GATE Chemical Engineering

Sample Paper – 2

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 contains 25 mol% oxygen (molar mass 32) and 75 mol% nitrogen (molar mass 28). The average molar mass of the mixture is: **[1 mark]**

(A) 29.0

(B) 30.0

(C) 28.0

(D) 32.0

Q2. Methane is burnt completely following $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$. When 8 kg of methane (molar mass 16) is burnt completely, the mass of water (molar mass 18) formed is: **[1 mark]**

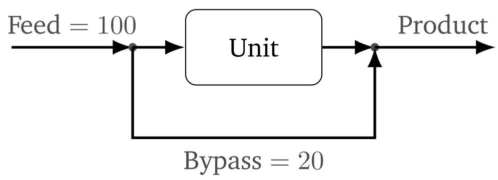
(A) 18 kg

(B) 9 kg

(C) 36 kg

(D) 22 kg

Q3. In the steady arrangement shown, a feed stream of 100 mol/h is split so that part of it passes through a processing unit while the remaining 20 mol/h bypasses the unit. The bypass fraction (bypass flow divided by total feed) is: **[1 mark]**



(A) 0.80

(B) 0.20

(C) 0.25

(D) 5.0

Q4. A gas is compressed inside a rigid, perfectly insulated cylinder. During the process 150 J of work is done *on* the gas and no heat crosses the boundary. By the first law of thermodynamics ($\Delta U = Q - W$, W being work done *by* the system), the change in the internal energy of the gas is: **[1 mark]**

(A) $+150$ J

(B) -150 J

(C) 0 J

(D) $+300$ J

Q5. Two moles of an ideal gas expand isothermally and reversibly to twice their initial volume. The entropy change of the gas, $\Delta S = nR\ln(V_2/V_1)$, is nearest to: **[1 mark]**

(A) 5.76 J/K

(B) 11.5 J/K

(C) 8.31 J/K

(D) 23.1 J/K

Q6. Carbon dioxide (molar mass 44) behaves as an ideal gas at a temperature of 300 K and a pressure of 1 bar (10^5 Pa). Taking $R = 8.314$ J/mol·K, the density of the gas, $\rho = PM/(RT)$, is nearest to: **[1 mark]**

(A) 0.88 kg/m^3

(B) 44.0 kg/m^3

(C) 1.76 kg/m^3

(D) 3.53 kg/m^3

Q7. For an exothermic gas-phase reaction at equilibrium, the temperature is increased at constant pressure. According to the van't Hoff relation, the thermodynamic equilibrium constant K of the reaction: **[1 mark]**

(A) increases

(B) remains unchanged

(C) decreases

(D) becomes exactly zero

Q8. A benzene (A)–toluene (B) liquid mixture behaves ideally. At the system temperature $P_A^{sat} = 120$ kPa and $P_B^{sat} = 80$ kPa. For a liquid of composition $x_A = 0.4$, the mole fraction of A in the equilibrium vapour, $y_A = x_A P_A^{sat}/P$, is: **[1 mark]**

(A) 0.40

(B) 0.60

(C) 0.44

(D) 0.50

Q9. One mole of a real gas occupies a volume of 0.010 m^3 at a temperature of 300 K and a pressure of 2×10^5 Pa. Taking $R = 8.314$ J/mol·K, the compressibility factor $Z = PV/(nRT)$ of the gas at this state is nearest to: **[1 mark]**

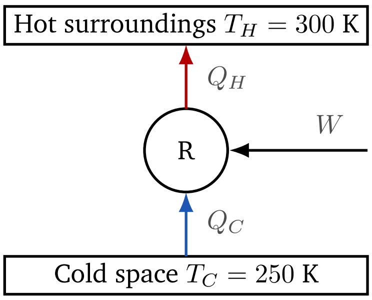
(A) 1.00

(B) 0.80

(C) 1.25

(D) 0.50

Q10. A reversible Carnot refrigerator maintains a cold space at 250 K while rejecting heat to surroundings at 300 K. Its coefficient of performance, COP $= T_C/(T_H - T_C)$, is: **[1 mark]**



(A) 6.0

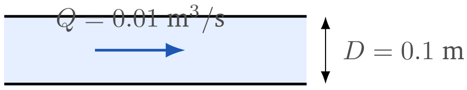
(B) 5.0

(C) 0.83

(D) 1.2

Fluid Mechanics & Mechanical Operations

Q11. Water flows steadily at a volumetric rate $Q = 0.01$ m^3/s through a circular pipe of internal diameter $D = 0.1$ m, as shown. From continuity, the mean flow velocity $V = Q/A$ (with $A = \frac{\pi}{4}D^2$) is nearest to: **[1 mark]**



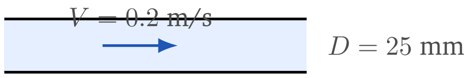
(A) 1.27 m/s

(B) 0.10 m/s

(C) 2.55 m/s

(D) 0.64 m/s

Q12. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 25 mm at a mean velocity of 0.2 m/s, as sketched. The Reynolds number $Re = \rho V D/\mu$ of the flow is: **[1 mark]**



(A) 2500

(B) 5000

(C) 10000

(D) 1250

Q13. Water flows through a horizontal pipe of length $L = 100$ m and diameter $D = 0.1$ m at a mean velocity $V = 2$ m/s. The Darcy friction factor is $f = 0.02$. The frictional head loss, $h_f = f \dfrac{L}{D}\dfrac{V^2}{2g}$, is nearest to: **[1 mark]**

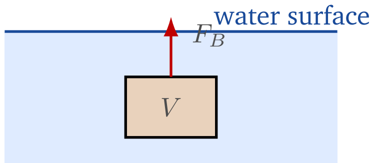
(A) 2.04 m

(B) 8.16 m

(C) 4.08 m

(D) 1.02 m

Q14. A solid body of volume 0.05 m^3 is fully submerged in water of density 1000 kg/m^3, as shown. The buoyant (upthrust) force on the body, $F_B = \rho_w \, g \, V$, is nearest to: **[1 mark]**



(A) 981 N

(B) 490.5 N

(C) 245 N

(D) 50 N

Q15. Air of density 1.2 kg/m^3 flows over a body at a free-stream velocity of 10 m/s. The dynamic (velocity) pressure of the stream, $q = \frac{1}{2}\rho V^2$, is: **[1 mark]**

(A) 60 Pa

(B) 120 Pa

(C) 6 Pa

(D) 12 Pa

Q16. A powder consists of uniform spherical particles of diameter $d = 1$ mm and solid density $\rho_p = 2000$ kg/m^3. The specific surface area per unit mass of solid, $a_w = 6/(\rho_p\, d)$, is: **[1 mark]**

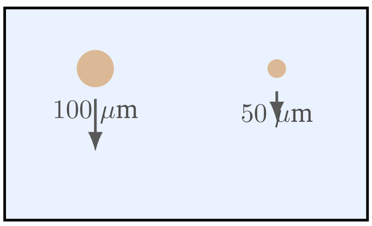
(A) 6.0 m^2/kg

(B) 3.0 m^2/kg

(C) 1.5 m^2/kg

(D) 12.0 m^2/kg

Q17. Two spherical particles of the same material (equal density) settle in the Stokes' law regime in the same liquid. Their diameters are 100 μm and 50 μm, as shown. Since $v_t \propto d^2$, the ratio of the terminal velocity of the larger particle to that of the smaller particle is: **[1 mark]**



(A) 2.0

(B) 0.5

(C) 0.25

(D) 4.0

Q18. For the flow of a fluid through a straight circular pipe, the flow is generally regarded as laminar as long as the Reynolds number stays below the accepted critical value of about: **[1 mark]**

(A) 4000

(B) 10000

(C) 2100

(D) 500

Q19. A centrifugal pump running at 1450 rpm delivers a discharge of $0.02\ \text{m}^3/\text{s}$. If the speed is doubled to 2900 rpm, then, from the pump affinity law $Q \propto N$, the new discharge is: **[1 mark]**

(A) $0.04\ \text{m}^3/\text{s}$

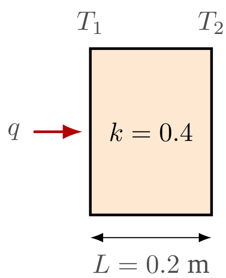
(B) $0.02\ \text{m}^3/\text{s}$

(C) $0.08\ \text{m}^3/\text{s}$

(D) $0.01\ \text{m}^3/\text{s}$

Heat Transfer

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



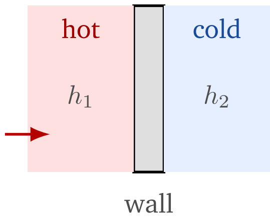
(A) 1.0 K/W

(B) 0.5 K/W

(C) 0.1 K/W

(D) 0.25 K/W

Q21. Heat is transferred from a hot fluid to a cold fluid across a plane wall whose own conduction resistance is negligible. The two convective film coefficients are $h_1 = 100$ W/m^2·K and $h_2 = 100$ W/m^2·K, as shown. The overall heat-transfer coefficient from $\frac{1}{U} = \frac{1}{h_1} + \frac{1}{h_2}$ is: **[2 marks]**



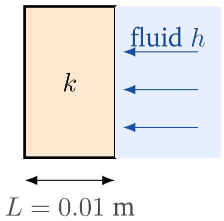
(A) 50 W/m^2·K

(B) 100 W/m^2·K

(C) 200 W/m^2·K

(D) 25 W/m^2·K

Q22. A slab of thickness $L = 0.01$ m and thermal conductivity $k = 50$ W/m·K is cooled at its surface by a fluid with convective coefficient $h = 100$ W/m^2·K, as sketched. The Biot number of the slab, $Bi = hL/k$, is: **[2 marks]**



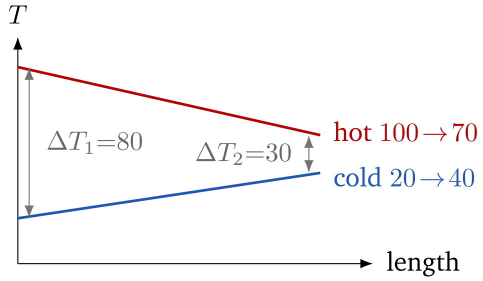
(A) 0.5

(B) 0.2

(C) 2.0

(D) 0.02

Q23. In the co-current (parallel-flow) double-pipe exchanger whose temperature profile is sketched, a hot fluid is cooled from 100 °C to 70 °C while a cold fluid is heated from 20 °C to 40 °C. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



(A) 51.0 °C

(B) 55.0 °C

(C) 40.0 °C

(D) 48.0 °C

Q24. In a heat exchanger the hot stream enters at 100 °C and the cold stream enters at 20 °C. The minimum heat-capacity rate is $C_{\min} = 1000$ W/K and the actual heat-transfer rate is 40,000 W. The exchanger effectiveness, $\varepsilon = \dfrac{Q_{\text{actual}}}{C_{\min}(T_{h,\text{in}} - T_{c,\text{in}})}$, is: **[2 marks]**

(A) 0.5

(B) 1.0

(C) 0.25

(D) 0.8

Q25. A gray surface of emissivity $\varepsilon = 0.8$ is held at a temperature of 400 K. Taking the Stefan–Boltzmann constant as $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the emissive power of the surface, $E = \varepsilon \sigma T^4$, is nearest to: **[2 marks]**

(A) 1452 W/m^2

(B) 1161 W/m^2

(C) 2322 W/m^2

(D) 581 W/m^2

Q26. Water flows inside a tube of diameter $D = 0.05$ m for which the Nusselt number is $Nu = 100$. Taking the thermal conductivity of water as $k = 0.6$ W/m·K, the convective heat-transfer coefficient, $h = Nu\,k/D$, is: **[2 marks]**

(A) 1200 $\text{W/m}^2\cdot\text{K}$

(B) 600 $\text{W/m}^2\cdot\text{K}$

(C) 2400 $\text{W/m}^2\cdot\text{K}$

(D) 120 $\text{W/m}^2\cdot\text{K}$

Q27. A heat exchanger must transfer $Q = 50{,}000$ W of heat. Its overall heat-transfer coefficient is $U = 500$ $\text{W/m}^2\cdot\text{K}$ and the logarithmic mean temperature difference is 50 K. From $Q = U A\,\Delta T_{lm}$, the required heat-transfer area is: **[2 marks]**

(A) 5.0 m^2

(B) 1.0 m^2

(C) 2.0 m^2

(D) 4.0 m^2

Mass Transfer & Separation Processes

Q28. Component A diffuses at steady state through a stagnant liquid film of thickness $\delta = 1 \times 10^{-3}$ m with molecular diffusivity $D_{AB} = 2 \times 10^{-9}$ m^2/s. Its concentration falls linearly from 5 mol/m^3 at one face to 1 mol/m^3 at the other. Using $N_A = D_{AB}(C_1 - C_2)/\delta$, the molar flux is: **[2 marks]**

(A) 2×10^{-6} $\text{mol/m}^2\cdot\text{s}$

(B) 4×10^{-6} $\text{mol/m}^2\cdot\text{s}$

(C) 1×10^{-5} $\text{mol/m}^2\cdot\text{s}$

(D) 8×10^{-6} $\text{mol/m}^2\cdot\text{s}$

Q29. For mass transfer into a falling liquid film the Sherwood number is $Sh = 200$, based on a characteristic length $L = 0.02$ m. The molecular diffusivity is $D = 2 \times 10^{-9}$ m^2/s. The convective mass-transfer coefficient, $k_c = Sh\, D/L$, is: **[2 marks]**

(A) 4×10^{-5} m/s

(B) 1×10^{-5} m/s

(C) 2×10^{-5} m/s

(D) 2×10^{-7} m/s

Q30. In a gas absorption process described by two-film theory, the gas-side resistance referred to the gas phase is $1/k_y = 0.3$ and the liquid-side resistance referred to the gas phase is $m/k_x = 0.2$ (in consistent units). Using $\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$, the overall gas-phase mass-transfer coefficient K_y is: **[2 marks]**

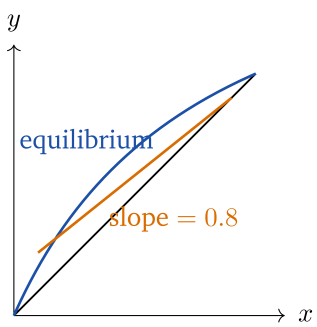
(A) 0.5

(B) 1.0

(C) 5.0

(D) 2.0

Q31. The McCabe–Thiele construction for a distillation column is shown. The rectifying-section operating line has a slope of 0.8, and this slope equals $R/(R+1)$, where R is the reflux ratio. The value of the reflux ratio R is: **[2 marks]**



(A) 2.0

(B) 3.0

(C) 4.0

(D) 5.0

Q32. A binary mixture with constant relative volatility $\alpha = 2.0$ is separated into a distillate of $x_D = 0.98$ and a bottoms of $x_W = 0.02$ (mole fractions of the light key). Using Fenske's equation, $N_{\text{min}} = \dfrac{\ln\left[(x_D/(1-x_D))((1-x_W)/x_W)\right]}{\ln\alpha}$ the minimum number of theoretical stages is nearest to: **[2 marks]**

(A) 7.8

(B) 5.6

(C) 9.0

(D) 11.2

Q33. In a stripping column the gas flow rate is $G = 100$ mol/h, the liquid flow rate is $L = 100$ mol/h and the equilibrium slope is $m = 2.0$. The stripping factor, defined as $S = mG/L$, is: **[2 marks]**

(A) 1.0

(B) 2.0

(C) 0.5

(D) 4.0

Q34. A packed absorption tower is designed using transfer units, with total packing height $Z = \text{HTU} \times \text{NTU}$. For a particular separation the packing height provided is $Z = 6$ m and the height of a transfer unit is $\text{HTU} = 1.5$ m. The number of transfer units achieved is: **[2 marks]**

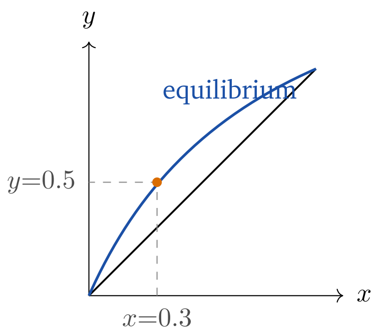
(A) 2.0

(B) 3.0

(C) 4.0

(D) 9.0

Q35. On the equilibrium (y–x) diagram of a binary mixture shown, a liquid of light-key mole fraction $x = 0.3$ is in equilibrium with a vapour of composition $y = 0.5$. The relative volatility of the light key, $\alpha = \dfrac{y/(1-y)}{x/(1-x)}$, is nearest to: **[2 marks]**



(A) 2.33

(B) 1.67

(C) 0.43

(D) 3.0

Q36. A wet solid containing 100 kg of bone-dry material is dried in its constant-rate period from a free-moisture content of $X_1 = 0.30$ kg/kg to $X_2 = 0.10$ kg/kg. The exposed drying area is $A = 5$ m^2 and the constant drying flux is $R_c = 2$ kg/m^2·h. The drying time, $t = \dfrac{L_s(X_1 - X_2)}{A\,R_c}$, is: **[2 marks]**

(A) 5.0 h

(B) 1.0 h

(C) 2.0 h

(D) 4.0 h

Reaction Engineering, Process Control & Plant Economics

Q37. A liquid-phase reaction is second order in the reactant, $-r_A = kC_A^2$, with rate constant $k = 0.05$ L/mol·min and initial concentration $C_{A0} = 2$ mol/L. The half-life, $t_{1/2} = 1/(k\,C_{A0})$, is: **[2 marks]**

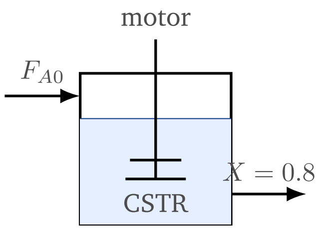
(A) 20.0 min

(B) 10.0 min

(C) 5.0 min

(D) 14.0 min

Q38. A first-order liquid-phase reaction ($-r_A = kC_A$, $k = 0.2$ min^{-1}) is carried out in the ideal CSTR shown to reach a conversion of $X = 0.8$. Using the CSTR design equation $\tau = X/[\,k(1-X)\,]$, the required space time is: **[2 marks]**



(A) 10 min

(B) 5 min

(C) 6.93 min

(D) 20 min

Q39. A first-order liquid-phase reaction with rate constant $k = 0.3$ min^{-1} is carried out in an ideal plug-flow reactor (PFR) with a space time of $\tau = 10$ min. Using $k\tau = -\ln(1-X)$, the fractional conversion at the reactor outlet is nearest to: **[2 marks]**

(A) 0.632

(B) 0.865

(C) 0.950

(D) 0.900

Q40. A homogeneous liquid-phase reaction is second order, $-r_A = kC_A^2$, with rate constant $k = 0.5$ L/mol·min. When the reactant concentration is $C_A = 2$ mol/L, the rate of reaction is: **[2 marks]**

(A) 2.0 mol/L·min

(B) 1.0 mol/L·min

(C) 4.0 mol/L·min

(D) 0.5 mol/L·min

Q41. An ideal CSTR of working volume 200 L is fed by a liquid stream at a constant volumetric flow rate of 25 L/min. The mean residence time of fluid in the reactor, $\tau = V/Q$, is: **[2 marks]**

(A) 25 min

(B) 200 min

(C) 5.0 min

(D) 8.0 min

Q42. A first-order catalytic reaction occurs in a flat porous catalyst slab whose Thiele modulus is $\phi = 2$. The internal effectiveness factor is $\eta = \tanh(\phi)/\phi$. Taking $\tanh(2) = 0.964$, the effectiveness factor is nearest to: **[2 marks]**

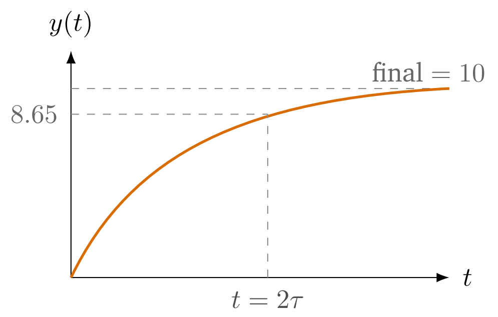
(A) 1.0

(B) 0.96

(C) 0.25

(D) 0.48

Q43. A first-order process with time constant $\tau = 5$ min and a steady-state output change of 10 units is subjected to a step input. Its response follows $y(t) = 10\,(1 - e^{-t/\tau})$, as sketched. The output change at $t = 2\tau$ (two time constants) is nearest to: **[2 marks]**



(A) 10.0

(B) 6.32

(C) 8.65

(D) 9.5

Q44. A closed-loop control system behaves as an underdamped second-order system with damping ratio $\zeta = 0.5$. For a step input the decay ratio is $\exp\left[-2\pi\zeta/\sqrt{1-\zeta^2}\right]$. Its value is nearest to: **[2 marks]**

(A) 0.163

(B) 0.027

(C) 0.500

(D) 0.079

Q45. A purely proportional (P-only) controller is used to regulate a first-order process subjected to a sustained step change in load. At the new steady state the controlled variable settles at a value that differs from the set point. This persistent steady-state deviation is called the: **[2 marks]**

(A) overshoot

(B) offset

(C) dead time

(D) decay ratio

Q46. A chemical plant requires a total capital investment of Rs. $10{,}00{,}000$ and is expected to generate a constant net annual cash flow of Rs. $2{,}00{,}000$. Neglecting the time value of money, the simple payback period, defined as investment divided by annual cash flow, is: **[2 marks]**

(A) 2 years

(B) 10 years

(C) 4 years

(D) 5 years

Detailed Solutions

Q1.

Solution

Concept – the average molar mass of a gas mixture is the mole-fraction weighted sum of the component molar masses: $\bar{M} = y_1 M_1 + y_2 M_2$.

Step 1 – list the mole fractions and molar masses: $y_{O_2} = 0.25$, $M_{O_2} = 32$; $y_{N_2} = 0.75$, $M_{N_2} = 28$.

Step 2 – form the weighted contribution of oxygen: $0.25 \times 32 = 8.0$

Step 3 – form the weighted contribution of nitrogen: $0.75 \times 28 = 21.0$

Step 4 – add the two contributions: $\bar{M} = 8.0 + 21.0$

$\bar{M} = 29.0$

Final Answer: $\bar{M} = 29.0 \Rightarrow \boxed{\text{A}}$

Answer: (A) 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 produces 2 moles of water.

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 $1:2$ **mole ratio for water:** $n_{H_2O} = 2 \times n_{CH_4} = 2 \times 0.5 = 1.0$ kmol

Step 3 – convert water moles to mass: $m_{H_2O} = n_{H_2O} \times M_{H_2O} = 1.0 \times 18$

$m_{H_2O} = 18$ kg

Final Answer: $m_{H_2O} = 18 \text{ kg} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept – the bypass fraction is the bypassed flow divided by the total feed flow: bypass fraction $= \dfrac{\text{bypass stream}}{\text{total feed}}$.

Step 1 – read the two streams from the diagram: Bypass $= 20$ mol/h, total feed $= 100$ mol/h.

Step 2 – form the ratio: bypass fraction $= \dfrac{20}{100}$

Step 3 – evaluate: bypass fraction $= 0.20$

Final Answer: bypass fraction $= 0.20 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q3

Q4.

Solution

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

Step 1 – assign the heat term: The cylinder is perfectly insulated, so $Q = 0$.

Step 2 – assign the work term: Work is done on the gas, so the work done *by* the system is negative: $W = -150$ J.

Step 3 – substitute into the first law: $\Delta U = 0 - (-150)$

Step 4 – evaluate: $\Delta U = +150$ J

Final Answer: $\Delta U = +150 \text{ J} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – entropy change for the isothermal reversible expansion of an ideal gas: $\Delta S = nR \ln \dfrac{V_2}{V_1}$.

Step 1 – list the data: $n = 2$ mol, $R = 8.314$ J/mol·K, $V_2/V_1 = 2$.

Step 2 – evaluate the logarithm: $\ln 2 = 0.6931$

Step 3 – multiply n and R: $nR = 2 \times 8.314 = 16.628$ J/K

Step 4 – multiply by the logarithm: $\Delta S = 16.628 \times 0.6931$

$\Delta S = 11.53 \text{ J/K} \approx 11.5 \text{ J/K}$

Final Answer: $\Delta S \approx 11.5 \text{ J/K} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – density of an ideal gas from the ideal-gas law: $PV = nRT$ gives $\rho = \frac{PM}{RT}$, with M the molar mass.

Step 1 – list the data in SI units: $P = 10^5$ Pa, $M = 0.044$ kg/mol, $R = 8.314$ J/mol·K, $T = 300$ K.

Step 2 – form the numerator: $PM = 10^5 \times 0.044 = 4400$

Step 3 – form the denominator: $RT = 8.314 \times 300 = 2494.2$

Step 4 – divide: $\rho = \frac{4400}{2494.2}$

$\rho = 1.764 \text{ kg/m}^3 \approx 1.76 \text{ kg/m}^3$

Final Answer: $\rho \approx 1.76 \text{ kg/m}^3 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – temperature dependence of the equilibrium constant (van't Hoff): $\frac{d(\ln K)}{dT} = \frac{\Delta H^\circ}{RT^2}$.

Step 1 – fix the sign of the heat of reaction: The reaction is exothermic, so $\Delta H^\circ < 0$.

Step 2 – interpret the van't Hoff slope: With $\Delta H^\circ < 0$, the term $\Delta H^\circ/(RT^2)$ is negative, so $\ln K$ decreases as T increases.

Step 3 – translate to K: If $\ln K$ decreases, then K itself decreases with rising temperature.

Final Answer: K decreases $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – vapour composition over an ideal solution: First get the total pressure by Raoult's law, then $y_A = \frac{x_A P_A^{sat}}{P}$.

Step 1 – list the data: $P_A^{sat} = 120$ kPa, $P_B^{sat} = 80$ kPa, $x_A = 0.4$, $x_B = 0.6$.

Step 2 – compute the partial pressure of A: $x_A P_A^{sat} = 0.4 \times 120 = 48$ kPa

Step 3 – compute the partial pressure of B: $x_B P_B^{sat} = 0.6 \times 80 = 48$ kPa

Step 4 – add for the total pressure: $P = 48 + 48 = 96$ kPa

Step 5 – form the vapour mole fraction of A: $y_A = \dfrac{48}{96} = 0.50$

Final Answer: $y_A = 0.50 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept – compressibility factor: $Z = \dfrac{PV}{nRT}$; $Z = 1$ for an ideal gas.

Step 1 – list the data in SI units: $P = 2 \times 10^5$ Pa, $V = 0.010$ m^3, $n = 1$ mol, $R = 8.314$ J/mol·K, $T = 300$ K.

Step 2 – form the numerator: $PV = 2 \times 10^5 \times 0.010 = 2000$

Step 3 – form the denominator: $nRT = 1 \times 8.314 \times 300 = 2494.2$

Step 4 – divide: $Z = \dfrac{2000}{2494.2}$

$Z = 0.802 \approx 0.80$

Final Answer: $Z \approx 0.80 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

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

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

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

Step 3 – divide the cold temperature by the difference: $\text{COP} = \dfrac{250}{50}$

Step 4 – evaluate: $\text{COP} = 5.0$

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

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – continuity for incompressible flow in a pipe: $Q = AV$, so $V = \dfrac{Q}{A}$ with $A = \dfrac{\pi}{4}D^2$.

Step 1 – list the data: $Q = 0.01\ \text{m}^3/\text{s}$, $D = 0.1$ m.

Step 2 – compute the cross-sectional area: $A = \dfrac{\pi}{4}(0.1)^2 = \dfrac{\pi}{4}(0.01)$

$A = 0.007854\ \text{m}^2$

Step 3 – divide the flow rate by the area: $V = \dfrac{0.01}{0.007854}$

Step 4 – evaluate: $V = 1.273\ \text{m/s} \approx 1.27\ \text{m/s}$

Final Answer: $V \approx 1.27\ \text{m/s} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

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

Step 1 – list the data in SI units: $\rho = 1000\ \text{kg/m}^3$, $V = 0.2$ m/s, $D = 25\ \text{mm} = 0.025$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – form the numerator: $\rho V D = 1000 \times 0.2 \times 0.025$

$= 5.0$

Step 3 – divide by the viscosity: $Re = \dfrac{5.0}{1 \times 10^{-3}}$

Step 4 – evaluate: $Re = 5000$

Final Answer: $Re = 5000 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – Darcy–Weisbach frictional 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, $g = 9.81\ \text{m/s}^2$.

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

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

Step 4 – combine all factors: $h_f = 0.02 \times 1000 \times 0.2039$

Step 5 – evaluate: $h_f = 20 \times 0.2039 = 4.077\ \text{m} \approx 4.08\ \text{m}$

Final Answer: $h_f \approx 4.08\ \text{m} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q13

Q14.

Solution

Concept – Archimedes' principle: The buoyant force equals the weight of the displaced fluid, $F_B = \rho_w\, g\, V$.

Step 1 – list the data: $\rho_w = 1000\ \text{kg/m}^3$, $g = 9.81\ \text{m/s}^2$, $V = 0.05\ \text{m}^3$.

Step 2 – multiply density and gravity: $\rho_w\, g = 1000 \times 9.81 = 9810$

Step 3 – multiply by the displaced volume: $F_B = 9810 \times 0.05$

Step 4 – evaluate: $F_B = 490.5\ \text{N}$

Final Answer: $F_B = 490.5\ \text{N} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

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

Step 1 – list the data: $\rho = 1.2\ \text{kg/m}^3$, $V = 10\ \text{m/s}$.

Step 2 – square the velocity: $V^2 = 10^2 = 100\ \text{m}^2/\text{s}^2$

Step 3 – multiply by the density: $\rho V^2 = 1.2 \times 100 = 120$

Step 4 – take one-half: $q = \frac{1}{2} \times 120 = 60\ \text{Pa}$

Final Answer: $q = 60\ \text{Pa} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q15

Q16.

Solution

Concept – specific surface area of uniform spheres per unit mass: For a sphere the surface-to-volume ratio is $6/d$; dividing by the solid density gives $a_w = \dfrac{6}{\rho_p\, d}$.

Step 1 – list the data in SI units: $d = 1\ \text{mm} = 1 \times 10^{-3}\ \text{m}$, $\rho_p = 2000\ \text{kg/m}^3$.

Step 2 – form the denominator: $\rho_p\, d = 2000 \times 1 \times 10^{-3} = 2.0$

Step 3 – divide 6 by the denominator: $a_w = \dfrac{6}{2.0}$

Step 4 – evaluate: $a_w = 3.0\ \text{m}^2/\text{kg}$

Final Answer: $a_w = 3.0\ \text{m}^2/\text{kg} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – Stokes'-law terminal velocity varies with the square of the particle diameter: $v_t = \dfrac{g\, d^2(\rho_p - \rho_f)}{18\mu}$, so for equal densities and fluid, $\dfrac{v_{t1}}{v_{t2}} = \left(\dfrac{d_1}{d_2}\right)^2$.

Step 1 – list the two diameters: $d_1 = 100\ \mu\text{m}$ (larger), $d_2 = 50\ \mu\text{m}$ (smaller).

Step 2 – form the diameter ratio: $\dfrac{d_1}{d_2} = \dfrac{100}{50} = 2$

Step 3 – square the ratio: $\left(\dfrac{d_1}{d_2}\right)^2 = 2^2 = 4$

Step 4 – state the velocity ratio: $\dfrac{v_{t1}}{v_{t2}} = 4.0$

Final Answer: $\dfrac{v_{t1}}{v_{t2}} = 4.0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q17

Q18.

Solution

Concept – laminar-to-turbulent transition in pipe flow: For flow in a straight circular pipe the flow is normally laminar while the Reynolds number is below a critical value.

Step 1 – recall the accepted lower critical Reynolds number: The transition value commonly used is $Re \approx 2100$.

Step 2 – interpret the regimes: For $Re < 2100$ the flow is laminar; above roughly

4000 it is fully turbulent, with a transition band in between.

Step 3 – select the laminar limit: The flow stays laminar below $Re \approx 2100$.

Final Answer: $Re \approx 2100 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – pump affinity law for discharge: At a fixed impeller diameter the discharge is proportional to the rotational speed, $\frac{Q_2}{Q_1} = \frac{N_2}{N_1}$.

Step 1 – list the data: $N_1 = 1450$ rpm, $Q_1 = 0.02\ \text{m}^3/\text{s}$, $N_2 = 2900$ rpm.

Step 2 – form the speed ratio: $\frac{N_2}{N_1} = \frac{2900}{1450} = 2$

Step 3 – apply the proportionality: $Q_2 = Q_1 \times \frac{N_2}{N_1} = 0.02 \times 2$

Step 4 – evaluate: $Q_2 = 0.04\ \text{m}^3/\text{s}$

Final Answer: $Q_2 = 0.04\ \text{m}^3/\text{s} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – conductive thermal resistance of a plane wall: $R = \frac{L}{kA}$.

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

Step 2 – form the denominator: $kA = 0.4 \times 2 = 0.8$

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

Step 4 – evaluate: $R = 0.25$ K/W

Final Answer: $R = 0.25\ \text{K/W} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – overall heat-transfer coefficient for two convective films in series (negligible wall resistance): $\frac{1}{U} = \frac{1}{h_1} + \frac{1}{h_2}$.

Step 1 – list the data: $h_1 = 100$ W/m^2·K, $h_2 = 100$ W/m^2·K.

Step 2 – add the two resistances: $\frac{1}{U} = \frac{1}{100} + \frac{1}{100}$

$\frac{1}{U} = 0.01 + 0.01 = 0.02$

Step 3 – invert to find U: $U = \frac{1}{0.02}$

Step 4 – evaluate: $U = 50$ W/m^2·K

Final Answer: $U = 50$ W/m^2·K $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – Biot number compares internal conduction resistance with surface convection resistance: $Bi = \frac{hL}{k}$.

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

Step 2 – form the numerator: $hL = 100 \times 0.01 = 1.0$

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

Step 4 – evaluate: $Bi = 0.02$

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

Answer: (D) Go Back to Q22

Q23.

Solution

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

Step 1 – find the terminal differences for parallel flow (both fluids enter at the same end): At inlet: $\Delta T_1 = 100 - 20 = 80$ °C.

At outlet: $\Delta T_2 = 70 - 40 = 30$ °C.

Step 2 – form the numerator: $\Delta T_1 - \Delta T_2 = 80 - 30 = 50$

Step 3 – form the logarithm: $\ln\frac{80}{30} = \ln 2.667 = 0.9808$

Step 4 – divide: $\text{LMTD} = \frac{50}{0.9808}$

$\text{LMTD} = 50.98\ ^\circ\text{C} \approx 51.0\ ^\circ\text{C}$

Final Answer: $\text{LMTD} \approx 51.0\ ^\circ\text{C} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – heat-exchanger effectiveness: $\varepsilon = \frac{Q_{\text{actual}}}{Q_{\text{max}}}$, where $Q_{\text{max}} = C_{\text{min}}(T_{h,\text{in}} - T_{c,\text{in}})$.

Step 1 – list the data: $C_{\text{min}} = 1000$ W/K, $T_{h,\text{in}} = 100\ ^\circ$C, $T_{c,\text{in}} = 20\ ^\circ$C, $Q_{\text{actual}} = 40{,}000$ W.

Step 2 – find the maximum inlet temperature difference: $T_{h,\text{in}} - T_{c,\text{in}} = 100 - 20 = 80$ K

Step 3 – compute the maximum possible heat rate: $Q_{\text{max}} = 1000 \times 80 = 80{,}000$ W

Step 4 – form the effectiveness: $\varepsilon = \frac{40{,}000}{80{,}000}$

Step 5 – evaluate: $\varepsilon = 0.5$

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

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – emissive power of a gray 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: $\sigma T^4 = 5.67 \times 10^{-8} \times 2.56 \times 10^{10}$

$\sigma T^4 = 1451.5$ W/m^2

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

$E = 1161.2$ W/m^2 ≈ 1161 W/m^2

Final Answer: $E \approx 1161 \text{ W/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – convective coefficient from the Nusselt number: $Nu = \dfrac{hD}{k}$, so $h = \dfrac{Nu\,k}{D}$.

Step 1 – list the data: $Nu = 100$, $k = 0.6$ W/m·K, $D = 0.05$ m.

Step 2 – form the numerator: $Nu\,k = 100 \times 0.6 = 60$

Step 3 – divide by the diameter: $h = \dfrac{60}{0.05}$

Step 4 – evaluate: $h = 1200 \text{ W/m}^2\text{·K}$

Final Answer: $h = 1200 \text{ W/m}^2\text{·K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – rating equation of a heat exchanger: $Q = UA\,\Delta T_{lm}$, so $A = \dfrac{Q}{U\,\Delta T_{lm}}$.

Step 1 – list the data: $Q = 50{,}000$ W, $U = 500 \text{ W/m}^2\text{·K}$, $\Delta T_{lm} = 50$ K.

Step 2 – form the denominator: $U\,\Delta T_{lm} = 500 \times 50 = 25{,}000$

Step 3 – divide the duty by the denominator: $A = \dfrac{50{,}000}{25{,}000}$

Step 4 – evaluate: $A = 2.0 \text{ m}^2$

Final Answer: $A = 2.0 \text{ m}^2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q27

Q28.

Solution

Concept – Fick's law for steady diffusion across a film: $N_A = \dfrac{D_{AB}(C_1 - C_2)}{\delta}$.

Step 1 – list the data in SI units: $D_{AB} = 2 \times 10^{-9}$ m^2/s, $C_1 = 5$ mol/m^3, $C_2 = 1$ mol/m^3, $\delta = 1 \times 10^{-3}$ m.

Step 2 – form the concentration difference: $C_1 - C_2 = 5 - 1 = 4 \text{ mol/m}^3$

Step 3 – form the numerator: $D_{AB}(C_1 - C_2) = 2 \times 10^{-9} \times 4 = 8 \times 10^{-9}$

Step 4 – divide by the film thickness: $N_A = \dfrac{8 \times 10^{-9}}{1 \times 10^{-3}}$

Step 5 – evaluate: $N_A = 8 \times 10^{-6} \text{ mol/m}^2\text{·s}$

Final Answer: $N_A = 8 \times 10^{-6} \text{ mol/m}^2\text{·s} \Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ Go Back to Q28

Q29.

Solution

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

Step 1 – list the data: $Sh = 200$, $D = 2 \times 10^{-9}$ m^2/s, $L = 0.02$ m.

Step 2 – form the numerator: $Sh\, D = 200 \times 2 \times 10^{-9} = 4 \times 10^{-7}$

Step 3 – divide by the characteristic length: $k_c = \dfrac{4 \times 10^{-7}}{0.02}$

Step 4 – evaluate: $k_c = 2 \times 10^{-5}$ m/s

Final Answer: $k_c = 2 \times 10^{-5}$ m/s $\Rightarrow \boxed{\text{C}}$

$\boxed{\text{Answer: (C)}}$ Go Back to Q29

Q30.

Solution

Concept – addition of resistances in the two-film theory: $\dfrac{1}{K_y} = \dfrac{1}{k_y} + \dfrac{m}{k_x}$.

Step 1 – list the two resistances: $\dfrac{1}{k_y} = 0.3$, $\dfrac{m}{k_x} = 0.2$.

Step 2 – add them: $\dfrac{1}{K_y} = 0.3 + 0.2 = 0.5$

Step 3 – invert to find K_y: $K_y = \dfrac{1}{0.5}$

Step 4 – evaluate: $K_y = 2.0$

Final Answer: $K_y = 2.0 \Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ Go Back to Q30

Q31.

Solution

Concept – slope of the rectifying operating line: slope $= \dfrac{R}{R+1}$, so R can be recovered from the slope.

Step 1 – set the given slope: $\dfrac{R}{R+1} = 0.8$

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

Step 3 – expand the right 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: $R = \dfrac{0.8}{0.2} = 4.0$

Final Answer: $R = 4.0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – Fenske equation for minimum stages at total reflux: $N_{\min} = \dfrac{\ln\left[(x_D/(1-x_D))((1-x_W)/x_W)\right]}{\ln\alpha}$.

Step 1 – list the data: $\alpha = 2.0$, $x_D = 0.98$, $x_W = 0.02$.

Step 2 – evaluate the distillate ratio: $\dfrac{x_D}{1-x_D} = \dfrac{0.98}{0.02} = 49$

Step 3 – evaluate the bottoms ratio: $\dfrac{1-x_W}{x_W} = \dfrac{0.98}{0.02} = 49$

Step 4 – multiply the two ratios: $49 \times 49 = 2401$

Step 5 – take the natural logarithm of the product: $\ln 2401 = 7.7835$

Step 6 – take the logarithm of the relative volatility: $\ln 2.0 = 0.6931$

Step 7 – divide: $N_{\min} = \dfrac{7.7835}{0.6931} = 11.23 \approx 11.2$

Final Answer: $N_{\min} \approx 11.2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q32

Q33.

Solution

Concept – stripping factor: $S = \dfrac{mG}{L}$.

Step 1 – list the data: $m = 2.0$, $G = 100$ mol/h, $L = 100$ mol/h.

Step 2 – form the numerator: $mG = 2.0 \times 100 = 200$

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

Step 4 – evaluate: $S = 2.0$

Final Answer: $S = 2.0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – packing height in terms of transfer units: $Z = \text{HTU} \times \text{NTU}$, so $\text{NTU} = \dfrac{Z}{\text{HTU}}$.

Step 1 – list the data: $Z = 6$ m, $\text{HTU} = 1.5$ m.

Step 2 – divide the height by the HTU: $\text{NTU} = \dfrac{6}{1.5}$

Step 3 – evaluate: $\text{NTU} = 4.0$

Final Answer: $\text{NTU} = 4.0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – relative volatility from a single equilibrium tie point: $\alpha = \dfrac{y/(1-y)}{x/(1-x)}$.

Step 1 – list the compositions: $x = 0.3$, $y = 0.5$.

Step 2 – form the vapour ratio: $\dfrac{y}{1-y} = \dfrac{0.5}{0.5} = 1.0$

Step 3 – form the liquid ratio: $\dfrac{x}{1-x} = \dfrac{0.3}{0.7} = 0.4286$

Step 4 – divide the vapour ratio by the liquid ratio: $\alpha = \dfrac{1.0}{0.4286}$

Step 5 – evaluate: $\alpha = 2.333 \approx 2.33$

Final Answer: $\alpha \approx 2.33 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – constant-rate drying time: $t = \dfrac{L_s(X_1 - X_2)}{A\,R_c}$, where L_s is the mass of bone-dry solid.

Step 1 – list the data: $L_s = 100$ kg, $X_1 = 0.30$ kg/kg, $X_2 = 0.10$ kg/kg, $A = 5$ m^2, $R_c = 2$ kg/m^2·h.

Step 2 – find the moisture removed per unit dry solid: $X_1 - X_2 = 0.30 - 0.10 = 0.20$ kg/kg

Step 3 – form the numerator (total water removed): $L_s(X_1 - X_2) = 100 \times 0.20 = 20$ kg

Step 4 – form the denominator (drying rate): $A\,R_c = 5 \times 2 = 10$ kg/h

Step 5 – divide: $t = \dfrac{20}{10} = 2.0$ h

Final Answer: $t = 2.0\text{ h} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q36

Q37.

Solution

Concept – half-life of a second-order reaction: For $-r_A = kC_A^2$ the half-life is $t_{1/2} = \dfrac{1}{k\,C_{A0}}$.

Step 1 – list the data: $k = 0.05$ L/mol·min, $C_{A0} = 2$ mol/L.

Step 2 – form the denominator: $k\,C_{A0} = 0.05 \times 2 = 0.1\ \text{min}^{-1}$

Step 3 – take the reciprocal: $t_{1/2} = \dfrac{1}{0.1}$

Step 4 – evaluate: $t_{1/2} = 10.0$ min

Final Answer: $t_{1/2} = 10.0\text{ min} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – CSTR design equation for a first-order reaction: $\tau = \dfrac{X}{k(1-X)}$.

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

Step 2 – find the unconverted fraction: $1 - X = 1 - 0.8 = 0.2$

Step 3 – form the denominator: $k(1-X) = 0.2 \times 0.2 = 0.04$

Step 4 – divide the conversion by the denominator: $\tau = \dfrac{0.8}{0.04}$

Step 5 – evaluate: $\tau = 20\ \text{min}$

Final Answer: $\tau = 20\ \text{min} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – PFR performance for a first-order reaction: $k\tau = -\ln(1-X)$, so $X = 1 - e^{-k\tau}$.

Step 1 – list the data: $k = 0.3\ \text{min}^{-1}$, $\tau = 10\ \text{min}$.

Step 2 – form the product: $k\tau = 0.3 \times 10 = 3.0$

Step 3 – take the exponential of its negative: $e^{-3.0} = 0.0498$

Step 4 – subtract from one: $X = 1 - 0.0498$

Step 5 – evaluate: $X = 0.9502 \approx 0.950$

Final Answer: $X \approx 0.950 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – rate of a second-order reaction: $-r_A = k\,C_A^2$.

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

Step 2 – square the concentration: $C_A^2 = 2^2 = 4\ \text{mol}^2/\text{L}^2$

Step 3 – multiply by the rate constant: $-r_A = 0.5 \times 4$

Step 4 – evaluate: $-r_A = 2.0\ \text{mol/L·min}$

Final Answer: $-r_A = 2.0\ \text{mol/L·min} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – mean residence time of an ideal CSTR: $\tau = \dfrac{V}{Q}$.

Step 1 – list the data: $V = 200$ L, $Q = 25$ L/min.

Step 2 – divide the volume by the volumetric flow: $\tau = \dfrac{200}{25}$

Step 3 – evaluate: $\tau = 8.0$ min

Final Answer: $\tau = 8.0 \text{ min} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – effectiveness factor of a flat porous slab (first order): $\eta = \dfrac{\tanh\phi}{\phi}$.

Step 1 – list the data: $\phi = 2$, $\tanh(2) = 0.964$.

Step 2 – substitute into the formula: $\eta = \dfrac{0.964}{2}$

Step 3 – evaluate: $\eta = 0.482 \approx 0.48$

Final Answer: $\eta \approx 0.48 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – step response of a first-order system: $y(t) = A\,(1 - e^{-t/\tau})$, with A the final change.

Step 1 – list the data: $A = 10$, and the time of interest is $t = 2\tau$, so $t/\tau = 2$.

Step 2 – evaluate the exponential term: $e^{-2} = 0.1353$

Step 3 – subtract from one: $1 - 0.1353 = 0.8647$

Step 4 – multiply by the final change: $y(2\tau) = 10 \times 0.8647$

Step 5 – evaluate: $y(2\tau) = 8.647 \approx 8.65$

Final Answer: $y(2\tau) \approx 8.65 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q43

Q44.

Solution

Concept – decay ratio of an underdamped second-order system: decay ratio $= \exp\left[\dfrac{-2\pi\zeta}{\sqrt{1-\zeta^2}}\right]$.

Step 1 – list the data: $\zeta = 0.5$.

Step 2 – evaluate the denominator root: $\sqrt{1-\zeta^2} = \sqrt{1-0.25} = \sqrt{0.75} = 0.8660$

Step 3 – form the exponent: $\dfrac{-2\pi \times 0.5}{0.8660} = \dfrac{-3.1416}{0.8660} = -3.628$

Step 4 – take the exponential: $e^{-3.628} = 0.0266$

Step 5 – round to the given precision: decay ratio ≈ 0.027

Final Answer: decay ratio $\approx 0.027 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – steady-state behaviour of a proportional controller: A P-only controller needs a non-zero error to produce the corrective output that balances a sustained load change.

Step 1 – recognise the residual error: Because the controller output is proportional to the error, the error cannot return to zero if a steady output is required.

Step 2 – name the residual deviation: This permanent difference between the controlled variable and the set point at the new steady state is the *offset*.

Step 3 – reject the other terms: Overshoot, dead time and decay ratio describe transient or timing features, not the residual steady-state error.

Final Answer: offset $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – simple payback period (no discounting): $\text{payback} = \dfrac{\text{total capital investment}}{\text{annual cash flow}}$.

Step 1 – list the data: Investment = Rs. $10{,}00{,}000$, annual cash flow = Rs. $2{,}00{,}000$.

Step 2 – divide the investment by the annual cash flow: $\text{payback} = \dfrac{10{,}00{,}000}{2{,}00{,}000}$

Step 3 – evaluate: $\text{payback} = 5$ years

Final Answer: $\text{payback} = 5 \text{ years} \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q46**

Answer Key

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