2007
CH: Chemical Engineering

Duration : Three Hours | Maximum Marks :150

Read the following instructions carefully.

1. This question paper contains 85 objective type questions. Q.1 to Q.20 carry **one** mark each and Q.21 to Q.85 carry **two** marks each.
2. Attempt all the questions.
3. Questions must be answered on **O**bjective **R**esponse **S**heet (**ORS**) by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the **ORS**. **Each question has only one correct answer.** In case you wish to change an answer, erase the old answer completely.
4. Wrong answers will carry NEGATIVE marks. In Q.1 to Q.20, **0.25** mark will be deducted for each wrong answer. In Q.21 to Q.76, Q.78, Q.80, Q.82 and in Q.84, **0.5** mark will be deducted for each wrong answer. However, there is no negative marking in Q.77, Q.79, Q.81, Q.83 and in Q.85. More than one answer bubbled against a question will be taken as an incorrect response. Unattempted questions will not carry any marks.
5. Write your registration number, your name and name of the examination centre at the specified locations on the right half of the **ORS**.
6. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.
7. Calculator is allowed in the examination hall.
8. Charts, graph sheets or tables are NOT allowed in the examination hall.
9. Rough work can be done on the question paper itself. Additionally blank pages are given at the end of the question paper for rough work.
10. This question paper contains **36** printed pages including pages for rough work. Please check all pages and report, if there is any discrepancy.

Q. 1 – Q. 20 carry one mark each.

Q.1 Given $i = \sqrt{-1}$, the ratio

$$\frac{(i+3)}{(i+1)}$$

is given by

(A) i (B) -2 (C) $-i+2$ (D) $i+1$

Q.2 The value of "a" for which the following set of equations

$$\begin{aligned} y + 2z &= 0 \\ 2x + y + z &= 0 \\ ax + 2y &= 0 \end{aligned}$$

have non-trivial solution, is

(A) 0 (B) 8 (C) -2 (D) 3

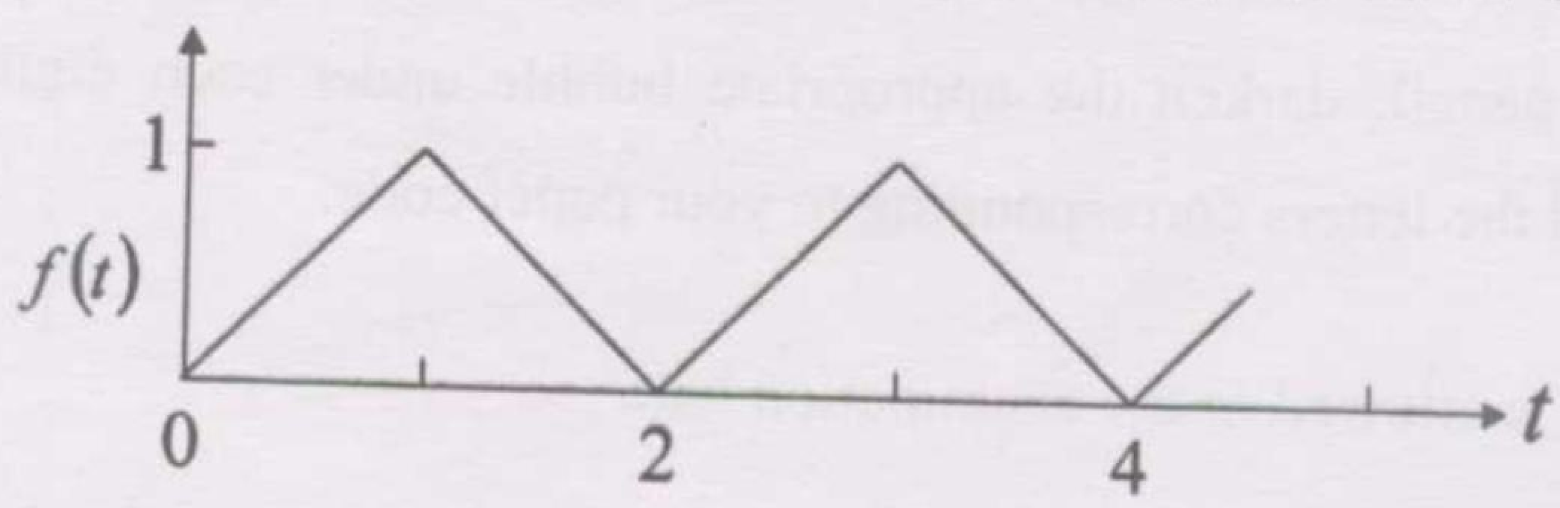
Q.3 The initial condition for which the following equation

$$\left(x^2 + 2x\right)\frac{dy}{dx} = 2(x+1)y\,; \quad y(x_0) = y_0$$

has infinitely many solutions, is

(A) $y(x=0)=5$ (B) $y(x=0)=1$ (C) $y(x=2)=1$ (D) $y(x=-2)=0$

Q.4 Given that the Laplace transform of the function below over a single period $0 < t < 2$ is $\frac{1}{s^2}\left(1-e^{-s}\right)^2$, the Laplace transform of the periodic function over $0 < t < \infty$ is



(A) $\frac{1}{s}\left(1-e^{-s}\right)^2$ (B) $\frac{1}{s}\left(1-e^{-s}\right)^2$ (C) $\frac{1}{s^2}\frac{\left(1-e^{-s}\right)}{\left(1+e^{-s}\right)}$ (D) $\frac{1}{s}\tanh\frac{s}{2}$

Q.5 If T_A and T_B are the boiling points of pure A and pure B respectively and T_{AB} is that of a non-homogeneous immiscible mixture of A and B, then

(A) $T_{AB} < T_A$ and T_B
(B) $T_{AB} > T_A$ and T_B
(C) $T_A > T_{AB} > T_B$
(D) $T_B > T_{AB} > T_A$

Q.6 The state of an ideal gas is changed from (T_1, P_1) to (T_2, P_2) in a constant volume process. To calculate the change in enthalpy, Δh, ALL of the following properties/variables are required.

(A) C_v , P_1 , P_2
(B) C_p , T_1 , T_2
(C) C_p , T_1 , T_2 , P_1 , P_2
(D) C_v , P_1 , P_2 , T_1 , T_2

Q.7 The change in entropy of the system, ΔS_{sys}, undergoing a cyclic irreversible process is

(A) greater than 0
(B) equal to zero
(C) less than zero
(D) equal to the $\Delta S_{surroundings}$

Q.8 Parameters 'a' and 'b' in the van der Waals and other cubic equations of state represent

(A) a -- molecular weight b -- molecular polarity
(B) a -- molecular size b -- molecular attraction
(C) a -- molecular size b -- molecular speed
(D) a -- molecular attraction b -- molecular size

Q.9 If m_i, $\overline{m_i}$, m_i^R, m_i^E are molar, partial molar, residual and excess properties respectively for a pure species "i", the mixture property M of a binary non-ideal mixture of components 1 and 2, is given by

(A) $x_1\overline{m_1} + x_2\overline{m_2}$
(B) $x_1 m_1^R + x_2 m_2^R$
(C) $x_1 m_1 + x_2 m_2$
(D) $x_1 m_1^E + x_2 m_2^E$

Q.10 Consider a soap film bubble of diameter D. If the external pressure is P_o and the surface tension of the soap film is σ, the expression for the pressure inside the bubble is

(A) P_o

(B) $P_o + \frac{2\sigma}{D}$

(C) $P_o + \frac{4\sigma}{D}$

(D) $P_o + \frac{8\sigma}{D}$

Q.11 In Tyler series, the ratio of the aperture size of a screen to that of the next smaller screen is

(A) $1/\sqrt{2}$ (B) $\sqrt{2}$ (C) 1.5 (D) 2

Q.12 Size reduction of coarse hard solids using a crusher is accomplished by

(A) attrition (B) compression (C) cutting (D) impact

Q.13 In constant pressure filtration, the rate of filtration follows the relation (v: filtrate volume, t: time, k and c: constants).

(A) $\frac{dv}{dt} = kv + c$

(B) $\frac{dv}{dt} = \frac{1}{kv + c}$

(C) $\frac{dv}{dt} = kv$

(D) $\frac{dv}{dt} = kv^2$

Q.14 Sticky materials are transported by

(A) apron conveyor
(B) screw conveyor
(C) belt conveyor
(D) hydraulic conveyor

Q.15 The Grashof Number is

(A) thermal diffusivity/mass diffusivity
(B) inertial force/surface tension force
(C) sensible heat/latent heat
(D) buoyancy force/viscous force

Q.16 An operator was told to control the temperature of a reactor at 60 °C. The operator set the set-point of the temperature controller at 60. The scale actually indicated 0 to 100% of a temperature range of 0 to 200 °C. This caused a runaway reaction by over-pressurizing the vessel, which resulted in injury to the operator. The actual set-point temperature was

(A) 200 °C (B) 60 °C (C) 120 °C (D) 100 °C

Q.17 Select the most appropriate pump from Group 2 to handle each fluid flow given in Group 1.

Group1	**Group 2**
P. Highly viscous fluid flow	(1) piston pump
Q. Fluid containing large amount of abrasive solids	(2) gear pump
	(3) plunger pump
	(4) centrifugal pump

(A) P-(2), Q-(1)
(B) P-(2), Q-(4)
(C) P-(3), Q-(4)
(D) P-(4), Q-(3)

Q.18 A cylindrical storage tank can have a self supported conical roof,

(A) if its diameter is less than 20m
(B) if its diameter is more than 50m
(C) if the thickness of the roof is more than that of the cylindrical shell
(D) whatever is the diameter

Q.19 Which of the following is desirable in gasoline but undesirable in kerosene?

(A) Aromatics
(B) Mercaptans
(C) Naphthenic Acid
(D) Paraffins

Q.20 In the Sulfite process for paper manufacture, the 'cooking liquor' is

(A) magnesium bisulfite and sulfur dioxide in acid medium
(B) magnesium sulfite and magnesium dicarbonate
(C) sodium sulfite and magnesium sulfite
(D) sodium sulfite, sodium bisulfite and sulfur dioxide

Q. 21 to Q. 75 carry two marks each.

Q.21 If $z = x + iy$ is a complex number, where $i = \sqrt{-1}$ then the derivative of $z\bar{z}$ at $2+i$ is

(A) 0 (B) 2 (C) 4 (D) does not exist

Q.22 $\underline{\underline{A}}$ and $\underline{\underline{B}}$ are two 3×3 matrix such that

$$\underline{\underline{A}} = \begin{bmatrix} -2 & 4 & 6 \\ 1 & 2 & 1 \\ 0 & 4 & 4 \end{bmatrix},\ \underline{\underline{B}} = \underline{\underline{0}}$$

and $\underline{\underline{A}}\underline{\underline{B}} = \underline{\underline{0}}$. Then the rank of matrix $\underline{\underline{B}}$ is

(A) $r = 2$ (B) $r < 3$ (C) $r \leq 3$ (D) $r = 3$

Q.23 The solution of the following differential equation

$$x\frac{dy}{dx} + y(x^2 - 1) = 2x^3$$

is

(A) 0 (B) $2 + ce^{-\frac{x^2}{2}}$ (C) $c_1x + c_2x^2$ (D) $2x + cxe^{-\frac{x^2}{2}}$

Q.24 The directional derivative of

$$f = \frac{1}{2}\sqrt{x^2 + y^2}$$

at $(1,1)$ in the direction of $\vec{b} = \vec{i} - \vec{j}$ is

(A) 0 (B) $1/\sqrt{2}$ (C) $\sqrt{2}$ (D) 2

Q.25 Evaluate the following integral ($n \neq 0$)

$$\oint(-xy^n dx + x^n y dy)$$

within the area of a triangle with vertices $(0,0)$, $(1,0)$ and $(1,1)$ (counter-clockwise)

(A) 0 (B) $1/(n+1)$ (C) $1/2$ (D) $n/2$

Q.26 The family of curves that is orthogonal to

$$xy = c$$

is

(A) $y = c_1 x$ (B) $y = c_1/x$ (C) $y^2 + x^2 = c_1$ (D) $y^2 - x^2 = c_1$

Q.27 The Laplace transform of

$$f(t) = \frac{1}{\sqrt{t}}$$

is

(A) $\sqrt{\frac{\pi}{s}}$ (B) $\frac{1}{\sqrt{s}}$ (C) $\frac{1}{s^{\frac{3}{2}}}$ (D) does not exist

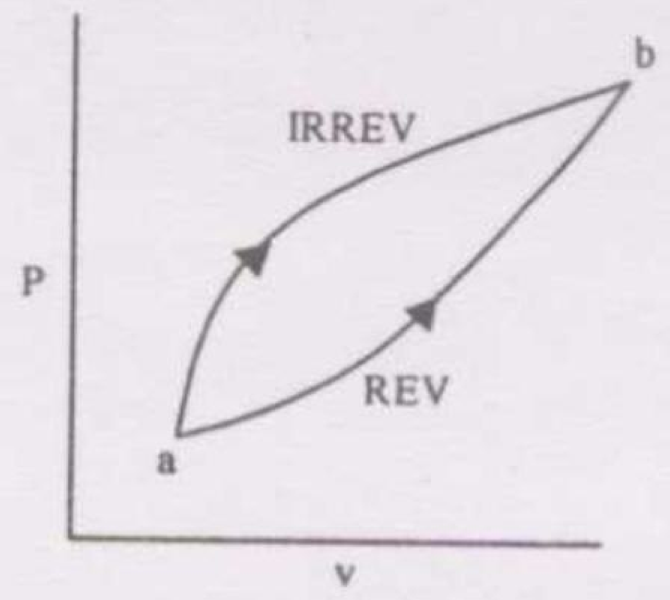
Q.28 The thickness of a conductive coating in micrometers has a probability density function of $600x^{-2}$ for $100\ \mu m < x < 120 \mu m$. The mean and the variance of the coating thickness is

(A) 1 μm, 108.39 μm^2
(B) 33.83 μm, 1 μm^2
(C) 105 μm, 11 μm^2
(D) 109.39 μm, 33.83 μm^2

Q.29 If the percent humidity of air (30 °C, total pressure 100 kPa) is 24 % and the saturation pressure of water vapor at that temperature is 4 kPa, the percent relative humidity and the absolute humidity of air are

(A) 25.2, 0.0062 (B) 25, 0.0035 (C) 20.7, 0.0055 (D) 18.2, 0.0035

Q.30 For the two paths as shown in the figure, one reversible and one irreversible, to change the state of the system from a to b,



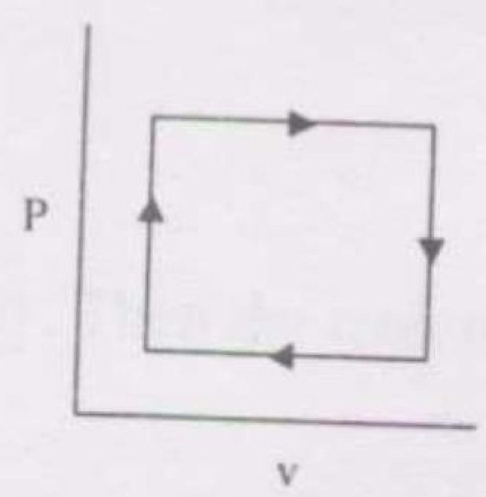
(A) ΔU, Q, W are same
(B) ΔU is same
(C) Q, W are same
(D) ΔU, Q are different

Q.31 For a pure substance, the Maxwell's relation obtained from the fundamental property relation $du = Tds - Pdv$ is

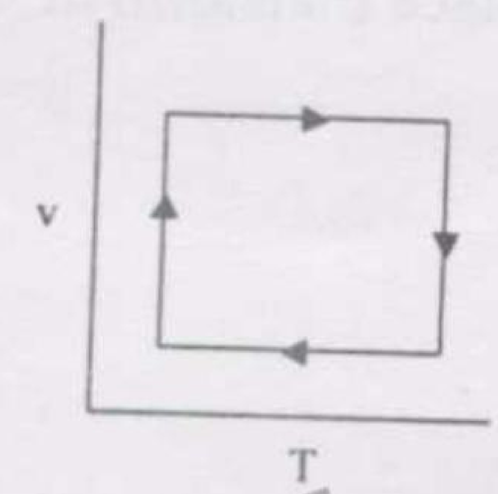
(A) $(\partial T/\partial v)_s = -(\partial P/\partial s)_v$
(B) $(\partial P/\partial T)_v = (\partial s/\partial v)_T$
(C) $(\partial T/\partial P)_s = (\partial v/\partial s)_P$
(D) $(\partial v/\partial T)_P = -(\partial s/\partial P)_T$

Q.32 Which of the following represents the Carnot cycle (ideal engine) ?

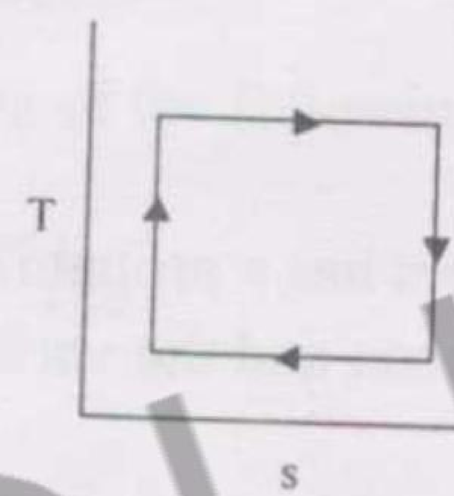
(A)



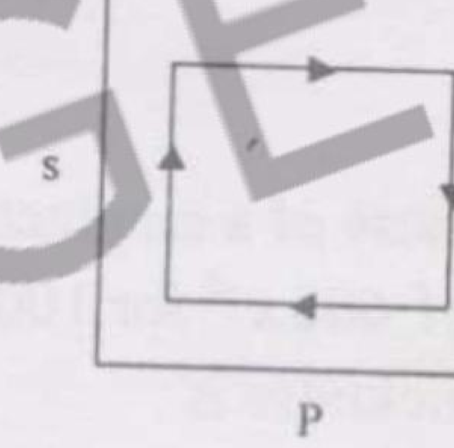
(B)



(C)



(D)



Q.33 2 kg of steam in a piston-cylinder device at 400 kPa and 175 °C undergoes a mechanically reversible, isothermal compression to a final pressure such that the steam becomes just saturated. What is the work, W, required for the process.
Data:

T = 175°C, P = 400 kPa -- $v = 0.503\ m^3/kg$, u = 2606 kJ/kg, s = 7.055 kJ/kg-K
T = 175°C, satd. vapor -- $v = 0.216\ m^3/kg$, u = 2579 kJ/kg, s = 6.622 kJ/kg-K

(A) 0 kJ (B) 230 kJ (C) 334 kJ (D) 388 kJ

Q.34 Vapor phase hydration of C_2H_4 to ethanol by the following reaction

$$C_2H_4\,(g) + H_2O\,(g) \leftrightarrow C_2H_5OH\,(g)$$

attains equilibrium at 400 K and 3 bar. The standard Gibbs free energy change of reaction at these conditions is $\Delta g^\circ = 4000$ J/mol. For 2 moles of an equimolar feed of ethylene and steam, the equation in terms of the extent of reaction ε (in mols) at equilibrium is

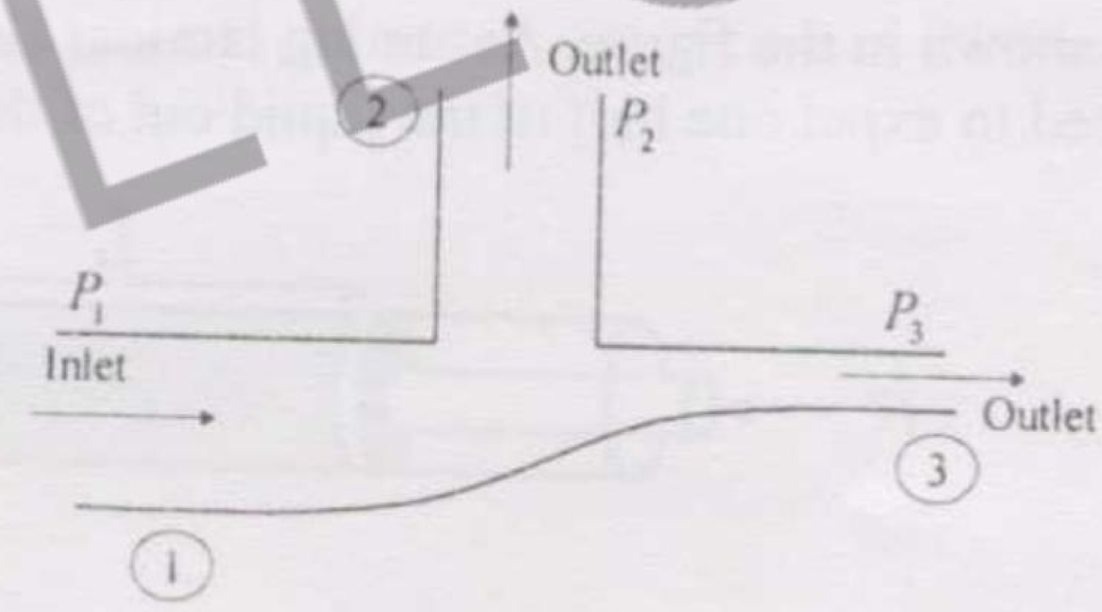
(A) $\dfrac{\varepsilon(2-\varepsilon)}{(1-\varepsilon)^2} - 0.3 = 0$

(B) $\dfrac{(1-\varepsilon)^2}{\varepsilon(2-\varepsilon)} - 0.9 = 0$

(C) $\dfrac{\varepsilon}{(1-\varepsilon)^2} - 0.3 = 0$

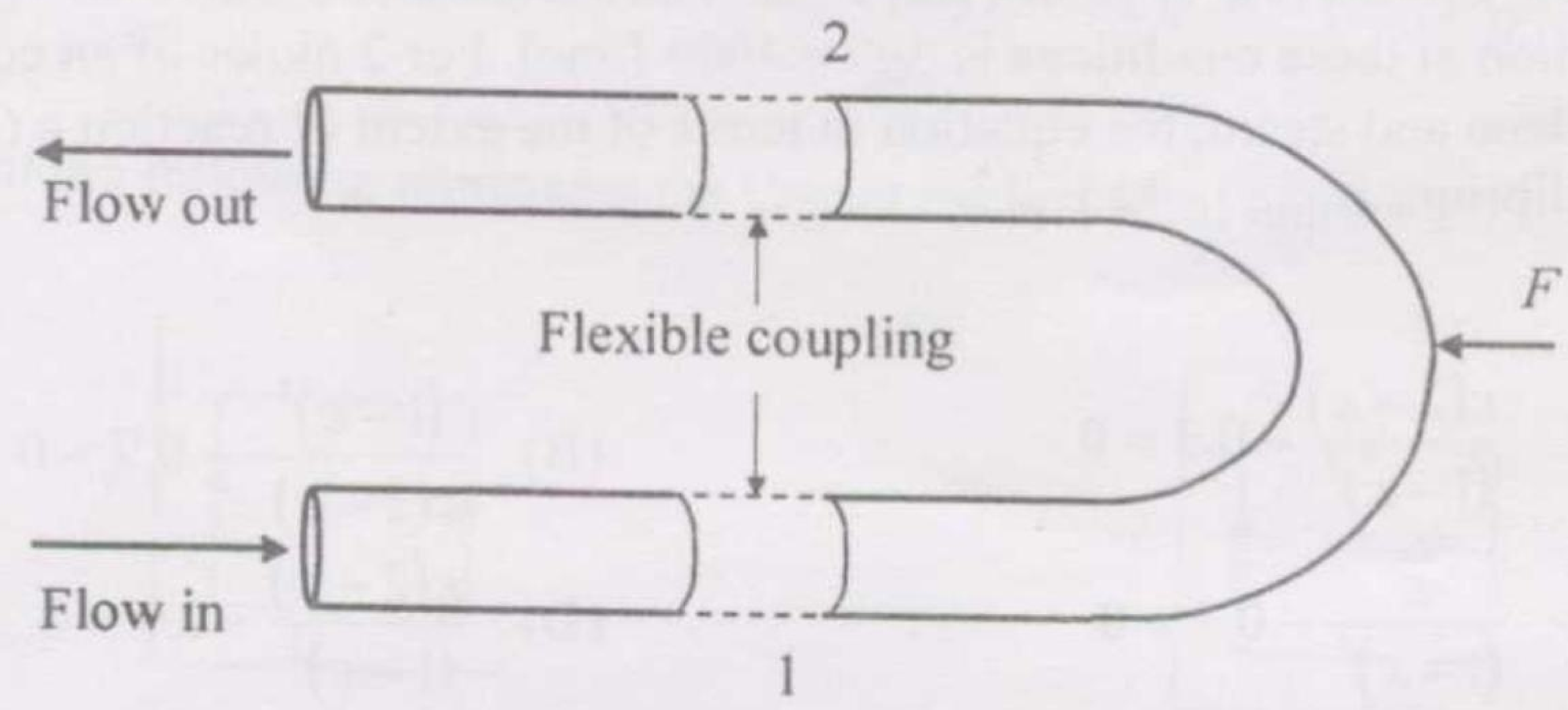
(D) $\dfrac{\varepsilon(2-\varepsilon)}{(1-\varepsilon)^2} - 0.9 = 0$

Q.35 A pipeline system carries crude oil of density 800 kg/m^3. The volumetric flow rate at point 1 is 0.28 m^3/s. The cross sectional areas of the branches 1,2 and 3 are 0.012, 0.008 and 0.004 m^2 respectively. All the three branches are in a horizontal plane and the friction is negligible. If the pressures at the points 1 and 3 are 270 kPa and 240 kPa respectively, then the pressure at point 2 is



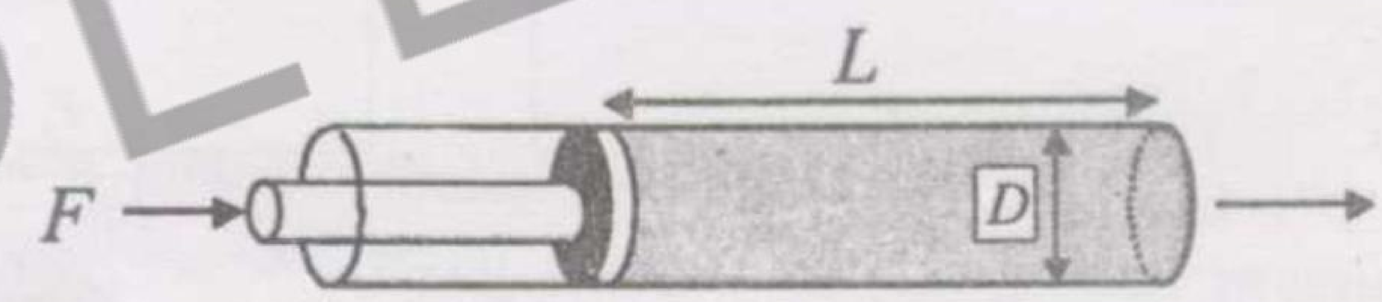
(A) 202 kPa (B) 240 kPa (C) 284 kPa (D) 355 kPa

Q.36 The figure shows the idealized view of a return elbow or U bend, which is connected to two pipes by flexible hoses that transmit no force. Water with density 1000 kg/m^3 flows at velocity of 10 m/s through the pipe, which has a uniform ID of 0.1m. The gauge pressure at points 1 and 2 are 304 kPa and 253 kPa respectively. The horizontal force F required to keep the elbow in position is



(A) 1574 N (B) 1970 N (C) 5942 N (D) 7533 N

Q.37 A tube of diameter D and length L is initially filled with a liquid of density ρ and viscosity μ. It is then pushed out by the application of a constant force F to the plunger as shown in the figure. Assuming laminar flow and pseudo steady state, the time required to expel one half of the liquid out of the tube is



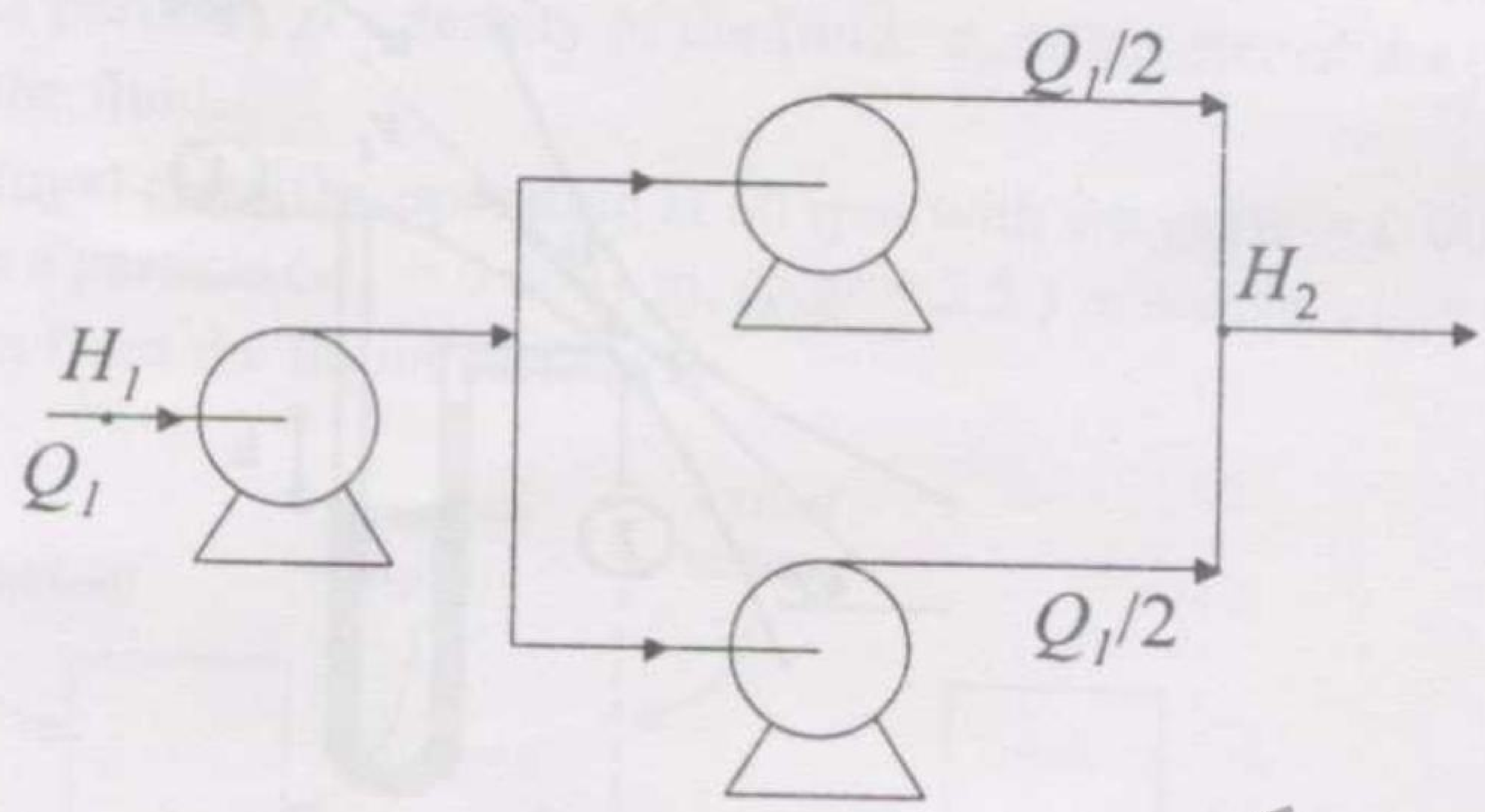
(A) $\frac{3\pi\mu L^2}{F}$

(B) $\frac{3\pi\mu D^2}{F}$

(C) $\frac{6\pi\mu L^2}{F}$

(D) $\frac{6\pi\mu DL}{F}$

Q.38 The figure shows a series-parallel configuration of three identical centrifugal pumps. The head increase ΔH across a single such pump varies with flowrate Q according to $\Delta H = a - bQ^2$. The expression for the total head increase $\Delta H = H_2 - H_1$ in terms of a and b and the total flowrate Q_1 for this configuration is given by



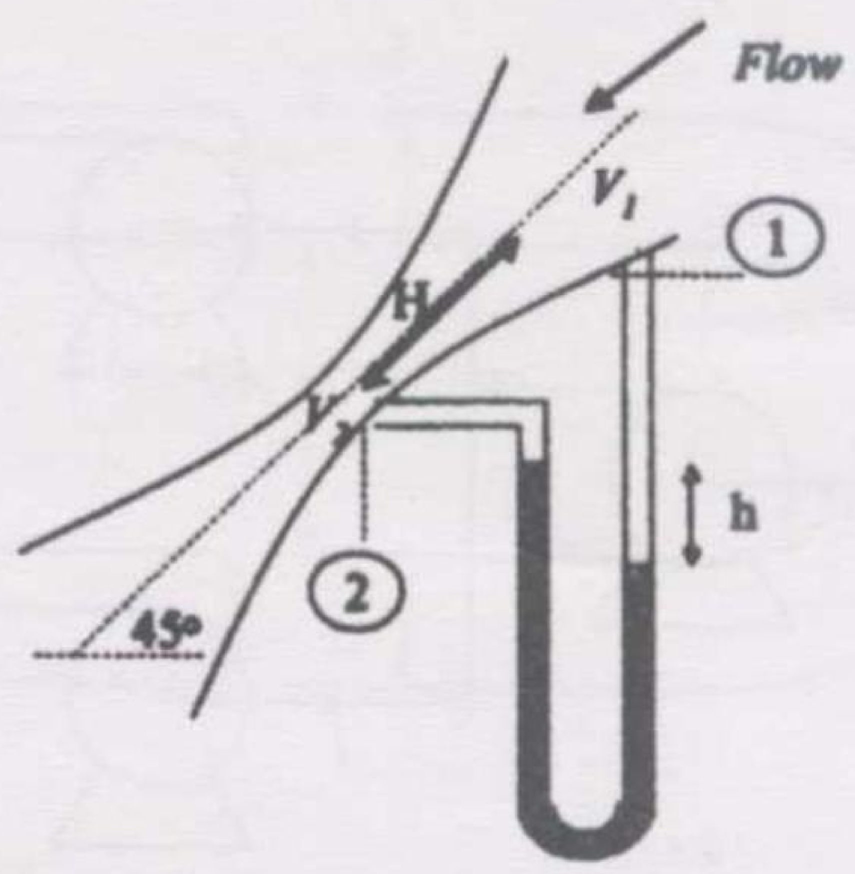
(A) $2a - \frac{5}{4}bQ_1^2$

(B) $2a - bQ_1^2$

(C) $2a - 2bQ_1^2$

(D) $a - bQ_1^2$

Q.39 The pressure differential across a venturimeter, inclined at 45° to the vertical (as shown in the figure) is measured with the help of a manometer to estimate the flowrate of a fluid flowing through it. If the density of the flowing fluid is ρ and the density of the manometer fluid is ρ_m, the velocity of the fluid at the throat can be obtained from the expression



(A) $\frac{V_2^2 - V_1^2}{2g} = \frac{h(\rho_m - \rho)}{\rho} + H \sin 45^o$

(B) $\frac{V_2^2 - V_1^2}{2g} = \frac{h\rho_m}{\rho} + H \sin 45^o$

(C) $\frac{V_2^2 - V_1^2}{2g} = \frac{h\rho_m}{\rho}$

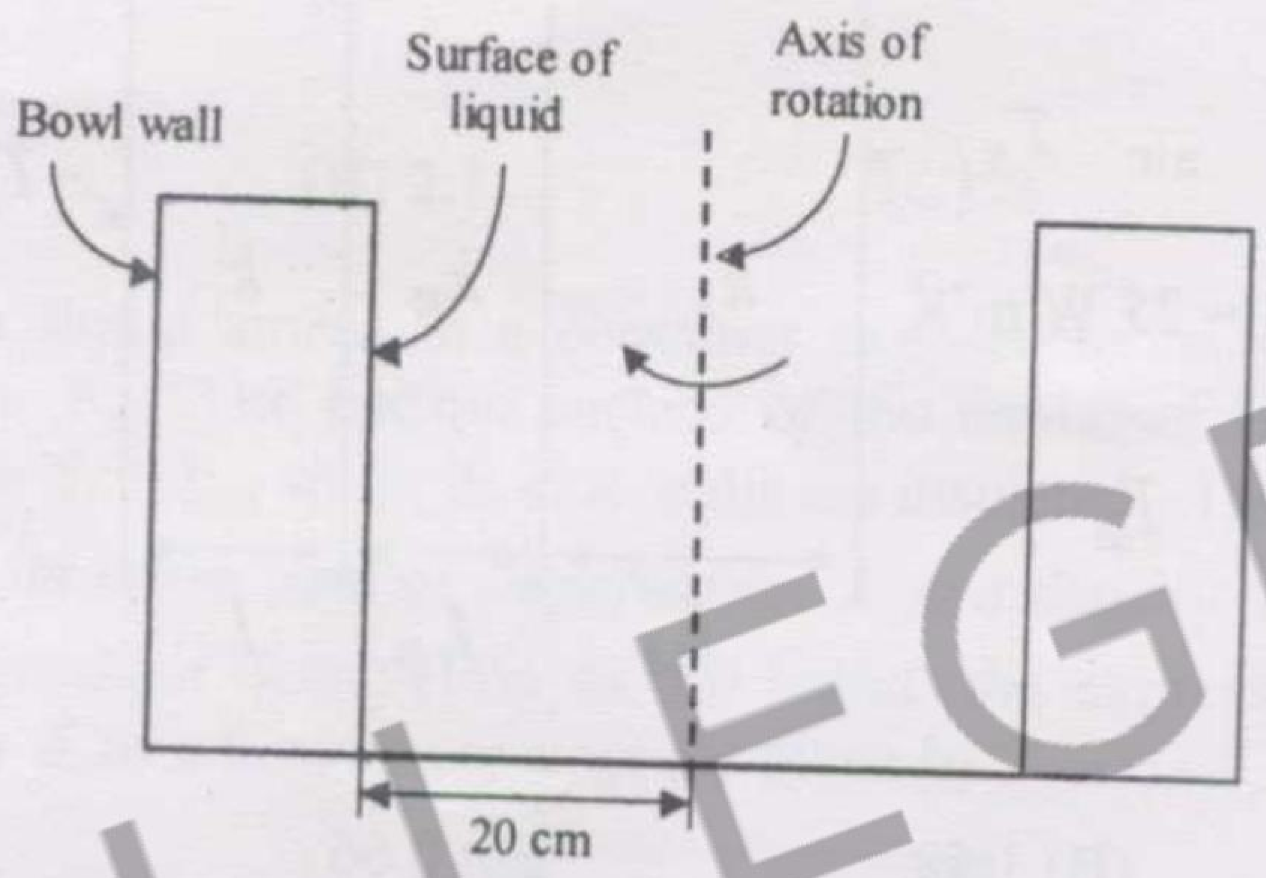
(D) $\frac{V_2^2 - V_1^2}{2g} = \frac{h(\rho_m - \rho)}{\rho}$

Q.40 In the Stokes regime, the terminal velocity of particles for centrifugal sedimentation is given by

$$U_t = \omega^2 r(\rho_p - \rho)d_p^2/18\mu$$

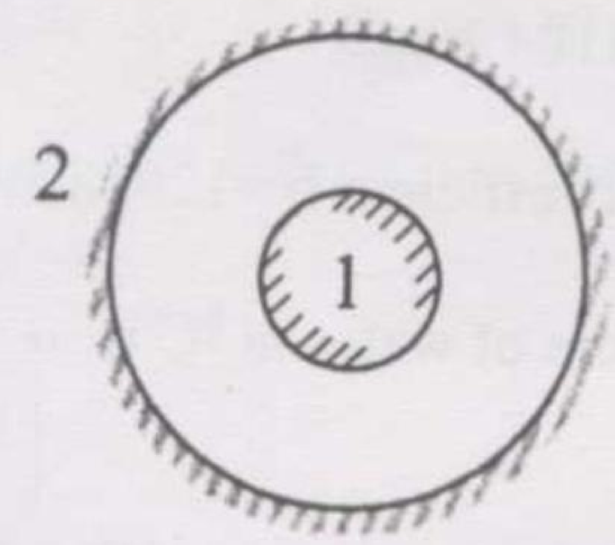
where, ω : angular velocity; r : distance of the particle from the axis of rotation; ρ_P : density of the particle; ρ : density of the fluid; d_P : diameter of the particle and μ : viscosity of the fluid.

In a Bowl centrifugal classifier operating at 60 rpm with water ($\mu = 0.001$ kg/m.s), the time taken for a particle ($d_P = 0.0001$ m, sp.gr = 2.5) in seconds to traverse a distance of 0.05 m from the liquid surface is



(A) 4.8 (B) 5.8 (C) 6.8 (D) 7.8

Q.41 For the two long concentric cylinders with surface areas A_1 and A_2, the view factor F_{22} is given by

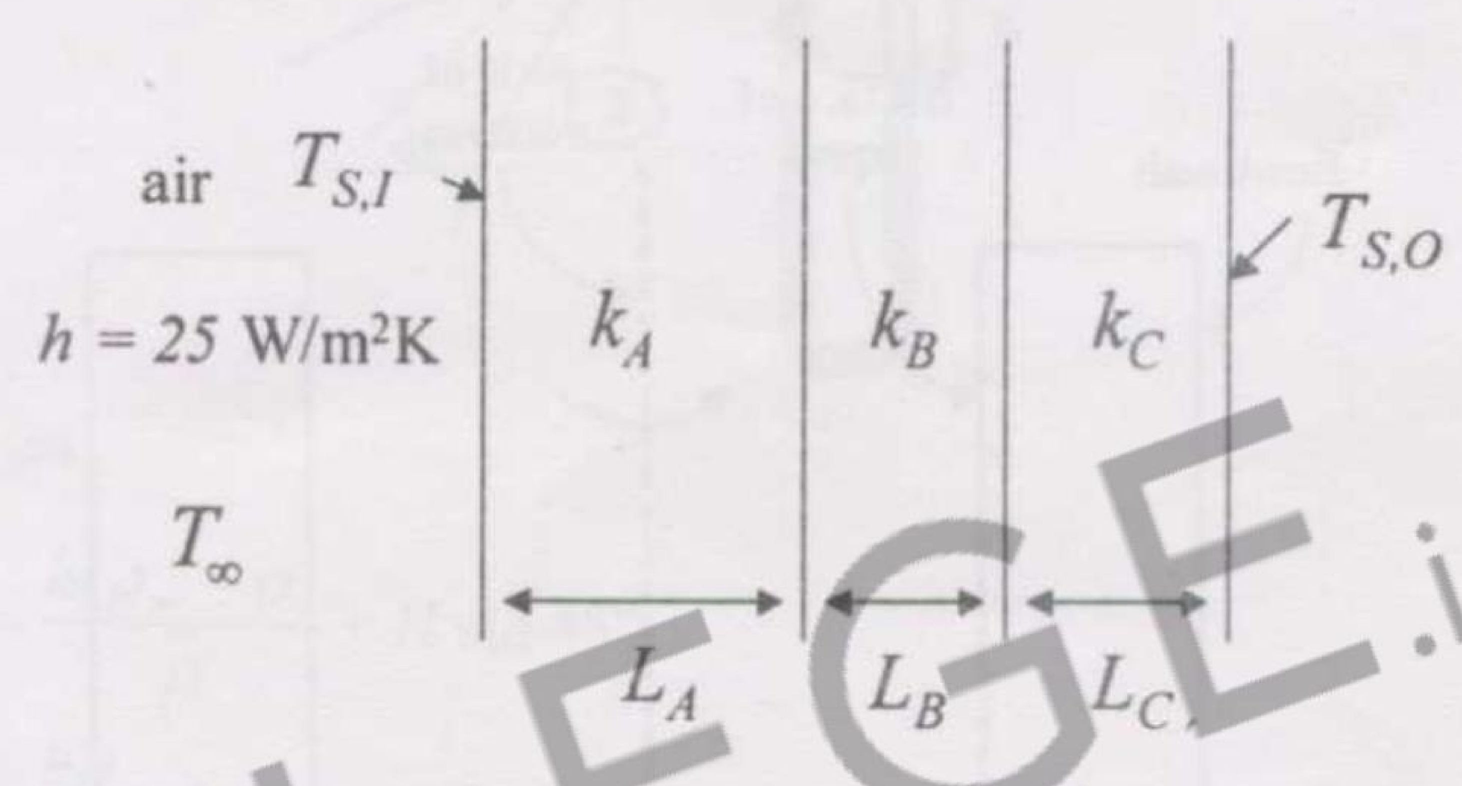


(A) 0 (B) 1 (C) $1 - A_1/A_2$ (D) A_1/A_2

Q.42 The composite wall of an oven consists of three materials A, B and C. Under steady state operating conditions, the outer surface temperature T_{so} is 20 °C, the inner surface temperature T_{si} is 600 °C and the oven air temperature is T_{∞} = 800 °C. For the following data

thermal conductivities k_A = 20 W/(m K) and k_C =50 W/(m K),
thickness L_A = 0.3m, L_B = 0.15m and L_C = 0.15m,
inner-wall heat transfer coefficient h = 25 W/(m^2 K),

the thermal conductivity k_B (W/(mK) of the material B, is calculated as



(A) 35 (B) 1.53 (C) 0.66 (D) 0.03

Q.43 Water enters a thin walled tube (L=1 m, D =3 mm) at an inlet temperature of 97°C and mass flow rate 0.015 kg/s. The tube wall is maintained at a constant temperature of 27°C. Given the following data for water

Density, ρ = 1000 kg/m^3
Viscosity, μ = 489 10^{-6} Ns/m^2
Specific heat C_p = 4184 J/kg/k

Inside heat transfer coefficient h =12978 W/(m^2 K),

the outlet temperature of water in °C is,

(A) 28 (B) 37 (C) 62 (D) 96

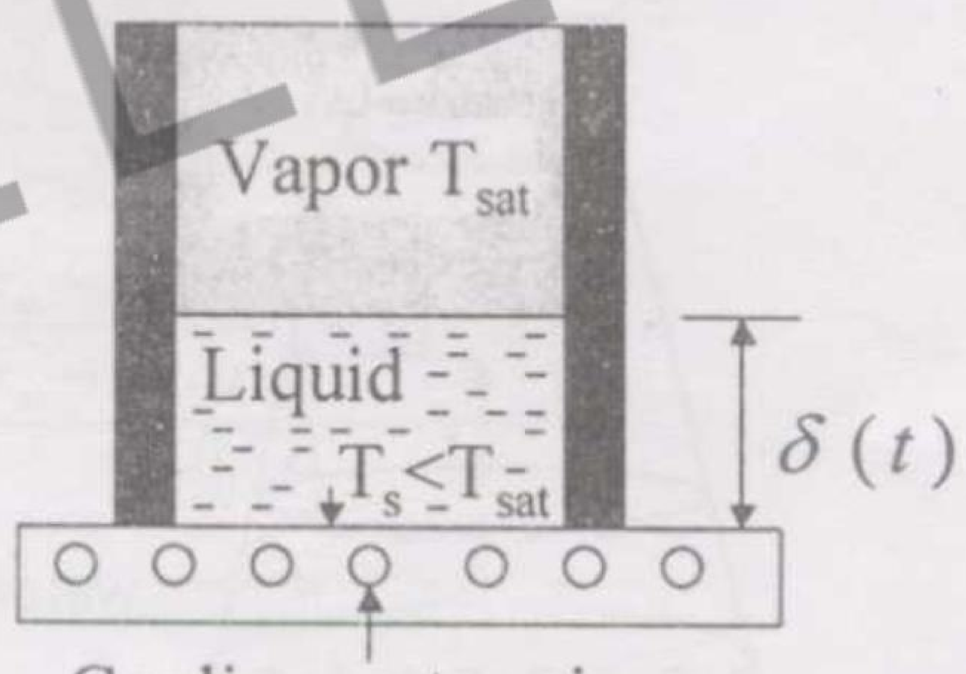
Q.44 A hot fluid entering a well-stirred vessel is cooled by feeding cold water through a jacket around the vessel. Assume the jacket is well-mixed. For the following data,

mass flowrates of the hot fluid = 0.25 kg/s,
mass flow rate of cold water = 0.4 kg/s,
specific heats of oil = 6000 J/kgK
specific heat of cold water = 4184 J/kgK
the inlet and exit temperature of the hot fluid is 150 °C and 100 °C respectively.
inlet temperature of cold water = 20 °C
the overall heat transfer coefficient is 500 W/m^{2}K.

the heat transfer area in m^2, is

(A) 1.82 (B) 2.1 (C) 3 (D) 4.26

Q.45 Consider a liquid stored in a container exposed to its saturated vapor at constant temperature T_{sat}. The bottom surface of the container is maintained at a constant temperature $T_s < T_{sat}$ while its side walls are insulated. The thermal conductivity k_l of the liquid, its latent heat of vaporisation λ and density ρ_l are known. Assuming a linear temperature distribution in the liquid, the expression for the growth of the liquid layer δ as a function of time t is given by



(A) $\delta(t)=\left[\frac{4k_l(T_{sat}-T_s)}{\rho_l\lambda}t\right]^{1/2}$

(B) $\delta(t)=\left[\frac{k_l(T_{sat}-T_s)}{2\rho_l\lambda}t\right]^{1/2}$

(C) $\delta(t)=\left[\frac{2k_l(T_{sat}-T_s)}{\rho_l\lambda}t\right]^{1/2}$

(D) $\delta(t)=\left[\frac{k_l(T_{sat}-T_s)}{\rho_l\lambda}t\right]^{1/2}$

Q.46 The following list of options P, Q, R and S are some of the important considerations in the design of a shell and tube heat exchanger.

P) square pitch permits the use of more tubes in a given shell diameter

Q) the tube side clearance should not be less than one fourth of the tube diameter

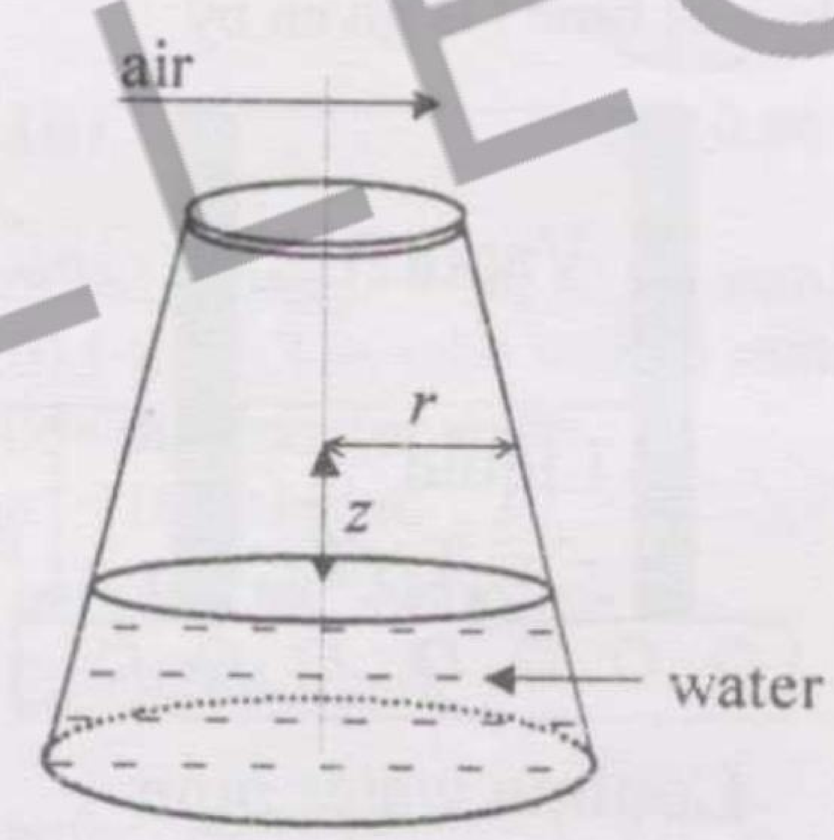
R) baffle spacing is not greater than the diameter of the shell or less than one-fifth of the shell diameter

S) The pressure drop on the tube side is less than 10 psi

Pick out the correct combination of 'TRUE' statements from the following:

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

Q.47 The following figure depicts steady one-dimensional diffusion of water vapour from the surface of water taken in a conical flask at room temperature. Derive the governing equation for determining the concentration profile of water vapour in the gas medium. Neglect change of level of water due to condensation. The temperatures of the gas and the liquid media are identical and constant.



(A) $\frac{d}{dz}\left[r^2\frac{CD_{WA}}{1-x_W}\frac{dx_W}{dz}\right]=0$

(B) $\frac{d}{dz}\left[\frac{CD_{WA}}{1-x_W}\frac{dx_W}{dz}\right]=0$

(C) $\frac{d}{dz}\left[r\frac{CD_{WA}}{1-x_W}\frac{dx_W}{dz}\right]=0$

(D) $\frac{d}{dz}\left[rCD_{WA}\frac{dx_W}{dz}\right]=0$

Q.48 In a distillation operation, it is desired to have a very high purity bottom product. Initially, a kettle-type reboiler is used at the bottom of the column and the following analytical equation is used to obtain the equilibrium trays in the exhausting section of the column

$$N_P - m + 1 = \frac{\log\left[\frac{x_m - x_w/\alpha}{x_w - x_w/\alpha}\left(1-\overline{A}\right)+\overline{A}\right]}{\log\left(1/\overline{A}\right)}$$

where x_m is the composition of the liquid leaving tray m. Tray m is the last equilibrium tray obtained by a McCabe Thiele graph of the exhausting section. If the kettle-type reboiler is replaced by a thermo-syphon reboiler, the analytical equation, for the exhausting section will be

(A) $N_P - m + 1 = \frac{\log\left[\frac{x_m - x_w/\alpha}{x_w - x_w/\alpha}\left(1-\overline{A}\right)+\overline{A}\right]}{\log\left(1/\overline{A}\right)}$

(B) $N_P + 1 = \frac{\log\left[\frac{x_m - x_w/\alpha}{x_w - x_w/\alpha}\left(1-\overline{A}\right)+\overline{A}\right]}{\log\left(1/\overline{A}\right)}$

(C) $N_P - m = \frac{\log\left[\frac{x_m - x_w/\alpha}{x_w - x_w/\alpha}\left(1-\overline{A}\right)+\overline{A}\right]}{\log\left(1/\overline{A}\right)}$

(D) $N_P - m + 2 = \frac{\log\left[\frac{x_m - x_w/\alpha}{x_w - x_w/\alpha}\left(1-\overline{A}\right)+\overline{A}\right]}{\log\left(1/\overline{A}\right)}$

Q.49 A 50cm X 50 cm X 1 cm flat wet sheet weighing 2 kg initially, was dried from both the sides under constant drying rate period. It took 1000 secs for the weight of the sheet to reduce to 1.75 kg. Another 1m X 1m X 1cm flat sheet is to be dried from one side only. Under the same drying rate and other conditions, time required for drying (in secs) from initial weight of 4 kg to 3 kg is

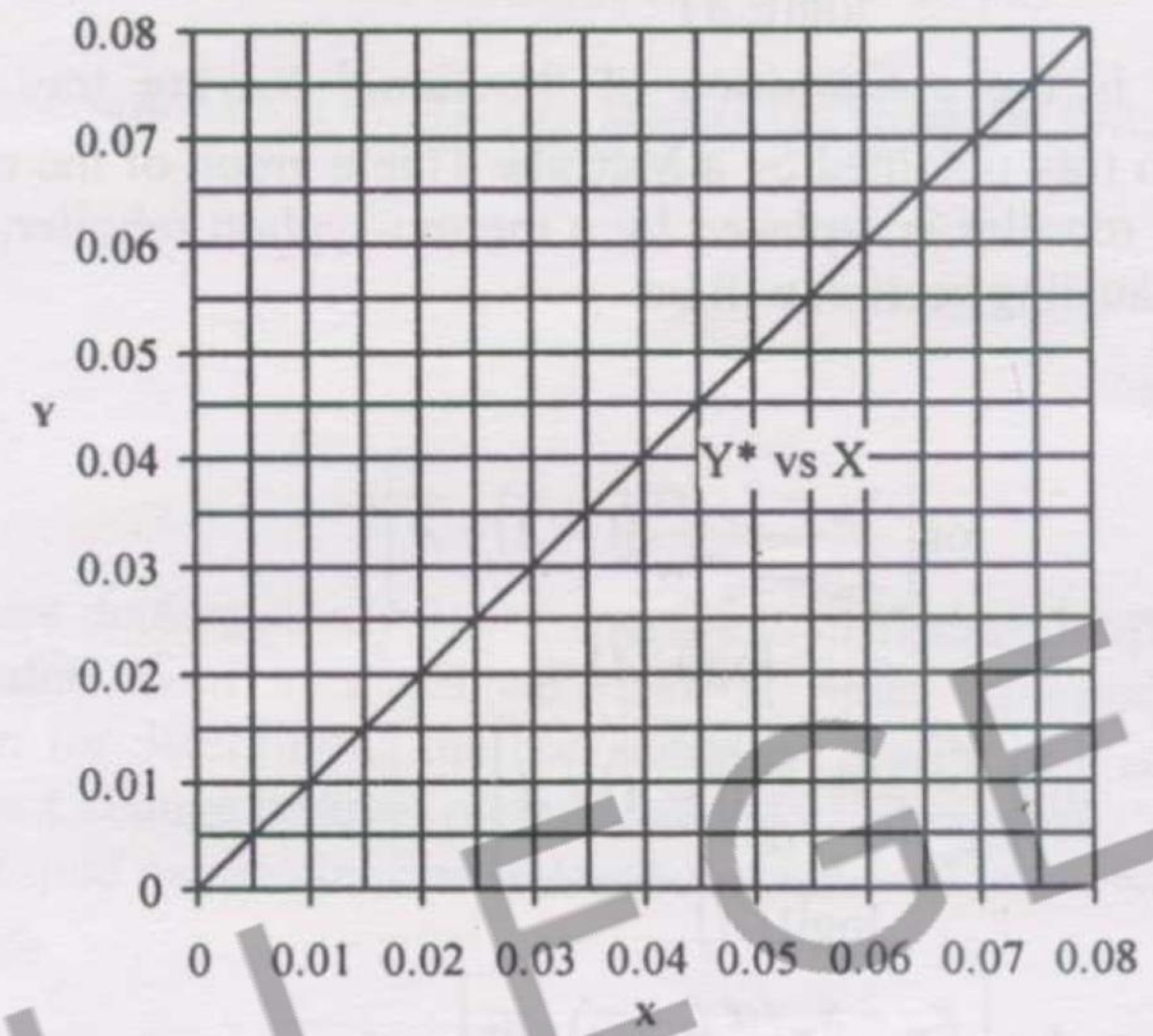
(A) 1000 (B) 1500 (C) 2000 (D) 2500

Q.50 It is desired to reduce the concentration of pyridine in 500 kg of aqueous solution from 20 weight percent to 5 wt percent in a single batch extraction using chlorobenzene as solvent. Equilibrium compositions (end points of the tie line) in terms of weight percent of pyridine-water-chlorobenzene are (5, 95, 0) and (11, 0, 89).

The amount of pure solvent required in kg for the operation is

(A) 607 (B) 639 (C) 931 (D) 1501

Q.51 Benzene in an air-benzene mixture is to be reduced from 5.2 mol % in the feed to 0.5 mol % by contacting with wash oil in a multistage countercurrent gas absorber. The inlet flowrate of air-benzene mixture is 10 mol/s while benzene free wash oil comes in at 9.5 mol/s. If the equilibrium curve is given as $Y^* = X$, where Y^* and X are equilibrium mole ratios of benzene in air and benzene in oil, the number of equilibrium stages required to achieve the above separation is



(A) 12 (B) 10 (C) 8 (D) 6

Q.52 A well-stirred reaction vessel is operated as a semi-batch reactor in which it is proposed to conduct a liquid phase first order reaction of the type $A \rightarrow B$. The reactor is fed with the reactant A at a constant rate of 1 liter/min having feed concentration equal to 1 mol/liter. The reactor is initially empty. Given $k = 1 \text{ min}^{-1}$, the conversion of reactant A based on moles of A fed at $t = 2$ min is

(A) 0.136 (B) 0.43 (C) 0.57 (D) 0.864

Q.53 A liquid phase exothermic first order reaction is being conducted in a batch reactor under isothermal conditions by removing heat generated in the reactor with the help of cooling water. The cooling water flows at a very high rate through a coil immersed in the reactor such that there is negligible rise in its temperature from inlet to outlet of the coil. If the rate constant is given as k, heat of reaction $(-\Delta H)$, volume of the reactor, V, initial concentration as C_{A0}, overall heat transfer coefficient, U, heat transfer area of the coil is equal to A, the required cooling water inlet temperature, T_{ci} is given by the following equation:

(A) $T_{ci} = T - \dfrac{(-\Delta H)VkC_{A0}}{UA}$

(B) $T_{ci} = T - \dfrac{(-\Delta H)VkC_{A0}e^{-kt}}{UA}$

(C) $T_{ci} = T - \dfrac{(-\Delta H)VC_{A0}e^{-kt}}{UAt}$

(D) $T_{ci} = T - \dfrac{(-\Delta H)VC_{A0}}{UAt}$

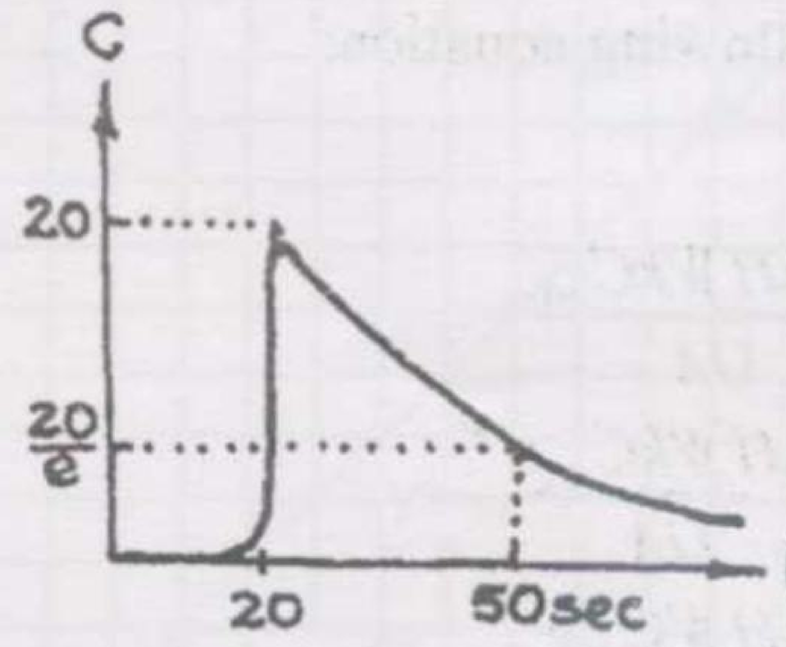
Q.54 The following liquid phase reaction is taking place in an isothermal CSTR

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$
$$2A \xrightarrow{k_3} D$$

Reaction mechanism is same as the stoichiometry given above. Given $k_1 = 1$ min^{-1}; $k_2 = 1$ min^{-1}; $k_3 = 0.5$ lit/(mol)(min); C_{A0} = 10 mol/litre, $C_{B0} = 0$ mol/litre and $C_B = 1$ mol/litre, the solution for F/V (flow rate/reactor volume in min^{-1}) yields

(A) 6.7 (B) 6 and 0.5 (C) 2 and 4/3 (D) 8

Q.55 A pulse of concentrated KCl solution is introduced as tracer into the fluid entering a reaction vessel having volume equal to 1 m^3 and flow rate equal to 1 m^3/min. The concentration of tracer measured in the fluid leaving the vessel is shown in the figure given below. The flow model parameters that fit the measured RTD in terms of one or all of the following mixing elements, namely, volume of plug flow reactor, V_p, mixed flow volume, V_m, and dead space, V_d, are



(A) $V_p = 1/6\ m^3\ V_m = 1/2\ m^3,\ V_d = 1/3\ m^3$

(B) $V_p = V_m = V_d = 1/3\ m^3$

(C) $V_p = 1/3\ m^3\ V_m = 1/2\ m^3,\ V_d = 1/6\ m^3$

(D) $V_m = 5/6\ m^3\ V_d = 1/6\ m^3$

Q.56 The first order reaction of A to R is run in an experimental mixed flow reactor.Find the role played by pore diffusion in the run given below. C_{A0} is 100 and W is fixed. Agitation rate was found to have no effect on conversion.

d_p	F_{A0}	X_A
4	2	0.8
6	4	0.4

(A) strong pore diffusion control
(B) diffusion free
(C) intermediate role by pore diffusion
(D) external mass transfer

Q.57 A packed bed reactor converts A to R by first order reaction with 9 mm pellets in strong pore diffusion regime to 63.2% level. If 18 mm pellets are used what is the conversion.

(A) 0.39 (B) 0.61 (C) 0.632 (D) 0.865

Q.58 The following rate-concentration data are calculated from experiment. Find the activation energy temperature (E/R) of the first order reaction.

d_p	C_A	$-r_A$	T
1	20	1	480
2	40	2	480
2	40	3	500

(A) 2432.8 (B) 4865.6 (C) 9731.2 (D) 13183.3

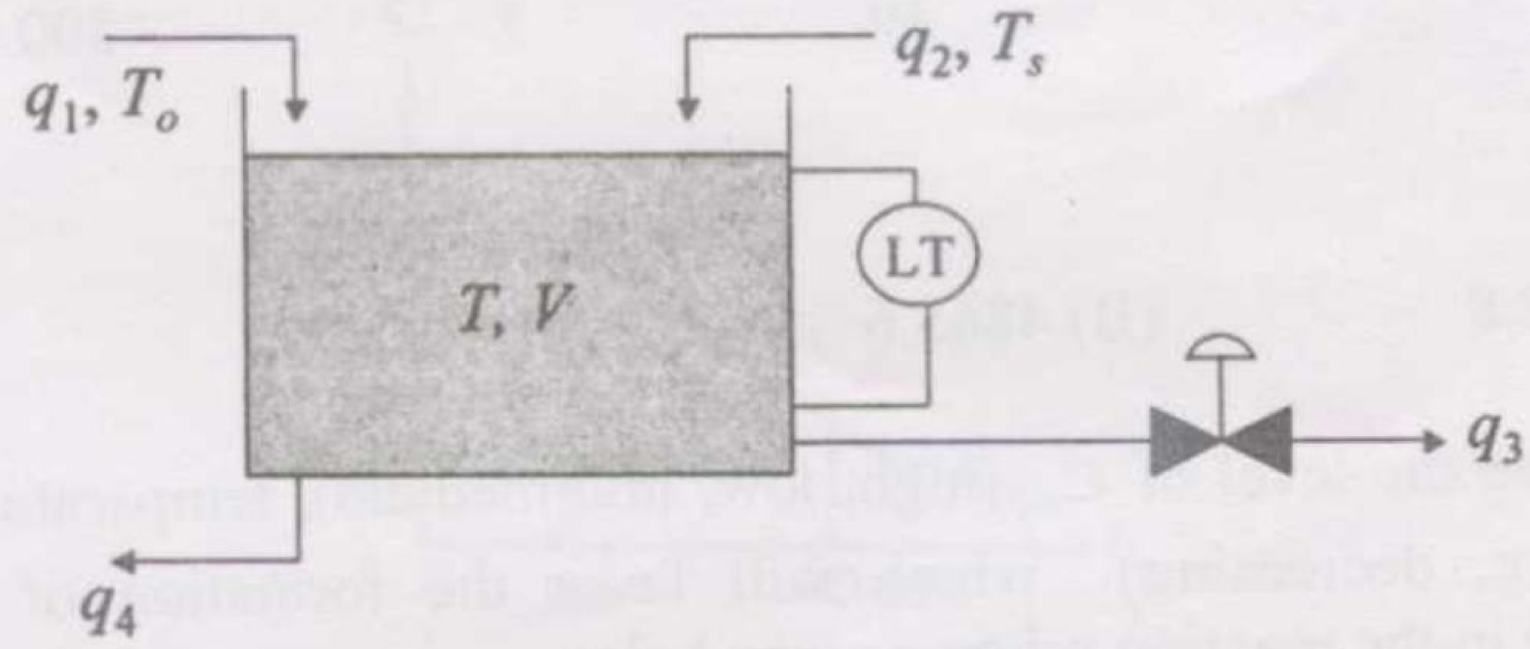
Q.59 Determine the level of C_{A0} (high, low, intermediate), temperature profile (high, low, increasing, decreasing) which will favor the formation of the desired product indicated in the reaction scheme given below.

$$A \xrightarrow{1} R \xrightarrow{3} S_{desired}$$
$$A \xrightarrow{2} U$$

n_1	E_1	n_2	E_2	n_3	E_3
2	25	1	35	3	45

(A) High C_{A0}, increasing T, plug flow reactor
(B) Low C_{A0}, increasing T, plug flow reactor
(C) High C_{A0}, decreasing T, mixed flow reactor
(D) High C_{A0}, decreasing T, plug flow reactor

Q.60 The dynamic model for a mixing tank open to atmosphere at its top as shown below is to be written. The objective of mixing is to cool the hot water stream entering the tank at a flow rate q_2 and feed temperature of T_s with a cold water feed stream entering the tank at a flow rate q_1 and feed temperature of T_0. A water stream is drawn from the tank bottom at a flow rate of q_4 by a pump and the level in the tank is proposed to be controlled by drawing another water stream at a flow rate q_3. Neglect evaporation and other heat losses from the tank



The dynamic model for the tank is given as

(A) $\dfrac{dV}{dt} = q_1 + q_2 - q_3,\qquad V\dfrac{dT}{dt} = q_1T_o + q_2T_s - q_3T$

(B) $\dfrac{dV}{dt} = q_1 - q_4,\qquad \dfrac{d(VT)}{dt} = q_1T_s - q_4T$

(C) $\dfrac{dV}{dt} = q_1 + q_2 - q_4,\qquad \dfrac{d(VT)}{dt} = q_1T_o + q_2T_s - q_4T$

(D) $\dfrac{dV}{dt} = q_1 + q_2 - q_3 - q_4,\qquad V\dfrac{dT}{dt} = q_1(T_o - T) + q_2(T_s - T)$

Q.61 Match the transfer functions with the responses to a unit step input shown in the figure.

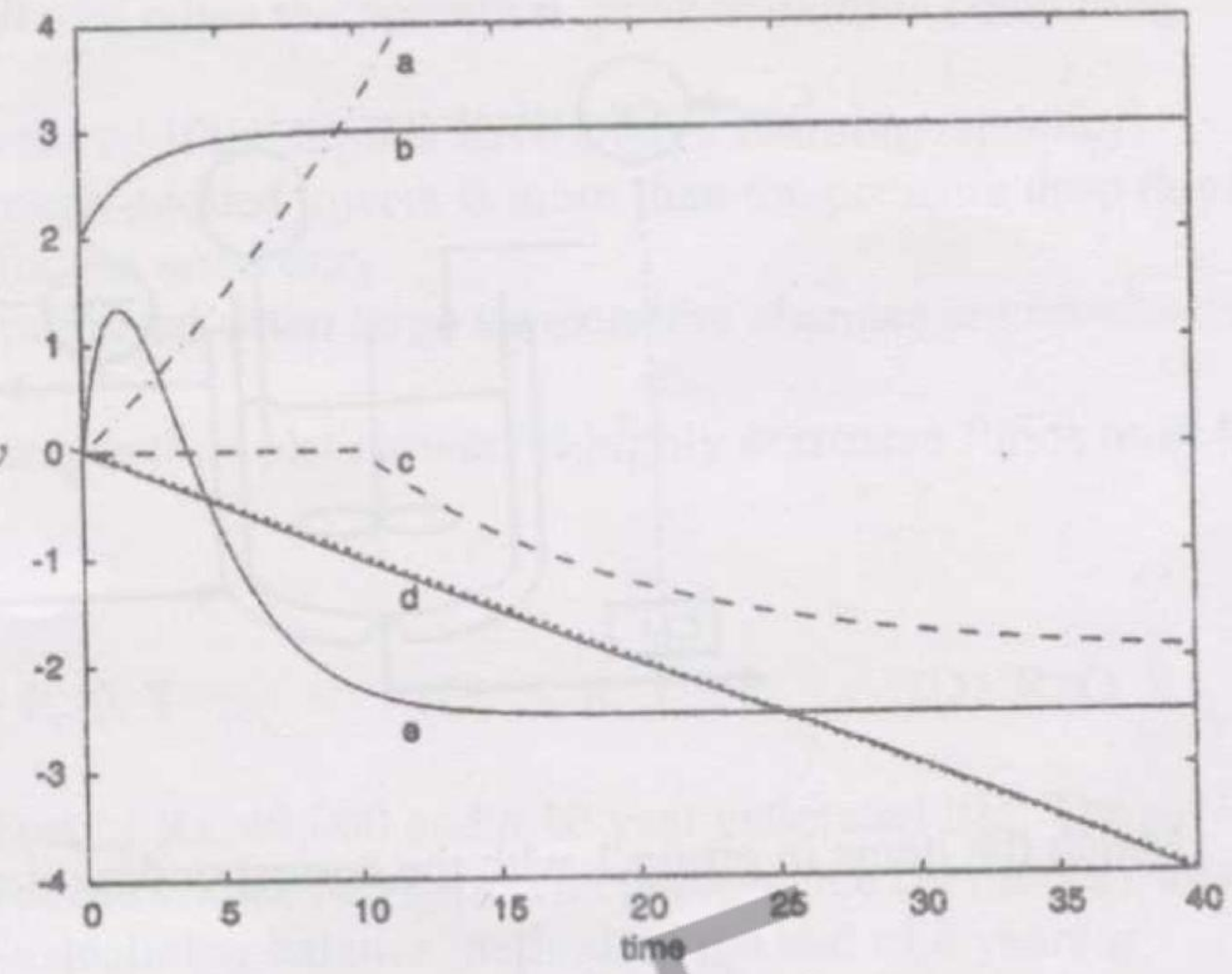
i. $\dfrac{-2.5(-4s+1)}{4s^2+4s+1}$

ii. $\dfrac{-2e^{-10s}}{10s+1}$

iii. $\dfrac{-5}{-20s+1}$

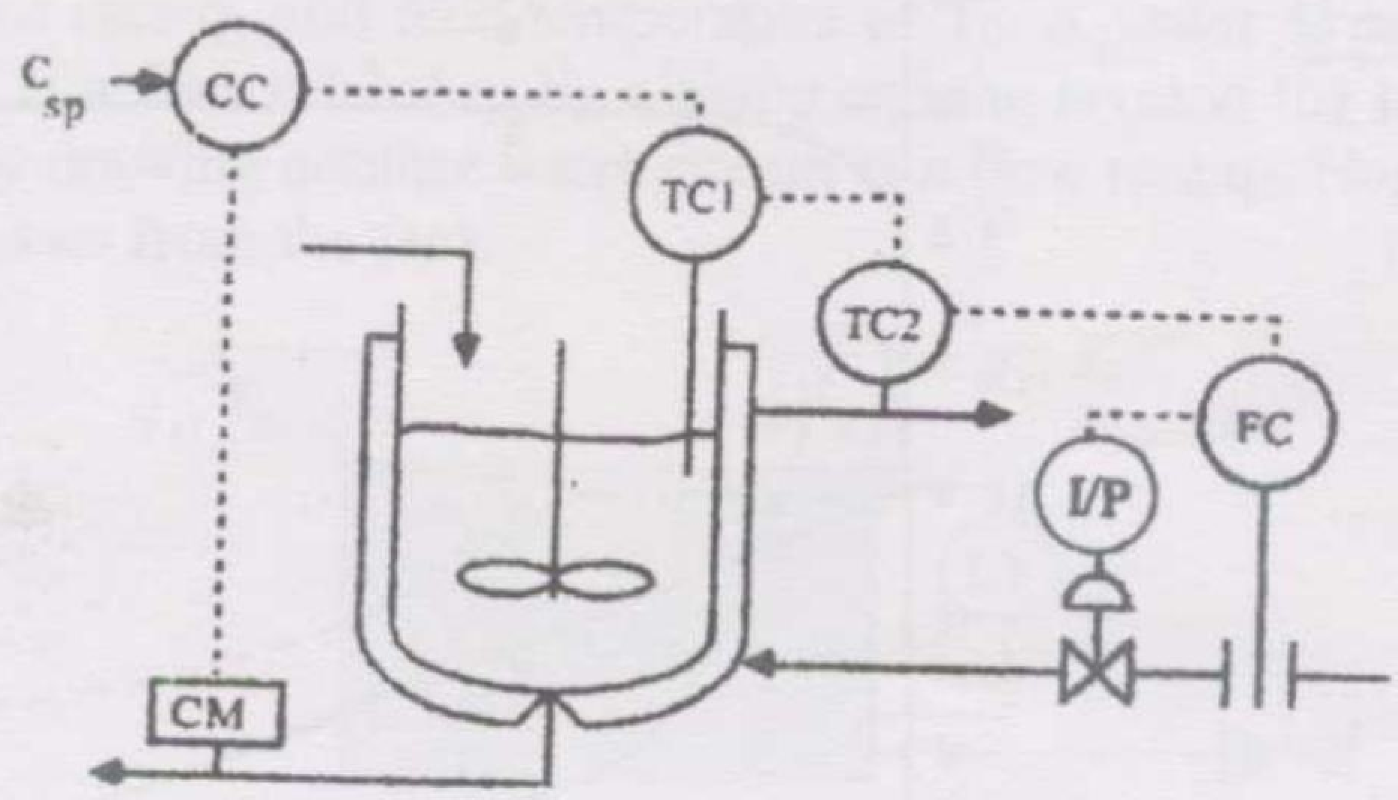
iv. $\dfrac{-0.1}{s}$

v. $\dfrac{4s+3}{2s+1}$



(A) i-e, ii-c, iii-a, iv-d, v-b
(B) i-a, ii-b, iii-c, iv-d, v-e
(C) i-b, ii-a, iii-c, iv-e, v-d
(D) i-e, ii-a, iii-c, iv-b, v-d

Q.62 Consider the following instrumentation diagram for a chemical reactor. C_{sp} represents a concentration setpoint.



Match the items in group 1 with the corresponding items given in column B.

Column A	Column B
P) control strategy	1) feed forward control
Q) primary control variable	2) cascade control
R) slowest controller	3) concentration in the reactor
S) fastest controller	4) reactor temperature
	5) jacket temperature
	6) concentration controller
	7) reactor temperature controller
	8) jacket temperature controller
	9) flow controller
	10) selective control

(A) P-2, Q-3, R-6, S-9
(B) P-1, Q-4, R-8, S-7
(C) P-10, Q-7, R-9, S-6
(D) P-1, Q-8, R-5, S-9

Q.63 The first two rows of Routh's tabulation of a third order equation are

$$\begin{array}{ccc} s^3 & 2 & 2 \\ s^2 & 4 & 4 \end{array}$$

Select the correct answer from the following choices:

(A) The equation has one root in the right half s-plane
(B) The equation has two roots on the j axis at s = j and –j. The third root is in the left half plane
(C) The equation has two roots on the j axis at s = 2j and s= -2j. The third root is in the left half plane.
(D) The equation has two roots on the j axis at s= 2j and s=-2j. The third root is in the right half plane

Q.64 Given the following statements listed from P to T, select the correct **combination** of **TRUE** statements from the choices that follow this list.

P) Plate columns are preferred when the operation involves liquids containing suspended solids.
Q) Packed towers are preferred if the liquids have a large foaming tendency.
R) The pressure drop through packed towers is more than the pressure drop through plate columns designed for the same duty.
S) Packed columns are preferred when large temperature changes are involved in distillation operations.
T) Packed towers are cheaper than plate towers if highly corrosive fluids must be handled.

(A) T, S, P (B) P, Q, T (C) S, R, T (D) R, Q, S

Q.65 A pump has an installed cost of Rs. 40,000 and a 10 year estimated life. The salvage value of the pump is zero at the end of 10 years. The pump value (in rupees), after depreciation by the double declining balance method, at the end of 6 years is

(A) 4295 (B) 10486 (C) 21257 (D) 37600

Q.66 In a double pipe heat exchanger the ID and OD of the inner pipe are 4cm and 5cm respectively. The ID of the outer pipe is 10cm with a wall thickness of 1cm. Then, the equivalent diameters (in cm) of the annulus for heat transfer and pressure drop respectively are

(A) 15, 5 (B) 21, 6 (C) 6, 19 (D) 15, 21

Q.67 Match the chemicals in Group1 with their function in Group 2

Group1	Group 2
P. styrene	(1) buffer
Q. tert-dodecyl mercaptan	(2) catalyst
R. potassium pyrophosphate	(3) modifier
	(4) monomer

(A) P-1, Q-4, R-4 (B) P-4, Q-1, R-2 (C) P-4, Q-1, R-3 (D) P-4, Q-3, R-1

Q.68 Match the product in Group1 with its application in the industries of Group 2.

Group1	Group 2
P. lithium stearate	(1) cosmetics
Q. magnesium stearate	(2) paper
R. aluminium sulphate	(3) dry Cleaning
	(4) greases

(A) P-2, Q-3, R-1 (B) P-3, Q-4, R-2 (C) P-4, Q-2, R-3 (D) P-4, Q-1, R-2

Q.69 Match the synthetic fibres in Group1 with their classification in Group 2.

Group1	Group 2
P) Rayon	(1) polyamide
Q) Orlon	(2) polyester
R) Dacron	(3) cellulose
	(4) acrylic

(A) P-2, Q-3, R-1 (B) P-3, Q-4, R-2 (C) P-3, Q-1, R-3 (D) P-3, Q-3, R-4

Q.70 Match the Petrochemical derivative in Group1 with the raw materials in Group 2

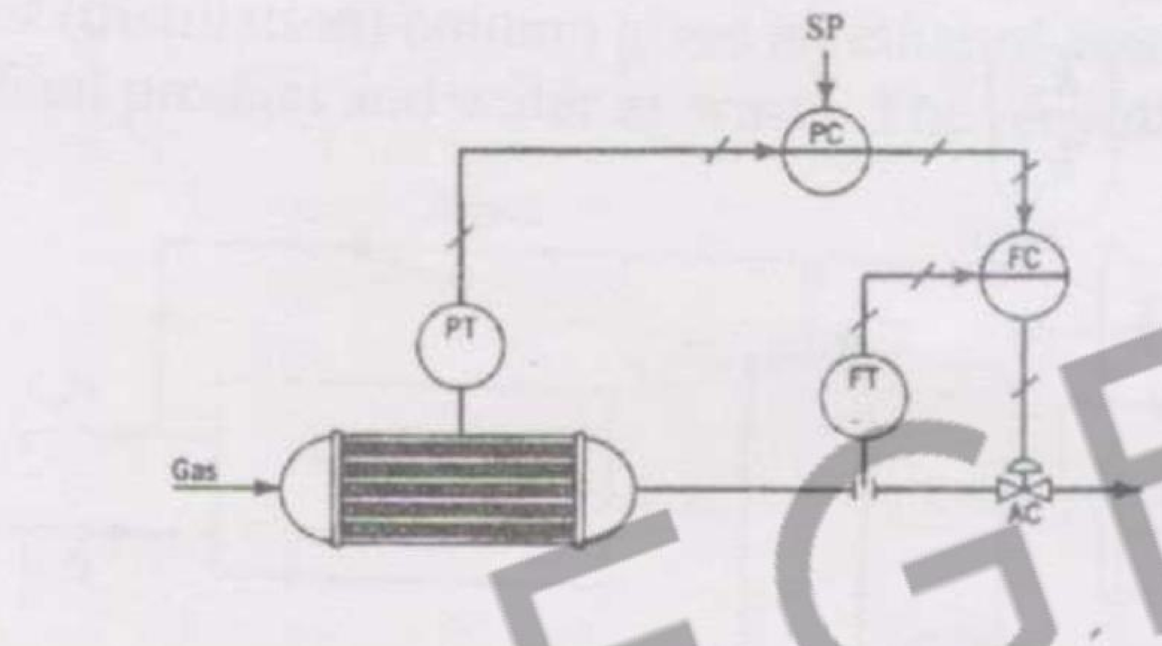
Group1	Group 2
P) acrylonitrile	(1) methane
Q) ammonia	(2) ethane
R) dodecene	(3) ethylene
	(4) propylene

(A) P-1, Q-2, R-1 (B) P-2, Q-1, R-2 (C) P-3, Q-4, R-3 (D) P-4, Q-1, R-4

Common Data Questions

Common Data for Questions 71,72,73:

Q.71 A cascade control system for pressure control is shown in the figure given below. The pressure transmitter has a range of 0 to 6 bar(g) and the flow transmitter range is 0 to 81 nm^3/hr. The normal flow rate through the valve is 32.4 nm^3/hr corresponding to the value of set point for pressure = 1bar(g) and to give the flow, the valve must be 40% opened. The control valve has linear characteristics and is fail-open (air to close). Error, set point and control variable are expressed in percentage transmitter output(% TO). Proportional gain is expressed in the units of % controller output (CO/%TO).



The types of action for the two controllers are

(A) direct acting for the pressure control and direct acting for the flow control
(B) indirect acting for the pressure control and indirect acting for the flow control
(C) direct acting for the pressure control and indirect acting for the flow control
(D) indirect acting for the pressure control and direct acting for the flow control

Q.72 The bias values for the two controllers, so that no offset occurs in either controller are

(A) Pressure controller : 40%; Flow controller : 60%
(B) Pressure controller :33% ; Flow controller : 67%
(C) Pressure controller: 67%; Flow controller: 33%
(D) Pressure controller: 60% ; Flow controller: 40%

Q.73 Given that the actual tank pressure is 4 bar(g) and a proportional controller is employed for pressure control, the proportional band setting of the pressure controller required to obtain a set point to the flow controller equal to 54 nm^3/hr is

(A) 50% (B) 100% (C) 150% (D) 187%

Common Data for Questions 74, 75:

Q.74 The following liquid phase reaction is taking place in an isothermal batch reactor

$$A \xrightarrow{k_1\ (first\ order)} B \xrightarrow{k_2\ (zero\ order)} C$$

Feed concentration = 1 mol/litre

The time at which the concentration of B will reach its maximum value is given by

(A) $t = \frac{1}{k_1}\ln\left(\frac{k_1}{k_2}\right)$

(B) $t = \frac{1}{k_2 - k_1}\ln\left(\frac{k_2}{k_1}\right)$

(C) $t = \frac{1}{k_2}\ln\left(\frac{k_2}{k_1}\right)$

(D) $t = \frac{1}{k_2}\ln\left(\frac{k_1}{k_2}\right)$

Q.75 The time at which the concentration of B will become zero is given by the following equation:

(A) $\left(1 - e^{-k_1 t}\right) = k_2 t$ (B) $t = \infty$

(C) $t = \frac{1}{k_2}$ (D) $t = \frac{1}{k_1}$

Linked Answer Questions: Q.76 to Q.85 carry two marks each.

Statement for Linked Answer Questions 76 & 77:

Q.76 A methanol-water vapor liquid system is at equilibrium at 60 °C and 60 kPa. The mole fraction of methanol in liquid is 0.5 and in vapor is 0.8. Vapor pressure of methanol and water at 60 °C are 85 kPa and 20 kPa respectively. Assuming vapor phase to be an ideal gas mixture, what is the activity coefficient of water in the liquid phase ?

(A) 0.3 (B) 1.2

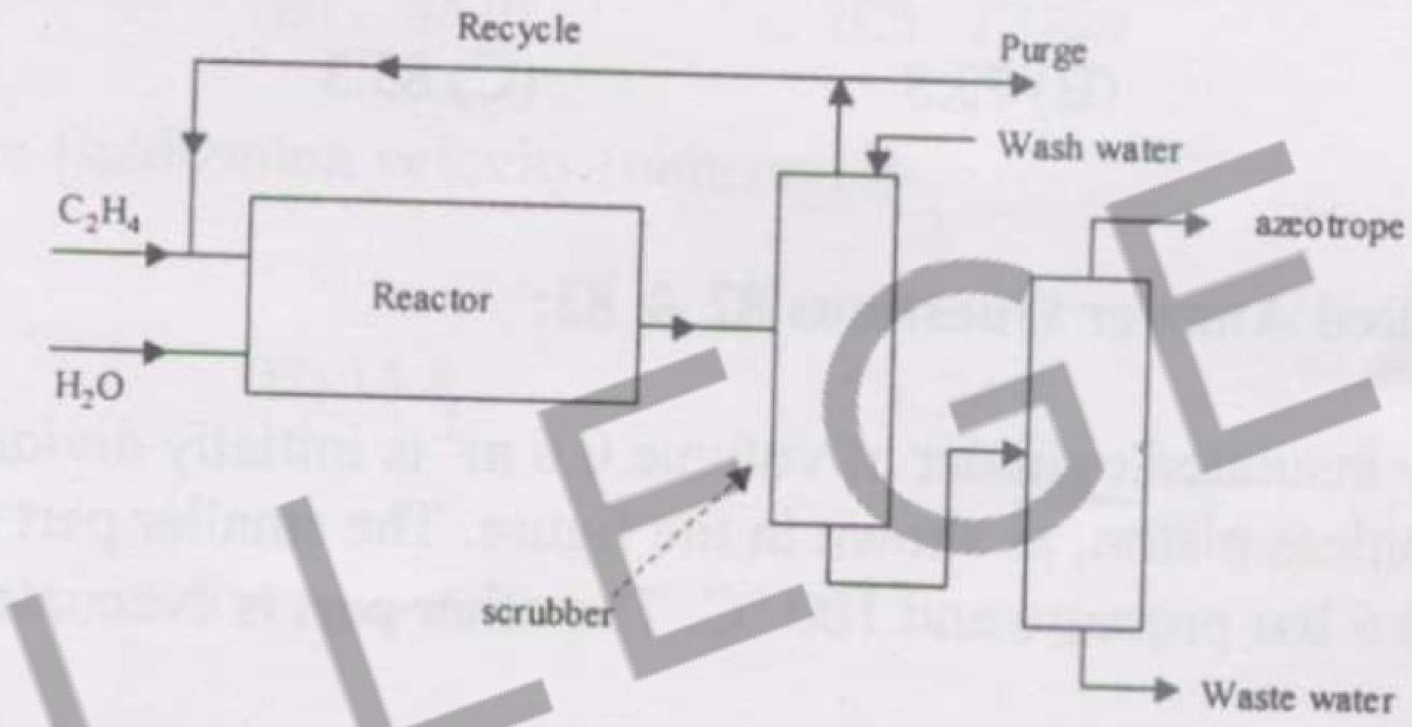
(C) 1.6 (D) 7.5

Q.77 What is the excess Gibbs free energy (g^E , in J/mol) of the liquid mixture ?

(A) 9.7
(B) 388
(C) 422
(D) 3227

Statement for Linked Answer Questions 78 & 79:

Q.78 A simplified flowsheet is shown in the figure for production of ethanol from ethylene. The conversion of ethylene in the reactor is 30 % and the scrubber following the reactor completely separates ethylene (as top stream) and ethanol and water as bottoms. The last (distillation) column gives an ethanol-water azeotrope (90 mol % ethanol) as the final product and water as waste. The recycle to purge ratio is 34.



The reaction is : $C_2H_4\,(g) + H_2O\,(g) \rightarrow C_2H_5OH\,(g)$

For an azeotrope product rate of 500 mols/hr, the recycle gas flowrate in mols/hr is

(A) 30
(B) 420
(C) 1020
(D) 1500

Q.79 For the same process, if fresh H_2O feed to the reactor is 600 mol/hr and wash water for scrubbing is 20 % of the condensables coming out of the reactor, the water flowrate in mols/hr from the distillation column as bottoms is

(A) 170
(B) 220
(C) 270
(D) 430

Statement for Linked Answer Questions 80 & 81:

Q.80 44 kg of C_3H_8 is burnt with 1160 kg of air (Mol. Wt. = 29) to produce 88 kg of CO_2 and 14 kg of CO

$$C_3H_8 + 5\,O_2 = 3\,CO_2 + 4\,H_2O$$

What is the percent excess air used ?

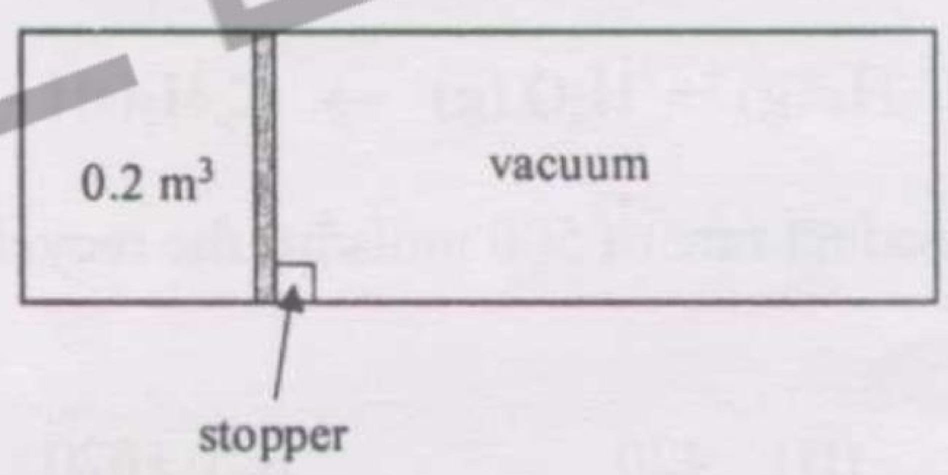
(A) 55 (B) 60 (C) 65 (D) 68

Q.81 What is the % carbon burnt?

(A) 63.3 (B) 73.3 (C) 83.3 (D) 93.3

Statement for Linked Answer Questions 82 & 83:

Q.82 A perfectly insulated cylinder of volume 0.6 m^3 is initially divided into two parts by a thin, frictionless piston, as shown in the figure. The smaller part of volume 0.2 m^3 has ideal gas at 6 bar pressure and 100 °C. The other part is evacuated.



At certain instant of time t, the stopper is removed and the piston moves out freely to the other end. The final temperature is

(A) - 149 °C (B) - 33 °C (C) 33 °C (D) 100 °C

Q.83 The cylinder insulation is now removed and the piston is pushed back to restore the system to its initial state. If this is to be achieved only by doing work on the system (no heat addition, only heat removal allowed), what is the minimum work required ?

(A) 3.4 kJ (B) 107 kJ (C) 132 kJ (D) 240 kJ

Statement for Linked Answer Questions 84 & 85:

Q.84 A fluidized bed (0.5m dia ,0.5m high) of spherical particles (diameter = 2000 μm, specific gravity = 2.5) uses water as the medium. The porosity of the bed is 0.4. The Ergun eqn for the system is

$$\Delta P/L = 4 \times 10^5 U_{mf} + 1 \times 10^7 U_{mf}^2$$

(SI unit, U_{mf} in m/s).

$\Delta P/L$ (SI unit) at minimum fluidization condition is
($g = 9.8$ m/sec^2)

(A) 900 (B) 8820 (C) 12400 (D) 17640

Q.85 The minimum fluidization velocity (mm/sec) is

(A) 12.8 (B) 15.8 (C) 24.8 (D) 28.8

END OF THE QUESTION PAPER