General Aptitude

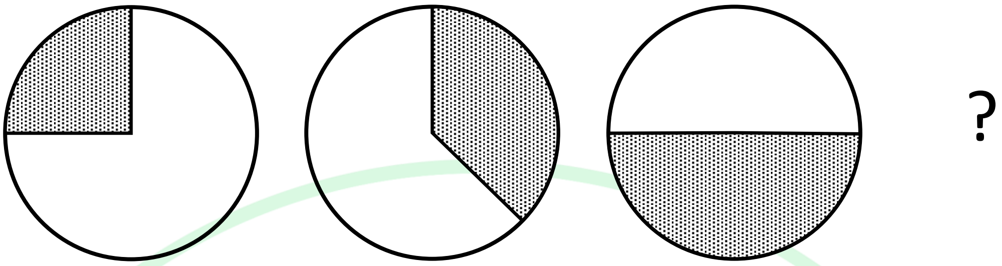
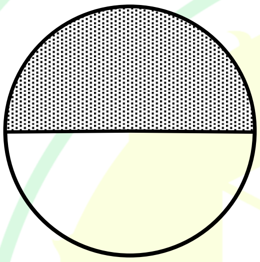
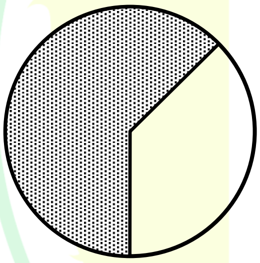
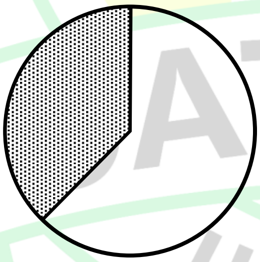
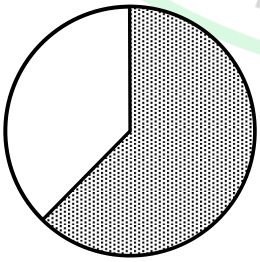
Q.1 – Q.5 Carry ONE mark Each

Q.1	Is there any good show _______ television tonight? Select the most appropriate option to complete the above sentence.
(A)	in
(B)	at
(C)	within
(D)	on

Q.2	As the police officer was found guilty of embezzlement, he was _______ dismissed from the service in accordance with the Service Rules. Select the most appropriate option to complete the above sentence.
(A)	sumptuously
(B)	brazenly
(C)	unintentionally
(D)	summarily

Q.3	The sum of the following infinite series is:
	$$\frac{1}{1!}+\frac{1}{2!}+\frac{1}{3!}+\frac{1}{4!}+\frac{1}{5!}+\cdots$$
(A)	π
(B)	$1+e$
(C)	$e-1$
(D)	e

Q.4	A thin wire is used to construct all the edges of a cube of 1 m side by bending, cutting and soldering the wire. If the wire is 12 m long, what is the minimum number of cuts required to construct the wire frame to form the cube?
(A)	3
(B)	4
(C)	6
(D)	12

Q.5	The figures I, II and III are parts of a sequence. Which one of the following options comes next in the sequence at IV?
	 I II III IV
(A)	
(B)	
(C)	
(D)	

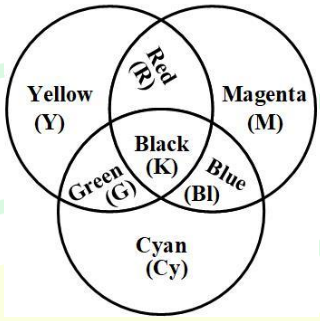
Q.6 – Q.10 Carry TWO marks Each

Q.6	"Why do they pull down and do away with crooked streets, I wonder, which are my delight, and hurt no man living? Every day the wealthier nations are pulling down one or another in their capitals and their great towns: they do not know why they do it; neither do I. It ought to be enough, surely, to drive the great broad ways which commerce needs and which are the life-channels of a modern city, without destroying all history and all the humanity in between: the islands of the past." (From Hilaire Belloc's "The Crooked Streets") Based only on the information provided in the above passage, which one of the following statements is true?
(A)	The author of the passage takes delight in wondering.
(B)	The wealthier nations are pulling down the crooked streets in their capitals.
(C)	In the past, crooked streets were only built on islands.
(D)	Great broad ways are needed to protect commerce and history.

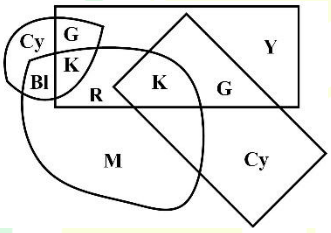
Q.7	Rohit goes to a restaurant for lunch at about 1 PM. When he enters the restaurant, he notices that the hour and minute hands on the wall clock are exactly coinciding. After about an hour, when he leaves the restaurant, he notices that the clock hands are again exactly coinciding. How much time (in minutes) did Rohit spend at the restaurant?
(A)	$64\frac{6}{11}$
(B)	$66\frac{5}{13}$
(C)	$65\frac{5}{11}$
(D)	$66\frac{6}{13}$

Q.8 A color model is shown in the figure with color codes: Yellow (Y), Magenta (M), Cyan (Cy), Red (R), Blue (Bl), Green (G), and Black (K).

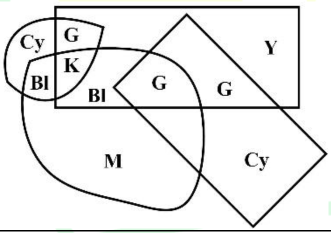
Which one of the following options displays the color codes that are consistent with the color model?



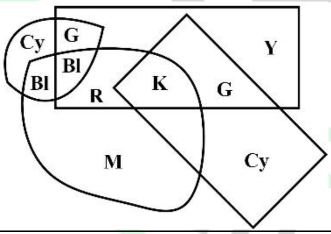
(A)



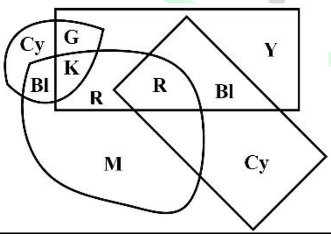
(B)



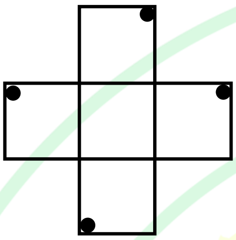
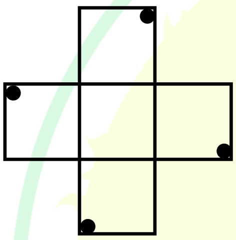
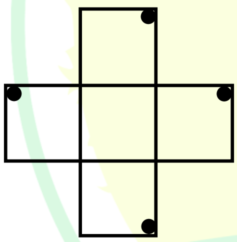
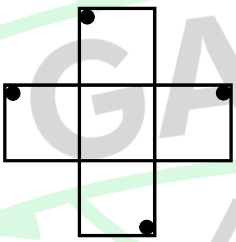
(C)



(D)



Q.9	A circle with center at $(x, y) = (0.5,\ 0)$ and radius = 0.5 intersects with another circle with center at $(x, y) = (1, 1)$ and radius = 1 at two points. One of the points of intersection (x, y) is:
(A)	$(0, 0)$
(B)	$(0.2, 0.4)$
(C)	$(0.5, 0.5)$
(D)	$(1, 2)$

Q.10	An object is said to have an n-fold rotational symmetry if the object, rotated by an angle of $\frac{2\pi}{n}$, is identical to the original. Which one of the following objects exhibits 4-fold rotational symmetry about an axis perpendicular to the plane of the screen? Note: The figures shown are representative.
(A)	
(B)	
(C)	
(D)	

Q.11 – Q.35 Carry ONE mark Each

Q.11	To manufacture paper from __(i)__, the __(ii)__ must be freed from the binding matrix of __(iii)__ in the pulping step. Which one of the following is the CORRECT option to fill in the gaps (i), (ii) and (iii)?
(A)	(i) wood, (ii) cellulose fibers, (iii) lignin
(B)	(i) lignin, (ii) cellulose fibers, (iii) wood
(C)	(i) lignin, (ii) wood, (iii) cellulose fibers
(D)	(i) wood, (ii) lignin, (iii) cellulose fibers
Q.12	Consider a Cartesian coordinate system defined over a 3-dimensional vector space with orthogonal unit basis vectors $\hat{\imath}, \hat{\jmath}$ and $\hat{k}$. Let vector $\boldsymbol{a} = \sqrt{2}\hat{\imath} + \frac{1}{\sqrt{2}}\hat{\jmath} + \hat{k}$, and vector $\boldsymbol{b} = \frac{1}{\sqrt{2}}\hat{\imath} + \sqrt{2}\hat{\jmath} - \hat{k}$. The inner product of these vectors $(\boldsymbol{a} \cdot \boldsymbol{b})$ is
(A)	0
(B)	1
(C)	-1
(D)	2

Q.13	Consider two complex numbers $z_1 = 1 - i$ and $z_2 = i$. The argument of $z_1 z_2$ is
(A)	0
(B)	$\frac{\pi}{4}$
(C)	$\frac{\pi}{2}$
(D)	π
Q.14	A box contains 3 identical green balls and 7 identical blue balls. Two balls are randomly drawn without replacement from the box. The probability of drawing 1 green and 1 blue ball is
(A)	$\frac{{}^{3}P_1 \times {}^{7}P_1}{{}^{10}P_2}$
(B)	$\frac{{}^{10}P_3 \times {}^{10}P_7}{{}^{10}P_2}$
(C)	$\frac{{}^{10}C_3 \times {}^{10}C_7}{{}^{10}C_2}$
(D)	$\frac{{}^{3}C_1 \times {}^{7}C_1}{{}^{10}C_2}$

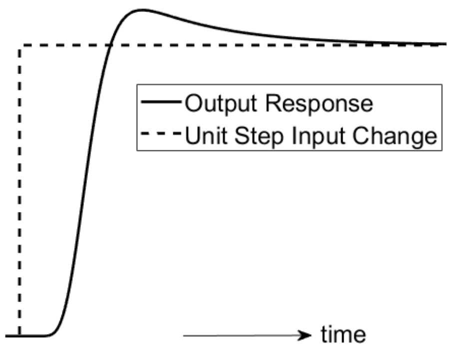
Q.15	The number of independent intensive variables that need to be specified to determine the thermodynamic state of a ternary mixture at vapor-liquid-liquid equilibrium is
(A)	0
(B)	1
(C)	2
(D)	3
Q.16	The boundary of a system does not allow exchange of either mass or energy (in the form of heat and/or work) with the surroundings. The system is termed
(A)	Isolated
(B)	Open
(C)	Adiabatic
(D)	Closed

Q.17	In industrial heat exchanger design, the overall heat transfer coefficient U is estimated from the equation $$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o}$$ where h_i and h_o are the convective heat transfer coefficients on the inner and outer side of the tube, respectively. This is valid for ___(i)___ tube of ___(ii)___ thermal conductivity. Which one of the following is the CORRECT option to fill in the gaps (i) and (ii)?
(A)	(i) thick-walled, (ii) high
(B)	(i) thin-walled, (ii) high
(C)	(i) thin-walled, (ii) low
(D)	(i) thick-walled, (ii) low
Q.18	The sum of the components of the force due to pressure and shear at the solid-fluid boundary of a solid body in the direction normal to the flow is
(A)	Drag
(B)	Friction
(C)	Lift
(D)	Buoyancy

Q.19	Choose the CORRECT option for pathlines, streaklines and streamlines for a STEADY flow field.
(A)	All three lines are identical
(B)	Only pathlines and streaklines are identical
(C)	Only pathlines and streamlines are identical
(D)	Only streamlines and streaklines are identical
Q.20	Choose the CORRECT ordering of the diameter d of the different types of pores in a solid catalyst.
(A)	$d_{\text{Micro-pore}} < d_{\text{Macro-pore}} < d_{\text{Meso-pore}}$
(B)	$d_{\text{Macro-pore}} < d_{\text{Meso-pore}} < d_{\text{Micro-pore}}$
(C)	$d_{\text{Meso-pore}} < d_{\text{Micro-pore}} < d_{\text{Macro-pore}}$
(D)	$d_{\text{Micro-pore}} < d_{\text{Meso-pore}} < d_{\text{Macro-pore}}$

Q.21	Schmidt number is defined as
(A)	$\dfrac{\text{Mass Diffusivity}}{\text{Thermal Diffusivity}}$
(B)	$\dfrac{\text{Momentum Diffusivity}}{\text{Mass Diffusivity}}$
(C)	$\dfrac{\text{Momentum Diffusivity}}{\text{Thermal Diffusivity}}$
(D)	$\dfrac{\text{Thermal Diffusivity}}{\text{Mass Diffusivity}}$
Q.22	If k is the mass transfer coefficient and D_v is the molecular diffusivity, which one of the following statements is NOT CORRECT with respect to mass transfer theories?
(A)	For Film theory, $k \propto D_v$
(B)	For Penetration theory, $k \propto D_v^{1/3}$
(C)	For Surface Renewal theory, $k \propto D_v^{1/2}$
(D)	For Boundary Layer theory, $k \propto D_v^{2/3}$

Q.23	Choose the CORRECT statement that describes the dependence of the variance (σ_Θ^2) of the residence time distribution (RTD) with respect to the number of tanks (n) in the Tanks-in-Series model of non-ideal reactors.
(A)	σ_Θ^2 monotonically increases with n
(B)	σ_Θ^2 first increases and then decreases with n
(C)	σ_Θ^2 first decreases and then increases with n
(D)	σ_Θ^2 monotonically decreases with n
Q.24	The vortex shedding meter is primarily used for measuring
(A)	Fluid Flow Rate
(B)	Liquid Level
(C)	Fluid Temperature
(D)	Fluid Pressure

Q.25	Choose the transfer function that best fits the output response to a unit step input change shown in the figure 
(A)	$\dfrac{(\alpha s+1)e^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)^2}$
(B)	$\dfrac{(\alpha s+1)e^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)}$
(C)	$\dfrac{(\alpha s+1)}{(\tau_1 s+1)(\tau_2 s+1)^2}$
(D)	$\dfrac{(\alpha s+1)^2 e^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)^2}$

Q.26	The capital cost (CC) of an industrial equipment varies with its capacity (S) as $CC \propto S^{\beta}$. The rule-of-thumb value of the exponent β is
(A)	0.4
(B)	0.6
(C)	0.8
(D)	1.0
Q.27	In the production of polyvinyl chloride (PVC) from ethylene and chlorine, the sequential order of reactions is
(A)	Chlorination followed by Dehydrochlorination
(B)	Dehydrochlorination followed by Chlorination
(C)	Hydrogenation followed by Chlorination
(D)	Dehydrochlorination followed by Hydrogenation

Q.28	In the CONTACT PROCESS for manufacturing sulphuric acid, the reaction converting SO_2 to SO_3 is
(A)	Exothermic and reversible
(B)	Endothermic and reversible
(C)	Exothermic and irreversible
(D)	Endothermic and irreversible

Q.29	Choose the option that correctly matches the items in Group 1 with those in Group 2.

Group 1		Group 2	
(P)	Coking	(I)	Prolonged exposure of catalyst to high temperature
(Q)	Poisoning	(II)	Deposition of carbonaceous material on catalyst surface
(R)	Sintering	(III)	Irreversible chemisorption of molecules on active sites of catalyst

(A)	(P) – (III), (Q) – (I), (R) – (II)
(B)	(P) – (II), (Q) – (III), (R) – (I)
(C)	(P) – (II), (Q) – (I), (R) – (III)
(D)	(P) – (I), (Q) – (III), (R) – (II)

Q.30	Which of the following statements regarding multiple effect evaporators is/are TRUE?
(A)	The pressure of the effect with fresh steam is the lowest for both forward feed and backward feed.
(B)	Backward feed is preferred over forward feed for cold feed.
(C)	Backward feed is preferred over forward feed for highly viscous concentrated product.
(D)	The temperature of the effect with fresh steam is the lowest for both forward feed and backward feed.
Q.31	Consider an enzymatic reaction that follows Michaelis-Menten kinetics. Let K_M, S, and V_{max} denote the Michaelis constant, substrate concentration, and maximum reaction rate, respectively. Which of the following statements is/are TRUE?
(A)	For $S \ll K_M$, the reaction is apparent first-order in S.
(B)	For $S \gg K_M$, the reaction rate is nearly independent of S.
(C)	For $S = K_M$, the rate of reaction equals V_{max}.
(D)	K_M is independent of the total enzyme concentration.

Q.32 The following data is given for a ternary ABC gas mixture at 12 MPa and 308 K:

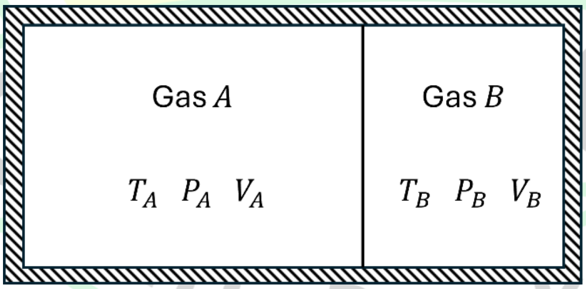
Component i →	A	B	C
y_i	0.55	0.20	0.25
$\hat{\phi}_i$	0.75	0.80	0.95

y_i: mole fraction of component i in the gas mixture

$\hat{\phi}_i$: fugacity coefficient of component i in the gas mixture at 12 MPa and 308 K

The fugacity of the gas mixture is _____ MPa (*rounded off to 3 decimal places*).

Q.33 Ideal nonreacting gases A and B are contained inside a perfectly insulated chamber, separated by a thin partition, as shown in the figure. The partition is removed, and the two gases mix till final equilibrium is reached. The change in total entropy for the process is ____ J/K (*rounded off to 1 decimal place*).



$T_A = T_B = 273$ K

$P_A = P_B = 1$ atm

$V_B = 22.4$ L

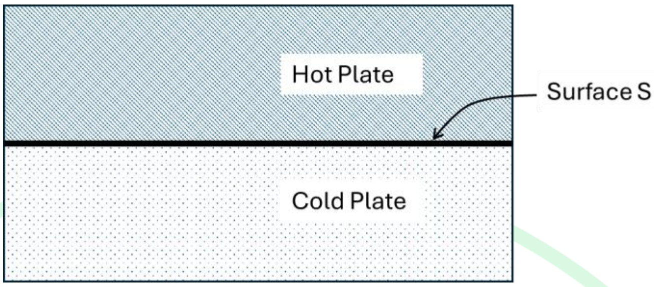
$V_A = 3V_B$

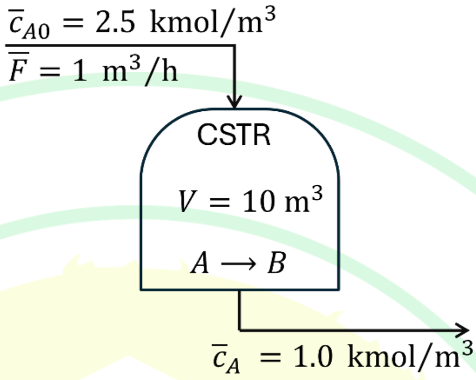
GIVEN: Universal gas constant $R = 8.314$ J/(mol K)

Q.34	Oil is extracted from mustard seeds having 20 wt% oil and 80 wt% solids, using hexane as a solvent. After extraction, the hexane-free residual cake contains 1 wt% oil. Assuming negligible dissolution of cake in hexane, the percentage oil recovery in hexane is ____% (*rounded off to the nearest integer*).
Q.35	The residence-time distribution (RTD) function of a reactor (in min^{-1}) is $$E(t) = \begin{cases} 1 - 2t\,, & t \leq 0.5 \text{ min} \\ 0, & t > 0.5 \text{ min} \end{cases}$$ The mean residence time of the reactor is ____ min (*rounded off to 2 decimal places*).

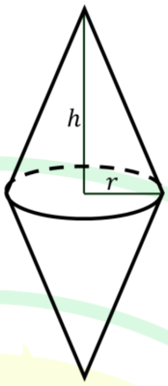
Q.36 – Q.65 Carry TWO marks Each

Q.36	Consider a Cartesian coordinate system with orthogonal unit basis vectors $\hat{\imath}, \hat{\jmath}$ defined over a domain: $x, y \in [0,1]$. Choose the condition for which the divergence of the vector field $\boldsymbol{v} = ax\hat{\imath} - by\hat{\jmath}$ is zero.
(A)	$a - b = 0$
(B)	$a < b$
(C)	$a > b$
(D)	$a + b = 0$
Q.37	A probability distribution function is given as $$p(x) = \begin{cases} \frac{1}{a}, & x \in (0, a) \\ 0, & \text{otherwise} \end{cases}$$ where a is a positive constant. For a function $f(x) = x^2$, the expectation of $f(x)$ is
(A)	$\frac{a^2}{3}$
(B)	$\frac{a^3}{3}$
(C)	$\frac{2a^2}{3}$
(D)	$\frac{2a^3}{3}$

Q.38	A hot plate is placed in contact with a cold plate of a different thermal conductivity as shown in the figure. The initial temperature (at time $t = 0$) of the hot plate and cold plate are T_h and T_c, respectively. Assume perfect contact between the plates.  Which one of the following is an appropriate boundary condition at the surface S for solving the unsteady state, one-dimensional heat conduction equations for the hot plate and cold plate for $t > 0$?
(A)	Temperature at S is same for both the plates
(B)	Gradient of temperature at S is same for both the plates
(C)	Gradient of temperature vanishes at S
(D)	Temperature at S is the average of T_h and T_c

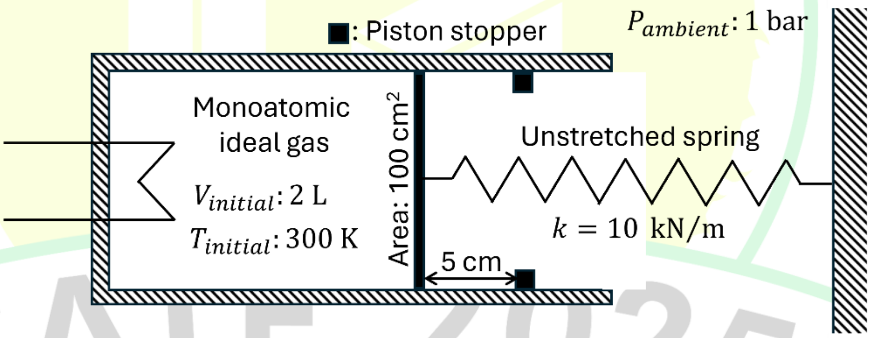
Q.39	The first-order irreversible liquid phase reaction $A \longrightarrow B$ occurs inside a constant volume (V) isothermal CSTR with the initial steady state conditions shown in the figure. The gain, in $\frac{\mathrm{kmol/m^3}}{\mathrm{m^3/h}}$, of the transfer function relating the reactor effluent A concentration, c_A, to the inlet flow rate, F, is 
(A)	1.2
(B)	0.4
(C)	0.6
(D)	0.8

Q.40	500 mg of a dry adsorbent is added to a beaker containing 100 mL solution of concentration 100 mg phenol/(L solution). The adsorbent is separated out after 5 h of rigorous mixing. If the residual concentration in the solution after separating the adsorbent is 30 mg phenol/(L solution), the amount of phenol adsorbed (in mg per gram of dry adsorbent) is
(A)	7
(B)	14
(C)	28
(D)	18

Q.41	A catalyst particle is modeled as a symmetrical double cone solid as shown in the figure. For each conical sub-part, the radius of the base is r and the height is h. The sphericity of the particle is given by 
(A)	$\dfrac{2\left(\dfrac{r^2h}{2}\right)^{1/3}}{r\sqrt{(r^2+h^2)}}$
(B)	$\dfrac{\left(\dfrac{r^2h}{2}\right)^{1/3}}{r\sqrt{(r^2+h^2)}}$
(C)	$\dfrac{2\left(\dfrac{r^2h}{2}\right)^{2/3}}{r\sqrt{(r^2+h^2)}}$
(D)	$\dfrac{\left(\dfrac{r^2h}{2}\right)^{2/3}}{r\sqrt{(r^2+h^2)}}$

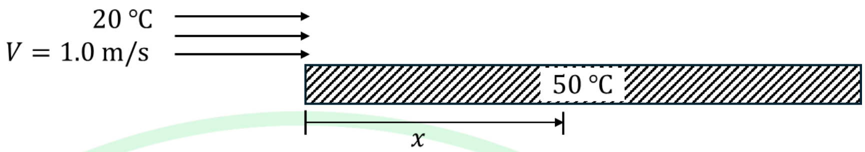
Q.42	A zero-order gas phase reaction $A \rightarrow B$ with rate $(-r_A) = k = 100$ mol/(L min) is carried out in a mixed flow reactor of volume 1 L. Pure A is fed to the reactor at a rate of 1 mol/min. At time $t = 0$, the outlet flow is stopped while the inlet flow rate and reactor temperature remain unchanged. Assume that the reactor was operating under steady state before the flow was stopped ($t < 0$). The rate of consumption of A, $-dC_A/dt$, in mol/(L min), at $t = 1$ min is
(A)	63.2
(B)	36.8
(C)	90.6
(D)	99.0
Q.43	For a steady state, fully developed laminar flow of a Newtonian fluid through a cylindrical pipe at a constant volumetric flow rate, which of the following statements regarding the pressure drop across the pipe (ΔP) is/are TRUE?
(A)	ΔP increases with fluid viscosity
(B)	ΔP increases with pipe length
(C)	ΔP increases with pipe diameter
(D)	ΔP remains unchanged with fluid viscosity

Q.44	Consider the differential equation $$\frac{dy}{dx} + \frac{y}{x} = 0$$ Choose the CORRECT option(s) for the solution y.
(A)	$y = x + c$; c is a constant
(B)	$y = \frac{c}{x}$; c is a constant
(C)	$y = -x + c$; c is a constant
(D)	$y = 0$
Q.45	Consider the matrix $$\boldsymbol{A} = \begin{bmatrix} 2 & 3 \\ 1 & 2 \end{bmatrix}$$ The eigenvalues of the matrix are 0.27 and ____ (*rounded off to 2 decimal places*).
Q.46	The Newton-Raphson method is used to find the root of $$f(x) \equiv x^2 - x - 1 = 0$$ Starting with an initial guess $x_{(0)} = 1$, the second iterate $x_{(2)}$ is ____ (*rounded off to 2 decimal places*).

Q.47	Consider moist air with absolute humidity of 0.02 (kg moisture)/(kg dry air) at 1 bar pressure. The vapour pressure of water is given by the equation $$\ln P^{sat} = 12 - \frac{4000}{T - 40}$$ where P^{sat} is in bar and T is in K. The molecular weight of water and dry air are 18 kg/kmol and 29 kg/kmol, respectively. The dew temperature of the moist air is _____ °C (*rounded off to the nearest integer*).
Q.48	An ideal monoatomic gas is contained inside a cylinder-piston assembly connected to a Hookean spring as shown in the figure. The piston is frictionless and massless. The spring constant is 10 kN/m. At the initial equilibrium state (shown in the figure), the spring is unstretched. The gas is expanded reversibly by adding 362.5 J of heat. At the final equilibrium state, the piston presses against the stoppers. Neglecting the heat loss to the surroundings, the final equilibrium temperature of the gas is ____ K (*rounded off to the nearest integer*).  GIVEN: For a monoatomic ideal gas, $C_v = \frac{3}{2}R$, where $R = 8.314$ J/(mol K)

Q.49	A leaf filter is operated at 1 atm (gauge). The volume of filtrate collected (V in m^3) is related with the volumetric flow rate of the filtrate (q in m^3/s) as: $$\frac{1}{q} = \frac{1}{dV/dt} = 50\,V + 100$$ The volumetric flow rate of the filtrate at 1 hour is ____ $\times 10^{-3}$ m^3/s (*rounded off to 2 decimal places*).
Q.50	An adiabatic pump of efficiency 40% is used to increase the water pressure from 200 kPa to 600 kPa. The flow rate of water is 600 L/min. The specific heat of water is 4.2 kJ/(kg °C). Assuming water is incompressible with a density of 1000 kg/m^3, the maximum temperature rise of water across the pump is ____°C (*rounded off to 3 decimal places*).
Q.51	Water flowing at 70 kg/min is heated from 25 °C to 65 °C in a counter-flow double pipe heat exchanger using hot oil. The oil enters at 110 °C and exits at 65 °C. If the overall heat transfer coefficient is 300 W/(m^2 K), the heat exchanger area is ____ m^2 (*rounded off to 1 decimal place*). GIVEN: Specific heat of water and oil are 4.2 kJ/(kg °C) and 2 kJ/(kg °C), respectively.

Q.52 Consider laminar flow of water over a wide flat plate maintained at a uniform temperature of 50 °C as shown in the figure. The freestream velocity and temperature of water are 1.0 m/s (parallel to the plate) and 20 °C, respectively. The distance x from the leading edge, at which the thermal boundary layer thickness δ_T = 0.01 m, is ____ m (*rounded off to 1 decimal place*).



GIVEN: kinematic viscosity: $\nu = 1.0 \times 10^{-6}$ m^2/s

Prandtl number: $Pr = 7.01$

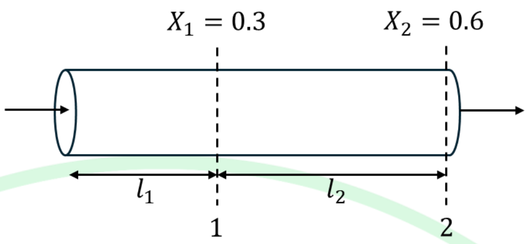
velocity boundary layer thickness: $\delta_H = \dfrac{4.91x}{\sqrt{\dfrac{Vx}{\nu}}}$

Q.53 An electrical wire of 2 mm diameter and 5 m length is insulated with a plastic layer of thickness 2 mm and thermal conductivity k = 0.1 W/(m K). It is exposed to ambient air at 30 °C. For a current of 5 A, the potential drop across the wire is 2 V. The air-side heat transfer coefficient is 20 W/(m^2 K). Neglecting the thermal resistance of the wire, the steady state temperature at the wire-insulation interface is ____°C (*rounded off to 1 decimal place*).

Q.54 A binary AB liquid mixture containing 30 mol% A is subjected to differential (Rayleigh) distillation at atmospheric pressure in order to recover 60 mol% A in the distillate. Assuming a constant relative volatility α_{AB} = 2.2, the average composition of the collected distillate is ____ mol% A (*rounded off to nearest integer*).

Q.55	Gas containing 0.8 mol% component A is to be scrubbed with pure water in a packed bed column to reduce the concentration of A to 0.1 mol% in the exit gas. The inlet gas and water flow rates are 0.1 kmol/s and 3.0 kmol/s, respectively. For the dilute system, both the operating and equilibrium curves are considered linear. If the slope of the equilibrium line is 24, the number of transfer units, based on the gas side, N_{OG} is ____ (*rounded off to 1 decimal place*).
Q.56	Solute A is absorbed from a gas into water in a packed bed operating at steady state. The absorber operating pressure and temperature are 1 atm and 300 K, respectively. At the gas-liquid interface $$y_i = 1.5\, x_i$$ where y_i and x_i are the interfacial gas and liquid mole fractions of A, respectively. At a particular location in the absorber, the mole fractions of A in the bulk gas and in the bulk water are 0.02 and 0.002, respectively. If the ratio of the local individual mass transfer coefficients for the transport of A on the gas-side (k_y) to that on the water-side (k_x), $\frac{k_y}{k_x} = 2$, then y_i equals ____ (*rounded off to 3 decimal places*).
Q.57	Components A and B form an azeotrope. The saturation vapour pressures of A and B at the boiling temperature of the azeotrope are 87 kPa and 72.7 kPa, respectively. The azeotrope composition is ____ mol% A (*rounded off to the nearest integer*). GIVEN: $$\ln \frac{\gamma_A}{\gamma_B} = 0.9(x_B^2 - x_A^2)$$ where x_i and γ_i are the liquid phase mole fraction and activity coefficient of component i, respectively.

Q.58 The reaction $A \rightarrow products$ with reaction rate, $(-r_A) = kC_A^3$, occurs in an isothermal PFR operating at steady state. The conversion (X) at two axial locations (1 and 2) of the PFR is shown in the figure.



The value of l_1/l_2 is _____ (*rounded off to 2 decimal places*).

Q.59 The catalytic gas phase reaction $A \rightarrow products$ is carried out in an isothermal batch reactor of 10 L volume using 0.1 kg of a solid catalyst. The reaction is first-order with

$$(-r_A) = k'a(t)C_A$$

where

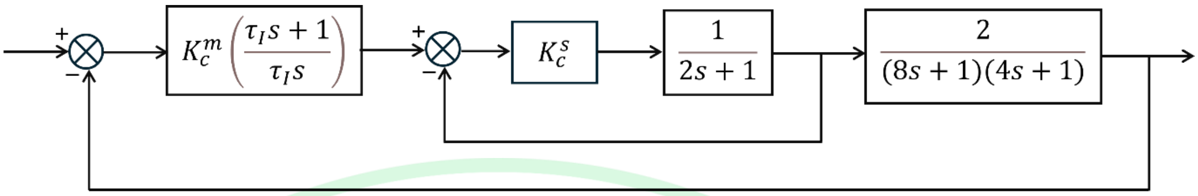
$$k' = 1\ \frac{\mathrm{L}}{(\mathrm{kg\ catalyst})(\mathrm{h})}$$

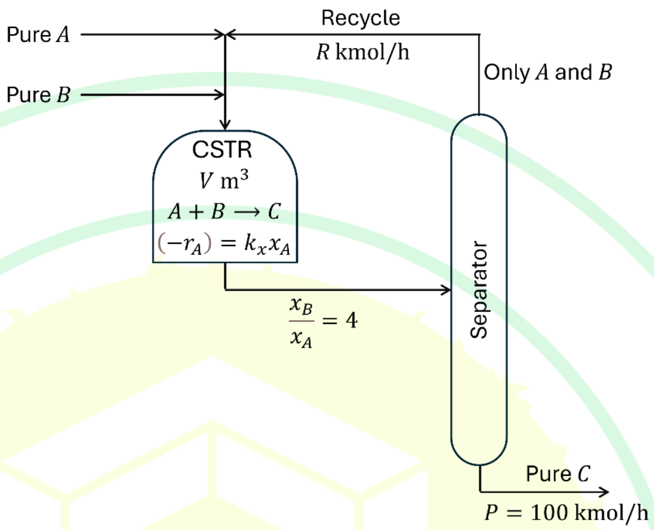
and C_A is the concentration of A in mol/L.

The catalyst activity $a(t)$ undergoes first-order decay with rate constant k_d= 0.01 per hour and $a(0) = 1$.

The reactant conversion after 1 day of operation is _____ (*rounded off to 2 decimal places*).

Q.60	Consider a process with transfer function $$G_p = \frac{2e^{-s}}{(5s+1)^2}$$ A first-order plus dead time (FOPDT) model is to be fitted to the unit step process reaction curve (PRC) by applying the maximum slope method. Let τ_m and θ_m denote the time constant and dead time, respectively, of the fitted FOPDT model. The value of $\frac{\tau_m}{\theta_m}$ is _____ (*rounded off to 2 decimal places*). GIVEN: For $$G = \frac{1}{(\tau s+1)^2}$$ the unit step output response: $$y_{(t)} = 1 - \left(1 + \frac{t}{\tau}\right) e^{-t/\tau}$$ $$\frac{dy_{(t)}}{dt} = \frac{t}{\tau^2} e^{-t/\tau}$$ $$\frac{d^2y_{(t)}}{dt^2} = \frac{1}{\tau^2}\left(1 - \frac{t}{\tau}\right) e^{-t/\tau}$$
Q.61	Methanol is produced by the reversible, gas-phase hydrogenation of carbon monoxide as $$CO + 2H_2 \leftrightarrow CH_3OH$$ CO and H_2 are charged to a reactor and the reaction proceeds to equilibrium at 453 K and 2 atm. The reaction equilibrium constant, which depends only on the temperature, is 1.68 at the reaction conditions. The mole fraction of H_2 in the product is 0.4. Assuming ideal gas behaviour, the mole fraction of methanol in the product is _____ (*rounded off to 2 decimal places*).

Q.62	The block diagram of a series cascade control system (with time in minutes) is shown in the figure. For $\tau_I = 8$ min and $K_c^s = 1$, the maximum value of K_c^m, below which the cascade control system is stable, is _____ (*rounded off to the nearest integer*). 
Q.63	It is proposed to install thermal insulation in a residence to save on the summer-monsoon season air-conditioning costs. The estimated yearly saving is 20 thousand rupees. The cost of installation of the insulation is 150 thousand rupees. The life of the insulation is 12 years. For a compound interest rate of 9% per annum, the minimum salvage value of the insulation for which the proposal is competitive, is _____ thousand rupees (*rounded off to nearest integer*).

Q.64	Consider the flowsheet in the figure for manufacturing C via the reaction $A + B \longrightarrow C$ in an isothermal CSTR. The split in the separator is perfect so that the recycle stream is free of C and the product stream is pure C. Let x_i denote the mole fraction of species i ($i = A, B, C$) in the CSTR, which is operated in excess B with $x_B/x_A = 4$. The reaction is first-order in A with the reaction rate $(-r_A) = k_x\, x_A$, where $k_x = 5.0$ kmol/(m^3 h).  The reactor volume V in m^3 is to be optimized to minimize the cost objective $J = V + 0.25R$, where R is the recycle rate in kmol/h. For a product rate $P = 100$ kmol/h, the optimum value of V is _____ m^3 (*rounded off to the nearest integer*). GIVEN: $\frac{d}{dz}\left(\frac{z}{1-z}\right) = \frac{1}{(1-z)^2}$
Q.65	A wet solid of 100 kg containing 30 wt% moisture is to be dried to 2 wt% moisture in a tray dryer. The critical moisture content is 10 wt% and the equilibrium moisture content is 1 wt%. The drying rate during the constant rate period is 10 kg/(h m^2). The drying curve in the falling rate period is linear. If the drying area is 5 m^2, the time required for drying is _____ h (*rounded off to 1 decimal place*). *Note: All the moisture values given are on dry-solid basis.*