GATE Chemical Engineering

Sample Paper – 1

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 caustic solution is prepared by dissolving 30 kg of NaOH in 120 kg of water. The mass fraction of NaOH in the resulting solution is: **[1 mark]**

(A) 0.25

(B) 0.20

(C) 0.30

(D) 0.15

Q2. Carbon is burnt completely in oxygen following $C + O_2 \rightarrow CO_2$. The mass of oxygen (molar mass 32) required to burn 24 kg of carbon (molar mass 12) completely is: **[1 mark]**

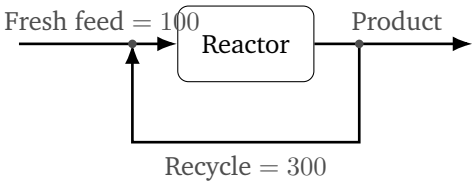
(A) 32 kg

(B) 48 kg

(C) 96 kg

(D) 64 kg

Q3. In the steady process shown below, a reactor is fed by a fresh feed stream and a recycle stream. The fresh feed is 100 mol/h and the recycle stream is 300 mol/h. The recycle ratio (recycle flow divided by fresh-feed flow) is: **[1 mark]**



(A) 3.0

(B) 0.33

(C) 4.0

(D) 1.5

Q4. A closed system receives 500 J of heat from its surroundings and performs 200 J of work on the surroundings. By the first law of thermodynamics, the change in the internal energy of the system is: **[1 mark]**

(A) $+300$ J

(B) $+700$ J

(C) -300 J

(D) $+100$ J

Q5. A thermal reservoir at a constant temperature of 400 K reversibly transfers 400 kJ of heat to a system. The change in the entropy of the reservoir associated with this heat transfer has a magnitude of: **[1 mark]**

(A) 1.6 kJ/K

(B) 0.8 kJ/K

(C) 400 kJ/K

(D) 1.0 kJ/K

Q6. One mole of an ideal gas is held at a temperature of 300 K and a pressure of 1 bar (10^5 Pa). Taking $R = 8.314$ J/mol·K, the molar volume occupied by the gas is nearest to: **[1 mark]**

(A) 0.0224 m^3

(B) 0.0249 m^3

(C) 2.49 m^3

(D) 0.0125 m^3

Q7. For a gas-phase reaction $A \rightleftharpoons B$ at a given temperature the standard Gibbs free energy change of reaction is $\Delta G^\circ = 0$. Using $\Delta G^\circ = -RT \ln K$, the thermodynamic equilibrium constant K of the reaction is: **[1 mark]**

(A) 1.0

(B) 0

(C) infinite

(D) 2.72

Q8. A binary liquid mixture of benzene (A) and toluene (B) behaves ideally and obeys Raoult's law. At the system temperature the saturation (vapour) pressures are $P_A^{sat} = 100$ kPa and $P_B^{sat} = 40$ kPa. For a liquid of composition $x_A = 0.5$, the total pressure over the liquid is: **[1 mark]**

(A) 70 kPa

(B) 50 kPa

(C) 100 kPa

(D) 140 kPa

Q9. A pure gas behaves as an ideal gas at a pressure of 5 bar. The fugacity of the gas at this state is: **[1 mark]**

(A) 1 bar

(B) 0 bar

(C) 5 bar

(D) 25 bar

Q10. A reversible Carnot heat engine operates between a hot reservoir at 600 K and a cold reservoir at 300 K. The thermal efficiency of the engine is: **[1 mark]**

(A) 0.25

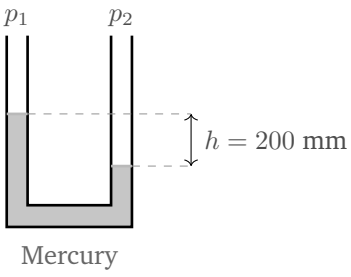
(B) 0.75

(C) 0.50

(D) 1.0

Fluid Mechanics & Mechanical Operations

Q11. A U-tube mercury manometer connected across two points of a gas line shows a steady difference in mercury levels of $h = 200$ mm, as shown. Taking the density of mercury as 13600 kg/m^3 and neglecting the gas column, the pressure difference $(p_1 - p_2)$ is nearest to: **[1 mark]**



(A) 26.7 kPa

(B) 2.67 kPa

(C) 1.96 kPa

(D) 13.6 kPa

Q12. Water discharges freely to the atmosphere through a small orifice in the side of a large open tank. The centre of the orifice is 5 m below the free surface of the water. Neglecting all losses, the ideal velocity of the jet issuing from the orifice ($V = \sqrt{2gh}$) is nearest to: **[1 mark]**

(A) 5.0 m/s

(B) 7.0 m/s

(C) 9.90 m/s

(D) 98.1 m/s

Q13. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 50 mm at a mean velocity of 0.032 m/s. For fully developed laminar flow the Darcy friction factor is $f = 64/Re$. The value of f for this flow is: **[1 mark]**

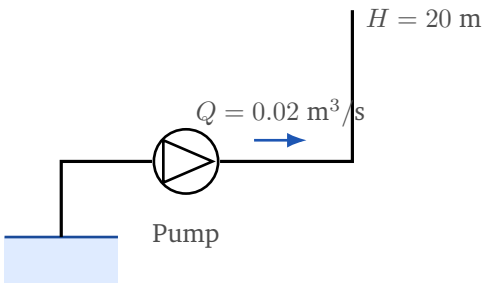
(A) 0.020

(B) 0.016

(C) 0.005

(D) 0.040

Q14. A centrifugal pump delivers water at a rate of $Q = 0.02$ m^3/s against a total head of $H = 20$ m, as shown. Taking $\rho_w = 1000$ kg/m^3, the hydraulic (water) power delivered by the pump, $P = \rho g Q H$, is nearest to: **[1 mark]**



(A) 1.96 kW

(B) 0.39 kW

(C) 7.85 kW

(D) 3.92 kW

Q15. A large tank is open to the atmosphere and holds still water. Taking $\rho_w = 1000$ kg/m^3 and $g = 9.81$ m/s^2, the gauge pressure of the water at a depth of 10 m below the free surface is: **[1 mark]**

(A) 98.1 kPa

(B) 9.81 kPa

(C) 981 kPa

(D) 100 kPa

Q16. A spherical particle of diameter 100 μm and density 2000 kg/m^3 settles under gravity in a still liquid of density 1000 kg/m^3 and viscosity 1×10^{-3} Pa·s. Assuming Stokes' law, the terminal settling velocity $v_t = gd^2(\rho_p - \rho_f)/(18\mu)$ is nearest to: **[1 mark]**

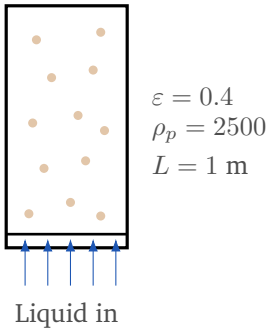
(A) 10.9 mm/s

(B) 2.72 mm/s

(C) 1.0 mm/s

(D) 5.45 mm/s

Q17. A liquid of density $\rho_f = 1000$ kg/m^3 is passed upward through the bed of solids shown to bring it to incipient (minimum) fluidization. The bed has voidage $\varepsilon = 0.4$, particle density $\rho_p = 2500$ kg/m^3 and height $L = 1$ m. The pressure drop across the fluidized bed, $\Delta P = (1-\varepsilon)(\rho_p - \rho_f)gL$, is nearest to: **[1 mark]**



(A) 14.7 kPa

(B) 24.5 kPa

(C) 8.83 kPa

(D) 5.89 kPa

Q18. In size reduction, which law states that the energy required per unit mass of feed is proportional to the new surface area created, and is therefore best suited to fine grinding? **[1 mark]**

(A) Bond's law

(B) Kick's law

(C) Fick's law

(D) Rittinger's law

Q19. A ball mill has an internal diameter of 1.5 m (the ball diameter is negligible). Using the critical-speed relation $n_c = 42.3/\sqrt{D}$ rpm, with D in metres, the critical speed of the mill is nearest to: **[1 mark]**

(A) 42.3 rpm

(B) 34.5 rpm

(C) 28.2 rpm

(D) 54.6 rpm

Q20. Steady one-dimensional conduction occurs through a plane wall of thermal conductivity 0.5 W/m·K, area 1 m^2 and thickness 0.1 m. The two faces are held at temperatures differing by 100 K. The rate of heat conduction through the wall ($q = kA\,\Delta T/L$) is: **[1 mark]**

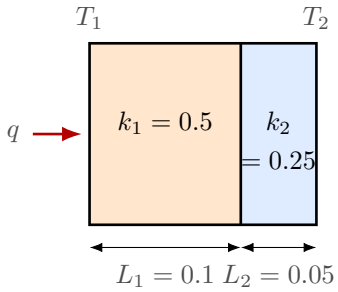
(A) 500 W

(B) 50 W

(C) 5000 W

(D) 250 W

Q21. Steady heat conduction occurs through the two-layer composite wall shown, with layer thicknesses $L_1 = 0.1$ m ($k_1 = 0.5$ W/m·K) and $L_2 = 0.05$ m ($k_2 = 0.25$ W/m·K). The overall temperature difference across the wall is 200 K. The steady heat flux through the wall is: **[2 marks]**



(A) 1000 W/m^2

(B) 250 W/m^2

(C) 500 W/m^2

(D) 400 W/m^2

Q22. A very long (effectively infinite) circular pin fin of diameter 10 mm is made of a metal of thermal conductivity $k = 200$ W/m·K. The surrounding convective coefficient is $h = 25$ W/m^2·K and the base-to-ambient temperature excess is $\theta_b = 100$ K. The heat dissipated by the fin, $Q = \sqrt{hPkA_c}\,\theta_b$, is nearest to: **[2 marks]**

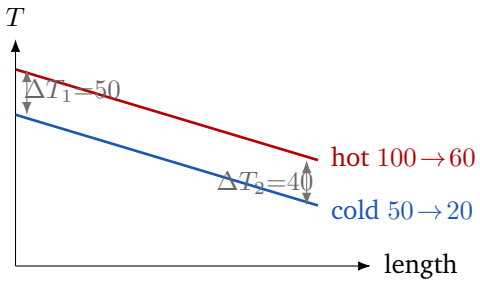
(A) 11.1 W

(B) 5.55 W

(C) 22.2 W

(D) 1.11 W

Q23. In the counter-current double-pipe exchanger whose temperature profile is sketched, a hot fluid is cooled from 100 °C to 60 °C while a cold fluid is heated from 20 °C to 50 °C. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



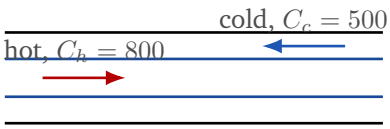
(A) 45.0 °C

(B) 50.0 °C

(C) 40.0 °C

(D) 44.8 °C

Q24. A double-pipe heat exchanger has an overall conductance $UA = 1000$ W/K. The two streams have heat-capacity rates $C_h = 800$ W/K and $C_c = 500$ W/K, as indicated. In the effectiveness–NTU method the number of transfer units is NTU $= UA/C_{\min}$. Its value here is: **[2 marks]**



Double-pipe exchanger, $UA = 1000$ W/K

(A) 2.0

(B) 0.5

(C) 1.0

(D) 4.0

Q25. A hot vertical plate of surface area 2 m^2 loses heat to surrounding air by convection. The convective heat-transfer coefficient is 50 W/m^2·K and the plate surface is 30 K hotter than the air. The rate of convective heat loss ($q = hA\,\Delta T$) is: **[2 marks]**

(A) 1500 W

(B) 750 W

(C) 3000 W

(D) 300 W

Q26. A surface behaves as a black body at a temperature of 500 K. Taking the Stefan–Boltzmann constant as $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the total emissive power of the surface ($E = \sigma T^4$) is nearest to: **[2 marks]**

(A) 1772 W/m^2

(B) 3544 W/m^2

(C) 7088 W/m^2

(D) 283.5 W/m^2

Q27. A single-effect evaporator evaporates 900 kg/h of water from a feed while consuming 1000 kg/h of saturated steam. The steam economy of the evaporator (mass of water evaporated per unit mass of steam supplied) is: **[2 marks]**

(A) 1.11

(B) 1.0

(C) 0.5

(D) 0.90

Mass Transfer & Separation Processes

Q28. Component A diffuses at steady state through a stagnant film of thickness 0.01 m. The molar diffusivity is $D_{AB} = 1 \times 10^{-5}$ m^2/s and the concentration of A falls linearly from 2 mol/m^3 at one face to 0 at the other. Using Fick's law $N_A = D_{AB}(C_1 - C_2)/\delta$, the molar flux of A is: **[2 marks]**

(A) 1×10^{-3} mol/m^2·s

(B) 2×10^{-3} mol/m^2·s

(C) 4×10^{-3} mol/m^2·s

(D) 2×10^{-5} mol/m^2·s

Q29. According to film theory, a solute diffuses across a stagnant liquid film of thickness $\delta = 1$ mm with a molecular diffusivity $D = 2 \times 10^{-5}$ m^2/s. The film mass-transfer coefficient ($k_c = D/\delta$) is: **[2 marks]**

(A) 0.04 m/s

(B) 0.02 m/s

(C) 0.01 m/s

(D) 0.002 m/s

Q30. In a gas absorption process described by two-film theory, the individual coefficients give $1/k_g = 0.5$ and the liquid-side contribution referred to the gas phase gives $m/k_l = 0.5$ (in consistent units). Using $1/K_g = 1/k_g + m/k_l$, the overall gas-phase mass-transfer coefficient K_g is: **[2 marks]**

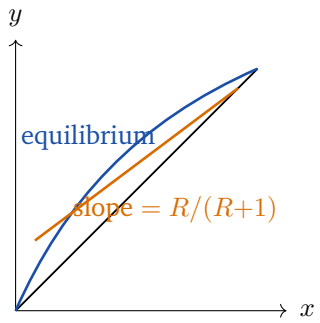
(A) 1.0

(B) 2.0

(C) 0.5

(D) 0.25

Q31. The McCabe–Thiele construction for a distillation column is shown. The rectifying-section operating line has a slope equal to $R/(R+1)$, where R is the reflux ratio. If the reflux ratio is $R = 3$, the slope of this operating line is: **[2 marks]**



(A) 0.25

(B) 0.50

(C) 0.75

(D) 1.0

Q32. A binary mixture with a constant relative volatility $\alpha = 2.5$ is to be separated into a distillate of $x_D = 0.95$ and a bottoms of $x_W = 0.05$ (mole fractions of the light key). Using Fenske's equation, the minimum number of theoretical stages, $N_{\min} = \dfrac{\ln\left[(x_D/(1-x_D))((1-x_W)/x_W)\right]}{\ln \alpha}$, is nearest to: **[2 marks]**

(A) 3.2

(B) 5.0

(C) 9.0

(D) 6.43

Q33. In a gas absorber the liquid flow rate is $L = 100$ mol/h, the gas flow rate is $G = 50$ mol/h and the equilibrium slope is $m = 1.0$. The absorption factor, defined as $A = L/(mG)$, is: **[2 marks]**

(A) 0.5

(B) 1.0

(C) 2.0

(D) 4.0

Q34. A packed absorption tower is designed on the basis of transfer units, so that the packing height is $Z = \text{HTU} \times \text{NTU}$. For a particular separation the height of a transfer unit is 0.5 m and the number of transfer units required is 6. The required height of packing is: **[2 marks]**

(A) 1.5 m

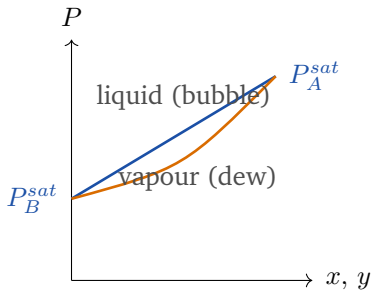
(B) 3.0 m

(C) 6.0 m

(D) 12.0 m

Q35. The pressure–composition (P–x–y) diagram of an ideal binary mixture is shown; the upper straight (bubble) line follows Raoult's law. At the

system temperature the pure-component saturation pressures are $P_A^{sat} = 100$ kPa and $P_B^{sat} = 40$ kPa. The relative volatility of A with respect to B, $\alpha = P_A^{sat}/P_B^{sat}$, is: **[2 marks]**



(A) 2.5

(B) 0.4

(C) 1.0

(D) 40

Q36. A wet solid is being dried in its constant-rate period, during which the drying flux (rate of water removal per unit exposed area) is 2 kg/m^2·h over an exposed surface area of 5 m^2. The rate of water removal from the solid is: **[2 marks]**

(A) 5 kg/h

(B) 10 kg/h

(C) 2.5 kg/h

(D) 20 kg/h

Reaction Engineering, Process Control & Plant Economics

Q37. A homogeneous liquid-phase reaction is first order in the reactant, with a rate constant $k = 0.02$ min^{-1}. The half-life of the reactant, $t_{1/2} = \ln 2/k$, is nearest to: **[2 marks]**

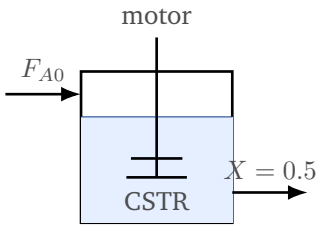
(A) 50.0 min

(B) 34.66 min

(C) 69.3 min

(D) 17.3 min

Q38. A first-order liquid-phase reaction ($-r_A = kC_A$, $k = 0.1$ min^{-1}) is carried out in the ideal continuous stirred-tank reactor (CSTR) shown to achieve a conversion of $X = 0.5$. 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 $k = 0.2$ min^{-1} is carried out in an ideal plug-flow reactor (PFR) with a space time of $\tau = 5$ min. Using $k\tau = -\ln(1 - X)$, the fractional conversion at the reactor outlet is nearest to: **[2 marks]**

(A) 0.500

(B) 0.865

(C) 0.800

(D) 0.632

Q40. A reaction has an Arrhenius activation energy of $E_a = 50$ kJ/mol. Taking $R = 8.314$ J/mol·K, the factor by which the rate constant increases when the temperature is raised from 300 K to 310 K, given by $\dfrac{k(310)}{k(300)} = \exp\!\left[\dfrac{E_a}{R}\left(\dfrac{1}{300} - \dfrac{1}{310}\right)\right]$, is nearest to: **[2 marks]**

(A) 1.0

(B) 2.5

(C) 1.91

(D) 0.52

Q41. An ideal CSTR of working volume 100 L is fed by a liquid stream at a constant volumetric flow rate of 20 L/min. The mean residence time of fluid in the reactor ($\tau = V/Q$) is: [2 marks]

(A) 20 min

(B) 100 min

(C) 5.0 min

(D) 0.2 min

Q42. A porous catalyst pellet operates in the strong pore-diffusion (large Thiele modulus) regime, where the internal effectiveness factor is approximately $\eta = 1/\phi$. For a Thiele modulus of $\phi = 5$, the effectiveness factor is nearest to: [2 marks]

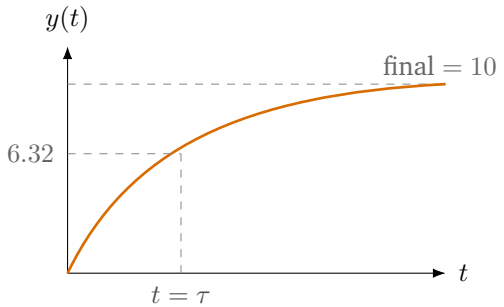
(A) 1.0

(B) 0.2

(C) 5.0

(D) 0.5

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



(A) 10.0

(B) 5.0

(C) 8.65

(D) 6.32

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

(A) 25%

(B) 16.3%

(C) 9%

(D) 50%

Q45. A linear feedback control system is described by its closed-loop characteristic equation. For the system to be asymptotically stable, all the roots of this equation (the closed-loop poles) must lie strictly in the: **[2 marks]**

(A) right half of the s-plane

(B) imaginary axis of the s-plane

(C) left half of the s-plane

(D) origin of the s-plane

Q46. A process equipment is purchased for Rs. $10{,}00{,}000$ and has an estimated salvage value of Rs. $1{,}00{,}000$ at the end of a service life of 9 years. Using the straight-line method, the annual depreciation charge, $D = (\text{cost} - \text{salvage})/\text{life}$, is: **[2 marks]**

(A) Rs. $1{,}11{,}111$

(B) Rs. $1{,}00{,}000$

(C) Rs. $90{,}000$

(D) Rs. $9{,}00{,}000$

Detailed Solutions

Q1.

Solution

Concept – mass fraction is the mass of a component divided by the total mass of the solution: $w_{\text{NaOH}} = \dfrac{\text{mass of NaOH}}{\text{mass of NaOH} + \text{mass of water}}$.

Step 1 – list the masses: Mass of NaOH $= 30$ kg, mass of water $= 120$ kg.

Step 2 – find the total mass of the solution: $m_{\text{total}} = 30 + 120$

$m_{\text{total}} = 150$ kg

Step 3 – form the mass fraction: $w_{\text{NaOH}} = \dfrac{30}{150}$

Step 4 – evaluate: $w_{\text{NaOH}} = 0.20$

Final Answer: $w_{\text{NaOH}} = 0.20 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – use the stoichiometry of the combustion reaction: $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$, so 1 mole of carbon needs 1 mole of oxygen.

Step 1 – find the moles of carbon burnt: $n_{\text{C}} = \dfrac{24 \text{ kg}}{12 \text{ kg/kmol}} = 2 \text{ kmol}$

Step 2 – apply the $1:1$ mole ratio: $n_{\text{O}_2} = n_{\text{C}} = 2$ kmol

Step 3 – convert oxygen moles to mass: $m_{\text{O}_2} = n_{\text{O}_2} \times M_{\text{O}_2} = 2 \times 32$

$m_{\text{O}_2} = 64$ kg

Final Answer: $m_{\text{O}_2} = 64 \text{ kg} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – the recycle ratio is the recycle flow divided by the fresh-feed flow: Recycle ratio $= \dfrac{\text{recycle stream}}{\text{fresh feed}}$.

Step 1 – read the two streams from the diagram: Recycle $= 300$ mol/h, fresh feed $= 100$ mol/h.

Step 2 – form the ratio: Recycle ratio $= \dfrac{300}{100}$

Step 3 – evaluate: Recycle ratio $= 3.0$

Final Answer: recycle ratio $= 3.0 \Rightarrow \boxed{\text{A}}$

Answer: (A) 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 signs to the two energy terms: Heat added to the system $Q = +500$ J; work done by the system $W = +200$ J.

Step 2 – substitute into the first law: $\Delta U = 500 - 200$

Step 3 – evaluate: $\Delta U = +300$ J

Final Answer: $\Delta U = +300$ J $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – entropy change of a reservoir at constant temperature: $|\Delta S| = \dfrac{|Q|}{T}$, since the reservoir stays at a fixed temperature T.

Step 1 – list the data: $Q = 400$ kJ, $T = 400$ K.

Step 2 – substitute into the formula: $|\Delta S| = \dfrac{400}{400}$

Step 3 – evaluate: $|\Delta S| = 1.0$ kJ/K

Final Answer: $|\Delta S| = 1.0$ kJ/K $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – ideal-gas law solved for molar volume: $PV = nRT$, so for $n = 1$ mole the molar volume is $V = \dfrac{RT}{P}$.

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

Step 2 – compute the numerator: $RT = 8.314 \times 300 = 2494.2$ J/mol

Step 3 – divide by the pressure: $V = \dfrac{2494.2}{10^5}$

Step 4 – evaluate: $V = 0.024942\ \text{m}^3 \approx 0.0249\ \text{m}^3$

Why option A is wrong: $0.0224\ \text{m}^3$ is the molar volume at 273 K (STP), not at 300 K.

Final Answer: $V \approx 0.0249\ \text{m}^3 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q6

Q7.

Solution

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

Step 1 – set the given condition: $\Delta G^\circ = 0$.

Step 2 – substitute into the relation: $0 = -RT \ln K$

Step 3 – since $RT \neq 0$, the logarithm must vanish: $\ln K = 0$

Step 4 – solve for K: $K = e^0 = 1.0$

Final Answer: $K = 1.0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q7

Q8.

Solution

Concept – Raoult's law for an ideal binary solution: $P = x_A P_A^{sat} + x_B P_B^{sat}$.

Step 1 – list the data: $P_A^{sat} = 100$ kPa, $P_B^{sat} = 40$ kPa, $x_A = 0.5$.

Step 2 – find the second mole fraction: $x_B = 1 - x_A = 1 - 0.5 = 0.5$

Step 3 – substitute into Raoult's law: $P = (0.5)(100) + (0.5)(40)$

Step 4 – evaluate each term: $P = 50 + 20$

$P = 70$ kPa

Final Answer: $P = 70$ kPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – fugacity of an ideal gas: For an ideal gas the fugacity coefficient is $\phi = 1$, so the fugacity equals the pressure, $f = \phi P = P$.

Step 1 – note the ideal-gas behaviour: $\phi = 1$.

Step 2 – apply $f = \phi P$: $f = 1 \times 5$ bar

Step 3 – evaluate: $f = 5$ bar

Final Answer: $f = 5$ bar $\Rightarrow$ C

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – Carnot efficiency depends only on the reservoir temperatures: $\eta = 1 - \dfrac{T_C}{T_H}$, with the temperatures in kelvin.

Step 1 – list the temperatures: $T_H = 600$ K, $T_C = 300$ K.

Step 2 – form the temperature ratio: $\dfrac{T_C}{T_H} = \dfrac{300}{600} = 0.5$

Step 3 – subtract from unity: $\eta = 1 - 0.5$

$\eta = 0.50$

Final Answer: $\eta = 0.50 \Rightarrow$ C

Answer: (C) Go Back to Q10

Q11.

Solution

Concept – manometer relation for a differential reading: $p_1 - p_2 = \rho_m\, g\, h$, where ρ_m is the density of the manometer fluid and h the difference in its levels.

Step 1 – list the data in SI units: $\rho_m = 13600$ kg/m^3, $g = 9.81$ m/s^2, $h = 200$ mm $= 0.2$ m.

Step 2 – substitute: $p_1 - p_2 = 13600 \times 9.81 \times 0.2$

Step 3 – multiply the first two factors: $13600 \times 9.81 = 133{,}416$

Step 4 – multiply by the height: $p_1 - p_2 = 133{,}416 \times 0.2 = 26{,}683$ Pa

Step 5 – express in kilopascals: $p_1 - p_2 \approx 26.7$ kPa

Final Answer: $p_1 - p_2 \approx 26.7$ kPa $\Rightarrow$ A

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – Torricelli's result from Bernoulli's equation: For free efflux under a head h, the ideal jet velocity is $V = \sqrt{2gh}$.

Step 1 – list the data: $g = 9.81$ m/s^2, $h = 5$ m.

Step 2 – form the product under the root: $2gh = 2 \times 9.81 \times 5$

$2gh = 98.1$ m^2/s^2

Step 3 – take the square root: $V = \sqrt{98.1}$

$V = 9.905$ m/s ≈ 9.90 m/s

Why option D is wrong: 98.1 is the value of $2gh$ (with units m^2/s^2), not the velocity; the square root must still be taken.

Final Answer: $V \approx 9.90$ m/s $\Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – for laminar pipe flow the Darcy friction factor is $f = 64/Re$: First find the Reynolds number, then divide.

Step 1 – write the Reynolds number: $Re = \dfrac{\rho V D}{\mu}$

Step 2 – substitute the data: $Re = \dfrac{1000 \times 0.032 \times 0.05}{1 \times 10^{-3}}$

Step 3 – evaluate the numerator: $1000 \times 0.032 \times 0.05 = 1.6$

Step 4 – divide by the viscosity: $Re = \dfrac{1.6}{1 \times 10^{-3}} = 1600$

Step 5 – the flow is laminar ($Re < 2300$), so apply $f = 64/Re$: $f = \dfrac{64}{1600}$

Step 6 – evaluate: $f = 0.040$

Final Answer: $f = 0.040 \Rightarrow$ D

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – hydraulic power delivered to the fluid: $P = \rho\, g\, Q\, H$, the product of specific weight, volumetric flow and head.

Step 1 – list the data: $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $Q = 0.02$ m^3/s, $H = 20$ m.

Step 2 – multiply the specific weight terms: $\rho g = 1000 \times 9.81 = 9810$ N/m^3

Step 3 – multiply by the discharge: $\rho g Q = 9810 \times 0.02 = 196.2$

Step 4 – multiply by the head: $P = 196.2 \times 20 = 3924$ W

Step 5 – express in kilowatts: $P = 3.924$ kW ≈ 3.92 kW

Final Answer: $P \approx 3.92$ kW $\Rightarrow$ D

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – gauge pressure due to a column of liquid: $p = \rho\, g\, h$, measured relative to the free surface.

Step 1 – list the data: $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $h = 10$ m.

Step 2 – substitute: $p = 1000 \times 9.81 \times 10$

Step 3 – multiply: $p = 98{,}100$ Pa

Step 4 – express in kilopascals: $p = 98.1$ kPa

Final Answer: $p = 98.1$ kPa $\Rightarrow$ A

Answer: (A) Go Back to Q15

Q16.

Solution

Concept – Stokes' law for the terminal velocity of a small sphere: $v_t = \dfrac{g\, d^2 (\rho_p - \rho_f)}{18\, \mu}$.

Step 1 – list the data in SI units: $d = 100\ \mu$m $= 1 \times 10^{-4}$ m, $\rho_p = 2000$ kg/m^3, $\rho_f = 1000$ kg/m^3, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – square the diameter: $d^2 = (1 \times 10^{-4})^2 = 1 \times 10^{-8}$ m^2

Step 3 – form the density difference: $\rho_p - \rho_f = 2000 - 1000 = 1000$ kg/m^3

Step 4 – assemble the numerator: $g\, d^2 (\rho_p - \rho_f) = 9.81 \times 1 \times 10^{-8} \times 1000$

$= 9.81 \times 10^{-5}$

Step 5 – form the denominator: $18\,\mu = 18 \times 1 \times 10^{-3} = 0.018$

Step 6 – divide: $v_t = \dfrac{9.81 \times 10^{-5}}{0.018} = 5.45 \times 10^{-3}$ m/s

$v_t = 5.45$ mm/s

Final Answer: $v_t \approx 5.45$ mm/s $\Rightarrow$ D

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – at fluidization the bed pressure drop supports the buoyant weight of the solids: $\Delta P = (1-\varepsilon)(\rho_p - \rho_f)\, g\, L$.

Step 1 – list the data: $\varepsilon = 0.4$, $\rho_p = 2500$ kg/m^3, $\rho_f = 1000$ kg/m^3, $L = 1$ m.

Step 2 – evaluate the solids fraction: $1 - \varepsilon = 1 - 0.4 = 0.6$

Step 3 – take the buoyant density difference: $\rho_p - \rho_f = 2500 - 1000 = 1500$ kg/m^3

Step 4 – substitute all terms: $\Delta P = 0.6 \times 1500 \times 9.81 \times 1$

Step 5 – multiply stepwise: $0.6 \times 1500 = 900$

$900 \times 9.81 = 8829$

$8829 \times 1 = 8829$ Pa

Step 6 – express in kilopascals: $\Delta P \approx 8.83$ kPa

Final Answer: $\Delta P \approx 8.83$ kPa $\Rightarrow$ C

Answer: (C) Go Back to Q17

Q18.

Solution

Concept – the three classic laws of size reduction differ in what the energy is proportional to: Kick's law $\rightarrow$ size ratio; Bond's law $\rightarrow$ intermediate (crack length); Rittinger's law $\rightarrow$ new surface created.

Step 1 – recall Rittinger's statement: Energy per unit mass is proportional to the increase in specific surface area, i.e. to $\left(\frac{1}{d_2} - \frac{1}{d_1}\right)$.

Step 2 – match it to the application: Because fine grinding creates a large amount of new surface, Rittinger's law fits fine grinding best.

Why the other options are wrong:

- Bond's law: energy $\propto \left(\frac{1}{\sqrt{d_2}} - \frac{1}{\sqrt{d_1}}\right)$, used for intermediate crushing.
- Kick's law: energy $\propto \ln(d_1/d_2)$, suited to coarse crushing.
- Fick's law: a diffusion law, not a size-reduction law at all.

Final Answer: Rittinger's law $\Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – critical speed of a ball mill: $n_c = \dfrac{42.3}{\sqrt{D}}$ rpm, with the mill diameter D in metres.

Step 1 – list the data: $D = 1.5$ m.

Step 2 – take the square root of the diameter: $\sqrt{1.5} = 1.2247$

Step 3 – divide: $n_c = \dfrac{42.3}{1.2247}$

Step 4 – evaluate: $n_c = 34.5$ rpm

Final Answer: $n_c \approx 34.5$ rpm $\Rightarrow$ B

Answer: (B) Go Back to Q19

Q20.

Solution

Concept – Fourier's law of steady one-dimensional conduction: $q = \dfrac{k\,A\,\Delta T}{L}$.

Step 1 – list the data: $k = 0.5$ W/m·K, $A = 1$ m^2, $\Delta T = 100$ K, $L = 0.1$ m.

Step 2 – substitute: $q = \dfrac{0.5 \times 1 \times 100}{0.1}$

Step 3 – evaluate the numerator: $0.5 \times 1 \times 100 = 50$

Step 4 – divide by the thickness: $q = \dfrac{50}{0.1} = 500$ W

Final Answer: $q = 500$ W $\Rightarrow$ A

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – for layers in series the thermal resistances add, and $q = \Delta T / R_{\text{total}}$ per unit area: $R = \dfrac{L_1}{k_1} + \dfrac{L_2}{k_2}$.

Step 1 – resistance of the first layer (per unit area): $R_1 = \dfrac{L_1}{k_1} = \dfrac{0.1}{0.5} = 0.2\ \text{m}^2\cdot\text{K/W}$

Step 2 – resistance of the second layer: $R_2 = \dfrac{L_2}{k_2} = \dfrac{0.05}{0.25} = 0.2\ \text{m}^2\cdot\text{K/W}$

Step 3 – add the resistances: $R_{\text{total}} = 0.2 + 0.2 = 0.4\ \text{m}^2\cdot\text{K/W}$

Step 4 – divide the temperature difference by the total resistance: $q = \dfrac{\Delta T}{R_{\text{total}}} = \dfrac{200}{0.4}$

Step 5 – evaluate: $q = 500\ \text{W/m}^2$

Final Answer: $q = 500\ \text{W/m}^2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – heat dissipated by an infinitely long fin: $Q = \sqrt{h\,P\,k\,A_c}\;\theta_b$, where P is the perimeter and A_c the cross-sectional area.

Step 1 – geometry of the circular fin ($d = 0.01$ m): Perimeter $P = \pi d = \pi \times 0.01 = 0.03142$ m.

Step 2 – cross-sectional area: $A_c = \dfrac{\pi d^2}{4} = \dfrac{\pi (0.01)^2}{4} = 7.854 \times 10^{-5}\ \text{m}^2$

Step 3 – form the product $hPkA_c$: $hPkA_c = 25 \times 0.03142 \times 200 \times 7.854 \times 10^{-5}$

Step 4 – multiply stepwise: $25 \times 0.03142 = 0.7855$

$0.7855 \times 200 = 157.1$

$157.1 \times 7.854 \times 10^{-5} = 0.01234$

Step 5 – take the square root: $\sqrt{0.01234} = 0.1111$

Step 6 – multiply by the base excess temperature: $Q = 0.1111 \times 100 = 11.11$ W

Final Answer: $Q \approx 11.1$ W $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q22

Q23.

Solution

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

Step 1 – temperature difference at end 1 (hot-in / cold-out): $\Delta T_1 = 100 - 50 = 50\ ^\circ\text{C}$

Step 2 – temperature difference at end 2 (hot-out / cold-in): $\Delta T_2 = 60 - 20 = 40\ ^\circ\text{C}$

Step 3 – take the difference of the two: $\Delta T_1 - \Delta T_2 = 50 - 40 = 10$

Step 4 – take the log of the ratio: $\ln\left(\dfrac{50}{40}\right) = \ln(1.25) = 0.2231$

Step 5 – divide: $\text{LMTD} = \dfrac{10}{0.2231} = 44.8\ ^\circ\text{C}$

Why option A is wrong: $45.0\ ^\circ\text{C}$ is the arithmetic mean $(50+40)/2$; the log mean is always slightly smaller.

Final Answer: $\text{LMTD} \approx 44.8\ ^\circ\text{C} \Rightarrow$ D

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – number of transfer units: $\text{NTU} = \dfrac{UA}{C_{\min}}$, where $C_{\min}$ is the smaller of the two heat-capacity rates.

Step 1 – identify $C_{\min}$: $C_h = 800$ W/K and $C_c = 500$ W/K, so $C_{\min} = 500$ W/K.

Step 2 – substitute into the NTU definition: $\text{NTU} = \dfrac{1000}{500}$

Step 3 – evaluate: $\text{NTU} = 2.0$

Final Answer: $\text{NTU} = 2.0 \Rightarrow$ A

Answer: (A) Go Back to Q24

Q25.

Solution

Concept – Newton's law of cooling for convective heat loss: $q = h\,A\,\Delta T$.

Step 1 – list the data: $h = 50$ W/m^2·K, $A = 2$ m^2, $\Delta T = 30$ K.

Step 2 – substitute: $q = 50 \times 2 \times 30$

Step 3 – multiply stepwise: $50 \times 2 = 100$

$100 \times 30 = 3000$

Step 4 – state the result: $q = 3000$ W

Final Answer: $q = 3000$ W $\Rightarrow$ C

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – Stefan–Boltzmann law for a black body: $E = \sigma T^4$.

Step 1 – list the data: $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, $T = 500$ K.

Step 2 – raise the temperature to the fourth power: $T^4 = (500)^4 = 6.25 \times 10^{10}$ K^4

Step 3 – multiply by the constant: $E = 5.67 \times 10^{-8} \times 6.25 \times 10^{10}$

Step 4 – combine the powers of ten and mantissas: $E = (5.67 \times 6.25) \times 10^2 = 35.44 \times 10^2$

$E = 3544$ W/m^2

Final Answer: $E \approx 3544$ W/m^2 $\Rightarrow$ B

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – steam economy of an evaporator: economy $= \dfrac{\text{mass of water evaporated}}{\text{mass of steam supplied}}$.

Step 1 – list the data: Water evaporated $= 900$ kg/h, steam supplied $= 1000$ kg/h.

Step 2 – form the ratio: economy $= \dfrac{900}{1000}$

Step 3 – evaluate: economy $= 0.90$

Note: a single-effect evaporator has an economy a little below 1, consistent with

this result.

Final Answer: economy $= 0.90 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q27

Q28.

Solution

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

Step 1 – list the data: $D_{AB} = 1 \times 10^{-5}$ m^2/s, $C_1 = 2$ mol/m^3, $C_2 = 0$, $\delta = 0.01$ m.

Step 2 – form the concentration difference: $C_1 - C_2 = 2 - 0 = 2$ mol/m^3

Step 3 – substitute: $N_A = \dfrac{1 \times 10^{-5} \times 2}{0.01}$

Step 4 – evaluate the numerator: $1 \times 10^{-5} \times 2 = 2 \times 10^{-5}$

Step 5 – divide by the film thickness: $N_A = \dfrac{2 \times 10^{-5}}{0.01} = 2 \times 10^{-3}$ mol/m^2·s

Final Answer: $N_A = 2 \times 10^{-3}$ mol/m^2·s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q28

Q29.

Solution

Concept – film mass-transfer coefficient from film theory: $k_c = \dfrac{D}{\delta}$.

Step 1 – list the data in SI units: $D = 2 \times 10^{-5}$ m^2/s, $\delta = 1$ mm $= 1 \times 10^{-3}$ m.

Step 2 – substitute: $k_c = \dfrac{2 \times 10^{-5}}{1 \times 10^{-3}}$

Step 3 – divide the mantissas and subtract the exponents: $k_c = 2 \times 10^{-5-(-3)} = 2 \times 10^{-2}$

Step 4 – state the result: $k_c = 0.02$ m/s

Final Answer: $k_c = 0.02$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – two-film (additive-resistance) model for the overall coefficient: $\frac{1}{K_g} = \frac{1}{k_g} + \frac{m}{k_l}$.

Step 1 – list the two resistances: $\frac{1}{k_g} = 0.5$ and $\frac{m}{k_l} = 0.5$.

Step 2 – add the resistances: $\frac{1}{K_g} = 0.5 + 0.5 = 1.0$

Step 3 – invert to get the overall coefficient: $K_g = \frac{1}{1.0} = 1.0$

Final Answer: $K_g = 1.0 \Rightarrow$ A

Answer: (A) Go Back to Q30

Q31.

Solution

Concept – slope of the rectifying-section operating line in McCabe–Thiele: $\text{slope} = \frac{R}{R+1}$.

Step 1 – list the reflux ratio: $R = 3$.

Step 2 – form the denominator: $R + 1 = 3 + 1 = 4$

Step 3 – form the slope: $\text{slope} = \frac{3}{4}$

Step 4 – evaluate: $\text{slope} = 0.75$

Final Answer: $\text{slope} = 0.75 \Rightarrow$ C

Answer: (C) Go Back to Q31

Q32.

Solution

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

Step 1 – compute the distillate ratio: $\frac{x_D}{1-x_D} = \frac{0.95}{0.05} = 19$

Step 2 – compute the bottoms ratio: $\frac{1-x_W}{x_W} = \frac{0.95}{0.05} = 19$

Step 3 – multiply the two ratios: $19 \times 19 = 361$

Step 4 – take the natural log of the product: $\ln(361) = 5.889$

Step 5 – take the natural log of the relative volatility: $\ln(2.5) = 0.9163$

Step 6 – divide: $N_{\min} = \dfrac{5.889}{0.9163} = 6.43$

Final Answer: $N_{\min} \approx 6.43 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q32

Q33.

Solution

Concept – absorption factor: $A = \dfrac{L}{m\,G}$.

Step 1 – list the data: $L = 100$ mol/h, $G = 50$ mol/h, $m = 1.0$.

Step 2 – form the denominator: $m\,G = 1.0 \times 50 = 50$

Step 3 – divide: $A = \dfrac{100}{50}$

Step 4 – evaluate: $A = 2.0$

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

Answer: (C) Go Back to Q33

Q34.

Solution

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

Step 1 – list the data: HTU $= 0.5$ m, NTU $= 6$.

Step 2 – multiply: $Z = 0.5 \times 6$

Step 3 – evaluate: $Z = 3.0$ m

Final Answer: $Z = 3.0$ m $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – relative volatility of an ideal mixture from saturation pressures: $\alpha = \dfrac{P_A^{sat}}{P_B^{sat}}$.

Step 1 – list the saturation pressures: $P_A^{sat} = 100$ kPa, $P_B^{sat} = 40$ kPa.

Step 2 – form the ratio: $\alpha = \dfrac{100}{40}$

Step 3 – evaluate: $\alpha = 2.5$

Final Answer: $\alpha = 2.5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – in the constant-rate period the total drying rate is the flux times the area: $\dot{m} = R_c \times A$.

Step 1 – list the data: Drying flux $R_c = 2$ kg/m^2·h, area $A = 5$ m^2.

Step 2 – multiply: $\dot{m} = 2 \times 5$

Step 3 – evaluate: $\dot{m} = 10$ kg/h

Final Answer: $\dot{m} = 10$ kg/h $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – half-life of a first-order reaction: $t_{1/2} = \dfrac{\ln 2}{k}$, independent of the initial concentration.

Step 1 – list the data: $k = 0.02$ min^{-1}, $\ln 2 = 0.6931$.

Step 2 – substitute: $t_{1/2} = \dfrac{0.6931}{0.02}$

Step 3 – evaluate: $t_{1/2} = 34.66$ min

Final Answer: $t_{1/2} \approx 34.66$ min $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – CSTR design equation for a first-order reaction: $\tau = \dfrac{C_{A0}\,X}{-r_A} = \dfrac{X}{k(1-X)}$, since $-r_A = kC_{A0}(1-X)$.

Step 1 – list the data: $k = 0.1$ min^{-1}, $X = 0.5$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.5 = 0.5$

Step 3 – compute the denominator: $k(1-X) = 0.1 \times 0.5 = 0.05$

Step 4 – divide the conversion by the denominator: $\tau = \dfrac{0.5}{0.05}$

Step 5 – evaluate: $\tau = 10$ min

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

Answer: (A) Go Back to Q38

Q39.

Solution

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

Step 1 – list the data: $k = 0.2$ min^{-1}, $\tau = 5$ min.

Step 2 – form the product $k\tau$: $k\tau = 0.2 \times 5 = 1.0$

Step 3 – take the exponential of $-k\tau$: $e^{-1.0} = 0.3679$

Step 4 – subtract from unity: $X = 1 - 0.3679 = 0.632$

Final Answer: $X \approx 0.632 \Rightarrow$ D

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – ratio of Arrhenius rate constants at two temperatures: $\dfrac{k(T_2)}{k(T_1)} = \exp\left[\dfrac{E_a}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right)\right]$.

Step 1 – list the data: $E_a = 50{,}000$ J/mol, $R = 8.314$ J/mol·K, $T_1 = 300$ K, $T_2 = 310$ K.

Step 2 – evaluate E_a/R: $\dfrac{E_a}{R} = \dfrac{50000}{8.314} = 6014$ K

Step 3 – evaluate the reciprocal-temperature difference: $\dfrac{1}{300} - \dfrac{1}{310} = \dfrac{310-300}{300 \times 310} = \dfrac{10}{93000} = 1.0753 \times 10^{-4}$ K^{-1}

Step 4 – form the exponent: $6014 \times 1.0753 \times 10^{-4} = 0.6467$

Step 5 – take the exponential: $\dfrac{k(310)}{k(300)} = e^{0.6467} = 1.909$

Final Answer: ratio $\approx 1.91 \Rightarrow$ C

Answer: (C) Go Back to Q40

Q41.

Solution

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

Step 1 – list the data: $V = 100$ L, $Q = 20$ L/min.

Step 2 – substitute: $\tau = \dfrac{100}{20}$

Step 3 – evaluate: $\tau = 5.0$ min

Final Answer: $\tau = 5.0$ min $\Rightarrow$ C

Answer: (C) Go Back to Q41

Q42.

Solution

Concept – internal effectiveness factor in the strong-diffusion limit: For a large Thiele modulus the effectiveness factor is $\eta \approx \dfrac{1}{\phi}$.

Step 1 – list the data: $\phi = 5$.

Step 2 – substitute: $\eta = \dfrac{1}{5}$

Step 3 – evaluate: $\eta = 0.2$

Note: $\eta < 1$ confirms that internal pore diffusion limits the reaction rate.

Final Answer: $\eta = 0.2 \Rightarrow$ B

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – step response of a first-order system: $y(t) = K\left(1 - e^{-t/\tau}\right)$; at $t = \tau$ the response reaches 63.2% of the final change.

Step 1 – set $t = \tau$: $\dfrac{t}{\tau} = 1$, so $e^{-t/\tau} = e^{-1} = 0.3679$.

Step 2 – form the bracket: $1 - e^{-1} = 1 - 0.3679 = 0.6321$

Step 3 – multiply by the final change ($= 10$): $y(\tau) = 10 \times 0.6321$

Step 4 – evaluate: $y(\tau) = 6.32$

Final Answer: $y(\tau) \approx 6.32 \Rightarrow$ D

Answer: (D) Go Back to Q43

Q44.

Solution

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

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: $\dfrac{-\pi \times 0.5}{0.8660} = \dfrac{-1.5708}{0.8660} = -1.814$

Step 4 – take the exponential: $e^{-1.814} = 0.163$

Step 5 – convert to a percentage: $\text{overshoot} = 16.3\%$

Final Answer: $\text{overshoot} \approx 16.3\% \Rightarrow$ B

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – stability criterion for a linear system in the s-plane: A linear time-invariant system is asymptotically stable if and only if every closed-loop pole has a negative real part.

Step 1 – interpret "negative real part": Poles with a negative real part lie in the left half of the complex s-plane.

Step 2 – reject the boundary and unstable regions: Poles on the imaginary axis give sustained oscillation (marginal), and poles in the right half give a growing response (unstable).

Step 3 – state the requirement: All roots must lie strictly in the left half of the s-plane.

Final Answer: left half of the s-plane $\Rightarrow$ C

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – straight-line (linear) depreciation: $D = \dfrac{\text{initial cost} - \text{salvage value}}{\text{service life}}$.

Step 1 – list the data: Cost $=$ Rs. $10{,}00{,}000$, salvage $=$ Rs. $1{,}00{,}000$, life $= 9$ years.

Step 2 – find the depreciable amount: $10{,}00{,}000 - 1{,}00{,}000 = 9{,}00{,}000$

Step 3 – divide by the service life: $D = \dfrac{9{,}00{,}000}{9}$

Step 4 – evaluate: $D =$ Rs. $1{,}00{,}000$ per year

Final Answer: $D =$ Rs. $1{,}00{,}000 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q46

Answer Key

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