GATE Chemical Engineering

Sample Paper – 10

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

Instructions

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

Process Calculations & Thermodynamics

Q1. A gas mixture contains 3 mol of oxygen and 7 mol of nitrogen. The mole fraction of oxygen in the mixture is: **[1 mark]**

(A) 0.70

(B) 0.40

(C) 0.30

(D) 0.50

Q2. Hydrogen is burnt completely in oxygen following $2H_2 + O_2 \rightarrow 2H_2O$. The mass of oxygen (molar mass 32) required to burn 4 kg of hydrogen (molar mass 2) completely is: **[1 mark]**

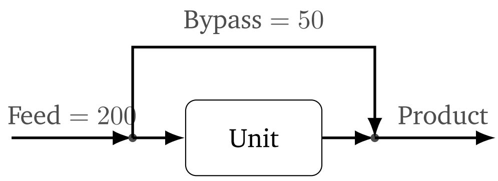
(A) 32 kg

(B) 16 kg

(C) 64 kg

(D) 8 kg

Q3. In the steady process shown, a feed stream of 200 mol/h is split so that a bypass stream of 50 mol/h is sent around the process unit. The bypass fraction (bypass flow divided by total feed) is: **[1 mark]**



(A) 4.0

(B) 0.25

(C) 0.75

(D) 0.50

Q4. A closed system rejects 150 J of heat to its surroundings while 400 J of work is done on the system by the surroundings. By the first law of thermodynamics ($\Delta U = Q - W$, with Q the heat added to and W the work done by the system), the change in internal energy is: **[1 mark]**

(A) -250 J

(B) $+550$ J

(C) $+250$ J

(D) -550 J

Q5. A thermal reservoir at a constant temperature of 300 K reversibly transfers 600 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) 2.0 kJ/K

(B) 0.5 kJ/K

(C) 1.0 kJ/K

(D) 1800 kJ/K

Q6. A rigid vessel of volume 0.0249 m^3 holds an ideal gas at a pressure of 2 bar (2×10^5 Pa) and a temperature of 300 K. Taking $R = 8.314$ J/mol·K, the number of moles of gas in the vessel ($n = PV/RT$) is nearest to: **[1 mark]**

(A) 1 mol

(B) 4 mol

(C) 0.5 mol

(D) 2 mol

Q7. For a chemical reaction the standard Gibbs free energy change and the equilibrium constant are related by $\Delta G^\circ = -RT \ln K$. If the equilibrium constant is greater than one ($K > 1$) at the reaction temperature, then ΔG° is: **[1 mark]**

(A) positive

(B) negative

(C) exactly zero

(D) infinite

Q8. A binary liquid mixture of benzene (A) and toluene (B) obeys Raoult's law. At the system temperature $P_A^{sat} = 120$ kPa and $P_B^{sat} = 40$ kPa. For a liquid of composition $x_A = 0.5$, the mole fraction of A in the vapour in equilibrium with it, $y_A = x_A P_A^{sat}/P$, is: **[1 mark]**

(A) 0.50

(B) 0.60

(C) 0.375

(D) 0.75

Q9. The fugacity coefficient ϕ of a pure gas is defined by $f = \phi P$, where f is the fugacity and P the pressure. For a gas that behaves as an ideal gas, the value of the fugacity coefficient is: **[1 mark]**

(A) 1.0

(B) 0

(C) equal to the pressure

(D) infinite

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

(A) 6.0

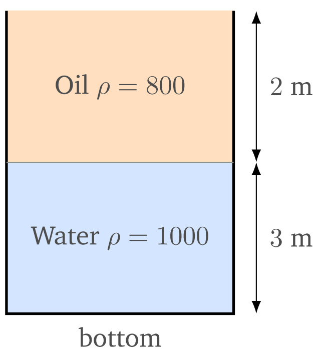
(B) 5.0

(C) 0.2

(D) 1.2

Fluid Mechanics & Mechanical Operations

Q11. An open tank holds a 2 m layer of oil ($\rho = 800$ kg/m^3) resting on a 3 m layer of water ($\rho = 1000$ kg/m^3), as shown. Taking $g = 9.81$ m/s^2 and neglecting the atmosphere, the gauge pressure of the liquid at the bottom of the tank is nearest to: **[1 mark]**



(A) 45.1 kPa

(B) 29.4 kPa

(C) 15.7 kPa

(D) 49.1 kPa

Q12. Water flows at a mean velocity of 2 m/s through a circular pipe of internal diameter 0.1 m. Using $Q = AV$ with the cross-sectional area $A = \frac{\pi}{4}D^2$, the volumetric flow rate through the pipe is nearest to: **[1 mark]**

(A) $0.0314\ m^3/s$

(B) $0.0157\ m^3/s$

(C) $0.00785\ m^3/s$

(D) $0.0200\ m^3/s$

Q13. Water of density $1000\ kg/m^3$ and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 0.02 m at a mean velocity of 0.05 m/s. The Reynolds number of the flow, $Re = \rho VD/\mu$, is: **[1 mark]**

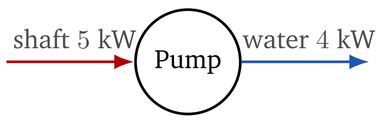
(A) 1000

(B) 2000

(C) 500

(D) 100

Q14. A centrifugal pump receives 5 kW of shaft power from its motor and delivers 4 kW of hydraulic (water) power to the fluid, as shown. The efficiency of the pump (hydraulic power divided by shaft power) is: **[1 mark]**



(A) 125%

(B) 20%

(C) 90%

(D) 80%

Q15. A solid body of volume $0.01\ \text{m}^3$ is fully submerged in water of density $1000\ \text{kg/m}^3$. Taking $g = 9.81\ \text{m/s}^2$, the buoyant (upthrust) force acting on the body, $F_B = \rho g V$, is: **[1 mark]**

(A) 98.1 N

(B) 9.81 N

(C) 981 N

(D) 100 N

Q16. A spherical particle of diameter $50\ \mu\text{m}$ and density $2650\ \text{kg/m}^3$ settles under gravity in a still liquid of density $1000\ \text{kg/m}^3$ 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]**

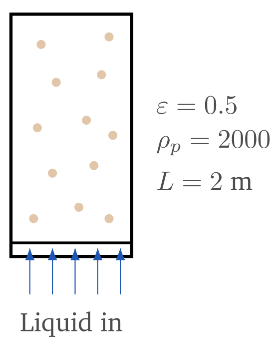
(A) 4.50 mm/s

(B) 1.12 mm/s

(C) 9.00 mm/s

(D) 2.25 mm/s

Q17. A liquid of density $\rho_f = 1000\ \text{kg/m}^3$ flows upward through the bed of solids shown, bringing it to incipient fluidization. The bed has voidage $\varepsilon = 0.5$, particle density $\rho_p = 2000\ \text{kg/m}^3$ and height $L = 2$ m. The pressure drop across the fluidized bed, $\Delta P = (1-\varepsilon)(\rho_p - \rho_f)gL$, is nearest to: **[1 mark]**



(A) 19.6 kPa

(B) 9.81 kPa

(C) 4.91 kPa

(D) 14.7 kPa

Q18. In size reduction, which law states that the energy required per unit mass of feed depends only on the size-reduction ratio (through its logarithm) and is therefore best suited to coarse crushing? **[1 mark]**

(A) Kick's law

(B) Rittinger's law

(C) Bond's law

(D) Stokes' law

Q19. A ball mill has an internal diameter of 1.0 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: **[1 mark]**

(A) 42.3 rpm

(B) 21.2 rpm

(C) 84.6 rpm

(D) 34.5 rpm

Heat Transfer

Q20. Steady one-dimensional conduction occurs through a plane wall of thermal conductivity 2 W/m·K, area 0.5 m^2 and thickness 0.2 m. The two faces are held at temperatures differing by 40 K. The rate of heat conduction through the wall ($q = kA\,\Delta T/L$) is: **[1 mark]**

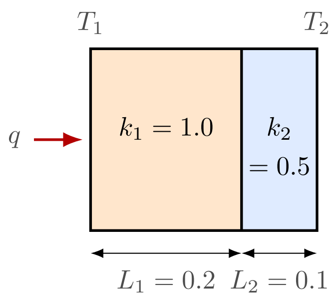
(A) 400 W

(B) 100 W

(C) 200 W

(D) 800 W

Q21. Steady heat conduction occurs through the two-layer composite wall shown, with layer thicknesses $L_1 = 0.2$ m ($k_1 = 1.0$ W/m·K) and $L_2 = 0.1$ m ($k_2 = 0.5$ W/m·K). The overall temperature difference across the wall is 300 K. The steady heat flux through the wall is: **[2 marks]**



(A) 1500 W/m^2

(B) 750 W/m^2

(C) 500 W/m^2

(D) 375 W/m^2

Q22. A solid body cooling by convection has a convective coefficient $h = 100$ W/m^2·K, a characteristic length $L_c = 0.01$ m and a thermal conductivity $k = 50$ W/m·K. The Biot number, Bi $= hL_c/k$, is: **[2 marks]**

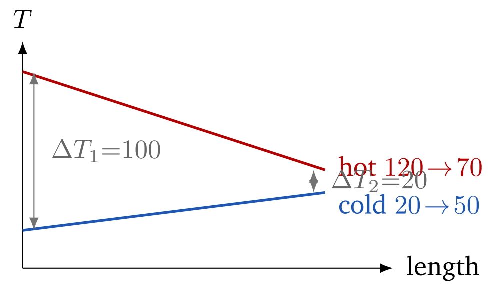
(A) 0.5

(B) 0.02

(C) 2.0

(D) 0.2

Q23. In the parallel-flow (co-current) double-pipe exchanger whose temperature profile is sketched, a hot fluid is cooled from 120 °C to 70 °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]**



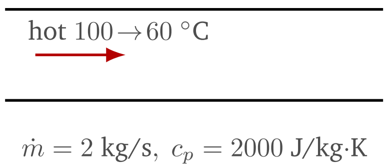
(A) 60.0 °C

(B) 40.0 °C

(C) 49.7 °C

(D) 55.0 °C

Q24. In the double-pipe exchanger shown, a hot stream of mass flow rate $\dot{m} = 2$ kg/s and specific heat $c_p = 2000$ J/kg·K is cooled from 100 °C to 60 °C. The rate of heat given up by the hot stream, $\dot{Q} = \dot{m}\, c_p\, \Delta T$, is: **[2 marks]**



(A) 80 kW

(B) 320 kW

(C) 160 kW

(D) 40 kW

Q25. The two sides of a clean, thin-walled heat exchanger tube have convective coefficients $h_i = 1000$ W/m^2·K and $h_o = 1000$ W/m^2·K. Neglecting the wall resistance, the overall heat-transfer coefficient from $1/U = 1/h_i + 1/h_o$ 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 surface behaves as a black body at a temperature of 1000 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: **[2 marks]**

(A) 5670 W/m^2

(B) 22680 W/m^2

(C) 14175 W/m^2

(D) 56700 W/m^2

Q27. A single-effect evaporator operates with a steam economy (mass of water evaporated per unit mass of steam) of 0.8. To evaporate 1200 kg/h of water from a feed, the mass flow rate of saturated steam required is: **[2 marks]**

(A) 960 kg/h

(B) 1500 kg/h

(C) 1200 kg/h

(D) 750 kg/h

Mass Transfer & Separation Processes

Q28. Component A diffuses at steady state through a stagnant film of thickness 0.005 m. The molar diffusivity is $D_{AB} = 2 \times 10^{-5}$ m^2/s and the concentration of A falls linearly from 3 mol/m^3 at one face to 1 mol/m^3 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) 4×10^{-3} mol/m^2·s

(B) 8×10^{-3} mol/m^2·s

(C) 1.6×10^{-2} mol/m^2·s

(D) 2×10^{-3} mol/m^2·s

Q29. According to film theory, a solute diffuses across a stagnant liquid film of thickness $\delta = 1.5$ mm with a molecular diffusivity $D = 3 \times 10^{-5}$ m^2/s. The film mass-transfer coefficient ($k_c = D/\delta$) is: **[2 marks]**

(A) 0.02 m/s

(B) 0.01 m/s

(C) 0.04 m/s

(D) 0.002 m/s

Q30. In a gas absorption process described by two-film theory, the gas-side resistance gives $1/k_g = 2$ and the liquid-side contribution referred to the gas phase gives $m/k_l = 2$ (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]**

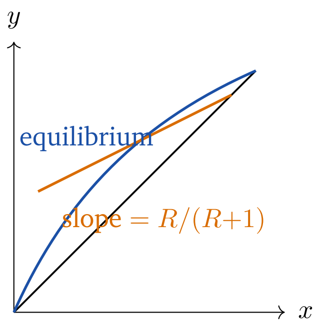
(A) 1.0

(B) 0.5

(C) 2.0

(D) 0.25

Q31. The McCabe–Thiele 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 $R = 1$, the slope of this operating line is: **[2 marks]**



(A) 0.75

(B) 0.50

(C) 0.25

(D) 1.0

Q32. A binary mixture with a constant relative volatility $\alpha = 3.0$ is to be separated into a distillate of $x_D = 0.90$ and a bottoms of $x_W = 0.10$ (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) 4.0

(B) 6.0

(C) 2.0

(D) 8.0

Q33. In a gas stripper the liquid flow rate is $L = 50$ mol/h, the gas flow rate is $G = 100$ mol/h and the equilibrium slope is $m = 2.0$. The stripping factor, defined as $S = mG/L$, is: **[2 marks]**

(A) 0.25

(B) 1.0

(C) 4.0

(D) 2.0

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 required packing height is 4.5 m and the height of a transfer unit is 0.75 m. The number of transfer units is: **[2 marks]**

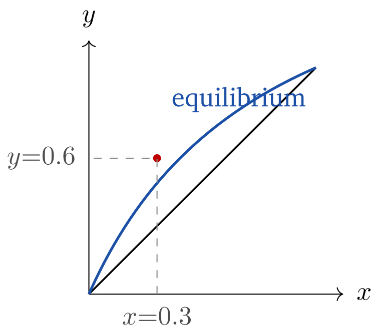
(A) 3.0

(B) 4.5

(C) 6.0

(D) 12.0

Q35. The vapour–liquid equilibrium (y–x) diagram of a binary mixture is shown, with an equilibrium point at $x = 0.3$, $y = 0.6$ (mole fractions of the light component). The relative volatility of the light component, $\alpha = \dfrac{y/(1-y)}{x/(1-x)}$, at this point is nearest to: [2 marks]



(A) 2.0

(B) 1.0

(C) 0.286

(D) 3.5

Q36. A wet solid is dried in its constant-rate period, during which the drying flux (rate of water removal per unit exposed area) is 1.5 kg/m^2·h over an exposed area of 4 m^2. The time required to remove 3 kg of water from the solid is: [2 marks]

(A) 2.0 h

(B) 1.0 h

(C) 0.5 h

(D) 4.0 h

Reaction Engineering, Process Control & Plant Economics

Q37. A homogeneous liquid-phase reaction is first order in the reactant, with a rate constant $k = 0.04$ min^{-1}. The half-life of the reactant, $t_{1/2} = \ln 2/k$, is nearest to: [2 marks]

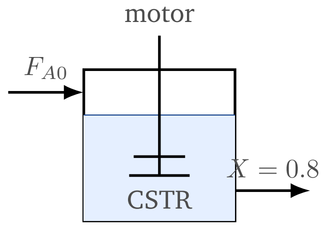
(A) 50.0 min

(B) 34.66 min

(C) 69.3 min

(D) 17.33 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 to achieve a conversion of $X = 0.8$. Using the CSTR design equation $\tau = X/[\,k(1 - X)\,]$, the required space time is: **[2 marks]**



(A) 10 min

(B) 5 min

(C) 20 min

(D) 40 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). Using $k\tau = -\ln(1 - X)$, the space time τ required to reach a fractional conversion of $X = 0.9$ is nearest to: **[2 marks]**

(A) 2.3 min

(B) 9.0 min

(C) 4.6 min

(D) 1.8 min

Q40. A reaction has an Arrhenius activation energy of $E_a = 80$ 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) 1.0

(B) 1.8

(C) 2.5

(D) 0.55

Q41. An ideal CSTR of working volume 200 L is fed by a liquid stream at a constant volumetric flow rate of 50 L/min. The mean residence time of fluid in the reactor ($\tau = V/Q$) is: **[2 marks]**

(A) 4.0 min

(B) 40 min

(C) 0.25 min

(D) 10 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 $\phi = 4$, the effectiveness factor is: **[2 marks]**

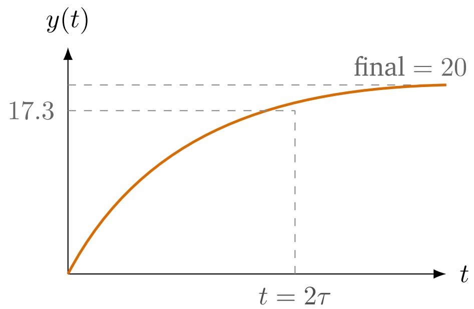
(A) 1.0

(B) 4.0

(C) 0.25

(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 20 units is subjected to a step change in its input. Its response follows $y(t) = 20\,(1 - e^{-t/\tau})$, as sketched. The value of the output change at $t = 2\tau$ (two time constants) is nearest to: **[2 marks]**



(A) 20.0

(B) 17.3

(C) 12.6

(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) 9.5%

(B) 16.3%

(C) 25%

(D) 50%

Q45. A pure proportional (P-only) controller is used to regulate a first-order process. When the process is subjected to a sustained step change in load, the steady-state closed-loop response characteristically shows: **[2 marks]**

(A) zero offset (the output returns exactly to the set point)

(B) sustained undamped oscillation

(C) an unbounded, unstable response

(D) a nonzero steady-state offset (residual error)

Q46. A process plant requires a fixed capital investment of Rs. $20{,}00{,}000$ and is expected to yield a constant net annual cash flow of Rs. $5{,}00{,}000$. The simple (non-discounted) payback period, defined as investment divided by annual cash flow, is: **[2 marks]**

(A) 0.25 years

(B) 2 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: $y_{O_2} = \dfrac{n_{O_2}}{n_{O_2} + n_{N_2}}$.

Step 1 – list the moles: $n_{O_2} = 3$ mol, $n_{N_2} = 7$ mol.

Step 2 – find the total moles: $n_{\text{total}} = 3 + 7$

$n_{\text{total}} = 10$ mol

Step 3 – form the mole fraction: $y_{O_2} = \dfrac{3}{10}$

Step 4 – evaluate: $y_{O_2} = 0.30$

Final Answer: $y_{O_2} = 0.30 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – use the stoichiometry of the combustion reaction: $2H_2 + O_2 \rightarrow 2H_2O$, so 2 moles of hydrogen need 1 mole of oxygen.

Step 1 – find the moles of hydrogen burnt: $n_{H_2} = \dfrac{4 \text{ kg}}{2 \text{ kg/kmol}} = 2$ kmol

Step 2 – apply the $2:1$ mole ratio: $n_{O_2} = \dfrac{n_{H_2}}{2} = \dfrac{2}{2} = 1$ kmol

Step 3 – convert oxygen moles to mass: $m_{O_2} = n_{O_2} \times M_{O_2} = 1 \times 32$

$m_{O_2} = 32$ kg

Final Answer: $m_{O_2} = 32 \text{ kg} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

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

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

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

Step 3 – evaluate: Bypass fraction $= 0.25$

Final Answer: bypass fraction $= 0.25 \Rightarrow \boxed{\text{B}}$

Answer: (B) 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 is rejected, so $Q = -150$ J; work is done on the system, so the work done by the system is $W = -400$ J.

Step 2 – substitute into the first law: $\Delta U = (-150) - (-400)$

Step 3 – simplify the subtraction: $\Delta U = -150 + 400$

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

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

Answer: (C) 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: $Q = 600$ kJ, $T = 300$ K.

Step 2 – substitute into the formula: $|\Delta S| = \dfrac{600}{300}$

Step 3 – evaluate: $|\Delta S| = 2.0$ kJ/K

Final Answer: $|\Delta S| = 2.0 \text{ kJ/K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – ideal-gas law solved for the number of moles: $PV = nRT$, so $n = \frac{PV}{RT}$.

Step 1 – list the data in SI units: $P = 2 \times 10^5$ Pa, $V = 0.0249$ m^3, $R = 8.314$ J/mol·K, $T = 300$ K.

Step 2 – compute the numerator: $PV = 2 \times 10^5 \times 0.0249 = 4980$ J

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

Step 4 – divide: $n = \frac{4980}{2494.2}$

Step 5 – evaluate: $n = 1.997 \approx 2$ mol

Final Answer: $n \approx 2$ mol $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

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

Step 1 – use the given condition: $K > 1$.

Step 2 – take the logarithm: For $K > 1$, $\ln K > 0$ (the natural log of a number greater than one is positive).

Step 3 – substitute into the relation: $\Delta G^\circ = -RT$ (a positive number)

Step 4 – determine the sign: Since R, T and $\ln K$ are all positive, $-RT \ln K$ is negative.

Final Answer: ΔG° is negative $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – Raoult's law gives the total pressure, then the vapour composition: $P = x_A P_A^{sat} + x_B P_B^{sat}$ and $y_A = \frac{x_A P_A^{sat}}{P}$.

Step 1 – list the data: $P_A^{sat} = 120$ 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 – find the total pressure: $P = (0.5)(120) + (0.5)(40)$

$P = 60 + 20 = 80$ kPa

Step 4 – find the partial pressure of A: $x_A P_A^{sat} = (0.5)(120) = 60$ kPa

Step 5 – form the vapour composition: $y_A = \dfrac{60}{80}$

Step 6 – evaluate: $y_A = 0.75$

Final Answer: $y_A = 0.75 \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q8**

Q9.

Solution

Concept – fugacity coefficient of an ideal gas: The fugacity coefficient is defined by $\phi = \dfrac{f}{P}$, and for an ideal gas the fugacity equals the pressure, $f = P$.

Step 1 – write the ideal-gas result: $f = P$.

Step 2 – substitute into the definition: $\phi = \dfrac{f}{P} = \dfrac{P}{P}$

Step 3 – evaluate: $\phi = 1.0$

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

Answer: (A) **Go Back to Q9**

Q10.

Solution

Concept – coefficient of performance of a Carnot refrigerator: $\text{COP} = \dfrac{T_C}{T_H - T_C}$, with 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 – form the ratio: $\text{COP} = \dfrac{250}{50}$

Step 4 – evaluate: $\text{COP} = 5.0$

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

Answer: (B) **Go Back to Q10**

Q11.

Solution

Concept – pressure builds up additively through stacked liquid layers: $p_{\text{bottom}} = \rho_{\text{oil}}\, g\, h_{\text{oil}} + \rho_{\text{water}}\, g\, h_{\text{water}}$.

Step 1 – list the data: $\rho_{\text{oil}} = 800$ kg/m^3, $h_{\text{oil}} = 2$ m, $\rho_{\text{water}} = 1000$ kg/m^3, $h_{\text{water}} = 3$ m, $g = 9.81$ m/s^2.

Step 2 – pressure from the oil layer: $\rho_{\text{oil}}\, g\, h_{\text{oil}} = 800 \times 9.81 \times 2$

$= 15{,}696$ Pa

Step 3 – pressure from the water layer: $\rho_{\text{water}}\, g\, h_{\text{water}} = 1000 \times 9.81 \times 3$

$= 29{,}430$ Pa

Step 4 – add the two contributions: $p_{\text{bottom}} = 15{,}696 + 29{,}430 = 45{,}126$ Pa

Step 5 – express in kilopascals: $p_{\text{bottom}} \approx 45.1$ kPa

Final Answer: $p_{\text{bottom}} \approx 45.1$ kPa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – volumetric flow rate from the continuity relation: $Q = AV$, with the pipe area $A = \frac{\pi}{4}D^2$.

Step 1 – list the data: $D = 0.1$ m, $V = 2$ m/s.

Step 2 – square the diameter: $D^2 = (0.1)^2 = 0.01$ m^2

Step 3 – find the cross-sectional area: $A = \frac{\pi}{4} \times 0.01 = 0.7854 \times 0.01 = 0.007854$ m^2

Step 4 – multiply by the velocity: $Q = 0.007854 \times 2$

Step 5 – evaluate: $Q = 0.01571 \approx 0.0157$ m^3/s

Final Answer: $Q \approx 0.0157$ m^3/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

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

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

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

Step 3 – multiply step by step: $1000 \times 0.05 = 50$

$50 \times 0.02 = 1.0$

Step 4 – divide by the viscosity: $Re = \dfrac{1.0}{1 \times 10^{-3}}$

Step 5 – evaluate: $Re = 1000$

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

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – pump efficiency is useful output over power input: $\eta = \dfrac{\text{hydraulic (water) power}}{\text{shaft power}}$.

Step 1 – read the two powers from the diagram: Water power $= 4$ kW, shaft power $= 5$ kW.

Step 2 – form the ratio: $\eta = \dfrac{4}{5}$

Step 3 – evaluate as a fraction: $\eta = 0.80$

Step 4 – express as a percentage: $\eta = 80\%$

Final Answer: $\eta = 80\% \Rightarrow \boxed{\text{D}}$

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 fluid.

Step 1 – list the data: $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $V = 0.01$ m^3.

Step 2 – substitute: $F_B = 1000 \times 9.81 \times 0.01$

Step 3 – multiply the first two factors: $1000 \times 9.81 = 9810$

Step 4 – multiply by the volume: $F_B = 9810 \times 0.01 = 98.1$ N

Final Answer: $F_B = 98.1 \text{ N} \Rightarrow \boxed{\text{A}}$

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: $d = 50\ \mu\text{m} = 5 \times 10^{-5}$ m, $\rho_p = 2650$ kg/m^3, $\rho_f = 1000$ kg/m^3, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – square the diameter: $d^2 = (5 \times 10^{-5})^2 = 2.5 \times 10^{-9}$ m^2

Step 3 – form the density difference: $\rho_p - \rho_f = 2650 - 1000 = 1650$ kg/m^3

Step 4 – assemble the numerator: $g\,d^2(\rho_p - \rho_f) = 9.81 \times 2.5 \times 10^{-9} \times 1650$

$= 9.81 \times 4.125 \times 10^{-6}$

$= 4.047 \times 10^{-5}$

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

Step 6 – divide: $v_t = \dfrac{4.047 \times 10^{-5}}{0.018} = 2.25 \times 10^{-3}$ m/s

Step 7 – express in mm/s: $v_t = 2.25$ mm/s

Final Answer: $v_t \approx 2.25 \text{ mm/s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – pressure drop across a fluidized bed at incipient fluidization: $\Delta P = (1 - \varepsilon)(\rho_p - \rho_f)\,g\,L$.

Step 1 – list the data: $\varepsilon = 0.5$, $\rho_p = 2000$ kg/m^3, $\rho_f = 1000$ kg/m^3, $g = 9.81$ m/s^2, $L = 2$ m.

Step 2 – find the solids fraction: $1 - \varepsilon = 1 - 0.5 = 0.5$

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

Step 4 – substitute: $\Delta P = 0.5 \times 1000 \times 9.81 \times 2$

Step 5 – multiply step by step: $0.5 \times 1000 = 500$

$500 \times 9.81 = 4905$

$4905 \times 2 = 9810$ Pa

Step 6 – express in kilopascals: $\Delta P = 9.81$ kPa

Final Answer: $\Delta P \approx 9.81$ kPa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – the three comminution laws differ in how energy scales with particle size: Rittinger's law scales with new surface area (fine grinding), Bond's law is intermediate, and Kick's law scales with the logarithm of the size-reduction ratio.

Step 1 – recall Kick's law: $E \propto \ln\left(\frac{L_1}{L_2}\right)$, the energy per unit mass depending only on the size-reduction ratio.

Step 2 – match to the described behaviour: The question specifies dependence on the size-reduction ratio through its logarithm, which is Kick's law, best suited to coarse crushing.

Step 3 – reject the distractors: Rittinger's law suits fine grinding, Bond's law is the intermediate correlation, and Stokes' law is a settling relation, not a comminution law.

Final Answer: Kick's law $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q18

Q19.

Solution

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

Step 1 – list the data: $D = 1.0$ m.

Step 2 – take the square root of the diameter: $\sqrt{D} = \sqrt{1.0} = 1.0$

Step 3 – divide: $n_c = \frac{42.3}{1.0}$

Step 4 – evaluate: $n_c = 42.3$ rpm

Final Answer: $n_c = 42.3$ rpm $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – Fourier's law for steady conduction through a plane wall: $q = \dfrac{k\,A\,\Delta T}{L}$.

Step 1 – list the data: $k = 2$ W/m·K, $A = 0.5$ m^2, $\Delta T = 40$ K, $L = 0.2$ m.

Step 2 – form the numerator: $k\,A\,\Delta T = 2 \times 0.5 \times 40$

Step 3 – multiply step by step: $2 \times 0.5 = 1.0$

$1.0 \times 40 = 40$

Step 4 – divide by the thickness: $q = \dfrac{40}{0.2}$

Step 5 – evaluate: $q = 200$ W

Final Answer: $q = 200 \text{ W} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – series conduction resistance of a composite wall (per unit area): $q = \dfrac{\Delta T}{\dfrac{L_1}{k_1} + \dfrac{L_2}{k_2}}$.

Step 1 – list the data: $L_1 = 0.2$ m, $k_1 = 1.0$ W/m·K, $L_2 = 0.1$ m, $k_2 = 0.5$ W/m·K, $\Delta T = 300$ K.

Step 2 – resistance of layer 1: $\dfrac{L_1}{k_1} = \dfrac{0.2}{1.0} = 0.2$ m^2·K/W

Step 3 – resistance of layer 2: $\dfrac{L_2}{k_2} = \dfrac{0.1}{0.5} = 0.2$ m^2·K/W

Step 4 – add the resistances in series: $R = 0.2 + 0.2 = 0.4$ m^2·K/W

Step 5 – divide the temperature difference by the resistance: $q = \dfrac{300}{0.4}$

Step 6 – evaluate: $q = 750$ W/m^2

Final Answer: $q = 750 \text{ W/m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

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

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

Step 2 – form the numerator: $h\,L_c = 100 \times 0.01 = 1.0$

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

Step 4 – evaluate: $\mathrm{Bi} = 0.02$

Final Answer: $\mathrm{Bi} = 0.02 \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – logarithmic mean temperature difference: $\mathrm{LMTD} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$, where the two end temperature differences are taken for parallel flow at the same ends.

Step 1 – find the temperature difference at the inlet end: $\Delta T_1 = T_{h,\mathrm{in}} - T_{c,\mathrm{in}} = 120 - 20 = 100$ °C

Step 2 – find the temperature difference at the outlet end: $\Delta T_2 = T_{h,\mathrm{out}} - T_{c,\mathrm{out}} = 70 - 50 = 20$ °C

Step 3 – form the numerator: $\Delta T_1 - \Delta T_2 = 100 - 20 = 80$

Step 4 – form the logarithm: $\ln\left(\dfrac{100}{20}\right) = \ln 5 = 1.6094$

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

Step 6 – evaluate: $\mathrm{LMTD} = 49.7$ °C

Final Answer: $\mathrm{LMTD} \approx 49.7$ °C $\Rightarrow \boxed{\mathrm{C}}$

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – sensible heat given up by a stream: $\dot{Q} = \dot{m}\, c_p\, \Delta T$.

Step 1 – list the data: $\dot{m} = 2$ kg/s, $c_p = 2000$ J/kg·K, $\Delta T = 100 - 60 = 40$ K.

Step 2 – multiply the mass flow and specific heat: $\dot{m}\, c_p = 2 \times 2000 = 4000$ W/K

Step 3 – multiply by the temperature drop: $\dot{Q} = 4000 \times 40$

Step 4 – evaluate: $\dot{Q} = 160{,}000$ W

Step 5 – express in kilowatts: $\dot{Q} = 160$ kW

Final Answer: $\dot{Q} = 160$ kW $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – overall heat-transfer coefficient from series convective resistances: $\dfrac{1}{U} = \dfrac{1}{h_i} + \dfrac{1}{h_o}$ (wall resistance neglected).

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

Step 2 – add the two resistances: $\dfrac{1}{U} = \dfrac{1}{1000} + \dfrac{1}{1000}$

Step 3 – combine the fractions: $\dfrac{1}{U} = \dfrac{2}{1000} = 0.002$

Step 4 – invert to get U: $U = \dfrac{1}{0.002}$

Step 5 – evaluate: $U = 500$ W/m^2·K

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

Answer: (D) 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, $T = 1000$ 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 constant: $E = 5.67 \times 10^{-8} \times 1 \times 10^{12}$

Step 4 – combine the powers of ten: $E = 5.67 \times 10^4$

Step 5 – write out the value: $E = 56{,}700\ \text{W/m}^2$

Final Answer: $E = 56{,}700\ \text{W/m}^2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – steam economy relates water evaporated to steam supplied: $\text{economy} = \dfrac{\text{water evaporated}}{\text{steam supplied}}$, so $\text{steam} = \dfrac{\text{water evaporated}}{\text{economy}}$.

Step 1 – list the data: Water evaporated $= 1200$ kg/h, economy $= 0.8$.

Step 2 – rearrange for the steam rate: $\text{steam} = \dfrac{1200}{0.8}$

Step 3 – evaluate: steam $= 1500$ kg/h

Final Answer: steam $= 1500$ kg/h $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

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

Step 1 – list the data: $D_{AB} = 2 \times 10^{-5}\ \text{m}^2/\text{s}$, $C_1 = 3\ \text{mol/m}^3$, $C_2 = 1\ \text{mol/m}^3$, $\delta = 0.005$ m.

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

Step 3 – form the numerator: $D_{AB}(C_1 - C_2) = 2 \times 10^{-5} \times 2 = 4 \times 10^{-5}$

Step 4 – divide by the film thickness: $N_A = \dfrac{4 \times 10^{-5}}{0.005}$

Step 5 – evaluate: $N_A = 8 \times 10^{-3}\ \text{mol/m}^2\cdot\text{s}$

Final Answer: $N_A = 8 \times 10^{-3}\ \text{mol/m}^2\cdot\text{s} \Rightarrow \boxed{\text{B}}$

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: $D = 3 \times 10^{-5}$ m^2/s, $\delta = 1.5$ mm $= 1.5 \times 10^{-3}$ m.

Step 2 – substitute: $k_c = \dfrac{3 \times 10^{-5}}{1.5 \times 10^{-3}}$

Step 3 – divide the coefficients: $\dfrac{3}{1.5} = 2$

Step 4 – divide the powers of ten: $\dfrac{10^{-5}}{10^{-3}} = 10^{-2}$

Step 5 – combine: $k_c = 2 \times 10^{-2} = 0.02$ m/s

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

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – two-film addition of resistances referred to the gas phase: $\dfrac{1}{K_g} = \dfrac{1}{k_g} + \dfrac{m}{k_l}$.

Step 1 – list the data: $\dfrac{1}{k_g} = 2$, $\dfrac{m}{k_l} = 2$.

Step 2 – add the two resistances: $\dfrac{1}{K_g} = 2 + 2 = 4$

Step 3 – invert to get K_g: $K_g = \dfrac{1}{4}$

Step 4 – evaluate: $K_g = 0.25$

Final Answer: $K_g = 0.25 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – slope of the rectifying-section operating line: slope $= \dfrac{R}{R+1}$.

Step 1 – list the data: $R = 1$.

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

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

Step 4 – evaluate: slope $= 0.50$

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

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – Fenske 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: $\alpha = 3.0$, $x_D = 0.90$, $x_W = 0.10$.

Step 2 – evaluate the distillate ratio: $\dfrac{x_D}{1-x_D} = \dfrac{0.90}{0.10} = 9$

Step 3 – evaluate the bottoms ratio: $\dfrac{1-x_W}{x_W} = \dfrac{0.90}{0.10} = 9$

Step 4 – form the product inside the logarithm: $9 \times 9 = 81$

Step 5 – take the logarithm of the product: $\ln 81 = 4.394$

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

Step 7 – divide: $N_{\min} = \dfrac{4.394}{1.0986}$

Step 8 – evaluate: $N_{\min} = 4.0$

Final Answer: $N_{\min} \approx 4.0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – stripping factor for a gas stripper: $S = \dfrac{mG}{L}$.

Step 1 – list the data: $m = 2.0$, $G = 100$ mol/h, $L = 50$ mol/h.

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

Step 3 – divide by the liquid flow: $S = \dfrac{200}{50}$

Step 4 – evaluate: $S = 4.0$

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

Answer: (C) Go Back to Q33

Q34.

Solution

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

Step 1 – list the data: $Z = 4.5$ m, $\text{HTU} = 0.75$ m.

Step 2 – rearrange and substitute: $\text{NTU} = \dfrac{4.5}{0.75}$

Step 3 – evaluate: $\text{NTU} = 6.0$

Final Answer: $\text{NTU} = 6.0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

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

Step 1 – list the data: $x = 0.3$, $y = 0.6$.

Step 2 – form the vapour ratio: $\dfrac{y}{1-y} = \dfrac{0.6}{0.4} = 1.5$

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

Step 4 – divide the two ratios: $\alpha = \dfrac{1.5}{0.4286}$

Step 5 – evaluate: $\alpha = 3.5$

Final Answer: $\alpha \approx 3.5 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – in the constant-rate period the water removal rate is the flux times the exposed area: $\dot{m}_w = (\text{flux}) \times A$, and time $= \dfrac{\text{water to remove}}{\dot{m}_w}$.

Step 1 – list the data: Flux $= 1.5$ kg/m^2·h, $A = 4$ m^2, water to remove $= 3$ kg.

Step 2 – find the rate of water removal: $\dot{m}_w = 1.5 \times 4 = 6$ kg/h

Step 3 – divide the mass by the rate: $t = \dfrac{3}{6}$

Step 4 – evaluate: $t = 0.5$ h

Final Answer: $t = 0.5 \text{ h} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q36

Q37.

Solution

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

Step 1 – list the data: $k = 0.04\ \text{min}^{-1}$, $\ln 2 = 0.6931$.

Step 2 – substitute: $t_{1/2} = \dfrac{0.6931}{0.04}$

Step 3 – evaluate: $t_{1/2} = 17.33\ \text{min}$

Final Answer: $t_{1/2} \approx 17.33\ \text{min} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q37

Q38.

Solution

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

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

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

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

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

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

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

Answer: (C) Go Back to Q38

Q39.

Solution

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

Step 1 – list the data: $k = 0.5\ \text{min}^{-1}$, $X = 0.9$.

Step 2 – find the unconverted fraction: $1 - X = 1 - 0.9 = 0.1$

Step 3 – take the logarithm: $-\ln(0.1) = 2.3026$

Step 4 – divide by the rate constant: $\tau = \dfrac{2.3026}{0.5}$

Step 5 – evaluate: $\tau = 4.605 \approx 4.6$ min

Final Answer: $\tau \approx 4.6$ min $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – Arrhenius ratio of 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: $E_a = 80{,}000$ J/mol, $R = 8.314$ J/mol·K, $T_1 = 400$ K, $T_2 = 410$ K.

Step 2 – evaluate the reciprocal temperatures: $\dfrac{1}{400} = 2.5000 \times 10^{-3}$ K^{-1}

$\dfrac{1}{410} = 2.4390 \times 10^{-3}$ K^{-1}

Step 3 – subtract: $\dfrac{1}{400} - \dfrac{1}{410} = 6.098 \times 10^{-5}$ K^{-1}

Step 4 – form the pre-factor: $\dfrac{E_a}{R} = \dfrac{80{,}000}{8.314} = 9622$

Step 5 – form the exponent: $9622 \times 6.098 \times 10^{-5} = 0.5868$

Step 6 – take the exponential: $e^{0.5868} = 1.798 \approx 1.8$

Final Answer: ratio $\approx 1.8 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q40

Q41.

Solution

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

Step 1 – list the data: $V = 200$ L, $Q = 50$ L/min.

Step 2 – substitute: $\tau = \dfrac{200}{50}$

Step 3 – evaluate: $\tau = 4.0$ min

Final Answer: $\tau = 4.0$ min $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

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

Step 1 – list the data: $\phi = 4$.

Step 2 – substitute: $\eta = \dfrac{1}{4}$

Step 3 – evaluate: $\eta = 0.25$

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

Answer: (C) **Go Back to Q42**

Q43.

Solution

Concept – step response of a first-order process: $y(t) = y_\infty\left(1 - e^{-t/\tau}\right)$, where y_∞ is the final change.

Step 1 – list the data: $y_\infty = 20$, and the required time is $t = 2\tau$.

Step 2 – form the exponent at $t = 2\tau$: $\dfrac{t}{\tau} = \dfrac{2\tau}{\tau} = 2$

Step 3 – evaluate the exponential: $e^{-2} = 0.1353$

Step 4 – form the fractional approach: $1 - e^{-2} = 1 - 0.1353 = 0.8647$

Step 5 – multiply by the final value: $y(2\tau) = 20 \times 0.8647$

Step 6 – evaluate: $y(2\tau) = 17.29 \approx 17.3$

Final Answer: $y(2\tau) \approx 17.3 \Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q43**

Q44.

Solution

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

Step 1 – list the data: $\zeta = 0.6$.

Step 2 – evaluate the term under the root: $1 - \zeta^2 = 1 - 0.36 = 0.64$

Step 3 – take the square root: $\sqrt{0.64} = 0.80$

Step 4 – form the exponent: $\dfrac{-\pi \times 0.6}{0.80} = \dfrac{-1.885}{0.80} = -2.356$

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

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

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

Answer: (A) Go Back to Q44

Q45.

Solution

Concept – proportional-only control leaves a residual error: A P-only controller changes its output only in proportion to the error, so it needs a nonzero error to hold the corrective action against a sustained load.

Step 1 – reason about the steady state: To keep the manipulated variable at the new value demanded by the sustained load, the error cannot fall to zero.

Step 2 – identify the resulting behaviour: The controlled variable settles at a value away from the set point, that is, a steady-state offset.

Step 3 – reject the distractors: Zero offset needs integral action, sustained oscillation and instability arise only at high gains, none of which is the characteristic steady behaviour here.

Final Answer: a nonzero steady-state offset $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q45

Q46.

Solution

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

Step 1 – list the data: Investment = Rs. $20{,}00{,}000$, annual cash flow = Rs. $5{,}00{,}000$.

Step 2 – substitute: payback $= \dfrac{20{,}00{,}000}{5{,}00{,}000}$

Step 3 – evaluate: payback $= 4$ years

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

Answer: (D) Go Back to Q46

Answer Key

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