GATE Chemical Engineering

Sample Paper – 5

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 is made up of 2 kmol of nitrogen and 3 kmol of hydrogen. The mole fraction of hydrogen in the mixture is: **[1 mark]**

(A) 0.40

(B) 0.60

(C) 0.50

(D) 0.667

Q2. Methane is burnt completely following $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$. The mass of carbon dioxide (molar mass 44) produced by completely burning 8 kg of methane (molar mass 16) is: **[1 mark]**

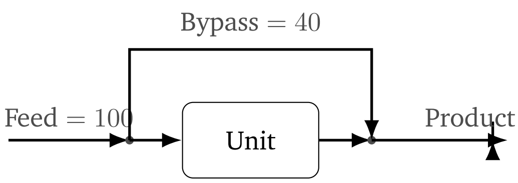
(A) 44 kg

(B) 16 kg

(C) 8 kg

(D) 22 kg

Q3. In the steady flow arrangement shown, a feed stream of 100 mol/h is split at a point: 40 mol/h bypasses the process unit while the remainder passes through it. The fraction of the feed that is bypassed is: **[1 mark]**



(A) 0.60

(B) 0.40

(C) 0.67

(D) 1.50

Q4. A closed system undergoes an adiabatic process during which 300 J of work is done **on** the system by the surroundings. Using the first law $\Delta U = Q - W$ (with W the work done **by** the system), the change in internal energy of the system is: **[1 mark]**

(A) -300 J

(B) 0 J

(C) $+150$ J

(D) $+300$ J

Q5. A reversible Carnot refrigerator operates between a cold space at 250 K and warm surroundings at 300 K. Its coefficient of performance, COP $= \dfrac{T_C}{T_H - T_C}$, is: **[1 mark]**

(A) 6.0

(B) 5.0

(C) 0.20

(D) 1.20

Q6. A fixed mass of an ideal gas is confined in a rigid, closed vessel at 300 K and 100 kPa. The gas is heated at constant volume until its pressure has doubled. The final temperature of the gas is: **[1 mark]**

(A) 150 K

(B) 300 K

(C) 450 K

(D) 600 K

Q7. The Gibbs phase rule for a non-reacting system is $F = C - P + 2$. For a single pure substance ($C = 1$) existing at its triple point, where three phases coexist ($P = 3$), the number of degrees of freedom F is: **[1 mark]**

(A) 2

(B) 1

(C) 0

(D) 3

Q8. A benzene (A)–toluene (B) liquid mixture obeys Raoult's law. At the system temperature $P_A^{sat} = 120$ kPa and $P_B^{sat} = 80$ kPa. For a liquid of composition $x_A = 0.4$, the partial pressure of A over the liquid, $p_A = x_A P_A^{sat}$, is: **[1 mark]**

(A) 48 kPa

(B) 96 kPa

(C) 80 kPa

(D) 32 kPa

Q9. The compressibility factor of a gas is defined as $Z = \dfrac{PV}{nRT}$. For a gas that behaves ideally at the given state, the value of Z is: **[1 mark]**

(A) 0

(B) infinite

(C) 1.0

(D) 0.5

Q10. A heat engine receives 1000 kJ of heat from a high-temperature source and rejects 600 kJ of heat to a low-temperature sink per cycle. The thermal efficiency of the engine, $\eta = \dfrac{W_{net}}{Q_{in}}$, is: **[1 mark]**

(A) 0.60

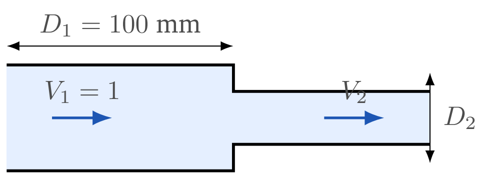
(B) 0.40

(C) 0.50

(D) 1.67

Fluid Mechanics & Mechanical Operations

Q11. Water flows steadily through the pipe contraction shown, where the diameter reduces from 100 mm to 50 mm. The mean velocity in the larger section is 1 m/s. Using continuity $A_1V_1 = A_2V_2$, the mean velocity in the smaller section is: **[1 mark]**



(A) 2.0 m/s

(B) 4.0 m/s

(C) 0.25 m/s

(D) 8.0 m/s

Q12. Water of density 1000 kg/m^3 and dynamic viscosity 1×10^{-3} Pa·s flows through a pipe of diameter 25 mm at a mean velocity of 2 m/s. The Reynolds number of the flow, $Re = \dfrac{\rho V D}{\mu}$, is: **[1 mark]**

(A) $50{,}000$

(B) 5000

(C) 500

(D) $25{,}000$

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 $h_f = f\dfrac{L}{D}\dfrac{V^2}{2g}$, the frictional head loss is nearest to: **[1 mark]**

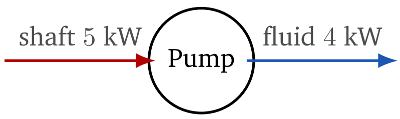
(A) 2.04 m

(B) 8.15 m

(C) 1.02 m

(D) 4.08 m

Q14. A centrifugal pump delivers hydraulic (water) power of 4 kW to the fluid while its shaft (brake) power input is 5 kW, as indicated. The pump efficiency, $\eta = \dfrac{P_{hydraulic}}{P_{shaft}}$, is: **[1 mark]**



$\eta = P_{hyd}/P_{shaft}$

(A) 1.25

(B) 0.20

(C) 0.50

(D) 0.80

Q15. A solid body of volume 0.002 m^3 is fully submerged and held at rest in water of density 1000 kg/m^3. Taking $g = 9.81$ m/s^2, the buoyant (upthrust) force on the body, $F_B = \rho\, g\, V$, is: **[1 mark]**

(A) 9.81 N

(B) 39.24 N

(C) 19.62 N

(D) 2.0 N

Q16. A small spherical particle settles under gravity in a liquid in the Stokes' law regime, where the terminal velocity varies as $v_t \propto d^2$. If the particle diameter is doubled while all other properties are unchanged, the terminal settling velocity changes by a factor of: **[1 mark]**

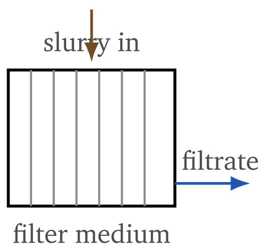
(A) 4

(B) 2

(C) 8

(D) 0.5

Q17. In the constant-pressure filtration shown, the volume of clear filtrate collected grows in proportion to the square root of time, $V \propto \sqrt{t}$. If 10 L of filtrate is collected in 100 s, the volume collected in 400 s is: **[1 mark]**



(A) 40 L

(B) 20 L

(C) 15 L

(D) 10 L

Q18. Which law of size reduction states that the work required per unit mass is proportional to the logarithm of the size-reduction ratio, $\ln(d_1/d_2)$, and is best suited to coarse crushing? **[1 mark]**

(A) Kick's law

(B) Rittinger's law

(C) Bond's law

(D) Stokes' law

Q19. A spherical particle settles in the creeping-flow (Stokes) regime, in which the drag coefficient is $C_D = \dfrac{24}{Re_p}$. For a particle Reynolds number of $Re_p = 0.5$, the drag coefficient is: **[1 mark]**

(A) 24

(B) 48

(C) 12

(D) 96

Q20. A plane wall has thickness $L = 0.2$ m, thermal conductivity $k = 0.4$ W/m·K and face area $A = 2\ \text{m}^2$. The conductive thermal resistance of the wall, $R = \dfrac{L}{kA}$, is: **[1 mark]**

(A) 0.25 K/W

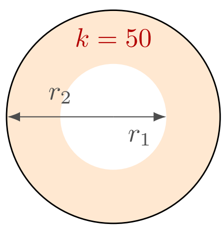
(B) 0.50 K/W

(C) 1.0 K/W

(D) 0.10 K/W

Heat Transfer

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



(A) 22.7 kW

(B) 31.4 kW

(C) 45.3 kW

(D) 90.7 kW

Q22. A solid object of characteristic length $L_c = 0.01$ m and thermal conductivity $k = 20$ W/m·K is suddenly exposed to a fluid with convective coefficient $h = 100$ W/m^2·K. The Biot number, $Bi = \frac{hL_c}{k}$, is: **[2 marks]**

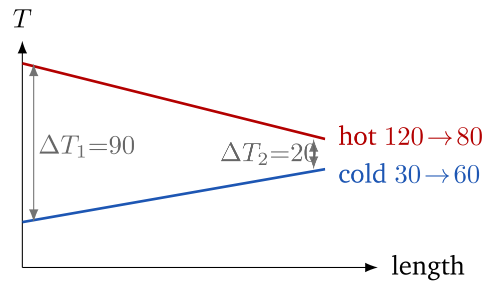
(A) 0.50

(B) 0.20

(C) 0.05

(D) 2.0

Q23. The temperature profile of the parallel-flow (co-current) double-pipe exchanger sketched below has a hot stream cooling from 120 °C to 80 °C and a cold stream heating from 30 °C to 60 °C. The logarithmic mean temperature difference (LMTD) for the exchanger is nearest to: **[2 marks]**



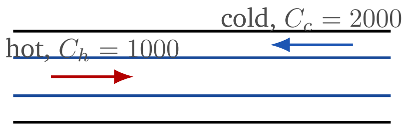
(A) 55.0 °C

(B) 42.4 °C

(C) 90.0 °C

(D) 46.5 °C

Q24. A double-pipe heat exchanger, sketched below, has two streams with heat-capacity rates $C_h = 1000$ W/K and $C_c = 2000$ W/K. In the effectiveness–NTU method the heat-capacity ratio is $C_r = \frac{C_{\min}}{C_{\max}}$. Its value here is: **[2 marks]**



Double-pipe exchanger

(A) 2.0

(B) 1.0

(C) 0.50

(D) 0.25

Q25. Heat flows steadily across a plane wall that has a convective film on each face. Referred to unit area, the resistances are $1/h_1 = 0.01$, $L/k = 0.02$ and $1/h_2 = 0.01$ (all in m^2·K/W). Using $\frac{1}{U} = \frac{1}{h_1} + \frac{L}{k} + \frac{1}{h_2}$, the overall heat-transfer coefficient U is: **[2 marks]**

(A) 40 W/m^2·K

(B) 25 W/m^2·K

(C) 50 W/m^2·K

(D) 4 W/m^2·K

Q26. A grey surface of emissivity $\varepsilon = 0.6$ is maintained at a temperature of 400 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) 871 W/m^2

(B) 1452 W/m^2

(C) 435 W/m^2

(D) 2560 W/m^2

Q27. A shell-and-tube heat exchanger must transfer a heat duty of $Q = 50{,}000$ W. The overall heat-transfer coefficient is $U = 500$ W/m^2·K and the log-mean temperature difference is $\Delta T_{lm} = 40$ K. Using $Q = U A\,\Delta T_{lm}$, the required heat-transfer area A is: **[2 marks]**

(A) 5.0 m^2

(B) 2.5 m^2

(C) 1.25 m^2

(D) 10 m^2

Mass Transfer & Separation Processes

Q28. For convective mass transfer the Sherwood number is $Sh = \dfrac{k_c\,L}{D_{AB}}$. In a particular film, $Sh = 100$, the diffusivity is $D_{AB} = 1 \times 10^{-9}$ m^2/s and the characteristic length is $L = 1 \times 10^{-3}$ m. The mass-transfer coefficient $k_c = \dfrac{Sh\,D_{AB}}{L}$ is: **[2 marks]**

(A) 1×10^{-6} m/s

(B) 1×10^{-3} m/s

(C) 1×10^{-4} m/s

(D) 1×10^{-2} m/s

Q29. By the penetration theory of mass transfer, the liquid-film coefficient is $k_c = 2\sqrt{\dfrac{D}{\pi\,t_c}}$, where t_c is the surface contact time. For $D = 1 \times 10^{-9}$ m^2/s and $t_c = 1$ s, the mass-transfer coefficient is nearest to: **[2 marks]**

(A) 1.78×10^{-5} m/s

(B) 6.37×10^{-5} m/s

(C) 1.0×10^{-5} m/s

(D) 3.57×10^{-5} m/s

Q30. A sparingly soluble gas dissolves in a liquid according to Henry's law, $p_A = H\,x_A$, where the Henry constant is $H = 50$ kPa (mole-fraction basis). For a dissolved-liquid mole fraction of $x_A = 0.02$, the equilibrium partial pressure of A in the gas is: **[2 marks]**

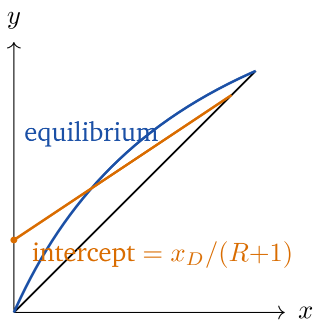
(A) 1.0 kPa

(B) 2.5 kPa

(C) 0.5 kPa

(D) 25 kPa

Q31. In the McCabe–Thiele diagram shown, the rectifying-section operating line meets the y-axis at the intercept $\dfrac{x_D}{R+1}$, where x_D is the distillate composition and R the reflux ratio. For $x_D = 0.9$ and $R = 2$, the value of this y-axis intercept is: **[2 marks]**



(A) 0.45

(B) 0.90

(C) 0.30

(D) 0.60

Q32. At a point on a binary equilibrium curve the light-key mole fractions are $x = 0.4$ in the liquid and $y = 0.6$ in the vapour. The relative volatility, defined by $\alpha = \dfrac{y/(1-y)}{x/(1-x)}$, is: **[2 marks]**

(A) 1.5

(B) 1.0

(C) 2.25

(D) 0.44

Q33. In a gas stripping column the stripping factor is defined as $S = \dfrac{mG}{L}$, where m is the equilibrium slope, G the gas rate and L the liquid rate. Given $m = 2$, $G = 50$ mol/h and $L = 200$ mol/h, the stripping factor is: **[2 marks]**

(A) 1.0

(B) 0.5

(C) 2.0

(D) 0.25

Q34. A dilute gas absorber has a nearly negligible equilibrium back-pressure, so the number of transfer units reduces to NTU $= \ln\frac{y_{in}}{y_{out}}$. For an inlet mole fraction $y_{in} = 0.05$ reduced to an outlet mole fraction $y_{out} = 0.005$, the number of transfer units is nearest to: **[2 marks]**

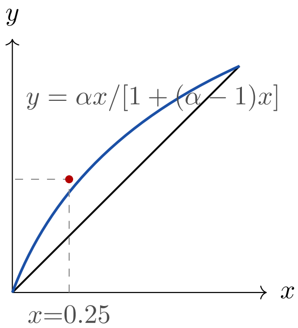
(A) 1.0

(B) 2.30

(C) 4.61

(D) 0.90

Q35. The vapour–liquid equilibrium curve of an ideal binary of constant relative volatility $\alpha = 3$ is sketched below. The vapour composition in equilibrium with a liquid of light-key mole fraction $x = 0.25$ follows $y = \dfrac{\alpha x}{1+(\alpha-1)x}$, and equals: **[2 marks]**



(A) 0.25

(B) 0.75

(C) 0.60

(D) 0.50

Q36. The free-moisture content of a wet solid is the total moisture minus the equilibrium moisture the solid would eventually reach with the surrounding air. For a solid whose total moisture is 0.30 and whose equilibrium moisture is 0.05 (both in kg water per kg dry solid), the free-moisture content is: **[2 marks]**

(A) 0.25

(B) 0.35

(C) 0.30

(D) 0.05

Reaction Engineering, Process Control & Plant Economics

Q37. A homogeneous liquid-phase reaction is first order with rate constant $k = 0.1$ min^{-1}. The time required to achieve 90% conversion, given by $t = \dfrac{\ln[1/(1-X)]}{k}$, is nearest to: **[2 marks]**

(A) 6.93 min

(B) 23.03 min

(C) 10.0 min

(D) 46.1 min

Q38. A first-order liquid-phase reaction with rate constant $k = 0.5$ min^{-1} is carried out in an ideal plug-flow reactor (PFR) to a conversion of $X = 0.8$. Using the PFR design relation $\tau = \dfrac{-\ln(1-X)}{k}$, the required space time is nearest to: **[2 marks]**

(A) 1.6 min

(B) 8.0 min

(C) 2.0 min

(D) 3.22 min

Q39. A first-order liquid-phase reaction with rate constant $k = 0.2\ \text{min}^{-1}$ is run in an ideal continuous stirred-tank reactor (CSTR) with a space time of $\tau = 10$ min. Using $X = \dfrac{k\tau}{1 + k\tau}$, the fractional conversion at the reactor outlet is nearest to: **[2 marks]**

(A) 0.667

(B) 0.500

(C) 0.800

(D) 0.333

Q40. The experimentally determined rate constant of a homogeneous reaction is found to have the units of s^{-1}. From the dimensions of this rate constant, the overall order of the reaction is: **[2 marks]**

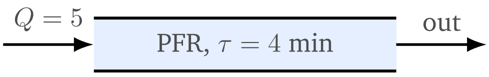
(A) zero order

(B) second order

(C) half order

(D) first order

Q41. An ideal plug-flow reactor (PFR), sketched below, requires a space time of $\tau = 4$ min for the desired conversion. The feed enters at a constant volumetric flow rate of $Q = 5$ L/min. The reactor volume, $V = \tau\, Q$, is: **[2 marks]**



(A) 20 L

(B) 1.25 L

(C) 0.80 L

(D) 9 L

Q42. For a catalyst pellet the observed reaction rate is the product of the internal effectiveness factor and the intrinsic rate, $r_{obs} = \eta\, r_{int}$. If $\eta = 0.5$

and the intrinsic rate is $r_{int} = 0.02$ mol/(g · s), the observed rate is: **[2 marks]**

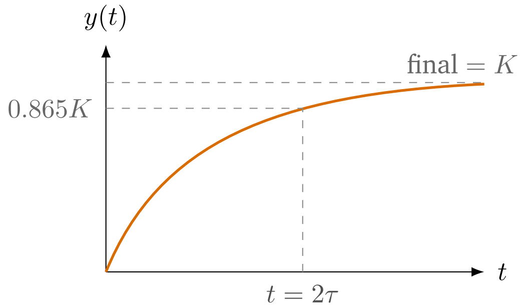
(A) 0.04 mol/(g · s)

(B) 0.02 mol/(g · s)

(C) 0.005 mol/(g · s)

(D) 0.01 mol/(g · s)

Q43. A first-order process responds to a step input as $y(t) = K\left(1 - e^{-t/\tau}\right)$, as sketched. The fraction of its ultimate (final) change that the output has completed at a time equal to two time constants, $t = 2\tau$, is nearest to: **[2 marks]**



(A) 0.632

(B) 0.950

(C) 0.865

(D) 0.982

Q44. A liquid-level process under proportional-only feedback control retains a steady-state offset after a unit-step load change, given by offset $= \dfrac{1}{1 + K_cK_p}$. For a controller gain $K_c = 4$ and a process gain $K_p = 1$, the offset is: **[2 marks]**

(A) 0.50

(B) 0.25

(C) 0.20

(D) 0.80

Q45. In a feedback control loop, which single controller mode, when added, is able to completely eliminate the steady-state offset that a proportional-only controller leaves after a sustained step change? **[2 marks]**

(A) Integral action

(B) Proportional action

(C) Derivative action

(D) On–off action

Q46. A chemical plant project requires a capital investment of Rs. $5{,}00{,}000$ and is expected to generate a constant net annual cash profit of Rs. $1{,}00{,}000$. The simple payback period, $\frac{\text{investment}}{\text{annual profit}}$, is: **[2 marks]**

(A) 5 years

(B) 4 years

(C) 10 years

(D) 2 years

Detailed Solutions

Q1.

Solution

Concept – mole fraction is the moles of a component divided by the total moles: $y_{H_2} = \dfrac{n_{H_2}}{n_{H_2} + n_{N_2}}$.

Step 1 – list the mole amounts: $n_{N_2} = 2$ kmol, $n_{H_2} = 3$ kmol.

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

$n_{\text{total}} = 5$ kmol

Step 3 – form the mole fraction of hydrogen: $y_{H_2} = \dfrac{3}{5}$

Step 4 – evaluate: $y_{H_2} = 0.60$

Final Answer: $y_{H_2} = 0.60 \Rightarrow \boxed{\text{B}}$

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 yields 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 the 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: $m_{CO_2} = 22 \text{ kg} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

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

Step 1 – read the two streams from the diagram: Bypass $= 40$ mol/h, feed $= 100$ mol/h.

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

Step 3 – evaluate: bypass fraction $= 0.40$

Final Answer: bypass fraction $= 0.40 \Rightarrow \boxed{\text{B}}$

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 the process conditions: The process is adiabatic, so $Q = 0$.

Step 2 – assign the sign of the work: Work is done **on** the system, so the work done **by** the system is $W = -300$ J.

Step 3 – substitute into the first law: $\Delta U = 0 - (-300)$

Step 4 – evaluate: $\Delta U = +300$ J

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

Answer: (D) Go Back to Q4

Q5.

Solution

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

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

Step 4 – evaluate: COP $= 5.0$

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

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – for a fixed mass at constant volume the pressure is proportional to the absolute temperature (Gay-Lussac's law): $\dfrac{P_1}{T_1} = \dfrac{P_2}{T_2}$.

Step 1 – list the data: $T_1 = 300$ K, $P_1 = 100$ kPa, $P_2 = 2P_1 = 200$ kPa.

Step 2 – rearrange for the final temperature: $T_2 = T_1 \times \dfrac{P_2}{P_1}$

Step 3 – substitute the pressure ratio: $T_2 = 300 \times \dfrac{200}{100}$

Step 4 – evaluate: $T_2 = 300 \times 2 = 600$ K

Final Answer: $T_2 = 600 \text{ K} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – Gibbs phase rule: $F = C - P + 2$, where C is the number of components and P the number of phases in equilibrium.

Step 1 – list the data for a pure substance at the triple point: $C = 1$, $P = 3$.

Step 2 – substitute into the phase rule: $F = 1 - 3 + 2$

Step 3 – evaluate: $F = 0$

Interpretation: $F = 0$ means the triple point is invariant, fixing both temperature and pressure uniquely.

Final Answer: $F = 0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – partial pressure of a component in an ideal solution (Raoult's law): $p_A = x_A P_A^{sat}$.

Step 1 – list the data: $x_A = 0.4$, $P_A^{sat} = 120$ kPa.

Step 2 – substitute into Raoult's law: $p_A = 0.4 \times 120$

Step 3 – evaluate: $p_A = 48$ kPa

Final Answer: $p_A = 48 \text{ kPa} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – compressibility factor: $Z = \dfrac{PV}{nRT}$. For an ideal gas the equation of state is $PV = nRT$.

Step 1 – substitute the ideal-gas relation into the definition: $Z = \dfrac{PV}{nRT} = \dfrac{nRT}{nRT}$

Step 2 – cancel common factors: $Z = 1.0$

Interpretation: an ideal gas always has $Z = 1$; deviations from unity measure non-ideality.

Final Answer: $Z = 1.0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – thermal efficiency of a heat engine: $\eta = \dfrac{W_{net}}{Q_{in}}$, where $W_{net} = Q_{in} - Q_{out}$.

Step 1 – list the data: $Q_{in} = 1000$ kJ, $Q_{out} = 600$ kJ.

Step 2 – find the net work: $W_{net} = 1000 - 600 = 400$ kJ

Step 3 – form the efficiency: $\eta = \dfrac{400}{1000}$

Step 4 – evaluate: $\eta = 0.40$

Final Answer: $\eta = 0.40 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – steady incompressible continuity: $A_1V_1 = A_2V_2$, so $V_2 = V_1\left(\dfrac{D_1}{D_2}\right)^2$ for circular sections.

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

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

Step 3 – square the ratio (area varies as diameter squared): $\left(\frac{D_1}{D_2}\right)^2 = 2^2 = 4$

Step 4 – multiply by the upstream velocity: $V_2 = 1 \times 4 = 4$ m/s

Final Answer: $V_2 = 4.0$ m/s $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q11

Q12.

Solution

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

Step 1 – list the data in SI units: $\rho = 1000\,\text{kg/m}^3$, $V = 2$ m/s, $D = 25$ mm $= 0.025$ m, $\mu = 1 \times 10^{-3}$ Pa·s.

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

$\rho V D = 50$

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

Step 4 – evaluate: $Re = 50{,}000$

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

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – Darcy–Weisbach frictional head loss: $h_f = f\,\dfrac{L}{D}\,\dfrac{V^2}{2g}$.

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

Step 2 – form the length-to-diameter ratio: $\dfrac{L}{D} = \dfrac{100}{0.1} = 1000$

Step 3 – form the velocity-head term: $\dfrac{V^2}{2g} = \dfrac{2^2}{2 \times 9.81} = \dfrac{4}{19.62} = 0.2039$ m

Step 4 – multiply the friction and geometry factors: $f\,\dfrac{L}{D} = 0.02 \times 1000 = 20$

Step 5 – multiply by the velocity head: $h_f = 20 \times 0.2039$

$h_f = 4.077$ m ≈ 4.08 m

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

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – pump efficiency: $\eta = \dfrac{P_{hydraulic}}{P_{shaft}}$, the ratio of useful power given to the fluid to the shaft power supplied.

Step 1 – list the data: $P_{hydraulic} = 4$ kW, $P_{shaft} = 5$ kW.

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

Step 3 – evaluate: $\eta = 0.80$

Note: the efficiency is below 1 because part of the shaft power is lost to friction and turbulence inside the pump.

Final Answer: $\eta = 0.80 \Rightarrow \boxed{\text{D}}$

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 liquid.

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

Step 2 – substitute: $F_B = 1000 \times 9.81 \times 0.002$

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

Step 4 – multiply by the volume: $F_B = 9810 \times 0.002 = 19.62$ N

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

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – Stokes'-law terminal velocity depends on the square of the diameter: $v_t = \dfrac{g\, d^2(\rho_p - \rho_f)}{18\,\mu} \propto d^2$ when the other quantities are fixed.

Step 1 – write the ratio of the two terminal velocities: $\dfrac{v_{t,2}}{v_{t,1}} = \left(\dfrac{d_2}{d_1}\right)^2$

Step 2 – substitute the diameter ratio (doubled): $\dfrac{d_2}{d_1} = 2$

Step 3 – square the ratio: $\dfrac{v_{t,2}}{v_{t,1}} = 2^2 = 4$

Final Answer: the terminal velocity increases by a factor of $4 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – in constant-pressure filtration the filtrate volume grows with the square root of time: $V = C\sqrt{t}$, so $\dfrac{V_2}{V_1} = \sqrt{\dfrac{t_2}{t_1}}$.

Step 1 – list the data: $V_1 = 10$ L at $t_1 = 100$ s; $t_2 = 400$ s.

Step 2 – form the time ratio: $\dfrac{t_2}{t_1} = \dfrac{400}{100} = 4$

Step 3 – take the square root: $\sqrt{4} = 2$

Step 4 – multiply by the first volume: $V_2 = 10 \times 2 = 20$ L

Final Answer: $V_2 = 20 \text{ L} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q17

Q18.

Solution

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

Step 1 – recall Kick's statement: Energy per unit mass is proportional to $\ln(d_1/d_2)$, the logarithm of the size-reduction ratio.

Step 2 – match it to the application: Because coarse crushing involves a modest reduction ratio on large feed, Kick's law fits coarse crushing best.

Why the other options are wrong:

- Rittinger's law: energy $\propto \left(\frac{1}{d_2} - \frac{1}{d_1}\right)$, suited to fine grinding.
- Bond's law: energy $\propto \left(\frac{1}{\sqrt{d_2}} - \frac{1}{\sqrt{d_1}}\right)$, for intermediate crushing.
- Stokes' law: a settling law, not a size-reduction law.

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

Answer: (A) Go Back to Q18

Q19.

Solution

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

Step 1 – list the data: $Re_p = 0.5$.

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

Step 3 – evaluate: $C_D = 48$

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

Answer: (B) Go Back to 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, $k = 0.4$ W/m·K, $A = 2$ m^2.

Step 2 – form the denominator: $k\,A = 0.4 \times 2 = 0.8$ W/K

Step 3 – divide the thickness by the denominator: $R = \dfrac{0.2}{0.8}$

Step 4 – evaluate: $R = 0.25$ K/W

Final Answer: $R = 0.25$ K/W $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

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

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

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

$= 31{,}416$

Step 3 – evaluate the radius ratio and its logarithm: $\dfrac{r_2}{r_1} = \dfrac{0.10}{0.05} = 2$

$\ln 2 = 0.6931$

Step 4 – divide: $Q = \dfrac{31{,}416}{0.6931} = 45{,}326$ W

Step 5 – express in kilowatts: $Q \approx 45.3$ kW

Final Answer: $Q \approx 45.3$ kW $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q21

Q22.

Solution

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

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

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

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

Step 4 – evaluate: $Bi = 0.05$

Note: since $Bi < 0.1$, the lumped-capacitance model is valid for this body.

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

Answer: (C) Go Back to Q22

Q23.

Solution

Concept – log-mean temperature difference for a parallel-flow exchanger: $\text{LMTD} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$, where the ends are taken at the inlet and outlet.

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

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

Step 3 – take the difference of the two: $\Delta T_1 - \Delta T_2 = 90 - 20 = 70$

Step 4 – take the log of the ratio: $\ln\left(\dfrac{90}{20}\right) = \ln(4.5) = 1.5041$

Step 5 – divide: $\text{LMTD} = \dfrac{70}{1.5041} = 46.5$ °C

Final Answer: LMTD ≈ 46.5 °C $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q23

Q24.

Solution

Concept – heat-capacity ratio in the effectiveness–NTU method: $C_r = \dfrac{C_{\min}}{C_{\max}}$.

Step 1 – identify the smaller and larger capacity rates: $C_h = 1000$ W/K and $C_c = 2000$ W/K, so $C_{\min} = 1000$ and $C_{\max} = 2000$.

Step 2 – form the ratio: $C_r = \dfrac{1000}{2000}$

Step 3 – evaluate: $C_r = 0.50$

Final Answer: $C_r = 0.50 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – for resistances in series the overall coefficient adds reciprocally: $\dfrac{1}{U} = \dfrac{1}{h_1} + \dfrac{L}{k} + \dfrac{1}{h_2}$.

Step 1 – list the three resistances (per unit area): $\dfrac{1}{h_1} = 0.01$, $\dfrac{L}{k} = 0.02$, $\dfrac{1}{h_2} = 0.01$ (in m^2·K/W).

Step 2 – add the resistances: $\dfrac{1}{U} = 0.01 + 0.02 + 0.01 = 0.04$ m^2·K/W

Step 3 – invert to get the overall coefficient: $U = \dfrac{1}{0.04}$

Step 4 – evaluate: $U = 25$ W/m^2·K

Final Answer: $U = 25$ W/m^2·K $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q25

Q26.

Solution

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

Step 1 – list the data: $\varepsilon = 0.6$, $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4, $T = 400$ K.

Step 2 – raise the temperature to the fourth power: $T^4 = (400)^4 = 2.56 \times 10^{10}$ K^4

Step 3 – multiply the constant by T^4: $\sigma T^4 = 5.67 \times 10^{-8} \times 2.56 \times 10^{10}$

$= (5.67 \times 2.56) \times 10^2 = 14.52 \times 10^2 = 1452$ W/m^2

Step 4 – multiply by the emissivity: $E = 0.6 \times 1452 = 871$ W/m^2

Final Answer: $E \approx 871\ \text{W/m}^2 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – exchanger design equation: $Q = U A\, \Delta T_{lm}$, so $A = \dfrac{Q}{U\, \Delta T_{lm}}$.

Step 1 – list the data: $Q = 50{,}000$ W, $U = 500$ W/m^2·K, $\Delta T_{lm} = 40$ K.

Step 2 – form the denominator: $U\, \Delta T_{lm} = 500 \times 40 = 20{,}000$

Step 3 – divide the duty by the denominator: $A = \dfrac{50{,}000}{20{,}000}$

Step 4 – evaluate: $A = 2.5\ \text{m}^2$

Final Answer: $A = 2.5\ \text{m}^2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – Sherwood number relates the mass-transfer coefficient to diffusion: $Sh = \dfrac{k_c\, L}{D_{AB}}$, so $k_c = \dfrac{Sh\, D_{AB}}{L}$.

Step 1 – list the data: $Sh = 100$, $D_{AB} = 1 \times 10^{-9}$ m^2/s, $L = 1 \times 10^{-3}$ m.

Step 2 – evaluate the numerator: $Sh\, D_{AB} = 100 \times 1 \times 10^{-9} = 1 \times 10^{-7}$

Step 3 – divide by the length: $k_c = \dfrac{1 \times 10^{-7}}{1 \times 10^{-3}}$

Step 4 – subtract the exponents: $k_c = 1 \times 10^{-7-(-3)} = 1 \times 10^{-4}$ m/s

Final Answer: $k_c = 1 \times 10^{-4}\ \text{m/s} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q28

Q29.

Solution

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

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

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

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

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

$k_c = 3.57 \times 10^{-5}$ m/s

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

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – Henry's law for a sparingly soluble gas: $p_A = H\,x_A$.

Step 1 – list the data: $H = 50$ kPa, $x_A = 0.02$.

Step 2 – substitute: $p_A = 50 \times 0.02$

Step 3 – evaluate: $p_A = 1.0$ kPa

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

Answer: (A) Go Back to Q30

Q31.

Solution

Concept – y**-axis intercept of the rectifying operating line in McCabe–Thiele:** intercept $= \dfrac{x_D}{R+1}$.

Step 1 – list the data: $x_D = 0.9$, $R = 2$.

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

Step 3 – form the intercept: intercept $= \dfrac{0.9}{3}$

Step 4 – evaluate: intercept $= 0.30$

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

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – relative volatility from an equilibrium (x, y) **pair:** $\alpha = \dfrac{y/(1-y)}{x/(1-x)}$.

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

Step 2 – compute the liquid ratio: $\dfrac{x}{1-x} = \dfrac{0.4}{0.6} = 0.6667$

Step 3 – divide the vapour ratio by the liquid ratio: $\alpha = \dfrac{1.5}{0.6667}$

Step 4 – evaluate: $\alpha = 2.25$

Final Answer: $\alpha = 2.25 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q32

Q33.

Solution

Concept – stripping factor: $S = \dfrac{m\,G}{L}$.

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

Step 2 – form the numerator: $m\,G = 2 \times 50 = 100$

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

Step 4 – evaluate: $S = 0.5$

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

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – number of transfer units for a dilute absorber with negligible back-pressure: $\text{NTU} = \ln \dfrac{y_{in}}{y_{out}}$.

Step 1 – list the data: $y_{in} = 0.05$, $y_{out} = 0.005$.

Step 2 – form the concentration ratio: $\dfrac{y_{in}}{y_{out}} = \dfrac{0.05}{0.005} = 10$

Step 3 – take the natural logarithm: $\text{NTU} = \ln(10)$

Step 4 – evaluate: $\text{NTU} = 2.303 \approx 2.30$

Final Answer: $\text{NTU} \approx 2.30 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

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

Step 1 – list the data: $\alpha = 3$, $x = 0.25$.

Step 2 – evaluate the numerator: $\alpha x = 3 \times 0.25 = 0.75$

Step 3 – evaluate the denominator: $1+(\alpha-1)x = 1+(3-1)(0.25) = 1+0.5 = 1.5$

Step 4 – divide: $y = \dfrac{0.75}{1.5}$

Step 5 – evaluate: $y = 0.50$

Final Answer: $y = 0.50 \Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q35**

Q36.

Solution

Concept – free-moisture content: $X_{free} = X_{total} - X^*$, the total moisture minus the equilibrium moisture.

Step 1 – list the data: $X_{total} = 0.30$, $X^* = 0.05$ (kg water per kg dry solid).

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

Step 3 – evaluate: $X_{free} = 0.25$

Note: only the free moisture can be removed by drying; the equilibrium moisture stays with the solid.

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

Answer: (A) **Go Back to Q36**

Q37.

Solution

Concept – time for a given conversion in a first-order batch reaction: $t = \dfrac{\ln[1/(1-X)]}{k}$.

Step 1 – list the data: $k = 0.1\ \text{min}^{-1}$, $X = 0.90$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.90 = 0.10$

Step 3 – take the logarithm of its reciprocal: $\ln\left(\dfrac{1}{0.10}\right) = \ln(10) = 2.303$

Step 4 – divide by the rate constant: $t = \dfrac{2.303}{0.1}$

Step 5 – evaluate: $t = 23.03$ min

Final Answer: $t \approx 23.03 \text{ min} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

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

Step 1 – list the data: $k = 0.5 \text{ min}^{-1}$, $X = 0.80$.

Step 2 – form the unreacted fraction: $1 - X = 1 - 0.80 = 0.20$

Step 3 – take the natural log: $\ln(0.20) = -1.609$

Step 4 – change sign and divide by k: $\tau = \dfrac{-(-1.609)}{0.5} = \dfrac{1.609}{0.5}$

Step 5 – evaluate: $\tau = 3.22$ min

Final Answer: $\tau \approx 3.22 \text{ min} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q38

Q39.

Solution

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

Step 1 – list the data: $k = 0.2 \text{ min}^{-1}$, $\tau = 10$ min.

Step 2 – form the product $k\tau$: $k\tau = 0.2 \times 10 = 2.0$

Step 3 – form the denominator: $1 + k\tau = 1 + 2.0 = 3.0$

Step 4 – divide: $X = \dfrac{2.0}{3.0}$

Step 5 – evaluate: $X = 0.667$

Final Answer: $X \approx 0.667 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – the units of a rate constant reveal the overall reaction order: For an n-th order reaction $-r_A = kC_A^n$, the rate constant has units of $(\text{concentration})^{1-n}(\text{time})^{-1}$.

Step 1 – write the units of k for a first-order reaction ($n = 1$): $(\text{concentration})^{1-1}(\text{time})^{-1} = (\text{concentration})^0\,\text{s}^{-1} = \text{s}^{-1}$

Step 2 – compare with the given units: The given rate constant has units of s^{-1}, which matches $n = 1$.

Why the others are wrong: A zero-order k has units $\text{mol}\,\text{m}^{-3}\text{s}^{-1}$, and a second-order k has units $\text{m}^3\text{mol}^{-1}\text{s}^{-1}$; neither is s^{-1}.

Final Answer: first order $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q40

Q41.

Solution

Concept – reactor volume from the space time: $\tau = \dfrac{V}{Q}$, so $V = \tau Q$.

Step 1 – list the data: $\tau = 4$ min, $Q = 5$ L/min.

Step 2 – substitute: $V = 4 \times 5$

Step 3 – evaluate: $V = 20$ L

Final Answer: $V = 20$ L $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – the observed rate is the effectiveness factor times the intrinsic rate: $r_{obs} = \eta\, r_{int}$.

Step 1 – list the data: $\eta = 0.5$, $r_{int} = 0.02$ mol/(g · s).

Step 2 – substitute: $r_{obs} = 0.5 \times 0.02$

Step 3 – evaluate: $r_{obs} = 0.01$ mol/(g · s)

Final Answer: $r_{obs} = 0.01$ mol/(g · s) $\Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ Go Back to Q42

Q43.

Solution

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

Step 1 – set $t = 2\tau$: $\dfrac{t}{\tau} = 2$, so $e^{-t/\tau} = e^{-2}$.

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

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

Step 4 – round the result: ≈ 0.865

Final Answer: fraction $\approx 0.865 \Rightarrow \boxed{\text{C}}$

$\boxed{\text{Answer: (C)}}$ Go Back to Q43

Q44.

Solution

Concept – steady-state offset of a proportional-only controller: offset $= \dfrac{1}{1 + K_cK_p}$.

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

Step 2 – form the loop-gain product: $K_cK_p = 4 \times 1 = 4$

Step 3 – form the denominator: $1 + K_cK_p = 1 + 4 = 5$

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

Step 5 – evaluate: offset $= 0.20$

Final Answer: offset $= 0.20 \Rightarrow \boxed{\text{C}}$

$\boxed{\text{Answer: (C)}}$ Go Back to Q44

Q45.

Solution

Concept – integral action removes steady-state offset: The integral mode keeps changing the controller output as long as any error persists, so at steady state the error must be zero.

Step 1 – recall the proportional-only limitation: A proportional controller needs a non-zero error to sustain the output change that balances a load, so it leaves a residual offset.

Step 2 – identify the mode that drives the offset to zero: Adding integral action integrates the error over time; the output keeps adjusting until the error vanishes.

Why the other options are wrong:

- Proportional action alone is exactly what leaves the offset.
- Derivative action responds to the rate of change of error, not its steady value, so it cannot remove offset.
- On–off action produces continuous cycling rather than a steady offset-free value.

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

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – simple payback period: payback $= \dfrac{\text{capital investment}}{\text{net annual profit}}$.

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

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

Step 3 – evaluate: payback $= 5$ years

Final Answer: payback period $= 5$ years $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q46

Answer Key

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