GATE Chemical Engineering

Sample Paper – 6

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 8 kg of oxygen (molar mass 32) and 14 kg of nitrogen (molar mass 28). The mole fraction of oxygen in the mixture is: **[1 mark]**

(A) 0.25

(B) 0.333

(C) 0.50

(D) 0.667

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 by complete combustion of 8 kg of methane (molar mass 16) is: **[1 mark]**

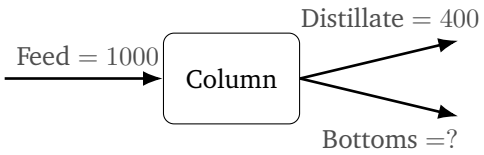
(A) 8 kg

(B) 16 kg

(C) 22 kg

(D) 44 kg

Q3. In the steady flow splitter shown, a feed stream of 1000 kg/h is separated into a distillate stream of 400 kg/h and a bottoms stream. Applying an overall mass balance, the bottoms flow rate is: **[1 mark]**



(A) 400 kg/h

(B) 1400 kg/h

(C) 600 kg/h

(D) 500 kg/h

Q4. A closed system undergoes a process during which its internal energy increases by 150 J while it absorbs 400 J of heat from the surroundings. By the first law of thermodynamics, the work done by the system on the surroundings is: **[1 mark]**

(A) $+250$ J

(B) $+550$ J

(C) -250 J

(D) $+150$ J

Q5. One mole of an ideal gas expands reversibly and isothermally at 300 K so that its volume doubles. Taking $R = 8.314$ J/mol·K, the entropy change of the gas ($\Delta S = R\ln(V_2/V_1)$) is nearest to: **[1 mark]**

(A) 11.5 J/K

(B) 5.76 J/K

(C) 2.88 J/K

(D) 0 J/K

Q6. An ideal gas of molar mass 28 g/mol (0.028 kg/mol) is held at 300 K and 1 bar (10^5 Pa). Taking $R = 8.314$ J/mol·K, the density of the gas ($\rho = PM/RT$) is nearest to: **[1 mark]**

(A) 0.561 kg/m^3

(B) 1.12 kg/m^3

(C) 2.24 kg/m^3

(D) 11.2 kg/m^3

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

(A) increase

(B) remain unchanged

(C) decrease

(D) become zero

Q8. A binary liquid mixture behaves ideally and obeys Raoult's law. At the system temperature the saturation pressures are $P_A^{sat} = 120$ kPa and $P_B^{sat} = 40$ kPa. For a liquid of composition $x_A = 0.25$, the total pressure over the liquid is: **[1 mark]**

(A) 80 kPa

(B) 40 kPa

(C) 120 kPa

(D) 60 kPa

Q9. A real gas at 10^5 Pa and 300 K is found to have a molar volume of 0.020 m^3/mol. Taking $R = 8.314$ J/mol·K, the compressibility factor of the gas ($Z = PV/RT$) is nearest to: **[1 mark]**

(A) 1.00

(B) 0.50

(C) 0.90

(D) 0.80

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

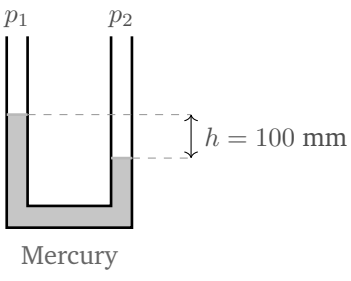
(B) 0.83

(C) 5.0

(D) 1.2

Fluid Mechanics & Mechanical Operations

Q11. A U-tube mercury manometer connected across two points of a gas line shows a steady difference in mercury levels of $h = 100$ mm, as shown. Taking the density of mercury as 13600 kg/m^3 and neglecting the gas column, the pressure difference $(p_1 - p_2)$ is nearest to: **[1 mark]**



(A) 26.7 kPa

(B) 13.3 kPa

(C) 1.33 kPa

(D) 6.67 kPa

Q12. Water discharges freely to the atmosphere through a small orifice in the side of a large open tank. The centre of the orifice is 10 m below the free surface of the water. Neglecting all losses, the ideal velocity of the jet issuing from the orifice ($V = \sqrt{2gh}$) is nearest to: **[1 mark]**

(A) 10.0 m/s

(B) 7.0 m/s

(C) 14.0 m/s

(D) 196 m/s

Q13. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 25 mm at a mean velocity of 0.10 m/s. The Reynolds number of the flow ($Re = \rho V D/\mu$) is: **[1 mark]**

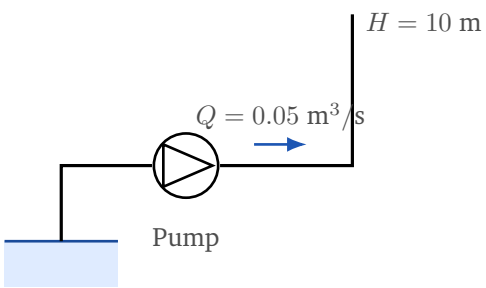
(A) 1250

(B) 2500

(C) 5000

(D) 25000

Q14. A centrifugal pump delivers water at a rate of $Q = 0.05$ m^3/s against a total head of $H = 10$ m, as shown. Taking $\rho_w = 1000$ kg/m^3, the hydraulic (water) power delivered by the pump, $P = \rho g Q H$, is nearest to: **[1 mark]**



(A) 4.9 kW

(B) 9.81 kW

(C) 2.45 kW

(D) 0.49 kW

Q15. A large tank is open to the atmosphere and holds still water. The local atmospheric pressure is 101.3 kPa. Taking $\rho_w = 1000$ kg/m^3 and $g = 9.81$ m/s^2, the absolute pressure of the water at a depth of 5 m below the free surface is nearest to: **[1 mark]**

(A) 49.1 kPa

(B) 101.3 kPa

(C) 150.4 kPa

(D) 52.1 kPa

Q16. A spherical particle of diameter 50 μm and density 2650 kg/m^3 settles under gravity in a still liquid of density 1000 kg/m^3 and viscosity 1×10^{-3} Pa·s. Assuming Stokes' law, the terminal settling velocity $v_t = gd^2(\rho_p - \rho_f)/(18\mu)$ is nearest to: **[1 mark]**

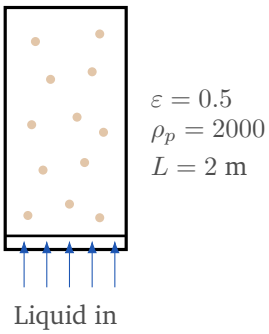
(A) 1.12 mm/s

(B) 2.25 mm/s

(C) 4.50 mm/s

(D) 0.90 mm/s

Q17. A liquid of density $\rho_f = 1000$ kg/m^3 is passed upward through the bed of solids shown to bring it to incipient (minimum) fluidization. The bed has voidage $\varepsilon = 0.5$, particle density $\rho_p = 2000$ 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) 9.81 kPa

(B) 19.6 kPa

(C) 4.90 kPa

(D) 14.7 kPa

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

(A) Rittinger's law

(B) Kick's law

(C) Bond's law

(D) Stokes' law

Q19. A ball mill has an internal diameter of 2.25 m (the ball diameter is negligible). Using the critical-speed relation $n_c = 42.3/\sqrt{D}$ rpm, with D in metres, the critical speed of the mill is nearest to: **[1 mark]**

(A) 42.3 rpm

(B) 34.5 rpm

(C) 28.2 rpm

(D) 21.2 rpm

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

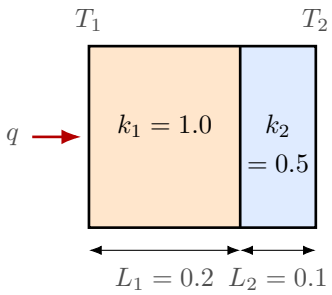
(B) 100 W

(C) 200 W

(D) 800 W

Heat Transfer

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) 250 W/m^2

(C) 500 W/m^2

(D) 750 W/m^2

Q22. A bare pipe carrying a hot fluid is to be covered with insulation of thermal conductivity $k = 0.5$ W/m·K, while the outside convective coefficient is $h = 10$ W/m^2·K. The critical radius of insulation for the cylindrical pipe ($r_c = k/h$) is: [2 marks]

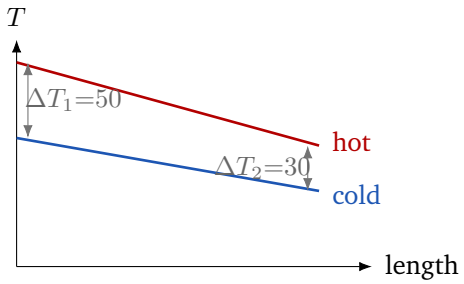
(A) 5 mm

(B) 500 mm

(C) 25 mm

(D) 50 mm

Q23. In the counter-current double-pipe exchanger whose temperature profile is sketched, the terminal temperature differences are $\Delta T_1 = 50$ °C at one end and $\Delta T_2 = 30$ °C at the other. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



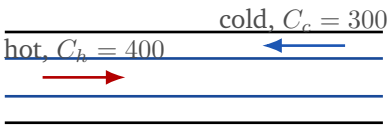
(A) 40.0 °C

(B) 45.0 °C

(C) 39.2 °C

(D) 35.0 °C

Q24. A double-pipe heat exchanger has an overall conductance $UA = 600$ W/K. The two streams have heat-capacity rates $C_h = 400$ W/K and $C_c = 300$ W/K, as indicated. In the effectiveness–NTU method the capacity-rate ratio is defined as $C_r = C_{\min}/C_{\max}$. Its value here is: **[2 marks]**



Double-pipe exchanger, $UA = 600$ W/K

(A) 1.33

(B) 0.75

(C) 0.50

(D) 1.0

Q25. A hot vertical plate of surface area 0.5 m^2 loses heat to surrounding air by convection. The convective heat-transfer coefficient is 100 W/m^2·K and the plate surface is 20 K hotter than the air. The rate of convective heat loss ($q = hA\,\Delta T$) is: **[2 marks]**

(A) 1000 W

(B) 2000 W

(C) 500 W

(D) 4000 W

Q26. A surface behaves as a black body at a temperature of 600 K. Taking the Stefan–Boltzmann constant as $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, the total emissive power of the surface ($E = \sigma T^4$) is nearest to: **[2 marks]**

(A) 7348 W/m^2

(B) 3544 W/m^2

(C) 14696 W/m^2

(D) 1837 W/m^2

Q27. A triple-effect evaporator system evaporates 2700 kg/h of water while consuming 1000 kg/h of saturated steam in the first effect. The steam economy of the system (mass of water evaporated per unit mass of steam supplied) is: **[2 marks]**

(A) 0.37

(B) 2.7

(C) 1.0

(D) 3.0

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) 8×10^{-3} mol/m^2·s

(B) 4×10^{-3} mol/m^2·s

(C) 2×10^{-3} mol/m^2·s

(D) 1.6×10^{-2} mol/m^2·s

Q29. According to film theory, a solute diffuses across a stagnant liquid film of thickness $\delta = 0.5$ mm with a molecular diffusivity $D = 1.5 \times 10^{-5}$ m^2/s. The film mass-transfer coefficient ($k_c = D/\delta$) is: **[2 marks]**

(A) 0.03 m/s

(B) 0.015 m/s

(C) 0.06 m/s

(D) 0.003 m/s

Q30. In a gas absorption process described by two-film theory, the individual coefficients give $1/k_g = 0.3$ and the liquid-side contribution referred to the gas phase gives $m/k_l = 0.9$ (in consistent units). Using $1/K_g = 1/k_g + m/k_l$, the overall gas-phase mass-transfer coefficient K_g is nearest to: **[2 marks]**

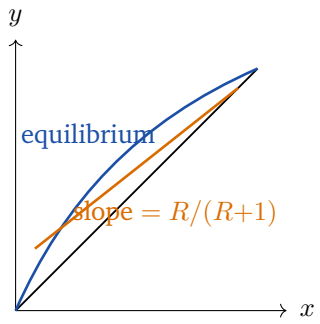
(A) 1.2

(B) 0.5

(C) 1.0

(D) 0.833

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 slope of this operating line is measured to be 0.8, the reflux ratio R is: **[2 marks]**



(A) 0.8

(B) 5.0

(C) 1.25

(D) 4.0

Q32. A binary mixture with a constant relative volatility $\alpha = 3.0$ is to be 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) 7.09

(B) 4.0

(C) 9.0

(D) 5.5

Q33. In a gas absorber the liquid flow rate is $L = 120$ mol/h, the gas flow rate is $G = 60$ mol/h and the equilibrium slope is $m = 1.5$. The absorption factor, defined as $A = L/(mG)$, is nearest to: **[2 marks]**

(A) 2.0

(B) 1.33

(C) 0.75

(D) 1.0

Q34. A packed absorption tower is designed on the basis of transfer units, so that the packing height is $Z = \text{HTU} \times \text{NTU}$. For a particular separation

the height of a transfer unit is 0.8 m and the number of transfer units required is 5. The required height of packing is: **[2 marks]**

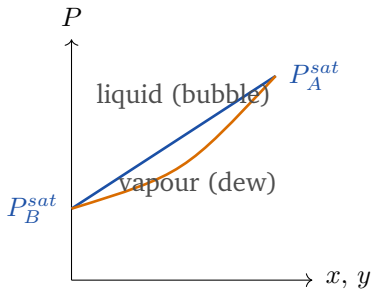
(A) 3.0 m

(B) 4.0 m

(C) 6.4 m

(D) 5.8 m

Q35. The pressure–composition (P–x–y) diagram of an ideal binary mixture is shown; the upper straight (bubble) line follows Raoult's law. At the system temperature the pure-component saturation pressures are $P_A^{sat} = 90$ kPa and $P_B^{sat} = 30$ kPa. The relative volatility of A with respect to B, $\alpha = P_A^{sat}/P_B^{sat}$, is: **[2 marks]**



(A) 2.5

(B) 0.33

(C) 1.5

(D) 3.0

Q36. A wet solid is being dried in its constant-rate period, during which the drying flux (rate of water removal per unit exposed area) is 1.5 kg/m^2·h over an exposed surface area of 8 m^2. The rate of water removal from the solid is: **[2 marks]**

(A) 5.3 kg/h

(B) 9.5 kg/h

(C) 12 kg/h

(D) 16 kg/h

Reaction Engineering, Process Control & Plant Economics

Q37. A homogeneous liquid-phase reaction is first order in the reactant, with a rate constant $k = 0.05$ min^{-1}. The half-life of the reactant, $t_{1/2} = \ln 2/k$, is nearest to: **[2 marks]**

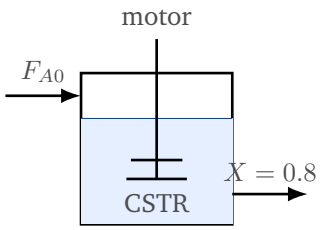
(A) 20.0 min

(B) 13.86 min

(C) 5.0 min

(D) 27.7 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) 20 min

(B) 10 min

(C) 8 min

(D) 4 min

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

(A) 0.632

(B) 0.865

(C) 0.900

(D) 0.950

Q40. A liquid-phase reaction is second order in reactant A, with a rate constant $k = 0.5$ L/mol·min and an initial concentration $C_{A0} = 2$ mol/L. Using the batch integrated rate law $\frac{1}{C_A} = \frac{1}{C_{A0}} + kt$, the concentration of A after 2 min is nearest to: **[2 marks]**

(A) 0.667 mol/L

(B) 1.0 mol/L

(C) 1.5 mol/L

(D) 0.5 mol/L

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

(A) 20 min

(B) 100 min

(C) 5.0 min

(D) 8.0 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 nearest to: **[2 marks]**

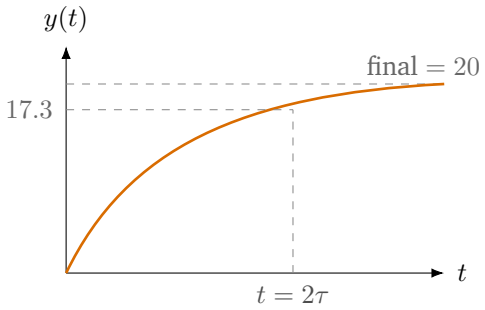
(A) 1.0

(B) 4.0

(C) 0.5

(D) 0.25

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) 17.3

(B) 12.6

(C) 20.0

(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) 25%

(C) 5%

(D) 9.5%

Q45. In a feedback control loop, a proportional-only controller leaves a persistent steady-state offset after a sustained load change. Which single control action, when added to the controller, will eliminate this steady-state offset? **[2 marks]**

(A) Integral action

(B) Proportional action

(C) Derivative action

(D) On–off action

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

(A) 2 years

(B) 10 years

(C) 4 years

(D) 5 years

Detailed Solutions

Q1.

Solution

Concept – mole fraction is the moles of a component divided by the total moles: first convert each mass to moles using its molar mass, then form the ratio.

Step 1 – moles of oxygen: $n_{O_2} = \dfrac{8}{32}$

$n_{O_2} = 0.25$ kmol

Step 2 – moles of nitrogen: $n_{N_2} = \dfrac{14}{28}$

$n_{N_2} = 0.50$ kmol

Step 3 – total moles: $n_{\text{total}} = 0.25 + 0.50 = 0.75$ kmol

Step 4 – form the mole fraction of oxygen: $y_{O_2} = \dfrac{0.25}{0.75}$

Step 5 – evaluate: $y_{O_2} = 0.333$

Final Answer: $y_{O_2} = 0.333 \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – use the stoichiometry of the combustion reaction: $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$, so 1 mole of methane produces 1 mole of carbon dioxide.

Step 1 – find the moles of methane burnt: $n_{CH_4} = \dfrac{8 \text{ kg}}{16 \text{ kg/kmol}} = 0.5$ kmol

Step 2 – apply the $1:1$ mole ratio for CO_2: $n_{CO_2} = n_{CH_4} = 0.5$ kmol

Step 3 – convert carbon dioxide moles to mass: $m_{CO_2} = n_{CO_2} \times M_{CO_2} = 0.5 \times 44$

$m_{CO_2} = 22$ kg

Final Answer: $m_{CO_2} = 22$ kg $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – steady-state overall mass balance: mass in equals mass out, so Feed = Distillate + Bottoms.

Step 1 – read the streams from the diagram: Feed = 1000 kg/h, Distillate = 400 kg/h.

Step 2 – write the balance: $1000 = 400 + \text{Bottoms}$

Step 3 – solve for the bottoms flow: $\text{Bottoms} = 1000 - 400$

Step 4 – evaluate: Bottoms = 600 kg/h

Final Answer: Bottoms = 600 kg/h $\Rightarrow$ C

Answer: (C) Go Back to Q3

Q4.

Solution

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

Step 1 – assign the two energy terms: Heat added to the system $Q = +400$ J; change in internal energy $\Delta U = +150$ J.

Step 2 – rearrange the first law for work: $W = Q - \Delta U$

Step 3 – substitute the values: $W = 400 - 150$

Step 4 – evaluate: $W = +250$ J

Final Answer: $W = +250$ J $\Rightarrow$ A

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – entropy change for isothermal reversible expansion of an ideal gas: $\Delta S = nR \ln \dfrac{V_2}{V_1}$, with $n = 1$ mole here.

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

Step 2 – take the logarithm of the volume ratio: $\ln 2 = 0.6931$

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

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

Final Answer: $\Delta S \approx 5.76$ J/K $\Rightarrow$ B

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – density of an ideal gas from the ideal-gas law: $PV = nRT$ and $\rho = \frac{nM}{V}$ combine to give $\rho = \frac{PM}{RT}$.

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: $\rho = \frac{2800}{2494.2}$

Step 5 – evaluate: $\rho = 1.1226$ kg/m^3 ≈ 1.12 kg/m^3

Final Answer: $\rho \approx 1.12$ kg/m^3 $\Rightarrow$ B

Answer: (B) Go Back to Q6

Q7.

Solution

Concept – effect of temperature on the equilibrium constant of an exothermic reaction: the van't Hoff equation $\frac{d\ln K}{dT} = \frac{\Delta H^\circ}{RT^2}$ governs the shift.

Step 1 – note the sign of the enthalpy: For an exothermic reaction $\Delta H^\circ < 0$.

Step 2 – apply the van't Hoff relation: With ΔH° negative, $\frac{d\ln K}{dT}$ is negative, so K falls as T rises.

Step 3 – confirm with Le Chatelier's principle: Adding heat (raising T) shifts an exothermic equilibrium toward the reactants, lowering K.

Step 4 – state the result: K decreases.

Final Answer: K decreases $\Rightarrow$ C

Answer: (C) Go Back to Q7

Q8.

Solution

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

Step 1 – list the data: $P_A^{sat} = 120$ kPa, $P_B^{sat} = 40$ kPa, $x_A = 0.25$.

Step 2 – find the second mole fraction: $x_B = 1 - x_A = 1 - 0.25 = 0.75$

Step 3 – substitute into Raoult's law: $P = (0.25)(120) + (0.75)(40)$

Step 4 – evaluate each term: $P = 30 + 30$

$P = 60$ kPa

Final Answer: $P = 60$ kPa $\Rightarrow$ D

Answer: (D) Go Back to Q8

Q9.

Solution

Concept – the compressibility factor measures departure from ideal-gas behaviour: $Z = \dfrac{PV}{RT}$, where V is the molar volume.

Step 1 – list the data in SI units: $P = 10^5$ Pa, $V = 0.020$ m^3/mol, $R = 8.314$ J/mol·K, $T = 300$ K.

Step 2 – compute the numerator: $PV = 10^5 \times 0.020 = 2000$

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

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

Step 5 – evaluate: $Z = 0.8019 \approx 0.80$

Final Answer: $Z \approx 0.80 \Rightarrow$ D

Answer: (D) Go Back to Q9

Q10.

Solution

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

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

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

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

Step 4 – evaluate: COP $= 5.0$

Final Answer: COP $= 5.0 \Rightarrow$ C

Answer: (C) Go Back to Q10

Q11.

Solution

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

Step 1 – list the data in SI units: $\rho_m = 13600$ kg/m^3, $g = 9.81$ m/s^2, $h = 100$ mm $= 0.1$ m.

Step 2 – substitute: $p_1 - p_2 = 13600 \times 9.81 \times 0.1$

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

Step 4 – multiply by the height: $p_1 - p_2 = 133{,}416 \times 0.1 = 13{,}341.6$ Pa

Step 5 – express in kilopascals: $p_1 - p_2 \approx 13.3$ kPa

Final Answer: $p_1 - p_2 \approx 13.3$ kPa $\Rightarrow$ B

Answer: (B) Go Back to Q11

Q12.

Solution

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

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

Step 2 – form the product under the root: $2gh = 2 \times 9.81 \times 10$

$2gh = 196.2$ m^2/s^2

Step 3 – take the square root: $V = \sqrt{196.2}$

$V = 14.01$ m/s ≈ 14.0 m/s

Why option D is wrong: 196.2 is the value of $2gh$ (units m^2/s^2), not the velocity; the square root must still be taken.

Final Answer: $V \approx 14.0$ m/s $\Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – the Reynolds number compares inertial to viscous forces: $Re = \dfrac{\rho V D}{\mu}$.

Step 1 – list the data in SI units: $\rho = 1000$ kg/m^3, $V = 0.10$ m/s, $D = 25$ mm $= 0.025$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

Step 2 – evaluate the numerator: $\rho V D = 1000 \times 0.10 \times 0.025$

$\rho V D = 2.5$

Step 3 – divide by the viscosity: $Re = \dfrac{2.5}{1 \times 10^{-3}}$

Step 4 – evaluate: $Re = 2500$

Final Answer: $Re = 2500 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q13

Q14.

Solution

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

Step 1 – list the data: $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $Q = 0.05$ m^3/s, $H = 10$ m.

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

Step 3 – multiply by the discharge: $\rho g Q = 9810 \times 0.05 = 490.5$

Step 4 – multiply by the head: $P = 490.5 \times 10 = 4905$ W

Step 5 – express in kilowatts: $P = 4.905$ kW ≈ 4.9 kW

Final Answer: $P \approx 4.9$ kW $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – absolute pressure is atmospheric plus the gauge (hydrostatic) pressure: $p_{\text{abs}} = p_{\text{atm}} + \rho\, g\, h$.

Step 1 – list the data: $p_{\text{atm}} = 101.3$ kPa, $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2, $h = 5$ m.

Step 2 – compute the hydrostatic (gauge) pressure: $\rho g h = 1000 \times 9.81 \times 5 = 49{,}050$ Pa

Step 3 – express the gauge pressure in kilopascals: $\rho g h = 49.05$ kPa

Step 4 – add the atmospheric pressure: $p_{\text{abs}} = 101.3 + 49.05$

Step 5 – evaluate: $p_{\text{abs}} = 150.35$ kPa ≈ 150.4 kPa

Final Answer: $p_{\text{abs}} \approx 150.4$ kPa $\Rightarrow$ C

Answer: (C) 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: $g\, d^2 (\rho_p - \rho_f) = 9.81 \times 2.5 \times 10^{-9} \times 1650$ $= 4.047 \times 10^{-5}$

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

Step 6 – divide: $v_t = \dfrac{4.047 \times 10^{-5}}{0.018} = 2.248 \times 10^{-3}$ m/s

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

Final Answer: $v_t \approx 2.25$ mm/s $\Rightarrow$ B

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – pressure drop across a fluidized bed balances the net weight of solids: $\Delta P = (1 - \varepsilon)(\rho_p - \rho_f)\, g\, L$.

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

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

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

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

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 $\Rightarrow$ A

Answer: (A) Go Back to Q17

Q18.

Solution

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

Step 1 – recall Kick's law: $E = C \ln(\frac{L_1}{L_2})$, so the energy per unit mass is proportional to the logarithm of the size-reduction ratio.

Step 2 – match to the description: Energy proportional to $\ln(L_1/L_2)$ and best for coarse crushing is exactly Kick's law.

Step 3 – reject the distractors: Rittinger's law scales with new surface area (fine grinding); Bond's law scales with $L^{-1/2}$; Stokes' law is a settling law, not a comminution law.

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

Answer: (B) Go Back to Q18

Q19.

Solution

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

Step 1 – list the data: $D = 2.25$ m.

Step 2 – take the square root of the diameter: $\sqrt{2.25} = 1.5$

Step 3 – substitute into the formula: $n_c = \dfrac{42.3}{1.5}$

Step 4 – evaluate: $n_c = 28.2$ rpm

Final Answer: $n_c = 28.2$ rpm $\Rightarrow$ C

Answer: (C) 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: $kA\Delta T = 2 \times 0.5 \times 40$

$kA\Delta T = 40$

Step 3 – divide by the thickness: $q = \dfrac{40}{0.2}$

Step 4 – evaluate: $q = 200$ W

Final Answer: $q = 200$ W $\Rightarrow$ C

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – series conduction resistances add, and the flux is the overall ΔT over the total resistance: $q = \dfrac{\Delta T}{(L_1/k_1) + (L_2/k_2)}$ per unit area.

Step 1 – resistance of layer 1 (per unit area): $R_1 = \dfrac{L_1}{k_1} = \dfrac{0.2}{1.0} = 0.2$ m^2·K/W

Step 2 – resistance of layer 2 (per unit area): $R_2 = \dfrac{L_2}{k_2} = \dfrac{0.1}{0.5} = 0.2$ m^2·K/W

Step 3 – total resistance: $R_{\text{total}} = 0.2 + 0.2 = 0.4$ m^2·K/W

Step 4 – divide the overall temperature difference by the total resistance: $q = \dfrac{300}{0.4}$

Step 5 – evaluate: $q = 750$ W/m^2

Final Answer: $q = 750$ W/m^2 $\Rightarrow$ D

Answer: (D) Go Back to Q21

Q22.

Solution

Concept – critical radius of insulation for a cylinder: $r_c = \dfrac{k}{h}$, the radius at which total resistance is a minimum.

Step 1 – list the data: $k = 0.5$ W/m·K, $h = 10$ W/m^2·K.

Step 2 – substitute into the formula: $r_c = \dfrac{0.5}{10}$

Step 3 – evaluate: $r_c = 0.05$ m

Step 4 – express in millimetres: $r_c = 50$ mm

Final Answer: $r_c = 50$ mm $\Rightarrow$ D

Answer: (D) Go Back to Q22

Q23.

Solution

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

Step 1 – list the terminal differences: $\Delta T_1 = 50$ °C, $\Delta T_2 = 30$ °C.

Step 2 – form the numerator: $\Delta T_1 - \Delta T_2 = 50 - 30 = 20$

Step 3 – form the ratio inside the logarithm: $\dfrac{\Delta T_1}{\Delta T_2} = \dfrac{50}{30} = 1.6667$

Step 4 – take the logarithm: $\ln(1.6667) = 0.5108$

Step 5 – divide: $\text{LMTD} = \dfrac{20}{0.5108}$

Step 6 – evaluate: $\text{LMTD} = 39.15$ °C ≈ 39.2 °C

Final Answer: LMTD ≈ 39.2 °C $\Rightarrow$ C

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – capacity-rate ratio in the effectiveness–NTU method: $C_r = \dfrac{C_{\min}}{C_{\max}}$, formed from the smaller and larger heat-capacity rates.

Step 1 – identify the two capacity rates: $C_h = 400$ W/K, $C_c = 300$ W/K.

Step 2 – pick the minimum and maximum: $C_{\min} = 300$ W/K, $C_{\max} = 400$ W/K.

Step 3 – form the ratio: $C_r = \dfrac{300}{400}$

Step 4 – evaluate: $C_r = 0.75$

Note: the value of UA is needed for NTU, not for the capacity-rate ratio, so it does not enter here.

Final Answer: $C_r = 0.75 \Rightarrow$ B

Answer: (B) Go Back to Q24

Q25.

Solution

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

Step 1 – list the data: $h = 100$ W/m^2·K, $A = 0.5$ m^2, $\Delta T = 20$ K.

Step 2 – multiply the coefficient and area: $hA = 100 \times 0.5 = 50$

Step 3 – multiply by the temperature difference: $q = 50 \times 20$

Step 4 – evaluate: $q = 1000$ W

Final Answer: $q = 1000$ W $\Rightarrow$ A

Answer: (A) 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, $T = 600$ K.

Step 2 – square the temperature: $T^2 = 600^2 = 360{,}000$

Step 3 – square again to get the fourth power: $T^4 = (360{,}000)^2 = 1.296 \times 10^{11}$

Step 4 – multiply by the constant: $E = 5.67 \times 10^{-8} \times 1.296 \times 10^{11}$

Step 5 – evaluate: $E = 7348$ W/m^2

Final Answer: $E \approx 7348$ W/m^2 $\Rightarrow$ A

Answer: (A) Go Back to Q26

Q27.

Solution

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

Step 1 – list the data: Water evaporated $= 2700$ kg/h, steam supplied $= 1000$ kg/h.

Step 2 – form the ratio: $\text{economy} = \dfrac{2700}{1000}$

Step 3 – evaluate: $\text{economy} = 2.7$

Note: an economy above 1 is normal for a multiple-effect system, where the vapour from each effect heats the next.

Final Answer: economy $= 2.7 \Rightarrow$ B

Answer: (B) Go Back to Q27

Q28.

Solution

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

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

Step 2 – form the concentration difference: $C_1 - C_2 = 3 - 1 = 2$ 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: $N_A = 8 \times 10^{-3}$ mol/m^2·s

Final Answer: $N_A = 8 \times 10^{-3}$ mol/m^2·s $\Rightarrow$ A

Answer: (A) 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: $D = 1.5 \times 10^{-5}$ m^2/s, $\delta = 0.5$ mm $= 5 \times 10^{-4}$ m.

Step 2 – substitute: $k_c = \dfrac{1.5 \times 10^{-5}}{5 \times 10^{-4}}$

Step 3 – evaluate: $k_c = 0.03$ m/s

Final Answer: $k_c = 0.03$ m/s $\Rightarrow$ A

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – two-film addition of resistances for the overall gas-phase coefficient: $\frac{1}{K_g} = \frac{1}{k_g} + \frac{m}{k_l}$.

Step 1 – list the two resistance contributions: $\frac{1}{k_g} = 0.3$, $\frac{m}{k_l} = 0.9$.

Step 2 – add the resistances: $\frac{1}{K_g} = 0.3 + 0.9 = 1.2$

Step 3 – invert to obtain K_g: $K_g = \frac{1}{1.2}$

Step 4 – evaluate: $K_g = 0.833$

Final Answer: $K_g \approx 0.833 \Rightarrow$ D

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – slope of the rectifying operating line in the McCabe–Thiele method: slope $= \frac{R}{R+1}$, which can be inverted to find R.

Step 1 – write the equation with the measured slope: $\frac{R}{R+1} = 0.8$

Step 2 – clear the denominator: $R = 0.8\,(R+1)$

Step 3 – expand the right-hand side: $R = 0.8R + 0.8$

Step 4 – collect the R terms: $R - 0.8R = 0.8$

$0.2R = 0.8$

Step 5 – solve for R: $R = \frac{0.8}{0.2} = 4.0$

Final Answer: $R = 4.0 \Rightarrow$ D

Answer: (D) Go Back to Q31

Q32.

Solution

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

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

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

Step 3 – multiply the two ratios: $49 \times 49 = 2401$

Step 4 – take the logarithm of the product: $\ln(2401) = 7.7836$

Step 5 – take the logarithm of the relative volatility: $\ln(3.0) = 1.0986$

Step 6 – divide: $N_{\min} = \dfrac{7.7836}{1.0986}$

Step 7 – evaluate: $N_{\min} = 7.086 \approx 7.09$

Final Answer: $N_{\min} \approx 7.09 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

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

Step 1 – list the data: $L = 120$ mol/h, $m = 1.5$, $G = 60$ mol/h.

Step 2 – form the denominator: $m\,G = 1.5 \times 60 = 90$

Step 3 – divide: $A = \dfrac{120}{90}$

Step 4 – evaluate: $A = 1.333$

Final Answer: $A \approx 1.33 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – packed height from transfer units: $Z = \text{HTU} \times \text{NTU}$.

Step 1 – list the data: HTU $= 0.8$ m, NTU $= 5$.

Step 2 – multiply: $Z = 0.8 \times 5$

Step 3 – evaluate: $Z = 4.0$ m

Final Answer: $Z = 4.0$ m $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – relative volatility for an ideal (Raoult's-law) binary: $\alpha = \dfrac{P_A^{sat}}{P_B^{sat}}$.

Step 1 – list the data: $P_A^{sat} = 90$ kPa, $P_B^{sat} = 30$ kPa.

Step 2 – form the ratio: $\alpha = \dfrac{90}{30}$

Step 3 – evaluate: $\alpha = 3.0$

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

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – in the constant-rate period the drying rate is flux times exposed area: rate $=$ (flux) $\times A$.

Step 1 – list the data: flux $= 1.5$ kg/m^2·h, $A = 8$ m^2.

Step 2 – multiply: rate $= 1.5 \times 8$

Step 3 – evaluate: rate $= 12$ kg/h

Final Answer: rate $= 12$ kg/h $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q36

Q37.

Solution

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

Step 1 – list the data: $k = 0.05$ min^{-1}, $\ln 2 = 0.6931$.

Step 2 – substitute: $t_{1/2} = \dfrac{0.6931}{0.05}$

Step 3 – evaluate: $t_{1/2} = 13.86$ min

Final Answer: $t_{1/2} \approx 13.86$ min $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

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

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

Step 2 – form 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: $\tau = 20\ \text{min} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q38

Q39.

Solution

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

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

Step 2 – form the product: $k\tau = 0.3 \times 10 = 3$

Step 3 – evaluate the exponential: $e^{-3} = 0.0498$

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

Step 5 – evaluate: $X = 0.950$

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

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – integrated rate law for a second-order batch reaction: $\dfrac{1}{C_A} = \dfrac{1}{C_{A0}} + kt$.

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

Step 2 – compute the reciprocal of the initial concentration: $\dfrac{1}{C_{A0}} = \dfrac{1}{2} = 0.5$

Step 3 – compute the kt term: $kt = 0.5 \times 2 = 1.0$

Step 4 – add the two terms: $\dfrac{1}{C_A} = 0.5 + 1.0 = 1.5$

Step 5 – invert to find C_A: $C_A = \dfrac{1}{1.5}$

Step 6 – evaluate: $C_A = 0.667$ mol/L

Final Answer: $C_A \approx 0.667$ mol/L $\Rightarrow$ A

Answer: (A) Go Back to Q40

Q41.

Solution

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

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

Step 2 – substitute: $\tau = \dfrac{200}{25}$

Step 3 – evaluate: $\tau = 8.0$ min

Final Answer: $\tau = 8.0$ min $\Rightarrow$ D

Answer: (D) Go Back to Q41

Q42.

Solution

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

Step 1 – list the data: $\phi = 4$.

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

Step 3 – evaluate: $\eta = 0.25$

Final Answer: $\eta = 0.25 \Rightarrow$ D

Answer: (D) Go Back to Q42

Q43.

Solution

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

Step 1 – list the data: $y_\infty = 20$, evaluate at $t = 2\tau$, so $t/\tau = 2$.

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

Step 3 – form the bracket: $1 - e^{-2} = 1 - 0.1353 = 0.8647$

Step 4 – multiply by the final change: $y(2\tau) = 20 \times 0.8647$

Step 5 – evaluate: $y(2\tau) = 17.29 \approx 17.3$

Note: at one time constant the response reaches 63.2%; at two time constants it reaches 86.5% of the final value.

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

Answer: (A) 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 the denominator root: $\sqrt{1-\zeta^2} = \sqrt{1-0.36} = \sqrt{0.64} = 0.8$

Step 3 – form the exponent: $\dfrac{-\pi \times 0.6}{0.8} = \dfrac{-1.885}{0.8} = -2.356$

Step 4 – take the exponential: $e^{-2.356} = 0.0948$

Step 5 – convert to a percentage: $\text{overshoot} = 9.48\% \approx 9.5\%$

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

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – offset removal by controller action: integral (reset) action keeps adjusting the output as long as any error remains, driving the steady-state error to zero.

Step 1 – recall the proportional-only limitation: a proportional controller needs a non-zero error to hold a new output, so it leaves an offset.

Step 2 – introduce integral action: the integral term $\frac{1}{\tau_I}\int e\,dt$ grows while $e \neq 0$ and only stops changing when $e = 0$.

Step 3 – conclude: integral action eliminates the steady-state offset.

Step 4 – reject the distractors: derivative action speeds response but does not remove offset; on–off action cycles about the set point.

Final Answer: integral action $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

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

Step 1 – list the data: Fixed capital $=$ Rs. $10{,}00{,}000$, annual cash flow $=$ Rs. $2{,}50{,}000$.

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

Step 3 – evaluate: $\text{payback} = 4$ years

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

Answer: (C) Go Back to Q46

Answer Key

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