

# PART I : PHYSICS

## SECTION – 1 : (Only One Option Correct Type)

This section contains 10 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONLY ONE option is correct.

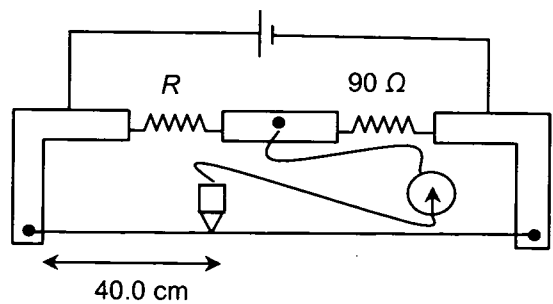
1. A metal surface is illuminated by light of two different wavelengths  $248 \text{ nm}$  and  $310 \text{ nm}$ . The maximum speeds of the photoelectrons corresponding to these wavelengths are  $u_1$  and  $u_2$ , respectively. If the ratio  $u_1 : u_2 = 2 : 1$  and  $hc = 1240 \text{ eV nm}$ , the work function of the metal is nearly  
 (A) 3.7 eV                      (B) 3.2 eV                      (C) 2.8 eV                      (D) 2.5 eV

2. If  $\lambda_{\text{Cu}}$  is the wavelength of  $K_\alpha$  X-ray line of copper (atomic number 29) and  $\lambda_{\text{Mo}}$  is the wavelength of the  $K_\alpha$  X-ray line of molybdenum (atomic number 42), then the ratio  $\lambda_{\text{Cu}}/\lambda_{\text{Mo}}$  is close to  
 (A) 1.99                      (B) 2.14                      (C) 0.50                      (D) 0.48

3. Parallel rays of light of intensity  $I = 912 \text{ Wm}^{-2}$  are incident on a spherical black body kept in surroundings of temperature  $300 \text{ K}$ . Take Stefan-Boltzmann constant  $\sigma = 5.7 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$  and assume that the energy exchange with the surroundings is only through radiation. The final steady state temperature of the black body is close to  
 (A) 330 K                      (B) 660 K                      (C) 990 K                      (D) 1550 K

4. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at  $40.0 \text{ cm}$  using a standard resistance of  $90 \Omega$ , as shown in the figure. The least count of the scale used in the metre bridge is  $1 \text{ mm}$ . The unknown resistance is

$$\frac{1}{40 \times 10} = \frac{0.25}{10}$$



$$\frac{R}{90} = \frac{40}{100}$$

$$R = \frac{40 \times 90}{100} = 36$$

- (A)  $60 \pm 0.15 \Omega$                       (B)  $135 \pm 0.56 \Omega$                       (C)  $60 \pm 0.25 \Omega$                       (D)  $135 \pm 0.23 \Omega$

Space for Rough Work

$$\frac{120}{2} = u$$

$$\frac{11}{1} = u$$

$$W = \frac{1240}{u}$$

$$V_1 = 5, V_2 = 4$$

$$\phi = 1240x$$

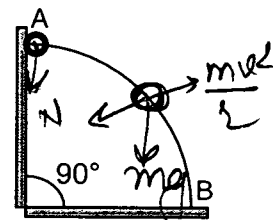
$$\phi = \frac{1240}{248}$$

$$\phi = \frac{1240}{810}$$



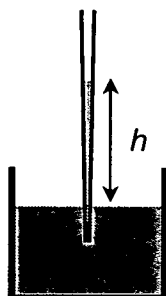
5. A planet of radius  $R = \frac{1}{10} \times$  (radius of Earth) has the same mass density as Earth. Scientists dig a well of depth  $\frac{R}{5}$  on it and lower a wire of the same length and of linear mass density  $10^{-3} \text{ kgm}^{-1}$  into it. If the wire is not touching anywhere, the force applied at the top of the wire by a person holding it in place is (take the radius of Earth =  $6 \times 10^6 \text{ m}$  and the acceleration due to gravity on Earth is  $10 \text{ ms}^{-2}$ )  
 (A) 96 N (B) 108 N (C) 120 N (D) 150 N

6. A wire, which passes through the hole in a small bead, is bent in the form of quarter of a circle. The wire is fixed vertically on ground as shown in the figure. The bead is released from near the top of the wire and it slides along the wire without friction. As the bead moves from A to B, the force it applies on the wire is  
 (A) always radially outwards.  
 (B) always radially inwards.  
 (C) radially outwards initially and radially inwards later.  
 (D) radially inwards initially and radially outwards later.

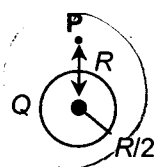


7. A glass capillary tube is of the shape of a truncated cone with an apex angle  $\alpha$  so that its two ends have cross sections of different radii. When dipped in water vertically, water rises in it to a height  $h$ , where the radius of its cross section is  $b$ . If the surface tension of water is  $S$ , its density is  $\rho$ , and its contact angle with glass is  $\theta$ , the value of  $h$  will be ( $g$  is the acceleration due to gravity)

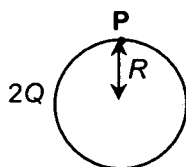
- (A)  $\frac{2S}{b\rho g} \cos(\theta - \alpha)$   
 (B)  $\frac{2S}{b\rho g} \cos(\theta + \alpha)$   
 (C)  $\frac{2S}{b\rho g} \cos(\theta - \alpha/2)$   
 (D)  $\frac{2S}{b\rho g} \cos(\theta + \alpha/2)$



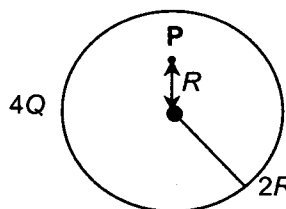
8. Charges  $Q$ ,  $2Q$  and  $4Q$  are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii  $R/2$ ,  $R$  and  $2R$  respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance  $R$  from the centre of spheres 1, 2 and 3 are  $E_1$ ,  $E_2$  and  $E_3$  respectively, then



Sphere 1



Sphere 2



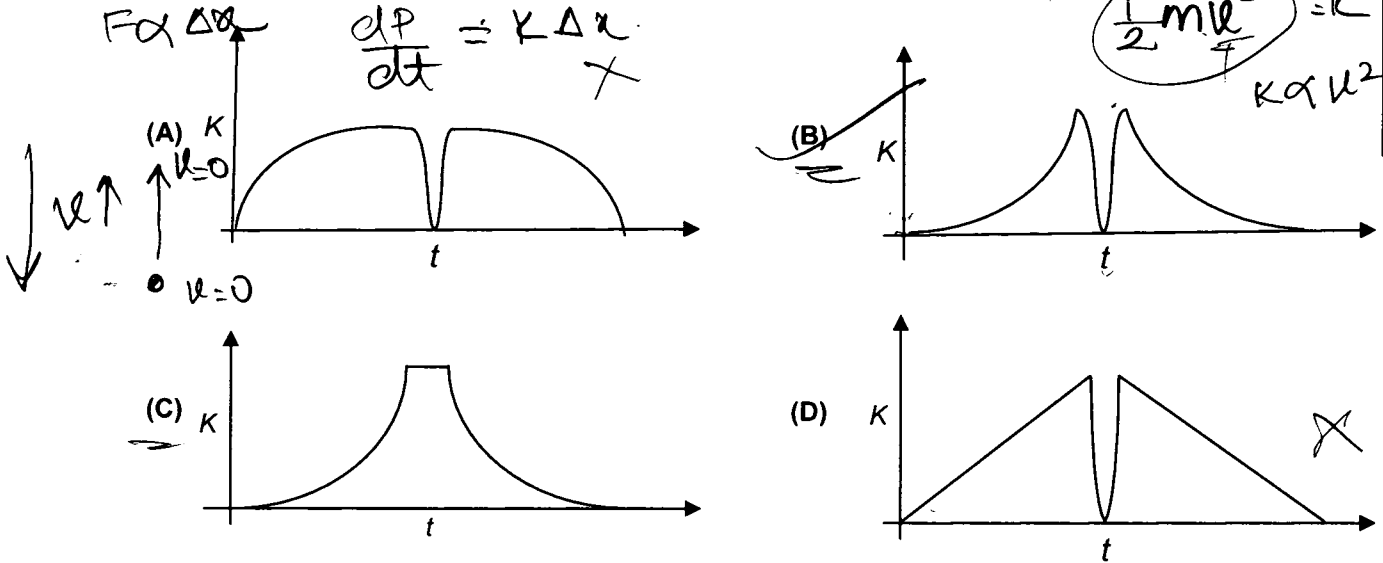
Sphere 3

- (A)  $E_1 > E_2 > E_3$  (B)  $E_3 > E_1 > E_2$  (C)  $E_2 > E_1 > E_3$  (D)  $E_3 > E_2 > E_1$

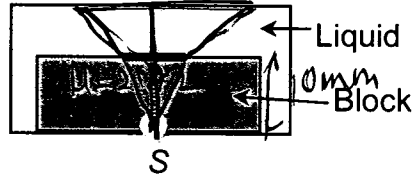
Space for Rough Work



9. A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy  $K$  with time  $t$  most appropriately? The figures are only illustrative and not to the scale.



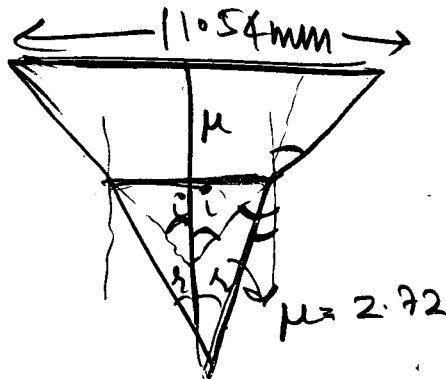
10. A point source  $S$  is placed at the bottom of a transparent block of height  $10\text{ mm}$  and refractive index  $2.72$ . It is immersed in a lower refractive index liquid as shown in the figure. It is found that the light emerging from the block to the liquid forms a circular bright spot of diameter  $11.54\text{ mm}$  on the top of the block. The refractive index of the liquid is



- (A) 1.21      (B) 1.30      (C) 1.36      (D) 1.42

Space for Rough Work

$K = \frac{1}{2} m g t^2$   
 $K \propto t^2$

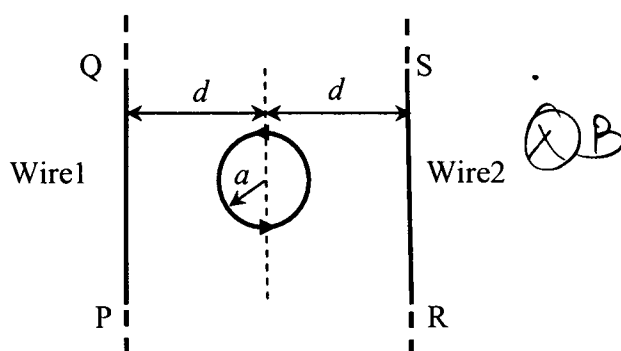


**SECTION – 2 : Comprehension Type (Only One Option Correct)**

This section contains 3 paragraphs, each describing theory, experiments, data etc. Six questions relate to the three paragraphs with two questions on each paragraph. Each question has only one correct answer among the four given options (A), (B), (C) and (D).

**Paragraph For Questions 11 & 12**

The figure shows a circular loop of radius  $a$  with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the centre of the loop is  $d$ . The loop and the wires are carrying the same current  $I$ . The current in the loop is in the counterclockwise direction if seen from above.



$\frac{126}{105}$

$\otimes B$

11. When  $d \approx a$  but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height  $h$  above the loop. In that case
- (A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and  $h \approx a$
  - (B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and  $h \approx a$
  - (C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and  $h \approx 1.2a$
  - (D) current in wire 1 and wire 2 is the direction PQ and RS, respectively and  $h \approx 1.2a$

12. Consider  $d \gg a$ , and the loop is rotated about its diameter parallel to the wires by  $30^\circ$  from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)

- (A)  $\frac{\mu_0 I^2 a^2}{d}$
- (B)  $\frac{\mu_0 I^2 a^2}{2d}$
- (C)  $\frac{\sqrt{3} \mu_0 I^2 a^2}{d}$
- (D)  $\frac{\sqrt{3} \mu_0 I^2 a^2}{2d}$

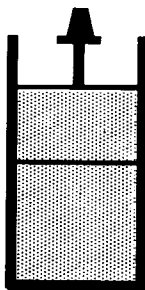
Space for Rough Work

$$\tau = \vec{M} \times \vec{B}$$



**Paragraph For Questions 13 & 14**

In the figure a container is shown to have a movable (without friction) piston on top. The container and the piston are all made of perfectly insulating material allowing no heat transfer between outside and inside the container. The container is divided into two compartments by a rigid partition made of a thermally conducting material that allows slow transfer of heat. The lower compartment of the container is filled with 2 moles of an ideal monatomic gas at 700 K and the upper compartment is filled with 2 moles of an ideal diatomic gas at 400 K. The heat capacities per mole of an ideal monatomic gas are  $C_V = \frac{3}{2}R$ ,  $C_P = \frac{5}{2}R$ , and those for an ideal diatomic gas are  $C_V = \frac{5}{2}R$ ,  $C_P = \frac{7}{2}R$ .



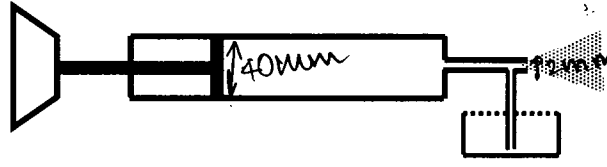
13. Consider the partition to be rigidly fixed so that it does not move. When equilibrium is achieved, the final temperature of the gases will be  
 (A) 550 K                      (B) 525 K                      (C) 513 K                      (D) 490 K
14. Now consider the partition to be free to move without friction so that the pressure of gases in both compartments is the same. Then total work done by the gases till the time they achieve equilibrium will be  
 (A) 250 R                      (B) 200 R                      (C) 100 R                      (D) -100 R

Space for Rough Work



Paragraph For Questions 15 & 16

A spray gun is shown in the figure where a piston pushes air out of a nozzle. A thin tube of uniform cross section is connected to the nozzle. The other end of the tube is in a small liquid container. As the piston pushes air through the nozzle, the liquid from the container rises into the nozzle and is sprayed out. For the spray gun shown, the radii of the piston and the nozzle are 20 mm and 1 mm respectively. The upper end of the container is open to the atmosphere.



$A_1 v_1 = A_2 v_2$   
 $\pi r_1^2 v_1 = \pi r_2^2 v_2$   
 $20 \times 20 \times 5 = 1 \times 1 \times v_2$

15. If the piston is pushed at a speed of  $5 \text{ mms}^{-1}$ , the air comes out of the nozzle with a speed of  
 (A)  $0.1 \text{ ms}^{-1}$       (B)  $1 \text{ ms}^{-1}$       (C)  $2 \text{ ms}^{-1}$       (D)  $8 \text{ ms}^{-1}$
16. If the density of air is  $\rho_a$  and that of the liquid  $\rho_\ell$ , then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to  
 (A)  $\sqrt{\frac{\rho_a}{\rho_\ell}}$       (B)  $\sqrt{\rho_a \rho_\ell}$       (C)  $\sqrt{\frac{\rho_\ell}{\rho_a}}$       (D)  $\rho_\ell$

Space for Rough Work

$\rho_a A_1 v_1 = \rho_\ell A_2 v_2$

$\frac{V}{t} \Rightarrow \frac{A \cdot l}{t} \Rightarrow A v$



## SECTION – 3 : Matching List Type (Only One Option Correct)

This section contains four questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D), out of which one is correct.

17. A person in a lift is holding a water jar, which has a small hole at the lower end of its side. When the lift is at rest, the water jet coming out of the hole hits the floor of the lift at a distance  $d$  of 1.2 m from the person. In the following, state of the lift's motion is given in List I and the distance where the water jet hits the floor of the lift is given in List II. Match the statements from List I with those in List II and select the correct answer using the code given below the lists.

List I	List II
P. Lift is accelerating vertically up.	1. $d = 1.2\text{ m}$
Q. Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.	2. $d > 1.2\text{ m}$
R. Lift is moving vertically up with constant speed.	3. $d < 1.2\text{ m}$
S. Lift is falling freely.	4. No water leaks out of the jar

Code :

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

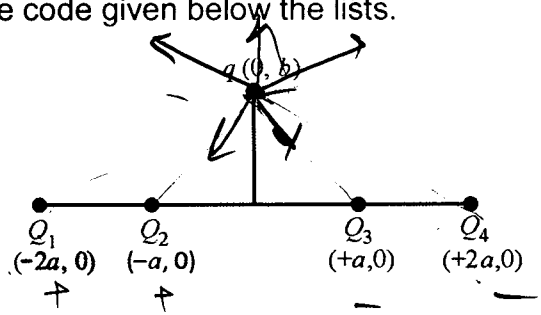
Space for Rough Work



18. Four charges  $Q_1, Q_2, Q_3$  and  $Q_4$  of same magnitude are fixed along the  $x$  axis at  $x = -2a, -a, +a$  and  $+2a$ , respectively. A positive charge  $q$  is placed on the positive  $y$  axis at a distance  $b > 0$ . Four options of the signs of these charges are given in List I. The direction of the forces on the charge  $q$  is given in List II. Match List I with List II and select the correct answer using the code given below the lists.

- List I**
- P.  $Q_1, Q_2, Q_3, Q_4$  all positive
  - Q.  $Q_1, Q_2$  positive;  $Q_3, Q_4$  negative
  - R.  $Q_1, Q_4$  positive;  $Q_2, Q_3$  negative
  - S.  $Q_1, Q_3$  positive;  $Q_2, Q_4$  negative

- List II**
- 1.  $+x$
  - 2.  $-x$
  - 3.  $+y$
  - 4.  $-y$



**Code :**

(A) P-3, Q-1, R-4, S-2

(B) P-4, Q-2, R-3, S-1

(C) P-3, Q-1, R-2, S-4

(D) P-4, Q-2, R-1, S-3

19. Four combinations of two thin lenses are given in List I. The radius of curvature of all curved surfaces is  $r$  and the refractive index of all the lenses is 1.5. Match lens combinations in List I with their focal length in List II and select the correct answer using the code given below the lists.

- List I**
- P.
  - Q.
  - R.
  - S.

- List II**
- 1.  $2r$
  - 2.  $r/2$
  - 3.  $-r$
  - 4.  $r$

**Code :**

(A) P-1, Q-2, R-3, S-4

(B) P-2, Q-4, R-3, S-1

(C) P-4, Q-1, R-2, S-3

(D) P-2, Q-1, R-3, S-4

**Space for Rough Work**



$$\frac{1}{f} = (1.5 - 1) \left( \frac{2}{r} \right)$$

$$f_1 = 2 \quad f_3 = 2$$

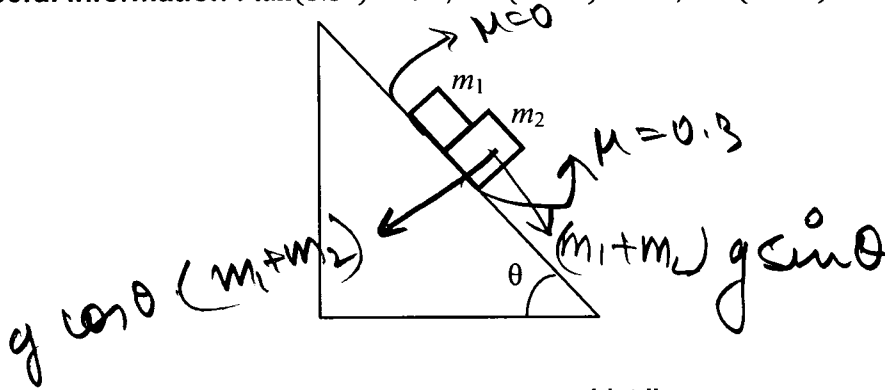
$$f_2 = -2$$





20. A block of mass  $m_1 = 1 \text{ kg}$  another mass  $m_2 = 2 \text{ kg}$ , are placed together (see figure) on an inclined plane with angle of inclination  $\theta$ . Various values of  $\theta$  are given in List I. The coefficient of friction between the block  $m_1$  and the plane is always zero. The coefficient of static and dynamic friction between the block  $m_2$  and the plane are equal to  $\mu = 0.3$ . In List II expressions for the friction on block  $m_2$  are given. Match the correct expression of the friction in List II with the angles given in List I, and choose the correct option. The acceleration due to gravity is denoted by  $g$ .

[Useful information :  $\tan(5.5^\circ) \approx 0.1$ ;  $\tan(11.5^\circ) \approx 0.2$ ;  $\tan(16.5^\circ) \approx 0.3$ ]



- List I**
- P.  $\theta = 5^\circ$  ✓
  - Q.  $\theta = 10^\circ$  ✓
  - R.  $\theta = 15^\circ$  ✓
  - S.  $\theta = 20^\circ$

- List II**
1.  $m_2 g \sin \theta$
  2.  $(m_1 + m_2) g \sin \theta$
  3.  $\mu m_2 g \cos \theta$
  4.  $\mu (m_1 + m_2) g \cos \theta$

Code :

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

Space for Rough Work



# PART II : CHEMISTRY

## SECTION – 1 : (Only One Option Correct Type)

This section contains 10 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONLY ONE option is correct.

21. For the identification of  $\beta$ -naphthol using dye test, it is necessary to use  
 (A) dichloromethane solution of  $\beta$ -naphthol. (B) acidic solution of  $\beta$ -naphthol.  
 (C) neutral solution of  $\beta$ -naphthol. (D) alkaline solution of  $\beta$ -naphthol.

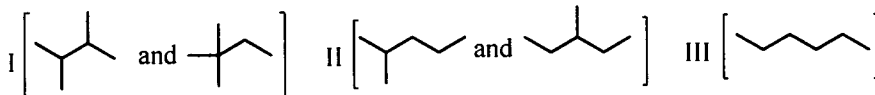
22. For the elementary reaction  $M \rightarrow N$ , the rate of disappearance of  $M$  increases by a factor of 8 upon doubling the concentration of  $M$ . The order of the reaction with respect to  $M$  is  
 (A) 4 (B) 3 (C) 2 (D) 1

23. For the process  

$$H_2O(l) \rightarrow H_2O(g)$$
 at  $T = 100^\circ C$  and 1 atmosphere pressure, the correct choice is  
 (A)  $\Delta S_{system} > 0$  and  $\Delta S_{surroundings} > 0$  (B)  $\Delta S_{system} > 0$  and  $\Delta S_{surroundings} < 0$   
 (C)  $\Delta S_{system} < 0$  and  $\Delta S_{surroundings} > 0$  (D)  $\Delta S_{system} < 0$  and  $\Delta S_{surroundings} < 0$

24. Isomers of hexane, based on their branching, can be divided into three distinct classes as shown in the figure.

[Figure]



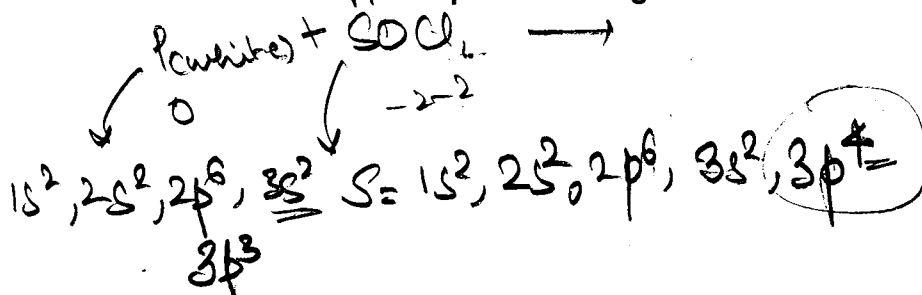
The correct order of their boiling point is

- (A) I > II > III (B) III > II > I (C) II > III > I (D) III > I > II

25. Assuming 2s-2p mixing is NOT operative, the paramagnetic species among the following is  
 (A)  $Be_2$  (B)  $B_2$  (C)  $C_2$  (D)  $N_2$

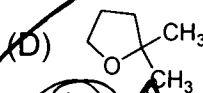
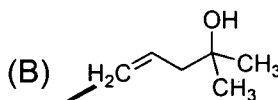
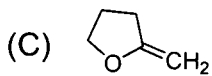
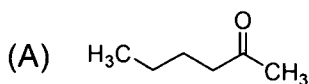
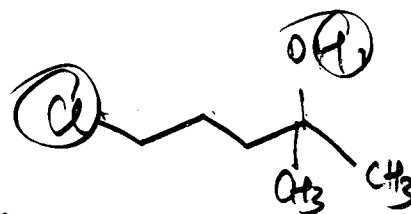
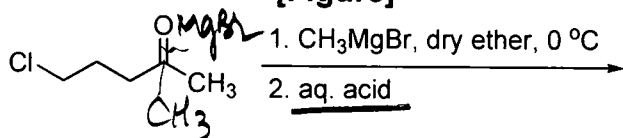
26. The product formed in the reaction of  $SOCl_2$  with white phosphorous is  
 (A)  $PCl_3$  (B)  $SO_2Cl_2$  (C)  $SO_2$  (D)  $POCl_3$

Space for Rough Work



27. The major product in the following reaction is

[Figure]



28. Hydrogen peroxide in its reaction with  $\text{KIO}_4$  and  $\text{NH}_2\text{OH}$  respectively, is acting as a

(A) reducing agent, oxidising agent

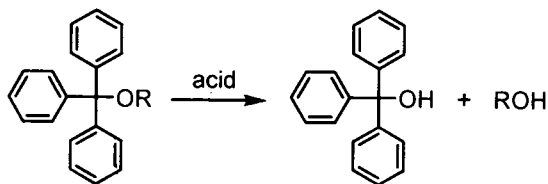
(B) reducing agent, reducing agent

(C) oxidising agent, oxidising agent

(D) oxidising agent, reducing agent

29. The acidic hydrolysis of ether (X) shown below is fastest when

[Figure]



[X]

(A) one phenyl group is replaced by a methyl group.

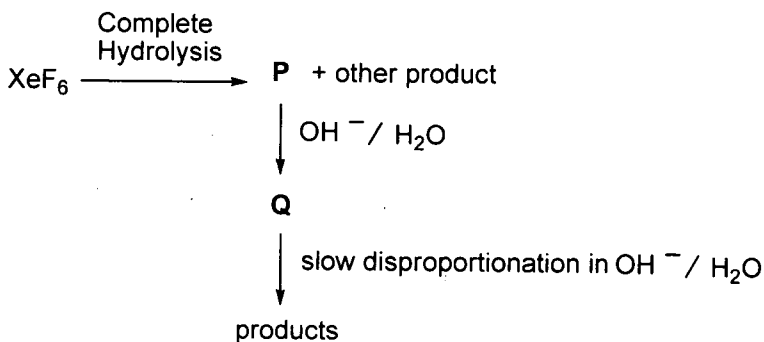
(B) one phenyl group is replaced by a *para*-methoxyphenyl group.

(C) two phenyl groups are replaced by two *para*-methoxyphenyl groups.

(D) no structural change is made to X.

30

Under ambient conditions, the total number of gases released as products in the final step of the reaction scheme shown below is



(A) 0

(B) 1

(C) 2

(D) 3

Space for Rough Work

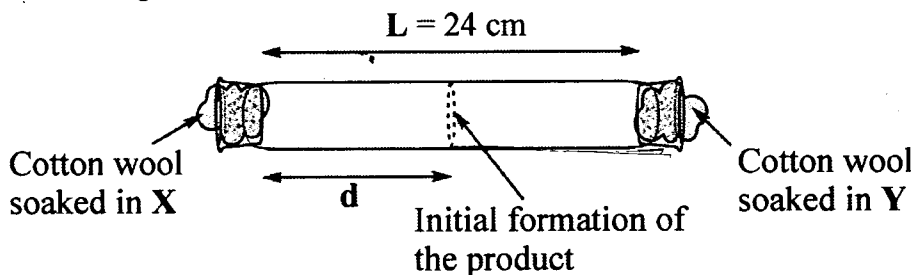


SECTION – 2 : Comprehension Type (Only One Option Correct)

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~~Paragraph~~ Paragraph For Questions 31 and 32

X and Y are two volatile liquids with molar weights of  $10 \text{ g mol}^{-1}$  and  $40 \text{ g mol}^{-1}$  respectively. Two cotton plugs, one soaked in X and the other soaked in Y, are simultaneously placed at the ends of a tube of length  $L = 24 \text{ cm}$ , as shown in the figure. The tube is filled with an inert gas at 1 atmosphere pressure and a temperature of 300 K. Vapours of X and Y react to form a product which is first observed at a distance  $d \text{ cm}$  from the plug soaked in X. Take X and Y to have equal molecular diameters and assume ideal behaviour for the inert gas and the two vapours.



31. The value of  $d$  in cm (shown in the figure), as estimated from Graham's law, is  
 (A) 8 (B) 12 (C) 16 (D) 20
32. The experimental value of  $d$  is found to be smaller than the estimate obtained using Graham's law. This is due to  
 (A) larger mean free path for X as compared to that of Y.  
 (B) larger mean free path for Y as compared to that of X.  
 (C) increased collision frequency of Y with the inert gas as compared to that of X with the inert gas.  
 (D) increased collision frequency of X with the inert gas as compared to that of Y with the inert gas.

Space for Rough Work

~~24~~

$$\frac{d}{L-d} = \sqrt{\frac{M_2}{M_1}}$$

$$\frac{12}{24-12} = \frac{1}{300} \sqrt{\frac{40}{10}}$$

$$12 = 24 - 12$$

$$\frac{24-x}{24} = \frac{1}{300} \sqrt{\frac{40}{10}}$$

$$24 \times 150 = 24 - x$$

$$\frac{24-x}{24 \times 12} = \frac{1}{150 \times 75}$$

$$x = 24 - \frac{12}{75}$$

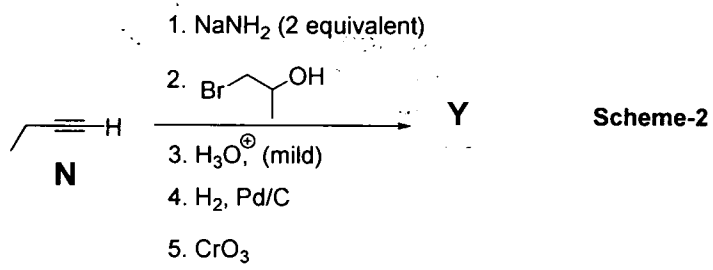
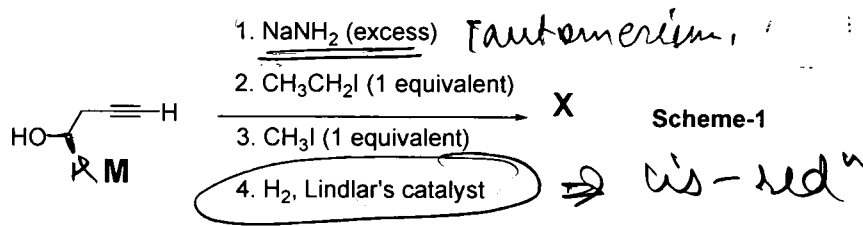
$$= \frac{24 \times 75 - 12}{75}$$



~~24 x 75~~

Paragraph For Questions 33 and 34

Schemes 1 and 2 describe sequential transformation of alkynes M and N. Consider only the major products formed in each step for both the schemes.



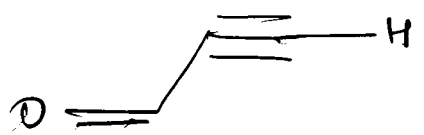
33. The product X is

- (A) CC(O)C#C  $\xrightarrow{\text{steps 1-4}}$  CC(O)C#C **(A)**
- (B) CC(O)C#C  $\xrightarrow{\text{steps 1-4}}$  CC(O)C#C **(B)**
- (C) CC(O)C#C  $\xrightarrow{\text{steps 1-4}}$  CC(O)C#C **(C)**
- (D) CC(O)C#C  $\xrightarrow{\text{steps 1-4}}$  CC(O)C#C **(D)**

34. The correct statement with respect to product Y is

- (A) It gives a positive Tollens test and is a functional isomer of X.
- (B) It gives a positive Tollens test and is a geometrical isomer of X.  $\times$
- (C) It gives a positive iodoform test and is a functional isomer of X.
- (D) It gives a positive iodoform test and is a geometrical isomer of X.  $\times$

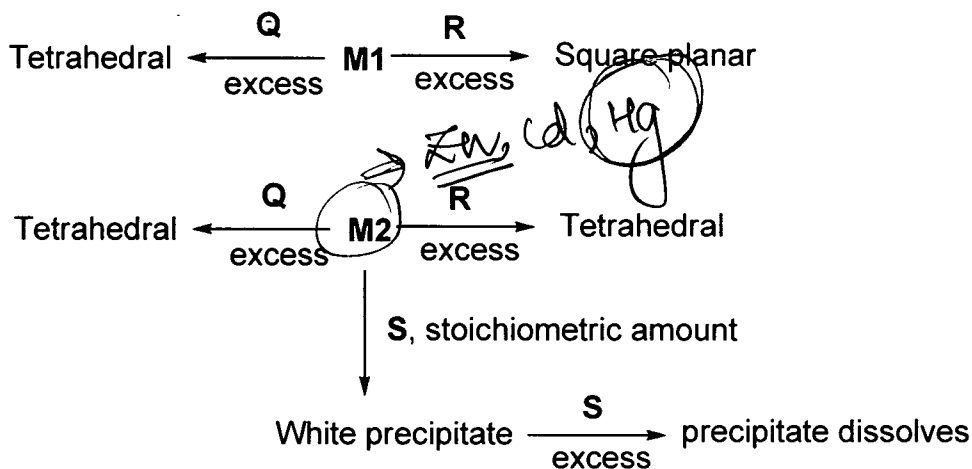
Space for Rough Work



Paragraph For Questions 35 and 36

An aqueous solution of metal ion **M1** reacts separately with reagents **Q** and **R** in excess to give tetrahedral and square planar complexes, respectively. An aqueous solution of another metal ion **M2** always forms tetrahedral complexes with these reagents. Aqueous solution of **M2** on reaction with reagent **S** gives white precipitate which dissolves in excess of **S**. The reactions are summarized in the scheme given below:

**SCHEME:**



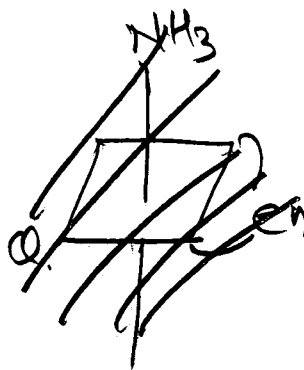
35. **M1**, **Q** and **R**, respectively are

- (A)  $\text{Zn}^{2+}$ , KCN and HCl      (B)  $\text{Ni}^{2+}$ , HCl and KCN  
 (C)  $\text{Cd}^{2+}$ , KCN and HCl      (D)  $\text{Co}^{2+}$ , HCl and KCN

36. Reagent **S** is

- (A)  $\text{K}_4[\text{Fe}(\text{CN})_6]$       (B)  $\text{Na}_2\text{HPO}_4$       (C)  $\text{K}_2\text{CrO}_4$       (D) KOH

Space for Rough Work



$$\begin{aligned} (a+b)^2 - c^2 &= ab \\ a^2 + b^2 - c^2 &= -ab \\ \frac{a^2 + b^2 - c^2}{2ab} &= -\frac{1}{2} \end{aligned}$$

$$\cos e = \frac{2\sqrt{3}}{3}$$



**SECTION – 3 : Matching List Type (Only One Option Correct)**

This section contains four questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D), out of which one is correct.

37. Match each coordination compound in List-I with an appropriate pair of characteristics from List-II and select the correct answer using the code given below the lists.

{en = H<sub>2</sub>NCH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>; atomic numbers: Ti = 22; Cr = 24; Co = 27; Pt = 78}

List-I

- P. [Cr(NH<sub>3</sub>)<sub>4</sub>Cl<sub>2</sub>]Cl  
 Q. [Ti(H<sub>2</sub>O)<sub>5</sub>Cl](NO<sub>3</sub>)<sub>2</sub>  
 R. [Pt(en)(NH<sub>3</sub>)Cl]NO<sub>3</sub>  
 S. [Co(NH<sub>3</sub>)<sub>4</sub>(NO<sub>3</sub>)<sub>2</sub>]NO<sub>3</sub>

List-II

1. Paramagnetic and exhibits ionisation isomerism  
 2. Diamagnetic and exhibits *cis-trans* isomerism  
 3. Paramagnetic and exhibits *cis-trans* isomerism  
 4. Diamagnetic and exhibits ionisation isomerism

Code :

	P	Q	R	S
(A)	4	2	3	1 X
(B)	3	1	4	2
(C)	2	1	3	4
(D)	1	3	4	2 X

4s<sup>2</sup>, 3d<sup>2</sup>

3d<sup>1</sup>

d<sup>2</sup> s<sup>2</sup> →

d<sup>2</sup> π ↑

↑ ↓ ↓

38. Match the orbital overlap figures shown in List-I with the description given in List-II and select the correct answer using the code given below the lists.

List-I

List-II

P.



1. p – d π antibonding

Q.



2. d – d σ bonding

R.



3. p – d π bonding

S.



4. d – d σ antibonding

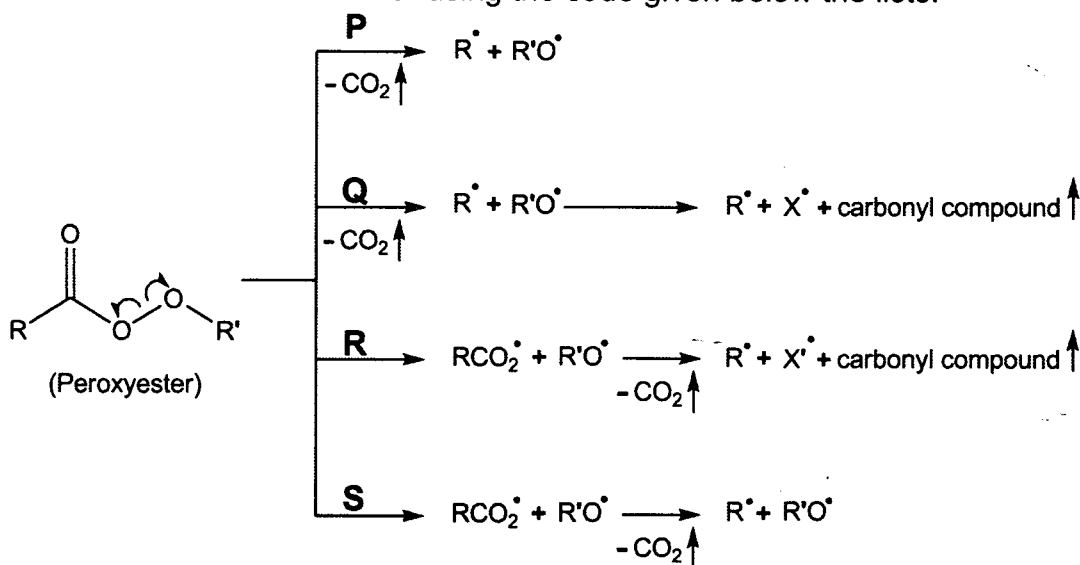
Code :

	P	Q	R	S
(A)	2	1	3	4 X
(B)	4	3	1	2
(C)	2	3	1	4 X
(D)	4	1	3	2

Space for Rough Work



39. Different possible **thermal** decomposition pathways for peroxyesters are shown below. Match each pathway from **List I** with an appropriate structure from **List II** and select the correct answer using the code given below the lists.



**List-I**

- P. Pathway P
- Q. Pathway Q
- R. Pathway R
- S. Pathway S

**List-II**

- 1.
- 2.
- 3.
- 4.

**Codes :**

	P	Q	R	S
(A) <del>1</del>	3	4	2	
(B) 2	4	3	1	
(C) 4	1	2	3	
(D) 3	2	1	4	

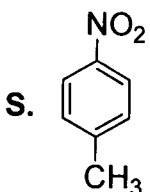
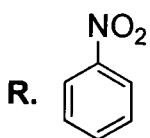
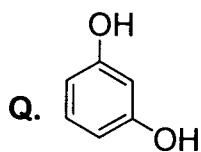
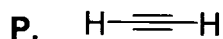
Space for Rough Work





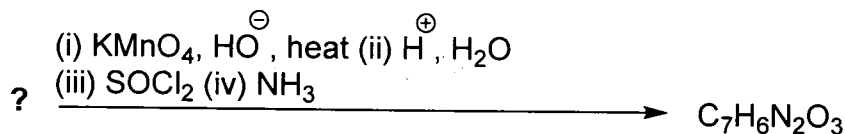
40. Match the four starting materials (P, Q, R, S) given in List I with the corresponding reaction schemes (I, II, III, IV) provided in List II and select the correct answer using the code given below the lists.

List-I

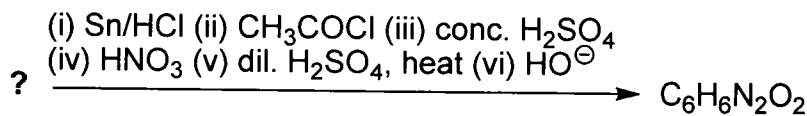


List-II

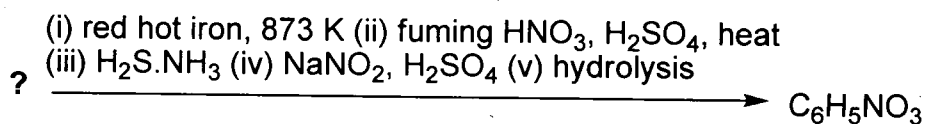
1. Scheme I



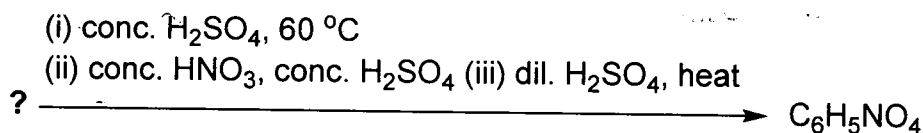
2. Scheme II



3. Scheme III



4. Scheme IV



Code :

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

Space for Rough Work



4. 7. 1  
+ 6. 7. 12  
+ 4. 3. 6  
+ 1. 7. 6

$$t^2 + 2t + 2 = 0$$

$$t = \frac{-2 \pm \sqrt{4 - 8}}{2}$$

$$\Rightarrow t = \frac{-2 \pm \sqrt{-4}}{2}$$

# PART III : MATHEMATICS

## SECTION - 1 : (Only One Option Correct Type)

This section contains 10 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONLY ONE option is correct.

41. In a triangle the sum of two sides is  $x$  and the product of the same two sides is  $y$ . If  $x^2 - c^2 = y$ , where  $c$  is the third side of the triangle, then the ratio of the in-radius to the circum-radius of the triangle is

- (A)  $\frac{3y}{2x(x+c)}$  (B)  $\frac{3y}{2c(x+c)}$  (C)  $\frac{3y}{4x(x+c)}$  (D)  $\frac{3y}{4c(x+c)}$

42. The common tangents to the circle  $x^2 + y^2 = 2$  and the parabola  $y^2 = 8x$  touch the circle at the points  $P, Q$  and the parabola at the points  $R, S$ . Then the area of the quadrilateral  $PQRS$  is

- (A) 3 (B) 6 (C) 9 (D) 15

43. The quadratic equation  $p(x) = 0$  with real coefficients has purely imaginary roots. Then the equation

$$p(p(x)) = 0$$

$$(x^2 + d)^2 + k$$

$$x^4 + k^2 + 2x^2k + d$$

$$x^4 + 2x^2k + d^2 + d = 0$$

- has  
(A) only purely imaginary roots  
(B) all real roots  
(C) two real and two purely imaginary roots  
(D) neither real nor purely imaginary roots

44. Six cards and six envelopes are numbered 1, 2, 3, 4, 5, 6 and cards are to be placed in envelopes so that each envelope contains exactly one card and no card is placed in the envelope bearing the same number and moreover the card numbered 1 is always placed in envelope numbered 2. Then the number of ways it can be done is

- (A) 264 (B) 265 (C) 53 (D) 67

45. Three boys and two girls stand in a queue. The probability, that the number of boys ahead of every girl is at least one more than the number of girls ahead of her, is

- (A)  $\frac{1}{2}$  (B)  $\frac{1}{3}$  (C)  $\frac{2}{3}$  (D)  $\frac{3}{4}$

Space for Rough Work

$\frac{dy}{dx} + y \left( \frac{2x}{x^2-1} \right) = \frac{2x+2}{\sqrt{1-x^2}}$   
 $1-x^2 = t$   
 $-2x dx = dt$   
 $2x dx = -dt$   
 $x dx = \frac{-dt}{2}$   
 $y = \int \left( \frac{x^4 + 2x}{\sqrt{1-x^2}} \right) dx$   
 $x = \frac{\Delta}{\dots}$



SECTION – 2 : Comprehension Type (Only One Option Correct)

This section contains 3 paragraphs, each describing theory, experiments, data etc. Six questions relate to the three paragraphs with two questions on each paragraph. Each question has only one correct answer among the four given options (A), (B), (C) and (D).

Paragraph For Questions 51 and 52

Box 1 contains three cards bearing numbers (1, 2, 3), box 2 contains five cards bearing numbers (1, 2, 3, 4, 5) and box 3 contains seven cards bearing numbers (1, 2, 3, 4, 5, 6, 7). A card is drawn from each of the boxes. Let  $x_i$  be the number on the card drawn from the  $i^{th}$  box,  $i = 1, 2, 3$ .

51. The probability that  $x_1 + x_2 + x_3$  is odd, is

(A)  $\frac{29}{105}$

(B)  $\frac{53}{105}$

(C)  $\frac{57}{105}$

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

$$\frac{2}{3} + \frac{2}{5} + \frac{3}{7}$$

52. The probability that  $x_1, x_2, x_3$  are in an arithmetic progression, is

(A)  $\frac{9}{105}$

(B)  $\frac{10}{105}$

(C)  $\frac{11}{105}$

(D)  $\frac{7}{105}$

Space for Rough Work

Handwritten work for question 51:

~~108~~

1, 2, 3 ✓  
 2, 3, 4 ✓  
 3, 4, 5 ✓

~~108~~

~~70 + 42 + 45~~  
~~105~~

~~15~~

~~1 - (1/3 + 2/5 + 3/7)~~

~~1 - (25 + 42 + 45)~~  
~~105~~

~~122 - 105~~  
~~105~~

~~17~~  
~~105~~

$1 + \frac{3}{5} + \frac{3}{2}$

$\frac{35 + 9}{35}$

\*\*\* 4

22

Paragraph For Questions 53 and 54

Let  $a, r, s, t$  be nonzero real numbers. Let  $P(at^2, 2at)$ ,  $Q$ ,  $R(ar^2, 2ar)$  and  $S(as^2, 2as)$  be distinct points on the parabola  $y^2 = 4ax$ . Suppose that  $PQ$  is the focal chord and lines  $QR$  and  $PK$  are parallel, where  $K$  is the point  $(2a, 0)$ .

$PQ = 4a$

53. The value of  $r$  is

- (A)  $-\frac{1}{t}$  (B)  $\frac{t^2+1}{t}$  (C)  $\frac{1}{t}$  (D)  $\frac{t^2-1}{t}$

54. If  $st = 1$ , then the tangent at  $P$  and the normal at  $S$  to the parabola meet at a point whose ordinate is

- (A)  $\frac{(t^2+1)^2}{2t^3}$  (B)  $\frac{a(t^2+1)^2}{2t^3}$  (C)  $\frac{a(t^2+1)^2}{t^3}$  (D)  $\frac{a(t^2+2)^2}{t^3}$

Paragraph For Questions 55 and 56

Given that for each  $a \in (0, 1)$ ,

$$\lim_{h \rightarrow 0^+} \int_h^{1-h} t^{-a}(1-t)^{a-1} dt$$

$1-t = x \Rightarrow t = 1-x$   
 $-dt = dx$

exists. Let this limit be  $g(a)$ . In addition, it is given that the function  $g(a)$  is differentiable on  $(0, 1)$ .

55. The value of  $g\left(\frac{1}{2}\right)$  is

- (A)  $\pi$  (B)  $2\pi$  (C)  $\frac{\pi}{2}$  (D)  $\frac{\pi}{4}$

56. The value of  $g'\left(\frac{1}{2}\right)$  is

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

Space for Rough Work

$\frac{(x)^{a-1}}{(1-x)^a}$   
 $h+1-h$

$\lim_{h \rightarrow 0^+} \int_h^{1-h} \frac{(1-t)^{a-1}}{t^a} dt$   
 $\lim_{h \rightarrow 0}$

MATHEMATICS



SECTION – 3 : Matching List Type (Only One Option Correct)

This section contains four questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D), out of which one is correct.

57. **List I** **List II**
- P. The number of polynomials  $f(x)$  with non-negative integer coefficients of degree  $\leq 2$ , satisfying  $f(0) = 0$  and  $\int_0^1 f(x) dx = 1$ , is 1. 8
- Q. The number of points in the interval  $[-\sqrt{13}, \sqrt{13}]$  at which  $f(x) = \sin(x^2) + \cos(x^2)$  attains its maximum value, is 2. 2
- R.  $\int_{-2}^2 \frac{3x^2}{(1+e^x)} dx$  equals 3. 4
- S.  $\frac{\int_{-\frac{1}{2}}^{\frac{1}{2}} \cos 2x \log\left(\frac{1+x}{1-x}\right) dx}{\int_0^{\frac{1}{2}} \cos 2x \log\left(\frac{1+x}{1-x}\right) dx}$  equals 4. 0

	P	Q	R	S
(A)	3	2	4	1 X
(B)	2	3	4	1 X
(C)	3	2	1	4
(D)	2	3	1	4

Handwritten notes for Q57:  
 $\int_0^2 (3x^2 + \frac{3x^2 e^x}{1+e^x}) dx$   
 $\Rightarrow \int_0^2 3x^2 dx$   
 $\Rightarrow [x^3]_0^2 = 8$

58. **List I** **List II**
- P. Let  $y(x) = \cos(3 \cos^{-1} x), x \in [-1, 1], x \neq \pm \frac{\sqrt{3}}{2}$ . Then  $\frac{1}{y(x)} \left\{ (x^2 - 1) \frac{d^2 y(x)}{dx^2} + x \frac{dy(x)}{dx} \right\}$  equals 1. 1
- Q. Let  $A_1, A_2, \dots, A_n$  ( $n > 2$ ) be the vertices of a regular polygon of  $n$  sides with its centre at the origin. Let  $\vec{a}_k$  be the position vector of the point  $A_k, k = 1, 2, \dots, n$ . If  $|\sum_{k=1}^{n-1} (\vec{a}_k \times \vec{a}_{k+1})| = |\sum_{k=1}^{n-1} (\vec{a}_k \cdot \vec{a}_{k+1})|$ , then the minimum value of  $n$  is 2. 2
- R. If the normal from the point  $P(h, 1)$  on the ellipse  $\frac{x^2}{6} + \frac{y^2}{3} = 1$  is perpendicular to the line  $x + y = 8$ , then the value of  $h$  is 3. 8
- S. Number of positive solutions satisfying the equation  $\tan^{-1}\left(\frac{1}{2x+1}\right) + \tan^{-1}\left(\frac{1}{4x+1}\right) = \tan^{-1}\left(\frac{2}{x^2}\right)$  is 4. 9

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

Space for Rough Work

\*\* 4

$\frac{2x}{6} + \frac{2y}{3} \frac{dy}{dx} = 0$

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

$m = -\frac{h}{2}$   
 $\frac{2}{h}x + 1 = 1$



59. Let  $f_1: \mathbb{R} \rightarrow \mathbb{R}$ ,  $f_2: [0, \infty) \rightarrow \mathbb{R}$ ,  $f_3: \mathbb{R} \rightarrow \mathbb{R}$  and  $f_4: \mathbb{R} \rightarrow [0, \infty)$  be defined by

$$f_1(x) = \begin{cases} |x| & \text{if } x < 0, \\ e^x & \text{if } x \geq 0; \end{cases} \quad \begin{cases} -x & x < 0 \\ e^x & x \geq 0 \end{cases}$$

$$f_2(x) = x^2;$$

$$f_3(x) = \begin{cases} \sin x & \text{if } x < 0, \\ x & \text{if } x \geq 0 \end{cases}$$

and

$$f_4(x) = \begin{cases} f_2(f_1(x)) & \text{if } x < 0, \\ f_2(f_1(x)) - 1 & \text{if } x \geq 0. \end{cases}$$

List I

- P.  $f_4$  is
- Q.  $f_3$  is
- R.  $f_2 \circ f_1$  is
- S.  $f_2$  is

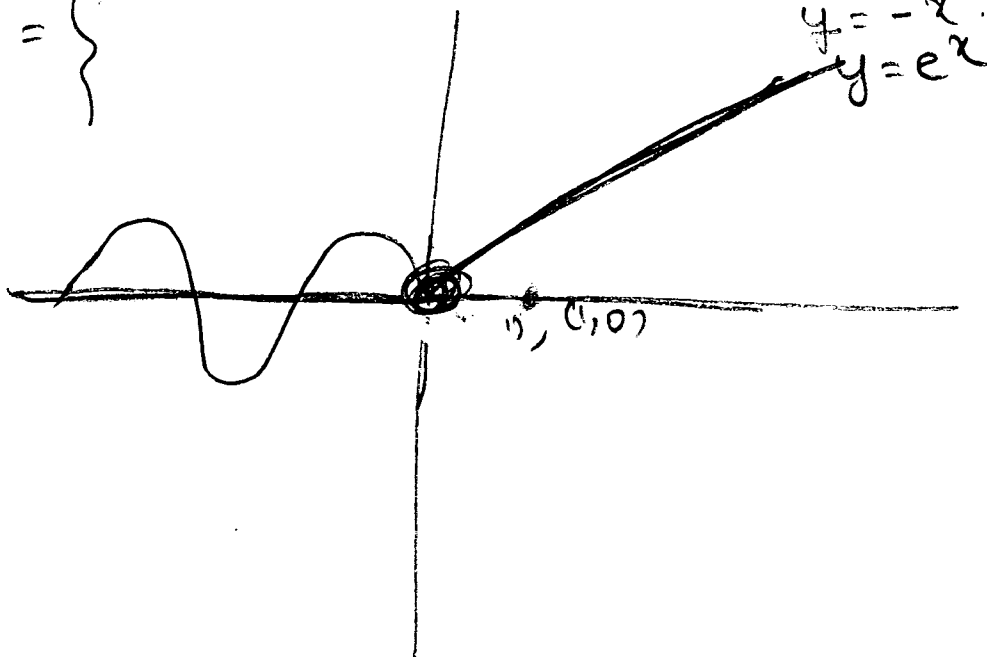
List II

- 1. onto but not one-one
- 2. neither continuous nor one-one
- 3. differentiable but not one-one
- 4. continuous and one-one

	P	Q	R	S
(A)	3	1	4	2 X
(B)	1	3	4	2 X
(C)	3	1	2	4
(D)	1	3	2	4

Space for Rough Work

$$f_4(x) = \begin{cases} \end{cases}$$



$$I_2 = e^{\frac{2\pi}{10}} = e^{\frac{k\pi}{5}}$$

60. Let  $z_k = \cos\left(\frac{2k\pi}{10}\right) + i \sin\left(\frac{2k\pi}{10}\right); k = 1, 2, \dots, 9$ .

List I

List II

P. For each  $z_k$  there exists a  $z_j$  such that  $z_k \cdot z_j = 1 = e^0$

1. True

Q. There exists a  $k \in \{1, 2, \dots, 9\}$  such that  $z_1 \cdot z = z_k$  has no solution  $z$  in the set of complex numbers.

2. False

R.  $\frac{|1-z_1||1-z_2|\dots|1-z_9|}{10}$  equals

3. 1

S.  $1 - \sum_{k=1}^9 \cos\left(\frac{2k\pi}{10}\right)$  equals

4. 2

	P	Q	R	S
(A)	1	2	4	3
<del>(B)</del>	2	1	3	4 ✓
(C)	1	2	3	4
<u>(D)</u>	2	1	4	3 ✓

Space for Rough Work

$$1 - \left( \cos \frac{\pi}{5} + \cos \frac{2\pi}{5} + \cos \frac{3\pi}{5} + \dots + \cos \frac{9\pi}{5} \right)$$

$$1 - (2 \cos \dots)$$

