General Aptitude

Q.1 to Q.5 Carry one mark each

Question 1

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) AOM are addressing the core problems and are likely to succeed.

(B) The proposed AOM addresses the core problems that cause obesity.

(C) AOM are addressing the problem superficially.

(D) If obesity reduces, poverty will naturally reduce, since obesity causes poverty.

Ans. **(C)**

Sol. For summarizing the passage, the best suitable option is (C).

As superficially means apparently/seemingly.

Hence, the correct option is (C).

Question 2

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? Options

(A) Only conclusion I correct.

(B) Only conclusion II is correct.

(C) Either conclusion I or II is correct.

(D) Neither conclusion I nor II is correct.

Ans. **(D)**

Sol. **Given :**

S1 : All bacteria are microorganisms.

S2 : All pathogens are microorganisms.

According to the statement given in the question we can form Venn diagram as shown below,

There are two possibilities,

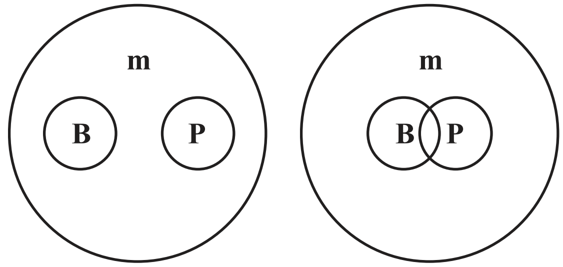


Fig. (a) Fig. (b)

Conclusion 1 : Some pathogens are bacteria.

From fig. (a) conclusion 1 does not follow.

Conclusion 2 : All pathogens are not bacteria.

From possibility of case present in fig. (b) conclusion 2 does not follow.

Hence, the correct option is (D).

Question 3

_____ is to **surgery** as **writer** is to ____

Which one of the following options maintains a similar logical relation in the above sentence?

(A) Doctor, book (B) Hospital, library

(C) Medicine, grammar (D) Plan, outline

Ans. (A)

Sol. As Doctor preforms surgery

Writer writes a Book.

Hence, the correct option is (A).

Question 4

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) 0.8125 (B) 0.6976

(C) 0.3024 (D) 0.4235

Ans. (B)

Sol. P(No two chocolates are identical)

$$=\frac{10\times9\times8\times7\times6}{10^5}=\frac{30240}{10^5}=0.3024$$

P(At least two chocolates are identical)

$$=1$$

$-P$(No two chocolates are identical)

$$=1-0.3024=0.6976$$

Hence, the correct option is (B).

Question 5

We have 2 rectangular sheets of paper, M and N, of dimensions $6\text{ cm} \times 1\text{cm}$ 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) $\frac{9}{\pi}$ (B) 3π (C) $\frac{\pi}{2}$ (D) $\frac{3}{\pi}$

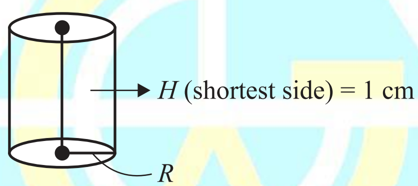
Ans. **(A)**

Sol. **Given :**

The dimension of rectangular sheet M and $N = 6\text{ cm} \times 1\text{ cm}$

According to the question,

M is folded along shortest side to form a cylinder,



$$2\pi R = 6\text{cm}$$

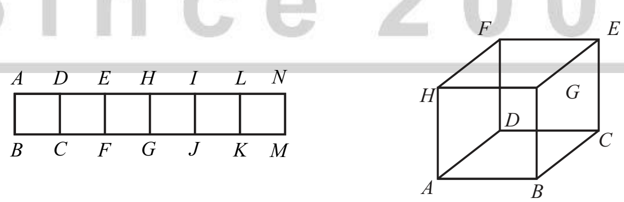
$$R = \frac{3}{\pi}\text{cm}$$

Volume of a right circular cylinder $= \pi R^2 H$

Volume of folded figure $= \pi \times \frac{3}{\pi} \times \frac{3}{\pi} \times 1$

$$= \frac{9}{\pi}\text{cm}^3$$

N is cutted as square to form a cube i.e.



Since, Volume of cube $= (\text{Side})^3$

Thus, Volume of formed cube from $N = 1\text{cm}^3$

The ratio of volume of cylinder to cube

$$= \frac{9/\pi}{1} = 9:\pi$$

Thus, ratio of the volume of the cylinder to that of the cube is 9 : π.

Hence, the correct option is (A).

Key Point

Volume of a right circular cylinder $= \pi R^2 H$

Volume of cube $= (\text{Side})^3$

Question 6

Items	Cost (₹)	Profit (%)	Marked Price (₹)
P	5400	-	5860
Q	-	25	10000

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 marked price and selling price. The profit percentage is calculated as the ratio of difference between selling price and cost price, to the cost price.

$$\text{Profit }\% = \frac{\text{Selling Price} - \text{Cost Price}}{\text{Cost Price}} \times 100$$

The discount on item *Q*, as a % of its marked price, is ______.

(A) 25 (B) 12.5 (C) 10 (D) 5

Ans. **(C)**

Sol. **Given :**

Ratio of the cost price of P to $Q = 3:4$

Cost of $P = 3x = 5400$

$x = 1800$

Cost of $Q = 4x = 7200$

Profit % of $Q = 25\%$

Selling price of

$$Q = 7200\,(\text{C.P.}) + 7200 \times 25\%\,(\text{Profit})$$

$$= 9000$$

$$\text{Discount }\% = \frac{MP - SP}{MP} \times 100\%$$

Discount % for $Q = \frac{1000}{10000} \times 100\% = 10\%$

Hence, the correct option is (C).

Question 7

The ratio of boys to girls in 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) 73 (C) 37 (D) 50

Ans. (D)

Sol. Given :

Ratio of Boys to Girls = 7 : 3

Total number of student in the class

$= 7x + 3x$

$= 10x$ (here, x must be an integer)

$= 50$ (As only option (D) satisfies above condition)

Hence, the correct option is (D).

Question 8

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 incorrect and (ii) is unambiguous

(B) (i) is grammatically correct and (ii) is unambiguous

(C) (i) is grammatically correct and (ii) is ambiguous

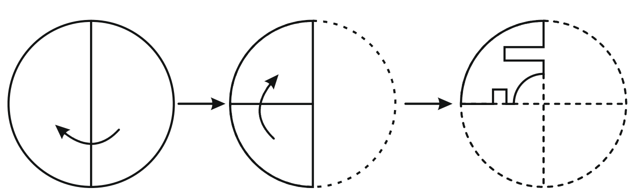
(D) (i) is grammatically incorrect and (ii) is ambiguous

Ans. (C)

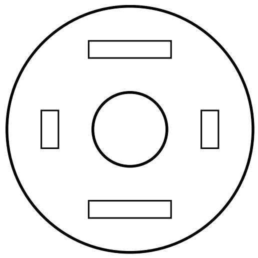
Sol. It is an ambiguous statement because it has more than one possible meaning as who enjoys playing chess is not clear from the given sentence. It may be Babu or Dinesh.

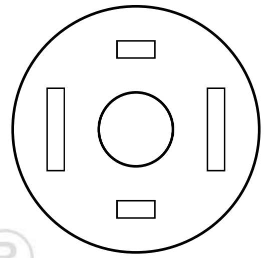
Hence, the correct option is (C).

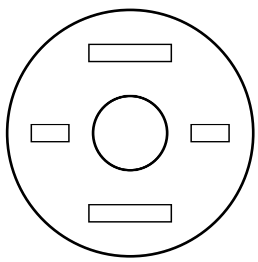
Question 9

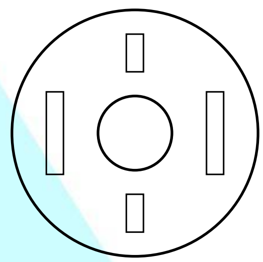


A circular sheet of paper is folded along the lines in the directions shown. The paper, after being punched in the final folded state as shown and unfolded in the reverse order of folding, will look like________.

(A) 

(B) 

(C) 

(D) 

Ans. (A)

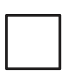
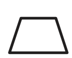
Sol. While we unfold in the reverse order of folding the punched sheet of paper step by step, the figure will look alike option (A).

Hence, the correct option is (A).

Question 10

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.

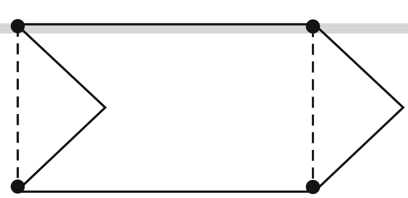
Which one of the following is NOT a convex polygon?

(A)  (B)  (C)  (D) 

Ans. (C)

Sol. **Method 1**

From option (C),

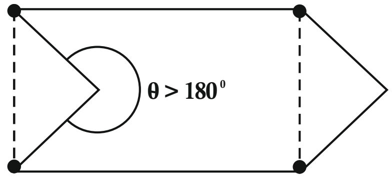


Clearly, we can see that some part is outside the segment line.

Hence, the correct option is (C).

Method 2

Concave polygon is one who have one interior angle more than 180^0.



Hence, the correct option is (C).

Technical Section

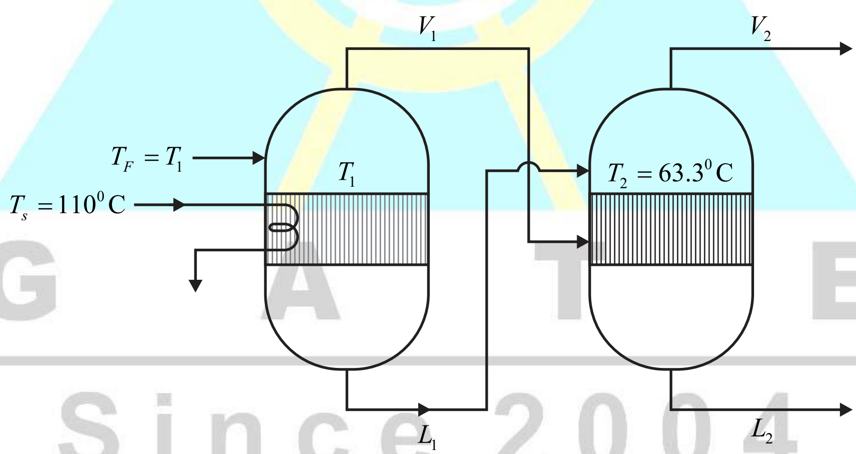
Question 1

A double-effect evaporator is used to concentrate a solution. Steam is sent to the first effect at 110^0C and the boiling point of the solution in the second effect is 63.3^0C. The overall heat transfer coefficient in the first effect and second effect are $2000\ Wm^{-2}K^{-1}$ and $1500\ Wm^{-2}K^{-1}$, 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 _______ ^0C. (round off to nearest integer)

Ans. **89 to 91**

Sol.



LMTD $U_1 = 2000\ W/m^2K, U_2 = 1500\ W/m^2K$

$$q_1 = q_2$$

$$Q = UA\Delta T \Rightarrow \frac{Q}{A} = q = U\Delta T$$

as $$q_1 = q_2$$

$$U_1(\Delta T)_1 = U_2(\Delta T)_2$$

$$2000(T_s - T_1) = 1500(T_1 - T_2)$$

$$2000(110 - T_1) = 1500(T_1 - 63.3)$$

$$440 - 4T_1 = 3T_1 - 189.9$$

$$7T_1 = 629.9$$

$$T_1 = 89.98^0\text{C}$$ **Ans.**

Question 2

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

Density of seawater $= 1025 \text{ kgm}^{-3}$

Density of resin beads $= 1330 \text{ kgm}^{-3}$

Diameter of resin beads $= 50\ \mu\text{m}$

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

Acceleration due to gravity $= 9.81 \text{ ms}^{-2}$

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

Ans. **1790 to 1800**

Sol. Sea water is passed through a column containing a bed of resin beads

Seawater $(P_{water})\,P_f = 1025 \text{ kg/m}^3$

Density of resin bed $(P_P) = 1330 \text{ kg/m}^3$

Diameter of resin beads $= 50$ mm

gravity $= 9.81 \text{ m/sec}^2$

Void fractions $\varepsilon = 0.4$

Presure drop per unit length of the Bed at the onset (incipient) fluidization

$$\frac{\Delta P}{L} = (\rho_p - \rho_f)(1-\varepsilon)(g)$$

$$\frac{\Delta P}{L} = (1330 - 1025)(1 - 0.4)(9.81)$$

$$\frac{\Delta P}{L} = 1795.23 \text{ Pa/m}$$

Question 3

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) Open loop transfer function must have an amplitude ratio less than 1 at the critical frequency.

(C) All the elements in the left (first) column of the Routh array must have the same sign.

(D) Roots of the characteristic equation must have negative real part.

Ans. (A)

Question 4

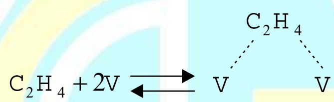
Which of the following is NOT a standard to transmit measurement and control signals?

(A) 3-15 psig (B) 4-20 mA (C) 1-5 VDC (D) 0-100 %

Ans. (D)

Question 5

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) $N_T = N_V + 2N_{C_2H_4}$

(B) $N_T = N_V + 0.5N_{C_2H_4}$

(C) $N_T = 2N_V + N_{C_2H_4}$

(D) $N_T = N_V + N_{C_2H_4}$

Ans. (A)

Question 6

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

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

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 $\frac{\alpha_{\text{turbulent}}}{\alpha_{\text{laminar}}}$ is _______. (round off to 2 decimal places)

Ans. **0.52 to 0.54**

Sol. Kinetic energy correction factor for turbulent

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

$\bar{V}-$ average velocity, V_0- Centerline velocity

and given

$$\frac{\bar{V}}{V_0} = \frac{2n^2}{(n+1)(2n+1)} \quad \text{for turbulent } n = 7$$

$$\frac{\alpha_{tub}}{\alpha_{laminar}} = ?$$

$$\frac{\bar{V}}{V_0} = \frac{2n^2}{(n+1)(2n+1)} = \frac{2\times 7^2}{(7+1)(2\times 7+1)} = \frac{90}{8\times 15}$$

$$= 0.8167$$

$$\alpha_{tub} = \left(\frac{1}{0.01167}\right)^3 \frac{2\times 7^2}{(3+7)\times(3+2\times 7)} = 1.05038$$

For laminar $\alpha_{laminar} = 2$

$\therefore$ $$\frac{\alpha_{tub}}{\alpha_{laminar}} = \frac{1.05038}{2} = 0.52919$$ **Ans.**

Question 7

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 ______.

Ans. **2**

Sol. **Given :** An algebraic equation $f(x)=0$

$$x_{n+1} = g(x_n)$$

$$g(x) = x - \frac{f(x)}{f'(x)}$$

The given iterative formula for algebraic equation is known as Newton Raphson method for solution of algebraic equation.

The order of convergence for this iterative scheme is 2.

Hence, the correct answer is 2.

Key Point

(i) Newton Raphson method does not converge when $f'(x)=0$.

(ii) Order of convergence for Bisection method is 1.

(iii) Order of convergence for Regula-Falsi method is 1.

(iv) Order of convergence for Secant method is 1.62.

Question 8

Match the common name of chemicals in Group-1 with their chemical formulae is 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.**	$CaCO_3MgCO_3$

The correct combination is :

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

Ans. **(A)**

Question 9

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)

Ans. **73 to 77**

Sol. $L=\alpha C^{\beta}$

Given, $L=60, C=2\times10^4$

$L=70, C=6\times10^4$

$L=?\ \ C=10^5$

$$60=\alpha(2\times10^4)^{\beta} \quad \dots (1)$$

$$70=\alpha(6\times10^4)^{\beta} \quad \dots (2)$$

Divide (1)/(2)

$$\frac{6}{7}=\left(\frac{1}{3}\right)^{\beta}$$

$$\ln\left(\frac{6}{7}\right)=\beta\ln\left(\frac{1}{3}\right)^{\beta}$$

$$\beta=0.14$$

$$60=\alpha(2\times10^{4})^{0.14}$$

$$\alpha=14.95$$

$$L=14.95(10^{5})^{0.14}$$

$$L=75.19=75$$

Ans.

Question 10

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)

Ans. **43**

Sol.

$$mL=\sqrt{\left(\frac{hr}{K}\right)\times4\times2\times4\times\frac{L}{D}}$$

$$mL=\sqrt{(0.04)\times4\times2\times4(4)}$$

$$mL=2.2627$$

$$\eta_{fin}=\frac{\tanh(mL)}{(mL)}$$

$$\eta_{fin}=\frac{\tanh(2.2627)}{2.2627}$$

$$\eta_{fin}=0.43$$

$$\eta_{fin}=43\%$$

Ans.

Question 11

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).

Ans. **0.167**

Sol. **Given :** $$\frac{d^3y}{dt^3}+\frac{6d^2y}{dt^2}+11\frac{dy}{dt}+6y=1$$

Applying Laplace transform on both side

$$s^3Y(s)+6s^2Y(s)+11sY(s)+6Y(s)=\frac{1}{s}$$

$$Y(s)(s^3+6s^2+11s+6)=\frac{1}{s}$$

$$Y(s)=\frac{\frac{1}{s}}{s^3+6s^2+11s+6}$$

$$Y(s)=\frac{1}{s(s^3+6s^2+11s+6)}$$

Applying final value theorem (FVT) :

$$\lim_{t\to\infty} y(t)=\lim_{s\to 0} sY(s)$$

$$y(\infty)=\lim_{s\to 0}\frac{s}{s(s^3+6s^2+11s+6)}$$

$$y(\infty)=\frac{1}{6}$$

$$y(\infty)=0.167$$

Hence, the correct answer is 0.167.

Key Point

Initial value theorem

$$\lim_{t\to 0} y(t)=\lim_{s\to\infty} sY(s)$$

Question 12

Formaldehyde is produced by the oxidation of methane in a reactor. The following two parallel reactions occur.

$$CH_4+O_2\rightarrow HCHO+H_2O$$

$$CH_4+2O_2\rightarrow CO_2+2H_2O$$

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 flow rate (in mol s^{-1}) of CH_4, O_2 and CO_2 leaving the reactor are 26, 2 and 4 respectively. The molar flow rate of oxygen entering the reactor is _______ mol s^{-1}.

Ans. **40 to 40**

Sol.

Question 13

The function $\cos(x)$ is approximated using Taylor series around $x=0$ as $\cos(x)\approx 1+ax+bx^2+cx^3+dx^4$. The values of a, b, c and d are

(A) $a=0,\ b=-0.5,\ c=0,\ d=0.042$

(B) $a=-0.5,\ b=0,\ c=0.042,\ d=0$

(C) $a=1,\ b=-0.5,\ c=-1,\ d=-0.25$

(D) $a=0,\ b=0.5,\ c=0,\ d=0.042$

Ans. **(A)**

Sol. **Given :** $f(x)=\cos x\approx 1+ax+bx^2+cx^3+dx^4$ … (i)

The Taylor series of function $f(x)$ is given by,

$$f(x)=f(a)+(x-a)f'(a)+(x-a)^2\frac{f''(a)}{2!}+\ldots$$

Taylor series expansion around $x=0$ implies $a=0$

So, $$f(x)=f(0)+xf'(0)+x^2\frac{f''(0)}{2!}+x^3\frac{f'''(0)}{3!}+\ldots \quad \ldots \text{(ii)}$$

From equation (i) and (ii) we get

$$a=f'(0),\quad b=\frac{f''(0)}{2!},\quad c=\frac{f'''(0)}{3!},\quad d=\frac{f''''(0)}{4!}$$

$$f(x)=\cos x$$

$$f'(x)=-\sin x$$

$$f'(0)=a=-\sin 0=0$$

$$f''(x)=-\cos x$$

$$f''(0)=-1$$

$$b=\frac{f''(0)}{2!}=\frac{-1}{2}=-0.5 \quad [\because\ f''(0)=-1]$$

$$f'''(x)=\sin x$$

$$f'''(0)=0$$

$$c=\frac{f'''(0)}{3!}=0 \quad [\because\ f'''(0)=0]$$

$$f''''(x) = \cos x$$

$$f''''(0) = 1$$

$$d = \frac{f''''(0)}{4!} = \frac{1}{24} = 0.042 \qquad [\because\ f''''(0) = 1]$$

$$a = 0,\ b = -0.5,\ c = 0,\ d = 0.042$$

Hence, the correct option is (A).

Question 14

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.

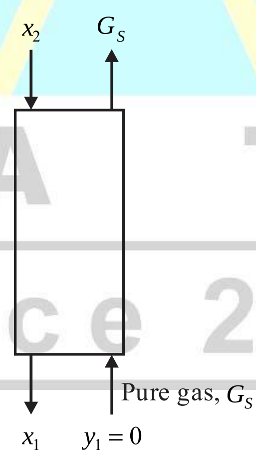
Let x_1 be the mole fraction of the solute in the leaving liquid and x_2 be the mole fraction of solute in the entering liquid.

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. NTUOL is given by

(A) $\ln\left(\frac{x_2 + x_1}{x_2 - x_1}\right)$ (B) $\frac{x_2 + x_1}{x_2 - x_1}$ (C) $\ln\left(\frac{x_2}{x_1}\right)$ (D) $\frac{x_2 - x_1}{x_1}$

Ans. **(D)**

Sol.



When the ratio of liquid to gas flow rates is equal to *m*, this means absorption factor is 1

i.e., $$A = \frac{LS}{mGS} = 1$$

In this case, $$NTU_{OL} = \frac{\text{Change in liquid mole reactions of solute}}{\text{Driving force at bottom of the column}}$$

$$NTU_{OL} = \frac{x_2 - x_1}{x_1 - x_1^*}$$

Where, x_1^* is the concentration that is in equilibrium with bulk gas phase

$\Rightarrow$ $y_1^* = mx_1^* = 0$ {as gas is pure}

So, $$NTU_{OL} = \frac{x_2 - x_1}{x_1}$$

Question 15

The van der Waals equation of state is given by

$$P_r = \frac{8T_r}{3v_r - 1} - \frac{3}{v_r^2}$$

When 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 $\frac{3}{8}$.

If $v_r = 3$ and $T_r = \frac{4}{3}$, then the compressibility factor based on the van der Waals equation of state is _______. (round off to 2 decimal places)

Ans. 0.83 to 0.85

Sol. $$P_r = \frac{8T_r}{3V_r - 1} - \frac{3}{V_r^2}$$

Given, $Z_c = \frac{3}{8}, T_r = \frac{4}{3}, V_r = 3$

$$P_r = \frac{8 \times \frac{4}{3}}{3 \times 3 - 1} - \frac{3}{3^2}$$

$$P_r = 1$$

$$Z = \frac{PV}{RT} \quad \text{... (i)}$$

$$Z_c = \frac{P_c V_c}{RT_c} \quad \text{... (ii)}$$

$$\frac{Z}{Z_c} = Z_r = \frac{\left(\frac{P}{P_c}\right)\left(\frac{V}{V_c}\right)}{\frac{T}{T_c}} = \frac{P_r V_R}{T_r}$$

$$Z_r = \frac{1\times 3}{\frac{4}{3}} = \frac{9}{4}$$

$$Z = \frac{9}{4}\times Z_c = \frac{9}{4}\times\frac{3}{8} = \frac{27}{32}$$

$Z = 0.84$ **Ans.**

Question 16

The heat of combustion of methane, carbon monoxide and hydrogen are P, Q and R respectively. For the reaction below,

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

The heat of reaction is given by

(A) $Q+3R-P$ (B) $Q+R-P$ (C) $P-Q-3R$ (D) $P-Q-R$

Ans. **(C)**

Sol.

Question 17

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)

Ans. **0.63 to 0.65**

Sol. At total Reflux $\Rightarrow$ Minimum number of plates

Given, $x_w = 0.1,\ \alpha_{AB} = 4$

We know by Fenske Equation

$$Nm+1 = \frac{\log\left[\frac{x_D}{1-x_D}\cdot\frac{(1-x_w)}{x_w}\right]}{\log\alpha}$$

Where $Nm =$ Plates inside column

$$\therefore \quad Nm+1 = 2 = \frac{\log\left[\frac{x_D}{1-x_D}\cdot\frac{(1-0.1)}{0.1}\right]}{\log 4}$$

$$\Rightarrow \quad 2\log 4 = \log\left[\frac{9x_D}{1-x_D}\right]$$

$\Rightarrow \quad \log 16 = \log\left[\dfrac{9x_D}{1-x_D}\right]$

$\Rightarrow \quad 16 = \dfrac{9x_D}{1-x_D}$

$\Rightarrow \quad 16 - 16x_D = 9x_D$

$\Rightarrow \quad x_D = 0.64$

Question 18

Let A be a square matrix of size $n \times n (n > 1)$. The elements of $A = \{a_{ij}\}$ are given by

$$a_{ij} = \begin{cases} i \times j, & \text{if } i \geq j \\ 0, & \text{if } i < j \end{cases}$$

The determinant of A is

(A) $n!$ (B) 1 (C) $(n!)^2$ (D) 0

Ans. **(C)**

Sol. **Given :** $A = \{a_{ij}\}$

$$a_{ij} = \begin{cases} i \times j & \text{if } i \geq j \\ 0 & \text{if } i < j \end{cases}$$

$$[A] = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & ..... \\ a_{21} & a_{22} & a_{23} & a_{24} & ..... \\ a_{31} & a_{32} & a_{33} & a_{34} & ..... \\ a_{41} & a_{42} & a_{43} & a_{44} & ..... \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n\times 1} & a_{n\times 2} & a_{n\times 3} & ..... & a_{n\times n} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & ..... & 0 \\ 2 & 4 & 0 & 0 & 0 & ..... & 0 \\ 3 & 6 & 9 & . & . & ..... & 0 \\ . & . & . & . & . & ..... & 0 \\ . & . & . & . & . & ..... & 0 \\ n\times 1 & n\times 2 & . & . & . & ..... & n\times n \end{bmatrix}$$

Matrix A is a lower triangular matrix for which eigen values are principle diagonal element itself.

So, determinant of [A] = Product of eigen values

$$|A| = [(1\times1)\times(2\times2)\times(3\times3)\times.....\times(n\times n)]$$

$$|A| = [1^2\times2^2\times3^2\times4^2.....n^2]$$

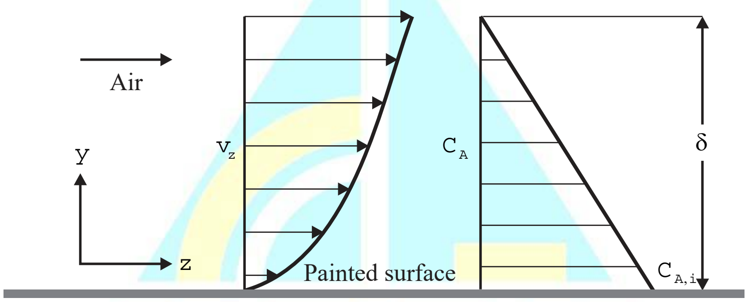
$$|A| = [1\times2\times3\times......n]^2$$

$$|A| = (n!)^2$$

Hence, the correct option is (C).

Question 19

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 his 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 ms^{-1} and its velocity profile (in ms^{-1}) is given by

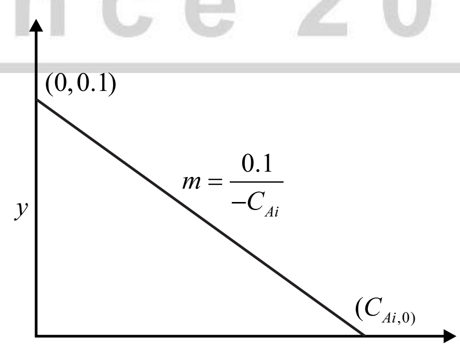
$$v_z(y) = 10y^2$$

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)

Ans. **0.24 to 0.26**

Sol.



G A T E Since 2004

$$y = \frac{0.1}{-C_{Ai}} C_A + 0.1$$

$$C_A = C_{Ai}(1 - 10y)$$

Given, $\delta = 0.1$ m, $\bar{V} = 0.033$ m/sec, $V_2(y) = 10y^2$

$$\frac{C_{AM}}{C_{Ai}} = ?$$

For unit width of plate, Area average molar flow rate (mol/sec) is given by –

$$\dot{m}\,(\text{mol/sec}) = A\bar{V}C_{Am} = \int_0^{\delta} V_2(y)\, C_A(y)\, dy \cdot 1$$

$$= (\delta \times 1)\bar{V}C_{Am} = \int_0^{0.1} 10y^2 C_{Ai}(1 - 10y)\, dy$$

$$0.1 \times 0.033 C_{Am} = C_{Ai} \int_0^{0.1} (10y^2 - 100y)\, dy$$

$$\frac{C_{Am}}{C_{Ai}} = 0.25$$ **Ans.**

Question 20

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

$\frac{C_p}{R} = 2.46 + 45.4 \times 10^{-3} T - 14.1 \times 10^{-6} T^2$. Take $R = 8.314\ \text{J mol}^{-1}\text{K}^{-1}$.

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

Ans. **0.27 to 0.29**

Sol. Given, $\frac{C_P}{R} = a + bT - CT^2$

$a = 2.46$

$b = 45.4 \times 10^{-3}$

$c = 14.1 \times 10^{-6}$

Find $\left.\frac{dS}{dT}\right| = ?$

$dS = \oint \frac{dQ}{T}$ at constant pressure $dQ = dH = C_P dT$

$$dS = \oint \frac{dH}{T} = \oint \frac{C_P dT}{T}$$

$$\left.\frac{dS}{dT}\right|_P = \frac{C_P}{T} = R\left[\frac{a+bT-CT^2}{T}\right]$$

$$= R\left[\frac{a}{T}+b-CT\right]$$

$$\left.\frac{dS}{dT}\right|_P = 8.314\left[\frac{2.46}{1000}+45.4\times10^{-3}-14.1\times10^{-3}\right]$$

$$\left.\frac{dS}{dT}\right|_P = 0.28$$

Question 21

A gaseous mixture at 1 bar and 300 K consist of 20 mol % CO_2 and 80 mol % inert gas.

Assume the gases to be ideal. Take $R = 8.314 \text{ J mol}^{-1}\text{K}^{-1}$.

The magnitude of minimum work required to separated 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)

Ans. 124 to 126

Sol. Given, $y_1 = 0.2, y_2 = 0.8$

$n = 100$ mol

$P = 1$ bar, $T = 300$ K

Work done = Energy change in Gibbs free charge of mixing

$$W = \Delta G_{mix} = nRT \sum y_i \ln y_i$$

$$W = (100)8.314\times300[0.2\ln0.2+0.8\ln0]$$

$$W = -124.8 \text{ kJ}$$

Work done on system must be positive

$= 125$ kJ **Ans.**

Question 22

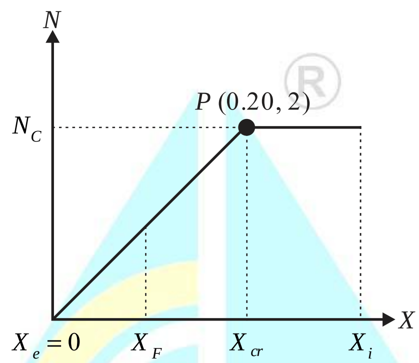
In a batch drying experiment a solid with a critical moisture content of 0.2 kg H_2O/kg dry solid is dried from an initial moisture content of 0.35 kg H_2O/kg dry solid to a final moisture content of $0.1 \text{ kg H}_2\text{O/kg}$ dry solid in 5h. In the constant rate regime, the rate of drying is $2 \text{ kg H}_2\text{O/(m}^2\text{h)}$.

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)

Ans. **34 to 35**

Sol.



Given,

$$X_i = 0.35$$

$$X_{cr} = 0.20$$

$$X_F = 0.10$$

$$N_C = 2 \text{ kg } \frac{\text{H}_2\text{O}}{(\text{m}^2\text{h})}$$

Total drying time $= t_C + t_F = 5h$

Where, $t_C =$ Constant rate drying time

$t_F =$ Falling rate drying time

We know, $N = \frac{-S_S}{A}\frac{dX}{dt}$

For constant rate, $N_C = \frac{-S_S}{A}\frac{[X_{cr} - X_i]}{t_C}$

$$2 = \frac{S_S}{At_C}[0.35 - 0.20]$$

$$t_C = \frac{S_S}{A}(0.075) \quad \text{… (i)}$$

Slope of falling rate period line $= \frac{2}{0.20} = 10$

Equation of falling rate period line, $N = 10X$

By Formula, $N = \frac{-S_S}{A}\frac{dX}{dt}$

$$t_F = \frac{-S_S}{A}\int_{X_{cr}}^{X_F}\frac{dX}{10X}$$

$$t_F = \frac{S_S}{10A}\ln\frac{X_{cr}}{X_F}$$

$$t_F = \frac{S_S}{10A}\ln\frac{0.2}{0.1}$$

$$t_F = \frac{S_S}{A}\frac{\ln 2}{10}$$

$$t_F = \frac{S_S}{A}0.0693 \qquad \ldots \text{(ii)}$$

Adding (i) and (ii)

$$0.075\frac{S_S}{A} + 0.0693\frac{S_S}{A} = 5$$

On solving, $\frac{S_S}{A} = 34.65 \text{ kg/m}^2$

$$\frac{S_S}{A} = 35 \qquad \{\text{Nearest integer}\}$$

Question 23

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

$$C_{piping} = 45.92\, D$$

Here, D is the inner diameter of the pipe in meter, q is the volumetric flowrate of the liquid in m^3s^{-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 $10^{-4}\ \text{m}^3\text{s}^{-1}$, the economic inner diameter of the pipe is _______ meter. (round off to 3 decimal places)

Ans. **0.014 to 0.016**

Sol. **Given,**

$$C_{Pump} = \frac{48.13q^2M}{D^4}, q = 10^{-4}\ \text{m}^3/\text{s}$$

$$C_{Piping} = 45.92\,D, M = 20\times10^{-3}\ \text{Pa-s}$$

Total annual cost $= C_{Pump} + C_{Piping}$

$$\frac{d}{dD}[\text{Total annual cost}] = 0, \text{ for economic inner diameter calculation.}$$

$$\frac{48.13\times q^2\times M}{D^4} + 45.92\,D = \text{T.A.C.}$$

Differentiating and equating to zero

$$\frac{-4\times48.13\times q^2\times M}{D^5} + 45.92 = 0$$

Solving by substituting q and M

$$D = 0.0153\ \text{m}$$

Answer range is 0.014-0.016

Question 24

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

$$-r_A = \frac{0.01C_A}{0.05 + C_A}\ (\text{mol L}^{-1}\ \text{min}^{-1})$$

If the initial concentration of A is $0.02\ \text{mol L}^{-1}$, the time taken to achieve 50% conversion of A is _______ min. (round off to 2 decimal places)

Ans. **4.44 to 4.51**

Sol.

Given, $$-r_A = \frac{0.01C_A}{0.05 + C_A}$$

$$C_{A0} = 0.02\ \text{mol/litre} \quad t_{batch} = ?$$

$$X_A = 0.5$$

$$\frac{t_{batch}}{C_{A0}} = \int_0^{X_A} \frac{dX_A}{-r_A} \quad \Rightarrow \quad \frac{t_{batch}}{0.02} = \int_0^{0.5} \frac{dX_A}{\frac{0.01C_A}{0.05+C_A}}$$

$$t_{batch} = 0.02\left[\int_0^{0.5} \frac{0.05 + C_A}{0.01C_A}\right] dX_A$$

$$t_{batch} = 0.02\left[5\int_0^{0.5}\frac{1}{C_A}dX_A + 100\int_0^{0.5}dX_A\right]dX_A$$

$$t_{batch} = 0.02\left[\frac{5}{C_{A0}}\int_0^{0.5}\frac{dX_A}{(1-X_A)} + 100\,[0.5-0]\right]$$

$$t_{batch} = 0.02\left[\frac{5}{0.02}[-\ln(1-X_A)]_0^{0.5} + 50\right]$$

$$t_{batch} = 5[-\ln[0.5]+1]$$

$$t_{batch} = 4.46 \text{ min}$$

Question 25

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) 8.0 (B) 0.8 (C) 4.0 (D) 0.06

Ans. **(A)**

Sol. **Given :** $\frac{dy}{dx} = 2y,\ y(0)=1,\ h=0.5$

Analytical solution is given by,

$$y(x) = e^{2x}$$

At $x = 0.5$, analytical solution is

$$y(0.5) = e^{2\times 0.5} = e^1 = 2.718$$

According to question

$$f(x,y) = 2y$$

By Runge-kutta 2nd order method,

(i) $K_1 = hf\,(x_0, y_0) = h(2y_0)$

$K_1 = 0.5(2\times 1) = 1$

(ii) $K_2 = h\left[f(x_0 + h, y_0 + K_1)\right]$

$K_2 = h[2(1+1)]$

$K_2 = 0.5 \times 4 = 2$

(iii) $K = \frac{K_1 + K}{2} = \frac{1+2}{2} = 1.5$

(iv) $y_1 = y_0 + K = 1 + 1.5 = 2.5$

$$y_{numerical} = y_1 = 2.5$$

$$\varepsilon = \left|\frac{y_{analytical} - y_{numerical}}{y_{analytical}}\right| \times 100$$

$$\varepsilon = \left|\frac{2.718 - 2.5}{2.718}\right| \times 100$$

$$\varepsilon = \frac{0.218}{2.718} \times 100 = 8\%$$

Hence, the correct option is (A).

Question 26

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 _______.

Ans. **40 to 40**

Sol. Given, $G(s) = \frac{3e^{-4s}}{12s+1}$

$$G(s) = \frac{\tilde{y}(s)}{\tilde{u}(s)} = \frac{3e^{-4s}}{12s+1}$$

Now, a step change of magnitude 'M' is given

So, $\tilde{u}(s) = \frac{M}{S}$

$$\tilde{y}(s) = \frac{3e^{-4s}}{12s+1} \cdot \frac{M}{S}$$

Final value of system output is given by

$$\lim_{s \to 0} s.\tilde{y}(s) = 120$$

$\Rightarrow$ $= 0.1$

$\Rightarrow \quad 3M = 120$

$\Rightarrow \quad M = 40$

Question 27

The following isothermal autocatalytic reaction,

$$A + B \longrightarrow 2B \quad (-r_A) = 0.1 C_A C_B \quad (\text{mol L}^{-1}\,\text{s}^{-1})$$

is carried out in an ideal continuous stirred tank reactor (CSTR) operating at steady state. Pure A at $1\ \text{mol L}^{-1}$ is fed, and 90% of A is converted in the CSTR. The space time of the CSTR is _______ seconds.

Ans. **100 to 100**

Sol. Given, $-r_A = 0.1 C_A C_B$

$C_{A0} = 1$ mol/litre $\qquad X_A = 0.9$

$\tau_m = ?$ $\qquad \underset{C_{A0}}{A} + \underset{C_{B0}}{B} \longrightarrow \underset{0}{2B}$

$$\tau_m = \frac{C_{A0} - C_A}{(-r_A)_{exit}}$$

$t = 0$

$$\tau_m = \frac{1 - 0.51}{0.1 C_A C_B} \qquad C_A = C_{A0}(1 - X_A)$$

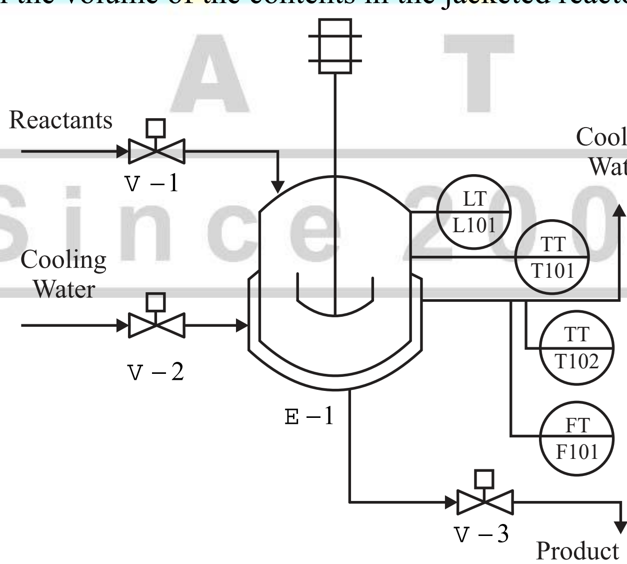
$$\tau_m = \frac{0.5}{0.1 \times 0.1 \times 0.9} = \frac{1}{0.01} = 100 \text{ seconds} \qquad C_A = 1 \times (1 - 0.9) = 0.1$$

$= 100$ sec $\qquad C_B = C_{A0} X_A$

$C_B = 1 \times 0.5 = 0.9$

Question 28

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?

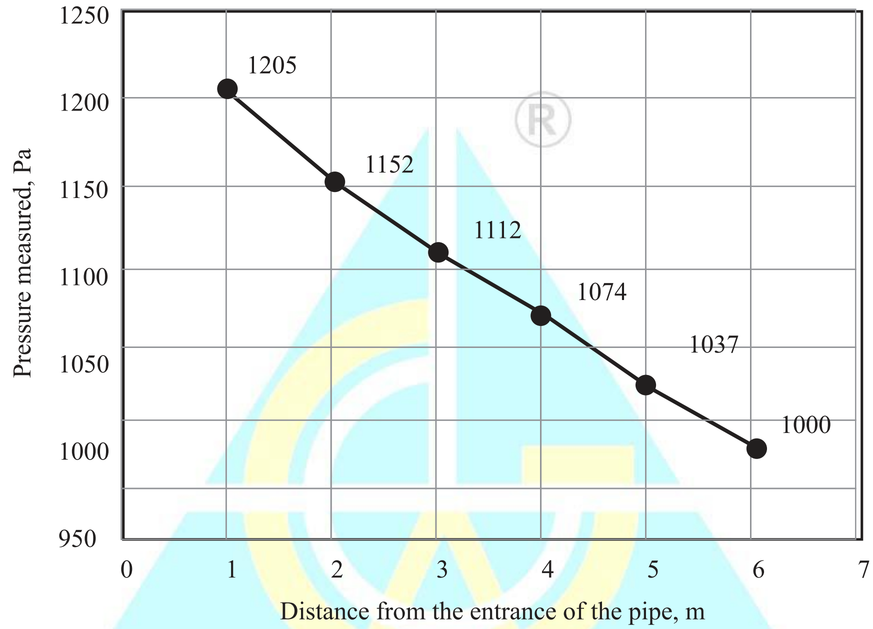
(A) Measure F101 and manipulate valve V-1 $\qquad$ (B) Measure L101 and manipulate valve V-3

(C) Measure T101 and manipulate valve V-1 (D) Measure L101 and manipulate valve V-2

Ans. **(B)**

Question 29

Water of density $1000\ \text{kg m}^{-3}$ flows in a horizontal pipe of 10 cm diameter at an average velocity of $0.5\ \text{m s}^{-1}$. 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

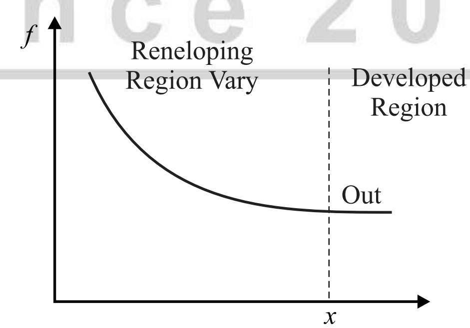
(A) 0.0082 (B) 0.0074 (C) 0.0106 (D) 0.0012

Ans. **(B)**

Sol. Water $(P) = 1000\ \text{kg/m}^3$

(d) diameter $= 10$ cm, $r = 5\times10^{-2}$ cm

$V_{avg} = 0.5\ \text{m/sec} = 5\times10^{-1}$



Find out panning friction factor in the pipe when the flow is fully developed is

$$f = ?$$

$$f = \frac{2\tau_\omega}{Pu_{avg}^2} \quad \ldots \text{(i)}$$

and $$\tau_r = -\left(\frac{dP}{dx}\right)\frac{r}{2}$$

at wall $$\tau_\omega = -\left(\frac{dP}{dx}\right)\frac{R}{2} \quad \ldots \text{(ii)}$$

From 1074 to 1037 to 1000 constant

$$\left(\frac{dP}{dx}\right)_{wall} = \frac{-37}{1} = -37$$

$$f = \frac{2\left[-\left(\frac{dP}{dx}\right)_{wall} \times \frac{R}{2}\right]}{Pu^2} = \frac{-(-37)\times 5\times 10^{-2}}{1000\times(5\times 10^{-1})^2}$$

$$= \frac{37\times 5\times 10^{-2}}{1000\times 5\times 5\times 10^{-2}} = 0.0074$$

Ans.

Question 30

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 differentiable at $x = 1$

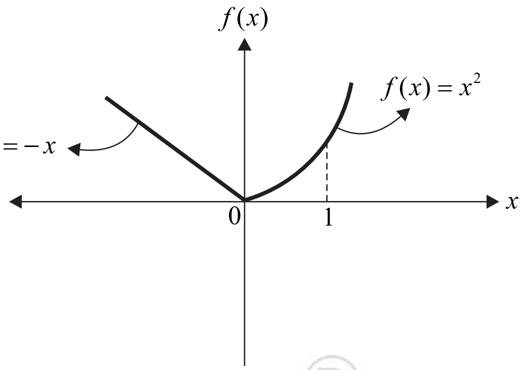
(B) $f(x)$ is differentiable at $x = 0$

(C) $f(x)$ is continuous at $x = 1$

(D) $f(x)$ is continuous at $x = 0$

Ans. (A, C, D)

Sol. Given : $f(x) = \begin{cases} -x, & x < 0 \\ x^2, & x \geq 0 \end{cases}$



$f(x)$ is continuous at $x = 0$ and $x = 1$ as there is no discontinuity present at $x = 0$ and $x = 1$.

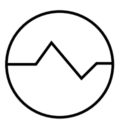
$f(x)$ is differentiable at $x = 1$.

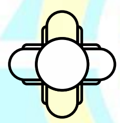
But not differentiable at $x = 0$ due to formation of cusp at $x = 0$.

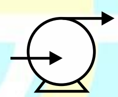
Hence, the correct statements are *A*, *C* and *D*.

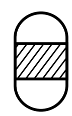
Question 31

Which of these symbols can be found in piping and instrumentation diagrams?

(P) 

(Q) 

(R) 

(S) 

(A) (P), (Q), (R) and (S)

(B) (P), (R) and (S) only

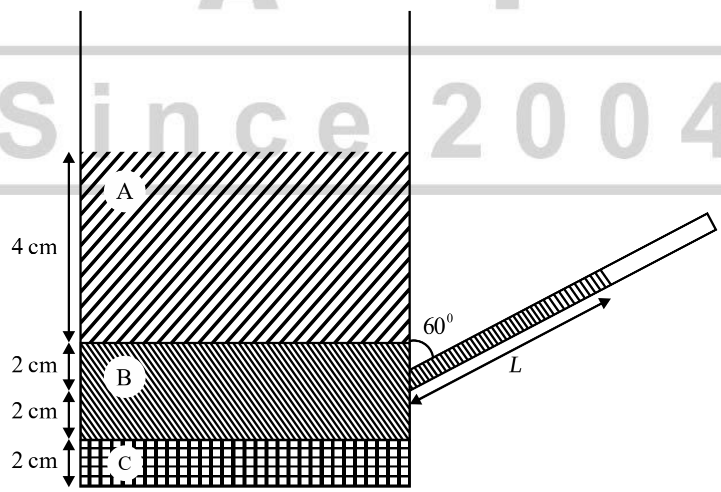
(C) (P), (Q) and (R) only

(D) (Q) and (S) only

Ans. **(B)**

Question 32

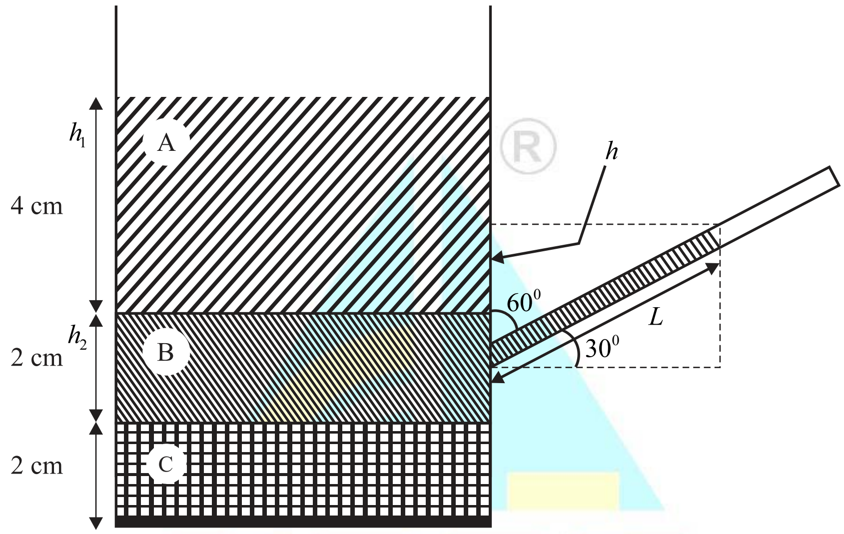
Consider a tank filled with 3 immiscible liquids *A*, *B* and *C* at static equilibrium, as shown in the figure. At 2 cm below the liquid *A* – liquid *B* interface, a tube is connected from the side of the tank. Both the tank and the tube are open to the atmosphere.



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.

Ans. **8 to 8**

Sol.



$(SG)_A = 1, (SG)_B = 2, (SG)_C = 4$

Pressure Balance

$$P_A g h_A + P_B g h_B = P_B g h \quad \text{Bothside}$$

$$P_A h_A + P_B h_B = P_B h$$

$$\frac{P_A}{P_B} h_A + \frac{P_B h}{P_B} = h$$

$$\frac{1}{2} \times 4^2 + 2 = h$$

$$4 = h$$

Ist $\quad h = L\cos 60^0 = 4$

$$L = \frac{4}{\cos 60^0} = 8 \text{ cm}$$

IInd $\quad h = L\sin 30^0$

$$4 = L \times \frac{1}{2}$$

$$L = 8 \text{ cm}$$

Question 33

For a shell-and-tube heat exchanger, the overall heat transfer coefficient is calculated as $250 \text{ W m}^{-2}\text{K}^{-1}$ for a specific process condition. It is expected that the heat exchanger may be fouled during the operation, and a fouling resistance of $0.001 \text{ m}^2\text{K W}^{-1}$ is prescribed. The dirt overall heat transfer coefficient is _______ $\text{W m}^{-2}\text{K}^{-1}$.

(A) 200 (B) 100 (C) 150 (D) 250

Ans. (A)

Sol.

$$U_{clean} = 250 \text{ W/m}^2\text{K}$$

$$R_f = 0.001 \text{ m}^2\text{K/W}$$

$$U_{dirt} = ?$$

$$\frac{1}{U_{dirt}} = \frac{1}{U_{clean}} + R_f$$

$$\frac{1}{U_{dirt}} = \frac{1}{250} + 0.001$$

$$U_{dirt} = 200 \text{ W/m}^2\text{K}$$

Question 34

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 $298 \text{ K} = -282 \text{ kJ mol}^{-1}$. At constant pressure, the molar heat capacities of N_2 and CO_2 are $33.314 \text{ J mol}^{-1}\text{K}^{-1}$ and $58.314 \text{ J mol}^{-1}\text{K}^{-1}$, respectively. Assume the heat capacities to be independent of temperature, and the gases are ideal. Take $R = 8.314 \text{ J mol}^{-1}\text{K}^{-1}$.

The final pressure in the vessel at the completion of the reaction is _______ bar. (round off to 1 decimal place)

Ans. 8.9 to 9.1

Question 35

A process has a transfer function $G(s) = \dfrac{Y(s)}{X(s)} = \dfrac{20}{90000s^2 + 240s + 1}$. 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)

Ans. 102.4 to 102.6

Sol. Given, $G(s)=\frac{Y(s)}{X(s)}=\frac{20}{90000s^2+240s+1}$

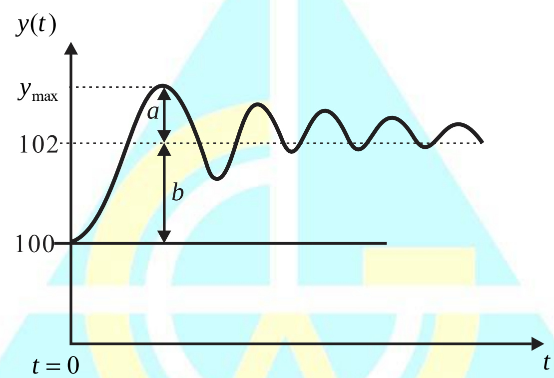
$x(t=0)=0.4$ and $y(t=0)=100$

For a step change of 0.5-0.4 $=0.1$ magnitude

$$Y(s)=\frac{20}{90000s^2+240s+1}\times\frac{0.1}{s}$$

Final value of this system

$$\lim_{s\to 0} SY(s)=\frac{2}{90000s^2+240s+1}\times\frac{s}{s}=2$$



We have to calculate value of y_{max} is this question.

From, $G(s)=\frac{20}{90000s^2+240s+1}$

$t^2=90000 \Rightarrow t=300$

$2t\rho=240 \Rightarrow \rho=0.4$

We know, overshoot $=\frac{a}{b}=\exp\left[\frac{-\pi\rho}{\sqrt{1-\rho^2}}\right]$

$a=y_{max}-102$

$b=102-100$

On solving, $\frac{y_{max}-102}{102-100}=\exp\left[\frac{-\pi(0.4)}{\sqrt{1-(0.4)^2}}\right]$

$$\frac{y_{max}-102}{2}=\exp\left[\frac{-1.2568}{0.9165}\right]$$

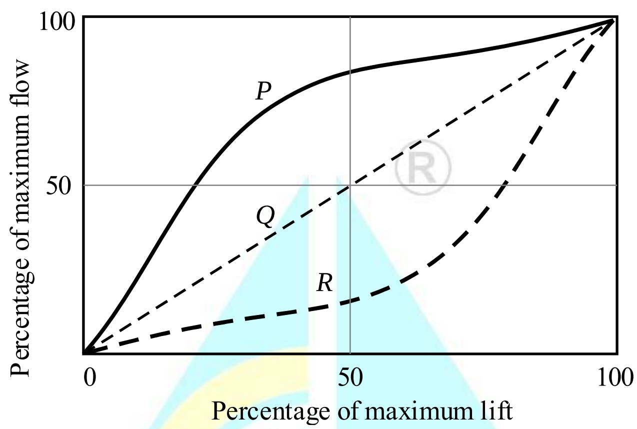
$$\frac{y_{max}-102}{2}=0.253$$

$$y_{max} - 102 = 0.5077$$

So, $y_{max} = 102.5077$

Question 36

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

Ans. **(A, D)**

Question 37

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).

Ans. **2.5 to 2.5**

Sol. $TCI = 10 \text{ lacs}$

Reverse $= 4$ lacs

$$\text{ROR} = 15\% = \frac{\text{Profit}}{TCI} \times 100 = \frac{P}{10} \times 100$$

$$P = 1.5 \text{ lacs}$$

Reverse – Operating cost = Profit

$$4 - 1.5 = 2.5 \text{ lacs operating cost}$$

Question 38

The probability distribution function of a random variable *X* is shown in the following figure.

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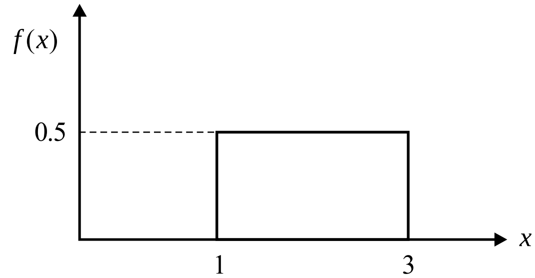
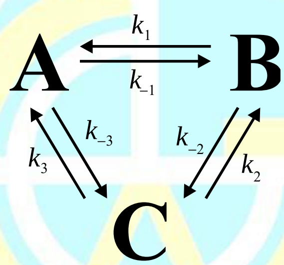


From this distribution, random samples with sample size $n = 68$ are taken. If $\bar{X}$ is the sample mean, the standard deviation of the probability distribution of $\bar{X}$, i.e. $\sigma_{\bar{X}}$ is _______. (round off to 3 decimal places)

Ans. **0.069 to 0.071**

Question 39

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}. (correct to 1 decimal place).

Ans. **0.5 to 0.5**

Sol.
$$\frac{C_C}{C_A} = \frac{1}{K_3} = K_1 \times K_2$$

$$\Rightarrow \quad \frac{P_{2-3}}{P_{23}} = \frac{P_{21}}{P_{2-1}} \times \frac{P_{22}}{P_{2-2}}$$

$$P_{2-3} = 10\left(\frac{0.1}{0.2}\right)\left(\frac{1}{10}\right)$$

$$P_{2-3} = 0.5$$

Question 40

A three dimensional velocity field is given by $V = 5x^2yi + Cyj - 10xyzk$, 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) 0 (B) 1 (C) 5 (D) -1

Ans. **(A)**

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Sol. **Given,**

$$V = 5x^2 yi + cyj - 10xyzk$$

For an incompressible flow

$$\frac{2U}{2x} + \frac{2V}{2y} + \frac{2W}{2z} = 0$$

$$U = 5x^2 y, V = cy, W = -10xyz$$

$$10xy + C - 10xy = 0$$

Hence value of $C = 0$

Question 41

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) Equal to the amount obtained when using an effective interest rate of 27.18 %.

(C) Lower than the amount obtained when the interest rate is compounded annually.

(D) Equal to 1.365 times the principal amount.

Ans. **(A)**

Sol. Final amount will be always greater, when the number of compounding intervals are increased. Option A is correct.

For Continuous Compounding

$$i_{eff} = e^r - 1 = e^{0.1} - 1 \quad \Rightarrow \quad 10.51\%$$

For monthly compounding,

$$i_{eff} = \left(1 + \frac{r}{m}\right)^m - 1 = \left(1 + \frac{0.1}{12}\right) - 1a = 10.47\%$$

Question 42

Turnover ratio is defined as

(A) $\frac{\text{Fixed capital investment}}{\text{Average selling price of the product}}$

(B) $\frac{\text{Gross annual sales}}{\text{Fixed capital investment}}$

(C) $\frac{\text{Fixed capital investment}}{\text{Gross annual sales}}$

(D) $\frac{\text{Gross annual sales}}{\text{Average selling price of the product}}$

Ans. **(B)**

Question 43

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) fluid 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 ${}^0\text{C}$, and x is in meter.

The logarithmic mean temperature difference (in ${}^0\text{C}$) is

(A) 50.0 (B) 24.6 (C) 27.9 (D) 30.0

Ans. **(C)**

Sol.

Sol.

$$T_h(x) = 80 - 3x$$

$$T_c(x) = 20 + 2x$$

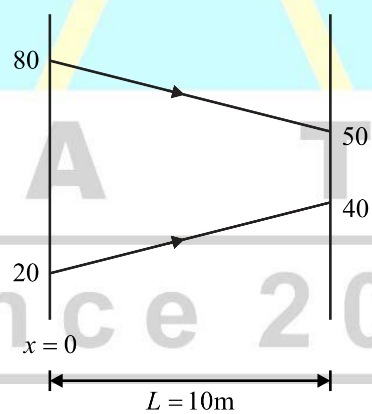
For hot fluid –

$$T_h(0) = 80 - 3(0) \Rightarrow T_h(0) = 80$$

$$T_h(10) = 80 - 3(10) \Rightarrow T_h(10) = 50$$

$$T_c(0) = 20 + 2(0) \Rightarrow T_c(0) = 40$$

$$T_c(10) = 20 + 2(10) \Rightarrow T_c(10) = 40$$



$$\text{LMTD} = \frac{60 - 10}{\ln\left(\frac{60}{10}\right)}$$

$$\text{LMTD} = 27.90$$

Thus option (3) is correct.

Question 44

Heat transfer coefficient for a vapor condensing as a film on a vertical surface is given by

(A) Dittus-Boelter equation
(B) Chilton-Colburn analogy
(C) Sieder-Tate equation
(D) Nusselt theory

Ans. **(D)**

Sol. Nusselt theory

Question 45

The following homogeneous, irreversible reaction involving ideal gases,

$$A \rightarrow B + C \qquad (-r_A) = 0.5C_A \ (\text{mol L}^{-1}\text{s}^{-1})$$

Is carried out in a steady state ideal plug flow reactor (PFR operating at isothermal and isobaric conditions. The feed stream consist of pure A, entering at 2 ms^{-1}.

In order to achieve 50 % conversion of A, the required length of the PFR is _______ meter. (round off to 2 decimal places)

Ans. **3.49 to 3.61**

Sol.

$$\frac{V_P}{F_{A0}} = \int_0^{X_A} \frac{dX_A}{-\gamma_A} \qquad -\gamma_A = 0.5C_A$$

$$\frac{V_P}{F_{A0}} = \int_0^{0.5} \frac{dX_A}{\frac{0.5C_{A0}(1-X_A)}{(1+X_A)}} \qquad -\gamma_A = \frac{0.5C_A(1-X_A)}{(1+\epsilon_A X_A)}$$

$$\frac{AL_P}{AV^2C_{A0}} = \frac{1}{0.5C_{A0}}\int_0^{0.5}\left(\frac{1+X_A}{1-X_A}\right)dX_A \qquad X_A = 0.5$$

$$L_P = \frac{2}{0.5}\left[-2\ln(1-X_A) - X_A\right]_0^{0.5} \qquad \epsilon_A = yA_0\delta_A$$

$$L_P = 3.54 \text{ m} \qquad \epsilon_A = 1\times\frac{2-1}{1} = 1$$

$$v = 2 \text{ m/sec}$$

Question 46

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 $30 \ \mu\text{m}$ and density 1100 kg m^{-3}.

Type B are spherical particles of diameter $10 \ \mu\text{m}$ and density 1900 kg m^{-3}.

Assuming that Stoke's law is valid throughout the duration of the experiment, the settled bed would

(A) Consist of type B particles only.

(B) Be completely segregated with type B particles on top of type A particles.

(C) Consist of a homogeneous mixture of type A and type B particles.

(D) Be completely segregated with type A particles on top of type B particles.

Ans. **(C)**

Sol. Batch settling exp.

Water $(P_f) = 1000\ \text{kg/m}^3$

Equal No Type A and Type B particle

Stoke's law valid

Type A $-\rho_A = 1100\ \text{kg/m}^3, (d_P)_A = 30\ \text{mm}$

Type B $-\rho_B = 1900\ \text{kg/m}^3, (d_P)_B = 10\ \text{mm}$

Terminal velocity

Type A $-\rho_B = 1900\ \text{kg/m}^3, (d_P)_B = 10\ \text{mm}$

Terminal velocity

$$u_t = \frac{d_P^2 (P_p - P_f) g}{18\mu}$$

$$\frac{u_A}{u_B} = \frac{(d_P)_A^2 (P_A - P_f) g}{(d_P)_B^2 (P_B - P_f) g}$$

$$\frac{u_A}{u_B} = \left(\frac{3P}{10}\right)^2 \left(\frac{1100 - 1000}{1900 - 1000}\right)$$

$$\frac{u_A}{\mu_B} = (3)^2 \times \left(\frac{100}{900}\right)$$

$$= 9 \times \frac{1}{9}$$

$$\frac{u_A}{\mu_B} = 1$$

$$u_A = u_B$$

Option (3) consist of a homogeneous mixture of type β particles.

Question 47

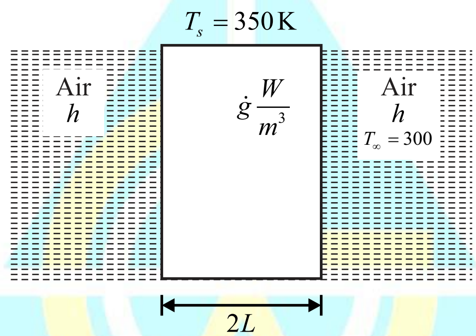
Consider a solid slab of thickness $2L$ and uniform cross section A. the volumetric rate of heat generation within the slab is $\dot{g}(\text{W m}^{-3})$. The slab loses heat by convection at both the ends to air with heat transfer coefficient *h*. Assuming steady state, one dimensional heat transfer, the temperature profile within the slab along the thickness is given by :

$$T(x)=\frac{\dot{g}L^2}{2k}\left[1-\left(\frac{x}{L}\right)^2\right]+T_s \text{ for } -L\le x\le L$$

Where k is the thermal conductivity of the slab and T_s is the surface temperature. If $T_s=350\text{ K}$, ambient air temperature $T_\infty=300\text{ K}$ and biot number (base on L as the characteristic length) is 0.5, the maximum temperature in the slab is _______ K. (round off to nearest integer)

Ans. **362 to 363**

Sol.



$$T(x)=\frac{\dot{g}L^2}{2\text{ K}}\left[1-\left(\frac{x}{L}\right)^2\right]+T_s$$

For $-L\le x\le L$

$$T_s=350\text{ K}, T_\infty=300\text{ K}$$

$$B_i=0.5$$

$$T_{max}=T_s+\frac{\dot{g}L^2}{2\text{ K}} \quad \dots \text{(i)}$$

$$\dot{g}\frac{W}{m^3}=(\dot{g}\times\text{Volume})W$$

$$\dot{g}(A)(2L)=2hA(T_s-T_\infty)$$

$$\dot{g}(L)=h(T_s-T_\infty) \quad \dots \text{(ii)}$$

$$B_i=\frac{hL}{K}=0.5$$

$$\dot{g}(L)=\frac{0.5K}{L}(T_s-T_\infty)$$

$$\dot{g} = \frac{0.5K}{L^2}(350-300)$$

$$\frac{\dot{g}L^2}{K} = 25$$

Evaluating this on equation (i)

$$T_{\max} = 350 + \left(\frac{25}{2}\right)$$

$$T_{\max} = 362.5 \text{ K}$$ **Ans.**

Question 48

Match the reaction in Group-1 with the reaction type in Group-2.

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

The correct combination is :

(A) P-II, Q-III, R-I, S-IV

(B) P-III, Q-IV, R-II, S-I

(C) P-I, Q-IV, R-III, S-II

(D) P-III, Q-IV, R-I, S-II

Ans. (D)

Question 49

A, B, C and D are vectors of length 4.

$$A = [a_1 \quad a_2 \quad a_3 \quad a_4]$$

$$B = [b_1 \quad b_2 \quad b_3 \quad b_4]$$

$$C = [c_1 \quad c_2 \quad c_3 \quad c_4]$$

$$D = [d_1 \quad d_2 \quad d_3 \quad d_4]$$

It is known that B is not a scalar multiple of A. Also, C is linearly independent of A and B. Further, $D = 3A + 2B + C$.

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 ________.

Ans. 3

Sol. **Given :**

$$A = [a_1 \quad a_2 \quad a_3 \quad a_4]$$
$$B = [b_1 \quad b_2 \quad b_3 \quad b_4]$$
$$C = [c_1 \quad c_2 \quad c_3 \quad c_4]$$
$$D = [d_1 \quad d_2 \quad d_3 \quad d_4]$$

According to question,

(i) B is not a scalar multiples of A

Hence, A and B are linearly independent

(ii) C is linearly independent of A and B $\Rightarrow$ $C \neq k_1 A + k_2 B$ where, k_1 and k_2 are arbitrary constant

(iii) $D = 3A + 2B + C$

So, D is linearly dependent on A, B, C

We know that, the rank of matrix is equal to no. of linearly independent row/column.

So, given matrix $\begin{bmatrix} a_1 & a_2 & a_3 & a_4 \\ b_1 & b_2 & b_3 & b_4 \\ c_1 & c_2 & c_3 & c_4 \\ d_1 & d_2 & d_3 & d_4 \end{bmatrix}$ have 3 linearly independent row

Hence, the rank of matrix is 3.

Question 50

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) $p_1 + \pi_1 = p_2 + \pi_2$

(B) $p_1 - \pi_1 = p_2 - \pi_2$

(C) $p_1 = p_2$

(D) $\pi_1 = \pi_2$

Ans. **(B)**

Sol. Reverse Osmosis (RO) occurs when the difference in hydraulic pressure equals the osmotic pressure difference across the membrane

i.e., $\pi_1 - \pi_2 = p_1 - p_2$

or $p_1 - \pi_1 = p_2 - \pi_2$

Question 51

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 $2\ \text{Nm}^{-2}$ has to be applied to keep the top plate moving with a velocity of $2\ \text{ms}^{-1}$, 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 $3\ \text{Nm}^{-2}$ has to be applied to keep the top plate moving with a velocity of $1\ \text{ms}^{-1}$, while the other plate is fixed.

In the range of shear rates studied, the rheological character of the fluid is

(A) Newtonian
(B) Ideal and inviscid
(C) Pseudoplastic
(D) Dilatant

Ans. **(C)**

Sol. Fluid confined between two horizontal parallel plates and sub.

Ist exp. (1)

$$\Delta y_1 = 1\ \text{mm}$$
$$\tau = 2\ \text{M/m}^2$$
$$V_{top} = 2\ \text{m/sec}$$
$$V_{Bottom} = 0$$
$$\Delta V_1 = 2\ \text{m/sec}$$

IInd exp. (2)

$$\Delta y_2 = 0.25\ \text{mm}$$
$$\tau = 3\ \text{M/m}^2$$
$$V_{top} = 1\ \text{m/sec}$$
$$V_{Bottom} = 0\ \text{m/sec}$$
$$\Delta V_2 = 1\ \text{m/sec}$$

Rheological character of the fluid

Model $$\tau = \mu\left[\frac{dV}{dy}\right]^n = \mu\left[\frac{\Delta V}{\Delta y}\right]^n$$

$$\frac{\tau_1}{\tau_2} = \frac{\mu\left(\frac{dV}{dy}\right)_1^n}{\mu\left(\frac{dV}{dy}\right)_2^n} =$$

$$\frac{2}{3}=\left[\frac{\Delta V_1\times\Delta y_2}{\Delta y_1\,\Delta V_2}\right]^n=\left[\frac{2\times 0.25}{1\times 1}\right]^n$$

$$\left(\frac{2}{3}\right)=(0.5)^n$$

$$\ln\left[\frac{2}{3}\right]=n\ln 0.5$$

$\therefore$ $$n=\frac{\ln\left[\frac{2}{3}\right]}{\ln[0.5]}$$

$$n=0.58$$

$\therefore$ if $n<1$ Pseudo plastic

Question 52

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, In γ_1 vs. x_1 and In γ_2 vs. x_1 are plotted. A tangent drawn to the In γ_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 In γ_2 vs. x_1 curve at the same mole fraction is ________. (correct to 3 decimal places)

Ans. **0.432 to 0.432**

Sol. Given, $$\frac{d\ln\gamma_1}{dX_1}=-1.728$$

$$x_1=0.2, x_2=0.8$$

$$m_2=\frac{d\ln Y_2}{dx_1}=?$$

From Gibbs duhem equation

$$x_1\frac{d\ln Y_1}{dx_1}+x_2\frac{d\ln Y_2}{dx_1}=0$$

$$0.2(-1.732)=-(0.8)\frac{d\ln Y_2}{dx_1}$$

$$\frac{d\ln Y_2}{dx_1}=0.432$$ **Ans.**

Question 53

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 _______.

Ans. **8790 to 8800**

Sol. Given,

Number of particles emitted from 1 cm $= 14$

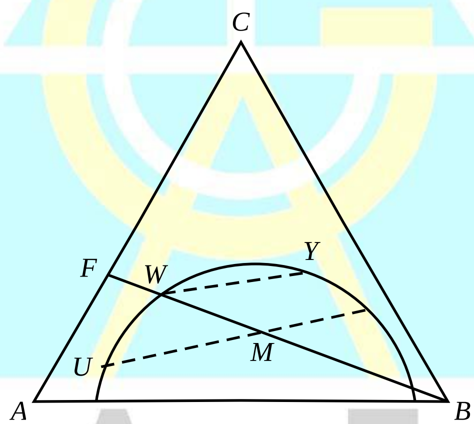
Perimeter of circle $= 2\pi \times 100 = 200\pi$

$= 628$ cm

Number of particles emitted from entire perimeter $= 628 \times 14 = 8792$

Question 54

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) *Y* represents the composition of extract when minimum amount of solvent is used

(B) Maximum amount of solvent is required if the mixture composition is at *W*

(C) For the tie-lines shown, concentration of solute in the extract is higher than that in the raffinate

(D) *U* represents the raffinate composition if the mixture composition is at *M*

Ans. **(A, C, D)**

Question 55

A feedforward controller can be used only if

(A) the disturbance variable can be ignored

(B) regulatory control is not required

(C) the disturbance variable can be measured

(D) the disturbance variable can be manipulated

Ans. **(C)**

❖❖❖❖

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