GATE Chemical Engineering

Sample Paper – 7

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 solution is prepared by dissolving 18 g of glucose (molar mass 180) in 90 g of water (molar mass 18). The mole fraction of glucose in the solution is nearest to: **[1 mark]**

(A) 0.100

(B) 0.0196

(C) 0.200

(D) 0.050

Q2. Methane is burned completely in oxygen following $\mathrm{CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O}$. The number of moles of $\mathrm{CO_2}$ produced per mole of $\mathrm{O_2}$ consumed is: **[1 mark]**

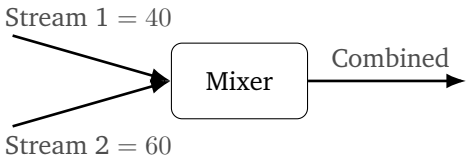
(A) 1.0

(B) 2.0

(C) 0.5

(D) 0.25

Q3. Two liquid streams are combined in the steady mixer shown. Stream 1 is 40 mol/h containing $20\,\mathrm{mol\%}$ of species A, and stream 2 is 60 mol/h containing $50\,\mathrm{mol\%}$ of A. The mole fraction of A in the combined outlet stream is: **[1 mark]**



(A) 0.35

(B) 0.30

(C) 0.38

(D) 0.42

Q4. A system executes a complete thermodynamic cycle during which it absorbs 800 J of heat from a hot source and rejects 300 J of heat to a cold sink. The net work done by the system per cycle is: **[1 mark]**

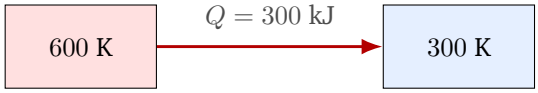
(A) 1100 J

(B) 500 J

(C) 300 J

(D) 800 J

Q5. As shown, 300 kJ of heat flows steadily from a thermal reservoir at 600 K to another reservoir at 300 K. Treating each reservoir as isothermal, the total entropy generated by this heat-transfer process is: **[1 mark]**



(A) 0.5 kJ/K

(B) 1.0 kJ/K

(C) 0 kJ/K

(D) 1.5 kJ/K

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

(A) 1.76 kg/m^3

(B) 0.88 kg/m^3

(C) 2.49 kg/m^3

(D) 44 kg/m^3

Q7. For a gas-phase reaction at 500 K the thermodynamic equilibrium constant is $K = e^2$. Using $\Delta G^\circ = -RT \ln K$ with $R = 8.314$ J/mol·K, the standard Gibbs free energy change of reaction is nearest to: **[1 mark]**

(A) $+8.31$ kJ/mol

(B) 0

(C) -8.31 kJ/mol

(D) -16.6 kJ/mol

Q8. A benzene (A)–toluene (B) liquid obeys Raoult's law. At the system temperature $P_A^{sat} = 100$ kPa and $P_B^{sat} = 40$ kPa. For a liquid of composition $x_A = 0.4$, the mole fraction of A in the vapour in equilibrium with it is nearest to: **[1 mark]**

(A) 0.625

(B) 0.400

(C) 0.360

(D) 0.500

Q9. A real gas at 10 bar (10^6 Pa) and 300 K has a compressibility factor $Z = 0.9$. Using $V = ZRT/P$ with $R = 8.314$ J/mol·K, the molar volume of the gas is nearest to: **[1 mark]**

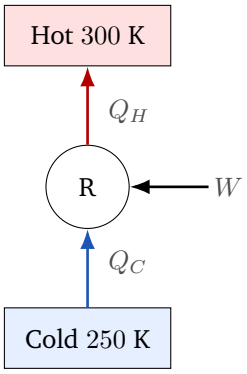
(A) 0.00249 m^3

(B) 0.00225 m^3

(C) 0.0224 m^3

(D) 0.00250 m^3

Q10. The reversible Carnot refrigerator shown maintains a cold space at 250 K while rejecting heat to surroundings at 300 K. Its coefficient of performance, COP $= \dfrac{T_C}{T_H - T_C}$, is: **[1 mark]**



(A) 6.0

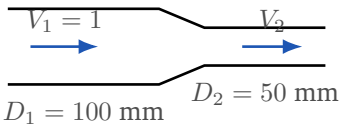
(B) 0.83

(C) 1.2

(D) 5.0

Fluid Mechanics & Mechanical Operations

Q11. Water flows steadily through the pipe shown, which contracts from an internal diameter of 100 mm to 50 mm. The mean velocity in the larger section is 1 m/s. Applying continuity $A_1V_1 = A_2V_2$ for the incompressible flow, the velocity in the smaller section is: **[1 mark]**



(A) 1.0 m/s

(B) 0.25 m/s

(C) 2.0 m/s

(D) 4.0 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 2 m/s. The Reynolds number of the flow, $Re = \rho V D/\mu$, is: **[1 mark]**

(A) $50{,}000$

(B) 5000

(C) 2500

(D) 1250

Q13. Water flows in a pipe with a mean velocity of 3 m/s. Taking $g = 9.81$ m/s^2, the velocity head of the flow, $V^2/(2g)$, is nearest to: **[1 mark]**

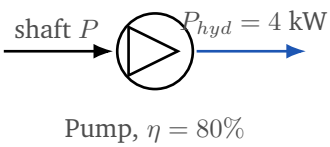
(A) 0.459 m

(B) 0.918 m

(C) 0.306 m

(D) 1.50 m

Q14. The centrifugal pump shown delivers a hydraulic (water) power of 4 kW to the fluid while operating at a pump efficiency of 80%. The shaft (brake) power that must be supplied to the pump, $P_{shaft} = P_{hyd}/\eta$, is: **[1 mark]**



(A) 3.2 kW

(B) 4.8 kW

(C) 4.0 kW

(D) 5.0 kW

Q15. A solid block of volume 0.02 m^3 is fully submerged in water of density 1000 kg/m^3. Taking $g = 9.81$ m/s^2, the buoyant (upthrust) force acting on the block, $F_B = \rho g V$, is: **[1 mark]**

(A) 98.1 N

(B) 196.2 N

(C) 20.0 N

(D) 200.0 N

Q16. In particle characterization, the sphericity of a particle is defined as the surface area of a sphere of the same volume divided by the actual surface area of the particle. For a perfectly cubic particle, the sphericity is nearest to: **[1 mark]**

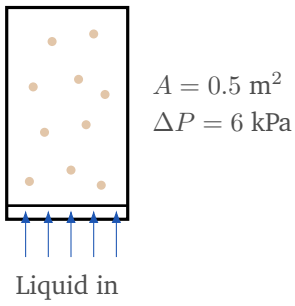
(A) 1.00

(B) 0.50

(C) 0.524

(D) 0.806

Q17. In the fluidized bed shown, an upward liquid flow just supports the solids. The bed has a cross-sectional area of 0.5 m^2 and the measured pressure drop across the bed at incipient fluidization is 6 kPa. The buoyant weight of the solids supported by the fluid, equal to $\Delta P \times A$, is: **[1 mark]**



(A) 12,000 N

(B) 3000 N

(C) 6000 N

(D) 1500 N

Q18. In constant-pressure cake filtration with negligible filter-medium resistance, the filtration time required is proportional to the square of the filtrate volume collected. If the volume of filtrate collected is doubled, the filtration time increases by a factor of: **[1 mark]**

(A) 2

(B) 8

(C) 4

(D) 16

Q19. A ball mill has an internal diameter of 1.2 m (ball diameter negligible) and is operated at 75% of its critical speed. Using the critical-speed relation $n_c = 42.3/\sqrt{D}$ rpm, with D in metres, the actual operating speed of the mill is nearest to: **[1 mark]**

(A) 38.6 rpm

(B) 51.5 rpm

(C) 42.3 rpm

(D) 29.0 rpm

Q20. Steady one-dimensional conduction occurs through a plane wall of thermal conductivity 2 W/m·K, area 4 m^2 and thickness 0.2 m. The conduc-

tion thermal resistance of the wall, $R = L/(kA)$, is: [1 mark]

(A) 0.025 K/W

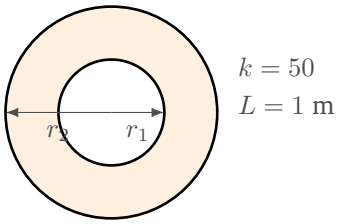
(B) 0.10 K/W

(C) 0.40 K/W

(D) 0.050 K/W

Heat Transfer

Q21. Steady radial conduction occurs through the wall of the hollow cylinder shown, of inner radius $r_1 = 0.05$ m, outer radius $r_2 = 0.10$ m, length 1 m and thermal conductivity $k = 50$ W/m·K. The two surfaces differ in temperature by 100 K. Using $Q = \dfrac{2\pi k L\,\Delta T}{\ln(r_2/r_1)}$, the heat conduction rate is nearest to: [2 marks]



(A) 45.3 kW

(B) 31.4 kW

(C) 22.7 kW

(D) 90.6 kW

Q22. A solid body of characteristic length $L_c = 0.01$ m and thermal conductivity $k = 20$ W/m·K is cooled by a fluid with convective coefficient $h = 100$ W/m^2·K. The Biot number, $Bi = hL_c/k$, is: [2 marks]

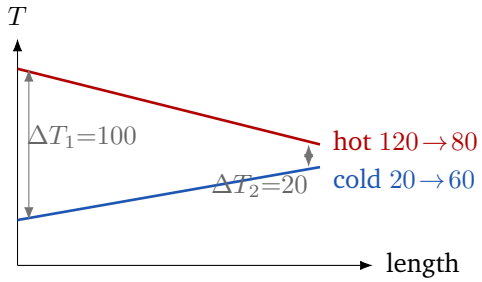
(A) 0.50

(B) 0.05

(C) 5.0

(D) 0.005

Q23. In the parallel-flow double-pipe exchanger whose temperature profile is sketched, the hot fluid is cooled from 120 °C to 80 °C while the cold fluid is heated from 20 °C to 60 °C. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



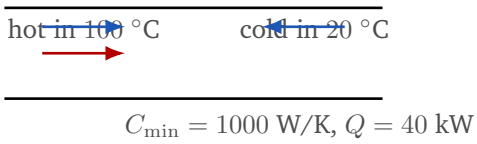
(A) 60.0 °C

(B) 44.8 °C

(C) 49.7 °C

(D) 20.0 °C

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



(A) 0.40

(B) 0.50

(C) 0.80

(D) 1.00

Q25. Two very large parallel plates behave as black bodies and face each other. One is at 500 K and the other at 400 K. Taking $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the net radiant heat flux exchanged between them, $q = \sigma(T_1^4 - T_2^4)$, is nearest to: **[2 marks]**

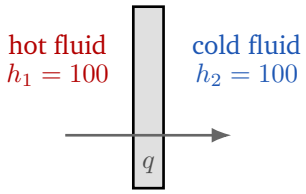
(A) 3544 W/m^2

(B) 1452 W/m^2

(C) 2092 W/m^2

(D) 6250 W/m^2

Q26. Heat passes from a hot fluid to a cold fluid across the thin wall shown. The inside convective coefficient is $h_1 = 100$ W/m^2·K and the outside coefficient is $h_2 = 100$ W/m^2·K; the wall's own conduction resistance is negligible. The overall heat-transfer coefficient from $\dfrac{1}{U} = \dfrac{1}{h_1} + \dfrac{1}{h_2}$ is: **[2 marks]**



(A) 100 W/m^2·K

(B) 200 W/m^2·K

(C) 25 W/m^2·K

(D) 50 W/m^2·K

Q27. Saturated steam condenses on the shell side of a condenser, releasing its latent heat of 2200 kJ/kg. If steam condenses at a rate of 0.5 kg/s, the heat duty of the condenser, $Q = \dot{m}\,\lambda$, is: **[2 marks]**

(A) 1100 kW

(B) 2200 kW

(C) 550 kW

(D) 1000 kW

Mass Transfer & Separation Processes

Q28. A mass-transfer process has a convective mass-transfer coefficient $k_c = 0.02$ m/s, a characteristic length $L = 0.1$ m and a molecular diffusivity $D = 1 \times 10^{-5}$ m^2/s. The Sherwood number, $Sh = k_c L / D$, is: **[2 marks]**

(A) 20

(B) 2000

(C) 100

(D) 200

Q29. For a gas the dynamic viscosity is $\mu = 1.8 \times 10^{-5}$ Pa·s, the density is $\rho = 1.2$ kg/m^3 and the molecular diffusivity of the diffusing species is $D = 2 \times 10^{-5}$ m^2/s. The Schmidt number, $Sc = \mu/(\rho D)$, is: **[2 marks]**

(A) 1.00

(B) 0.50

(C) 0.75

(D) 1.50

Q30. According to the penetration theory of mass transfer, the mass-transfer coefficient is $k_c = 2\sqrt{D/(\pi t_c)}$, where t_c is the contact time. For $D = 1 \times 10^{-9}$ m^2/s and a contact time $t_c = 1$ s, the value of k_c is nearest to: **[2 marks]**

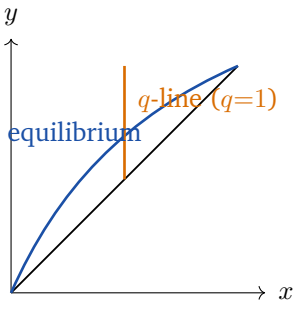
(A) 1.78×10^{-5} m/s

(B) 3.57×10^{-5} m/s

(C) 7.14×10^{-5} m/s

(D) 2.00×10^{-9} m/s

Q31. In the McCabe–Thiele diagram shown, the q-line (feed line) is drawn for a feed that enters as a saturated liquid, for which $q = 1$. The slope of this q-line, given by $q/(q-1)$, is: **[2 marks]**



(A) 0

(B) 1

(C) -1

(D) infinite (vertical)

Q32. A distillation column is fed with 100 mol/h of a mixture containing $50\,\text{mol}\%$ of the light key A. The distillate is withdrawn at 40 mol/h with a composition of $90\,\text{mol}\%$ A. From overall material balances, the mole fraction of A in the bottoms product is: **[2 marks]**

(A) 0.100

(B) 0.300

(C) 0.233

(D) 0.500

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

(A) 2.0

(B) 1.0

(C) 0.5

(D) 4.0

Q34. A packed distillation column that provides a separation equivalent to 5 theoretical stages has a total packing height of 2.5 m. The height equivalent to a theoretical plate (HETP), given by Z/N, is: **[2 marks]**

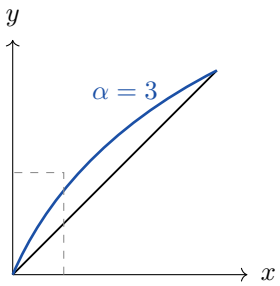
(A) 0.5 m

(B) 1.0 m

(C) 2.5 m

(D) 12.5 m

Q35. For an ideal binary mixture with a constant relative volatility $\alpha = 3$, the vapour–liquid equilibrium relation is $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$, plotted below. For a liquid of composition $x = 0.25$, the equilibrium vapour composition y is: **[2 marks]**



(A) 0.25

(B) 0.75

(C) 0.50

(D) 0.40

Q36. Moist air at a given temperature contains water vapour whose partial pressure is 2 kPa, while the saturation vapour pressure of water at that temperature is 4 kPa. The percentage relative humidity of the air, $\dfrac{p_w}{p_w^{sat}} \times 100$, is: **[2 marks]**

(A) 100%

(B) 25%

(C) 75%

(D) 50%

Reaction Engineering, Process Control & Plant Economics

Q37. A liquid-phase reaction is second order in the reactant, $-r_A = kC_A^2$, with a rate constant $k = 0.5$ L/mol·min. When the reactant concentration is $C_A = 2$ mol/L, the reaction rate $-r_A$ is: **[2 marks]**

(A) 1.0 mol/L·min

(B) 0.5 mol/L·min

(C) 2.0 mol/L·min

(D) 4.0 mol/L·min

Q38. A first-order liquid-phase reaction ($-r_A = kC_A$, $k = 0.5$ min^{-1}) is carried out in an ideal CSTR to a conversion of $X = 0.6$. Using the CSTR design equation $\tau = \dfrac{X}{k(1-X)}$, the required space time is: **[2 marks]**

(A) 1.2 min

(B) 5.0 min

(C) 6.0 min

(D) 3.0 min

Q39. A first-order liquid-phase reaction with rate constant $k = 0.5$ min^{-1} is carried out in an ideal plug-flow reactor (PFR) with a space time of $\tau = 1$ min. Using $k\tau = -\ln(1-X)$, the fractional conversion at the outlet is nearest to: **[2 marks]**

(A) 0.393

(B) 0.632

(C) 0.500

(D) 0.607

Q40. The rate constant of a reaction is observed to double when the temperature is increased from 300 K to 310 K. Using the Arrhenius relation, the activation energy from $E_a = \dfrac{R \ln 2}{(1/300) - (1/310)}$, with $R = 8.314$ J/mol·K, is nearest to: **[2 marks]**

(A) 50.0 kJ/mol

(B) 8.31 kJ/mol

(C) 100 kJ/mol

(D) 53.6 kJ/mol

Q41. An ideal reactor of working volume 50 L is fed continuously by a liquid stream at a volumetric flow rate of 100 L/min. The space velocity of

the reactor, defined as the volumetric feed rate divided by the reactor volume (Q/V), is: [2 marks]

(A) $0.5\ \text{min}^{-1}$

(B) $2.0\ \text{min}^{-1}$

(C) $5.0\ \text{min}^{-1}$

(D) $50\ \text{min}^{-1}$

Q42. A reactant A undergoes two competing parallel liquid-phase reactions: the desired $A \rightarrow R$ with rate $k_1 C_A$ and the undesired $A \rightarrow S$ with rate $k_2 C_A$, where $k_1 = 3$ and $k_2 = 1$ (same units). The instantaneous fractional yield of the desired product, $\dfrac{k_1}{k_1 + k_2}$, is: [2 marks]

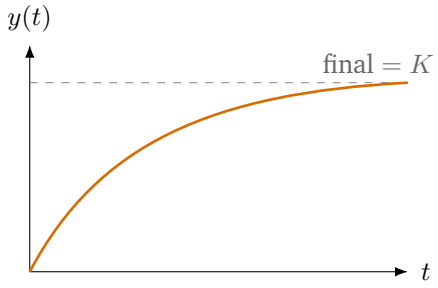
(A) 0.75

(B) 0.25

(C) 3.00

(D) 0.33

Q43. A first-order process has a time constant $\tau = 4$ min and a steady-state gain $K = 5$. A unit step change is applied to its input, so the response is $y(t) = K(1 - e^{-t/\tau})$, sketched below. The final (steady-state) value of the output is: [2 marks]



(A) 4.0

(B) 5.0

(C) 1.0

(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 decay ratio (the ratio of successive overshoot peaks) is $\exp\left[\frac{-2\pi\zeta}{\sqrt{1-\zeta^2}}\right]$. Its value is nearest to: **[2 marks]**

(A) 0.0266

(B) 0.163

(C) 0.500

(D) 0.750

Q45. A proportional-only controller with gain $K_c = 4$ is used on a process of steady-state gain $K_p = 1$. For a unit step change in the set point, the residual steady-state error (offset) is $\frac{1}{1 + K_c K_p}$. Its value is: **[2 marks]**

(A) 0.25

(B) 0.20

(C) 0.80

(D) 0

Q46. A process plant requires an initial investment of Rs. $5{,}00{,}000$ and is expected to generate a uniform net annual cash inflow of Rs. $1{,}00{,}000$. The simple payback period, given by (initial investment)/(annual cash inflow), is: **[2 marks]**

(A) 2 years

(B) 5 years

(C) 10 years

(D) 4 years

Detailed Solutions

Q1.

Solution

Concept – mole fraction is the moles of a component divided by the total moles: $x_{\text{glucose}} = \dfrac{n_{\text{glucose}}}{n_{\text{glucose}} + n_{\text{water}}}$.

Step 1 – convert the glucose mass to moles: $n_{\text{glucose}} = \dfrac{18}{180}$

$n_{\text{glucose}} = 0.10 \text{ mol}$

Step 2 – convert the water mass to moles: $n_{\text{water}} = \dfrac{90}{18}$

$n_{\text{water}} = 5.0 \text{ mol}$

Step 3 – add to get the total moles: $n_{\text{total}} = 0.10 + 5.0 = 5.10 \text{ mol}$

Step 4 – form the mole fraction: $x_{\text{glucose}} = \dfrac{0.10}{5.10}$

Step 5 – evaluate: $x_{\text{glucose}} = 0.0196$

Final Answer: $x_{\text{glucose}} \approx 0.0196 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – read the mole ratios straight from the balanced equation: $\text{CH}_4 + 2\,\text{O}_2 \rightarrow \text{CO}_2 + 2\,\text{H}_2\text{O}$.

Step 1 – note the stoichiometric coefficients: 2 moles of O_2 produce 1 mole of CO_2.

Step 2 – form the required ratio: $\dfrac{n_{\text{CO}_2}}{n_{\text{O}_2}} = \dfrac{1}{2}$

Step 3 – evaluate: $\dfrac{n_{\text{CO}_2}}{n_{\text{O}_2}} = 0.5$

Final Answer: 0.5 mol CO_2 per mol $\text{O}_2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – component balance on A over the mixer: $x_A = \dfrac{(A \text{ in stream 1}) + (A \text{ in stream 2})}{\text{total combined flow}}$.

Step 1 – moles of A in stream 1: $0.20 \times 40 = 8$ mol/h

Step 2 – moles of A in stream 2: $0.50 \times 60 = 30$ mol/h

Step 3 – total moles of A: $8 + 30 = 38$ mol/h

Step 4 – total combined flow: $40 + 60 = 100$ mol/h

Step 5 – form the mole fraction: $x_A = \dfrac{38}{100} = 0.38$

Final Answer: $x_A = 0.38 \Rightarrow$ C

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – over a complete cycle the internal energy returns to its start, so $\Delta U = 0$ and $W_{net} = Q_{net}$: $W_{net} = Q_{in} - Q_{out}$.

Step 1 – list the heat interactions: Heat absorbed $Q_{in} = 800$ J; heat rejected $Q_{out} = 300$ J.

Step 2 – apply $\Delta U = 0$ for the cycle: $Q_{net} = 800 - 300$

Step 3 – evaluate the net heat: $Q_{net} = 500$ J

Step 4 – set the net work equal to the net heat: $W_{net} = 500$ J

Final Answer: $W_{net} = 500$ J $\Rightarrow$ B

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – total entropy generated is the sum of the entropy changes of both reservoirs: $\Delta S_{gen} = \Delta S_{cold} + \Delta S_{hot}$, with each $\Delta S = Q/T$ evaluated with the correct sign.

Step 1 – entropy change of the hot reservoir (loses heat): $\Delta S_{hot} = \dfrac{-300}{600} = -0.5$ kJ/K

Step 2 – entropy change of the cold reservoir (gains heat): $\Delta S_{cold} = \dfrac{+300}{300} =$

$+1.0$ kJ/K

Step 3 – add the two contributions: $\Delta S_{gen} = -0.5 + 1.0$

Step 4 – evaluate: $\Delta S_{gen} = 0.5$ kJ/K

Note: $\Delta S_{gen} > 0$ confirms the heat flow from hot to cold is irreversible.

Final Answer: $\Delta S_{gen} = 0.5$ kJ/K $\Rightarrow$ A

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – density of an ideal gas from $PV = nRT$: $\rho = \dfrac{PM}{RT}$, where M is 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 – evaluate the numerator: $PM = 10^5 \times 0.044 = 4400$

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

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

Step 5 – evaluate: $\rho = 1.764$ kg/m^3 ≈ 1.76 kg/m^3

Final Answer: $\rho \approx 1.76$ kg/m^3 $\Rightarrow$ A

Answer: (A) Go Back to Q6

Q7.

Solution

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

Step 1 – take the logarithm of the equilibrium constant: $\ln K = \ln(e^2) = 2$

Step 2 – list the remaining data: $R = 8.314$ J/mol·K, $T = 500$ K.

Step 3 – substitute into the relation: $\Delta G^\circ = -(8.314)(500)(2)$

Step 4 – multiply stepwise: $8.314 \times 500 = 4157$

$4157 \times 2 = 8314$

Step 5 – apply the negative sign and convert to kJ: $\Delta G^\circ = -8314$ J/mol $= -8.31$ kJ/mol

Final Answer: $\Delta G^\circ \approx -8.31$ kJ/mol $\Rightarrow$ C

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – vapour composition from Raoult's law: $y_A = \dfrac{p_A}{P}$, where $p_A = x_A P_A^{sat}$ and $P = x_A P_A^{sat} + x_B P_B^{sat}$.

Step 1 – find the partial pressure of A: $p_A = 0.4 \times 100 = 40$ kPa

Step 2 – find the partial pressure of B ($x_B = 0.6$): $p_B = 0.6 \times 40 = 24$ kPa

Step 3 – sum to get the total pressure: $P = 40 + 24 = 64$ kPa

Step 4 – form the vapour mole fraction: $y_A = \dfrac{40}{64}$

Step 5 – evaluate: $y_A = 0.625$

Final Answer: $y_A = 0.625 \Rightarrow$ A

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – molar volume of a real gas through the compressibility factor: $V = \dfrac{ZRT}{P}$.

Step 1 – list the data in SI units: $Z = 0.9$, $R = 8.314$ J/mol·K, $T = 300$ K, $P = 10^6$ Pa.

Step 2 – evaluate RT: $RT = 8.314 \times 300 = 2494.2$

Step 3 – multiply by the compressibility factor: $ZRT = 0.9 \times 2494.2 = 2244.8$

Step 4 – divide by the pressure: $V = \dfrac{2244.8}{10^6}$

Step 5 – evaluate: $V = 2.245 \times 10^{-3}$ m^3 ≈ 0.00225 m^3

Final Answer: $V \approx 0.00225$ m^3 $\Rightarrow$ 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 reservoir 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: $\text{COP} = 5.0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – continuity for an incompressible flow means the volumetric flow is the same at every section: $A_1V_1 = A_2V_2$, so $V_2 = V_1(D_1/D_2)^2$.

Step 1 – form the diameter ratio: $\dfrac{D_1}{D_2} = \dfrac{100}{50} = 2$

Step 2 – square the ratio (area scales with diameter squared): $\left(\dfrac{D_1}{D_2}\right)^2 = 2^2 = 4$

Step 3 – multiply by the upstream velocity: $V_2 = 1 \times 4$

Step 4 – evaluate: $V_2 = 4$ m/s

Final Answer: $V_2 = 4$ m/s $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – Reynolds number characterises the flow regime in a pipe: $Re = \dfrac{\rho V D}{\mu}$.

Step 1 – list the data in SI units: $\rho = 1000$ kg/m^3, $V = 2$ m/s, $D = 0.025$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – evaluate the numerator: $\rho V D = 1000 \times 2 \times 0.025 = 50$

Step 3 – divide by the viscosity: $Re = \dfrac{50}{1 \times 10^{-3}}$

Step 4 – evaluate: $Re = 50{,}000$

Final Answer: $Re = 50{,}000 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – velocity head is the kinetic energy of the flow expressed as a height: $h_V = \dfrac{V^2}{2g}$.

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

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

Step 3 – evaluate the denominator: $2g = 2 \times 9.81 = 19.62$

Step 4 – divide: $h_V = \dfrac{9}{19.62}$

Step 5 – evaluate: $h_V = 0.459$ m

Final Answer: $h_V \approx 0.459$ m $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – pump efficiency links the useful hydraulic power to the shaft power supplied: $\eta = \dfrac{P_{hyd}}{P_{shaft}}$, so $P_{shaft} = \dfrac{P_{hyd}}{\eta}$.

Step 1 – list the data: $P_{hyd} = 4$ kW, $\eta = 0.80$.

Step 2 – substitute into the relation: $P_{shaft} = \dfrac{4}{0.80}$

Step 3 – evaluate: $P_{shaft} = 5.0$ kW

Why option C is wrong: 4 kW is the useful power delivered to the water, not the larger shaft power that must be supplied.

Final Answer: $P_{shaft} = 5.0$ kW $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – Archimedes' principle for a fully submerged body: $F_B = \rho\, g\, V$, the weight of the displaced water.

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

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

Step 3 – multiply by the volume: $F_B = 9810 \times 0.02$

Step 4 – evaluate: $F_B = 196.2$ N

Final Answer: $F_B = 196.2$ N $\Rightarrow$ B

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – sphericity compares the surface of the equal-volume sphere with the particle's own surface: $\Psi = \dfrac{\text{surface of equal-volume sphere}}{\text{surface of particle}}$.

Step 1 – take a cube of side a; its volume is: $V = a^3$

Step 2 – find the diameter of a sphere of the same volume: $\dfrac{\pi}{6}d^3 = a^3 \Rightarrow d = \left(\dfrac{6}{\pi}\right)^{1/3} a = 1.2407\, a$

Step 3 – surface area of that equal-volume sphere: $\pi d^2 = \pi(1.2407\, a)^2 = 4.836\, a^2$

Step 4 – surface area of the cube: $6a^2$

Step 5 – form the ratio: $\Psi = \dfrac{4.836\, a^2}{6\, a^2}$

Step 6 – evaluate: $\Psi = 0.806$

Final Answer: $\Psi \approx 0.806 \Rightarrow$ D

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – at incipient fluidization the pressure force on the bed supports the buoyant weight of the solids: $W_{buoyant} = \Delta P \times A$.

Step 1 – list the data in SI units: $\Delta P = 6$ kPa $= 6000$ Pa, $A = 0.5$ m^2.

Step 2 – multiply: $W_{buoyant} = 6000 \times 0.5$

Step 3 – evaluate: $W_{buoyant} = 3000$ N

Final Answer: $W_{buoyant} = 3000$ N $\Rightarrow$ B

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – for constant-pressure filtration with negligible medium resistance, time scales with the square of the filtrate volume: $t \propto V^2$.

Step 1 – write the ratio for the new and old volumes: $\frac{t_2}{t_1} = \left(\frac{V_2}{V_1}\right)^2$

Step 2 – insert the doubling of volume: $\frac{V_2}{V_1} = 2$

Step 3 – square the ratio: $\frac{t_2}{t_1} = 2^2$

Step 4 – evaluate: $\frac{t_2}{t_1} = 4$

Final Answer: time increases by a factor of $4 \Rightarrow$ C

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – the operating speed is a stated fraction of the critical speed: $n = 0.75\, n_c$, with $n_c = \frac{42.3}{\sqrt{D}}$ rpm.

Step 1 – take the square root of the diameter: $\sqrt{1.2} = 1.0954$

Step 2 – compute the critical speed: $n_c = \frac{42.3}{1.0954} = 38.62$ rpm

Step 3 – take 75% of the critical speed: $n = 0.75 \times 38.62$

Step 4 – evaluate: $n = 28.96 \approx 29.0$ rpm

Final Answer: $n \approx 29.0$ rpm $\Rightarrow$ D

Answer: (D) Go Back to Q19

Q20.

Solution

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

Step 1 – list the data: $L = 0.2$ m, $k = 2$ W/m·K, $A = 4$ m^2.

Step 2 – evaluate the denominator: $kA = 2 \times 4 = 8$

Step 3 – divide the thickness by the denominator: $R = \dfrac{0.2}{8}$

Step 4 – evaluate: $R = 0.025$ K/W

Final Answer: $R = 0.025$ K/W $\Rightarrow$ A

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – steady radial conduction through a cylindrical wall: $Q = \dfrac{2\pi k L\,\Delta T}{\ln(r_2/r_1)}$.

Step 1 – list the data: $k = 50$ W/m·K, $L = 1$ m, $\Delta T = 100$ K, $r_1 = 0.05$ m, $r_2 = 0.10$ m.

Step 2 – form the radius ratio and its logarithm: $\dfrac{r_2}{r_1} = \dfrac{0.10}{0.05} = 2 \Rightarrow \ln 2 = 0.6931$

Step 3 – evaluate the numerator: $2\pi k L\,\Delta T = 2 \times 3.1416 \times 50 \times 1 \times 100$

$= 31{,}416$

Step 4 – divide by the logarithm: $Q = \dfrac{31{,}416}{0.6931}$

Step 5 – evaluate: $Q = 45{,}325$ W ≈ 45.3 kW

Final Answer: $Q \approx 45.3$ kW $\Rightarrow$ A

Answer: (A) Go Back to Q21

Q22.

Solution

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

Step 1 – list the data: $h = 100$ W/m^2·K, $L_c = 0.01$ m, $k = 20$ W/m·K.

Step 2 – evaluate the numerator: $hL_c = 100 \times 0.01 = 1.0$

Step 3 – divide by the conductivity: $Bi = \dfrac{1.0}{20}$

Step 4 – evaluate: $Bi = 0.05$

Note: $Bi < 0.1$, so a lumped-capacitance analysis of the solid would be valid.

Final Answer: $Bi = 0.05 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – log-mean temperature difference for a parallel-flow exchanger: $\text{LMTD} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$, with the end differences taken at the same end.

Step 1 – temperature difference at the inlet end (both fluids enter): $\Delta T_1 = 120 - 20 = 100\ ^\circ\text{C}$

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

Step 3 – take the difference of the two: $\Delta T_1 - \Delta T_2 = 100 - 20 = 80$

Step 4 – take the log of the ratio: $\ln\left(\dfrac{100}{20}\right) = \ln 5 = 1.6094$

Step 5 – divide: $\text{LMTD} = \dfrac{80}{1.6094}$

Step 6 – evaluate: $\text{LMTD} = 49.7\ ^\circ\text{C}$

Final Answer: $\text{LMTD} \approx 49.7\ ^\circ\text{C} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – effectiveness is the actual heat transfer divided by the maximum possible: $\varepsilon = \dfrac{Q}{Q_{\max}}$, where $Q_{\max} = C_{\min}(T_{h,in} - T_{c,in})$.

Step 1 – find the maximum inlet temperature difference: $T_{h,in} - T_{c,in} = 100 - 20 = 80\ ^\circ\text{C}$ (i.e. 80 K)

Step 2 – compute the maximum possible heat transfer: $Q_{\max} = 1000 \times 80 = 80{,}000\ \text{W} = 80\ \text{kW}$

Step 3 – form the effectiveness ratio: $\varepsilon = \dfrac{40}{80}$

Step 4 – evaluate: $\varepsilon = 0.50$

Final Answer: $\varepsilon = 0.50 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – net radiation exchange between two large parallel black surfaces: $q = \sigma\left(T_1^4 - T_2^4\right)$.

Step 1 – raise each temperature to the fourth power: $T_1^4 = (500)^4 = 6.25 \times 10^{10}\ \text{K}^4$

$T_2^4 = (400)^4 = 2.56 \times 10^{10}\ \text{K}^4$

Step 2 – take the difference: $T_1^4 - T_2^4 = 6.25 \times 10^{10} - 2.56 \times 10^{10} = 3.69 \times 10^{10}$

Step 3 – multiply by the Stefan–Boltzmann constant: $q = 5.67 \times 10^{-8} \times 3.69 \times 10^{10}$

Step 4 – combine mantissas and powers of ten: $q = (5.67 \times 3.69) \times 10^2 = 20.92 \times 10^2$

$q = 2092\ \text{W/m}^2$

Final Answer: $q \approx 2092\ \text{W/m}^2 \Rightarrow$ C

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – with a negligible wall resistance the two convective resistances add in series: $\frac{1}{U} = \frac{1}{h_1} + \frac{1}{h_2}$.

Step 1 – evaluate each convective resistance: $\frac{1}{h_1} = \frac{1}{100} = 0.01$

$\frac{1}{h_2} = \frac{1}{100} = 0.01$

Step 2 – add the resistances: $\frac{1}{U} = 0.01 + 0.01 = 0.02$

Step 3 – invert to get the overall coefficient: $U = \frac{1}{0.02}$

Step 4 – evaluate: $U = 50\ \text{W/m}^2\cdot\text{K}$

Final Answer: $U = 50\ \text{W/m}^2\cdot\text{K} \Rightarrow$ D

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – condenser heat duty is the latent heat released by the condensing steam: $Q = \dot{m}\,\lambda$.

Step 1 – list the data: $\dot{m} = 0.5$ kg/s, $\lambda = 2200$ kJ/kg.

Step 2 – multiply: $Q = 0.5 \times 2200$

Step 3 – evaluate: $Q = 1100$ kW

Final Answer: $Q = 1100$ kW $\Rightarrow$ A

Answer: (A) Go Back to Q27

Q28.

Solution

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

Step 1 – list the data: $k_c = 0.02$ m/s, $L = 0.1$ m, $D = 1 \times 10^{-5}$ m^2/s.

Step 2 – evaluate the numerator: $k_c L = 0.02 \times 0.1 = 2 \times 10^{-3}$

Step 3 – divide by the diffusivity: $Sh = \dfrac{2 \times 10^{-3}}{1 \times 10^{-5}}$

Step 4 – evaluate: $Sh = 200$

Final Answer: $Sh = 200 \Rightarrow$ D

Answer: (D) Go Back to Q28

Q29.

Solution

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

Step 1 – list the data: $\mu = 1.8 \times 10^{-5}$ Pa·s, $\rho = 1.2$ kg/m^3, $D = 2 \times 10^{-5}$ m^2/s.

Step 2 – evaluate the denominator: $\rho D = 1.2 \times 2 \times 10^{-5} = 2.4 \times 10^{-5}$

Step 3 – divide the viscosity by the denominator: $Sc = \dfrac{1.8 \times 10^{-5}}{2.4 \times 10^{-5}}$

Step 4 – evaluate: $Sc = 0.75$

Final Answer: $Sc = 0.75 \Rightarrow$ C

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – penetration-theory mass-transfer coefficient: $k_c = 2\sqrt{\dfrac{D}{\pi t_c}}$.

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

Step 2 – form the ratio inside the root: $\dfrac{D}{\pi t_c} = \dfrac{1 \times 10^{-9}}{3.1416 \times 1} = 3.183 \times 10^{-10}$

Step 3 – take the square root: $\sqrt{3.183 \times 10^{-10}} = 1.784 \times 10^{-5}$

Step 4 – multiply by two: $k_c = 2 \times 1.784 \times 10^{-5}$

Step 5 – evaluate: $k_c = 3.568 \times 10^{-5}$ m/s $\approx 3.57 \times 10^{-5}$ m/s

Final Answer: $k_c \approx 3.57 \times 10^{-5}$ m/s $\Rightarrow$ B

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – slope of the q-line in the McCabe–Thiele method: slope $= \dfrac{q}{q-1}$.

Step 1 – substitute the feed condition for a saturated liquid: $q = 1$.

Step 2 – form the denominator: $q - 1 = 1 - 1 = 0$

Step 3 – interpret the ratio: slope $= \dfrac{1}{0}$, which is undefined and tends to infinity.

Step 4 – state the geometric meaning: An infinite slope means the q-line is vertical for a saturated-liquid feed.

Final Answer: the q-line is vertical (infinite slope) $\Rightarrow$ D

Answer: (D) Go Back to Q31

Q32.

Solution

Concept – overall and component material balances around the column: $F = D + W$ and $Fx_F = Dx_D + Wx_W$.

Step 1 – overall balance for the bottoms flow: $W = F - D = 100 - 40 = 60$ mol/h

Step 2 – moles of A in the feed: $Fx_F = 100 \times 0.50 = 50$ mol/h

Step 3 – moles of A in the distillate: $Dx_D = 40 \times 0.90 = 36$ mol/h

Step 4 – moles of A in the bottoms by difference: $Wx_W = 50 - 36 = 14$ mol/h

Step 5 – divide by the bottoms flow: $x_W = \dfrac{14}{60}$

Step 6 – evaluate: $x_W = 0.233$

Final Answer: $x_W \approx 0.233 \Rightarrow$ C

Answer: (C) Go Back to Q32

Q33.

Solution

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

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

Step 2 – evaluate the numerator: $mG = 2 \times 50 = 100$

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

Step 4 – evaluate: $S = 0.5$

Final Answer: $S = 0.5 \Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – HETP is the packing height that gives one equilibrium stage: $\text{HETP} = \dfrac{Z}{N}$.

Step 1 – list the data: $Z = 2.5$ m, $N = 5$ stages.

Step 2 – divide: $\text{HETP} = \dfrac{2.5}{5}$

Step 3 – evaluate: $\text{HETP} = 0.5$ m

Final Answer: $\text{HETP} = 0.5$ m $\Rightarrow$ A

Answer: (A) Go Back to Q34

Q35.

Solution

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

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: $y = 0.50 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – percentage relative humidity compares the actual vapour pressure with the saturation value: $\text{RH} = \dfrac{p_w}{p_w^{sat}} \times 100$.

Step 1 – list the data: $p_w = 2$ kPa, $p_w^{sat} = 4$ kPa.

Step 2 – form the ratio: $\dfrac{p_w}{p_w^{sat}} = \dfrac{2}{4} = 0.5$

Step 3 – multiply by 100**:** $\text{RH} = 0.5 \times 100$

Step 4 – evaluate: $\text{RH} = 50\%$

Final Answer: $\text{RH} = 50\% \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – rate law for a second-order reaction: $-r_A = kC_A^2$.

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

Step 2 – square the concentration: $C_A^2 = (2)^2 = 4$ mol^2/L^2

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

Step 4 – evaluate: $-r_A = 2.0$ mol/L·min

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

Answer: (C) 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: $k = 0.5\ \text{min}^{-1}$, $X = 0.6$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.6 = 0.4$

Step 3 – compute the denominator: $k(1-X) = 0.5 \times 0.4 = 0.2$

Step 4 – divide the conversion by the denominator: $\tau = \dfrac{0.6}{0.2}$

Step 5 – evaluate: $\tau = 3.0\ \text{min}$

Final Answer: $\tau = 3.0\ \text{min} \Rightarrow \boxed{\text{D}}$

Answer: (D) 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: $k = 0.5\ \text{min}^{-1}$, $\tau = 1$ min.

Step 2 – form the product $k\tau$: $k\tau = 0.5 \times 1 = 0.5$

Step 3 – take the exponential of $-k\tau$: $e^{-0.5} = 0.6065$

Step 4 – subtract from unity: $X = 1 - 0.6065 = 0.3935$

Final Answer: $X \approx 0.393 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – Arrhenius relation between two rate constants: $\ln\dfrac{k_2}{k_1} = \dfrac{E_a}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right)$, so $E_a = \dfrac{R\ln(k_2/k_1)}{(1/T_1) - (1/T_2)}$.

Step 1 – the rate constant doubles, so: $\dfrac{k_2}{k_1} = 2 \Rightarrow \ln 2 = 0.6931$

Step 2 – evaluate the reciprocal-temperature difference: $\frac{1}{300} - \frac{1}{310} = \frac{310-300}{300\times 310} = \frac{10}{93000} = 1.0753 \times 10^{-4}\ \text{K}^{-1}$

Step 3 – evaluate the numerator: $R\ln 2 = 8.314 \times 0.6931 = 5.763$

Step 4 – divide: $E_a = \frac{5.763}{1.0753 \times 10^{-4}}$

Step 5 – evaluate: $E_a = 53{,}590$ J/mol ≈ 53.6 kJ/mol

Final Answer: $E_a \approx 53.6$ kJ/mol $\Rightarrow$ D

Answer: (D) Go Back to Q40

Q41.

Solution

Concept – space velocity is the inverse of the space time, i.e. the feed rate per unit reactor volume: $SV = \frac{Q}{V}$.

Step 1 – list the data: $Q = 100$ L/min, $V = 50$ L.

Step 2 – divide: $SV = \frac{100}{50}$

Step 3 – evaluate: $SV = 2.0\ \text{min}^{-1}$

Note: this equals $1/\tau$, so the space time here is $\tau = 0.5$ min.

Final Answer: $SV = 2.0\ \text{min}^{-1} \Rightarrow$ B

Answer: (B) Go Back to Q41

Q42.

Solution

Concept – instantaneous fractional yield for two parallel first-order reactions: $\phi_R = \frac{k_1}{k_1 + k_2}$, since both rates share the same concentration dependence.

Step 1 – list the rate constants: $k_1 = 3$, $k_2 = 1$.

Step 2 – form the denominator: $k_1 + k_2 = 3 + 1 = 4$

Step 3 – divide: $\phi_R = \frac{3}{4}$

Step 4 – evaluate: $\phi_R = 0.75$

Final Answer: $\phi_R = 0.75 \Rightarrow$ A

Answer: (A) Go Back to Q42

Q43.

Solution

Concept – final value of a first-order step response: $y(\infty) = K \times (\text{step size})$; the exponential term vanishes as $t \to \infty$.

Step 1 – write the response and let $t \to \infty$: $y(t) = K(1 - e^{-t/\tau})$; as $t \to \infty$, $e^{-t/\tau} \to 0$.

Step 2 – substitute the limiting bracket: $y(\infty) = K(1 - 0) = K$

Step 3 – insert the gain and unit step: $y(\infty) = 5 \times 1$

Step 4 – evaluate: $y(\infty) = 5.0$

Why option D is wrong: 6.32 would be the response at one time constant (63.2% of the final change), not the final value.

Final Answer: $y(\infty) = 5.0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – decay ratio of an underdamped second-order system: $\text{DR} = \exp\left[\dfrac{-2\pi\zeta}{\sqrt{1-\zeta^2}}\right]$, which is the square of the overshoot.

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: $\text{DR} = e^{-3.628}$

Step 5 – evaluate: $\text{DR} = 0.0266$

Final Answer: $\text{DR} \approx 0.0266 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – offset (steady-state error) of a proportional-only controller: offset $= \dfrac{1}{1 + K_c K_p}$ for a unit set-point change.

Step 1 – list the data: $K_c = 4$, $K_p = 1$.

Step 2 – form the loop gain product: $K_c K_p = 4 \times 1 = 4$

Step 3 – add one: $1 + K_c K_p = 1 + 4 = 5$

Step 4 – take the reciprocal: offset $= \dfrac{1}{5}$

Step 5 – evaluate: offset $= 0.20$

Note: a higher controller gain would shrink this offset but never remove it entirely.

Final Answer: offset $= 0.20 \Rightarrow$ B

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – simple payback period ignores the time value of money: payback $= \dfrac{\text{initial investment}}{\text{annual cash inflow}}$.

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

Step 2 – divide: payback $= \dfrac{5{,}00{,}000}{1{,}00{,}000}$

Step 3 – evaluate: payback $= 5$ years

Final Answer: payback period $= 5$ 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	C	4	B	5	A
6	A	7	C	8	A	9	B	10	D
11	D	12	A	13	A	14	D	15	B
16	D	17	B	18	C	19	D	20	A
21	A	22	B	23	C	24	B	25	C
26	D	27	A	28	D	29	C	30	B
31	D	32	C	33	C	34	A	35	C
36	D	37	C	38	D	39	A	40	D
41	B	42	A	43	B	44	A	45	B
46	B								