CH: CHEMICAL ENGINEERING

EE25BTECH11042 - Nipun Dasari

1) The direction of largest increase of the function $xy^3 - x^2$ the point $(1, 1)$ is -

a) $3\hat{\imath} + 4\hat{\jmath}$ b) $3\hat{\imath} + 4\hat{\jmath}$ c) $3\hat{\imath} + 4\hat{\jmath}$ d) $3\hat{\imath} + 4\hat{\jmath}$

(GATE CH 2009)

2) The modulus of the complex number is $(1 + i)/\sqrt{2}$

a) $1/2$ b) $1/\sqrt{2}$ c) 1 d) $\sqrt{2}$

(GATE CH 2009)

3) The system of linear equations $\mathbf{Ax} = \mathbf{0}$, where $\mathbf{A}$ is an nxn matrix, has a non-trivial solution ONLY if-

a) rank of **A**>n
b) rank of **A**=n
c) rank of **A**<n
d) **A** is an identity matrix

(GATE CH 2009)

4) A dehumidifier (shown below) is used to completely remove water vapour from air

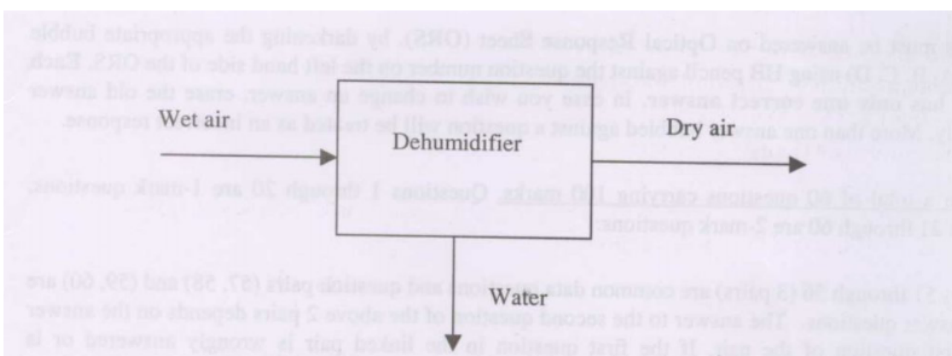

Fig. 1

Which **ONE** of the following statements is **TRUE**

a) Water is the ONLY tie component
b) Air is the ONLY tie component
c) BOTH water and air are tie components
d) There are NO tie components

(GATE CH 2009)

5) Dehydrogenation of ethane, H_6 (g) */rightarrow* H_4 (g) + H_2 (g), is carried out in a continuous stirred tank reactor (CSTR) The feed is pure ethane. If the reactor exit stream contains unconverted ethane along with the products, then the number of degrees of freedom for the CSTR is

a) 1 b) 2 c) 3 d) 4

(GATE CH 2009)

6) An ideal gas at temperature T_1 and pressure P_1 is compressed isothermally to pressure P_2 ($> P_1$) in a closed system. Which ONE of the following is TRUE for internal energy (U) and Gibbs free energy (G) of the gas at the two states?

a) $U_1 = U_2$, G_1¿ G_2
b) U_1=U_2, G_1¡ G_2
c) U_1¿U_2, $G_1 = G_2$
d) U_1¡U_2,$G_1 = G_2$

(GATE CH 2009)

7) Under fully turbulent flow conditions, the frictional pressure drop across a packed bed varies with the superficial velocity (V) of the fluid as -

a) V^{-1}
b) V
c) $V^{3/2}$
d) V^2

(GATE CH 2009)

8) For a mixing tank operating in the laminar regime, the power number varies with the Reynolds number (Re) as

a) $Re^{\frac{-1}{2}}$
b) $Re^{\frac{1}{2}}$
c) Re
d) $Re^{-}1$

(GATE CH 2009)

9) During the transient convective cooling of a solid object, Biot number $\rightarrow$ O indicates

a) uniform temperature throughout the object
b) negligible convection at surface of the object
c) significant thermal resistance within the object
d) significant temperature gradient within the object

(GATE CH 2009)

10) The Prandtl number of a fluid is the ratio of

a) thermal diffusivity to momentum diffusivity
b) momentum diffusivity to thermal diffusivity
c) conductive resistance to convective resistance
d) thermal diffusivity to kinematic viscosity

(GATE CH 2009)

11) According to the penetration theory of mass transfer, the mass transfer coefficient (k) varies with diffusion coefficient (D) of the diffusing species as

a) D
b) $D^{\frac{-1}{2}}$
c) $D^{\frac{1}{2}}$
d) $D^{\frac{3}{2}}$

(GATE CH 2009)

12) The ratio of the liquid to gas flow rate in a counter-current gas absorption column is increased, at otherwise identical conditions. Which ONE of the following statements is TRUE ?

a) The operating line shifts towards the equilibrium curve
b) The operating line shifts away from the equilibrium curve
c) The concentration of the absorbed species increases in the exit liquid stream
d) The operating line does not shift

(GATE CH 2009)

13) For a homogeneous reaction system, where
C_j is the concentration of j at time t N_j is the number of moles of j at time t V is the reaction volume at time t 1 is the reaction time The rate of reaction for species j is defined as

a) $\frac{dC_j}{dt}$
b) - $\frac{dC_j}{dt}$
c) $\frac{1}{V}\frac{dN_j}{dt}$
d) -$\frac{1}{V}\frac{dN_j}{dt}$

(GATE CH 2009)

14) The half-life of a first order liquid phase reaction is 30 seconds. Then the rate constant, in min^{-1}, is
   a) 0.0231
   b) 0.602
   c) 1.386
   d) 2.0

(GATE CH 2009)

15) For a solid catalyzed reaction, the Thiele modulus is proportional to
   a) $\sqrt{\frac{\text{intrinsic reaction rate}}{\text{diffusion rate}}}$
   b) $\sqrt{\frac{\text{diffusion rate}}{\text{intrinsic reaction rate}}}$
   c) $\frac{\text{intrinsic: reaction rate}}{\text{diffusion: rate}}$
   d) $\frac{\text{diffusion rate}}{\text{intrinsic: reaction rate}}$

(GATE CH 2009)

16) Which ONE of the following sensors is used for the measurement of temperature in a combustion process ($T > 1800°C$) ?
   a) Type J thermocouple
   b) Thermistor
   c) Resistance temperature detector
   d) Pyrometer

(GATE CH 2009)

17) The roots of the characteristic equation of an underdamped second order system are
   a) real, negative and equal
   b) real, negative and unequal
   c) real, positive and unequal
   d) complex conjugates

(GATE CH 2009)

18) The total fixed cost of a chemical plant is Rs. 10.0 lakhs; the internal rate of return is 15 per cent and annual operating cost is rs. 2.0 lakhs. The annualised cost of plant is
   a) 1.8
   b) 2.6
   c) 3.5
   d) 4.3

(GATE CH 2009)

19) In petroleum refining operations, the process used for converting paraffins and naphthenes to aromatics is
   a) catalytic reforming
   b) catalytic cracking
   c) hydrocracking
   d) alkylation

(GATE CH 2009)

20) The active component of catalysts used in steam reforming of methane to produce synthesis gas is
   a) Nickel
   b) Iron
   c) Platinum
   d) Palladium

(GATE CH 2009)

21) The value of the limit

$$\lim_{x\to\ \pi/2} \frac{cosx}{(x-\pi/2)^3}$$

a) $-\infty$ b) 0 c) 1 d) ∞

(GATE CH 2009)

22) The general solution of the differential equation

$$\frac{d^2y}{dx^2} - \frac{dy}{dx} - 6y = 0$$

, with C_1 and as constants of integration, is

a) $C_1 e^- 3x + C_2 e^- 2x$
c) $C_1 e^3 x + C_2 e^2 x$
b) $C_1 e^3 x + C_2 e^- 2x$
d) $C_1 e^- 3x + C_2 e^2 x$

(GATE CH 2009)

23) Using the residue theorem, the value of integral (*counterclockwise*)

$$\oint \frac{8-7z}{z-4}\, dz$$

around a circle with centre at z=0 and radius=8 $\left(\text{where z is a complex number and } i = \sqrt{-1}\right)$, is

a) -20π b) -40π c) -40πi d) 40πi

(GATE CH 2009)

24) Consider the integral $\iint (2xi - 2yj + 5zk) \,.\, n\, dS$ over the surface of a sphere of radius = 3 with center at the origin and surface unit normal n pointing away from the origin. Using the Gauss divergence theorem, the value of the integral is

a) -180π b) 0 c) 90π d) 180π

(GATE CH 2009)

25) Using the trapezoidal rule and 4 equal intervals $(n = 4)$, the calculated value of the integral (rounded to the first
$\left(\int_0^\pi sin\theta d\theta\right)$ is

a) 1.7 b) 1.9 c) 2.0 d) 2.1

(GATE CH 2009)

26) The eigenvalues of matrix A =

$$\begin{pmatrix} 1 & 2 \\ 5 & 3 \end{pmatrix} \tag{1}$$

are 5 and -1. Then the eigenvalues of $-2\mathbf{A} + 3\mathbf{I}$($\mathbf{I}f$is 2x2 identity matrix) are

a) -7 and 5 b) 7 and -5 c) -1/7 and 1/5 d) 1/7 and - 1/5

(GATE CH 2009)

27) A fair die is rolled. Let R denote the event of obtaining a number less than or equal to 5 and S denote the event of obtaining an odd number. Then which ONE of the following about the probability (P) is TRUE ?

a) P(R/S) = 1 b) P(R/S) = 0 c) P(S/R) = 1 d) P(S/R) = 0

(GATE CH 2009)

28) Pure water (*streamW*) is to be obtained from a feed containing 5 wt per cent salt using a desalination unit as shown below

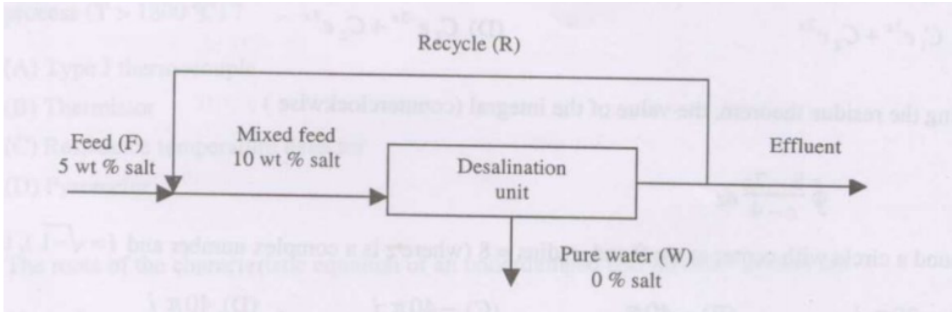

Fig. 2

If the overall recovery of pure water (through stream W) is 0.75 kg/kg feed, then the recycle ratio (R/F) is

a) 0.25 b) 0.5 c) 0.75 d) 1.0

(GATE CH 2009)

29) For a binary mixture at constant temperature and pressure, which ONE of the following relations between activity coefficient γ and mole fraction χ is thermodynamically consistent ?

a) $\ln \gamma_1 = -1+2\chi_1 - \chi_1^2$, $\ln \gamma_2 = \frac{1}{2}\chi_1^2$
b) $\ln \gamma_1 = -1+\chi_1 - \chi_1^2$, $\ln \gamma_2 = \chi_1^2$
c) $\ln \gamma_1 = -1+\chi_1 - \chi_1^2$, $\ln \gamma_2 = -\frac{1}{2}\chi_1^2$
d) $\ln \gamma_1 = -1+\chi_1 - \chi_1^2$, $\ln \gamma_2 = -\chi_1^2$

(GATE CH 2009)

30) Two identical reservoirs, open at the top, are drained through pipes attached to the bottom of the tanks as shown below. The two drain pipes are of the same length, but of different diameters $D_1 > D_2$

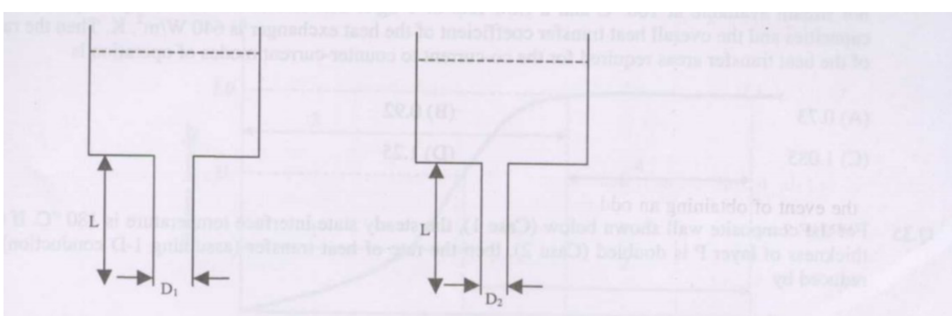

Fig. 3

Assuming the flow to be steady and laminar in both drain pipes, if the volumetric flow rate in the larger pipe is 16 times of that in the smaller pipe, the ratio D_1/D_2 is

a) 2 b) 4 c) 8 d) 16

(GATE CH 2009)

31) For an incompressible flow, the x- and y-components of the velocity vector are $v_y = 3(y+z)\, v_x = 2(x+y)$ where x, y, z are in metres and velocities are in m/s. Then the z-component of the velocity vector (v_z) of the flow for the boundary condition $v_z = 0$ at z = 0 is

a) 5z
b) -5z
c) 2x+3z
d) -2x-3z

(GATE CH 2009)

32) The terminal settling velocity mm diameter glass sphere $\left(\text{density: } 2500\text{kg} / m^3\right)$ in a viscous Newtonian liquid $\left(\text{density: } 1500\text{kg} / m^3\right)$ is 100 s /mu m/s .If the particle Reynolds small and the value of acceleration due to gravity is 9.81m $/s^2$ the viscosity of the liquid (in Pa.s) is

a) 100
b) 196.2
c) 245.3
d) 490.5

(GATE CH 2009)

33) A well-insulated hemispherical furnace ($radius = 1m$) is shown below:

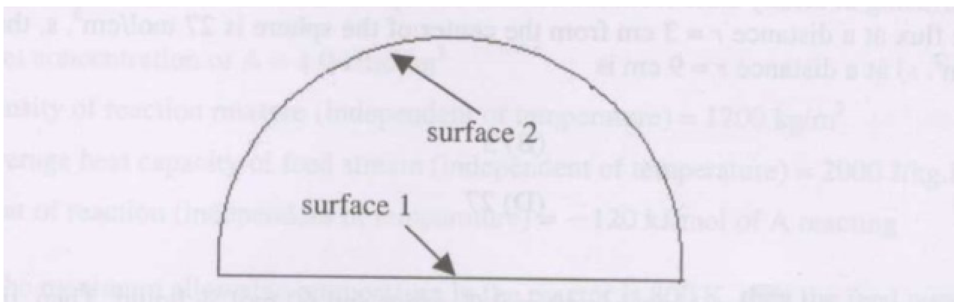

Fig. 4

The self-view factor of radiation for the curved surface 2 is

a) 1/4
b) 1/2
c) 2/3
d) 3/4

(GATE CH 2009)

34) A double-pipe heat exchanger is to be designed to heat 4 kg/s of a cold feed from 20 to 40$°C$ using a hot stream available at 160$°C$ and a flow rate of 1 kg/s. The two streams have equal specific heat capacities and the overall heat transfer coefficient of the heat exchanger is 640W $/m^2$ K. Then the ratio of the heat transfer areas required for the co-current to counter-current modes of operation

a) 0.92
b) 0.73
c) 1.085
d) 1.25

(GATE CH 2009)

35) For the composite wall shown below ($Case1$), the steady state interface temperature is 180$°C$ If the thickness of layer P is doubled ($Case2$), then the rate of heat transfer (assuming 1-D conduction) is reduced by

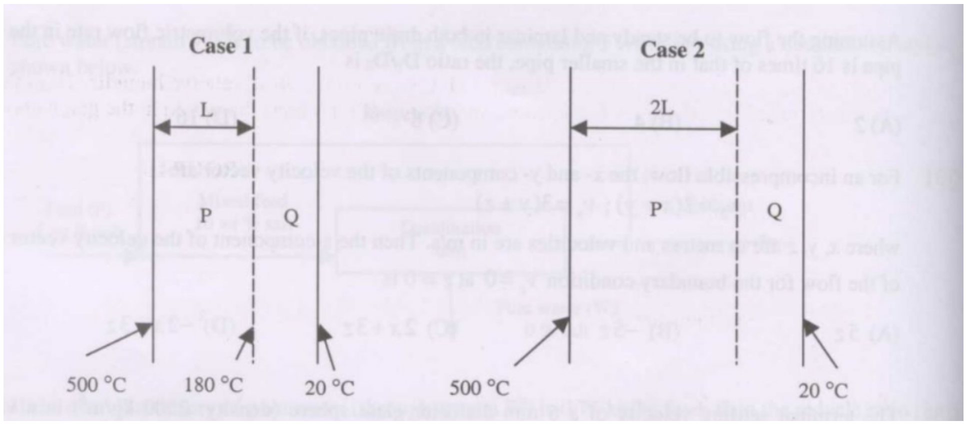

Fig. 5

a) 20%
b) 40%
c) 50%
d) 70%

(GATE CH 2009)

36) Species A is diffusing at steady state from the surface of a sphere (radius $= 1cm$) into a stagnant fluid. If the diffusive flux at a distance r = 3 cm from the center of the 27mol / cm^2 s, the diffusive flux $\left(\text{in mol/ } cm^2.s\right)$ at a distance r = 9 cm is

a) 1
b) 3
c) 9
d) 27

(GATE CH 2009)

37) The feed to a binary distillation column has 40 mol % vapor and 60 mol % liquid. Then, the slope of the q-line in the McCabe-Thiele plot is

a) -1.5
b) -0.6
c) 0.6
d) 1.5

(GATE CH 2009)

38) The equilibrium moisture curve for a solid is shown below:

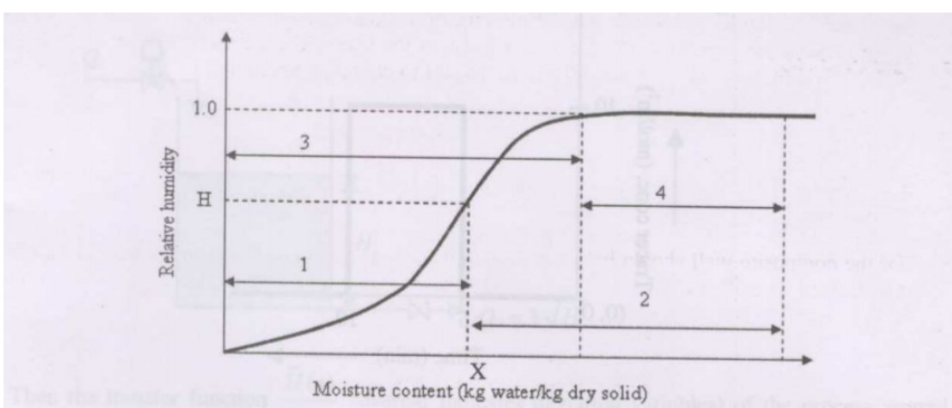

Fig. 6

The total moisture content of the solid is X and it is exposed to air of relative humidity H. In the table below. Group I lists the types of moisture, and Group II represents the region in the graph above.

	GROUP I	GROUP II
P.	Equilibrium moisture	1
Q.	Bound moisture	2
R.	Unbound moisture	3
S.	Free moisture	4

a) P-1, Q-2, R-3, S-4
b) P-1, Q-3, R-4, S-2
c) P-1, Q-4, R-2, S-3
d) P-1, Q-2, R-4, S-3

(GATE CH 2009)

39) The liquid-phase reaction A →B is conducted in an adiabatic plug flow reactor.
Data:

a) Inlet concentration of A = $4.0 kmol/m^3$
b) Density of reaction mixture (independent of temperature) = 1200kg/m Average heat capacity of feed stream ($independentoftemperature$) = 2000 J/kg.K
c) Heat of reaction (independent of temperature)120 kJ/mol of A reacting
d) If the maximum allowable temperature in the reactor is 800 K, then the feed temperature (in K) should not exceed

a) 400
b) 500
c) 600
d) 700

(GATE CH 2009)

40) An isothermal pulse test is conducted on a reactor and the variation of the outlet tracer concentration with time is shown below:

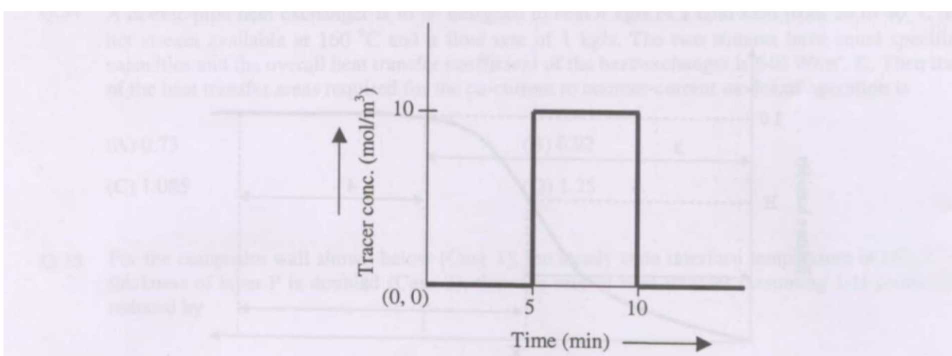

Fig. 7

The mean residence time of the fluid in the reactor (in minutes) is

a) 5.0
b) 7.5
c) 10.0
d) 15.0

(GATE CH 2009)

41) The inverse Laplace transform of is $\frac{1}{2s^2+3s+1}$

a) $e^{\frac{-t}{2}}$ - $e^{-}t$
b) $2e^{\frac{-t}{2}}$ - $e^{-}t$
c) $e^{\frac{-t}{2}}$ - $2e^{-}t$
d) $e^{\frac{-t}{2}}$ - $e^{-}t$

(GATE CH 2009)

42) The characteristic of a closed loop system using a proportional controller with gain K_c is

$$12s^3 + 19s^2 + 8s + 1 + K_c = 0$$

At the onset of instability, the value of K_c is

a) 35/3 b) 10 c) 25/3 d) 20/3

(GATE CH 2009)

43) The block diagram for a control system is shown below:

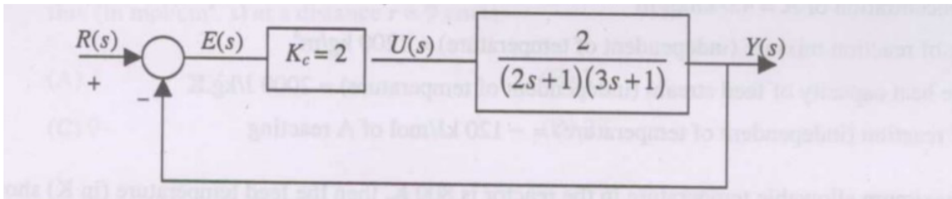

Fig. 8

For a unit step change in the set point, R(s) the steady state offset in the output Y(s) is

a) 0.2 b) 0.3 c) 0.4 d) 0.5

44) For a tank of cross-sectional area $100cm^2$ and inlet flow rate $\left(Q_i \text{ in } cm^3/s\right)$, the outlet flow rate $\left(Q_o \text{ in } cm^3/s\right)$ is related to the liquid height (H in cm as) $Q_o = 3\sqrt{(H)}$ (see figure below).

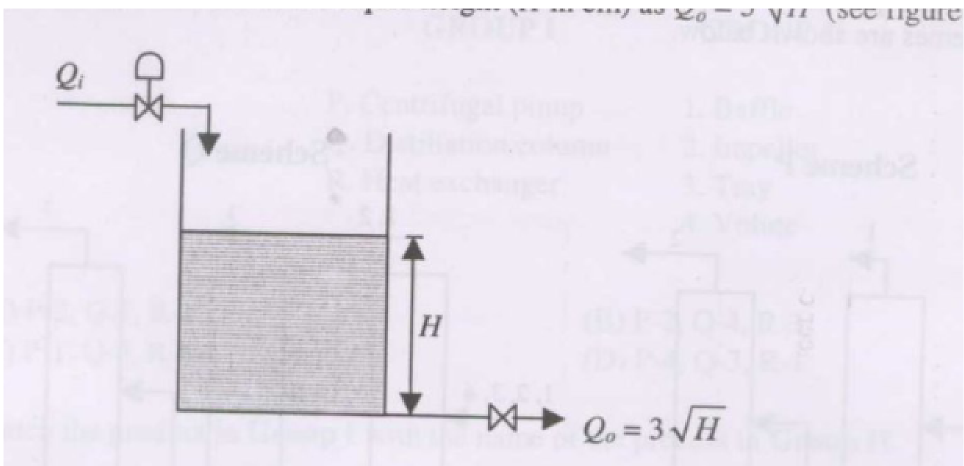

Fig. 9

Then the transfer function $\frac{H(s)}{Q(S)}$ of the process around the steady-state point, Q_{Lx} =18cm^3/s and H_x = 36cm is

a) $\frac{1}{100s+1}$
b) $\frac{2}{200s+1}$
c) $\frac{3}{300s+1}$
d) $\frac{4}{400s+1}$

(GATE CH 2009)

45) A column costs Rs. 5.0 lakhs and has a useful life of 10 years. Using the double declining balance depreciation method, the book value of the unit at the end of five years (in lakhs of Rs.) is

a) 1.21
b) 1.31
c) 1.64
d) 2.05

(GATE CH 2009)

46) An equi-molar mixture of four hydrocarbons $(1, 2, 3, 4)$ is to be separated into high purity individual components using a sequence of simple distillation columns (one overhead and one bottom stream). Four possible schemes are shown below.

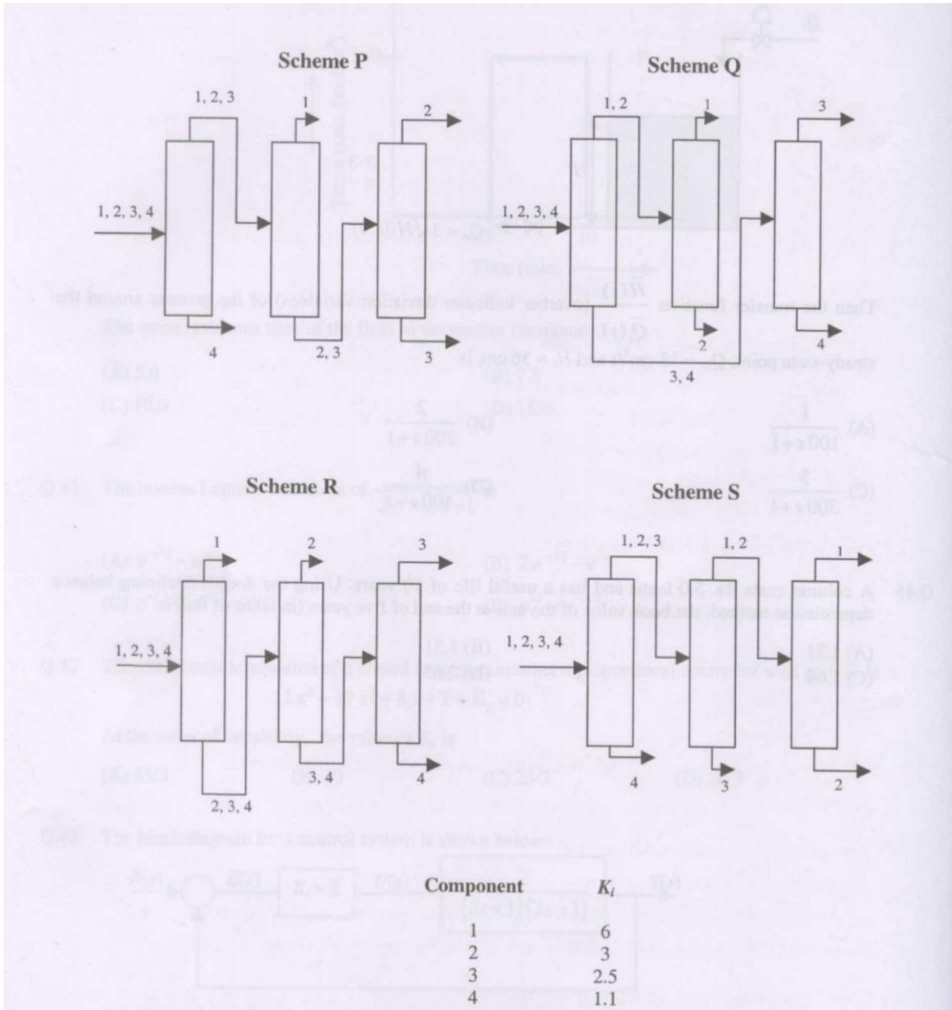

Fig. 10

Component	K_i
1	6
2	3
3	2.5
4	1.1

a) P b) Q c) R d) S

(GATE CH 2009)

47) Match the equipment in Group I to the internals in Group II

GROUP I		GROUP II	
P.	Centrifugal Pump	1.	Baffle
Q.	Distillation column	2.	Impeller
R.	Heat exchanger	3.	Tray
		4.	Volute

a) P-2, Q-1, R-4
b) P-2, Q-4, R-3
c) P-1, Q-3, R-4
d) P-4, Q-3, R-1

(GATE CH 2009)

48) Match the product in Group I with the name of the process in Group II.

	GROUP I		GROUP II
P.	Sodium carbonate	1.	Haber
Q.	Ammonia	2.	Solvay
R.	Sulphuric acid	3.	Fischer-Tropsch
		4.	Contact

a) P-2, Q-1, R-4
b) P-4, Q-1, R-2
c) P-3, Q-4, R-2
d) P-2, Q-1, R-3

(GATE CH 2009)

49) Match the product in Group I to the raw material in Group II.

	GROUP I		GROUP II
P.	Ethylene	1.	Natural gas
Q.	Methanol	2.	Synthesis gas
R.	Pthalic anhydride	3.	Naphtha
		4.	Naphtalene

a) P-1, Q-2, R-3
b) P-2, Q-1, R-4
c) P-3, Q-1, R-4
d) P-3, Q-2, R-4

(GATE CH 2009)

50) Match the unit process in Group I with the industry in Group II.

	GROUP I		GROUP II
P.	Steam cracking	1.	Petroleum refining
Q.	Hydrocracking	2.	Petrochemicals
R.	Condensation	3.	Polymers
		4.	Soaps and detergents

a) P-1, Q-2, R-3
b) P-2, Q-3, R-3
c) P-1, Q-2, R-4
d) P-2, Q-1, R-3

(GATE CH 2009)

Common Data for Questions 51 and 52 An ideal gas with molar heat capacity $C_p = 5/2 \times R$ ($where R = 8.314 J/molK$) is compressed adiabatically from 1 bar and 300 K to pressure P_2 in a closed system. The final temperature after compression is 600 K and the mechanical efficiency of compression is 50%.

51) The work required for compression (in kJ / mol) is

a) 3.74 b) 6.24 c) 7.48 d) 12.48

(GATE CH 2009)

52) The final pressure P_2 (in bar) is

a) $2^{\frac{3}{4}}$ b) $2^{\frac{5}{4}}$ c) $2^{\frac{3}{2}}$ d) $2^{\frac{5}{2}}$

(GATE CH 2009)

Common Data for questions 53 and 54

A slab of thickness L with one side ($x = 0$) insulated and the other side ($x = L$) maintained at a constant temperature T_0 is shown below.

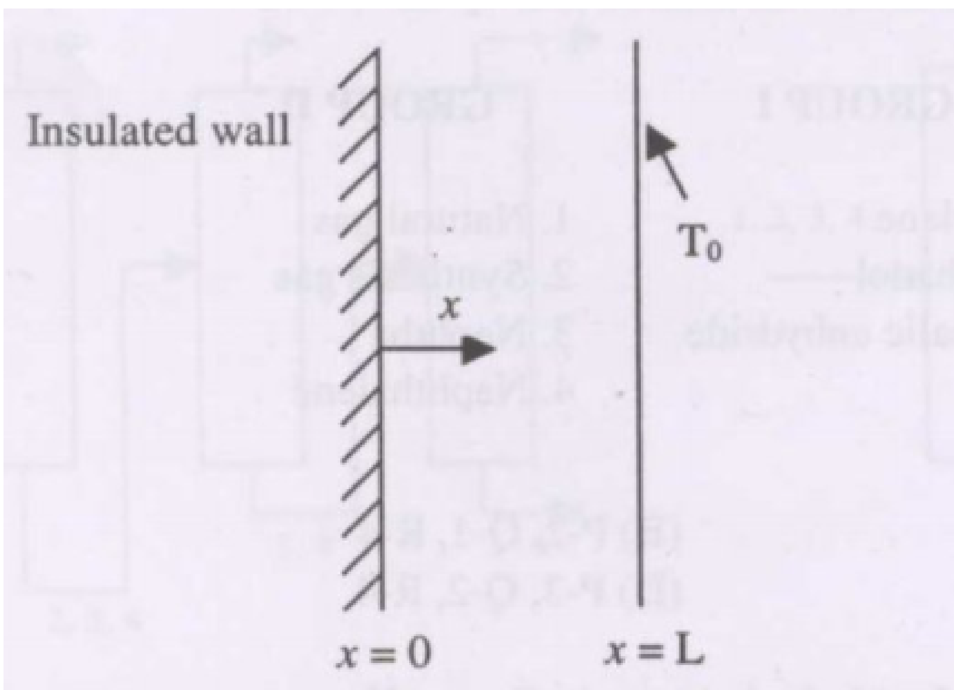

Fig. 11

A uniformly distributed internal heat source produces heat in the slab at the rate of SW / m^3 Assume the heat conduction to be steady and 1-D along the x-direction.

53) The maximum temperature in the slab occurs at x equal to

a) 0 b) L/4 c) L/2 d) L

(GATE CH 2009)

54) The heat flux at x = L is

a) 0 b) S L/4 c) S L/2 d) S L

(GATE CH 2009)

Common Data for Questions 55 and 56 A flash distillation drum (see figure below) is used to separate a methanol-water mixture. The mole fraction of methanol in the feed is 0.5, and the feed flow rate is 1000 kmol/hr. The feed is preheated in a heater with heat duty Q and is subsequently flashed in the drum. The flash drum can be assumed to be an equilibrium stage, operating adiabatically. The equilibrium relation between the mole fractions of methanol in the vapor and liquid phases is y = 4 x. The ratio of distillate to feed flow rate is 0.5.

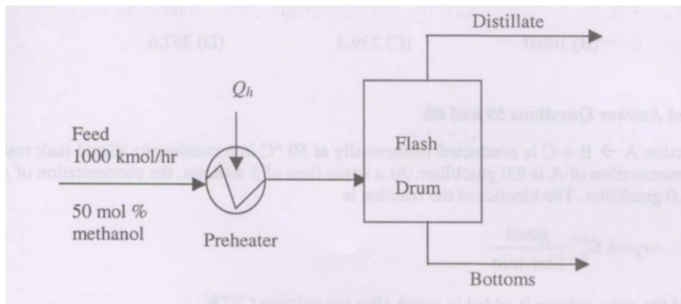

Fig. 12

55) The mole fraction of methanol in the distillate is

a) 0.2 b) 0.7 c) 0.8 d) 0.9

(GATE CH 2009)

56) If the enthalpy of the distillate with reference to the feed is 3000 kJ/kmol, and the enthalpy of the bottoms with reference to the feed is -1000 kJ/kmol, the heat duty of the preheater (Q in kJ / hr) is

a) -2×10^6 b) -1×10^6 c) 1×10^6 d) 2×10^6

(GATE CH 2009)

Statement for Linked Answer Questions 57 and 58

A free jet of water is emerging from a nozzle (diameter 75 mm) attached to a pipe (diameter 225 mm) as shown below.

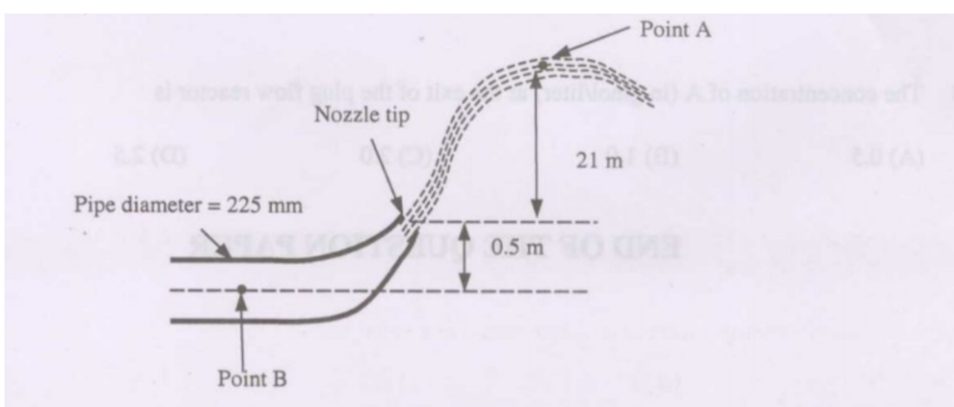

Fig. 13

The velocity of water at point A is 18 m/s. Neglect friction in the pipe and nozzle. Use g = 9.81 m/s^2 and density of water = $1000 kg/m^3$.

57) The velocity of water at the tip of the nozzle (in m / s) is

a) 13.4 b) 18.0 c) 23.2 d) 27.1

(GATE CH 2009)

58) The gauge pressure (in kPa) at point B is

a) 80.0 b) 100.0 c) 239.3 d) 367.6

(GATE CH 2009)

Statement for Linked Answer Questions 59 and 60

The liquid-phase reaction A →B + C is conducted isothermally at 50°C in a continuous stirred tank reactor ($CSTR$). The inlet concentration of A is 8.0 gmol/liter. At a space time of 5 minutes, the concentration of A at the exit of CSTR is 4.0 gmol/liter. The kinetics of the reaction is
$-r_A = \mathrm{k}^{0.5} C_A \frac{gmol}{liter.min}$
A plug flow reactor of the same volume is added in series after the existing CSTR.

59) The rate constant (k) for this reaction at 50°C is

a) $0.2\left(\frac{gmol}{liter}\right)^{0.5} min^{-1}$
c) $0.4\left(\frac{gmol}{liter}\right)^{0.5} min^{-1}$
b) $0.2\left(\frac{gmol}{liter}\right)^{0.5} min^{-1}$
d) $0.4\left(\frac{gmol}{liter}\right)^{0.5} min^{-1}$

(GATE CH 2009)

60) The concentration of A (in gmol/liter) at the exit of the plug flow reactor is

a) 0.5 b) 1.0 c) 2.0 d) 2.5

(GATE CH 2009)