): $\Delta T_1 = 120 - 30 = 90\ ^\circ\text{C}$

Step 2 – temperature difference at the outlet end: $\Delta T_2 = 80 - 60 = 20\ ^\circ\text{C}$

Step 3 – take the difference of the two: $\Delta T_1 - \Delta T_2 = 90 - 20 = 70$

Step 4 – take the log of the ratio: $\ln\left(\dfrac{90}{20}\right) = \ln(4.5) = 1.5041$

Step 5 – divide: $\text{LMTD} = \dfrac{70}{1.5041} = 46.54\ ^\circ\text{C}$

Step 6 – round: $\text{LMTD} \approx 46.5\ ^\circ\text{C}$

Final Answer: $\text{LMTD} \approx 46.5\ ^\circ\text{C} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – effectiveness of a counter-flow exchanger with a balanced capacity ratio ($C_r = 1$): $\varepsilon = \dfrac{\text{NTU}}{1 + \text{NTU}}$.

Step 1 – list the data: $\text{NTU} = 1$, $C_r = 1$.

Step 2 – form the denominator: $1 + \text{NTU} = 1 + 1 = 2$

Step 3 – form the ratio: $\varepsilon = \dfrac{1}{2}$

Step 4 – evaluate: $\varepsilon = 0.5$

Final Answer: $\varepsilon = 0.5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – thermal diffusivity relates conduction to thermal storage: $\alpha = \dfrac{k}{\rho\, c_p}$.

Step 1 – list the data: $k = 0.6$ W/m·K, $\rho = 1000$ kg/m^3, $c_p = 4200$ J/kg·K.

Step 2 – evaluate the denominator: $\rho\, c_p = 1000 \times 4200 = 4.2 \times 10^6$ J/m^3·K

Step 3 – divide: $\alpha = \dfrac{0.6}{4.2 \times 10^6}$

Step 4 – evaluate: $\alpha = 1.4286 \times 10^{-7}$ m^2/s $\approx 1.43 \times 10^{-7}$ m^2/s

Final Answer: $\alpha \approx 1.43 \times 10^{-7}$ m^2/s $\Rightarrow$ D

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – emissive power of a grey surface: $E = \varepsilon\, \sigma\, T^4$.

Step 1 – list the data: $\varepsilon = 0.8$, $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, $T = 400$ K.

Step 2 – raise the temperature to the fourth power: $T^4 = (400)^4 = 2.56 \times 10^{10}$ K^4

Step 3 – multiply by the Stefan–Boltzmann constant: $\sigma T^4 = 5.67 \times 10^{-8} \times 2.56 \times 10^{10}$

$= 1451.5$ W/m^2

Step 4 – multiply by the emissivity: $E = 0.8 \times 1451.5$

$E = 1161.2$ W/m^2

Step 5 – round: $E \approx 1161$ W/m^2

Why option B is wrong: 1451 W/m^2 is the black-body value σT^4; the grey surface emits only a fraction $\varepsilon = 0.8$ of it.

Final Answer: $E \approx 1161$ W/m^2 $\Rightarrow$ D

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – rate equation for an evaporator heating surface: $Q = U\,A\,\Delta T$, so $U = \dfrac{Q}{A\,\Delta T}$.

Step 1 – list the data in SI units: $Q = 200$ kW $= 200{,}000$ W, $A = 10$ m^2, $\Delta T = 20$ K.

Step 2 – evaluate the denominator: $A\,\Delta T = 10 \times 20 = 200$ m^2·K

Step 3 – divide: $U = \dfrac{200{,}000}{200}$

Step 4 – evaluate: $U = 1000$ W/m^2·K

Final Answer: $U = 1000$ W/m^2·K $\Rightarrow$ A

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – the Sherwood number is the dimensionless mass-transfer coefficient: $\mathrm{Sh} = \dfrac{k_c\,L}{D}$.

Step 1 – list the data: $k_c = 1 \times 10^{-2}$ m/s, $L = 0.1$ m, $D = 1 \times 10^{-5}$ m^2/s.

Step 2 – evaluate the numerator: $k_c\,L = 1 \times 10^{-2} \times 0.1 = 1 \times 10^{-3}$

Step 3 – divide by the diffusivity: $\mathrm{Sh} = \dfrac{1 \times 10^{-3}}{1 \times 10^{-5}}$

Step 4 – subtract the exponents: $\mathrm{Sh} = 1 \times 10^{-3-(-5)} = 1 \times 10^{2}$

Step 5 – state the result: $\mathrm{Sh} = 100$

Final Answer: $\mathrm{Sh} = 100 \Rightarrow$ C

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – the Schmidt number compares momentum diffusivity with mass diffusivity: $\mathrm{Sc} = \dfrac{\mu}{\rho\,D}$.

Step 1 – list the data: $\mu = 1 \times 10^{-3}$ Pa·s, $\rho = 1000$ kg/m^3, $D = 2 \times 10^{-9}$ m^2/s.

Step 2 – evaluate the denominator: $\rho\,D = 1000 \times 2 \times 10^{-9} = 2 \times 10^{-6}$

Step 3 – divide: $\mathrm{Sc} = \dfrac{1 \times 10^{-3}}{2 \times 10^{-6}}$

Step 4 – evaluate: $\mathrm{Sc} = 500$

Final Answer: $\mathrm{Sc} = 500 \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – Henry's law for a dilute solute: $p = H\,x$.

Step 1 – list the data: $H = 50$ kPa per unit mole fraction, $x = 0.02$.

Step 2 – substitute: $p = 50 \times 0.02$

Step 3 – evaluate: $p = 1.0$ kPa

Final Answer: $p = 1.0$ kPa $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – slope of the rectifying operating line in McCabe–Thiele: slope $= \dfrac{R}{R+1}$, which can be inverted to find R.

Step 1 – write the slope equation with the measured value: $\dfrac{R}{R+1} = 0.8$

Step 2 – cross-multiply: $R = 0.8\,(R+1)$

Step 3 – expand the right-hand side: $R = 0.8R + 0.8$

Step 4 – collect the R terms: $R - 0.8R = 0.8$

$0.2R = 0.8$

Step 5 – solve for R: $R = \dfrac{0.8}{0.2} = 4$

Final Answer: $R = 4 \Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – overall and component material balances on a distillation column: $F = D + W$ and $F\,x_F = D\,x_D + W\,x_W$.

Step 1 – list the data: $F = 100$ mol/h, $x_F = 0.5$, $x_D = 0.9$, $x_W = 0.1$.

Step 2 – write the overall balance: $W = F - D = 100 - D$

Step 3 – write the component balance: $100 \times 0.5 = 0.9\,D + 0.1\,W$

$50 = 0.9\,D + 0.1\,W$

Step 4 – substitute $W = 100 - D$: $50 = 0.9\,D + 0.1\,(100 - D)$

Step 5 – expand: $50 = 0.9\,D + 10 - 0.1\,D$

Step 6 – collect the D terms: $50 - 10 = 0.8\,D$

$40 = 0.8\,D$

Step 7 – solve for D: $D = \dfrac{40}{0.8} = 50$ mol/h

Final Answer: $D = 50$ mol/h $\Rightarrow$ B

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – stripping factor: $S = \dfrac{m\,G}{L}$.

Step 1 – list the data: $m = 2$, $G = 50$ mol/h, $L = 200$ mol/h.

Step 2 – evaluate the numerator: $m\,G = 2 \times 50 = 100$

Step 3 – divide by the liquid rate: $S = \dfrac{100}{200}$

Step 4 – evaluate: $S = 0.5$

Final Answer: $S = 0.5 \Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – packing height as a product of transfer-unit terms: $Z = \text{HTU} \times \text{NTU}$, so $\text{NTU} = \dfrac{Z}{\text{HTU}}$.

Step 1 – list the data: $Z = 4$ m, HTU $= 0.8$ m.

Step 2 – divide: NTU $= \dfrac{4}{0.8}$

Step 3 – evaluate: NTU $= 5$

Final Answer: NTU $= 5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – distribution (partition) coefficient in liquid–liquid extraction: $K_D = \dfrac{y}{x}$, so $y = K_D\, x$.

Step 1 – list the data: $K_D = 4$, $x = 0.05$.

Step 2 – substitute: $y = 4 \times 0.05$

Step 3 – evaluate: $y = 0.20$

Final Answer: $y = 0.20 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – free moisture is the moisture above the equilibrium value: $X_{\text{free}} = X_{\text{total}} - X^*$.

Step 1 – list the data: Total moisture $X_{\text{total}} = 0.30$ kg/kg, equilibrium moisture $X^* = 0.05$ kg/kg.

Step 2 – subtract: $X_{\text{free}} = 0.30 - 0.05$

Step 3 – evaluate: $X_{\text{free}} = 0.25$ kg/kg

Note: only the free moisture can be removed by drying; the equilibrium moisture stays with the solid.

Final Answer: $X_{\text{free}} = 0.25$ kg/kg $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – half-life of a second-order reaction: $t_{1/2} = \dfrac{1}{k\,C_{A0}}$ (it depends on the initial concentration).

Step 1 – list the data: $k = 0.5$ L/mol·min, $C_{A0} = 2$ mol/L.

Step 2 – evaluate the denominator: $k\,C_{A0} = 0.5 \times 2 = 1.0\ \text{min}^{-1}$

Step 3 – take the reciprocal: $t_{1/2} = \dfrac{1}{1.0}$

Step 4 – evaluate: $t_{1/2} = 1$ min

Final Answer: $t_{1/2} = 1$ min $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – CSTR design equation for a first-order reaction, then the reactor volume: $\tau = \dfrac{X}{k(1-X)}$ and $V = \tau\,Q$.

Step 1 – list the data: $k = 0.2\ \text{min}^{-1}$, $X = 0.8$, $Q = 10$ L/min.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.8 = 0.2$

Step 3 – compute the denominator: $k(1-X) = 0.2 \times 0.2 = 0.04\ \text{min}^{-1}$

Step 4 – compute the space time: $\tau = \dfrac{0.8}{0.04} = 20$ min

Step 5 – multiply by the volumetric flow to get the volume: $V = \tau\,Q = 20 \times 10$

Step 6 – evaluate: $V = 200$ L

Final Answer: $V = 200$ L $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – PFR design equation for a zero-order reaction: $\tau = \dfrac{C_{A0}\,X}{k}$ (the rate is constant until the reactant is exhausted).

Step 1 – list the data: $C_{A0} = 2$ mol/L, $X = 0.5$, $k = 0.1$ mol/L·min.

Step 2 – evaluate the numerator: $C_{A0}\,X = 2 \times 0.5 = 1.0$ mol/L

Step 3 – divide by the rate constant: $\tau = \dfrac{1.0}{0.1}$

Step 4 – evaluate: $\tau = 10$ min

Final Answer: $\tau = 10$ min $\Rightarrow$ C

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – reaction order from how the rate responds to concentration: if $-r_A = k\,C_A^n$, then doubling C_A multiplies the rate by 2^n.

Step 1 – write the observed rate ratio: $\dfrac{(-r_A)_2}{(-r_A)_1} = 2^n = 4$

Step 2 – express 4 as a power of 2: $4 = 2^2$

Step 3 – equate the exponents: $2^n = 2^2 \Rightarrow n = 2$

Final Answer: $n = 2 \Rightarrow$ A

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – space velocity is the volumetric feed rate per unit reactor volume: $\text{SV} = \dfrac{Q}{V}$ (the reciprocal of the space time).

Step 1 – list the data: $Q = 25$ L/min, $V = 50$ L.

Step 2 – divide: $\text{SV} = \dfrac{25}{50}$

Step 3 – evaluate: $\text{SV} = 0.5\ \text{min}^{-1}$

Final Answer: $\text{SV} = 0.5\ \text{min}^{-1} \Rightarrow$ A

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – Thiele modulus for a first-order reaction in a slab catalyst: $\phi = L\sqrt{\dfrac{k}{D_e}}$.

Step 1 – list the data: $L = 1 \times 10^{-3}$ m, $k = 4 \times 10^{-3}$ s^{-1}, $D_e = 1 \times 10^{-9}$ m^2/s.

Step 2 – form the ratio under the root: $\dfrac{k}{D_e} = \dfrac{4 \times 10^{-3}}{1 \times 10^{-9}} = 4 \times 10^{6}\ \text{m}^{-2}$

Step 3 – take the square root: $\sqrt{4 \times 10^{6}} = 2 \times 10^{3}\ \text{m}^{-1}$

Step 4 – multiply by the half-thickness: $\phi = 1 \times 10^{-3} \times 2 \times 10^{3}$

Step 5 – evaluate: $\phi = 2$

Final Answer: $\phi = 2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – ultimate response of a first-order system to a step input: as $t \to \infty$ the exponential term vanishes, leaving $y(\infty) = K\,\Delta u$.

Step 1 – list the data: $K = 5$, step magnitude $\Delta u = 2$.

Step 2 – take the limit of the response: As $t \to \infty$, $e^{-t/\tau} \to 0$, so $y(\infty) = K\,\Delta u\,(1 - 0)$.

Step 3 – multiply: $y(\infty) = 5 \times 2$

Step 4 – evaluate: $y(\infty) = 10$

Note: the time constant τ sets how fast the output approaches this value, but not the final value itself.

Final Answer: $y(\infty) = 10 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – damped natural frequency of an underdamped second-order system: $\omega_d = \omega_n\sqrt{1 - \zeta^2}$.

Step 1 – list the data: $\omega_n = 2$ rad/s, $\zeta = 0.5$.

Step 2 – evaluate ζ^2: $\zeta^2 = 0.5^2 = 0.25$

Step 3 – form the term under the root: $1 - \zeta^2 = 1 - 0.25 = 0.75$

Step 4 – take the square root: $\sqrt{0.75} = 0.8660$

Step 5 – multiply by the natural frequency: $\omega_d = 2 \times 0.8660$

Step 6 – evaluate: $\omega_d = 1.732$ rad/s ≈ 1.73 rad/s

Final Answer: $\omega_d \approx 1.73$ rad/s $\Rightarrow$ C

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – integral action removes steady-state offset: the integral term keeps changing the controller output as long as any error exists, so at steady state the error must be zero.

Step 1 – recall why proportional-only control leaves offset: A pure proportional controller needs a non-zero error to hold a non-zero output, so a residual offset remains.

Step 2 – add integral action: The integral mode integrates the error over time; its output stops changing only when the error becomes zero, which eliminates the offset.

Why the other options are wrong:

- Proportional action alone leaves the offset.
- Derivative action responds to the rate of change of error, not to a steady error, so it cannot remove offset.
- On–off action produces continuous cycling, not offset-free steady control.

Final Answer: integral action $\Rightarrow$ B

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – simple payback period: $\text{payback} = \dfrac{\text{fixed-capital investment}}{\text{net annual cash flow}}$.

Step 1 – list the data: Investment $=$ Rs. $5{,}00{,}000$, annual cash flow $=$ Rs. $1{,}25{,}000$.

Step 2 – form the ratio: $\text{payback} = \dfrac{5{,}00{,}000}{1{,}25{,}000}$

Step 3 – evaluate: payback $= 4$ years

Final Answer: payback $= 4$ years $\Rightarrow$ B

Answer: (B) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	D	4	A	5	B
6	C	7	D	8	A	9	A	10	D
11	B	12	C	13	B	14	C	15	B
16	D	17	D	18	B	19	C	20	D
21	A	22	D	23	A	24	A	25	D
26	D	27	A	28	C	29	B	30	B
31	C	32	B	33	C	34	A	35	A
36	D	37	B	38	D	39	C	40	A
41	A	42	C	43	A	44	C	45	B
46	B								