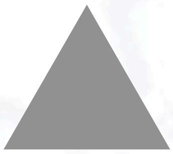
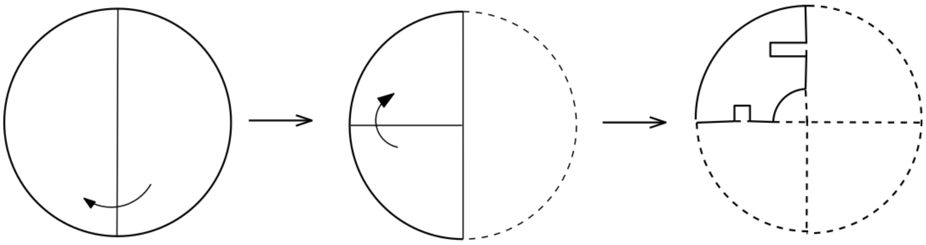
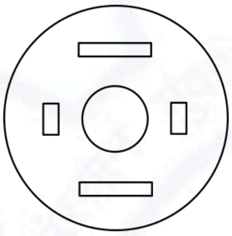
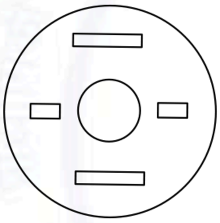
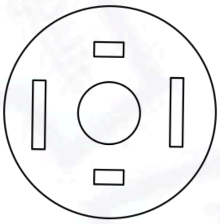
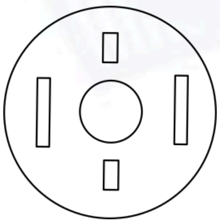
General Aptitude (GA)

Q.1 – Q.5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**The ratio of boys to girls in a class is 7 to 3.** **Among the options below, an acceptable value for the total number of students in the class is:**
(A)	21
(B)	37
(C)	50
(D)	73

Q.2	**A polygon is convex if, for every pair of points, P and Q belonging to the polygon, the line segment PQ lies completely inside or on the polygon.** **Which one of the following is <u>NOT</u> a convex polygon?**
(A)	
(B)	
(C)	
(D)	

Q.3	**Consider the following sentences:** **(i) Everybody in the class is prepared for the exam.** **(ii) Babu invited Danish to his home because he enjoys playing chess.** **Which of the following is the CORRECT observation about the above two sentences?**
(A)	(i) is grammatically correct and (ii) is unambiguous
(B)	(i) is grammatically incorrect and (ii) is unambiguous
(C)	(i) is grammatically correct and (ii) is ambiguous
(D)	(i) is grammatically incorrect and (ii) is ambiguous

Q.4	 **A circular sheet of paper is folded along the lines in the directions shown. The paper, after being punched in the final folded state as shown and unfolded in the reverse order of folding, will look like _______.**
(A)	
(B)	
(C)	
(D)	

Q.5	**_____ is to *surgery* as *writer* is to ________** **Which one of the following options maintains a similar logical relation in the above sentence?**
(A)	Plan, outline
(B)	Hospital, library
(C)	Doctor, book
(D)	Medicine, grammar

Q. 6 – Q. 10 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q.6	**We have 2 rectangular sheets of paper, M and N, of dimensions 6 cm x 1 cm each. Sheet M is rolled to form an open cylinder by bringing the short edges of the sheet together. Sheet N is cut into equal square patches and assembled to form the largest possible closed cube. Assuming the ends of the cylinder are closed, the ratio of the volume of the cylinder to that of the cube is __________**
(A)	$\frac{\pi}{2}$
(B)	$\frac{3}{\pi}$
(C)	$\frac{9}{\pi}$
(D)	3π

Q.7

Items	Cost (₹)	Profit %	Marked Price (₹)
P	5,400	---	5,860
Q	---	25	10,000

Details of prices of two items P and Q are presented in the above table. The ratio of cost of item P to cost of item Q is 3:4. Discount is calculated as the difference between the marked price and the selling price. The profit percentage is calculated as the ratio of the difference between selling price and cost, to the cost

($\text{Profit}\,\% = \frac{\text{Selling price} - \text{Cost}}{\text{Cost}} \times 100$).

The discount on item Q, as a percentage of its marked price, is ______

(A) 25

(B) 12.5

(C) 10

(D) 5

Q.8

There are five bags each containing identical sets of ten distinct chocolates. One chocolate is picked from each bag.

The probability that at least two chocolates are identical is ___________

(A) 0.3024

(B) 0.4235

(C) 0.6976

(D) 0.8125

Q.9	**Given below are two statements 1 and 2, and two conclusions I and II.** **Statement 1: All bacteria are microorganisms.** **Statement 2: All pathogens are microorganisms.** **Conclusion I: Some pathogens are bacteria.** **Conclusion II: All pathogens are not bacteria.** **Based on the above statements and conclusions, which one of the following options is logically CORRECT?**
(A)	Only conclusion I is correct
(B)	Only conclusion II is correct
(C)	Either conclusion I or II is correct.
(D)	Neither conclusion I nor II is correct.

Q.10	**Some people suggest anti-obesity measures (AOM) such as displaying calorie information in restaurant menus. Such measures sidestep addressing the core problems that cause obesity: poverty and income inequality.** **Which one of the following statements summarizes the passage?**
(A)	The proposed AOM addresses the core problems that cause obesity.
(B)	If obesity reduces, poverty will naturally reduce, since obesity causes poverty.
(C)	AOM are addressing the core problems and are likely to succeed.
(D)	AOM are addressing the problem superficially.

Chemical Engineering (CH)

Q.1 – Q.15 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**An ordinary differential equation (ODE), $\frac{dy}{dx} = 2y$, with an initial condition $y(0) = 1$, has the analytical solution $y = e^{2x}$.** **Using Runge-Kutta second order method, numerically integrate the ODE to calculate y at $x = 0.5$ using a step size of $h = 0.5$.** **If the relative percentage error is defined as,** $$\varepsilon = \left| \frac{y_{analytical} - y_{numerical}}{y_{analytical}} \right| \times 100$$ **then the value of ε at $x = 0.5$ is __________.**
(A)	0.06
(B)	0.8
(C)	4.0
(D)	8.0

Q.2	**The function $\cos(x)$ is approximated using Taylor series around $x = 0$ as $\cos(x) \approx 1 + a\,x + b\,x^2 + c\,x^3 + d\,x^4$. The values of a, b, c and d are**
(A)	$a = 1, \quad b = -0.5, \quad c = -1, \quad d = -0.25$
(B)	$a = 0, \quad b = -0.5, \quad c = 0, \quad d = 0.042$
(C)	$a = 0, \quad b = 0.5, \quad c = 0, \quad d = 0.042$
(D)	$a = -0.5, \quad b = 0, \quad c = 0.042, \quad d = 0$

Q.3	**The heat of combustion of methane, carbon monoxide and hydrogen are *P*, *Q* and *R* respectively. For the reaction below,** $$CH_4 + H_2O \longrightarrow CO + 3H_2$$ **the heat of reaction is given by**
(A)	$P - Q - 3R$
(B)	$Q + 3R - P$
(C)	$P - Q - R$
(D)	$Q + R - P$

Q.4	**A batch settling experiment is performed in a long column using a dilute dispersion containing equal number of particles of type A and type B in water (density 1000 kg m^{-3}) at room temperature.** **Type A are spherical particles of diameter 30 µm and density 1100 kg m^{-3}.** **Type B are spherical particles of diameter 10 µm and density 1900 kg m^{-3}.** **Assuming that Stokes' law is valid throughout the duration of the experiment, the settled bed would**
(A)	consist of a homogeneous mixture of type A and type B particles
(B)	consist of type B particles only
(C)	be completely segregated with type B particles on top of type A particles
(D)	be completely segregated with type A particles on top of type B particles

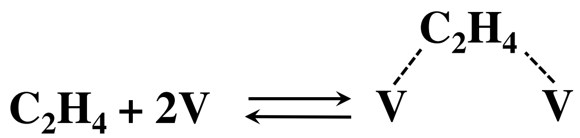
Q.5	**A three-dimensional velocity field is given by $V = 5x^2y\, i + Cy\, j - 10xyz\, k$, where i, j, k are the unit vectors in x, y, z directions, respectively, describing a cartesian coordinate system. The coefficient C is a constant. If V describes an incompressible fluid flow, the value of C is**
(A)	–1
(B)	0
(C)	1
(D)	5

Q.6	**Heat transfer coefficient for a vapor condensing as a film on a vertical surface is given by**
(A)	Dittus-Boelter equation
(B)	Nusselt theory
(C)	Chilton-Colburn analogy
(D)	Sieder-Tate equation

Q.7	**In a double-pipe heat exchanger of 10 m length, a hot fluid flows in the annulus and a cold fluid flows in the inner pipe. The temperature profiles of the hot (T_h) and cold (T_c) fluids along the length of the heat exchanger (x, such that $x \geq 0$), are given by** $$T_h(x) = 80 - 3x$$ $$T_c(x) = 20 + 2x$$ **where T_h and T_c are in °C, and x is in meter.** **The logarithmic mean temperature difference (in °C) is**
(A)	24.6
(B)	27.9
(C)	30.0
(D)	50.0

Q.8	**For a shell-and-tube heat exchanger, the clean overall heat transfer coefficient is calculated as 250 W m^{-2} K^{-1} for a specific process condition. It is expected that the heat exchanger may be fouled during the operation, and a fouling resistance of 0.001 m^2 K W^{-1} is prescribed. The dirt overall heat transfer coefficient is _____ W m^{-2} K^{-1}.**
(A)	100
(B)	150
(C)	200
(D)	250

Q.9	**In reverse osmosis, the hydraulic pressure and osmotic pressure at the feed side of the membrane are P_1 and π_1, respectively. The corresponding values are P_2 and π_2 at the permeate side. The membrane, feed, and permeate are at the same temperature. For equilibrium to prevail, the general criterion that should be satisfied is**
(A)	$\pi_1 = \pi_2$
(B)	$P_1 = P_2$
(C)	$P_1 + \pi_1 = P_2 + \pi_2$
(D)	$P_1 - \pi_1 = P_2 - \pi_2$

Q.10	Ethylene adsorbs on the vacant active sites V of a transition metal catalyst according to the following mechanism.  If N_T, N_V and $N_{C_2H_4}$ denote the total number of active sites, number of vacant active sites and number of adsorbed C_2H_4 molecules, respectively, the balance on the total number of active sites is given by
(A)	$N_T = N_V + N_{C_2H_4}$
(B)	$N_T = N_V + 2N_{C_2H_4}$
(C)	$N_T = 2N_V + N_{C_2H_4}$
(D)	$N_T = N_V + 0.5N_{C_2H_4}$

Q.11	Which of the following is NOT a standard to transmit measurement and control signals?
(A)	4 – 20 mA
(B)	3 – 15 psig
(C)	0 – 100 %
(D)	1 – 5 VDC

Q.12	**A feedforward controller can be used only if**
(A)	the disturbance variable can be measured
(B)	the disturbance variable can be manipulated
(C)	the disturbance variable can be ignored
(D)	regulatory control is not required

Q.13	**Turnover ratio is defined as**
(A)	$\frac{\text{Fixed capital investment}}{\text{Gross annual sales}}$
(B)	$\frac{\text{Gross annual sales}}{\text{Fixed capital investment}}$
(C)	$\frac{\text{Fixed capital investment}}{\text{Average selling price of the product}}$
(D)	$\frac{\text{Gross annual sales}}{\text{Average selling price of the product}}$

Q.14	**A principal amount is charged a nominal annual interest rate of 10%. If the interest rate is compounded continuously, the final amount at the end of one year would be**
(A)	higher than the amount obtained when the interest rate is compounded monthly
(B)	lower than the amount obtained when the interest rate is compounded annually
(C)	equal to 1.365 times the principal amount
(D)	equal to the amount obtained when using an effective interest rate of 27.18%

Q.15	**Match the common name of chemicals in Group – 1 with their chemical formulae in Group – 2.**

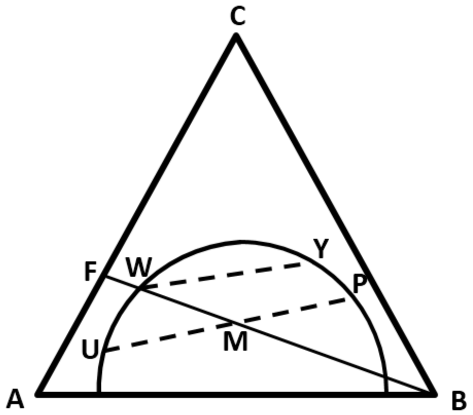
Group – 1		Group – 2	
P	Gypsum	I	$Ca(H_2PO_4)_2$
Q	Dolomite	II	$CaSO_4.2H_2O$
R	Triple superphosphate	III	$CaCO_3.MgCO_3$

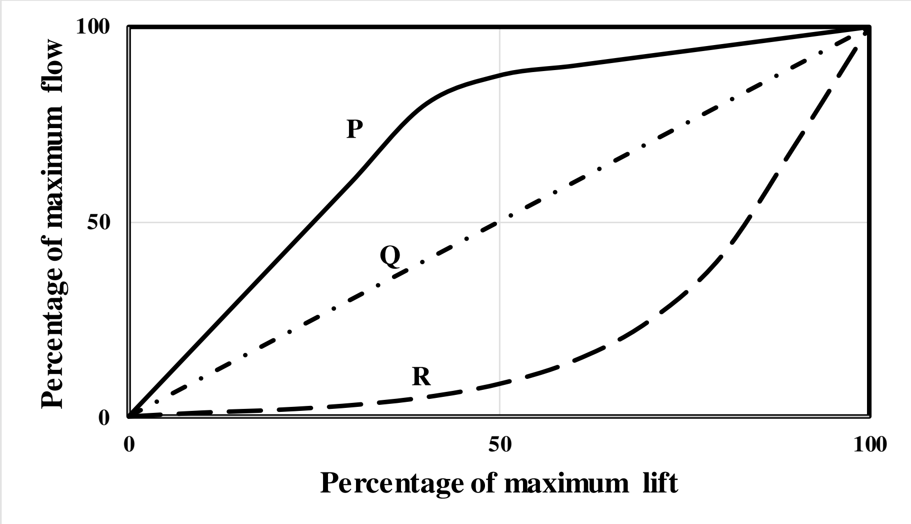
The correct combination is:

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

Q.16 – Q.18 Multiple Select Question (MSQ), carry ONE mark each (no negative marks).

Q.16	**For the function** $f(x) = \begin{cases} -x, & x < 0 \\ x^2, & x \geq 0 \end{cases}$ **the CORRECT statement(s) is/are**
(A)	$f(x)$ is continuous at $x = 1$
(B)	$f(x)$ is differentiable at $x = 1$
(C)	$f(x)$ is continuous at $x = 0$
(D)	$f(x)$ is differentiable at $x = 0$

Q.17	Feed solution **F** is contacted with solvent **B** in an extraction process. Carrier liquid in the feed is **A** and the solute is **C**. The ternary diagram depicting a single ideal stage extraction is given below. The dashed lines represent the tie-lines.  **The CORRECT option(s) is/are**
(A)	For the tie-lines shown, concentration of solute in the extract is higher than that in the raffinate
(B)	Maximum amount of solvent is required if the mixture composition is at W
(C)	Y represents the composition of extract when minimum amount of solvent is used
(D)	U represents the raffinate composition if the mixture composition is at M

Q.18	**The inherent characteristics of three control valves P, Q and R are shown in the figure.**  **The CORRECT option(s) is/are**
(A)	P is a quick opening valve
(B)	Q is a quick opening valve
(C)	P is an equal percentage valve
(D)	R is an equal percentage valve

Q.19 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.19	**A source placed at the origin of a circular sample holder (radius $r = 1\ m$) emits particles uniformly in all directions. A detector of length $l = 1\ cm$ has been placed along the perimeter of the sample holder. During an experiment, the detector registers 14 particles.** **The total number of particles emitted during the experiment is ____________.**

Q.20	$\boldsymbol{A}, \boldsymbol{B}, \boldsymbol{C}$ and $\boldsymbol{D}$ are vectors of length 4. $\boldsymbol{A} = [a_1 \quad a_2 \quad a_3 \quad a_4]$ $\boldsymbol{B} = [b_1 \quad b_2 \quad b_3 \quad b_4]$ $\boldsymbol{C} = [c_1 \quad c_2 \quad c_3 \quad c_4]$ $\boldsymbol{D} = [d_1 \quad d_2 \quad d_3 \quad d_4]$ It is known that $\boldsymbol{B}$ is not a scalar multiple of $\boldsymbol{A}$. Also, $\boldsymbol{C}$ is linearly independent of $\boldsymbol{A}$ and $\boldsymbol{B}$. Further, $\boldsymbol{D} = 3\,\boldsymbol{A} + 2\,\boldsymbol{B} + \boldsymbol{C}$. The rank of the matrix $\begin{bmatrix} a_1 & a_2 & a_3 & a_4 \\ b_1 & b_2 & b_3 & b_4 \\ c_1 & c_2 & c_3 & c_4 \\ d_1 & d_2 & d_3 & d_4 \end{bmatrix}$ is ______________.

Q.21	**The van der Waals equation of state is given by** $$\boldsymbol{P_r = \frac{8T_r}{3v_r - 1} - \frac{3}{v_r^2}}$$ **where P_r, T_r and v_r represent reduced pressure, reduced temperature and reduced molar volume, respectively. The compressibility factor at critical point (z_c) is $3/8$.** **If $v_r = 3$ and $T_r = 4/3$, then the compressibility factor based on the van der Waals equation of state is ______________ (round off to 2 decimal places).**

Q.22 Consider a steady flow of an incompressible, Newtonian fluid through a smooth circular pipe. Let $\alpha_{laminar}$ and $\alpha_{turbulent}$ denote the kinetic energy correction factors for laminar and turbulent flow through the pipe, respectively. For turbulent flow through the pipe

$$\alpha_{turbulent} = \left(\frac{V_0}{\bar{V}}\right)^3 \frac{2n^2}{(3+n)(3+2n)}$$

Here, $\bar{V}$ is the average velocity, V_0 is the centerline velocity, and n is a parameter. The ratio of average velocity to the centerline velocity for turbulent flow through the pipe is given by

$$\frac{\bar{V}}{V_0} = \frac{2n^2}{(n+1)(2n+1)}$$

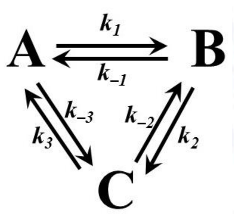
For $n = 7$, the value of $\frac{\alpha_{turbulent}}{\alpha_{laminar}}$ is ___________ (round off to 2 decimal places).

Q.23 The molar heat capacity at constant pressure C_p (in J mol^{-1} K^{-1}) for n-pentane as a function of temperature (T in K) is given by

$\frac{C_p}{R} = 2.46 + 45.4\times10^{-3}T - 14.1\times10^{-6}T^2$. Take R = 8.314 J mol^{-1} K^{-1}.

At 1000 K, the rate of change of molar entropy of n-pentane with respect to temperature at constant pressure is ___________ J mol^{-1} K^{-2} (round off to 2 decimal places).

Q.24 The following homogeneous liquid phase reactions are at equilibrium.



The values of rate constants are given by: $k_1 = 0.1$ s^{-1}, $k_{-1} = 0.2$ s^{-1}, $k_2 = 1$ s^{-1}, $k_{-2} = 10$ s^{-1}, $k_3 = 10$ s^{-1}.

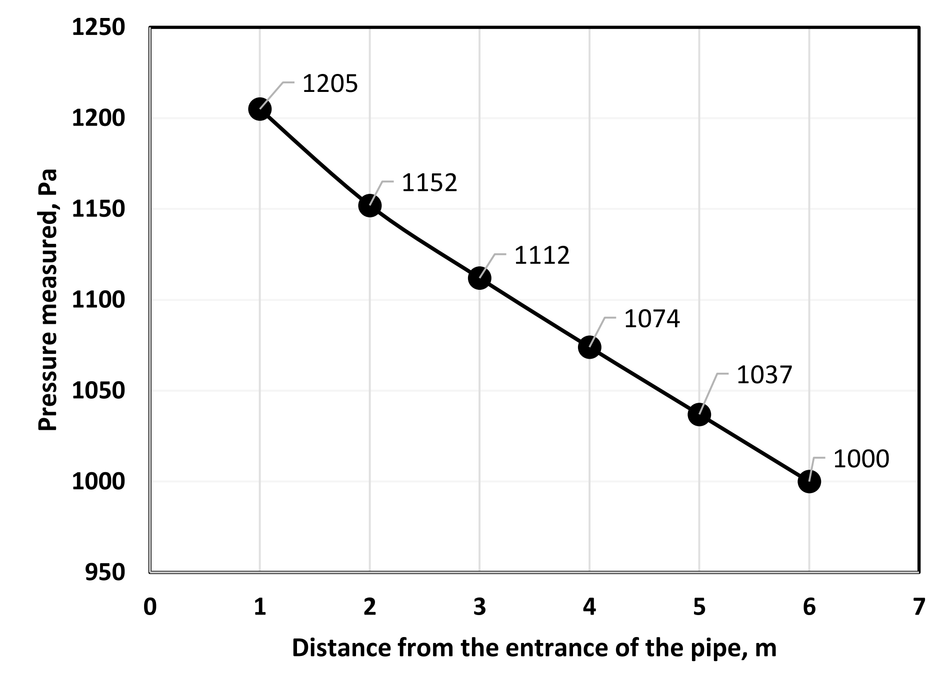
The value of rate constant k_{-3} is ______________ s^{-1} (round off to 1 decimal place).

Q.25	**A company invests in a recovery unit to separate valuable metals from effluent streams. The total initial capital investment of this unit is Rs. 10 lakhs. The recovered metals are worth Rs. 4 lakhs per year.** **If the annual return on this investment is 15%, the annual operating costs should be ________________ lakhs of rupees (correct to 1 decimal place).**

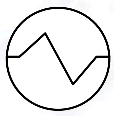
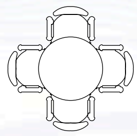
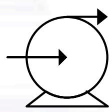
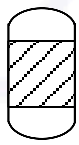
Q.26 – Q.33 Multiple Choice Question (MCQ), carry TWO mark each (for each wrong answer: – 2/3).

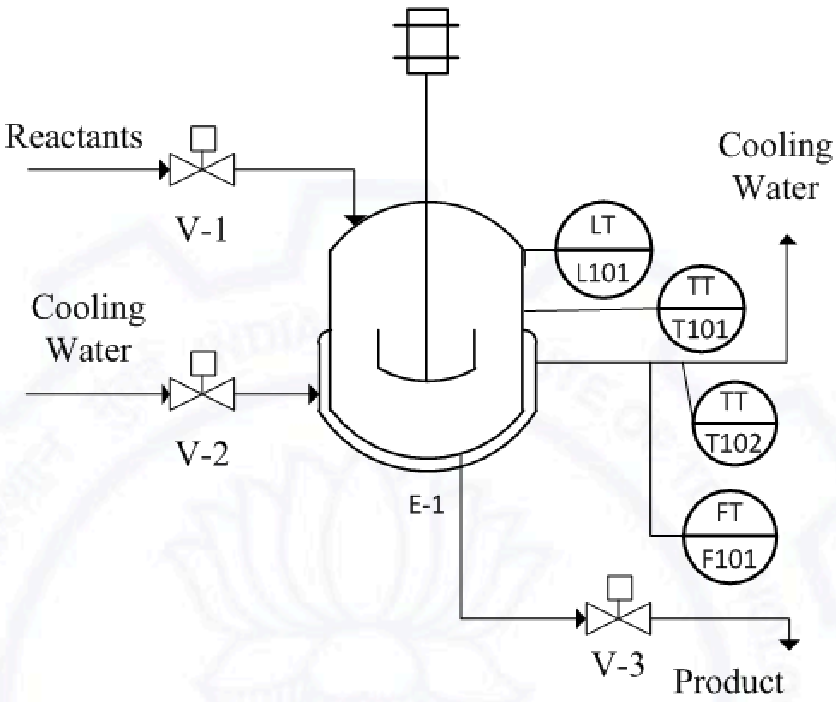
Q.26	**Let A be a square matrix of size $n \times n$ $(n > 1)$. The elements of $A = \{a_{ij}\}$ are given by** $$a_{ij} = \begin{cases} i \times j, & if\ i \geq j \\ 0, & if\ i < j \end{cases}$$ **The determinant of A is**
(A)	0
(B)	1
(C)	$n!$
(D)	$(n!)^2$

Q.27	**Consider a fluid confined between two horizontal parallel plates and subjected to shear flow.** **In the first experiment, the plates are separated by a distance of 1 mm. It is found that a shear stress of 2 N m^{-2} has to be applied to keep the top plate moving with a velocity of 2 m s^{-1}, while the other plate is fixed.** **In the second experiment, the plates are separated by a distance of 0.25 mm. It is found that a shear stress of 3 N m^{-2} has to be applied to keep the top plate moving with a velocity of 1 m s^{-1}, while the other plate is fixed.** **In the range of shear rates studied, the rheological character of the fluid is**
(A)	Newtonian
(B)	Pseudoplastic
(C)	Dilatant
(D)	Ideal and inviscid

Q.28	Water of density 1000 kg m^{-3} flows in a horizontal pipe of 10 cm diameter at an average velocity of 0.5 m s^{-1}. The following plot shows the pressure measured at various distances from the pipe entrance.  Using the data shown in the figure, the Fanning friction factor in the pipe when the flow is FULLY DEVELOPED is
(A)	0.0012
(B)	0.0074
(C)	0.0082
(D)	0.0106

Q.29	**In a solvent regeneration process, a gas is used to strip a solute from a liquid in a countercurrent packed tower operating under isothermal condition. Pure gas is used in this stripping operation. All solutions are dilute and Henry's law, $y^* = mx$, is applicable. Here, y^* is the mole fraction of the solute in the gas phase in equilibrium with the liquid phase of solute mole fraction x, and m is the Henry's law constant.** **Let x_1 be the mole fraction of the solute in the leaving liquid, and x_2 be the mole fraction of solute in the entering liquid.** **When the value of the ratio of the liquid-to-gas molar flow rates is equal to m, the overall liquid phase Number of Transfer Units, NTU_{OL}, is given by**
(A)	$\dfrac{x_2 - x_1}{x_1}$
(B)	$\dfrac{x_2 + x_1}{x_2 - x_1}$
(C)	$ln\left(\dfrac{x_2}{x_1}\right)$
(D)	$ln\left(\dfrac{x_2 + x_1}{x_2 - x_1}\right)$

Q.30	**Which of these symbols can be found in piping and instrumentation diagrams?**  (P)  (Q)  (R)  (S)
(A)	(Q) and (S) only
(B)	(P), (Q) and (R) only
(C)	(P), (R) and (S) only
(D)	(P), (Q), (R) and (S)

Q.31	**It is required to control the volume of the contents in the jacketed reactor shown in the figure.**  **Which one of the following schemes can be used for feedback control?**
(A)	Measure L101 and manipulate valve V-2
(B)	Measure T101 and manipulate valve V-1
(C)	Measure L101 and manipulate valve V-3
(D)	Measure F101 and manipulate valve V-1

Q.32	**Which of the following is NOT a necessary condition for a process under closed-loop control to be stable?**
(A)	Dead-time term(s) must be absent in the open-loop transfer function
(B)	Roots of the characteristic equation must have negative real part
(C)	All the elements in the left (first) column of the Routh array must have the same sign
(D)	Open-loop transfer function must have an amplitude ratio less than 1 at the critical frequency

Q.33	**Match the reaction in Group – 1 with the reaction type in Group – 2.**

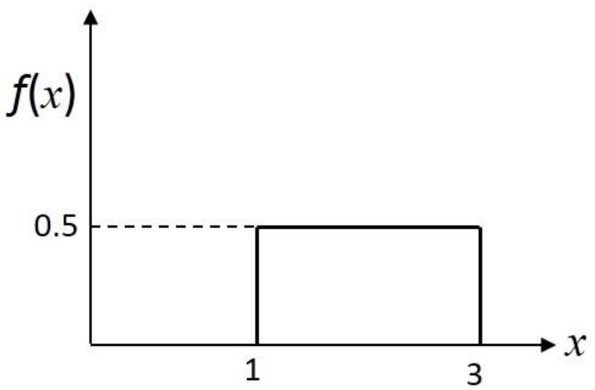
	Group – 1		**Group – 2**
P	Methylcyclohexane → Toluene + $3H_2$	I	Dehydrocyclization
Q	Ethylcyclopentane → Methylcyclohexane	II	Cracking
R	n-Octane → Ethylbenzene + $4H_2$	III	Dehydrogenation
S	n-Octane → n-Pentane + Propylene	IV	Isomerization

The correct combination is:

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

Q.34 – Q.55 Numerical Answer Type (NAT), carry TWO mark each (no negative marks).

Q.34	**To solve an algebraic equation** $f(x)=0$**, an iterative scheme of the type** $x_{n+1} = g(x_n)$ **is proposed, where** $g(x) = x - \frac{f(x)}{f'(x)}$. **At the solution** $x = s$, $g'(s) = 0$ **and** $g''(s) \neq 0$. **The order of convergence for this iterative scheme near the solution is** ________________.

Q.35	**The probability distribution function of a random variable** X **is shown in the following figure.**  **From this distribution, random samples with sample size** n **= 68 are taken. If** $\overline{X}$ **is the sample mean, the standard deviation of the probability distribution of** $\overline{X}$**, i.e.** $\sigma_{\overline{X}}$ **is** ____________ **(round off to 3 decimal places).**

Q.36	**For the ordinary differential equation** $\frac{d^3y}{dt^3} + 6\frac{d^2y}{dt^2} + 11\frac{dy}{dt} + 6y = 1$ **with initial conditions** $y(0) = y'(0) = y''(0) = y'''(0) = 0$**, the value of** $\lim_{t\to\infty} y(t) =$ _______________ **(round off to 3 decimal places).**

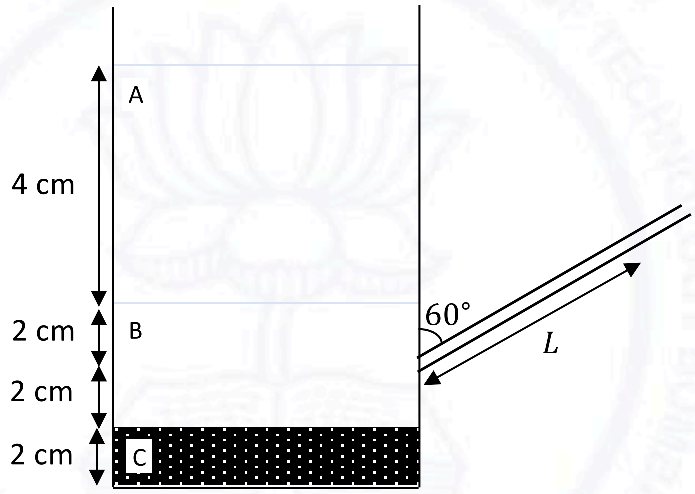
Q.37	Formaldehyde is produced by the oxidation of methane in a reactor. The following two parallel reactions occur. $$CH_4 + O_2 \longrightarrow HCHO + H_2O$$ $$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$ Methane and oxygen are fed to the reactor. The product gases leaving the reactor include methane, oxygen, formaldehyde, carbon dioxide and water vapor. 60 mol s^{-1} of methane enters the reactor. The molar flowrate (in mol s^{-1}) of CH_4, O_2 and CO_2 leaving the reactor are 26, 2 and 4, respectively. The molar flowrate of oxygen entering the reactor is ______________ mol s^{-1}.

Q.38	The combustion of carbon monoxide is carried out in a closed, rigid and insulated vessel. 1 mol of CO, 0.5 mol of O_2 and 2 mol of N_2 are taken initially at 1 bar and 298 K, and the combustion is carried out to completion. The standard molar internal energy change of reaction (Δu_R^o) for the combustion of carbon monoxide at 298 K = –282 kJ mol^{-1}. At constant pressure, the molar heat capacities of N_2 and CO_2 are 33.314 J mol^{-1} K^{-1} and 58.314 J mol^{-1} K^{-1}, respectively. Assume the heat capacities to be independent of temperature, and the gases are ideal. Take R = 8.314 J mol^{-1} K^{-1}. The final pressure in the vessel at the completion of the reaction is _______ bar (round off to 1 decimal place).

Q.39	A gaseous mixture at 1 bar and 300 K consists of 20 mol % CO_2 and 80 mol% inert gas. Assume the gases to be ideal. Take R = 8.314 J mol^{-1} K^{-1}. The magnitude of minimum work required to separate 100 mol of this mixture at 1 bar and 300 K into pure CO_2 and inert gas at the same temperature and pressure is _________________ kJ (round off to nearest integer).

Q.40	**A binary liquid mixture consists of two species 1 and 2. Let γ and x represent the activity coefficient and the mole fraction of the species, respectively. Using a molar excess Gibbs free energy model, $\ln\gamma_1$ vs. x_1 and $\ln\gamma_2$ vs. x_1 are plotted. A tangent drawn to the $\ln\gamma_1$ vs. x_1 curve at a mole fraction of $x_1 = 0.2$ has a slope $= -1.728$.** **The slope of the tangent drawn to the $\ln\gamma_2$ vs. x_1 curve at the same mole fraction is ____________________ (correct to 3 decimal places).**

Q.41 Consider a tank filled with 3 immiscible liquids A, B and C at static equilibrium, as shown in the figure. At 2 cm below the liquid A – liquid B interface, a tube is connected from the side of the tank. Both the tank and the tube are open to the atmosphere.



At the operating temperature and pressure, the specific gravities of liquids A, B and C are 1, 2 and 4, respectively. Neglect any surface tension effects in the calculations. The length of the tube L that is wetted by liquid B is ____________________ cm.

Q.42 Seawater is passed through a column containing a bed of resin beads.

Density of seawater = 1025 kg m^{-3}

Density of resin beads = 1330 kg m^{-3}

Diameter of resin beads = 50 μm

Void fraction of the bed at the onset of fluidization = 0.4

Acceleration due to gravity = 9.81 m s^{-2}

The pressure drop per unit length of the bed at the onset of fluidization is ________________ Pa m^{-1} (round off to nearest integer).

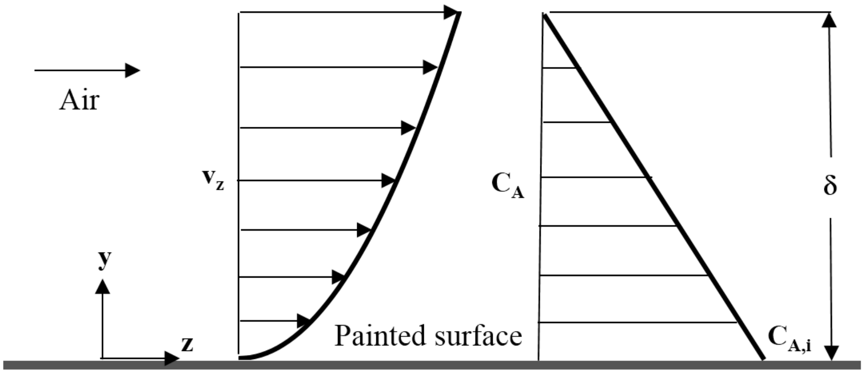
Q.43	**A straight fin of uniform circular cross section and adiabatic tip has an aspect ratio (length/diameter) of 4. If the Biot number (based on radius of the fin as the characteristic length) is 0.04, the fin efficiency is _______________ % (round off to nearest integer).**

Q.44	**A double-effect evaporator is used to concentrate a solution. Steam is sent to the first effect at 110 °C and the boiling point of the solution in the second effect is 63.3 °C. The overall heat transfer coefficient in the first effect and second effect are 2000 W m^{-2} K^{-1} and 1500 W m^{-2} K^{-1}, respectively. The heat required to raise the temperature of the feed to the boiling point can be neglected. The heat flux in the two evaporators can be assumed to be equal.** **The temperature at which the solution boils in the first effect is ________ °C (round off to nearest integer).**

Q.45	**Consider a solid slab of thickness 2L and uniform cross section A. The volumetric rate of heat generation within the slab is $\dot{g}$ (W m^{-3}). The slab loses heat by convection at both the ends to air with heat transfer coefficient h. Assuming steady state, one-dimensional heat transfer, the temperature profile within the slab along the thickness is given by:** $$T(x) = \frac{\dot{g}L^2}{2k}\left[1 - \left(\frac{x}{L}\right)^2\right] + T_s \quad for\ -L \le x \le L$$ **where k is the thermal conductivity of the slab and T_s is the surface temperature. If $T_s = 350$ K, ambient air temperature $T_\infty = 300$ K, and Biot number (based on L as the characteristic length) is 0.5, the maximum temperature in the slab is __________________ K (round off to nearest integer).**

Q.46	**A distillation column handling a binary mixture of A and B is operating at total reflux. It has two ideal stages including the reboiler. The mole fraction of the more volatile component in the residue (x_W) is 0.1. The average relative volatility α_{AB} is 4. The mole fraction of A in the distillate (x_D) is ________________ (round off to 2 decimal places).**

Q.47	**In a batch drying experiment, a solid with a critical moisture content of 0.2 kg H_2O/kg dry solid is dried from an initial moisture content of 0.35 kg H_2O/kg dry solid to a final moisture content of 0.1 kg H_2O/kg dry solid in 5 h. In the constant rate regime, the rate of drying is 2 kg $H_2O/(m^2.h)$.** **The entire falling rate regime is assumed to be uniformly linear. The equilibrium moisture content is assumed to be zero.** **The mass of the dry solid per unit area is ____________ kg/m^2 (round off to nearest integer).**

Q.48	**As shown in the figure below, air flows in parallel to a freshly painted solid surface of width 10 m, along the z-direction.**  **The equilibrium vapor concentration of the volatile component A in the paint, at the air-paint interface, is $C_{A,i}$. The concentration C_A decreases linearly from this value to zero along the y-direction over a distance δ of 0.1 m in the air phase. Over this distance, the average velocity of the air stream is 0.033 m s^{-1} and its velocity profile (in m s^{-1}) is given by** $$v_z(y) = 10y^2$$ **where y is in meter.** **Let $C_{A,m}$ represent the flow averaged concentration. The ratio of $C_{A,m}$ to $C_{A,i}$, is ______________ (round off to 2 decimal places).**

Q.49	**The following isothermal autocatalytic reaction,** $$A + B \longrightarrow 2B \qquad (-r_A) = 0.1 C_A C_B \text{ (mol L}^{-1}\text{ s}^{-1})$$ **is carried out in an ideal continuous stirred tank reactor (CSTR) operating at steady state. Pure A at 1 mol L^{-1} is fed, and 90% of A is converted in the CSTR. The space time of the CSTR is _______________ seconds.**

Q.50	**Reactant A decomposes to products B and C in the presence of an enzyme in a well-stirred batch reactor. The kinetic rate expression is given by** $$-r_A = \frac{0.01 C_A}{0.05 + C_A} \text{ (mol L}^{-1}\text{ min}^{-1})$$ **If the initial concentration of A is 0.02 mol L^{-1}, the time taken to achieve 50% conversion of A is _______________ min (round off to 2 decimal places).**

Q.51	**The following homogeneous, irreversible reaction involving ideal gases,** $$A \longrightarrow B + C \qquad (-r_A) = 0.5 C_A \text{ (mol L}^{-1}\text{ s}^{-1})$$ **is carried out in a steady state ideal plug flow reactor (PFR) operating at isothermal and isobaric conditions. The feed stream consists of pure A, entering at 2 m s^{-1}.** **In order to achieve 50% conversion of A, the required length of the PFR is _________________ meter (round off to 2 decimal places).**

Q.52	**A system has a transfer function** $G(s) = \frac{3e^{-4s}}{12s + 1}$**. When a step change of magnitude M is given to the system input, the final value of the system output is measured to be 120. The value of M is ______________.**

Q.53	**A process has a transfer function** $G(s) = \frac{Y(s)}{X(s)} = \frac{20}{90000s^2 + 240s + 1}$. **Initially the process is at steady state with $x(t=0) = 0.4$ and $y(t=0) = 100$. If a step change in x is given from 0.4 to 0.5, the maximum value of y that will be observed before it reaches the new steady state is ___________ (round off to 1 decimal place).**

Q.54	Operating labor requirements L in the chemical process industry is described in terms of the plant capacity C (kg day^{-1}) over a wide range (10^3 – 10^6) by a power law relationship $$L = \alpha C^{\beta}$$ where α and β are constants. It is known that *L* is 60 when *C* is 2×10^4 *L* is 70 when *C* is 6×10^4 The value of L when C is 10^5 kg day^{-1} is ______________ (round off to nearest integer).

Q.55	A viscous liquid is pumped through a pipe network in a chemical plant. The annual pumping cost per unit length of pipe is given by $$C_{pump} = \frac{48.13\, q^2 \mu}{D^4}$$ The annual cost of the installed piping system per unit length of pipe is given by $$C_{piping} = 45.92D$$ Here, D is the inner diameter of the pipe in meter, q is the volumetric flowrate of the liquid in m^3 s^{-1} and μ is the viscosity of the liquid in Pa.s. If the viscosity of the liquid is 20×10^{-3} Pa.s and the volumetric flow rate of the liquid is 10^{-4} m^3 s^{-1}, the economic inner diameter of the pipe is _________ meter (round off to 3 decimal places).

END OF THE QUESTION PAPER