CH: Chemical Engineering

GA - General Aptitude

Q1 - Q5 carry one mark each.

Q.No. 1 Rajiv Gandhi Khel Ratna Award was conferred_____Mary Kom, a six-time world champion in boxing, recently in a ceremony_____the Rashtrapati Bhawan (the President's official residence) in New Delhi.

(A) with, at
(B) on, in
(C) on, at
(D) to, at

Q.No. 2 Despite a string of poor performances, the chances of K. L. Rahul's selection in the team are_____.

(A) slim
(B) bright
(C) obvious
(D) uncertain

Q.No. 3 Select the word that fits the analogy:

Cover : Uncover :: Associate : _____

____

(A) Unassociate
(B) Inassociate
(C) Misassociate
(D) Dissociate

Q.No. 4 Hit by floods, the kharif (summer sown) crops in various parts of the country have been affected. Officials believe that the loss in production of the kharif crops can be recovered in the output of the rabi (winter sown) crops so that the country can achieve its food-grain production target of 291 million tons in the crop year 2019-20 (July-June). They are hopeful that good rains in July-August will help the soil retain moisture for a longer period, helping winter sown crops such as wheat and pulses during the November-February period.

Which of the following statements can be inferred from the given passage?

(A) Officials declared that the food-grain production target will be met due to good rains.
(B) Officials want the food-grain production target to be met by the November-February period.
(C) Officials feel that the food-grain production target cannot be met due to floods.
(D) Officials hope that the food-grain production target will be met due to a good rabi produce.

Q.No. 5 The difference between the sum of the first $2n$ natural numbers and the sum of the first n odd natural numbers is _____.

(A) $n^2 - n$
(B) $n^2 + n$
(C) $2n^2 - n$
(D) $2n^2 + n$

Q6 - Q10 carry two marks each.

Q.No. 6 Repo rate is the rate at which Reserve Bank of India (RBI) lends commercial banks, and reverse repo rate is the rate at which RBI borrows money from commercial banks.

Which of the following statements can be inferred from the above passage?

(A) Decrease in repo rate will increase cost of borrowing and decrease lending by commercial banks.
(B) Increase in repo rate will decrease cost of borrowing and increase lending by commercial banks.
(C)

Increase in repo rate will decrease cost of borrowing and decrease lending by commercial banks.

(D) Decrease in repo rate will decrease cost of borrowing and increase lending by commercial banks.

Q.No. 7 P, Q, R, S, T, U, V, and W are seated around a circular table.

I. S is seated opposite to W.
II. U is seated at the second place to the right of R.
III. T is seated at the third place to the left of R.
IV. V is a neighbour of S.

Which of the following must be true?

(A) P is a neighbour of R.
(B) Q is a neighbour of R.
(C) P is not seated opposite to Q.
(D) R is the left neighbour of S.

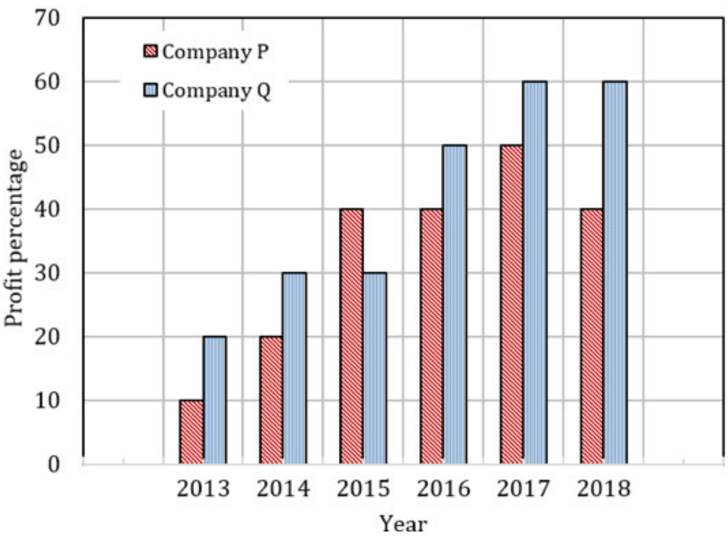
Q.No. 8 The distance between Delhi and Agra is 233 km. A car P started travelling from Delhi to Agra and another car Q started from Agra to Delhi along the same road 1 hour after the car P started. The two cars crossed each other 75 minutes after the car Q started. Both cars were travelling at constant speed. The speed of car P was 10 km/hr more than the speed of car Q. How many kilometers the car Q had travelled when the cars crossed each other?

(A) 66.6
(B) 75.2
(C) 88.2
(D) 116.5

Q.No. 9 For a matrix $M = [m_{ij}]$; $i, j = 1,2,3,4$, the diagonal elements are all zero and $m_{ij} = -m_{ji}$. The minimum number of elements required to fully specify the matrix is_____.

(A) 0
(B) 6
(C) 12
(D) 16

Q.No. 10 The profit shares of two companies P and Q are shown in the figure. If the two companies have invested a fixed and equal amount every year, then the ratio of the total revenue of company P to the total revenue of company Q, during 2013 - 2018 is_____.



(A) 15 : 17
(B) 16 : 17
(C) 17 : 15
(D) 17 : 16

CH: Chemical Engineering

Q1 - Q25 carry one mark each.

Q.No. 1

Which one of the following methods requires specifying an initial interval containing the root (i.e., bracketing) to obtain the solution of $f(x)=0$, where $f(x)$ is a continuous non-linear algebraic function?

(A) Newton-Raphson method

(B) regula falsi method

(C) secant method

(D) fixed point iteration method

Q.No. 2 Consider the hyperbolic functions in **Group – 1** and their definitions in **Group – 2**.

	Group – 1		**Group – 2**
P	$\tanh x$	**I**	$\dfrac{e^x+e^{-x}}{e^x-e^{-x}}$
Q	$\coth x$	**II**	$\dfrac{2}{e^x+e^{-x}}$
R	$\operatorname{sech} x$	**III**	$\dfrac{2}{e^x-e^{-x}}$
S	$\operatorname{cosech} x$	**IV**	$\dfrac{e^x-e^{-x}}{e^x+e^{-x}}$

The correct combination is

(A) P – IV, Q – I, R – III, S – II

(B) P – II, Q – III, R – I, S – IV

(C) P – IV, Q – I, R – II, S – III

(D) P – I, Q – II, R – IV, S – III

Q.No. 3 Consider the following continuously differentiable function

$$\mathbf{v}(x,y,z)=3x^2y\,\mathbf{i}+8y^2z\,\mathbf{j}+5xyz\,\mathbf{k}$$

where **i, j**, and **k** represent the respective unit vectors along the x, y, and z directions in the Cartesian coordinate system. The curl of this function is

(A) $-3x^2\,\mathbf{i}-8y^2\,\mathbf{j}+5z(x+y)\,\mathbf{k}$

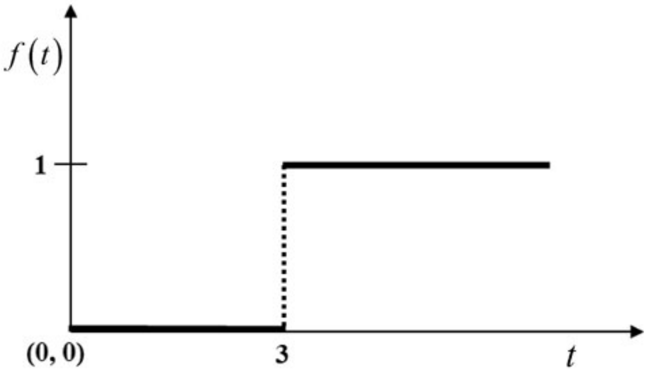
(B) $6xy\,\mathbf{i}-16yz\,\mathbf{j}+5xy\,\mathbf{k}$

(C) $(5xz-8y^2)\,\mathbf{i}-5yz\,\mathbf{j}-3x^2\,\mathbf{k}$

(D) $y(11x+16z)$

Q.No. 4

Consider the following unit step function.



The Laplace transform of this function is

(A) $\frac{e^{-3s}}{s}$

(B) $\frac{e^{-3s}}{s^2}$

(C) $\frac{e^{-3s}}{3s}$

(D) $\frac{e^{-6s}}{s}$

Q.No. 5 In a constant-pressure cake filtration with an incompressible cake layer, volume of the filtrate (V) is measured as a function of time t. The plot of t/V versus V results in a straight line with an intercept of 10^4 s m^{-3}. Area of the filter is 0.05 m^2, viscosity of the filtrate is 10^{-3} Pa s, and the overall pressure drop across the filter is 200 kPa. The value of the filter-medium resistance (in m^{-1}) is

(A) 1×10^9

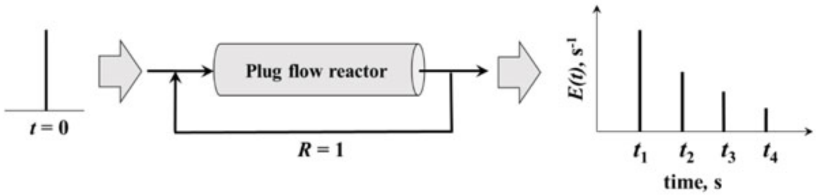
(B) 1×10^{10}

(C) 1×10^{11}

(D) 1×10^{12}

Q.No. 6

In a laboratory experiment, a unit pulse input of tracer is given to an ideal plug flow reactor operating at steady state with a recycle ratio, $R = 1$. The exit age distribution, $E(t)$, of the tracer at the outlet of the reactor is measured. The first four pulses observed at t_1, t_2, t_3, and t_4 are shown below.



In addition, use the following data and assumptions

- R is defined as ratio of the volume of fluid returned to the entrance of the reactor to the volume leaving the system
- No reaction occurs in the reactor
- Ignore any dead volume in the recycle loop

If the space time of the plug flow reactor is τ seconds, which one of the following is correct?

(A) $t_1 = \tau, t_2 = 2\tau, t_3 = 3\tau, t_4 = 4\tau$

(B) $t_1 = \frac{\tau}{2}, t_2 = \tau, t_3 = \frac{3\tau}{2}, t_4 = 2\tau$

(C) $t_1 = \frac{\tau}{2}, t_2 = \frac{\tau}{4}, t_3 = \frac{\tau}{8}, t_4 = \frac{\tau}{16}$

(D) $t_1 = \frac{\tau}{3}, t_2 = \frac{2\tau}{3}, t_3 = \tau, t_4 = \frac{4\tau}{3}$

Q.No. 7 The square of Thiele modulus, M_T, is given by $M_T^2 = \frac{L^2 k}{D_{eff}}$, where L is the characteristic length of the catalyst pellet, k is the rate constant of a first order reaction, and D_{eff} is the effective diffusivity of the species in the pores. M_T^2 is a measure of

(A) $\frac{\text{time scale of pore diffusion}}{\text{time scale of reaction}}$

(B) $\frac{\text{rate of pore diffusion}}{\text{rate of reaction}}$

(C) $\frac{\text{time scale of reaction}}{\text{time scale of pore diffusion}}$

(D) $\frac{\text{rate of reaction}}{\text{rate of external mass transfer}}$

Q.No. 8 Hot-wire anemometer is used for the measurement of

(A) composition

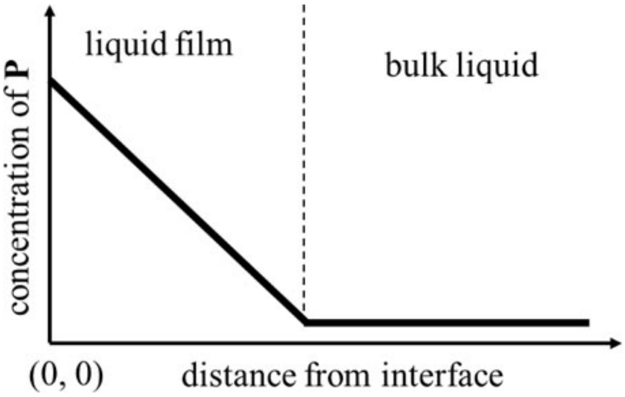
(B) flow

(C) pressure

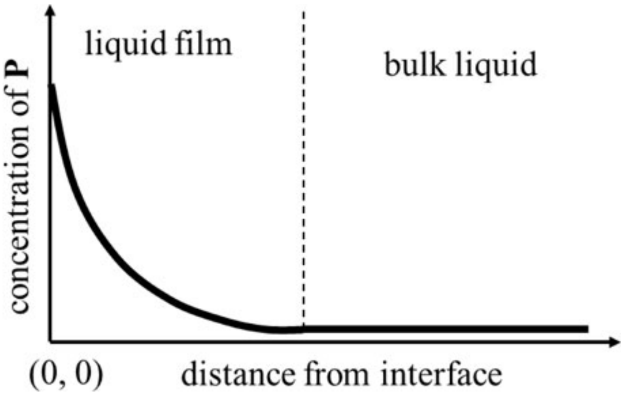
(D) temperature

Q.No. 9 Pure gas **P** is being absorbed into a liquid. The dissolved **P** undergoes an irreversible reaction in the liquid film. The reaction is first order with respect to **P**. Which one of the following represents the concentration profile of **P** in the liquid film at steady state?

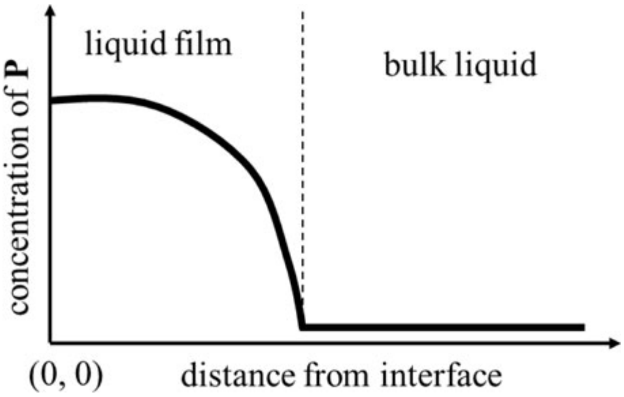
(A)



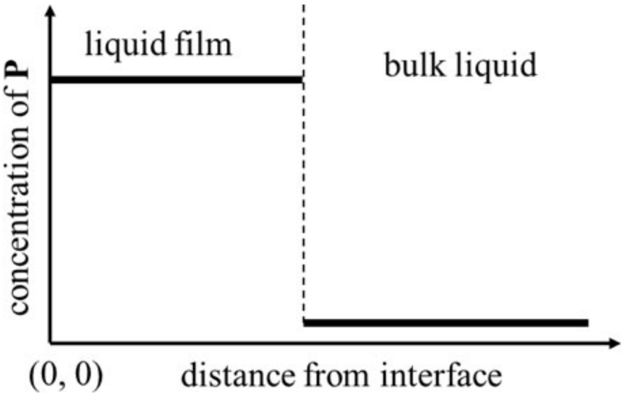
(B)



(C)



(D)



Q.No. 10 Consider a batch distillation process for an equimolar mixture of benzene and toluene at atmospheric pressure. The mole fraction of benzene in the distillate collected after 10 minutes is 0.6. The process is further continued for additional 10 minutes. The mole fraction of benzene in the total distillate collected after 20 minutes of operation is

(A) less than 0.6

(B) exactly equal to 0.6

(C) exactly equal to 0.7

(D) greater than 0.7

Q.No. 11 Which one of the following is **NOT CORRECT**?

(A) nylon-6,6 is produced by condensation polymerization

(B) phenol-formaldehyde resin is a thermosetting polymer
(C) high density polyethylene (HDPE) is produced by condensation polymerization
(D) poly(ethylene terephthalate) (PET) is a polyester

Q.No. 12 The operating temperature range for the Haber process is 350–500 °C. It is used for the production of ammonia at

(A) 20 MPa using Fe catalyst in an exothermic reaction
(B) 0.1 MPa using Fe catalyst in an exothermic reaction
(C) 20 MPa using Fe catalyst in an endothermic reaction
(D) 20 MPa using zeolite catalyst in an endothermic reaction

Q.No. 13 Consider the refinery processes in **Group – 1** and the catalysts in **Group – 2**.

	Group – 1		Group – 2
P	Hydrodesulfurization	**I**	Zeolites
Q	Fluid catalytic cracking (FCC)	**II**	Pt/Al_2O_3
R	Naphtha reforming	**III**	$Co\text{-}Mo/Al_2O_3$

The correct combination is

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

Q.No. 14 Consider the processes in **Group – 1** and the reactions in **Group – 2**.

	Group – 1		Group – 2
P	Solvay process	**I**	$RCOOH + NaOH \rightarrow RCOONa + H_2O$
Q	Oxo process	**II**	$CH_2{=}CH_2 + CO + H_2 \rightarrow CH_3CH_2CHO$
R	Saponification	**III**	$CaCO_3 + 2NaCl \rightarrow Na_2CO_3 + CaCl_2$

The correct combination is

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

Q.No. 15 Annual capacity of a plant producing phenol is 100 metric tons. Phenol sells at INR 200 per kg, and its production cost is INR 50 per kg. The sum of annual fixed charges, overhead costs and general expenses is INR 30,00,000. Taxes are payable at 18% on gross profit. Assuming the plant runs at full capacity and that all the phenol produced is sold, the annual net profit of the plant (in INR) is

(A) 1,39,40,000
(B) 1,50,00,000

(C) 98,40,000

(D) 1,20,00,000

Q.No. 16 A rigid spherical particle undergoes free settling in a liquid of density 750 kg m^{-3} and viscosity 9.81×10^{-3} Pa s. Density of the particle is 3000 kg m^{-3} and the particle diameter is 2×10^{-4} m. Acceleration due to gravity is 9.81 m s^{-2}. Assuming Stokes' law to be valid, the terminal settling velocity (in m s^{-1}) of the particle is

(A) 2×10^{-3}

(B) 3×10^{-3}

(C) 4×10^{-3}

(D) 5×10^{-3}

Q.No. 17 Consider an incompressible flow of a constant property fluid over a smooth, thin and wide flat plate. The free stream flows parallel to the surface of the plate along its length and its velocity is constant. Value of the Reynolds number at a distance of 2.0 m from the leading edge of the plate is 8000. The flow within the boundary layer at a distance of 1.0 m from the leading edge of the plate is

(A) laminar

(B) turbulent

(C) transitioning from laminar to turbulent

(D) inviscid

Q.No. 18 Ratio of momentum diffusivity to thermal diffusivity is

(A) Reynolds number

(B) Prandtl number

(C) Nusselt number

(D) Peclet number

Q.No. 19 Mole fraction and activity coefficient of component 1 in a binary liquid mixture are x_1 and γ_1, respectively. G^E is excess molar Gibbs energy of the mixture, R is universal gas constant and T is absolute temperature of the mixture. Which one of the following is always true?

(A) $$\lim_{x_1 \to 1} \frac{G^E}{RT} = 0$$

(B) $$\lim_{x_1 \to 1} \frac{G^E}{RT} = 0.5$$

(C) $$\lim_{x_1 \to 1} \gamma_1 = 0$$

(D) $$\lim_{x_1 \to 1} \gamma_1 = 0.5$$

Q.No. 20 Leidenfrost phenomenon refers to

(A) the condensation of vapour on a cold surface

(B) the exchange of heat between two solids

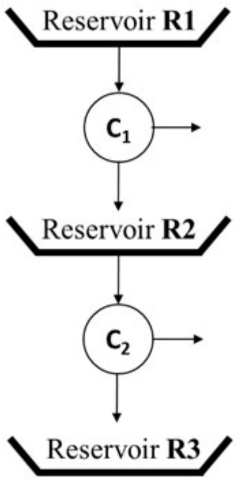
(C) the melting of frost

(D) film boiling and evaporation of liquid droplets falling on a very hot surface

Q.No. 21

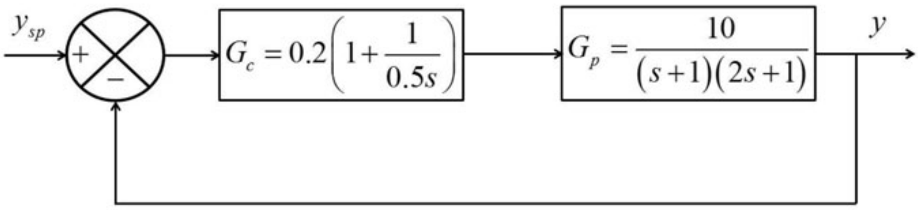
An irreversible gas phase reaction $2\mathbf{P} \longrightarrow 4\mathbf{Q} + \mathbf{R}$ is conducted in an isothermal and isobaric batch reactor. Assume ideal gas behavior. The feed is an equimolar mixture of the reactant **P** and an inert gas. After complete conversion of **P**, the fractional change in volume is __________ (round off to 2 decimal places).

Q.No. 22 Consider two Carnot engines $\mathbf{C_1}$ and $\mathbf{C_2}$ as shown in the figure.



The efficiencies of the engines $\mathbf{C_1}$ and $\mathbf{C_2}$ are 0.40 and 0.35, respectively. If the temperature of Reservoir **R1** is 800 K, then the temperature (in K) of Reservoir **R3** is __________ (round off to nearest integer).

Q.No. 23 Consider the following closed loop system with G_p and G_c as the transfer functions of the process and the controller, respectively.



For a unit step change in the set point (y_{sp}), the change in the value of the response (y) at steady state is __________ (round off to 1 decimal place).

Q.No. 24 The decomposition of acetaldehyde (**X**) to methane and carbon monoxide follows four-step free radical mechanism. The overall rate of decomposition of **X** is

$$-r_X = k_2\left(\frac{k_1}{2k_3}\right)^{1/2} C_X^{3/2} = k_{overall} C_X^{3/2}$$

where, k_1, k_2, and k_3 denote the rate constants of the elementary steps, with corresponding activation energies (in kJ mol^{-1}) of 320, 40, and 0, respectively. The temperature dependency of the rate constants is described by Arrhenius equation. C_X denotes the concentration of acetaldehyde. The rate constant for the overall reaction is $k_{overall}$. The activation energy for the overall reaction (in kJ mol^{-1}) is __________ (round off to nearest integer).

Q.No. 25

Sum of the eigenvalues of the matrix $\begin{bmatrix} 2 & 4 & 6 \\ 3 & 5 & 9 \\ 12 & 1 & 7 \end{bmatrix}$

is __________ (round off to nearest integer).

Q26 - Q55 carry two marks each.

Q.No. 26

In a box, there are 5 green balls and 10 blue balls. A person picks 6 balls randomly. The probability that the person has picked 4 green balls and 2 blue balls is

(A) $\frac{42}{1001}$

(B) $\frac{45}{1001}$

(C) $\frac{240}{1001}$

(D) $\frac{420}{1001}$

Q.No. 27

The maximum value of the function $f(x) = -\frac{5}{3}x^3 + 10x^2 - 15x + 16$ in the interval $(0.5, 3.5)$ is

(A) 0

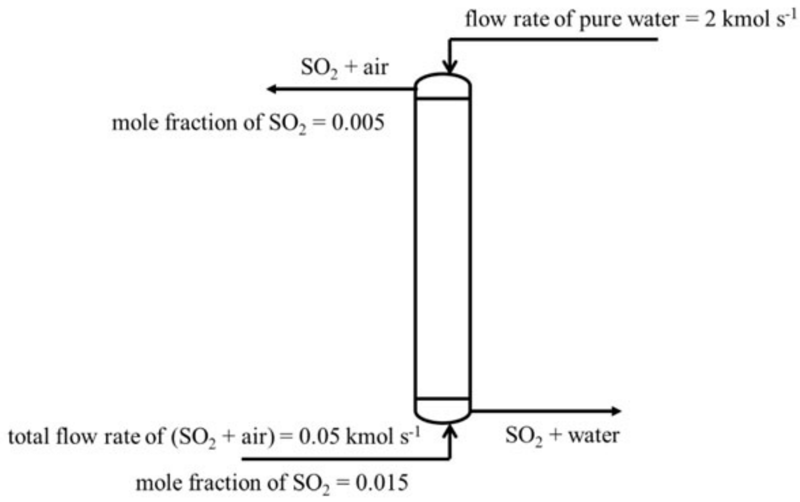
(B) 8

(C) 16

(D) 48

Q.No. 28

SO_2 from air is absorbed by pure water in a counter current packed column operating at constant pressure. The compositions and the flow rates of the streams are shown in the figure.



In addition, use the following data and assumptions

- Column operates under isothermal conditions
- At the operating temperature of the column, $y^* = 40x$, where y^* is the mole fraction of SO_2 in the gas that is in equilibrium with water containing SO_2 at a mole fraction of x
- Solution is dilute and the operating line is linear
- Negligible amount of water evaporates

The number of transfer units (NTU) for this column is

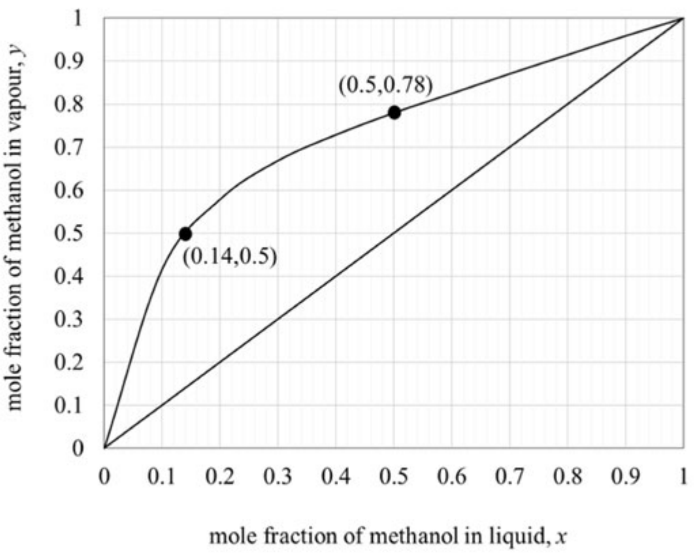
(A) 0.5
(B) 1.0
(C) 1.5
(D) 2.0

Q.No. 29 Two film theory applies for absorption of a solute from a gas mixture into a liquid solvent. The interfacial mass transfer coefficient (in mol m^{-2} s^{-1}) for the gas side is 0.1 and for the liquid side is 3. The equilibrium relationship is $y^* = 2x$, where x and y^* are mole fractions of the solute in the liquid and gas phases, respectively. The ratio of the mass transfer resistance in the liquid film to the overall resistance is

(A) 0.0161
(B) 0.0322
(C) 0.0625
(D) 0.0645

Q.No. 30

Consider the equilibrium data for methanol-water system at 1 bar given in the figure below.



A distillation column operating at 1.0 bar is required to produce 92 mol % methanol. The feed is a saturated liquid. It is an equimolar mixture of methanol and water. The minimum reflux ratio is

(A) 0.33
(B) 0.50
(C) 0.54
(D) 1.17

Q.No. 31 Consider the gas phase reaction $N_2O_4 \rightleftharpoons 2NO_2$ occurring in an isothermal and isobaric reactor maintained at 298 K and 1.0 bar. The standard Gibbs energy change of the reaction at 298 K is $\Delta G^o_{298} = 5253$ J mol^{-1}. The standard states are those of pure ideal gases at 1.0 bar. The equilibrium mixture in the reactor behaves as an ideal gas. The value of the universal gas constant is 8.314 J mol^{-1} K^{-1}. If one mole of pure N_2O_4 is initially charged to the reactor, the fraction of N_2O_4 that decomposes into NO_2 at equilibrium is

(A) 0
(B) 0.17
(C) 0.38
(D) 1

Q.No. 32

A tank initially contains a gas mixture with 21 mol % oxygen and 79 mol % nitrogen. Pure nitrogen enters the tank, and a gas mixture of nitrogen and oxygen exits the tank. The molar flow rate of both the inlet and exit streams is 8 mol s^{-1}.

In addition, use the following data and assumptions

- Assume the tank contents to be well mixed
- Assume ideal gas behavior
- The temperature and pressure inside the tank are held constant
- Molar density of the gas mixture in the tank is constant at 40 mol m^{-3}

If the volume of the tank is 20 m^3, then the time (in seconds) required for oxygen content in the tank to decrease to 1 mol % is

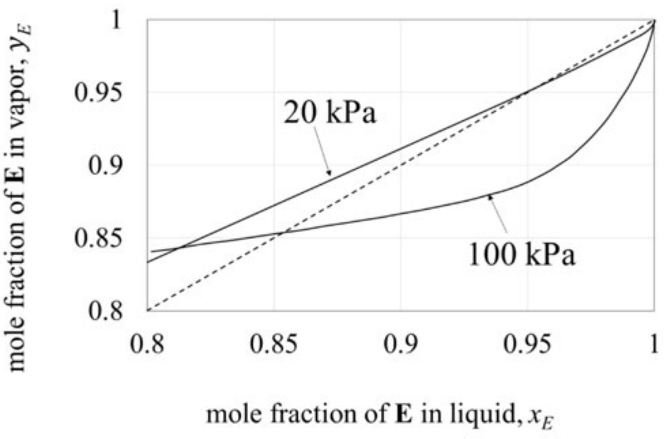
(A) 100.45
(B) 304.45
(C) 3.445
(D) 10

Q.No. 33 Consider steady, laminar, fully developed flow of an incompressible Newtonian fluid through two horizontal straight pipes, **I** and **II**, of circular cross section. The volumetric flow rates in both the pipes are the same. The diameter of pipe **II** is twice the diameter of pipe **I**, i.e., $d_{\mathrm{II}} = 2d_{\mathrm{I}}$. The ratio of the shear stress at the wall of pipe **I** to the shear stress at the wall of pipe **II** is

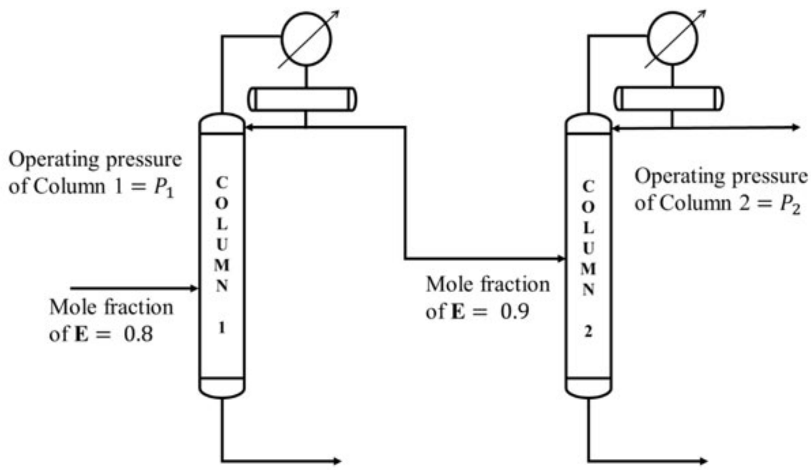
(A) 0.5
(B) 2
(C) 4
(D) 8

Q.No. 34

Equilibrium data for a binary mixture of **E** and **F** at two different pressures is shown in the figure.



It is desired to process a feed containing 80 mol % **E** and 20 mol % **F,** and obtain a product with a purity of 99.5 mol % **E**. A sequence of two distillation columns, one operating at pressure P_1 and another at P_2, is employed for this operation, as shown below.



Mole fraction of **E** in the distillate obtained from column 1 is 0.9. If the column pressures P_1 and P_2 are in kPa, which one of the following is correct?

(A) $P_1 = 100$, $P_2 = 20$, and high purity **E** is recovered from the top of column 2

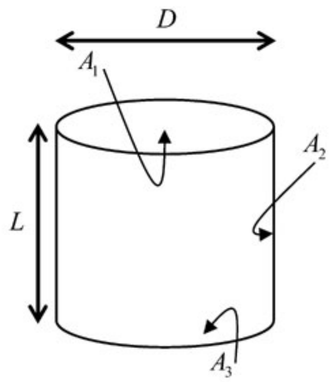
(B) $P_1 = 100$, $P_2 = 20$, and high purity **E** is recovered from the bottom of column 2

(C) $P_1 = 20$, $P_2 = 100$, and high purity **E** is recovered from the top of column 2

(D) $P_1 = 20$, $P_2 = 100$, and high purity **E** is recovered from the bottom of column 2

Q.No. 35

A hollow cylinder of equal length and inner diameter (i.e., $L = D$) is sealed at both ends with flat plate, as shown in the figure. Its inner surfaces, A_1, A_2, and A_3 radiate energy.



F_{ij} denotes the fraction of radiation energy leaving the surface A_i which reaches the surface A_j . It is also known that $F_{13} = 3-2\sqrt{2}$. Which one of the following is correct?

(A) $F_{21} = \sqrt{2}-1$

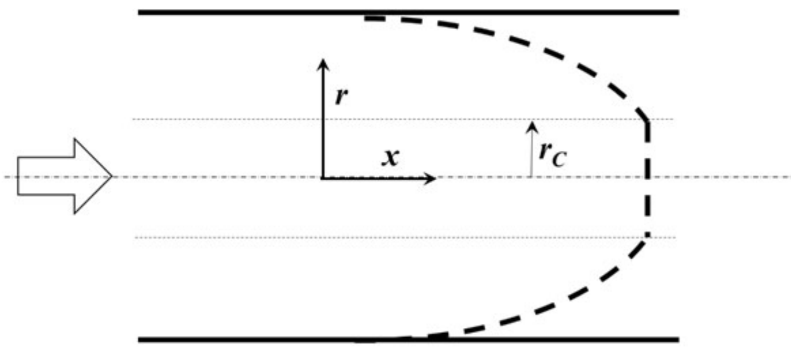
(B) $F_{21} = \dfrac{\sqrt{2}-1}{2}$

(C) $F_{21} = \dfrac{\sqrt{2}-1}{4}$

(D) $F_{21} = \dfrac{\sqrt{2}-1}{8}$

Q.No. 36

A student performs a flow experiment with Bingham Plastic under fully developed laminar flow conditions in a tube of radius 0.01 m with a pressure drop (ΔP) of 10 kPa over tube length (L) of 1.0 m. The velocity profile is flat for $r < r_c$ and parabolic for $r \geq r_c$, as shown in the figure.



Consider ***r*** and ***x*** as the radial and axial directions, and the shear stress is finite as *r* approaches zero. A force balance results in the following equation

$$\frac{d\left(r\tau_{rx}\right)}{dr} = r\frac{\left(-\Delta P\right)}{L}$$

where τ_{rx} is the shear stress. If r_c is 0.001 m, then the magnitude of yield stress for this Bingham Plastic (in Pa) is

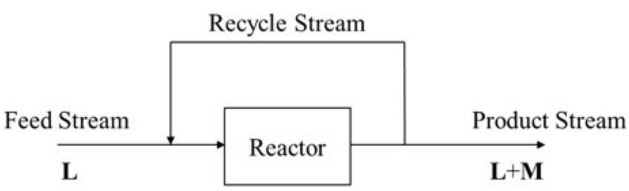
(A) 1

(B) 5

(C) 8

(D) 12

Q.No. 37 A feed stream containing pure species **L** flows into a reactor, where **L** is partly converted to **M** as shown in the figure.



The mass flow rate of the recycle stream is 20% of that of the product stream. The overall conversion of **L** (based on mass units) in the process is 30%. Assuming steady state operation, the one-pass conversion of **L** (based on mass units) through the reactor is

(A) 34.2%

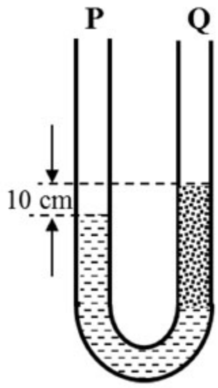
(B) 30%

(C) 26.3%

(D) 23.8%

Q.No. 38

A U-tube manometer contains two manometric fluids of densities 1000 kg m^{-3} and 600 kg m^{-3}. When both the limbs are open to atmosphere, the difference between the two levels is 10 cm at equilibrium, as shown in the figure.



The rest of the manometer is filled with air of negligible density. The acceleration due to gravity is 9.81 m s^{-2} and the atmospheric pressure is 100 kPa. How much absolute pressure (in kPa) has to be applied on the limb '**P**' to raise the fluid in the limb '**Q**' by another 20 cm?

(A) 100.175
(B) 103.924
(C) 547.231
(D) 833.206

Q.No. 39 A pure gas obeys the equation of state given by

$$\frac{PV}{RT} = 1 + \frac{BP}{RT}$$

where P is the pressure, T is the absolute temperature, V is the molar volume of the gas, R is the universal gas constant, and B is a parameter independent of T and P. The residual molar Gibbs energy, G^R, of the gas is given by the relation

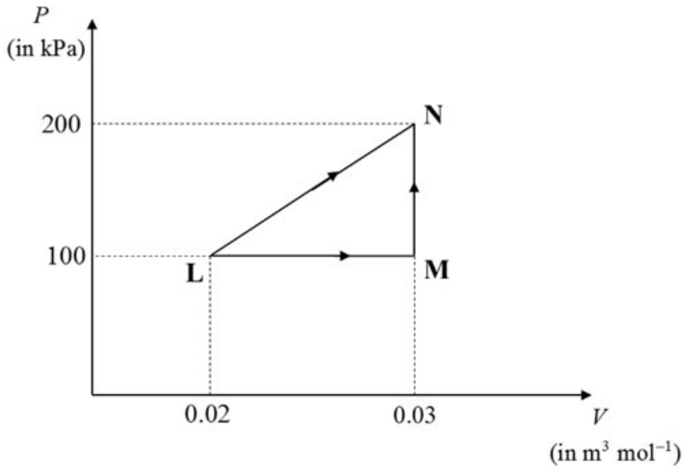
$$\frac{G^R}{RT} = \int_0^P (Z-1)\frac{dP}{P}$$

where Z is the compressibility factor and the integral is evaluated at constant T. If the value of B is 1×10^{-4} m^3 mol^{-1}, the residual molar enthalpy (in J mol^{-1}) of the gas at 1000 kPa and 300 K is

(A) 100
(B) 300
(C) 2494
(D) 30000

Q.No. 40

Consider one mole of an ideal gas in a closed system. It undergoes a change in state from **L** to **N** through two different non-isothermal processes, as shown in the *P*-*V* diagram (where *P* is the pressure and *V* is the molar volume of the gas). Process **I** is carried out in a single step, namely **LN**, whereas process **II** is carried out in two steps, namely **LM** and **MN**. All the steps are reversible.



The net heat flowing into the system for process **I** is Q_{I} and that for process **II** is Q_{II}. The value of $Q_{\mathrm{I}} - Q_{\mathrm{II}}$ (in J) is

(A) 250

(B) 500

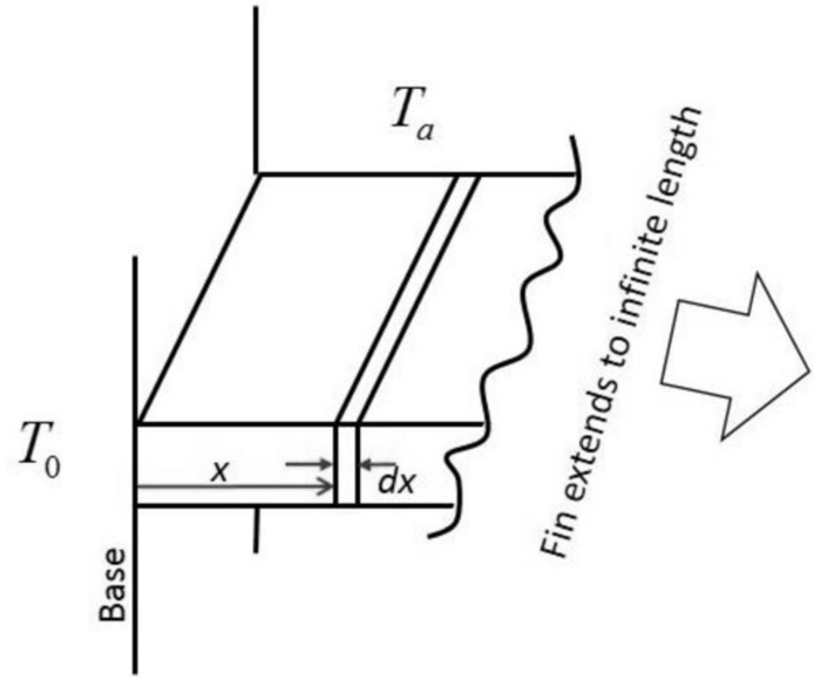
(C) 1000

(D) 1500

Q.No. 41 A fluid is heated from 40 °C to 60 °C in a countercurrent, double pipe heat exchanger. Hot fluid enters at 100 °C and exits at 70 °C. The log mean temperature difference, i.e. LMTD (in °C), is __________ (round off to 2 decimal places).

Q.No. 42

Consider an infinitely long rectangular fin exposed to a surrounding fluid at a constant temperature T_a = 27 °C.



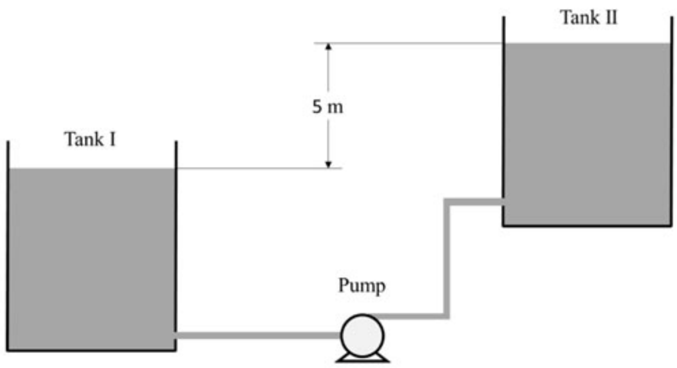
The steady state one dimensional energy balance on an element of the fin of thickness *dx* at a distance *x* from its base yields

$$\frac{d^2\theta}{dx^2} = m^2\theta$$

where $\theta = T_x - T_a$, T_x is the temperature of the fin at the distance *x* from its base in °C. The value of *m* is 0.04 cm^{-1} and the temperature at the base is T_0 = 227 °C. The temperature (in °C) at *x* = 25 cm is __________ (round off to 1 decimal place).

Q.No. 43

Liquid water is pumped at a volumetric flow rate of 0.02 m^3 s^{-1} from Tank I to Tank II, as shown in the figure.



Both the tanks are open to the atmosphere. The total frictional head loss for the pipe system is 1.0 m of water.

In addition, use the following data and assumptions

- Density of water is 1000 kg m^{-3}
- Acceleration due to gravity is 9.81 m s^{-2}
- Efficiency of the pump is 100%
- The liquid surfaces in the tanks have negligible velocities

The power supplied (in W) by the pump to lift the water is __________ (round off to 1 decimal place).

Q.No. 44 An elementary liquid phase reversible reaction $\mathbf{P} \rightleftarrows \mathbf{Q}$ is carried out in an ideal continuous stirred tank reactor (CSTR) operated at steady state. The rate of consumption of **P**, $-r_P$ (in mol liter $^{-1}$ minute^{-1}), is given by

$$-r_P = C_P - 0.5C_Q$$

where C_P and C_Q are the concentrations (in mol liter $^{-1}$) of **P** and **Q**, respectively.

The feed contains only the reactant **P** at a concentration of 1 mol liter $^{-1}$, and the conversion of **P** at the exit of the CSTR is 75% of the equilibrium conversion. Assume that there is no volume change associated with the reaction, and the temperature of the reaction mixture is constant throughout the operation. The space time (in minutes) of the CSTR is __________ (round off to 1 decimal place).

Q.No. 45

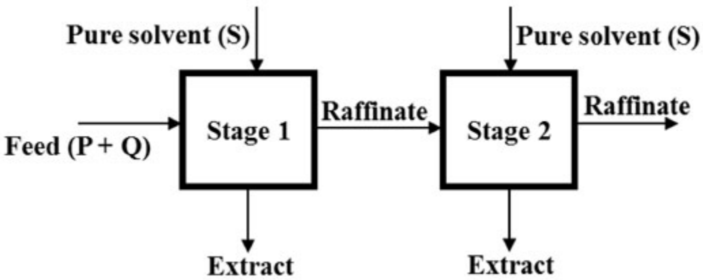
An aqueous suspension at 60 °C is fed to the first effect of a double effect forward feed evaporator with a mass flow rate of 1.25 kg s^{-1}. The sum of the rates of water evaporated from the first and second effects is 1.0 kg s^{-1}. Temperatures of the exit streams from the first and the second effects are 100 °C, and 60 °C, respectively. Consider the specific heat of the aqueous suspension, and the latent heat of phase change for water to be 4 kJ kg^{-1} K^{-1} and 2200 kJ kg^{-1}, respectively, over this temperature range. The steam economy (in kg per kg) is __________ (round off to 2 decimal places).

Q.No. 46

A vertically held packed bed has a height of 1 m, and a void fraction of 0.1, when there is no flow through the bed. The incipient (minimum) fluidization is set in by injection of a fluid of density 1 kg m^{-3}. The particle density (ρ_p) of the solids is 3000 kg m^{-3}. Acceleration due to gravity is 9.81 m s^{-2}. The pressure drop (in Pa) across the height of the bed is __________ (round off to nearest integer).

Q.No. 47

Two ideal cross-current stages operate to extract **P** from a feed containing **P** and **Q**, as shown below.



The mass flow rates of **P** and **Q** fed to Stage 1 are 1,000 kg h^{-1} and 10,000 kg h^{-1}, respectively. Pure solvent (**S**) is injected at mass flow rates of 5,000 kg h^{-1} and 15,000 kg h^{-1} to Stages 1 and 2, respectively. The components **Q** and **S** are immiscible. The equilibrium relation is given by $Y^*=1.5X$, where X is the mass of **P** per unit mass of **Q** in the raffinate, and Y^* is the mass of **P** per unit mass of **S** in the extract, which is in equilibrium with the raffinate. The mass flow rate of **P** (in kg h^{-1}) in the raffinate from Stage 2 is __________ (round off to nearest integer).

Q.No. 48

Consider a vertically falling film of water over an impermeable wall. The film is in contact with a static pool of non-reactive pure gas. The gas diffuses into the water film over the entire height of the falling film. The height of the film is 1.0 m, and its thickness is 10^{-4} m. The velocity of water, averaged over the film thickness, is 0.01 m s^{-1}. The gas concentration (in kg m^{-3}), averaged over the film thickness is

$$\overline{C_{A_y}} = C_{A_i}(1 - e^{-30y})$$

where y is the vertical position in meters measured from the top of the wall.

In addition, use the following data and assumptions

- The flow is fully developed
- The width of the film is much larger than the thickness of the film, and the dissolved gas concentration is invariant over this width
- The solubility of the gas in water, C_{A_i} , is constant
- Pure water enters at $y = 0$
- The evaporation of water is negligible

The mass transfer coefficient on the liquid side (in **mm s**$^{-1}$), averaged over the entire height of the falling film is __________ (round off to 3 decimal places).

Q.No. 49 An exothermic, aqueous phase, irreversible, first order reaction, $\mathbf{Y} \longrightarrow \mathbf{Z}$ is carried out in an ideal continuous stirred tank reactor (CSTR) operated adiabatically at steady state. Rate of consumption of **Y** (in mol liter $^{-1}$ minute^{-1}) is given by

$$-r_Y = 10^9 e^{-\frac{6500}{T}} C_Y$$

where C_Y is the concentration of **Y** (in mol liter $^{-1}$), and T is the temperature of the reaction mixture (in K). Reactant **Y** is fed at 50 ºC. Its inlet concentration is 1.0 mol liter $^{-1}$, and its volumetric flow rate is 1.0 liter minute^{-1}.

In addition, use the following data and assumptions

- Heat of the reaction = –42000 J mol^{-1}
- Specific heat capacity of the reaction mixture = 4.2 J g $^{-1}$ K^{-1}
- Density of the reaction mixture = 1000 g liter $^{-1}$
- Heat of the reaction, specific heat capacity and density of the reaction mixture do not vary with temperature
- Shaft work is negligible

If the conversion of **Y** at the exit of the reactor is 90%, the volume of the CSTR (in liter) is __________ (round off to 2 decimal places).

Q.No. 50

The liquid phase irreversible reactions, $\mathbf{P} \xrightarrow{k_1} \mathbf{Q}$ and $\mathbf{P} \xrightarrow{k_2} \mathbf{R}$, are carried out in an ideal continuous stirred tank reactor (CSTR) operating isothermally at steady state. The space time of the CSTR is 1 minute. Both the reactions are first order with respect to the reactant **P**, and k_1 and k_2 denote the rate constants of the two reactions. At the exit of the reactor, the conversion of reactant **P** is 60%, and the selectivity of **Q** with respect to **R** is 50%. The value of the first order rate constant k_1 (in minute^{-1}) is __________ (correct up to one decimal place).

Q.No. 51 A catalytic gas phase reaction $\mathbf{P} \longrightarrow \mathbf{Q}$ is conducted in an isothermal packed bed reactor operated at steady state. The reaction is irreversible and second order with respect to the reactant **P**. The feed is pure **P** with a volumetric flow rate of 1.0 liter minute^{-1} and concentration of 2.0 mol liter^{-1}.

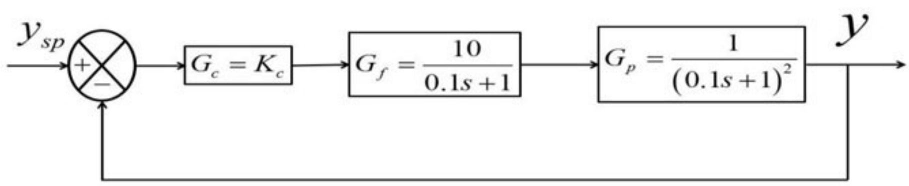
In addition, use the following assumptions

- The reactant and product are ideal gases
- There is no volume change associated with the reaction
- Ideal plug flow conditions prevail in the packed bed

When the mass of catalyst in the reactor is 4 g, the concentration of **P** measured at the exit is 0.4 mol liter^{-1}. The second order rate constant (in liter^2 $g_{catalyst}^{-1}$ mol^{-1} minute^{-1}) is __________ (correct up to one decimal place).

Q.No. 52 Flow of water through an equal percentage valve is 900 liter h^{-1} at 30% opening, and 1080 liter h^{-1} at 35% opening. Assume that the pressure drop across the valve remains constant. The flow rate (in liter h^{-1}) through the valve at 45% opening is __________ (round off to nearest integer).

Q.No. 53 Consider the following closed loop system.



G_c, G_f, and G_p are the transfer functions of the controller, the final control element and the process, respectively. y and y_{sp} are the response and its set point, respectively. For a gain margin of 1.6, the design value of K_c is __________ (correct up to one decimal place).

Q.No. 54 Given $\frac{dy}{dx} = y - 20$, and $y|_{x=0} = 40$, the value of y at $x = 2$ is ______________________ (round off to nearest integer).

Q.No. 55 Consider the following dataset.

x	1	3	5	15	25
$f(x)$	6	8	10	12	5

The value of the integral $\int_{1}^{25} f(x)\,dx$ using Simpson's 1/3rd rule is __________

(round off to 1 decimal place).