GATE Chemical Engineering

Sample Paper – 8

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 20 g of NaOH (molar mass 40 g/mol) in enough water to make a total solution volume of 0.5 litre. The molar concentration (molarity) of the solution is: **[1 mark]**

(A) 0.5 mol/L

(B) 2.0 mol/L

(C) 0.25 mol/L

(D) 1.0 mol/L

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

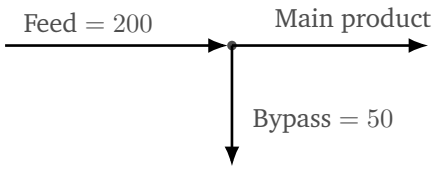
(A) 16 kg

(B) 44 kg

(C) 32 kg

(D) 88 kg

Q3. In the steady splitter shown below, a single feed stream of 200 mol/h is divided into a main product stream and a bypass stream. The bypass stream carries 50 mol/h. The fraction of the feed that is bypassed is: **[1 mark]**



(A) 0.50

(B) 0.75

(C) 0.25

(D) 4.0

Q4. An ideal gas is expanded slowly at a constant pressure of 2 bar (2×10^5 Pa) from a volume of 0.01 m^3 to a volume of 0.03 m^3. The work done *by* the gas on the surroundings ($W = P\,\Delta V$) is: **[1 mark]**

(A) 2000 J

(B) 4000 J

(C) 6000 J

(D) 400 J

Q5. One mole of an ideal gas undergoes a reversible isothermal expansion at 300 K during which its volume doubles. The change in the entropy of the gas, $\Delta S = nR\ln(V_2/V_1)$, is nearest to: **[1 mark]**

(A) 8.31 J/K

(B) 2.88 J/K

(C) 11.5 J/K

(D) 5.76 J/K

Q6. Nitrogen gas (molar mass $M = 0.028$ kg/mol) behaves ideally at a temperature of 300 K and a pressure of 1 bar (10^5 Pa). Using $\rho = PM/(RT)$, the mass density of the gas is nearest to: **[1 mark]**

(A) 0.028 kg/m^3

(B) 2.24 kg/m^3

(C) 1.12 kg/m^3

(D) 0.56 kg/m^3

Q7. For a reaction at a temperature of 300 K, the standard enthalpy change is $\Delta H^\circ = 100$ kJ/mol and the standard entropy change is $\Delta S^\circ = 200$ J/mol·K. Using $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$, the standard Gibbs free energy change of the reaction is: **[1 mark]**

(A) 100 kJ/mol

(B) 60 kJ/mol

(C) -20 kJ/mol

(D) 40 kJ/mol

Q8. A gas mixture at a total pressure of 200 kPa contains carbon dioxide at a mole fraction of 0.30. Assuming ideal-gas behaviour, the partial pressure of carbon dioxide (Dalton's law, $p_i = y_i P$) is: **[1 mark]**

(A) 200 kPa

(B) 30 kPa

(C) 60 kPa

(D) 140 kPa

Q9. At a given state a real gas has a molar volume of $0.0200\ \text{m}^3/\text{mol}$, whereas the ideal-gas law at the same temperature and pressure predicts a molar volume of $0.0250\ \text{m}^3/\text{mol}$. The compressibility factor $Z = V_{\text{real}}/V_{\text{ideal}}$ of the gas is: **[1 mark]**

(A) 1.0

(B) 1.25

(C) 0.80

(D) 0.50

Q10. A reversible Carnot refrigerator operates between a cold space at 250 K and warm surroundings at 300 K. Its coefficient of performance, COP $= T_C/(T_H - T_C)$, is: **[1 mark]**

(A) 5.0

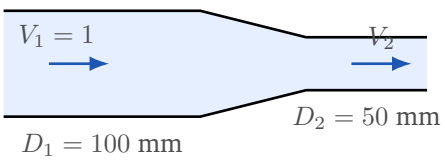
(B) 6.0

(C) 0.83

(D) 1.0

Fluid Mechanics & Mechanical Operations

Q11. Water flows steadily through the contracting pipe shown. The upstream diameter is 100 mm where the mean velocity is 1 m/s, and the pipe contracts to a downstream diameter of 50 mm. By continuity ($A_1V_1 = A_2V_2$), the mean velocity in the smaller section is: **[1 mark]**



(A) 4.0 m/s

(B) 2.0 m/s

(C) 0.25 m/s

(D) 1.0 m/s

Q12. Water of density 1000 kg/m^3 flows through a pipe at a mean velocity of 4 m/s. The dynamic pressure of the stream, $\frac{1}{2}\rho V^2$, is: **[1 mark]**

(A) 2 kPa

(B) 4 kPa

(C) 8 kPa

(D) 16 kPa

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

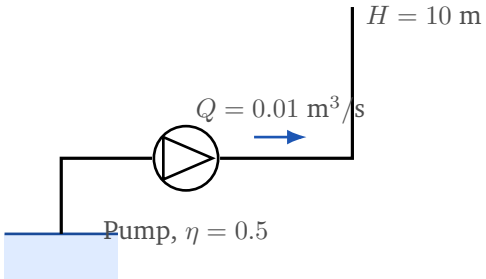
(A) 4.08 m

(B) 2.04 m

(C) 8.15 m

(D) 1.0 m

Q14. A centrifugal pump shown below delivers water at $Q = 0.01$ m^3/s against a total head of $H = 10$ m. The pump has an overall efficiency of 50%. Taking $\rho_w = 1000$ kg/m^3, the shaft power input required, $P = \rho g Q H/\eta$, is nearest to: **[1 mark]**



(A) 0.98 kW

(B) 1.96 kW

(C) 0.49 kW

(D) 3.92 kW

Q15. A solid body of total volume 0.002 m^3 is fully submerged in still water of density 1000 kg/m^3. The upward buoyant force on the body (Archimedes' principle, $F_B = \rho g V$) is: **[1 mark]**

(A) 2.0 N

(B) 9.81 N

(C) 4.9 N

(D) 19.62 N

Q16. A spherical particle settles through a liquid in the Stokes (creeping-flow) regime at a particle Reynolds number of $Re_p = 0.5$. In this regime the drag coefficient is $C_D = 24/Re_p$. The drag coefficient of the particle is: **[1 mark]**

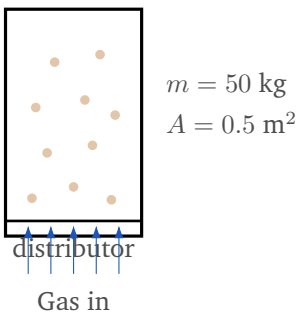
(A) 24

(B) 48

(C) 12

(D) 0.5

Q17. In the fluidized bed shown, a batch of solids of total mass 50 kg rests on a distributor plate of cross-sectional area 0.5 m^2. When the bed is fully fluidized, the pressure drop across it equals the buoyed weight of the solids per unit area; for this fully suspended bed $\Delta P \approx mg/A$. Its value is nearest to: **[1 mark]**



(A) 981 Pa

(B) 490 Pa

(C) 100 Pa

(D) 1962 Pa

Q18. In size reduction, which law states that the energy required per unit mass of feed is proportional to the logarithm of the ratio of feed size to product size, and is therefore best suited to coarse crushing? **[1 mark]**

(A) Rittinger's law

(B) Bond's law

(C) Kick's law

(D) Stokes' law

Q19. A single spherical particle has a diameter of 2 mm. For a sphere the specific surface (surface-area-to-volume ratio) is $a = 6/d$. The value of this ratio for the particle is: **[1 mark]**

(A) 3000 m^{-1}

(B) 6000 m^{-1}

(C) 1500 m^{-1}

(D) 300 m^{-1}

Heat Transfer

Q20. A plane wall has thermal conductivity $k = 2$ W/m·K, face area $A = 1$ m^2 and thickness $L = 0.2$ m. The conductive thermal resistance of the wall, $R = L/(kA)$, is: **[1 mark]**

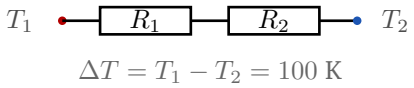
(A) 0.4 K/W

(B) 1.0 K/W

(C) 0.1 K/W

(D) 10 K/W

Q21. Two wall layers in series carry the same steady heat flow, as represented by the thermal-resistance network shown. Their conductive resistances are $R_1 = 0.1$ K/W and $R_2 = 0.3$ K/W, and the overall temperature difference across the pair is 100 K. The steady rate of heat conduction, $Q = \Delta T/(R_1 + R_2)$, is: **[2 marks]**



(A) 250 W

(B) 1000 W

(C) 100 W

(D) 500 W

Q22. A small metal sphere used as a temperature sensor has a characteristic length (volume/surface-area) of $L_c = 0.01$ m and thermal conductivity $k = 50$ W/m·K. It is exposed to a fluid with convective coefficient $h = 100$ W/m^2·K. The Biot number, $Bi = hL_c/k$, is: **[2 marks]**

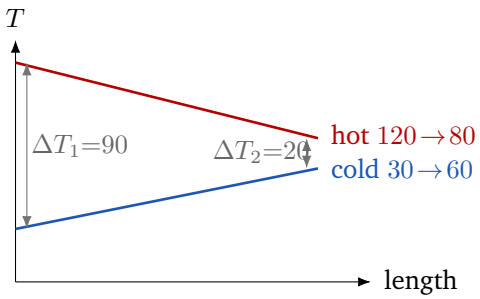
(A) 0.2

(B) 0.02

(C) 2.0

(D) 0.5

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



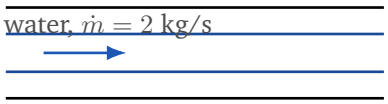
(A) 55.0 °C

(B) 40.0 °C

(C) 50.0 °C

(D) 46.5 °C

Q24. One stream in the heat exchanger shown is water flowing at a mass flow rate of $\dot{m} = 2$ kg/s with a specific heat capacity of $c_p = 4200$ J/kg·K. The heat-capacity rate of this stream, $C = \dot{m}\, c_p$, is: **[2 marks]**



Double-pipe exchanger, $c_p = 4200$ J/kg·K

(A) 2100 W/K

(B) 4200 W/K

(C) 8400 W/K

(D) 4.2 W/K

Q25. Heat is transferred across a wall from a hot fluid to a cold fluid. The two convective film coefficients are $h_1 = 1000$ W/m^2·K and $h_2 = 1000$ W/m^2·K, and the wall's own conductive resistance is negligible. Using $\dfrac{1}{U} = \dfrac{1}{h_1} + \dfrac{1}{h_2}$, the overall heat-transfer coefficient U is: **[2 marks]**

(A) 2000 W/m^2·K

(B) 1000 W/m^2·K

(C) 250 W/m^2·K

(D) 500 W/m^2·K

Q26. A gray surface has an emissivity of $\varepsilon = 0.5$ and is held at a temperature of 1000 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) 56700 W/m^2

(B) 28350 W/m^2

(C) 14175 W/m^2

(D) 5670 W/m^2

Q27. A single-effect evaporator vaporizes water from a dilute feed at a rate of 0.5 kg/s. The latent heat of vaporization at the boiling conditions is 2260 kJ/kg. Neglecting sensible-heat effects, the heat duty of the evaporator ($Q = \dot{m}\,\lambda$) is nearest to: **[2 marks]**

(A) 2260 kW

(B) 1130 kW

(C) 565 kW

(D) 4520 kW

Mass Transfer & Separation Processes

Q28. A dilute solute diffuses through a liquid of density $\rho = 1000$ kg/m^3 and dynamic viscosity $\mu = 1 \times 10^{-3}$ Pa·s. The molecular diffusivity of the solute is $D = 1 \times 10^{-9}$ m^2/s. The Schmidt number of the system, $Sc = \mu/(\rho D)$, is: **[2 marks]**

(A) 1000

(B) 100

(C) 1.0

(D) 0.001

Q29. In a mass-transfer test the film coefficient is $k_c = 0.01$ m/s, the characteristic length is $L = 0.1$ m and the diffusivity is $D = 1 \times 10^{-4}$ m^2/s. The Sherwood number, $Sh = k_c L/D$, is: **[2 marks]**

(A) 100

(B) 1.0

(C) 10

(D) 0.1

Q30. In a gas absorber described by two-film theory, the gas-side resistance is $1/k_g = 0.5$ and the liquid-side contribution referred to the gas phase is $m/k_l = 1.5$ (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]**

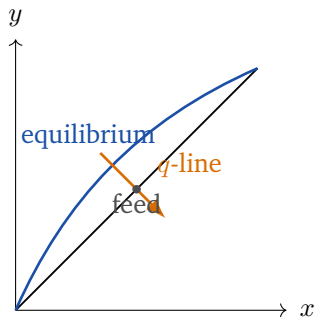
(A) 1.0

(B) 0.5

(C) 2.0

(D) 0.25

Q31. The McCabe–Thiele diagram shown includes the feed (q-) line for a partially vaporized feed. The slope of the q-line is $q/(q-1)$, where q is the fraction of the feed that is liquid. For a feed that is 50% vaporized ($q = 0.5$), the slope of the q-line is: **[2 marks]**



(A) 1.0

(B) -1.0

(C) 0.5

(D) 0

Q32. A binary mixture with a constant relative volatility $\alpha = 3.0$ 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, 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) 7.08

(B) 5.0

(C) 9.0

(D) 3.5

Q33. In a stripping column the liquid flow rate is $L = 200$ mol/h, the gas (vapour) flow rate is $G = 50$ mol/h and the equilibrium slope is $m = 2.0$. The stripping factor, defined as $S = mG/L$, is: **[2 marks]**

(A) 0.5

(B) 1.0

(C) 2.0

(D) 4.0

Q34. A packed distillation column is designed using the concept of an equivalent theoretical stage, so that the packed height is $Z = \text{HETP} \times N$, where HETP is the height equivalent to a theoretical plate. If HETP $= 0.4$ m and $N = 5$ theoretical stages are required, the packed height is: **[2 marks]**

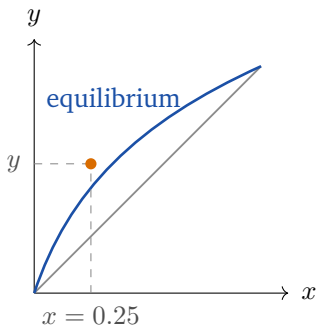
(A) 1.0 m

(B) 2.0 m

(C) 4.0 m

(D) 0.4 m

Q35. For a binary system of constant relative volatility $\alpha = 4.0$, the vapour composition in equilibrium with a liquid of mole fraction x is $y = \dfrac{\alpha x}{1 + (\alpha - 1)x}$, as plotted on the equilibrium curve shown. For a liquid composition of $x = 0.25$, the equilibrium vapour composition y is nearest to: **[2 marks]**



(A) 0.571

(B) 0.250

(C) 0.400

(D) 0.750

Q36. A wet solid contains a total moisture of 0.30 kg water per kg dry solid. At the drying-air conditions the equilibrium moisture content is 0.05 kg water per kg dry solid. The free moisture content of the solid (the moisture that can be removed by drying) is: **[2 marks]**

(A) 0.35

(B) 0.05

(C) 0.30

(D) 0.25

Reaction Engineering, Process Control & Plant Economics

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

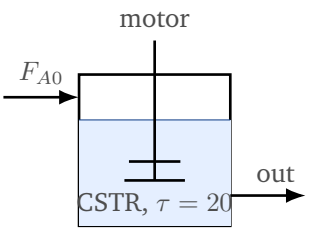
(A) 0.5 min

(B) 2.0 min

(C) 0.25 min

(D) 1.0 min

Q38. A first-order liquid-phase reaction ($-r_A = kC_A$, $k = 0.2$ min^{-1}) is carried out in the ideal continuous stirred-tank reactor (CSTR) shown, with a space time of $\tau = 20$ min. Using the CSTR result $X = \dfrac{k\tau}{1+k\tau}$, the conversion achieved is: **[2 marks]**



(A) 0.50

(B) 0.67

(C) 0.80

(D) 0.20

Q39. A first-order liquid-phase reaction with rate constant $k = 0.231$ min^{-1} is carried out in an ideal plug-flow reactor (PFR) with a space time of $\tau = 3$ min. Using $k\tau = -\ln(1 - X)$, the fractional conversion at the outlet is nearest to: **[2 marks]**

(A) 0.632

(B) 0.693

(C) 0.865

(D) 0.500

Q40. A reaction has an Arrhenius activation energy of $E_a = 100$ kJ/mol. Taking $R = 8.314$ J/mol·K, the factor by which the rate constant increases when the temperature is raised from 400 K to 410 K, given by $\dfrac{k(410)}{k(400)} = \exp\left[\dfrac{E_a}{R}\left(\dfrac{1}{400} - \dfrac{1}{410}\right)\right]$, is nearest to: **[2 marks]**

(A) 2.08

(B) 1.0

(C) 4.0

(D) 0.5

Q41. A first-order liquid-phase reaction with rate constant $k = 0.5$ min^{-1} is carried out in a reactor with a mean residence time (space time) of $\tau = 4$ min. The Damkohler number, defined for this first-order reaction as $Da = k\tau$, is: **[2 marks]**

(A) 0.5

(B) 8.0

(C) 4.0

(D) 2.0

Q42. A first-order reaction occurs in a catalyst slab for which the internal effectiveness factor is $\eta = \dfrac{\tanh \phi}{\phi}$, where ϕ is the Thiele modulus. For a Thiele modulus of $\phi = 1$, the effectiveness factor is nearest to: **[2 marks]**

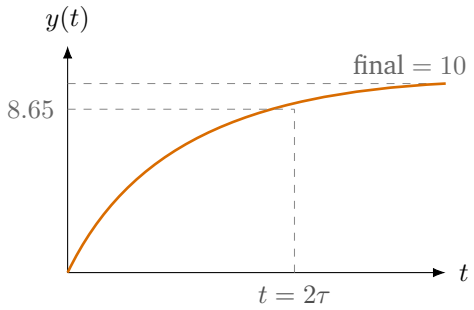
(A) 1.0

(B) 0.762

(C) 0.5

(D) 0.46

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



(A) 10.0

(B) 6.32

(C) 5.0

(D) 8.65

Q44. A closed-loop control system behaves as an underdamped second-order system with a damping ratio $\zeta = 0.6$. 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) 16.3%

(B) 9.5%

(C) 25%

(D) 5%

Q45. A process of steady-state gain $K_p = 2$ is controlled by a purely proportional controller of gain $K_c = 2$ in a negative-feedback loop. For a unit step change in set point, the fractional steady-state offset of a first-order process is $\frac{1}{1 + K_c K_p}$. Its value is: **[2 marks]**

(A) 1.0

(B) 0.8

(C) 0.2

(D) 0.25

Q46. A chemical plant requires a fixed-capital investment of Rs. $50{,}00{,}000$ and is expected to generate a uniform annual cash flow of Rs. $10{,}00{,}000$. The simple payback period, defined as (fixed-capital investment)/(annual cash flow), is: **[2 marks]**

(A) 10 years

(B) 2.5 years

(C) 5.0 years

(D) 0.2 years

Detailed Solutions

Q1.

Solution

Concept – molarity is the moles of solute divided by the volume of solution in litres: $C = \dfrac{n}{V}$, where $n = \dfrac{\text{mass}}{\text{molar mass}}$.

Step 1 – find the moles of NaOH: $n = \dfrac{20\ \text{g}}{40\ \text{g/mol}}$

$n = 0.5$ mol

Step 2 – note the solution volume: $V = 0.5$ litre

Step 3 – form the molarity: $C = \dfrac{0.5\ \text{mol}}{0.5\ \text{L}}$

Step 4 – evaluate: $C = 1.0$ mol/L

Final Answer: $C = 1.0$ mol/L $\Rightarrow$ D

Answer: (D) Go Back to Q1

Q2.

Solution

Concept – use the stoichiometry of the combustion reaction: $\text{CH}_4 + 2\,\text{O}_2 \rightarrow \text{CO}_2 + 2\,\text{H}_2\text{O}$, so 1 mole of methane gives 1 mole of carbon dioxide.

Step 1 – find the moles of methane burnt: $n_{\text{CH}_4} = \dfrac{16\ \text{kg}}{16\ \text{kg/kmol}} = 1$ kmol

Step 2 – apply the $1:1$ mole ratio to CO_2: $n_{\text{CO}_2} = n_{\text{CH}_4} = 1$ kmol

Step 3 – convert the carbon dioxide moles to mass: $m_{\text{CO}_2} = n_{\text{CO}_2} \times M_{\text{CO}_2} = 1 \times 44$

$m_{\text{CO}_2} = 44$ kg

Final Answer: $m_{\text{CO}_2} = 44$ kg $\Rightarrow$ B

Answer: (B) Go Back to Q2

Q3.

Solution

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

Step 1 – read the two streams from the diagram: Bypass $= 50$ mol/h, feed $= 200$ mol/h.

Step 2 – form the ratio: fraction $= \dfrac{50}{200}$

Step 3 – evaluate: fraction $= 0.25$

Final Answer: fraction bypassed $= 0.25 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – work done by a gas at constant pressure: $W = P\,\Delta V = P\,(V_2 - V_1)$.

Step 1 – list the data in SI units: $P = 2 \times 10^5$ Pa, $V_1 = 0.01$ m^3, $V_2 = 0.03$ m^3.

Step 2 – find the volume change: $\Delta V = 0.03 - 0.01 = 0.02$ m^3

Step 3 – substitute into $W = P\,\Delta V$: $W = 2 \times 10^5 \times 0.02$

Step 4 – evaluate: $W = 4000$ J

Final Answer: $W = 4000$ J $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

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

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

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

Step 3 – substitute into the formula: $\Delta S = 1 \times 8.314 \times 0.6931$

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

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

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – density of an ideal gas from the ideal-gas law: $PV = nRT$ with $n = m/M$ gives $\rho = \dfrac{PM}{RT}$.

Step 1 – list the data in SI units: $P = 10^5$ Pa, $M = 0.028$ kg/mol, $R = 8.314$ J/mol·K, $T = 300$ K.

Step 2 – compute the numerator: $PM = 10^5 \times 0.028 = 2800$

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

Step 4 – divide: $\rho = \dfrac{2800}{2494.2}$

Step 5 – evaluate: $\rho = 1.123$ kg/m$^3 \approx 1.12$ kg/m^3

Final Answer: $\rho \approx 1.12$ kg/m$^3 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – standard Gibbs energy from enthalpy and entropy: $\Delta G^\circ = \Delta H^\circ - T\,\Delta S^\circ$.

Step 1 – list the data in consistent (joule) units: $\Delta H^\circ = 100{,}000$ J/mol, $\Delta S^\circ = 200$ J/mol·K, $T = 300$ K.

Step 2 – evaluate the entropy term: $T\,\Delta S^\circ = 300 \times 200 = 60{,}000$ J/mol

Step 3 – subtract from the enthalpy term: $\Delta G^\circ = 100{,}000 - 60{,}000$

Step 4 – evaluate: $\Delta G^\circ = 40{,}000$ J/mol $= 40$ kJ/mol

Final Answer: $\Delta G^\circ = 40$ kJ/mol $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – Dalton's law for the partial pressure of a component: $p_i = y_i\,P$, the mole fraction times the total pressure.

Step 1 – list the data: $y_{CO_2} = 0.30$, $P = 200$ kPa.

Step 2 – substitute: $p_{CO_2} = 0.30 \times 200$

Step 3 – evaluate: $p_{CO_2} = 60$ kPa

Final Answer: $p_{CO_2} = 60$ kPa $\Rightarrow$ C

Answer: (C) Go Back to Q8

Q9.

Solution

Concept – the compressibility factor compares the real molar volume to the ideal-gas prediction: $Z = \dfrac{V_{\text{real}}}{V_{\text{ideal}}}$.

Step 1 – list the data: $V_{\text{real}} = 0.0200\ \text{m}^3/\text{mol}$, $V_{\text{ideal}} = 0.0250\ \text{m}^3/\text{mol}$.

Step 2 – form the ratio: $Z = \dfrac{0.0200}{0.0250}$

Step 3 – evaluate: $Z = 0.80$

Interpretation: $Z < 1$ indicates that attractive forces dominate, so the gas is more compressible than an ideal gas.

Final Answer: $Z = 0.80 \Rightarrow$ C

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – coefficient of performance of a 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 – find the temperature difference: $T_H - T_C = 300 - 250 = 50$ K

Step 3 – substitute into the formula: $\text{COP} = \dfrac{250}{50}$

Step 4 – evaluate: $\text{COP} = 5.0$

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

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – conservation of mass (continuity) for an incompressible flow: $A_1V_1 = A_2V_2$, so $V_2 = V_1\,(D_1/D_2)^2$ since $A \propto D^2$.

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

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

$V_2 = 4$ m/s

Final Answer: $V_2 = 4.0$ m/s $\Rightarrow$ A

Answer: (A) Go Back to Q11

Q12.

Solution

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

Step 1 – list the data: $\rho = 1000$ kg/m^3, $V = 4$ m/s.

Step 2 – square the velocity: $V^2 = 4^2 = 16$ m^2/s^2

Step 3 – substitute: $q = \frac{1}{2} \times 1000 \times 16$

Step 4 – evaluate: $q = 8000$ Pa $= 8$ kPa

Final Answer: $q = 8$ kPa $\Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – Darcy–Weisbach frictional head loss: $h_f = \dfrac{fLV^2}{2gD}$.

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

Step 2 – evaluate the numerator: $fLV^2 = 0.02 \times 100 \times 2^2 = 0.02 \times 100 \times 4 = 8$

Step 3 – evaluate the denominator: $2gD = 2 \times 9.81 \times 0.1 = 1.962$

Step 4 – divide: $h_f = \dfrac{8}{1.962}$

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

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

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – shaft power of a pump is the hydraulic power divided by the efficiency: $P = \dfrac{\rho\, g\, Q\, H}{\eta}$.

Step 1 – list the data: $\rho = 1000 \text{ kg/m}^3$, $g = 9.81 \text{ m/s}^2$, $Q = 0.01 \text{ m}^3/\text{s}$, $H = 10 \text{ m}$, $\eta = 0.5$.

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

Step 3 – multiply by the discharge: $\rho g Q = 9810 \times 0.01 = 98.1$

Step 4 – multiply by the head to get hydraulic power: $\rho g Q H = 98.1 \times 10 = 981$ W

Step 5 – divide by the efficiency: $P = \dfrac{981}{0.5} = 1962 \text{ W}$

Step 6 – express in kilowatts: $P = 1.962 \text{ kW} \approx 1.96 \text{ kW}$

Final Answer: $P \approx 1.96 \text{ kW} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

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

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

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

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

Step 4 – evaluate: $F_B = 19.62 \text{ N}$

Final Answer: $F_B = 19.62 \text{ N} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – in the Stokes (creeping-flow) regime the drag coefficient of a sphere is: $C_D = \dfrac{24}{Re_p}$.

Step 1 – list the data: $Re_p = 0.5$.

Step 2 – substitute into the relation: $C_D = \dfrac{24}{0.5}$

Step 3 – evaluate: $C_D = 48$

Final Answer: $C_D = 48 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – for a fully fluidized bed the pressure drop supports the whole weight of solids: $\Delta P = \dfrac{m\,g}{A}$.

Step 1 – list the data: $m = 50$ kg, $g = 9.81$ m/s^2, $A = 0.5$ m^2.

Step 2 – find the total weight of solids: $mg = 50 \times 9.81 = 490.5$ N

Step 3 – divide by the cross-sectional area: $\Delta P = \dfrac{490.5}{0.5}$

Step 4 – evaluate: $\Delta P = 981$ Pa

Final Answer: $\Delta P = 981$ Pa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – the three classical laws of size reduction differ in how energy scales with size: Rittinger (new surface), Kick (size ratio), Bond (intermediate).

Step 1 – recall Kick's law: Kick's law states the energy per unit mass is proportional to $\ln(D_f/D_p)$, the logarithm of the ratio of feed size to product size.

Step 2 – match it to the size range: Because it depends on the size ratio rather than on new surface, Kick's law best describes coarse crushing, where relatively little new surface is created.

Step 3 – reject the alternatives: Rittinger's law suits fine grinding (new surface), Bond's law suits intermediate crushing, and Stokes' law is a settling relation, not a comminution law.

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

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – specific surface (surface area per unit volume) of a sphere: $a = \dfrac{\text{surface area}}{\text{volume}} = \dfrac{\pi d^2}{\pi d^3/6} = \dfrac{6}{d}$.

Step 1 – convert the diameter to SI units: $d = 2$ mm $= 0.002$ m

Step 2 – substitute into $a = 6/d$: $a = \dfrac{6}{0.002}$

Step 3 – evaluate: $a = 3000\ \text{m}^{-1}$

Final Answer: $a = 3000\ \text{m}^{-1} \Rightarrow$ A

Answer: (A) Go Back to Q19

Q20.

Solution

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

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

Step 2 – evaluate the denominator: $kA = 2 \times 1 = 2$ W/K

Step 3 – divide: $R = \dfrac{0.2}{2}$

Step 4 – evaluate: $R = 0.1$ K/W

Final Answer: $R = 0.1$ K/W $\Rightarrow$ C

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – resistances in series add, and the heat flow follows Ohm's-law analogy: $Q = \dfrac{\Delta T}{R_1 + R_2}$.

Step 1 – list the data: $R_1 = 0.1$ K/W, $R_2 = 0.3$ K/W, $\Delta T = 100$ K.

Step 2 – add the series resistances: $R_1 + R_2 = 0.1 + 0.3 = 0.4$ K/W

Step 3 – divide the temperature difference by the total resistance: $Q = \dfrac{100}{0.4}$

Step 4 – evaluate: $Q = 250$ W

Final Answer: $Q = 250$ W $\Rightarrow$ A

Answer: (A) Go Back to Q21

Q22.

Solution

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

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

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

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

Step 4 – evaluate: $Bi = 0.02$

Interpretation: $Bi \ll 0.1$, so the lumped-capacitance model applies (internal gradients are negligible).

Final Answer: $Bi = 0.02 \Rightarrow$ B

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – LMTD for a parallel-flow (co-current) exchanger: LMTD $= \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$, where the terminal differences are taken at the two ends.

Step 1 – find the temperature difference at the inlet end (both fluids enter together): $\Delta T_1 = 120 - 30 = 90$ °C

Step 2 – find the temperature difference at the outlet end: $\Delta T_2 = 80 - 60 = 20$ °C

Step 3 – form the numerator: $\Delta T_1 - \Delta T_2 = 90 - 20 = 70$

Step 4 – form the logarithm of the ratio: $\ln\dfrac{90}{20} = \ln(4.5) = 1.5041$

Step 5 – divide: LMTD $= \dfrac{70}{1.5041}$

Step 6 – evaluate: LMTD $= 46.54$ °C ≈ 46.5 °C

Final Answer: LMTD ≈ 46.5 °C $\Rightarrow$ D

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – the heat-capacity rate of a stream is the product of its mass flow and specific heat: $C = \dot{m}\, c_p$.

Step 1 – list the data: $\dot{m} = 2$ kg/s, $c_p = 4200$ J/kg·K.

Step 2 – multiply: $C = 2 \times 4200$

Step 3 – evaluate: $C = 8400$ W/K

Final Answer: $C = 8400$ W/K $\Rightarrow$ C

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – for two convective resistances in series (negligible wall resistance): $\frac{1}{U} = \frac{1}{h_1} + \frac{1}{h_2}$.

Step 1 – list the data: $h_1 = 1000$ W/m^2·K, $h_2 = 1000$ W/m^2·K.

Step 2 – evaluate each reciprocal: $\frac{1}{h_1} = \frac{1}{1000} = 0.001, \quad \frac{1}{h_2} = \frac{1}{1000} = 0.001$

Step 3 – add the resistances: $\frac{1}{U} = 0.001 + 0.001 = 0.002$

Step 4 – invert to find U: $U = \frac{1}{0.002}$

Step 5 – evaluate: $U = 500$ W/m^2·K

Final Answer: $U = 500$ W/m^2·K $\Rightarrow$ D

Answer: (D) Go Back to Q25

Q26.

Solution

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

Step 1 – list the data: $\varepsilon = 0.5$, $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, $T = 1000$ K.

Step 2 – raise the temperature to the fourth power: $T^4 = (1000)^4 = 1 \times 10^{12}$ K^4

Step 3 – multiply by the Stefan–Boltzmann constant: $\sigma T^4 = 5.67 \times 10^{-8} \times 1 \times 10^{12} = 56{,}700$ W/m^2

Step 4 – multiply by the emissivity: $E = 0.5 \times 56{,}700$

Step 5 – evaluate: $E = 28{,}350$ W/m^2

Final Answer: $E \approx 28{,}350\ \text{W/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – heat duty to vaporize a liquid at its boiling point: $Q = \dot{m}\,\lambda$, the mass rate of vaporization times the latent heat.

Step 1 – list the data: $\dot{m} = 0.5$ kg/s, $\lambda = 2260$ kJ/kg.

Step 2 – substitute: $Q = 0.5 \times 2260$

Step 3 – evaluate: $Q = 1130$ kJ/s $= 1130$ kW

Final Answer: $Q = 1130$ kW $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – the Schmidt number is the ratio of momentum diffusivity to mass diffusivity: $Sc = \dfrac{\mu}{\rho\, D}$.

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

Step 2 – evaluate the denominator: $\rho D = 1000 \times 1 \times 10^{-9} = 1 \times 10^{-6}$

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

Step 4 – evaluate: $Sc = 1000$

Final Answer: $Sc = 1000 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

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

Step 1 – list the data: $k_c = 0.01$ m/s, $L = 0.1$ m, $D = 1 \times 10^{-4}$ m^2/s.

Step 2 – evaluate the numerator: $k_c L = 0.01 \times 0.1 = 1 \times 10^{-3}$

Step 3 – divide by the diffusivity: $Sh = \dfrac{1 \times 10^{-3}}{1 \times 10^{-4}}$

Step 4 – evaluate: $Sh = 10$

Final Answer: $Sh = 10 \Rightarrow$ C

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – addition of gas- and liquid-side resistances in two-film theory: $\dfrac{1}{K_g} = \dfrac{1}{k_g} + \dfrac{m}{k_l}$.

Step 1 – list the data: $\dfrac{1}{k_g} = 0.5$, $\dfrac{m}{k_l} = 1.5$.

Step 2 – add the two resistances: $\dfrac{1}{K_g} = 0.5 + 1.5 = 2.0$

Step 3 – invert to find K_g: $K_g = \dfrac{1}{2.0}$

Step 4 – evaluate: $K_g = 0.5$

Final Answer: $K_g = 0.5 \Rightarrow$ B

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – slope of the feed (q-) line in the McCabe–Thiele method: slope $= \dfrac{q}{q-1}$, where q is the fraction of feed that is liquid.

Step 1 – identify q for a 50% vaporized feed: The liquid fraction is $q = 0.5$.

Step 2 – form the denominator: $q - 1 = 0.5 - 1 = -0.5$

Step 3 – substitute into the slope formula: slope $= \dfrac{0.5}{-0.5}$

Step 4 – evaluate: slope $= -1.0$

Final Answer: slope $= -1.0 \Rightarrow$ B

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – Fenske's equation for the minimum number of 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: $\alpha = 3.0$, $x_D = 0.98$, $x_W = 0.02$.

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

Step 3 – form 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 logarithm of the product: $\ln(2401) = 7.7836$

Step 6 – take the logarithm of the relative volatility: $\ln(3.0) = 1.0986$

Step 7 – divide: $N_{\min} = \dfrac{7.7836}{1.0986}$

Step 8 – evaluate: $N_{\min} = 7.085 \approx 7.08$

Final Answer: $N_{\min} \approx 7.08 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – the stripping factor relates the equilibrium slope and the flow rates: $S = \dfrac{m\,G}{L}$.

Step 1 – list the data: $m = 2.0$, $G = 50$ mol/h, $L = 200$ mol/h.

Step 2 – evaluate the numerator: $mG = 2.0 \times 50 = 100$

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

Step 4 – evaluate: $S = 0.5$

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

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – packed height from the height equivalent to a theoretical plate: $Z = \text{HETP} \times N$.

Step 1 – list the data: $\text{HETP} = 0.4$ m, $N = 5$ stages.

Step 2 – multiply: $Z = 0.4 \times 5$

Step 3 – evaluate: $Z = 2.0$ m

Final Answer: $Z = 2.0$ m $\Rightarrow$ B

Answer: (B) Go Back to Q34

Q35.

Solution

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

Step 1 – list the data: $\alpha = 4.0$, $x = 0.25$.

Step 2 – evaluate the numerator: $\alpha x = 4.0 \times 0.25 = 1.0$

Step 3 – evaluate the denominator: $1 + (\alpha - 1)x = 1 + (4.0 - 1)(0.25) = 1 + (3)(0.25) = 1 + 0.75 = 1.75$

Step 4 – divide: $y = \dfrac{1.0}{1.75}$

Step 5 – evaluate: $y = 0.5714 \approx 0.571$

Final Answer: $y \approx 0.571 \Rightarrow$ A

Answer: (A) Go Back to Q35

Q36.

Solution

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

Step 1 – list the data: Total moisture $X = 0.30$, equilibrium moisture $X^* = 0.05$ (kg water per kg dry solid).

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

Step 3 – evaluate: $X_{\text{free}} = 0.25$ kg water per kg dry solid

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

Answer: (D) Go Back to Q36

Q37.

Solution

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

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

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

Step 3 – invert: $t_{1/2} = \dfrac{1}{1.0}$

Step 4 – evaluate: $t_{1/2} = 1.0$ min

Final Answer: $t_{1/2} = 1.0$ min $\Rightarrow$ D

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – conversion of a first-order reaction in an ideal CSTR: $X = \dfrac{k\tau}{1 + k\tau}$.

Step 1 – list the data: $k = 0.2\ \text{min}^{-1}$, $\tau = 20$ min.

Step 2 – form the product $k\tau$: $k\tau = 0.2 \times 20 = 4$

Step 3 – substitute into the CSTR relation: $X = \dfrac{4}{1 + 4}$

Step 4 – evaluate the denominator: $1 + 4 = 5$

Step 5 – divide: $X = \dfrac{4}{5} = 0.80$

Final Answer: $X = 0.80 \Rightarrow$ C

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – conversion of a first-order reaction in an ideal PFR: $k\tau = -\ln(1 - X)$, so $X = 1 - e^{-k\tau}$.

Step 1 – list the data: $k = 0.231\ \text{min}^{-1}$, $\tau = 3$ min.

Step 2 – form the product $k\tau$: $k\tau = 0.231 \times 3 = 0.693$

Step 3 – take the exponential of its negative: $e^{-0.693} = 0.500$

Step 4 – subtract from unity: $X = 1 - 0.500$

Step 5 – evaluate: $X = 0.500$

Note: $k\tau = \ln 2$, which corresponds exactly to 50% conversion.

Final Answer: $X \approx 0.500 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – temperature dependence of the rate constant (Arrhenius): $\dfrac{k(T_2)}{k(T_1)} = \exp\left[\dfrac{E_a}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right)\right]$.

Step 1 – list the data: $E_a = 100{,}000$ J/mol, $R = 8.314$ J/mol·K, $T_1 = 400$ K, $T_2 = 410$ K.

Step 2 – evaluate E_a/R: $\dfrac{E_a}{R} = \dfrac{100{,}000}{8.314} = 12{,}028$

Step 3 – evaluate the reciprocal-temperature difference: $\dfrac{1}{400} - \dfrac{1}{410} = \dfrac{410 - 400}{400 \times 410} = \dfrac{10}{164{,}000} = 6.098 \times 10^{-5}$

Step 4 – multiply to form the exponent: $12{,}028 \times 6.098 \times 10^{-5} = 0.7335$

Step 5 – take the exponential: $e^{0.7335} = 2.082$

Step 6 – round: $\dfrac{k(410)}{k(400)} \approx 2.08$

Final Answer: factor $\approx 2.08 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – for a first-order reaction the Damkohler number is the product of rate constant and space time: $Da = k\,\tau$.

Step 1 – list the data: $k = 0.5$ min^{-1}, $\tau = 4$ min.

Step 2 – multiply: $Da = 0.5 \times 4$

Step 3 – evaluate: $Da = 2.0$

Interpretation: $Da \sim 1$ means reaction and residence time are comparable, so a

moderate conversion is expected.

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

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – internal effectiveness factor of a first-order reaction in a catalyst slab: $\eta = \dfrac{\tanh \phi}{\phi}$.

Step 1 – list the data: $\phi = 1$.

Step 2 – evaluate the hyperbolic tangent: $\tanh(1) = 0.7616$

Step 3 – divide by the Thiele modulus: $\eta = \dfrac{0.7616}{1}$

Step 4 – evaluate: $\eta = 0.762$

Interpretation: η close to 1 shows that pore-diffusion resistance is small at this modest Thiele modulus.

Final Answer: $\eta \approx 0.762 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – step response of a first-order process: $y(t) = K\,(1 - e^{-t/\tau})$, here with final value 10.

Step 1 – set the time to two time constants: $t = 2\tau$, so $t/\tau = 2$.

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

Step 3 – form the fractional approach to the final value: $1 - e^{-2} = 1 - 0.1353 = 0.8647$

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

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

Note: after two time constants a first-order process reaches about 86.5% of its final value.

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

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: $\zeta = 0.6$.

Step 2 – evaluate ζ^2: $\zeta^2 = 0.36$

Step 3 – evaluate the denominator root: $\sqrt{1-0.36} = \sqrt{0.64} = 0.8$

Step 4 – form the exponent: $\dfrac{-\pi \times 0.6}{0.8} = \dfrac{-1.885}{0.8} = -2.356$

Step 5 – take the exponential: $e^{-2.356} = 0.0948$

Step 6 – convert to a percentage: $\text{overshoot} = 9.48\% \approx 9.5\%$

Final Answer: $\text{overshoot} \approx 9.5\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – steady-state offset of a first-order process under proportional-only control: $\text{offset} = \dfrac{1}{1+K_cK_p}$ for a unit set-point step.

Step 1 – list the data: $K_c = 2$, $K_p = 2$.

Step 2 – form the loop gain: $K_cK_p = 2 \times 2 = 4$

Step 3 – substitute into the offset expression: $\text{offset} = \dfrac{1}{1+4}$

Step 4 – evaluate the denominator: $1+4 = 5$

Step 5 – divide: $\text{offset} = \dfrac{1}{5} = 0.2$

Interpretation: proportional-only control always leaves a non-zero offset, which shrinks as the loop gain grows.

Final Answer: $\text{offset} = 0.2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

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

Step 1 – list the data: Fixed-capital investment $=$ Rs. $50{,}00{,}000$, annual cash flow $=$ Rs. $10{,}00{,}000$.

Step 2 – divide: $\text{payback} = \dfrac{50{,}00{,}000}{10{,}00{,}000}$

Step 3 – evaluate: $\text{payback} = 5.0$ years

Final Answer: $\text{payback} = 5.0$ years $\Rightarrow$ C

Answer: (C) Go Back to Q46

Answer Key

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