

**Chemical Engineering**

**Q. No. 1 – 25 Carry One Mark Each**

1. In a venturi meter,  $\Delta P_1$  and  $\Delta P_2$  are the pressure drops corresponding to volumetric flow rates  $Q_1$  and  $Q_2$ . If  $\frac{Q_2}{Q_1} = 2$ , then  $\frac{\Delta P_2}{\Delta P_1}$  equals
- (A) 2                                      (B) 4                                      (C) 0.5                                      (D) 0.25

**Key: B**

**Exp:**

$$\frac{\Delta p}{\rho g} = \frac{fLQ^2}{12D^5}$$

$$\Delta P \propto Q^2$$

$$\text{So } \frac{\Delta p_2}{\Delta p_1} = \left(\frac{Q_2}{Q_1}\right)^2 = 2^2 = 4$$

2. The volumetric properties of two gases M and N are described by the generalized compressibility chart which expresses the compressibility factor ( $Z$ ) as a function of reduced pressure and reduced temperature only. The operating pressure ( $P$ ) and temperature ( $T$ ) of two gases M and N along with their critical properties ( $P_c, T_c$ ) are given in the table below.

Gas	P(bar)	T(K)	$P_c$ (bar)	$T_c$ (K)
M	25	300	75	150
N	75	1000	225	500

$Z_M$  and  $Z_N$  are the compressibility factor of the gases M and N under the given operating conditions respectively.

The relation between  $Z_M$  and  $z_N$  is

- (A)  $z_M = 8Z_N$                                       (B)  $Z_M = 3Z_N$   
 (C)  $Z_M = Z_N$                                       (D)  $Z_M = 0.333Z_N$

**Key: C**

**Exp:** For gas M;  $P = 25$  bar,  $P_c = 75$  bar

$$P_r = \frac{P}{P_c} = \frac{25}{75} = \frac{1}{3}$$

For Gas N;  $P = 75$  bar,  $P_c = 225$  bar

$$P_r = \frac{75}{225} = \frac{1}{3}$$

$$\text{For Gas M; } T = 300\text{K, } T_c = 150\text{K, } T_r = \frac{T}{T_c} = 2$$

$$\text{For Gas N, } T = 1000\text{K, } T_c = 500\text{K, } T_r = \frac{T}{T_c} = 2$$

$$\text{Compressibility factor, } Z = k \frac{P_r}{T_r}$$

$$Z_m = \frac{K \left(\frac{1}{3}\right)}{2} = \frac{K}{6}$$

$$Z_n = \frac{K \left(\frac{1}{3}\right)}{2} = \frac{K}{6}$$

$$Z_m = Z_n$$

3. Match the polymerization process in Group-1 with the polymers in Group-2.

**Group-1**

- P) Free radical polymerization  
Q) Ziegler Natta polymerization  
R) Condensation polymerization  
Choose the correct set of combinations.

**Group-2**

- I) Nylon 6.6  
II) Polypropylene  
III) Poly vinyl chloride

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

Key: C

- Exp: P. Free Radical Polymerisation III) Poly Vinyl Chloride  
Q. Zeigler Natta Polymerisation II) Polypropylene  
R. condensation Polymerisation I) Nylon 6, 6

4. An LVDT (Linear Variable Differential Transformer) is a transducer used for converting

- (A) displacement to voltage (B) Voltage to displacement  
(C) resistance to voltage (D) voltage to current

Key: A

Exp: LVDT converts displacement to voltage.

5. Match the variables in Group-1 with the instruments in Group-2.

**Group-1**

- P) Temperature  
Q) Liquid level  
Choose the correct set of combinations.

**Group-2**

- I) Capacitance probe  
II) McLeod gauge

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

Key: C

6. The thickness of laminar boundary layer over a flat plate varies along the distance from the leading edge of the plate. As the distance increases, the boundary layer thickness
- (A) increases (B) decreases  
(C) initially increases and then decreases (D) initially decreases and then increases

Key: C

Exp:  $S \propto \sqrt{X}$

If  $X \uparrow \rightarrow S \uparrow$

7. The marks obtained by a set of students are 38, 84, 45, 70, 75, 60, 48. The mean and median marks, respectively, are
- (A) 45 and 75 (B) 55 and 48  
(C) 60 and 60 (D) 60 and 70

Key: C

Exp: Mean =  $\frac{38 + 84 + 45 + 70 + 75 + 60 + 48}{7} = 60$

In ascending order

38, 45, 48, **60**, 70, 75, 84

Median = Middle most observation = 60

8. In a heat exchanger, the inner diameter of a tube is 25 mm and its outer diameter is 30 mm. The overall heat transfer coefficient based on the inner area is  $360 \text{ W/m}^2 \cdot ^\circ\text{C}$ . Then, the overall heat transfer coefficient based on the outer area, rounded to the nearest integer, is \_\_\_  $\text{W/m}^2 \cdot ^\circ\text{C}$ .

Key: 300

Exp:

$D_i = 25 \text{ mm}$

$D_o = 30 \text{ mm}$

$V_i = 360 \text{ W/m}^2$

$\therefore V_i A_i = V_o A_o$

$V_o = V_i \frac{A_i}{A_o} = V_i \frac{D_i}{D_o}$

$= 360 \times \frac{25}{30}$

$= 300 \text{ W/m}^2 \cdot ^\circ\text{C}$

9. The cost of a new pump (including installation) is 24,000 Rupees. The pump has useful life of 10 years. Its salvage value is 4000 Rupees. Assuming straight line depreciation, the book value of the pump at the end of 4<sup>th</sup> year, rounded to the nearest integer, is \_\_\_ Rupees.

Key: 16000

Exp: Cost of new pump = Rs24000

Useful life of pump = 10 years

Slavage value of pump at the end of service life = 4000

Annual Depreciation using straight line method =  $(24000-4000)/10 = 2000$  Rs

Book Value at the end of 4<sup>th</sup> year = Cost of equipment – Accumulated Depreciation till the end of 4<sup>th</sup>yr

$$\begin{aligned} &= 24000 - (4 \times \text{yearly depreciation}) \\ &= 24000 - (4 \times 2000) \\ &= 24000 - 8000 \\ &= 16000 \text{ Rs} \end{aligned}$$

10. A gas bubble (gas density  $\rho_g = 2 \text{ kg/m}^3$ ; bubble diameter  $D = 10^{-4} \text{ m}$ ) is rising vertically through water (density  $\rho = 1000 \text{ kg/m}^3$ ; viscosity  $\mu = 0.001 \text{ Pa.s}$ ). Force balance on the bubble leads to the following equation,

$$\frac{dv}{dt} = -g \frac{\rho_g - \rho}{\rho_g} - \frac{18\mu}{\rho_g D^2} v$$

Where  $v$  is the velocity of the bubble at any given time  $t$ . Assume that the volume of the rising bubble does not change. The value of  $g = 9.81 \text{ m/s}^2$ .

The terminal rising velocity of the bubble (in cm/s), rounded to 2 decimal places, is \_\_\_ cm/s.

Key: 0.54

Exp: At terminal missing velocity

$$\frac{dv}{dt} = 0 = -g \frac{\rho_g - \rho}{\rho_g} - \frac{18\mu}{\rho_g D^2} v$$

We get,

$$\begin{aligned} v &= \frac{gD^2(\rho - \rho_g)}{18\mu} \\ &= \frac{9.81 \times (10^{-4})^2 (1000 - 2)}{18(0.001)} \\ &= 5.439 \times 10^{-3} \text{ m/s} \\ &= 0.54 \text{ cm/s} \end{aligned}$$

11. Water is heated at atmospheric pressure from  $40^\circ\text{C}$  to  $80^\circ\text{C}$  using two different processes. In process I, the heating is done by a source at  $80^\circ\text{C}$ . In process II, the water is first heated from  $40^\circ\text{C}$  to  $60^\circ\text{C}$  by a source at  $60^\circ\text{C}$ , and then from  $60^\circ\text{C}$  to  $80^\circ\text{C}$  by another source at  $80^\circ\text{C}$ .

Identify the correct statement.

- (A) Enthalpy change of water in process I is greater than enthalpy change in process II
- (B) Enthalpy change of water in process II is greater than enthalpy change in process I
- (C) Process I is closer to reversibility
- (D) Process II is closer to reversibility

Key: D

12. The DCDA (Double Contact Double Absorption) process is used the manufacture of  
 (A) Urea (B) Sulphuric acid (C) nitric acid (D) ammonia

**Key: B**

**Exp:** The contact process is the current method of producing sulphuric acid in the high concentrations needed for industrial processes. Platinum used to be the catalyst for this reaction; however, as it is susceptible to reacting with arsenic impurities in the sulphuric feedstock, vanadium (V) oxide ( $V_2O_5$ ) is now preferred.

13. The real part of  $6e^{i\pi/3}$  is \_\_\_\_

**Key: 3**

**Exp:**  $6e^{i\pi/3} = 6\left(\cos\frac{\pi}{3} + i\sin\frac{\pi}{3}\right)$

$$= 6\cos\frac{\pi}{3} + i\left(6\sin\frac{\pi}{3}\right)$$

Real part =  $6\cos\frac{\pi}{3}$

$$= 6 \times \frac{1}{2} = 3$$

14. Consider a first order catalytic reaction in a porous catalyst pellet. Given  $R$  - characteristic length of the pellet;  $D_e$  - effective diffusivity;  $k_c$  - mass transfer coefficient;  $k_1$  - rate constant based on volume of the catalyst pellet;  $C_s$  - concentration of reactant on the pellet surface.

The expression for Thiele modulus is

(A)  $\frac{k_c R}{D_e}$  (B)  $\sqrt{\frac{k_1}{D_e}}$  (C)  $R\sqrt{\frac{k_1 C_s}{D_e}}$  (D)  $R\sqrt{\frac{D_e}{k_1}}$

**Key: B**

15. Which of the following conditions are valid at the plait point?  
 P) Density difference between the extract and raffinate phases is zero  
 Q) Interfacial tension between the extract and raffinate phases is zero  
 R) Composition difference between the extract and raffinate phases is zero

(A) P and Q only (B) Q and R only (C) P and R only (D) P, Q and R

**Key: D**

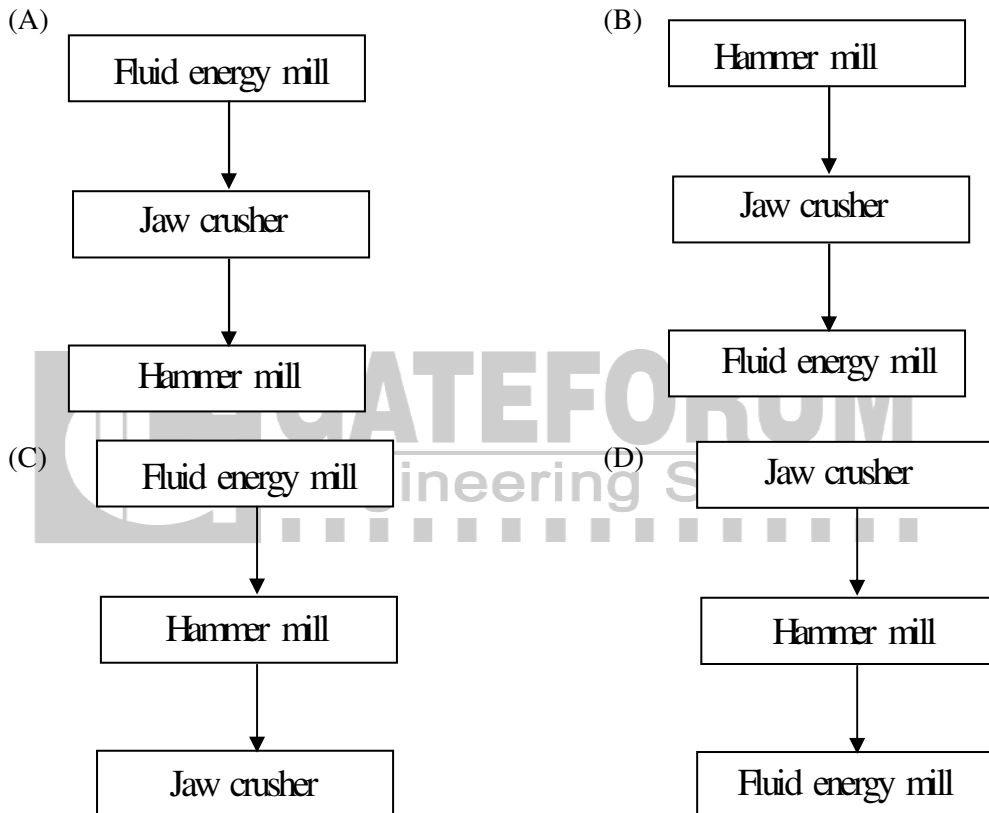
**Exp:** Plait point signifies the condition at which the composition of two liquid phases in equilibrium become identical and indeed transforms to a single phase. At this point interfacial tension and density difference between extract and raffinate phase is zero as both phases united to form one phase.

16. The purpose of the mathanation reaction used in ammonia plants is to

- (A) remove CO as it is a catalyst poison
- (B) increase the amount of hydrogen
- (C) remove sulphur as it is catalyst poison
- (D) utilize methane as a catalyst for ammonia synthesis

Key: A

17. Which of the following is the correct sequence of equipment for size reduction of solids?



Key: D

Exp: Solid is crushed into intermediate by jaw crusher after which grinding of solid is done by hammer mill. Ultrafine grinding is done by fluid energy mill.

18. Let  $\mathbf{i}$  and  $\mathbf{j}$  be the unit vectors in the  $x$  and  $y$  directions, respectively. For the function

$$F(x, y) = x^3 + y^2$$

the gradient of the function i.e..  $\nabla F$  is given by

- (A)  $3x^2 \mathbf{i} - 2y \mathbf{j}$
- (B)  $6x^2 y$
- (C)  $3x^2 \mathbf{i} + 2y \mathbf{j}$
- (D)  $2y \mathbf{i} - 3x^2 \mathbf{j}$

Key: C

Exp:  $\nabla F = \mathbf{i} \frac{\partial F}{\partial x} + \mathbf{j} \frac{\partial F}{\partial y} = \mathbf{i}(3x^2) + \mathbf{j}(2y)$

19. Consider steady state mass transfer of a solute A from a gas phase to a liquid phase. The gas phase bulk and interface mole fractions are  $y_{A,G}$  and  $y_{A,i}$  respectively. The liquid phase bulk and interface mole fractions are  $x_{A,L}$  and  $x_{A,i}$ , respectively. The ratio  $\frac{(x_{A,i} - x_{A,L})}{(y_{A,G} - y_{A,i})}$  is very close to zero.

The implies that mass transfer resistance is

- (A) negligible in the gas phase only
- (B) negligible in the liquid phase only
- (C) negligible in both the phases
- (D) considerable in both the phases

Key: B

Exp: Here  $\frac{(x_{A,i} - x_{A,L})}{(y_{A,G} - y_{A,i})} = 0$

Or  $x_{A,i} - x_{A,L} = 0$   
 $x_{A,i} = x_{A,L}$

Mole fraction of liquid phase interface is equal to mole fraction of liquid phase bulk. It means resistance in the liquid phase is negligible.

Option (B) is correct

20. The value of  $\lim_{x \rightarrow 0} \frac{\tan(x)}{x}$  is \_\_\_\_\_.

Key: 1

Exp:  $\lim_{x \rightarrow 0} \frac{\tan x}{x} = 1$

21. For a solid-catalyzed gas phase reversible reaction, which of the following statements is ALWAYS TRUE?
- (A) Adsorption is rate-limiting
  - (B) Desorption is rate-limiting
  - (C) Solid catalyst does not affect equilibrium conversion
  - (D) Temperature does not affect equilibrium conversion

Key: C

Exp: Solid catalyst does not effect the equilibrium conversion.

22. The one-dimensional unsteady heat conduction equation is

$$\rho C_p \frac{\partial T}{\partial t} = \frac{1}{r^n} \frac{\partial}{\partial r} \left( r^n k \frac{\partial T}{\partial r} \right)$$

Where, T – temperature, t – time, r – radial position, k – thermal conductivity,  $\rho$  - density, and  $C_p$  - specific heat.

For the cylindrical coordinate system, the value of n in the above equation is

- (A) 0
- (B) 1
- (C) 2
- (D) 3

Key: B

Exp:  $n = 1$  for cylindrical coordinate system

$$\frac{1}{r} \frac{\partial}{\partial r} \left( rk \frac{\partial T}{\partial r} \right) = \rho C_p \frac{\partial T}{\partial t}$$

23. The composition of vapour entering a tray in a distillation column is 0.47. The average composition of the vapour leaving the tray is 0.53. The equilibrium composition of the vapour corresponding to the liquid leaving this tray is 0.52. All the compositions are expressed in mole fraction of the more volatile component.

The Murphree efficiency based on the vapour phase, rounded to the nearest integer, is \_\_\_\_ %.

Key: 120

Exp: Murphree efficiency is defined as the actual change in average composition accomplished by a given tray divided by the change in average composition.  $\eta_m = \frac{y^1 - y}{y_e - y}$

$$\eta_m = \frac{0.53 - 0.47}{0.52 - 0.47} \times 100 = 120\%$$

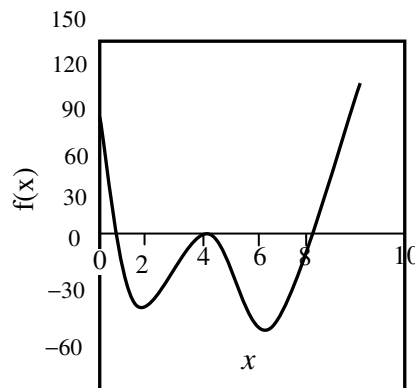
Where,

$y^1$  = Average composition of vapour leaving the tray.

$y_e$  = Equilibrium composition of vapour corresponding to the liquid leaving the tray.

$y$  = Composition of vapour entering the tray.

24. The number of positive roots of the function  $f(x)$  shown below in the range  $0 < x < 6$  is \_\_\_\_.



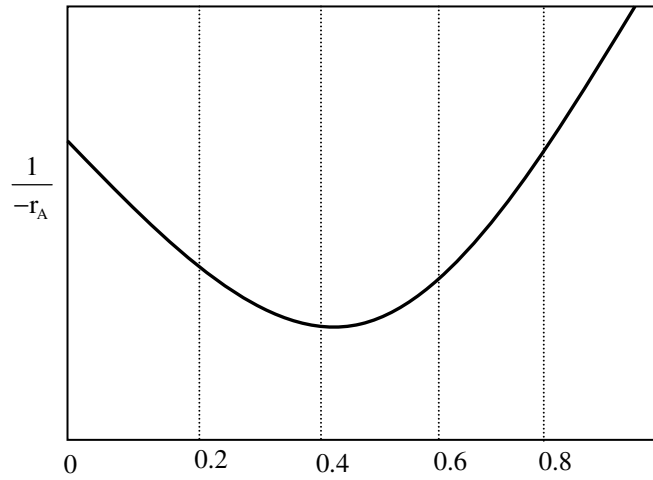
Key: 3

Exp: The graph of the function cuts x – axis in 3 times in  $0 < x < 6$

$\therefore$  The no. of positive roots=3



25. The following reaction rate curve is shown for a reaction  $A \rightarrow P$ . Here,  $(-r_A)$  and  $x_A$  represent reaction rate and conversion, respectively. The feed is pure A and 90% conversion is desired



Which amongst the following reactor configurations gives the lowest total volume of the reactor (s)?

- (A) CSTR followed by PFR (B) Two CSTRs in series  
(C) PFR followed by CSTR (D) A single PFR

Key: A

Exp: The performance equation for a PFR

$$\frac{\tau}{C_{Ao}} = \frac{V}{F_{Ao}} = \int_0^{x_A} \frac{dX_A}{-r_A}$$

Hence the volume required for the reactor for given conversion is

$$V = F_{Ao} \int_0^{x_A} \frac{dX_A}{-r_A}$$

Which is the area under curve between  $-\frac{1}{r_A}$  versus  $X_A$

The performance equation for a CSTR

$$\frac{\tau}{C_{Ao}} = \frac{V}{F_{Ao}} = \frac{X_A}{-r_A}$$

Hence the volume required for the reactor for given conversion is

$$V = F_{Ao} \frac{X_A}{-r_A}$$

Which is the volume of rectangle drawn on the graph between  $-\frac{1}{r_A}$  versus  $X_A$  for the given conversion.

For the given reaction,

The following options give the following volumes

Set up	Volume
CSTR followed by PFR	Area of rectangle from 0 to 0.5 and area under curve from 0.5 to 1
Two CSTRs in series	Area of two rectangles (from 0 to 0.5 and 0.5 to 1)
PFR followed by CSTR	Area under curve from 0 to 0.5 and area of rectangle from 0.5 to 1
A single PFR	Area under the curve.

Its clearly shown the combination of CSTR followed by PFR  
Hence answer is Option A.

**Q. No. 26 to 55 Carry Two Marks Each**

26. The total cost ( $C_T$ ) of an equipment in terms of the operation variables  $x$  and  $y$  is

$$C_T = 2x + \frac{12000}{xy} + y + 5$$

The optimal value of  $C_T$ , rounded to 1 decimal place, is \_\_\_\_.

Key: 91.5

Exp: The total cost of an equipment in terms of the operating variables  $x$  and  $y$  is

$$C_T = 2x + \frac{12000}{xy} + y + 5$$

To find optimum value of  $C_T$ ,

$$\frac{\partial C_T}{\partial x} = 0 \Rightarrow 2 - \frac{12000}{x^2 y} = 0$$

$$2x^2 y = 12000 \text{-----} \rightarrow (1)$$

and

$$\frac{\partial C_T}{\partial y} = 0 \Rightarrow 1 - \frac{12000}{xy^2} = 0$$

$$xy^2 = 12000 \text{-----} \rightarrow (2)$$

Solving equation (1) and (2) yields

$$X=14.4 \text{ and } y= 28.8$$

Hence the optimum value of  $C_T$  is 91.5

27. The vapour pressure of a pure substance at a temperature  $T$  is 30bar. The actual and ideal gas values of  $g / RT$  for the saturated vapour at this temperature  $T$  and 30 bar are 7.0 and 7.7, respectively. Here,  $g$  is the molar Gibbs free energy and  $R$  is the universal gas constant.

The fugacity of the saturated liquid at these conditions, rounded to 1 decimal place, is \_\_\_\_ bar.

Key: 15

Exp:  $\left(\frac{g}{RT}\right) = 7, \left(\frac{g}{RT}\right) = 7.7$

As we know

$$\phi_x = \frac{f_i}{p} = \exp\left(\frac{g^R}{RT}\right)$$

$$\frac{g^R}{RT} = \left(\frac{g}{RT}\right) - \left(\frac{g}{RT}\right)_{ig} = 7 - 7.7$$

$$\frac{g^R}{RT} = -0.7$$

$$= \frac{f_i}{p} = \rho \times p(-0.7)$$

$$f_i = 30 \exp(-0.7) = 14.9 \text{ bar}$$

28. The Sherwood number ( $Sh_L$ ) correlation for laminar flow over a flat plate of length  $L$  is given by

$$Sh_L = 0.664 Re_L^{0.5} Sc^{1/3}$$

Where  $Re_L$  and  $Sc$  represent Reynolds number and Schmidt number, respectively.

This correlation, expressed in the form of Chilton-Colburn  $j_D$  factor, is

- (A)  $j_D = 0.664$  (B)  $j_D = 0.664 Re_L^{-0.5}$   
(C)  $j_D = 0.664 Re_L$  (D)  $j_D = 0.664 Re_L^{0.5} Sc^{2/3}$

Key: B

Exp:  $Sh_L = 0.664 Re_L^{0.5} Sc^{1/3} \rightarrow (1)$

$$\text{Chilton- Colburn factor } j_D = \frac{Sh_L}{Re_L Sc^{1/3}}$$

$$Sh_L = j_D \cdot Re_L \cdot Sc^{1/3} \rightarrow (2)$$

From equation (1) & (2)

$$j_D Re_L \cdot Sc^{1/3} = 0.664 Re_L^{0.5} Sc^{1/3}$$

$$j_D = 0.664 Re_L^{-0.5}$$

29. For the initial value problem

$$\frac{dx}{dt} = \sin(t), \quad x(0) = 0$$

the value of  $x$  at  $t = \pi/3$ , is \_\_\_\_\_.

Key: 0.5

Exp:  $\frac{dx}{dt} = \sin t$

$$\Rightarrow \int dx = \int \sin t \, dt$$

$$\Rightarrow x = -\cos t + C$$

Given,

$$x(0) = 0 \Rightarrow \text{at } t = 0 \Rightarrow x = 0$$

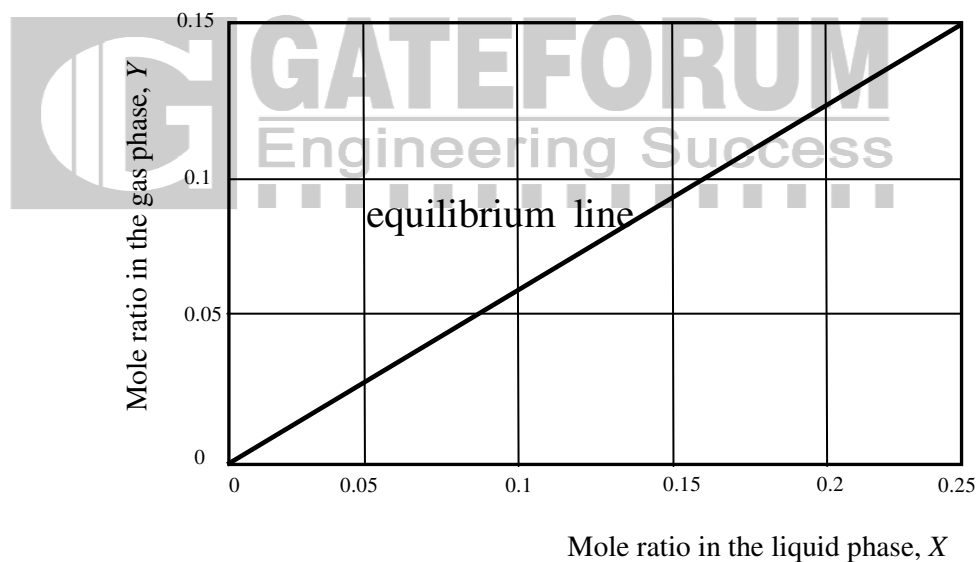
$$\Rightarrow 0 = -1 + C$$

$$\Rightarrow C = 1$$

$$\therefore x = -\cos t + 1$$

$$\begin{aligned} \text{at } t = \frac{\pi}{3}, x &= -\cos \frac{\pi}{3} + 1 \\ &= \frac{-1}{2} + 1 = \frac{1}{2} = 0.5 \end{aligned}$$

30. In a counter current stripping operation using pure steam the mole ratio of a solute in the liquid stream is reduced from 0.25 to 0.05. The liquid feed flowrate, on a solute-free basis, is 3 mole/s. The equilibrium line for the system is given in the figure below.



The MINIMUM flowrate of pure steam for this process, rounded to 1 decimal place, is \_\_\_\_ mol/s.

Key: 4

Exp: Equation of equilibrium line can be written as  $y = mX$

$$m = \text{slope of equilibrium line} = \frac{0.15}{0.25} = 0.6$$

$$y = 0.6X$$

$$\text{Material balance of solute gives } L(0.25 - 0.05) = G_{\min} [0.6(0.25)]$$

Here,  $L = 3 \text{ mol/sec}$ ,  $G = \text{minimum flow rate of pure steam}$

$$G_{\min} = \frac{3(0.25 - 0.05)}{0.6(0.25)}$$

$$= 4 \text{ mol / sec}$$

31. The Laplace transform of a function is  $\frac{S+1}{S(S+2)}$ . The initial and final values, respectively, of the function are

- (A) 0 and 1  
 (B) 1 and  $\frac{1}{2}$   
 (C)  $\frac{1}{2}$  and 1  
 (D)  $\frac{1}{2}$  and 0

**Key: B**

**Exp:**

For initial value, finding  $\lim_{s \rightarrow \infty} sF(s) = \lim_{s \rightarrow \infty} s \frac{S+1}{S(S+2)}$

$$= \lim_{s \rightarrow \infty} \frac{s \left(1 + \frac{1}{s}\right)}{s \left(1 + \frac{2}{s}\right)}$$

$$= \frac{1+0}{1+0} = 1$$

For final value, Finding  $\lim_{s \rightarrow 0} sF(s) = \lim_{s \rightarrow 0} s \frac{S+1}{S(S+2)}$

$$= \frac{1}{2}$$

32. The following table provides four sets of Fanning friction factor data, for different values of Reynolds number (Re) and roughness factor  $\left(\frac{k}{D}\right)$ .

	$R_e$	$10^2$	$10^3$	$10^5$	$10^5$
	$\left(\frac{k}{D}\right)$	0	0.001	0	0.001
<b>Set I</b>	<b><i>f</i></b>	<b>0.16</b>	<b>0.016</b>	$16 \times 10^{-5}$	$16 \times 10^{-5}$
<b>Set II</b>	<b><i>f</i></b>	<b>0.016</b>	<b>0.16</b>	<b>0.0055</b>	<b>0.0045</b>
<b>Set III</b>	<b><i>f</i></b>	<b>0.16</b>	<b>0.016</b>	<b>0.0045</b>	<b>0.0055</b>
<b>Set IV</b>	<b><i>f</i></b>	<b>0.0045</b>	<b>0.0055</b>	<b>0.016</b>	<b>0.16</b>

Which of the above sets of friction factor data is correct?

- (A) Set I (B) Set II (C) Set III (D) Set IV

**Key: C**

33. In a batch adsorption process, 5 g of fresh adsorbent is used to treat 1 litre of an aqueous phenol solution. The initial phenol concentration is 100 mg/litre. The equilibrium relation is given by  $q^* = 1.3C$  Where.  $q^*$  is the amount of phenol adsorbed in mg of phenol per gram of adsorbent; and  $C$  is the concentration of phenol adsorbed in mg/litre in the aqueous solution. When equilibrium is attained between the adsorbent and the solution, the concentration of phenol in the solution, rounded to 1 decimal place is \_\_\_\_\_ mg/litre.

Key: 13.34

Exp: Suppose  $y$  mg of phenol is adsorbed

$$q^* = \frac{\text{Amount of phenol adsorbed in mg}}{\text{wt.of fresh adsorbent}} = \frac{y}{5}$$

$$q^* = 1.3C$$

$$C = 100 - y$$

$$\frac{y}{5} = 1.3(100 - y)$$

$$0.15384y = 100 - y$$

$$y = 86.66 \text{ mg}$$

Concentration of phenol in solution

$$= 100 - 86.66$$

$$= 13.34 \text{ mg / lt}$$

34. A bond has a maturity value of 20,000 Rupees at the end of 4 years. The interest is compounded at the rate of 5% per year. The initial investment to be made, rounded to the nearest integer, is \_\_\_\_\_ Rupees.

Key: 16454

Exp: Maturity value = 20000

Bond life = 4 years

Interest rate = 5%

Amount of investment to be made can be found from present worth formula

$$= 20000 / (1 + 0.05)^4$$

$$= 16454.04$$

$$= 16454 \text{ Rs}$$

35. Size analysis was carried out on a sample of gravel. The data for mass fraction ( $x_i$ ) and average particle diameter ( $D_{pi}$ ) of the fraction is given in the table below:

$x_i$	$D_{Pi} \text{ (mm)}$
0.2	5
0.4	10
0.4	20

The mass mean diameter of the sample, to the nearest integer, is \_\_\_\_\_ mm.

Key: 13

Exp:  $\sum x_i = 1$

$$\begin{aligned} \text{Mass mean diameter of sample} &= \sum x_i D_{pi} / \sum x_i \\ &= (0.2 \times 5) + (0.4 \times 10) + (0.4 \times 20) \\ &= 13 \text{ mm} \end{aligned}$$

36. A propeller (diameter  $D = 15$  m) rotates at  $N = 1$  revolution per second (rps). To understand the flow around the propeller, a lab-scale model is made. Important parameters to study the flow are velocity of the propeller tip ( $V = \pi ND$ ), diameter  $D$  and acceleration due to gravity ( $g$ ). The lab-scale model is  $1/100^{\text{th}}$  of the size of the actual propeller.

The rotation speed of the lab-scale model, to the nearest integer, should be \_\_\_\_\_ rps.

37. The transfer function of a system is

$$\frac{1}{4S^2 + 1.2S + 1}$$

For a unit step increase in the input, the fractional overshoot, rounded to 2 decimal places, is \_\_\_\_\_.

Key: 37.23

Exp: Transfer function =  $\frac{1}{4S^2 + 1.2S + 1}$

$$\Rightarrow \frac{\frac{1}{4}}{\frac{4}{4}S^2 + \frac{1.2}{4}S + \frac{1}{4}} = \frac{0.25}{S^2 + 0.3S + 0.25}$$

Denominator is in the form of  $S^2 + 2Sw_n S + w_n^2$

We can infer  $w_n^2 = 0.25$

$$w_n = \sqrt{0.25} = 0.5$$

$$\text{and } 2Sw_n S = 2S \times 0.5 = 0.3$$

$$\text{damping rate, } S = \frac{0.3}{2 \times 0.5} = 0.3$$

$$\text{Peak over shoot} = \frac{-S\pi}{\sqrt{1-S^2}} \times 100$$

$$= \frac{-0.3\pi}{\sqrt{1-(0.3)^2}} \times 100$$

$$= 37.23\%$$

38. A fluid over a heated horizontal plate maintained at temperature  $T_w$ . The bulk temperature of the fluid is  $T_\infty$ . The temperature profile in the thermal boundary layer is given by:

$$T = T_w + (T_w - T_\infty) \left[ \frac{1}{2} \left( \frac{y}{\delta_t} \right)^3 - \frac{3}{2} \left( \frac{y}{\delta_t} \right) \right], \quad 0 \leq y \leq \delta_t$$

Here,  $y$  is the vertical distance from the plate,  $\delta_t$  is the thickness of the thermal boundary layer and  $k$  is the thermal conductivity of the fluid.

The local heat transfer coefficient is given by

(A)  $\frac{k}{2\delta_t}$                       (B)  $\frac{k}{\delta_t}$                       (C)  $\frac{3k}{2\delta_t}$                       (D)  $2\frac{k}{\delta_t}$

Key: C

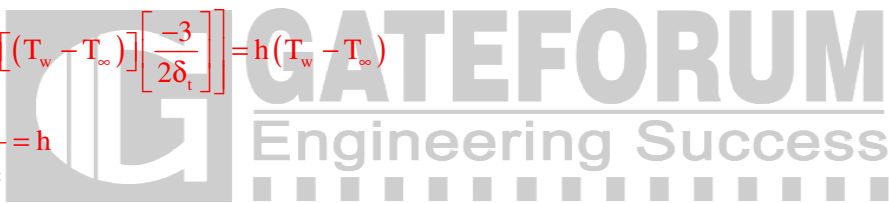
Exp:

$$T = T_{kl} + (T_{kl} - T_\infty) \left[ \frac{1}{2} \left[ \frac{y}{\delta_t} \right]^3 - \frac{3}{2} \left[ \frac{y}{\delta_t} \right] \right], \quad 0 \leq y \leq \delta_t$$

$$-k \left. \frac{\partial T}{\partial y} \right|_{y=0} = h(T_w - T_\infty)$$

$$-k \left[ (T_w - T_\infty) \left[ \frac{-3}{2\delta_t} \right] \right] = h(T_w - T_\infty)$$

$$\frac{3k}{2\delta_t} = h$$



39. The following liquid second-order reaction is carried out in an isothermal CSTR at steady state  $A \rightarrow R$  ( $-r_A$ ) = 0.005 $C_A^2$  mol / m<sup>3</sup>.hr where  $C_A$  is the concentration of the reactant in the CSTR. The reactor volume is 2 m<sup>3</sup>, the inlet flow rate is 0.5 m<sup>3</sup> / hr and the inlet concentration of the reactant is 1000mol / m<sup>3</sup>.

The fractional conversion, rounded to 2 decimal places, is \_\_\_\_\_.

Key:0.80

Exp: For a CSTR, The performance equation can be written as

$$V/F_0 = T/C_{A0} = X_A / -r_A$$

$$V/v_0 = T = C_{A0} X_A / -r_A$$

$$(2/0.5) = (C_{A0} X_A) / (0.005 C_A^2)$$

$$4 = (C_{A0} X_A) / (0.005 C_{A0}^2 (1 - X_A)^2)$$

Solving this equation yields,  $X_A$  as 0.80 or 80%.

40. Reaction  $A \rightarrow B$  is carried out in a reactor operating at steady state and 1 mol/s of pure A at 425°C enters the reactor. The outlet stream leaves the reactor at 325°C. The heat input to the reactor is 17. The heat of reaction at the reference temperature of 25°C is 30kJ/mol. The specific heat capacities (in kJ/mol.K) of A and B are 0.1 and 0.15, respectively.

The molar flowrate of B leaving the reactor, rounded to 2 decimal places, is \_\_\_\_ mol/s.

Key: 0.6



Exp:  $A \rightarrow B$

Suppose  $X$  be the conversion of reactant

$$T_1 = 425^\circ\text{C}, \Delta H_x = 30\text{ kJ/mol} = 30000\text{ J/mol}$$

$$Q = 17\text{ kW} = 17000\text{ J}, T_2 = 325^\circ\text{C}$$

$$T_{\text{tpf}} = 25^\circ\text{C}, F_{A_0} = 1\text{ mol/sec}, F_A = (1-x)F_{A_0}$$

$$C_{PA} = 0.1\text{ kJ/mol}, C_{PB} = 0.15\text{ kJ/mol}, F_B = xF_{A_0}$$

Heat balance gives

$$F_{A_0} C_{PA} (T_2 - T_{\text{tpf}}) = F_A C_{PA} (T_2 - T_{\text{tpf}}) + F_B C_{PB} (T_2 - T_{\text{tpf}})$$

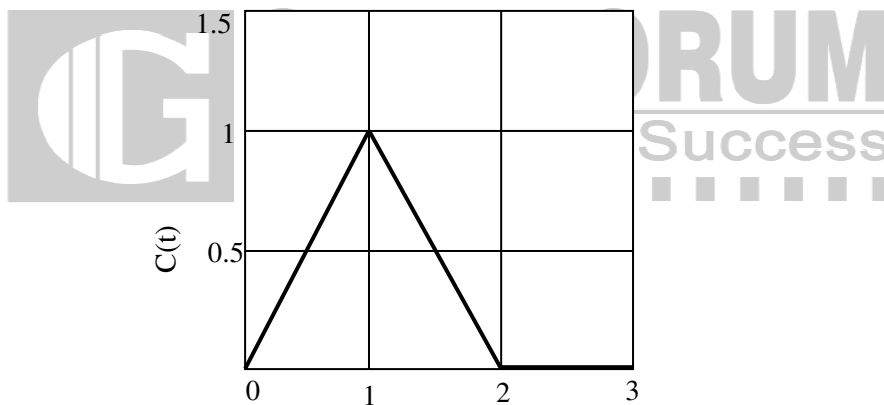
$$1 \times 0.1(425 - 25) = 0.1(1-x)(325 - 25) + x(0.15)(325 - 25)$$

$$40 = 30(1-x) + 45x$$

$$X = 0.6$$

$$F_B = F_{A_0} X = 0.6(1) = 0.6\text{ mol/sec}$$

41. The C-curve measured during a pulse tracer experiment is shown below. In the figure,  $C(t)$  is the concentration of the tracer measured at the reactor exit in mol/liter at time  $t$  seconds.



The mean residence time in the reactor, rounded to 1 decimal place, is \_\_\_\_\_ s.

Key: 0.6

Exp: The data can be drawn from the diagram is as follows

$C(t)$	$t$	$tC(t)$
0	0	0
1	1	1
0	2	0

$$\text{Mean residence time} = \frac{\sum tC}{\sum C} = \frac{(0+1+0)}{(0+1+0)} = 1\text{ s}$$

42. The reversible reaction of t-butyl alcohol (TBA) and ethanol (EtOH) to ethylt-butyl ether (ETBE) is  $TBA + EtOH \rightleftharpoons ETBE + \text{Water}$

The equilibrium constant for this reaction is  $K_c = 1$ . Initially, 74 g of TBA is mixed with 100g of aqueous solution containing 46 weight% ethanol. The molecular weights are: 74g of TBA, 46g/mol for EtOH, 102g/mol for ETBE, and 18 g/mol for water.

The mass of ETBE at equilibrium, rounded to 1 decimal place, is \_\_\_\_g.

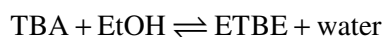
Key: 20.4

Exp: Let x mole of ETBE present of equilibrium mass of EtOH=46 g

Mass of water = 54g

$$\text{Moles of EtOH} = \frac{46}{46} = 1 \text{ mol}$$

$$\text{Moles of water} = \frac{54}{18} = 3 \text{ mol}$$



At	t = 0	1	1	0	3
At equilibrium		1 - x	1 - x	x	3 + x

$$K_c = \frac{(3+x)(x)}{(1-x)(1-x)} = 1$$

$$x = 0.2$$

Moles of ETBE = 0.2

Moles of ETBE = 0.2(102) = 20.4 gm

43. Let  $I_{b\lambda}$  be the spectral black body radiation intensity per unit wavelength about the wavelength  $\lambda$ . The blackbody radiation intensity emitted by a blackbody over all wavelengths is

(A)  $\frac{dI_{b\lambda}}{d\lambda}$       (B)  $\frac{d^2I_{b\lambda}}{d\lambda^2}$       (C)  $\int_0^\infty I_{b\lambda} d\lambda$       (D)  $\int_0^\infty \lambda I_{b\lambda} d\lambda$

Key: C

Exp:  $I_b = \int_0^\infty I_{b\lambda} d\lambda$

44. Match the equipment in Group-1 with the process in Group-2:

**Group-1**

- (P) Fluidized bed
- (Q) Multistage adiabatic reactor with Inter-stage cooling
- (R) Fourdrinier machine
- (S) Diaphragm cell

**Group-2**

- (I) Paper-making
- (II) Sodium hydroxide manufacturer
- (III) SO<sub>2</sub> oxidation
- (IV) Catalytic cracking

Choose the correct set of combinations.

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

Exp:

Key: C

45. Oil is being delivered at a steady state flowrate through a circular pipe of a radius  $1.25 \times 10^{-2}$  m and length 10m. The pressure drop across the pipe is 500 Pa.

The shear stress at the pipe wall, rounded to 2 decimal places \_\_\_\_\_ Pa

**Key:** 0.3125

**Exp:**  $r = 1.25 \times 10^{-2}$  m

$$L = 10 \text{ m}$$

$$\Delta p = 500 \text{ pa}$$

$$\bar{C}_w = ?$$

$$\bar{C}_w = \left( \frac{\Delta p}{L} \right) \frac{r}{2}$$

$$= \frac{500 \times 1.25 \times 10^{-2}}{10}$$

$$= 0.3125 \text{ pa}$$

46. Match the problem type in Group-1 with the numerical method in Group-2

**Group-1**

**Group-2**

(P) System of linear algebraic equations

(I) Newton-Raphson

(Q) Non-linear algebraic equations

(II) Gauss-seidel

(R) Ordinary differential equations

(III) Simpson's Rule

(S) Numerical integrations

(IV) Runge-Kutta

Choose the correct set of combinations.

(A) P – II, Q – I, R – III, S – IV

(B) P – I, Q – II, R – IV, S – III

(C) P – IV, Q – III, R – II, S – I

(D) P – II, Q – I, R – IV, S – III

**Key:** D

47. The following gas-phase reaction is carried out in a constant-volume isothermal batch reactor
- $$A + B \rightarrow R + S$$

The reactants A and B as well as the product S are non-condensable gases. At the operating temperature, the saturation pressure of the product R is 40 kPa.

Initially, the batch reactor contains equimolar amounts of A and B (and no products) at a total pressure of 100kPa. The initial concentrations of the reactants are  $C_{A,0} = C_{B,0} = 12.56 \text{ mol} / \text{m}^3$ .

The rate of reaction is given by  $(-r_A) = 0.08 C_A C_B \text{ mol} / \text{m}^3 \cdot \text{s}$ .

The time at which R just starts condensing, rounded to 1 decimal place, is \_\_\_\_\_

**Key:** 4

**Exp:**  $A + B \rightarrow R + S$

Let m moles of A and B present initially in the reactor

Initially                    m, m     0,0

After time t,            m – xm, m – xm    mx    mx

Total moles after time t =  $mx + mx + m - mx + m - mx = 2m$

$$\text{Partial pressure of R at time } t = \frac{(mx)P_t}{2m} = \frac{P_t x}{2} = P_R$$

At  $P_t = 40\text{kPa}$  R will start condensing

$$\text{Here, } P_t = 100\text{kPa}, P_R = 40 = \frac{100(x)}{2}$$

$$x = 0.8$$

$$C_A = C_{A_0}(1 - X) = 1.25(1 - 0.8)$$

$$C_A = 2.5\text{mol/m}^3$$

$$\text{Batch reactor } t = \int_{C_{A_0}}^{C_A} \frac{dC_A}{0.08C_A^2}$$

$$t = \frac{1}{0.08} \left( \frac{1}{C_A} - \frac{1}{C_{A_0}} \right) = \frac{1}{0.08} \left( \frac{1}{2.5} - \frac{1}{12.5} \right)$$

$$t = 4\text{sec}$$

48. The vapour phase composition and relative volatilities (with respect to n-propane) on an ideal tray of a distillation column are

Component	Methane	Ethane	n-Propane
Mole fraction in vapour	0.12	0.28	0.60
Relative volatility	10	4	1

The mole fraction of n-propane in the liquid phase, rounded to 2 decimal places, is \_\_\_\_.

Key: 0.88

Exp:  $y_A = 0.12, y_B = 0.28, y_C = 0.60$

$$\alpha_{AC} = 10 = \frac{y_A x_C}{y_C x_A} = \frac{0.12 x_C}{0.60}$$

$$x_A + x_B + x_C = 1$$

$$x_A = 1 - x_B - x_C$$

$$\text{We get, } \frac{0.12 x_C}{0.60(1 - x_B - x_C)} = 10$$

$$x_B = 1 - 1.02 x_C \rightarrow (1)$$

$$\alpha_{BC} = 4 = \frac{y_B x_C}{y_C x_B} = \frac{0.2 x_C}{0.60(1 - 0.02 x_C)} = 4$$

$$\text{We get } x_C = 0.88$$

49. The Characteristic equation of a closed-loop system is

$$6s^3 + 11s^2 + 6s + (1+k) = 0, \text{ Where, } k > 0$$

The value of  $K$  beyond which the system just becomes unstable, rounded to the nearest integer, is \_\_\_\_\_.

Key: 10

Exp: Characteristic equation

$$6S^3 + 11S^2 + 6S + (1+k) = 0$$

Use R – H criteria to find the value of  $k$ .

$S^3$	6	11
$S^2$	11	$(1+k)$
$S^1$	$\frac{66-6(1+k)}{11}$	0
$S^0$	$(1+k)$	

$$\frac{66-6(1+k)}{11} = 0$$

$$66-6(1+k) = 0$$

$$66 = 6(1+k)$$

$$11 = 1+k \quad k = 11 - 1 = 10$$

The value is 10.

50. A aqueous salt-solution enters a crystallizer operating at steady state at  $25^\circ\text{C}$ . The feed temperature is  $90^\circ\text{C}$  and the salt concentration in the feed is 40 weight%. The salt crystallizes as a pentahydrate. The crystals and the mother liquor leave the crystallizer. The molecular weight of the anhydrous salt is 135. The solubility of the salt at  $25^\circ\text{C}$  is 20 weight%.

The feed flowrate required for a production rate of 100 kg/s of hydrated salt, rounded to the nearest integer, is \_\_\_\_\_ kg/s.

Key: 200

Exp:  $x_F =$  Salt concentration in the feed (wt.%) = 0.4

Molecular wt. of  $5\text{H}_2\text{O}$  molecules =  $18 \times 5 = 90$

Molecular wt. of the anhydrous salt = 135

$$x_C = \text{wt \% of hydrated crystal} = \frac{135}{90+135} = 0.6$$

$x_L =$  Solubility of salt = 0.2

Total Mass balance gives

$$M_{\text{Feed}} = M_{\text{hydrated crystal}} + M_{\text{mother liquor}}$$

$$M_{\text{Feed}} = 100 + M_{\text{Mother liquor}} \quad (1)$$

Mass balance of salt gives

$$0.4M_{\text{Feed}} = 0.6(100) + 0.2 M_{\text{mother liquor}}$$

$$0.4M_{\text{Feed}} = 60 + 0.2M_{\text{mother liquor}} \rightarrow (2)$$

On solving (1) and (2) we get

$$M_{\text{feed}} = 200 \text{ kg / s}$$

51. The pressure of a liquid is increased isothermally. The molar volume of the liquid decreases from  $50.45 \times 10^{-6} \text{ m}^3 / \text{mol}$  to  $48 \times 10^{-6} \text{ m}^3 / \text{mol}$  during this process. The isothermal compressibility of the liquid is  $10^{-9} \text{ Pa}^{-1}$ , which can be assumed to be independent of pressure.

The change in the molar Gibbs free energy of the liquid, rounded to nearest integer, is \_\_\_\_ J/mol.

Key: 2511.4

Exp: As we know  $\beta = -\frac{1}{V} \left( \frac{dv}{dp} \right)_T \rightarrow (1)$

For isothermal process  $pv = \text{const}$

$$Pdv + Vdp = 0 \quad \frac{-dv}{dp} = \frac{V}{P_1}$$

From equation(1)

$$\beta = \frac{1}{P_1} \Rightarrow P_1 = \frac{1}{\beta} = 10^9 \text{ Pa}$$

At constant temperature

$$dG = Vdp - SdT \Rightarrow dG = VdP = \frac{RT}{P} dP$$

$$DG = RT \ln \left( \frac{P_2}{P_1} \right); P_1 V_1 = P_2 V_2 \Rightarrow \frac{P_2}{P_1} = \frac{V_1}{V_2}$$

$$P_1 V_1 = RT$$

$$DG = P_1 V_1 \ln \left( \frac{V_1}{V_2} \right)$$

$$P_1 = 10^9 \text{ pa}, V_1 = 50.45 \times 10^{-6} \text{ m}^3 / \text{mol}$$

$$V_2 = 48 \times 10^{-6} \text{ m}^3 / \text{mol}$$

$$\Delta G = 10^9 (50.45 \times 10^{-6}) \ln \left( \frac{50.45 \times 10^{-6}}{48 \times 10^{-6}} \right)$$

$$\Delta G = 50.45 \times 10^3 \ln(1.051)$$

$$\Delta G = 2511.48 \text{ J / mole}$$

52. The open loop transfer function of a process with a proportional controller (gain  $K_c$ ) is

$$G_{OL} = K_c \frac{e^{-2s}}{s}$$

Based on the Bode criterion for closed-loop stability, the ultimate gain of the controller, rounded to 2 decimal places, is\_\_\_\_\_.

Key: 0.78

$$\text{Exp: } G_{xL} = K_c \frac{p^{-25}}{s}$$

At ultimate gain.

phase angle is  $-180^\circ$

$$\phi = -\tan^{-1}\left(\frac{\omega}{0}\right) - \frac{2\omega}{\pi}(180) = -180^\circ$$

$$-90 - \frac{2\omega}{\pi}(180) = -180$$

$$\omega = \frac{\pi}{4}$$

$$\text{Amplitude ratio (AR)} = K_c \left(\frac{1}{\omega}\right) (1)$$

$$\text{AR} = \frac{K_c}{\omega}$$

At ultimate gain AR is 1

$$\frac{(K_c)_4}{\omega} = 1$$

$$(K_c)_4 = \omega = \frac{\pi}{4} = \frac{3.14}{4}$$

$$(K_c)_4 = 0.785$$

53. In nucleate boiling, the pressure inside a bubble is higher than the pressure of the surrounding liquid. Assuming that both the liquid and vapour are saturated, the temperature of the liquid will ALWAYS be

- (A) at  $100^\circ\text{C}$
- (B) lower than the temperature of the vapour
- (C) equal to the temperature of the vapour
- (D) higher than the temperature of the vapour

Key: B

Exp: The temperature of the liquid will always be lower than the temperature of the vapour

54. A box has 6 red balls and white balls. A ball is picked at random and replaced in the box, after which a second ball is picked.

The probability of both the balls being red, rounded to 2 decimal places, is \_\_\_\_.

Key: 0.36

$$\text{Exp: Required probability} = \frac{6}{10} \times \frac{6}{10} = \frac{36}{100} = 0.36$$

55. A sparingly soluble gas (solute) is in equilibrium with a solvent at 10 bar. The mole fraction of the solvent in the gas phase is 0.01. At the operating temperature and pressure, the fugacity coefficient of the solute in the gas phase and the Henry's law constant are 0.92 and 1000 bar, respectively. Assume that the liquid phase obeys Henry's law.

The MOLE PERCENTAGE of the solute in the liquid phase, rounded to 2 decimal places, is \_\_\_\_\_.

Key: 0.91

Exp:  $H = 1000 \text{ bar}$ ,  $\phi = 0.92$  for dilute solution

We can use Henry law For solute  $H_x = \phi y P$

$$1000x = 0.92(1 - 0.01)(10)$$

Here,  $y$  and  $x$  are mole fraction of solute in gas and liquid phase respectively

$$x = 9.108 \times 10^{-3}$$

Mole percentage of solute in liquid phase

$$= 100(9.108 \times 10^{-3}) = 0.91$$

### General Aptitude

#### Q. No. 1 - 5 Carry One Mark Each

1. Consider the following sentences:  
All benches are bed is a bulb. Some bulbs are lamps.  
Which of the following can be inferred?  
i. Some beds are lamps.  
ii. Some lamps are beds.  
(A) Only i (B) Only ii  
(C) Both i and ii (D) Neither i nor ii
2. The following sequence of numbers is arranged in increasing order: 1,  $x, x, x, y, y, 9, 16, 18$ .  
Given that the mean and median are equal, and are also equal to twice the mode, the value of  $y$  is  
(A) 5 (B) 6 (C) 7 (D) 8

Key: D

Exp: Given, Mean = Median = 2Mode

$$\Rightarrow \text{Mean} = \text{Median} = 2x [\because \text{Mode} = x] \rightarrow (1)$$

$$\therefore \text{Mean of the data} = \frac{3x + 2y + 44}{9}$$

$$\Rightarrow 2x = \frac{3x + 2y + 44}{9} \Rightarrow 15x - 2y = 44 \rightarrow (2)$$

$$\text{Mean of the data} = y \rightarrow (3)$$

$$\therefore y = 2x \rightarrow (4) [\because \text{Median} = 2\text{Mode}]$$

$$\text{From (2); } 11x = 44$$

$$\Rightarrow x = 4; \therefore y = 8$$



3. The bacteria in milk are destroyed when it \_\_\_\_\_ heated to 80 degree Celsius.  
(A) would be (B) will be (C) is (D) was

Key: C

4. If the radius of a right circular cone is increased by 50%, its volume increases by  
(A) 75% (B) 100% (C) 125% (D) 237.5%

Key: C

Exp: Given, radius of a right circular cone is increased by 50%.

Let, height of the circular cone=(h)

$$\text{Initially, Volume of the cone} = \frac{1}{3} \pi r^2 h \rightarrow (1)$$

$$\text{New volume of the cone} = \frac{1}{3} \pi r^2 (1.5r)^2 h \rightarrow (2)$$

$$\text{From (1) and (2); } \frac{1}{3} \pi r^2 h = \frac{1}{3} \pi (2.25)^2 h$$

$$\text{Volume increased by} = (1.25 \times 100)\% = 125\%$$

5. \_\_\_\_\_ with someone else's email account is now very serious offence.  
(A) Involving (B) Assisting (C) Tampering (D) Incubating

Key: C

**Q. No. 6- 10 Carry Two Marks Each**

6. Students applying for hostel rooms are allotted rooms in order of seniority. Students already staying in a room will move if they get a room in their preferred list. Preferences of lower ranked applicants are ignored during allocation. Given the data below, which room will Ajit stay in?

Names	Student Seniority	Current room	Room preference list
Amar	1	P	R,S,Q
Akbar	2	None	
Anthony	3	Q	P
Ajit	4	S	Q,P,R

- (A) P (B) Q (C) R (D) S



$$\begin{aligned} \text{The last digit of } (2173)^{11} &= (2173)^8 (2173)^3 \\ &= (2173)^{4n} (2173)^3 \text{ [Where, } n = 2] \end{aligned}$$

$$\begin{aligned} \text{Last digit of } (2173)^{4n} &= 1 \\ &= 1 \times 7 = 7 \end{aligned}$$

$$\begin{aligned} \text{The last digit of } (2174)^{13} &= (2174)^{12} (2174) \\ &= (2174)^{2n} (2174) [\because n = 6] \\ &= 6 \times 4 [\because (2174)^{2n} = \text{last digit} = 6] \end{aligned}$$

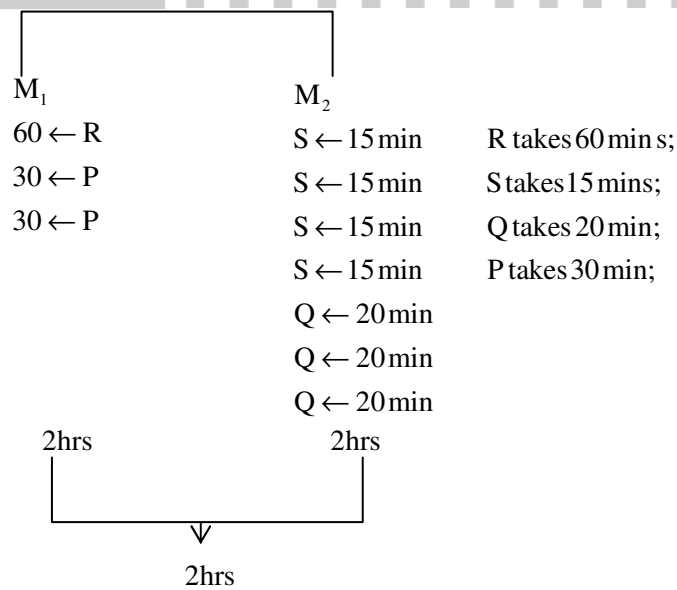
$$\begin{aligned} \text{Last digit of } (2174)^{2n} &= 6 \\ &= 24 \end{aligned}$$

$$\begin{aligned} \therefore \text{The last digit of } (2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13} \\ = 1 + 2 + 7 + 4 = 14 \end{aligned}$$

9. Two machines M1 and M2 are able to execute any of four jobs P, Q, R and S. The machines can perform one job on one object at a time. Jobs P, Q, R and S take 30 minutes, 20 minutes, 60 minutes and 15 minutes each respectively. There are 10 objects each requiring exactly 1 job. Job P is to be performed on 2 objects. Job Q on 3 objects. Job R on 1 object and Job S on 4 objects. What is the minimum time needed to complete all the jobs?

- (A) 2 hours      (B) 2.5 hours      (C) 3 hours      (D) 3.5 hours

Key: A  
Exp:



10. The old concert hall was demolished because of fears that the foundation would be affected by the construction tried to mitigate the impact of pressurized air pockets created by the excavation of large amounts of soil. But even with these safeguards, it was feared that the soil below the concert hall would not be stable.

From this, one can infer that

- (A) The foundations of old buildings create pressurized air pockets underground, which are difficult to handle during metro construction.
- (B) Metro construction has to be done carefully considering its impact on the foundations of existing buildings.
- (C) Old buildings in an area form an impossible hurdle to metro construction in that area.
- (D) Pressurized air can be used to excavate large amounts of soil from underground areas.

Key: A

