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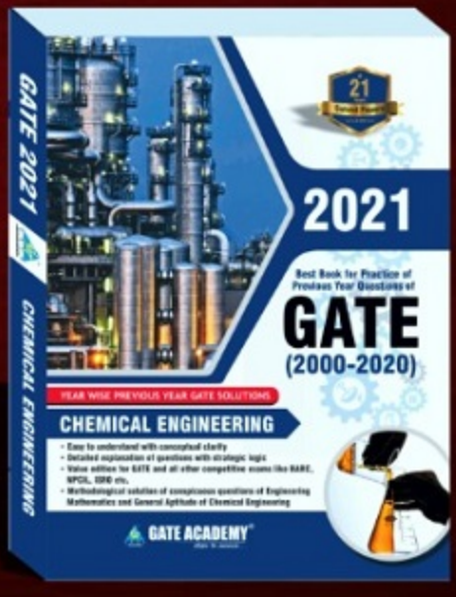

# CHEMICAL ENGINEERING

## Subjects :


1. Process Calculations
2. Thermodynamics
3. Fluid Mechanics
4. Mechanical Operations
5. Heat Transfer
6. Mass Transfer
7. Chemical Reaction Engineering
8. Instrumentation and Process Control
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# GATE 2021

## Chemical Engineering

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## IMPORTANCE of GATE

GATE examination has been emerging as one of the most prestigious competitive exam for engineers. Earlier it was considered to be an exam just for eligibility for pursuing PG courses, but now GATE exam has gained a lot of attention of students as this exam open an ocean of possibilities like:

**1. Admission into IISc, IITs, IIITs, NITs**

A good GATE score is helpful for getting admission into IISc, IITs, IIITs, NITs and many other renowned institutions for M.Tech./M.E./M.S. An M.Tech. graduate has a number of career opportunities in research fields and education industries. Students get ₹ 12,400 per month as stipend during their course.

**2. Selection in various Public Sector Undertakings (PSUs)**

A good GATE score is helpful for getting job in government-owned corporations termed as **Public Sector Undertakings** (**PSUs**) in India like IOCL, BHEL, NTPC, BARC, ONGC,PGCIL, DVC, HPCL, GAIL, SAIL & many more.

**3.** Direct recruitment to Group A level posts in Central government, i.e., Senior Field Officer (Tele), Senior Research Officer (Crypto) and Senior Research Officer (S&T) in Cabinet Secretariat, Government of India, is now being carried out on the basis of GATE score.

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**5. National Institute of Industrial Engg. (NITIE)**

- NITIE offers **PGDIE / PGDMM / PGDPM** on the basis of GATE scores. The shortlisted candidates are then called for Group Discussion and Personal Interview rounds.
- NITIE offers a Doctoral Level Fellowship Programme recognized by Ministry of HRD (MHRD) as equivalent to Ph.D. of any Indian University.
- Regular full time candidates those who will qualify for the financial assistance will receive ₹25,000 during 1st and 2nd year of the Fellowship programme and ₹28,000 during 3rd, 4th and 5th year of the Fellowship programme as per MHRD guidelines.

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- A fulltime residential researcher (RR) programme.

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- Application form is generally available in month of Sept. and Oct.

**Note : In near future, hopefully GATE exam will become a mandatory exit test for all engineering students, so take this exam seriously. Best of LUCK !**

## GATE Exam Pattern

| Section | Question No. | No. of Questions | Marks Per Question | Total Marks |
|---|---|---|---|---|
| General Aptitude | 1 to 5 | 5 | 1 | 5 |
| | 6 to 10 | 5 | 2 | 10 |
| Technical + Engineering Mathematics | 1 to 25 | 25 | 1 | 25 |
| | 26 to 55 | 30 | 2 | 60 |
| **Total Duration : 3 hours** | | **Total Questions : 65** | | **Total Marks : 100** |

**Note :**
**(i)** 40 to 45 marks will be allotted to Numerical Answer Type Questions.
**(ii)** MSQ also added from GATE 2021 for which **no negative** marking.

**Pattern of Questions :**

**GATE 2021** would contain questions of THREE different types in all the papers :

**(i)** **Multiple Choice Questions (MCQ)** carrying 1 or 2 marks each, in all the papers and sections. These questions are objective in nature, and each will have choice of four answers, out of which ONLY ONE choice is correct.

**Negative Marking for Wrong Answers :** For a wrong answer chosen in a MCQ, there will be negative marking. For 1-mark MCQ, 1/3 mark will be deducted for a wrong answer. Likewise, for 2-mark MCQ, 2/3 mark will be deducted for a wrong answer.

**(ii)** **Multiple Select Questions (MSQ)** carrying 1 or 2 marks each in all the papers and sections. These questions are objective in nature, and each will have choice of four answers, out of which ONE or MORE than ONE choice(s) are correct.

**Note :** There is **NO negative** marking for a wrong answer in MSQ questions. However, there is NO partial credit for choosing partially correct combinations of choices or any single wrong choice.

**(iii)** **Numerical Answer Type (NAT)** Questions carrying 1 or 2 marks each in most of the papers and sections. For these questions, the answer is a signed real number, which needs to be entered by the candidate using the virtual numeric keypad on the monitor (keyboard of the computer will be disabled). No choices will be shown for these types of questions. The answer can be a number such as 10 or -10 (an integer only). The answer may be in decimals as well, for example, 10.1 (one decimal) or 10.01 (two decimals) or -10.001 (three decimals). These questions will be mentioned with, up to which decimal places, the candidates need to present the answer. Also, for some NAT type problems an appropriate range will be considered while evaluating these questions so that the candidate is not unduly penalized due to the usual round-off errors. Candidates are advised to do the rounding off at the end of the calculation (not in between steps). Wherever required and possible, it is better to give NAT answer up to a maximum of three decimal places.

**Example :** If the wire diameter of a compressive helical spring is increased by 2%, the change in spring stiffness (in %) is _ (correct to two decimal places).

***Note :*** *There is NO negative marking for a wrong answer in NAT questions.*
*Also, there is NO partial credit in NAT questions.*

## PREFACE

It is our pleasure, that we insist on presenting **"GATE 2021 Chemical Engineering"** authored for **Chemical Engineering** to all of the aspirants and career seekers. The prime objective of this book is to respond to tremendous amount of ever growing demand for error free, flawless and succinct but conceptually empowered solutions to all the question over the period 2000 - 2020.

This book serves to the best supplement for GATE 2021 (CH) but shall be useful to a larger extent for other discipline as well.

Simultaneously having its salient features the book comprises :

- Step by step solution to all questions.
- Complete analysis of questions, i.e. year wise.
- Detailed explanation of all the questions.
- Solutions are presented in simple and easily understandable language.
- It covers all GATE questions from 2000 to 2020 (21 years).

The authors do not sense any deficit in believing that this title will in many aspects, be different from the similar titles within the search of student.

We would like to express our sincere appreciation to **Mrs. Sakshi Dhande Mam** (Co-Director, GATE ACADEMY Learning Pvt. Ltd.) for her constant support and constructive suggestions and comments in reviewing the script.

In particular, we wish to thank **GATE ACADEMY** expert team members for their hard work and consistency while designing the script.

The final manuscript has been prepared with utmost care. However, going a line that, there is always room for improvement in anything done, we would welcome and greatly appreciate the suggestions and corrections for further improvement.

**Umesh Dhande**

**(Director, GATE ACADEMY Learning Pvt. Ltd.)**

## CONTENTS

# 2 Thermodynamics

## 1 Mark Questions (CH)

### 2000 IIT Kharagpur

**2.1** Assume that benzene is insoluble in water. The normal boiling points of benzene and water are $80.1^0$C and $100^0$C respectively. At a pressure of 1 atm, the boiling point of a mixture of benzene and water is

(A) $80.1^0$C

(B) Less than $80.1^0$C

(C) $100^0$C

(D) Greater than $80.1^0$C but less than $100^0$C

**2.2** On a p-V diagram of an ideal gas, suppose a reversible adiabatic line intersects reversible isothermal line at point A. Then at point A, the slope of the reversible adiabatic line $\left(\frac{\partial P}{\partial V}\right)_S$ and the slope of the reversible isothermal line $\left(\frac{\partial P}{\partial V}\right)_T$ are related as

(A) $\left(\frac{\partial P}{\partial V}\right)_S = \left(\frac{\partial P}{\partial V}\right)_T$

(B) $\left(\frac{\partial P}{\partial V}\right)_S = \left[\left(\frac{\partial P}{\partial V}\right)_T\right]^\gamma$

(C) $\left(\frac{\partial P}{\partial V}\right)_S = \gamma\left(\frac{\partial P}{\partial V}\right)_T$

(D) $\left(\frac{\partial P}{\partial V}\right)_S = \frac{1}{\gamma}\left(\frac{\partial P}{\partial V}\right)_T$

Where $\gamma = C_p / C_v$

### 2001 IIT Kanpur

**2.3** A reasonably general expression for vapour-liquid phase equilibrium at low moderate pressures is $\phi_i Y_i P = \gamma_i X_i f_i^0$.

Where $\phi_i$ is a vapour fugacity coefficient $\gamma_i$ is the liquid activity coefficient, and $f_i$ is the fugacity of pure component i.

The $k_i$, value $(y_i = k_i, x_i)$ is therefore, in general, a function of

(A) Temperature only

(B) Temperature and pressure

(C) Temperature, pressure, and liquid composition $x_i$

(D) Temperature, pressure, liquid composition $x_i$ and vapour composition $y_i$

**2.4** High pressure stream is expanded adiabatically and reversibly through a well insulated turbine, which produces

some shaft work. If the enthalpy change and entropy change across the turbine are represented by $\Delta H$ and $\Delta S$, respectively, for this process

(A) $\Delta H = 0$ and $\Delta S = 0$

(B) $\Delta H \neq 0$ and $\Delta S = 0$

(C) $\Delta H \neq 0$ and $\Delta S \neq 0$

(D) $\Delta H = 0$ and $\Delta S \neq 0$

### 2002 IISc Bangalore

**2.5** Which of the following conditions are satisfied at the critical point by the p-V-T relation of a real fluid?

(A) $\left(\frac{\partial^2 P}{\partial V^2}\right)_T = \left(\frac{\partial P}{\partial V}\right)_T = 0$

(B) $\left(\frac{\partial^2 P}{\partial V^2}\right)_T > 0; \left(\frac{\partial P}{\partial V}\right)_T = 0$

(C) $\left(\frac{\partial^2 P}{\partial V^2}\right)_T < 0; \left(\frac{\partial P}{\partial V}\right)_T = 0$

(D) $\left(\frac{\partial^2 P}{\partial V^2}\right)_T > 0; \left(\frac{\partial P}{\partial V}\right)_T > 0$

## 2 Marks Questions (CH)

### 2000 IIT Kharagpur

**2.1** The thermal efficiency of reversible heat engine operating between two given thermal reservoirs is 0.4. The device is used either as a refrigerator or as a heat pump between the same reservoirs. Then the coefficient of performance as a refrigerator $(COP)_R$ and the coefficient of performance as a heat pump $(COP)_{HP}$ are

(A) $(COP)_R = (COP)_{HP} = 0.6$

(B) $(COP)_R = 2.5, (COP)_{HP} = 1.5$

(C) $(COP)_R = 1.5, (COP)_{HP} = 2.5$

(D) $(COP)_R = (COP)_{HP} = 2.5$

**2.2** At a given temperature $K_1$, $K_2$ and $K_3$ are the equilibrium constants for the following reactions 1, 2 and 3 respectively

$$CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$$

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

Then $K_1, K_2$ and $K_3$ are related as

(A) $K_3 = K_1 K_2$

(B) $K_3 = (K_1 K_2)^{0.5}$

(C) $K_3 = \frac{K_1 + K_2}{2}$

(D) $K_3 = (K_1 K_2)^2$

### 2001 IIT Kanpur

**2.3** The Maxwell relation derived from the differential expression for the Helmholtz free energy ( $dA$ ) is

(A) $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$

(B) $\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$

(C) $\left(\frac{\partial V}{\partial S}\right)_P = -\left(\frac{\partial T}{\partial P}\right)_S$

(D) $\left(\frac{\partial S}{\partial V}\right)_T = +\left(\frac{\partial P}{\partial T}\right)_V$

**2.4** At $100^0$C water and methyl cyclohexane both have vapour pressures of 1.0 atm. Also at $100^0$C the latent heats of

vaporization of these compounds are 40.63 kJ /mol for water and 31.55 kJ /mol for methyl cyclohexane. The vapour pressure of water at $150^0$C is 4.69 atm. At $150^0$C, the vapour pressure of methyl cyclohexane would be expected to be

(A) Significantly less than 4.69 atm

(B) Nearly equal to 4.69 atm

(C) Significantly more than 4.69 atm

(D) Indeterminate due to a lack of data

**2.5** Air enters an adiabatic compressor at 300 K. The exit temperature for a compression ratio of 3, assuming air to be an ideal gas ( $\gamma = C_P / C_V = 7/5$ ) and the process to be reversible, is

(A) $300(3^{2/7})$ (B) $300(3^{3/5})$

(C) $300(3^{3/7})$ (D) $300(3^{5/7})$

**Answers 1 Mark (CH)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.1 | B | 2.2 | C | 2.3 | C | 2.4 | B | 2.5 | A |

**Answers 2 Marks (CH)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.1 | C | 2.2 | A | 2.3 | B | 2.4 | A | 2.5 | A |

## Explanations 1 Mark (CH)

### 2.1 (B)

Benzene is insoluble in water. For immiscible mixture, the mixture will boil at below the least boiling point temperature so $T_b$ has least boiling point.

$\therefore$ The B.P of a mixture $< 80.1^0$C

Hence, the correct option is (B).

### 2.2 (C)

For reversible isothermal,

$$pV = C$$

Differentiating w.r.t. V,

$$v\left(\frac{\partial p}{\partial v}\right)_T + p = 0$$

$$\left(\frac{\partial p}{\partial v}\right)_T = -\frac{p}{v} \qquad \text{.....(i)}$$

For reversible adiabatic,

$$pV^{\gamma} = C$$

Differentiating w.r.t. V,

$$v^{\gamma}\left(\frac{\partial p}{\partial v}\right)_s + p \cdot \gamma V^{\gamma-1} = 0$$

$$\left(\frac{\partial p}{\partial v}\right)_s = -\gamma\frac{p}{V} \qquad \text{.....(ii)}$$

From equation (i) and (ii),

$$\left(\frac{\partial p}{\partial v}\right)_s = \gamma\left(\frac{\partial p}{\partial v}\right)_T$$

Hence, the correct option is (C).

### 2.3 (C)

**Given :** $\phi_i y_i p = \gamma_i x_i f_i$

The equilibrium constant,

$$k_i = \frac{y_i}{x_i}$$

Or $$k_i = \frac{\gamma_i f_i^0}{\phi_i p}$$

Since, $\gamma_i = f(T, p, x_i)$

$f_i = f(T, P)$

$\phi_i = f(T, P)$ at low pressure

$k_i = f(T, P, x_i)$

Hence, the correct option is (C).

### 2.4 (B)

For reversible adiabatic process,

$$\Delta S = 0 \text{ and } \Delta H \neq 0$$

Hence, the correct option is (B).

### 2.5 (A)

At critical point,

$$\left(\frac{\partial p}{\partial v}\right)_{T=T_c} = 0 \text{ and } \left(\frac{\partial^2 p}{\partial v^2}\right)_{T=T_c} = 0$$

Hence, the correct option is (A).

## Explanations 2 Marks (CH)

### 2.1 (C)

**Given,** $\eta = 1 - \frac{T_2}{T_1} = 0.4$

$\Rightarrow$ $$\frac{T_2}{T_1} = 0.6$$

$$(COP)_R = \frac{T_2}{T_1 - T_2}$$

$$(COP)_R = \frac{1}{\frac{T_1}{T_2} - 1} = \frac{1}{\frac{1}{0.6} - 1}$$

$$(COP)_R = \frac{0.6}{1 - 0.6} = 1.5$$

$$(COP)_{HP} = \frac{T_1}{T_1 - T_2}$$

$$(COP)_{HP} = \frac{\left(\frac{T_1}{T_2}\right)}{\left(\frac{T_1}{T_2}-1\right)} = \frac{\left(\frac{1}{0.6}\right)}{\left(\frac{1}{0.6}\right)-1}$$

$$(COP)_{HP} = \frac{1}{1-0.6} = 2.5$$

Hence, the correct option is (C).

**2.2 (A)**

$$k_1 = \frac{[CO][H_2]^3}{[CH_4][H_2O]} \quad \text{.....(i)}$$

$$k_2 = \frac{[CO_2][H_2]}{[CO][H_2O]} \quad \text{.....(ii)}$$

$$k_3 = \frac{[CO_2][H_2]^4}{[CH_4][H_2O]^2} \quad \text{.....(iii)}$$

From equation (i), (ii) and (iii), it can be seen that $k_3 = k_1 k_2$.

Hence, the correct option is (A).

**2.3 (B)**

We have,

$$A = U - TS$$

$$dA = dU - Tds - SdT$$

$$dA = (Tds - Pds) - Tds - SdT$$

$$dA = -pdV - SdT \quad \text{.....(i)}$$

Partial differentiation w.r.t, V

$$\left(\frac{\partial A}{\partial V}\right)_T = -P \quad \text{.....(ii)}$$

Also, from equation (i)

$$\left(\frac{\partial A}{\partial T}\right)_V = -S \quad \text{.....(iii)}$$

From equation (ii),

$$\left[\frac{\partial}{\partial T}\left(\frac{\partial A}{\partial V}\right)_T\right]_V = -\left(\frac{\partial P}{\partial T}\right)_V \quad \text{.....(iv)}$$

From equation (iii),

$$\left[\frac{\partial}{\partial V}\left(\frac{\partial A}{\partial T}\right)_V\right]_T = -\left(\frac{\partial S}{\partial V}\right) \quad \text{.....(v)}$$

Therefore, from equation (iv) and (v),

$$-\left(\frac{\partial p}{\partial T}\right)_V = -\left(\frac{\partial S}{\partial V}\right)_T$$

Or $$\left(\frac{\partial p}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

Hence, the correct option is (B).

**2.4 (A)**

Clausisus – Clapeyron equation

$$\ln\frac{P_1^{sat}}{P_2^{sat}} = \frac{\Delta H^{vap}}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

$\therefore$ for water,

$$\ln\frac{P^{sat}_{W,150^0\text{C}}}{P^{sat}_{W,100^0\text{C}}} = \frac{\Delta H_W^{vap}}{R}\left[\frac{1}{373.15} - \frac{1}{150+273.15}\right] \quad \text{.....(i)}$$

For methyl cyclohexane, (MCH),

$$\ln\frac{P^{sat}_{MCH,150^0\text{C}}}{P^{sat}_{MCH,100^0\text{C}}} = \frac{\Delta H_{MCH}^{vap}}{R}\left[\frac{1}{373.15} - \frac{1}{150+273.15}\right] \quad \text{.....(ii)}$$

$\therefore$ $$eq's \Rightarrow \frac{(2)}{(1)} = \frac{\ln P^{sat}_{MCH,150^0\text{C}}}{\ln P_{W,100^0\text{C}}} = \frac{31.55}{40.63}$$

$\Rightarrow$ $$\ln P^{sat}_{MCH,150^0\text{C}} = 3.32\,\text{atm}$$

vapour pressure of cyclohexane would be less than the 4.69 atm.

Hence, the correct option is (A).

**2.5 (A)**

For adiabatic process,

$$pV^{\gamma} = \text{Constant}$$

Or $$p\left(\frac{nRT}{P}\right)^{\gamma} = \text{Constant}$$

$$\frac{T^{\gamma}}{P^{\gamma-1}} = \text{Constant}$$

Or $$\frac{T_1}{P_1^{\gamma-1}} = \frac{T_2^{\gamma}}{P_2^{\gamma-1}}$$

$$T_2^{\gamma} = T_1^{\gamma}\left(\frac{P_2}{P_1}\right)^{\gamma-1}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

Given, $T_1 = 300\,\text{K}$

$$\frac{P_2}{P_1} = 3,\ \gamma = \frac{7}{5}$$

$\therefore$ $$T_2 = 300\times[3]^{\left(\frac{7}{5}-1\right)/\left(\frac{7}{5}\right)}$$

$$T_2 = 300\times 3^{\frac{2}{7}}$$

Hence, the correct option is (A).

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# 3 Fluid Mechanics

## 1 Mark Questions (CH)

### 2000 IIT Kharagpur

**3.1** For laminar flow of a shear thinning liquid in a pipe if the volumetric flow rate is double, the pressure gradient will increase by a factor of

(A) 2 (B) $< 2$

(C) $> 2$ (D) $\frac{1}{2}$

**3.2** In the laminar boundary layer flow over a flat plate, the ratio $(\delta / x)$ varies as

(A) Re (B) $\sqrt{\text{Re}}$

(C) $\frac{1}{\text{Re}}$ (D) $\frac{1}{\sqrt{\text{Re}}}$

Where, $\delta$ is the boundary layer thickness and x is the distance from the leading edge in the

**3.3** In a fully turbulent flow ($\text{Re} > 10^5$) in a pipe of diameter $d$ for a constant pressure gradient, the dependence of volumetric flow rate of an incompressible fluid is

(A) $d$ (B) $d^2$

(C) $d^{2.5}$ (D) $d^4$

### 2001 IIT Kanpur

**3.4** Applying a pressure drop across a capillary results in a volumetric flow rate Q under laminar flow conditions. The flow rate for the same pressure drop, in a capillary of the same length but half the radius is

(A) $\frac{Q}{2}$ (B) $\frac{Q}{4}$

(C) $\frac{Q}{8}$ (D) $\frac{Q}{16}$

**3.5** The operation of a rotameter is based on

(A) Variable flow area

(B) Rotation of a turbine

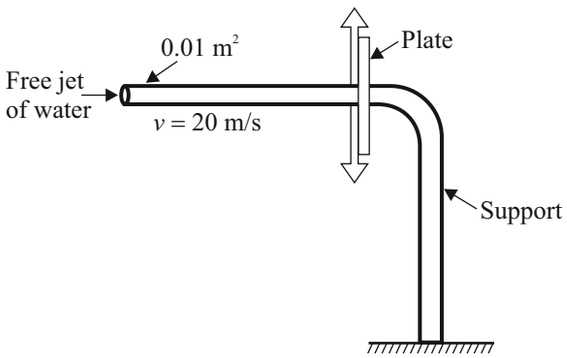
(C) Pressure drop across a nozzle

(D) Pressure at a stagnation point

## 2 Marks Questions (CH)

### 2000 IIT Kharagpur

**3.1** A free jet of water of cross-sectional area $0.01\,\text{m}^2$ and a velocity of 20 m/s strikes a plate and then flows in the plane parallel to the plate as shown in the figure below. The horizontal component of the force on the support is




(A) 200 N (B) 400 N
(C) 2000 N (D) 4000 N

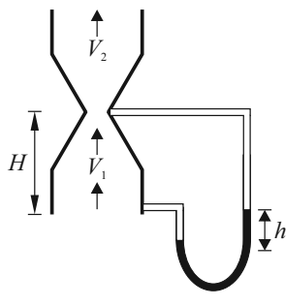
## 2001 IIT Kanpur

**3.2** A Bingham fluid of viscosity $\mu = 10$ Pa-s and yield stress $\tau_0 = 10$ kPa is sheared between flat parallel plates separated by a distance $10^{-3}$ m. The top plate is moving with a velocity of 1 m/s. The shear stress on plate is

(A) 10 kPa (B) 20 kPa
(C) 30 kPa (D) 40 kPa

## 2003 IIT Madras

**3.3** The pressure differential across a vertical venturimeter (shown in figure) is measured with the help of a mercury manometer to estimate flow rate of water flowing through it. The expression for the velocity of water at the throat is



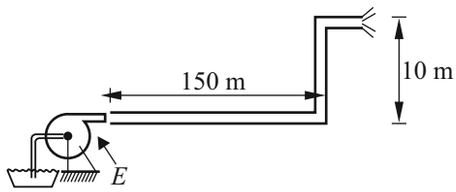

(A) $\dfrac{V_2^2 - V_1^2}{2g} = h\dfrac{\rho_m}{\rho_w}$

(B) $\dfrac{V_2^2 - V_1^2}{2g} = h\dfrac{(\rho_m - \rho_w)}{\rho_w}$

(C) $\dfrac{V_2^2}{2g} = H + h\dfrac{(\rho_m - \rho_w)}{\rho_w}$

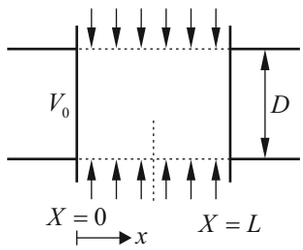
(D) $\dfrac{V_2^2 - V_1^2}{2g} = h\dfrac{(\rho_m - \rho_w)}{\rho_m}$

**3.4** A centrifugal pump is used to pump water through a horizontal distance of 150 m and then raised to an overhead tank 10 m above. The pipe is smooth with an ID of 50 mm. What head (of water) must the pump generate at its exit ($E$) to deliver water at a flow rate of $0.001\ m^3/s$? The Fanning friction factor $f$ is 0.0062.




(A) 10 m (B) 11 m
(C) 12 m (D) 20 m

**3.5** A pipe has a porous section of length $L$ as shown in the figure. Velocity at the start of this section is $V_0$. If fluid leaks into the pipe through the porous section at a volumetric rate per unit area $q\left(\dfrac{x}{L}\right)^2$, what will be the axial velocity in the pipe at any $x$? Assume incompressible one dimensional flow, i.e., no gradients in the radial direction.



(A) $V_x = V_0 + q\frac{x^3}{L^2 D}$

(B) $V_x = V_0 + \frac{1}{3}q\frac{x^3}{L^2}$

(C) $V_x = V_0 + 2q\frac{x^3}{LD}$

(D) $V_x = V_0 + \frac{4}{3}q\frac{x^3}{L^2 D}$

## Answers 1 Mark (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.1 | B | 3.2 | D | 3.3 | C | 3.4 | D | 3.5 | A |

## Answers 2 Marks (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.1 | D | 3.2 | B | 3.3 | B | 3.4 | B | 3.5 | D |

## Explanations 1 Mark (CH)

**3.1 (B)**

Shear thinning liquid means, on the application of shear stress its viscosity decreases.

$$\Delta P = \frac{32\mu L\bar{V}}{D^2} = \frac{32\mu LQ}{D^2 A}$$

The pressure greadient,

$$\frac{\Delta P}{L} \alpha Q \text{ and also } \frac{\Delta P}{L} \alpha \mu$$

If Q is doubled, then $\Delta P / L$ is becomes doubled and $\mu$ decreases because it is a Liquid.

So finally considering both of these conditions Pressure gradient will increase by a factor of < 2

Hence, the correct option is (B).

**3.2 (D)**

$$\frac{\delta}{x} \alpha \frac{1}{\sqrt{\text{Re}_x}}$$

Hence, the correct option is (D).

**3.3 (C)**

For turbulent flow

$$\frac{\Delta P}{L} = \frac{4fV^2\rho}{2D}$$

$$Q = AV$$

$$\frac{\Delta P}{L} = \frac{4fQ^2\rho}{2DA^2}$$

Where, $\frac{\Delta P}{L}$ = constant

$$Q^2 \alpha d^5 \Rightarrow Q \alpha d^{2.5}$$

Hence, the correct option is (C).

**3.4 (D)**

Flow rate $Q \alpha r^4$

$$\therefore \quad \frac{Q_2}{Q} = \left(\frac{r^2}{r}\right)^4$$

$$\frac{Q_2}{Q} = \left(\frac{\frac{r}{2}}{r}\right)^4$$

$$Q_2 = \frac{Q}{16}$$

Hence, the correct option is (D).

**3.5 (A)**

The operation of rotameter is based on variable flow area.

Hence, the correct option is (A).

## Explanations 2 Marks (CH)

### 3.1 (D)

**Given data :**

$$A = 0.01\text{m}^2, v = 20\text{m/s}$$

Horizontal component of force on the support

$$F = \rho.Qv$$

$$F = \rho.Av.v$$

$$F = 1000 \times 0.01 \times 20 \times 20$$

$$F = 4000\,\text{N}$$

Hence, the correct option is (D).

### 3.2 (B)

Given, $\mu = 10$ pa-s

$$\tau_0 = 10\text{kPa} = 10^4\text{ pa}$$

For Bingham fluid, shear stress is

$$\tau = \tau_0 + \mu\frac{du}{dy}$$

Here, $\frac{du}{dy} = \frac{1}{10^{-3}} = 10^3\delta$

$\therefore \quad \tau = 10^4 + 10 \times 10^3$

$$\tau = 2 \times 10^4\text{ pa}$$

$$\tau = 20\,\text{kpa}$$

Hence, the correct option is (B).

### 3.3 (B)

Applying Bernoulli's equation

$$\frac{p_1}{\rho} + gz_1 + \frac{1}{2}v_1^2 = \frac{p_2}{\rho} + gz_2 + \frac{1}{2}v_2^2$$

Or $$\frac{p_1 - p_2}{\rho g} + (z_1 - z_2) = \frac{1}{2g}(v_2^2 - v_1^2) \quad \ldots(\text{i})$$

Also, $$\left(\frac{p_1}{\rho} + z_1\right) - \left(\frac{p_2}{\rho} + z_2\right) = h\left(\frac{\rho_m}{\rho_w} - 1\right) \quad ..(\text{ii})$$

From Equation (i) and (ii),

$$\frac{v_2^2 - v_1^2}{2g} = \frac{h(\rho_m - \rho_w)}{\rho_w}$$

Hence, the correct option is (B).

### 3.4 (B)

**Given data :**

$$L = 150 + 10 = 160\,\text{m}$$

$$D = 50\,\text{mm} = 0.05\text{ m}$$

$$Q = 0.001\text{m}^3/s, f = 0.0062$$

Now, $$Q = AV = \frac{\pi D^2}{4}.V$$

$$0.001 = \frac{\pi \times (0.05^2)}{4} \times V$$

$$V = 0.51\,\text{m/s}$$

Now, friction loss

$$hf = \frac{4fLv^2}{2gD} = \frac{4 \times 0.0062 \times 160 \times (0.15)^2}{2 \times 9.8 \times 0.05}$$

$$hf = 1.05\,\text{m}$$

And velocity head $= \frac{v^2}{2g} = \frac{(0.51)^2}{2 \times 9.8} = 0.013$

Total = 1.05 + 0.013+10

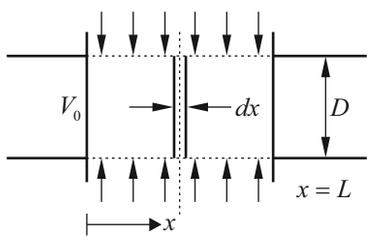
(10 m due to overhead)

$$\approx 11\,\text{m}$$

Hence, the correct option is (B).

### 3.5 (D)

Given, the velocity at the start $= V_0$




Flow rate at the start,

$$Q_0 = A.V_0$$

$$Q_0 = \frac{\pi D^2}{4}.V_0 \quad \ldots(\text{i})$$

Consider the small elemental section of width dx at a distance of x from the start.

Given,

Volumetric flow rate per unit area $= q\left(\frac{x}{L}\right)^2$

Or $$\frac{dQ}{\pi D.dx} = q\left(\frac{x}{L}\right)^2$$

$$\int_{Q_0}^{Q_x} dQ = \frac{\pi Dq}{L^2}\int_0^x x^2 dx$$

$$Q_x - Q_0 = \frac{\pi Dq}{3L^2}.x^3$$

Dividing by $\frac{\pi D^2}{4}$,

$$\frac{Q_x}{\left(\pi D^2/4\right)} - \frac{Q_0}{\left(\pi D^2/4\right)} = \frac{\pi Dq}{3L^2}.x^3.\frac{1}{\left(\pi D^2/4\right)}$$

$$V_x - V_0 = \frac{4}{3}q\frac{x^3}{DL^2}$$

Hence, the correct option is (D).

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# 6 Mass Transfer

## 1 Mark Questions (CH)

### 2000 IIT Kharagpur

**6.1** The McCabe $\Delta L$ law states that the

(A) Molar heat of vaporization of components are nearly equal.

(B) Linear crystal growth rate depends on the degree of super saturation.

(C) Linear crystal growth rate does not depend on the crystal size.

(D) Linear crystal growth rate depends on the crystal size.

**6.2** For the $n^{th}$ tray (counter from the bottom of a distillation column), the Murphree efficiency is given by

(A) $\frac{Y_{n+1}-Y_n}{Y_n^*-Y_{n-1}}$ (B) $\frac{Y_n-Y_{n-1}}{Y_n^*-Y_{n-1}}$

(C) $\frac{Y_{n-1}-Y_n}{Y_{n+1}-Y_n}$ (D) $\frac{Y_n^*-Y_{n-1}}{Y_n^*-Y_{n+1}}$

**6.3** At 750 K and 1 atm, the approximate value of the Schmidt number for air is

(A) 0.01 (B) 0.1

(C) 1 (D) 10

**6.4** The absorption factor is defined as

(A) $\frac{L}{mG}$ (B) $\frac{G}{mL}$

(C) $\frac{mL}{G}$ (D) $\frac{LG}{m}$

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**6.5** The Lewis relation for air-water humidification is given by ($k_Y$ = mass transfer coefficient of moisture in air, $h_G$ = heat transfer coefficient, $C_S$ = Heat capacity of vapour gas mixture)

(A) $\frac{h_G^2}{k_Y C_S}=1$ (B) $\frac{k_Y^2 C_S^2}{h_G}=1$

(C) $\frac{h_G}{k_Y C_S}=1$ (D) $\frac{k_Y^2 h_G}{C_S}=1$

## 2 Marks Questions (CH)

### 2000 IIT Kharagpur

**6.1** In a laboratory test run, the rate of drying was found to be $0.5\times10^{-3}$ kg/m$^2$ when the moisture content reduced from 0.4 to 0.1 on a dry basis. The critical moisture content of the material is 0.08 on a dry basis. A tray dryer is used to dry 100 kg (dry basis) of the same material under identical conditions. The surface area of the material is 0.04 m$^2$/kg of dry solid.

The time required (in second) to reduce the moisture content of the solids from 0.3 to 0.2 (dry basis) is

(A) 2000 (B) 4000

(C) 5000 (D) 6000

**6.2** The individual mass transfer coefficients ( $\text{mol/m}^2\text{-s}$ ) for absorption of a solute from a gas mixture into a liquid solvent are $K_L = 4.5$ and $K_G = 1.5$. The slope of the equilibrium line is 3. Which of the following resistance(s) is/are controlling?

(A) Liquid side

(B) Gas side

(C) Interfacial

(D) Both liquid and gas sides

## 2001 IIT Kanpur

**6.3** In a single stage extraction process, 10 kg of pure solvent S (containing no solute A) is mixed with 30 kg of feed F containing A at a mass fraction $X_F = 0.2$. The mixture splits into an extract phase E and a raffinate phase R, containing A at $X_E = 0.5$ and $X_R = 0.05$ respectively. The total mass of the extract phase is (in kg).

(A) 6.89 (B) 8.89

(C) 10 (D) 8.25

**6.4** 200 kg of solid (on dry basis) is subjected to a drying process for a period of 5000 s. The drying occurs in the constant rate period with the drying rate as $N_C = 0.5\times10^{-3}$ $\text{kg/m}^2\text{-s}$. The initial moisture content of the solid is 0.2 kg moisture/kg dry solid. The interfacial area available for drying is $4\,\text{m}^2/100\,\text{kg}$ of dry solid. The moisture content at the end of the drying period is (in kg moisture/kg dry solid)

(A) 0.5 (B) 0.05

(C) 0.1 (D) 0.15

**6.5** The interfacial area per unit volume of dispersion in a gas liquid contractor, for fractional hold-up of gas = 0.1 and gas bubble diameter = 0.5 mm is given by (in $\text{m}^2/\text{m}^3$)

(A) 500 (B) 1200

(C) 900 (D) 800

## Answers 1 Mark (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6.1 | A | 6.2 | B | 6.3 | B | 6.4 | A | 6.5 | C |

## Answers 2 Marks (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6.1 | C | 6.2 | D | 6.3 | B | 6.4 | C | 6.5 | B |

## Explanations 1 Mark (CH)

### 6.1 (A)

As per McCabe $\Delta L$ law, molar heat of vaporization of components are nearly equal.

Hence, the correct option is (A).

### 6.2 (B)

For nth tray,

$$\text{Murphree efficiency} = \frac{y_n - y_{n-1}}{y_n^* - y_{n-1}}$$

Hence, the correct option is (B).

**6.3 (B)**

At 750 K and 1 atm,

Sc (air) $= 0.1$

Hence, the correct option is (B).

**6.4 (A)**

Absorption factor $= \dfrac{L}{mG}$

Hence, the correct option is (A).

**6.5 (C)**

The Lewis relation for air-water humidification is given by $\dfrac{h_G}{k_y.C_s} = 1$

Hence, the correct option is (C).

## Explanations 2 Marks (CH)

**6.1 (C)**

**Given :**

$$R_c = 0.5\times10^{-3}\ \text{kg/m}^2\text{-s}$$

$$L_s = 100\,\text{kg}$$

$$A = 0.04\,\text{m}^2/\text{kg of dry solid}$$

$$= 0.04\times100 = 4\,\text{m}^2$$

Time required, $t = \dfrac{L_s}{A}\times\dfrac{\Delta x}{R_c}$

Here, $\Delta x = 0.3 - 0.2 = 0.1$

Putting values, $t = \dfrac{100}{4}\times\dfrac{0.1}{0.5\times10^{-3}}$

$$t = 5000\,\text{s}$$

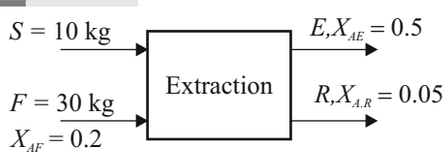
Hence, the correct option is (C).

**6.2 (D)**

Both liquid and gas side resistances are controlling.

Hence, the correct option is (D).

**6.3 (B)**




Applying overall material balance,

$$S + F = E + R$$

$$10 + 30 = E + R$$

$$E + R = 40$$

Applying balance for A,

$$FX_{A,F} = EX_{A,E} + RX_{A,R}$$

$$30\times0.2 = E\times0.5 + (40 - E)\times0.05$$

$$E = 8.89\,\text{kg}$$

Hence, the correct option is (B).

**6.4 (C)**

**Given :** $N_C = 0.5\times10^{-3}\ \text{kg/m}^2\text{-s}$

$$X_1 = 0.2,\ X_2 = ?,\ t = 5000\,\text{s}$$

$$A = 4\,\text{m}^2/100\,\text{kg of dry solid}$$

$$= 8\,\text{m}^2 \quad \text{(total)}$$

Now, $N_C = \dfrac{L_s}{A}\dfrac{(X_1 - X_2)}{t}$

Putting values,

$$0.5\times10^{-3}\,\frac{200}{8}\times\frac{(0.2 - X_2)}{5000}$$

$$X_2 = 0.1$$

Hence, the correct option is (C).

**6.5 (B)**

**Given :**

$$d = 0.5\,\text{mm} = 0.5\times10^{-3}\,\text{m}$$

$$\varepsilon = 0.1$$

Interfacial area per unit volume of dispersion,

$$a = \frac{6\varepsilon}{d},\ a = \frac{6 \times 0.1}{0.5 \times 10^{-3}}$$

$$a = 1200\,\text{m}^2/\text{m}^3$$

Hence, the correct option is (B).

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# 7 Chemical Reaction Engineering

## 1 Mark Questions (CH)

### 2000 IIT Kharagpur

**7.1** In solid catalyzed reactions, the diffusional effects are more likely to affect the overall rate of reaction

(A) Fast reactions in catalysts of small pore diameter

(B) Fast reactions in catalysts of large pore diameter

(C) Slow reactions in catalysts of small pore diameter

(D) Slow reactions in catalysts of large pore diameter

**7.2** For the liquid phase parallel reactions

$A \rightarrow R, r_R = k_1 C_A^2; E_1 = 80\text{kJ/mol}$

$A \rightarrow S, r_S = k_2 C_A; E_2 = 120\text{ kJ/mol}$

The desired product is R. A higher selectivity of R will be achieved, if the reaction is conducted at

(A) Low temperature in a CSTR

(B) High temperature in a CSTR

(C) Low temperature in a PFR

(D) High temperature in a PFR

**7.3** The reaction $A \rightarrow B$ is conducted in a isothermal batch reactor. If the conversion of A increases linearly with holding time, then the order of the reaction is

(A) 0 (B) 1

(C) 1.5 (D) 2

**7.4** The experimentally determined overall order for the reaction $A + B \rightarrow C + D$ is two. Then the

(A) Reaction is elementary with a molecularity of 2

(B) Molecularity of the reaction is 2 but the reaction may not be elementary

(C) Reaction may be elementary with a molecularity of 2

(D) Reaction is elementary but the molecularity may not be 2

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**7.5** The E-curve for a non-ideal reactor defines the fraction of fluid having age between $t$ and $t + dt$

(A) At the inlet

(B) At the outlet

(C) In the reactor

(D) Averaged over the inlet and outlet

## 2 Marks Questions (CH)

### 2000 IIT Kharagpur

**7.1** The rate controlling step for the heterogeneous irreversible catalytic reaction

$$A(g)+B(g)\rightarrow C(g)$$

Is the surface reaction of absorbed A with absorbed B to give absorbed C. The rate expression for this reaction can be written as

(A) $\dfrac{KK_AP_AP_B}{[1+K_AP_A+K_BP_B]}$

(B) $\dfrac{KK_AK_BP_AP_B}{[1+K_AP_A+K_BP_B]}$

(C) $\dfrac{KK_AK_BP_AP_B}{[1+K_AP_A+K_BP_B+K_CP_C]}$

(D) $\dfrac{KK_AK_BP_AP_B}{[1+K_AP_A+K_BP_B+K_CP_C]^2}$

**7.2** The reaction $A\rightarrow B$ is conducted in an adiabatic plug flow reactor (PFR). Pure A at a concentration of $2\,\text{k mol/m}^3$ is fed to the reactor at the rate of $0.01\ \text{m}^3/\text{s}$ and at a temperature of 500 K. If the exit conversion is 20% then the exit temperature (in kelvin) is

$\Delta H_2=-50000\,\text{kJ/k mol}$

$C_{PA}=C_{PB}=100\,\text{kJ/k mol-K}$

(A) 400 (B) 500

(C) 600 (D) 1000

**7.3** The first order series reaction $A\xrightarrow{K_1}B\xrightarrow{K_2}C$ is conducted in a batch reactor. The initial concentrations of $A$, $B$ and $C(C_{A0},C_{B0},C_{C0}$ respectively) are all non-zero. The variation of $C_B$ with reaction time will not show a maximum, if

(A) $K_2C_{B_0}>K_1C_{A_0}$

(B) $K_1C_{A_0}>K_2C_{B_0}$

(C) $C_{B_0}>C_{A_0}$

(D) $C_{A_0}>C_{B_0}$

**7.4** The following half-life data are available for the irreversible liquid phase reaction, $A\rightarrow$ products:

| Initial concentration ($\text{kmol/m}^3$) | Half-life (min) |
|---|---|
| 2 | 2 |
| 8 | 1 |

The overall order of the reaction is

(A) 0.5 (B) 1

(C) 1.5 (D) 2

**7.5** The conversion for a first-order liquid-phase reaction $A\rightarrow B$ in a CSTR is 50%. If another CSTR of the same volume is connected in series, then the percentage conversion at exit of the second reactor will be

(A) 60 (B) 75

(C) 90 (D) 100

### Answers 1 Mark (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.1 | B | 7.2 | C | 7.3 | B | 7.4 | C | 7.5 | B |

### Answers 2 Marks (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.1 | D | 7.2 | C | 7.3 | A | 7.4 | C | 7.5 | B |

## Explanations 1 Mark (CH)

**7.1 (B)**

Thiele modulus $\phi = \sqrt{\frac{K^{111}}{D}}L$ for fast reaction $K^{111}$ is high and for large pore diameter L is high. $\phi$ is high for fast reaction and large pore. If $\phi$ is high then diffusions effects are high.

Hence, the correct option is (B).

**7.2 (C)**

$$A \rightarrow R, r_R = k_1 C_A^2, E_1 = 80\,\text{kJ/mol}$$

$$A \rightarrow S, r_S = k_2 C_A^2, E_2 = 120\,\text{kJ/mol}$$

Higher conversion is achieved in a PFR if the desired product is R.

Since, the desired activation energy is less than undesired activation energy low temp is preffered.

Hence, the correct option is (C).

**7.3 (B)**

For isothermal batch reactor,

$$t = C_{A_0} \int_0^{X_A} \frac{dX}{(-r_A)}$$

For zero order, $-r_A = K$

$$\therefore \quad t = C_{A_0} \int_0^{X_A} \frac{dX}{K}$$

$$t = C_{A_0} \frac{X_A}{K}$$

$$X_A = \frac{K}{C_{A_0}}$$

Conversion increases linearly with holding time (t).

$\therefore$ Order of the reaction = 0

Hence, the correct option is (A).

**7.4 (C)**

The overall order of reaction for given reaction is 2 but rate of reaction is not given, so we can't decide the exact value of exponent, so reaction may be elementary with molecularity of 2.

Hence, the correct option is (C).

**7.5 (B)**

E-curve or exist age distribution is distribution of time for the stream of fluid leaving the vessel. Thus E-curve defines the fraction of fluid having age between t and $t + dt$ at the outlet of the reactor.

Hence, the correct option is (B).

## Explanations 2 Marks (CH)

**7.1 (D)**

$A + B \rightarrow C$ (Overall Reaction)

Sequence of steps

$$\left.\begin{aligned} A + S &\underset{K_1}{\overset{K_1}{\rightleftharpoons}} A.S \\ B + S &\underset{K_2}{\overset{K_2}{\rightleftharpoons}} B.S \end{aligned}\right\} \text{Adsorption}$$

$$A.S + B.S \xrightarrow[K_3]{} C.S + S (\text{Surface reaction})$$

$$C.S. \underset{K_4}{\overset{K_4}{\rightleftharpoons}} C + S (\text{Desorption})$$

Let $C_s$ = Conc:of uncovered surface on the catalyst.

$C_{A.S}$ = Conc:of Absorbed A

$C_{B.S}$ = Conc:of Absorbed B

$P_A$ = Conc:of A in the gas phase

$P_B$ = Conc:of B in the gas phase

Rate of Adsorption of A

$$r_{Ads} = K_1 P_A C_S - K_{-1} C_{A.S} \quad \rightarrow (1)$$

Similarly $r_B = K_2 P_B C_S - K_{-2} C_{B.S} \quad \rightarrow (2)$

Surface reaction

$$r_{Sur} = K_3 C_{A.S} C_{B.S} \quad \rightarrow (3)$$

Rate of Desorption

$$r_{Des} = K_4 C_{C.S} - K_{-4} P_C C_S$$

If the surface reaction is rate controlling. Then both adsorption and desorption occur at equilibrium

$\therefore$ (1) (2) and (4)equation we get.

$$K_1 P_A C_S - K_{-1} C_{A.S} = 0$$

$$\Rightarrow \quad K_A P_A C_S = C_{A.S}$$

Where, $K_A = \dfrac{K_1}{K_{-1}}$ = equilibrium Coefficient for Adsorption of A

$$(2) \Rightarrow C_{B.S} K_B P_B C_S$$

Similarly $(4) = C_{C.S} = K_C P_C C_S$

Where, $K_C = \dfrac{1}{K_{C^1}} = \dfrac{K_{-4}}{K_4}$

$K_{C'}$ & $K_C$ are desorption & Adsorption Coefficient of C.

$\therefore \quad (3) \Rightarrow r_{sur} = K_3 C_{A.S} C_{B.S}$

$$r_{surf} = K_3 K_A P_A C_S K_B P_B C_B$$

$C_T$ = Total Surface of catalyst

$$= C_{A.S} + C_{B.S} + C_{C.S} + C_S$$

$$C_T = K_A P_A C_S + K_B P_B C_S + K_C P_C C_S + C_S$$

$$C_S = \frac{C_T}{\left[K_A P_A + K_B P_B + K_C P_C + 1\right]}$$

$\therefore \quad r_{surf} = \dfrac{K_3 K_A K_B P_A P_B}{\left[K_A P_A + K_B P_B + K_C P_C + 1\right]^2}$

Hence, the correct option is (D).

**7.2 (C)**

**Given :** $C_{A_0} = 2\text{kmol/m}^3, v_0 = 0.01\,\text{m}^3/\text{s}$

$T_1 = 5000\,K, X_A = 0.2$

$C_{PA} = C_{PB} = 100\,\text{kJ/mol-K}$

$\Delta H = 50000$ kJ/kmol of A reacted

Applying energy balance,

$$V_0 C_{A0} C_{PB} T_2 - V_0 C_{A0} C_{PA} T_1 = \Delta H \times V_0 \times C_{A_0} X_A$$

$$C_{PB} T_2 - C_{PA} T_1 = \Delta H . X_A$$

Putting values, $100 T_2 - 100 \times 500 = 50000 \times 0.2$

$$T_2 = 600\,\text{K}$$

Hence, the correct option is (C).

**7.3 (A)**

$$r_B = k_1 C_A - k_2 C_B$$

The concentration and rate of reactant B is related as per Eq.(i) The concentration of B will increase as A react to form B and then concentration of B will decrease as B reacts to form C. Thus, it shows a maximum point in between. But concentration of B will not show a maximum, if rate of disappearance of B is higher than formation, i.e, when.

$$k_2 C_{B_0} > k_1 C_{A_0}$$

Hence, the correct option is (A).

**7.4 (C)**

For nth order,

$$-\frac{dC_A}{dt} = K C_A^n \qquad \ldots. (i)$$

$$-\int_{C_{A_0}}^{C_A} -\frac{dC_A}{C_A^n} = \int_0^t K\,dt$$

$$C_A^{1-n} - C_{A_0}^{1-n} = K(n-1)t$$

For half-life, $t = t_{1/2}$ and $C_A = \dfrac{C_{A_0}}{2}$

$$t_{1/2} = \frac{2^{n-1} - 1}{K(n-1)} C_{A_0}^{1-n} \qquad \ldots. (ii)$$

Putting values from given data,

$$2 = \frac{\left(2^{n-1} - 1\right)}{K(n-1)} \times 2^{1-n} \qquad \ldots. (iii)$$

and $$1 = \frac{\left(2^{n-1} - 1\right)}{K(n-1)} \times 8^{1-n} \qquad \ldots. (iv)$$

Dividing Equation (iv) by Equation (iii).

$$\frac{1}{2}=\left(\frac{8}{2}\right)^{1-n}$$

$$\frac{1}{2}=4^{1-n}$$

$$n=1.5$$

Hence, the correct option is (C).

**7.5 (B)**

For a CSTR, $\frac{\tau}{C_{A_0}}=\frac{X_A}{-r_A}$

$$\frac{\tau}{C_{A_0}}=\frac{X_A}{KC_{A_0}\left(1-X_A\right)}$$

For first order reaction, $K\tau=\frac{X_A}{1-X_A}$

Given, $X_A=0.5$

$\therefore \quad K\tau=\frac{0.5}{1-0.5}$

$$K\tau=1$$

Now, for two tanks of same volume in series,

$$\frac{K\tau}{N}=\left(1-X_A\right)^{-1/2}-1$$

Putting values, $\frac{2}{2}=\left(1-X_A\right)^{-1/2}-1$

$$\left(\text{Since, } K\tau=2K\tau_1=2\times1\right)$$

$$\left(1-X_A\right)^{-1/2}=2$$

$$1-X_A=\frac{1}{4}$$

$$X_A=\frac{3}{4}=0.75$$

Overall conversion = 75%

Hence, the correct option is (B).

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# 10 Chemical Technology

## 1 Mark Questions (CH)

### 2000 IIT Kharagpur

**10.1** Triple superphosphate is manufactured by reacting

(A) Phosphate rock with phosphoric acid

(B) Phosphate rock with sulphuric acid

(C) Phosphate rock with nitric acid

(D) Ammonium phosphate with phosphoric acid

**10.2** Commercially ethylene is produced from naphtha by

(A) Catalytic cracking

(B) Catalytic dehydrogenation

(C) Pyrolysis

(D) Hydro cracking

**10.3** In petroleum refining, the process used for conversion of hydrocarbon to aromatics is

(A) Catalytic cracking

(B) Catalytic reforming

(C) Hydro treating

(D) Alkylation

### 2001 IIT Kanpur

**10.4** In the Fluid Catalytic Cracker (FCC), the cracking reaction is --(a)-- and the regeneration is --(b)--

(A) (a) Exothermic, (b) Endothermic

(B) (a) Exothermic, (b) Exothermic

(C) (a) Endothermic, (b) Endothermic

(D) (a) Endothermic, (b) Exothermic

**10.5** Styrene is produced from ethylbenzene by the process of

(A) Dehydrogenation

(B) Oxidation

(C) Alkylation

(D) Dehydration

## 2 Marks Questions (CH)

### 2000 IIT Kharagpur

**10.1** Each of the products mentioned in the left hand column requires one or more of the reactants mentioned in the right-hand column. Match the products with the appropriate reactant(s).

| | |
|---|---|
| (I) Phthalic anhydride | (A) Benzene |
| (II) Cumene | (B) Naphthalene |
| | (C) Carbon monoxide |
| | (D) Phenol |
| | (E) Propylene |

(F) Air
(G) Ethyl benzene
(H) Hydrogen

(A) I-(B)(F), II- (A)
(B) I-(A)(F), II- (G)
(C) I-(H)(G), II- (D)
(D) I-(E)(B), II- (C)

**10.2** Synthesis gas is a mixture of
(A) Co and $H_2$
(B) $N_2$ and $H_2$
(C) $H_2$, $CH_4$ and Co
(D) $CO_2$ and $H_2$

## 2001 IIT Kanpur

**10.3** For the hydrogenation of oils (A)… is commonly used as catalyst, and …(B)… is a catalyst poison.

| | A | B |
|---|---|---|
| (A) | Platinum | Sulphur |
| (B) | Palladium | Oxygen |
| (C) | Nickel | Sulphur |
| (D) | Nickel | Oxygen |

**10.4** In the converter of the contact process for the manufacturing of $H_2SO_4$, the equilibrium conversion of $SO_2$ …(A)… with increase in the temperature and …(B)… with increase in mole ratio of $SO_2$ to air.

| | A | B |
|---|---|---|
| (A) | Increases | Decreases |
| (B) | Decreases | Increases |
| (C) | Increases | Increases |
| (D) | Decreases | Decreases |

## 2002 IISc Bangalore

**10.5** Consider the production of ammonia from methane and air as raw materials. The catalysts used are…(A)… for steam reforming of methane and …(B)… for ammonia synthesis.

| | A | B |
|---|---|---|
| (A) | $Ni/Al_2O_3$ | $Cu\text{-}ZnO/Al_2O_3$ |
| (B) | $Fe/Al_2O_3$ | $Cu\text{-}ZnO/Al_2O_3$ |
| (C) | $Ni/Al_2O_3$ | $Fe/Al_2O_3$ |
| (D) | $Fe/Al_2O_3$ | $Ni/Al_2O_3$ |

## Answers 1 Mark (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.1 | A | 10.2 | C | 10.3 | B | 10.4 | D | 10.5 | A |

## Answers 2 Marks (CH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.1 | A | 10.2 | A | 10.3 | C | 10.4 | B | 10.5 | C |

## Explanations 1 Mark (CH)

**10.1 (A)**

Triple superphosphate is manufactured by reacting phosphate rock with phosphoric acid.

Hence, the correct option is (A).

**10.2 (C)**

Commercially ethylene is produced from naphtha by steam cracking and pyrolysis.

Hence, the correct option is (C).

**10.3 (B)**

The reforming process is a catalytic process that converts low octane naphthas into higher octane reformate products for gasoline blending and rich aromatic reformate for the production of aromatics. This is followed by the major reactions in catalytic reforming

- Naphthenes dehydrogenation to the aromatics
- Paraffins and naphthenes are isomerised
- Paraffins dehydrocycling to aromatics

Hence, the correct option is (B).

**10.4 (D)**

Catalytic cracking in FCC is an endothermic process while catalyst regeneration is an exothermic process.

Hence, the correct option is (D).

**10.5 (A)**

Styrene is made by catalytic dehydrogenation of ethyl benzene.

$$C_6H_5CH_2CH_3 \rightarrow C_6H_5CH = CH_2 + H_2$$

Hence, the correct option is (A).

## Explanations 2 Marks (CH)

**10.1 (A)**

Phthalic anhydride is produced by catalytic oxidation of Naphthalene.

Cumene is produced by benzene.

Hence, the correct option is (A).

**10.2 (A)**

Synthesis gas is a mixture of CO & $H_2$.

Hence, the correct option is (A).

**10.3 (C)**

In hydrogenation of oil Ni is used as a catalyst but Sulphur present in vegetable oil or fat work as catalyst poison.

Hence, the correct option is (C).

**10.4 (B)**

In contact process, the equilibrium conversion of $SO_2$ decreases with increase intemperature and increases with increase in mole ratio of $SO_2$ to air.

Hence, the correct option is (B).

**10.5 (C)**

Process Catalyst

Steam reforming of methane - $Ni/Al_2O_3$

Ammonia synthesis - $Fe/Al_2O_3$

Hence, the correct option is (C).

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# 12 General Aptitude

## 1. Numerical Ability

**2010 IIT Guwahati**

**1.1** 5 skilled workers can build a wall in 20 days; 8 semi-skilled worker can build a wall in 25 days; 10 unskilled workers can build a wall in 30 days. If a team has 2 skilled, 6 semi-skilled and 5 unskilled workers, how long will it take to build the wall?

(A) 20 days (B) 18 days

(C) 16 days (D) 15 days

**1.2** If 137 + 276 = 435 how much is 731 + 672 ?

(A) 534 (B) 1403

(C) 1623 (D) 1513

**1.3** Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4. How many distinct 4 digit numbers greater than 3000 can be formed?

(A) 50 (B) 51

(C) 52 (D) 54

**1.4** 25 persons are in a room. 15 of them play hockey, 17 of them play football and 10 of them play both hockey and football. Then the number of persons playing neither hockey nor football is

(A) 2 (B) 17

(C) 13 (D) 3

**2011 IIT Madras**

**1.5** A container originally contains 10 litres of pure spirit. From this container 1 litre of spirit is replaced with 1 litre of water. Subsequently, 1 litre of the mixture is again replaced with 1 litre of water and this process is repeated one more time. How much spirit is now left in the container?

(A) 7.58 litres (B) 7.84 litres

(C) 7 litres (D) 7.29 litres

**2012 IIT Delhi**

**1.6** An automobile plant contracted to buy shock absorbers from two suppliers $X$ and $Y$. $X$ supplies 60% and $Y$ supplies 40% of the shock absorbers. All shock absorbers are subjected to a quality test. The ones that pass the quality test are considered reliable. Of $X's$ shock absorbers, 96% are reliable. Of $Y's$ shock absorbers, 72% are reliable. The probability that a randomly chosen shock absorber, which is found to be reliable, is made by $Y$ is

(A) 0.288 (B) 0.334

(C) 0.667 (D) 0.720

**2013 IIT Bombay**

**1.7** In a factory, two machines M1 and M2 manufactures 60% and 40% of the autocomponents respectively. Out of the total production, 2% of M1 and 3% of M2 are found to be defective. If a randomly drawn autocomponent from the combined lot is found defective, what is the probability that it was manufactured by M2?

(A) 0.35 (B) 0.45

(C) 0.5 (D) 0.4

**1.8** Velocity of an object fired directly in upward direction is given by $V = 80 - 32t$, where $t$ (time) is in seconds. When will the velocity be between 32 m/sec and 64 m/sec?

(A) 1, 3/2 (B) 1/2, 1

(C) 1/2, 3/2 (D) 1, 3

**2014 IIT Kharagpur**

**1.9** Find the odd one in the following group

ALRVX, EPVZB, ITZDF, OYEIK

(A) ALRVX (B) EPVZB

(C) ITZDF (D) OYEIK

**1.10** A foundry has a fixed daily cost of Rs 50,000 whenever it operates and a variable cost of Rs 800Q, where Q is the daily production in tonnes. What is the cost of production in Rs per tonne for a daily production of 100 tonnes?

## Answers Numerical Ability

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.1** | **D** | **1.2** | **C** | **1.3** | **B** | **1.4** | **D** | **1.5** | **D** |
| **1.6** | **B** | **1.7** | **C** | **1.8** | **800** | **1.9** | **D** | **1.10** | **1300** |

## Explanations Numerical Ability

**1.1 (D)**

Per day work or rate of 5 skilled workers

$$= \frac{1}{20}$$

Per day work or rate of one skilled worker

$$= \frac{1}{5 \times 20} = \frac{1}{100}$$

Similarly, per day work or rate of 8 semi-skilled workers $= \frac{1}{25}$

Per day work or rate of one semi-skill worker

$$= \frac{1}{8 \times 25} = \frac{1}{200}$$

and per day work or rate of 10 unskilled workers

$$= \frac{1}{30}$$

Per day work or rate of one unskilled worker

$$= \frac{1}{10 \times 30} = \frac{1}{300}$$

Thus total per day work of 2 skilled, 6 semi-skilled and 5 unskilled workers

$$= \frac{2}{100} + \frac{6}{200} + \frac{5}{300} = \frac{12 + 18 + 10}{600}$$

$$= \frac{40}{600} = \frac{1}{15}$$

Thus, time to complete the work is 15 days.

Hence, the correct option is (D).

**1.2 (C)**

**Given :** $137 + 276 = 435$

7 and 6 added is becoming 5 means the given two numbers are added on base 8.

$$\begin{array}{r} (137)_8 \\ +\ (276)_8 \\ \hline (435)_8 \end{array}$$

Add another two given set of numbers also on base 8.

$$\begin{array}{r} (731)_8 \\ +\ (672)_8 \\ \hline (1623)_8 \end{array}$$

Thus, the overall problem was based on identifying base which was 8 and adding numbers on base 8.

Hence, the correct option is (C).

**1.3 (B)**

**Given :** Digits are 2, 2, 3, 3, 3, 4, 4, 4, 4

As the number is greater than 3000. So thousand's place can be either 3 or 4

Let us consider the following two cases.

**Case 1 :** When thousand's place is 3

3 a b c

If there is no restriction on number of two's, three's and four's. Then each of $a$, $b$, $c$ can be filled with 2 or 3 or 4 each in 3 ways.

So, $3 \times 3 \times 3 = 27$ numbers are there. Out of which 3222, 3333 are invalid as 2 can be used twice and 3 thrice only.

So number of such valid numbers beginning with 3 are $27 - 2 = 25$

**Case 2 :** When thousand's place is 4

4 a b c

Without restriction on number of 2's, 3's and 4's $a$, $b$, $c$ can be filled in 27 ways (as explained in case 1)

Out of these 27 numbers, 4222 is only invalid as two have to be used twice only. So valid numbers are $27 - 1 = 26$

Total numbers from case 1 and case 2 is

$25 + 26 = 51$

Hence, the correct option is (B).

**1.4 (D)**

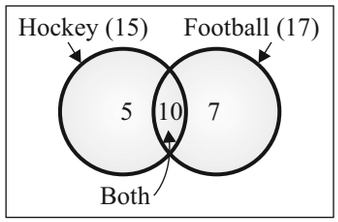
**Given :** There are 25 persons in a room.

**Method 1**

Total numbers of players

= Hockey only + Football only

+ Both hockey and football




From Venn diagram,

Total number of players $= 5 + 7 + 10 = 22$

Therefore, number of persons playing neither hockey nor football $= 25 - 22 = 3$

Hence, the correct option is (D).

**Method 2**

From set theory,

$n(A)$ : Number of people who play hockey $= 15$

$n(B)$ : Number of people who play football $= 17$

$n(A \cap B)$ : Persons who play both hockey and football = 10

$n(A \cup B)$ : Persons who play either hockey or football or both

From set theory,

$$n(A\cup B)=n(A)+n(B)-n(A\cap B)$$
$$n(A\cup B)=15+17-10$$
$$n(A\cup B)=22$$

Total number of persons $=25$

Therefore, people who play neither hockey nor football $=25-22=3$

Hence, the correct option is (D).

**1.5 (D)**

**Given :** Original quantity of spirit = 10 litres

Let $x$ be the total amount of solution and $y$ be the amount of solution which is replaced each time.

Then, $\left(1-\frac{y}{x}\right)^n=\frac{\text{Spirit left after 3rd operation}}{\text{Initial quantity of spirit}}$

Spirit left after 3rd operation

$$=10\left(1-\frac{1}{10}\right)^3=10\times\left(\frac{9}{10}\right)^3$$
$$=7.29 \text{ litres}$$

Hence, the correct option is (D).

**1.6 (B)**

**Given :**

(i) Probability that shock absorbers are supplied by $X=0.6$

(ii) Probability that shock absorbers are supplied by $Y=0.4$

(iii) 96% of $X's$ shock absorbers are reliable

i.e. $=0.6\times0.96$

(iv) 72% of $Y's$ shock absorbers are reliable

i.e. $=0.4\times0.72$

**Method 1**

According to Bayes' theorem, the probability that a randomly chosen shock absorber is found to be reliable, is supplied by $Y$ is,

$$P\left(\frac{Y}{R}\right)=\frac{P(Y\cap R)}{P(R)} \quad \ldots \text{(i)}$$

Where, $P(R)=$ Probability that shock absorber is reliable

$P(R)=$ Reliable when supplied by $X$ + Reliable when supplied by $Y$

$$P(R)=0.6\times0.96+0.4\times0.72$$
$$P(R)=0.864 \quad \ldots \text{(ii)}$$

$P(Y\cap R)=$ Probability that shock absorber is supplied by $Y$ and is reliable

$$P(Y\cap R)=0.4\times0.72=0.288 \quad \ldots \text{(iii)}$$

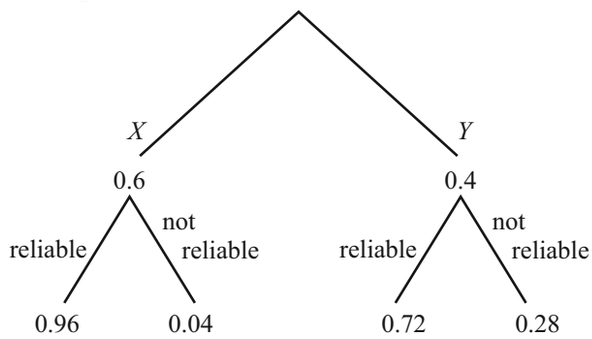
From equations (i), (ii) and (iii),

$$P\left(\frac{Y}{R}\right)=\frac{0.288}{0.864}=0.334$$

Hence, the correct option is (B).

**Method 2**

From given information we can draw,




By Bayes' theorem the probability that a randomly chosen shock absorber which is reliable, is made by $Y$ is,

$$=\frac{0.72\times0.4}{0.72\times0.4+0.96\times0.6}=0.33$$

Hence, the correct option is (B).

**1.7 (C)**

**Given :**

(i) Probability that autocomponents are manufactured by $M_1=0.6$

2% of autocomponents manufactured by

$M_1$ are defective i.e. $=0.6\times0.02$

(ii) Probability that autocomponents are manufactured by $M_2 = 0.4$

3% of autocomponents manufactured by

$M_2$ are defective i.e. $= 0.4 \times 0.03$

According to Bayes' theorem, if a component is defective then the probability that it was manufactured by $M_2$,

$$P\left(\frac{M_2}{D}\right) = \frac{P(M_2 \cap D)}{P(D)}$$

Where, $P(D) =$ Defective and produced by $M_1$ + Defective and produced by $M_2$

$$= 0.6 \times 0.02 + 0.4 \times 0.03$$

$$P(D) = 0.024$$

$P(M_2 \cap D) =$ Probability of being defective and manufactured by $M_2$

$$P(M_2 \cap D) = 0.4 \times 0.03 = 0.012$$

So, $$P\left(\frac{M_2}{D}\right) = \frac{0.012}{0.024} = 0.5$$

Hence, the correct option is (C).

**1.8 800**

**Given :** Tiger is 50 leap of its own behind deer.

The distance covered per leap by tiger, $l_t = 8$ m

The distance covered per leap by deer, $l_p = 5$ m

So, initial separation $= 50 \times 8 = 400$ m

Speed = Number of leaps × distance per leap

Speed of tiger and deer are :

$$v_T = 5 \times 8 = 40 \text{ m/minute}$$

$$v_D = 4 \times 5 = 20 \text{ m/minute}$$

Now relative distance of 400 m have to be covered with $(40 - 20) = 20$ m/min

$$\text{Required time} = \frac{\text{Distance}}{\text{Relative speed}}$$

$$= \frac{400 \text{ m}}{(40-20) \text{m/min}} = 20 \text{ min}$$

So, the distance travelled by tiger is

$$= 40 \text{ m/min} \times 20 \text{ min} = 800 \text{ m}$$

Hence, the distance is **800 m**.

**1.9 (D)**

**Given :** ALRVX, EPVZB, ITZDF, OYEIK

**Method 1**

Option (A) : It consists of only one vowel.

Option (B) : It consists of only one vowel.

Option (C) : It consists of only one vowel.

Option (D) : It consists of three vowels.

Hence, the correct option is (D).

**Method 2**

Option (A) : A – L – R – V – X

A – L : 10 alphabets between A and L.

L – R : 5 alphabets between L and R.

R – V : 3 alphabets between R and V.

V – X : 1 alphabet between V and X.

Similar for option (B) and (C).

Option (D) : OYEIK

O – Y : 9 alphabets between O and Y.

Y – E : 5 alphabets between Y and E.

E – I : 3 alphabets between E and I.

I – K : 1 alphabet between I and K.

Hence, the correct option is (D).

**1.10 1300**

**Given :**

(i) Fixed daily cost $= 50,000$

(ii) Variable cost $= 800Q$

where, $Q =$ daily production in tonnes.

For daily production of 100 tonnes,

Variable cost $= 800 \times 100 = 80,000$

Total cost

= Fixed daily cost + Variable daily cost

$$C_T = 50,000 + 80,000$$

$$C_T = 1,30,000$$

Total cost for 100 tonnes $= 1,30,000$

So, cost of production per tonne

$$= \frac{1,30,000}{100} = 1300 \text{ Rs.}$$

Hence, the cost of production in Rs. Per tonne for a daily production of 100 tonnes is **1300** Rs.

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# 2. Logical Reasoning

## 2010 IIT Guwahati

**2.1** Hari ($H$), Gita ($G$), Irfan ($I$) and Saira ($S$) are siblings (i.e. brothers and sisters). All were born on 1st January. The age difference between any two successive siblings (that is born one after another) is less than 3 years. Given the following facts :

(i) Hari's age + Gita's age > Irfan's age + Saira's age.

(ii) The age difference between Gita and Saira is 1 year. However, Gita is not the oldest and Saira is not the youngest.

(iii) There are no twins.

In what order were they born (oldest first)?

(A) *HSIG*

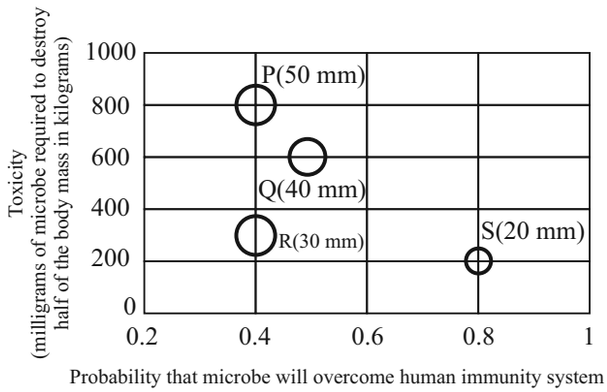
(B) *SGHI*

(C) *IGSH*

(D) *IHSG*

## 2011 IIT Madras

**2.2** P, Q, R and S are four types of dangerous microbes recently found in a human habitat. The area of each circle with its diameter printed in brackets represents the growth of a single microbe surviving human immunity system within 24 hours of entering the body. The danger to human beings varies proportionately with the toxicity, potency and growth attributed to a microbe shown in the figure below,




A pharmaceutical company is contemplating the development of a vaccine against the most dangerous microbe. Which microbe should the company target in its first attempt?

(A) P (B) Q

(C) R (D) S

**2.3** If

$$\log(P) = \left(\frac{1}{2}\right)\log(Q) = \left(\frac{1}{3}\right)\log(R)$$

then which of the following option is TRUE?

(A) $P^2 = Q^3R^2$ (B) $Q^2 = PR$

(C) $Q^2 = R^3P$ (D) $R = P^2Q^2$

**2.4** The variable cost (V) of manufacturing a product varies according to the equation $V = 4q$, where $q$ is the quantity produced. The fixed cost (F) of production of same product reduces with $q$ according to the equation $F = 100/q$. How many units should be produced to minimize the total cost $(V + F)$?

(A) 5 (B) 4

(C) 7 (D) 6

## 2012 IIT Delhi

**2.5** The cost function for a product in a firm is given by $5q^2$, where $q$ is the amount

of production. The firm can sell the product at a market price of Rs. 50 per unit. The number of units to produced by the firm such that the profit is maximized is

(A) 5 (B) 10

(C) 15 (D) 25

**2.6** A political party orders an arch for the entrance to the ground in which the annual convention is being held. The profile of the arch follows the equation $y = 2x - 0.1x^2$, where $y$ is the height of the arch in meters. The maximum possible height of the arch is

(A) 8 meters (B) 10 meters

(C) 12 meters (D) 14 meters

**2.7** Which of the following assertions are **CORRECT?**

P : Adding 7 to each entry in a list adds 7 to the mean of the list

Q : Adding 7 to each entry in a list adds 7 to the standard deviation of the list

R : Doubling each entry in a list doubles the mean of the list

S : Doubling each entry in a list leaves the standard deviation of the list unchanged

(A) P, Q (B) Q, R

(C) P, R (D) R, S

**2.8** Given the sequence of terms, AD CG FK JP, the next term is

(A) OV (B) OW

(C) PV (D) PW

**2013 IIT Bombay**

**2.9** Following table gives data on tourists from different countries visiting India in the year 2011.

| Country | Number of Tourists |
|---|---|
| USA | 2000 |
| England | 3500 |
| Germany | 1200 |
| Italy | 1100 |
| Japan | 2400 |
| Australia | 2300 |
| France | 1000 |

Which two countries contributed to the one third of the total number of tourists who visited India in 2011?

(A) USA and Japan

(B) USA and Australia

(C) England and France

(D) Japan and Australia

**2.10** All professors are researchers

Some scientists are professors

Which of the given conclusions is logically valid and is inferred from the above arguments :

(A) All scientists are researchers

(B) All professors are scientists

(C) Some researchers are scientists

(D) No conclusion follows

**Answers Logical Reasoning**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **2.1** | **B** | **2.2** | **D** | **2.3** | **B** | **2.4** | **A** | **2.5** | **A** |
| **2.6** | **B** | **2.7** | **C** | **2.8** | **A** | **2.9** | **C** | **2.10** | **C** |

## Explanations Logical Reasoning

### 2.1 (B)

Suppose : Hari's age : $H$, Gita's age : $G$, Saira's age : $S$, Irfan's age : $I$

According to question,

1. $H+G>I+S$
2. $G$ can't be oldest and $S$ can't be youngest.
   $G-S=1$ or $S-G=1$
3. There are no twins. Thus using statement (2) either $GS$ or $SG$ possible.

Checking from the options,

**Option (A) :** $HSIG$

Not possible as there is $I$ between $S$ and $G$ which is not possible using statement (2).

So, incorrect option.

**Option (B) :** $SGHI$

$SG$ order is possible.

$$S>G>H>I$$

Therefore, $S=G+1$ and $H+G>I+S$

$$H+G>I+G+1 \Rightarrow H>I+1$$

and $H\neq I$ which is possible

[From statement (3)] satisfying all the facts.

So, correct option.

**Option (C) :** $IGSH$

According to this $G=S+1$ and

$$H+G>I+S$$
$$H+S+1>I+S$$
$$H+1>I$$

and $H\neq I$ [from statement (3)]

Therefore, $H>I$

But in option $H<I$.

So, incorrect option.

**Option (D) :** $IHSG$

According to this $I>H$ and $S>G$ thus adding both inequalities $I+S>H+G$ which is opposite to statement (1), thus not possible.

Hence, the correct option is (B).

### 2.2 (D)

**Method 1**

In the given graph,

**X - Coordinate :** Number of miligrams of microbe required to destroy half of the body mass in kilogram.

Therefore, lesser the miligrams of microbe required, more is the danger to humans.

**Y - Coordinate :** Probability that microbe will overcome human immunity system. Therefore, more probability is danger to humans.

In the given graph, microbe S requires only 200 mg of toxicity to destroy half of the body mass in kg and it has highest probability to overcome human immunity system.

Hence, the correct option is (D).

**Method 2**

According to given information,

Most dangerous microbe

$\propto$ probability that microbe will over come human immune system

$\propto$ Area (growth of microbe)

$$\propto \frac{1}{\text{quantity required}}$$

So, most dangerous microbe

$$\propto \frac{\text{Probability}\times\text{Area}}{\text{quantity required}}$$

$$= \frac{K\times\text{Probability}\times\text{Area}}{\text{quantity required}}$$

Where $K$ is proportionality constant

$$= \frac{K\times\text{Probability}\times\pi d^2}{4\times\text{quantity required}}$$

**For microbe P**

$$\text{Most dangerous microbe} = \frac{\pi K}{4}\left(\frac{0.4\times 50^2}{800}\right)$$
$$= \frac{\pi K}{4}\left(\frac{5}{4}\right)$$

**For microbe Q**

$$\text{Most dangerous microbe} = \frac{\pi K}{4}\left(\frac{0.5\times 40^2}{600}\right)$$
$$= \frac{\pi K}{4}\left(\frac{4}{3}\right)$$

**For microbe R**

$$\text{Most dangerous microbe} = \frac{\pi K}{4}\left(\frac{0.4\times 30^2}{300}\right)$$
$$= \frac{\pi K}{4}\left(\frac{6}{5}\right)$$

**For microbe S**

$$\text{Most dangerous microbe} = \frac{\pi K}{4}\left(\frac{0.8\times 20^2}{200}\right)$$
$$= \frac{\pi K}{4}\left(\frac{8}{5}\right)$$

From this we can say that most dangerous microbe is S.

Hence, the correct option is (D).

**2.3 (B)**

Let $\log P = \frac{1}{2}\log Q = \frac{1}{3}\log R = K$

$P = 10^K$, $Q = 10^{2k}$, $R = 10^{3k}$

$Q^2 = 10^{4K}$

$P \times R = 10^{4K}$

So, $Q^2 = PR$

Hence, the correct option is (B).

**2.4 (A)**

**Given :**

(i) Variable cost, $V = 4q$

(ii) Fixed cost, $F = \frac{100}{q}$

Total cost, $c = V + F = 4q + \frac{100}{q}$

Differentiating above equation,

$$\frac{dc}{dq} = 4 - \frac{100}{q^2}$$

Condition of minima : $\frac{d^2c}{dq^2} = +\text{ve}$

$$\frac{dc}{dq} = 4 - \frac{100}{q^2}$$

Stationary point is given by,

$$\frac{dc}{dq} = 0$$

$$q = \pm 5$$

$$\frac{d^2c}{dq^2} = 0 + \frac{200}{q^3}$$

At $q = 5$,

$$\frac{d^2c}{dq^2} = 1.6(+\text{ve})$$

At $q = -5$,

$$\frac{d^2c}{dq^2} = -1.6(-\text{ve})$$

Therefore, at $q = 5$, the total cost will be minimum.

Hence, the correct option is (A).

**2.5 (A)**

**Given :**

(i) Cost function of a product $= 5q^2$

(ii) Selling price $= 50$/unit

For $q$ number of units, selling price function

$$= 50q$$

Total profit = Selling function – cost function

$$P = 50q - 5q^2$$

For maximum profit : $\frac{d^2P}{dq^2} = -\text{ve}$

$$\frac{dP}{dq} = 50 - 10q$$

Stationary point is given by,

$$\frac{dP}{dq} = 50 - 10q = 0$$

$$q = 5$$

$$\frac{d^2P}{dq^2} = 0 - 10 = -10(-\text{ve})$$

Therefore, for maximum profit, total number of units produced is 5.

Hence, the correct option is (A).

## 2.6 (B)

**Given :** $y = 2x - 0.1x^2$

Condition for maximum height of arch :

$$\frac{d^2y}{dx} = -\text{ve}$$

$$\frac{dy}{dx} = 2 - 0.2x$$

Stationary point is given by,

$$\frac{dy}{dx} = 0$$

$$2 - 0.2x = 0$$

$$x = 10 \text{ meters}$$

$$\frac{d^2y}{dx^2} = 0 - 0.2 = -0.2 = -\text{ve}$$

The condition of maxima is satisfied

The maximum height of the arch at $x = 10$ m is given by,

$$y\big|_{x=10} = 2\times10 - 0.1\times(10)^2$$

$$y\big|_{x=10} = 10 \text{ meters}$$

Hence, the correct option is (B).

## 2.7 (C)

Let us take an example of a list as shown below,

$$\text{list}(x) = \{1, 2, 3\}$$

**P :** Adding 7 to each entry in a list adds 7 to the mean of the list.

$$\text{Mean}(\bar{x})\ \frac{1+2+3}{3} = 2$$

$$\text{Mean}' = \frac{(1+7)+(2+7)+(3+7)}{3} = 9$$

$$\text{Mean}' = \text{Mean} + 7$$

Assertion '*P*' is correct.

**Q :** Adding 7 to each entry in a list adds 7 to the standard deviation of the list.

$$\text{Standard deviation} = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$\sigma = \sqrt{\frac{(1-2)^2+(2-2)^2+(3-2)^2}{3}}$$

$$\sigma = \sqrt{\frac{2}{3}} = 0.816$$

$$\sigma' = \sqrt{\frac{(1+7-2)^2+(2+7-2)^2+(3+7-2)^2}{3}}$$

$$\sigma' = \sqrt{\frac{149}{3}} = 7.047$$

$$\sigma' \neq \sigma + 7$$

This assertion is incorrect.

**R :** Doubling each entry in a list doubles the mean of the list.

$$\text{Mean}' = \frac{2\times1+2\times2+2\times3}{3}$$

$$\text{Mean}' = 4 = 2\times\text{Mean}$$

This assertion is correct.

**S :** Doubling each entry in a list leaves the standard deviation of the list unchanged.

$$SD' = \sqrt{\frac{\sum(2x-\bar{x})^2}{n}}$$

$$SD' = \sqrt{\frac{(2-2)^2+(2\times2-2)^2+(2\times3-2)^2}{3}}$$

$$SD' = \sqrt{\frac{20}{3}} \neq \sigma$$

This assertion is also incorrect.

Hence, the correct option is (C).

**2.8 (A)**

Given sequence : AD CG FK JP

(i) A _ _ D (2 spaces)

(ii) C _ _ _ G (3 spaces)

(iii) F _ _ _ _ K (4 spaces)

(iv) J _ _ _ _ _ P (5 spaces)

The space between each term is increasing by 1 and the 1st alphabet of the consecutive term is one less than last alphabet of the previous term.

Therefore, the 5th term will have 6 spaces and start from '$P$'−1 i.e. 'O'.

So, the next term is OV.

Hence, the correct option is (A).

**2.9 (C)**

**Given :**

| Country | Number of Tourists |
|---|---|
| USA | 2000 |
| England | 3500 |
| Germany | 1200 |
| Italy | 1100 |
| Japan | 2400 |
| Australia | 2300 |
| France | 1000 |

Total number of tourists who visited India in

$$2011 = 2000 + 3500 + 1200 + 1100 + 2400 + 1000 + 2300$$

$$= 13500$$

One-third of total tourists $= \frac{13500}{3} = 4500$

The two countries contributed to $\frac{1}{3}^{rd}$ of total tourists are England and France

Since, England $= 3500$

France $= 1000$

and $E + F = 4500$

Hence, the correct option is (C).

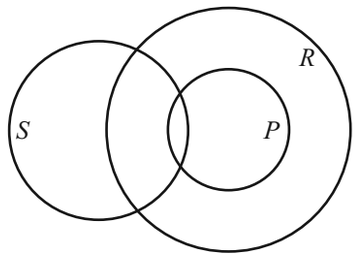
**2.10 (C)**

**Given :**

(i) All professors are researchers.

(ii) Some scientists are professors.

According to given data, venn diagram can be drawn as shown below,




From the given options, only option (C) logically follows.

Hence, the correct option is (C).

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