

Questions with Answers

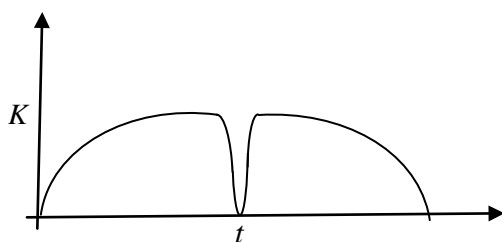
PART-1 PHYSICS

SECTION -1 (Only One Option Correct Type)

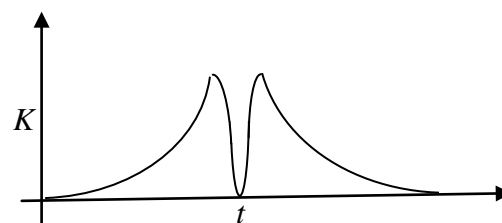
This section contains 10 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which only one option is correct.

1. A 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.

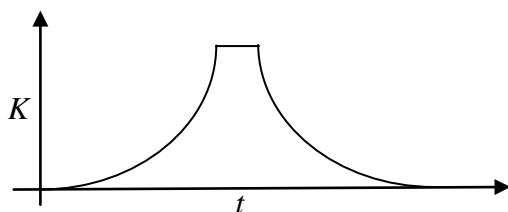
(A)



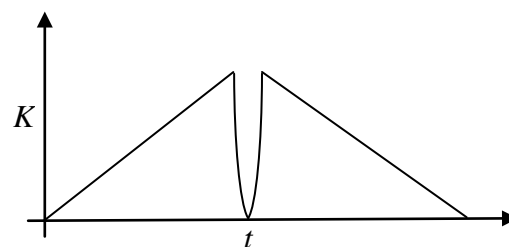
(B)



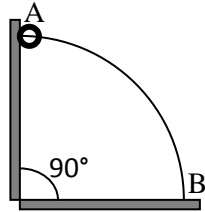
(C)



(D)

**Answer (B)**

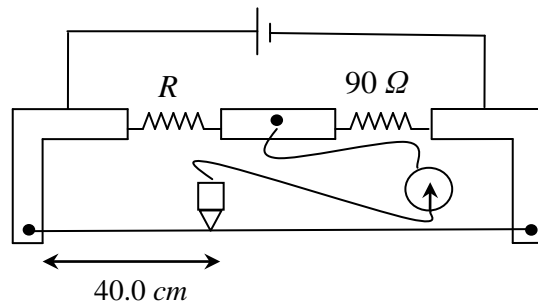
2. A wire, which passes through the hole in a small bead, is bent in the form of quarter of a circle. The wire is fixed vertically on ground as shown in the figure. The bead is released from near the top of the wire and it slides along the wire without friction. As the bead moves from A to B, the force 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.

Answer (D)

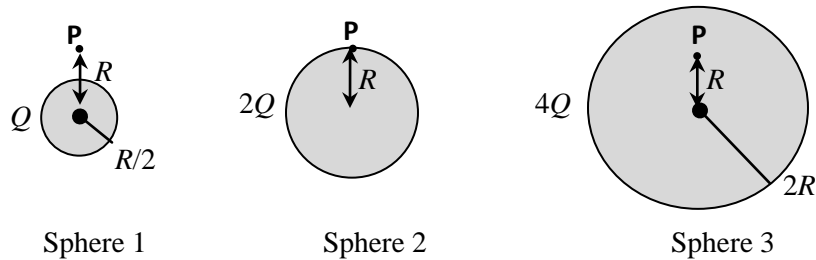
3. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of $90\ \Omega$, as shown in the figure. The least count of the scale used in the metre bridge is 1 mm . The unknown resistance is



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

Answer (C)

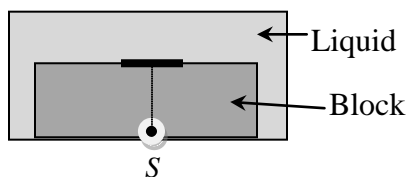
4. Charges Q , $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $R/2$, R and $2R$, respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the center of spheres 1, 2 and 3 are E_1 , E_2 and E_3 respectively, then



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

Answer (C)

5. A point source S is placed at the bottom of a transparent block of height 10 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 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

Answer (C)

6. Parallel rays of light of intensity $I = 912 \text{ Wm}^{-2}$ are incident on a spherical black body kept in surroundings of temperature 300 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

Answer (A)

7. A metal surface is illuminated by light of two different wavelengths 248 nm and 310 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

Answer (A)

8. If λ_{Cu} is the wavelength of K_α X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_α X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{Cu} / \lambda_{Mo}$ is close to

- (A) 1.99
- (B) 2.14
- (C) 0.50
- (D) 0.48

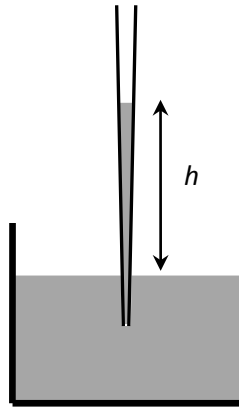
Answer (B)

9. 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 $10^{-3} \text{ kg m}^{-1}$ 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 ms^{-2})

- (A) 96 N
- (B) 108 N
- (C) 120 N
- (D) 150 N

Answer (B)

10. A glass capillary tube is of the shape of a truncated cone with an apex angle α 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 ρ , and its contact angle with glass is θ , 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) $\frac{2S}{b\rho g} \cos(\theta + \alpha/2)$

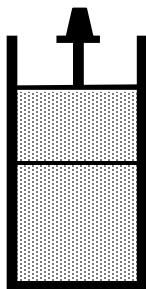
Answer (D)

Section -2 Comprehension Type

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

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 $C_V = \frac{5}{2}R$, $C_P = \frac{7}{2}R$.



11. 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

Answer (D)

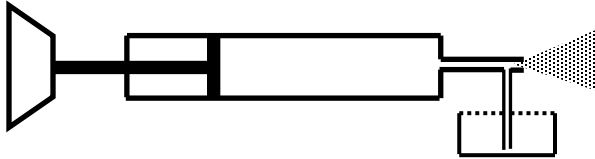
12. Now consider the partition to be free to move without friction so that the pressure of gases in both compartments is the same. Then total work done by the gases till the time they achieve equilibrium will be

- (A) $250 R$ (B) $200 R$ (C) $100 R$ (D) $-100 R$

Answer (D)

Paragraph For Questions 13 & 14

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.



13. If the piston is pushed at a speed of 5 mms^{-1} , the air comes out of the nozzle with a speed of

(A) 0.1 ms^{-1}

(B) 1 ms^{-1}

(C) 2 ms^{-1}

(D) 8 ms^{-1}

Answer (C)

14. If the density of air is ρ_a and that of the liquid ρ_ℓ , 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) $\sqrt{\rho_a \rho_\ell}$

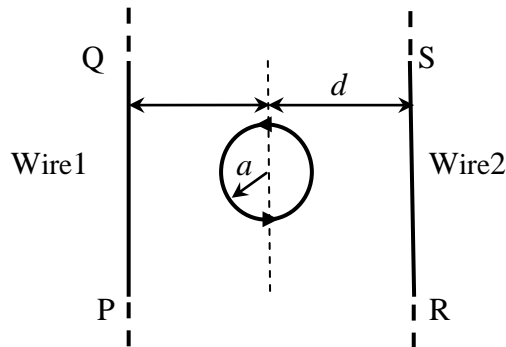
(C) $\sqrt{\frac{\rho_\ell}{\rho_a}}$

(D) ρ_ℓ

Answer (A)

Paragraph For Questions 15 & 16

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.



15. 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 $h \approx 1.2a$

Answer (C)

16. Consider $d \gg a$, and the loop is rotated about its diameter parallel to the wires by 30° 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)

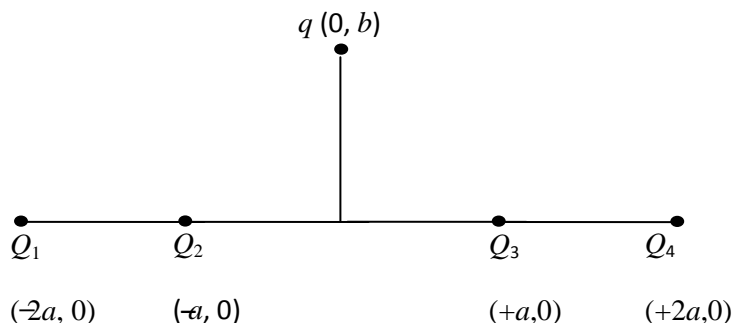
- (A) $\frac{\mu_0 I^2 a^2}{d}$
- (B) $\frac{\mu_0 I^2 a^2}{2d}$
- (C) $\frac{\sqrt{3} \mu_0 I^2 a^2}{d}$
- (D) $\frac{\sqrt{3} \mu_0 I^2 a^2}{2d}$

Answer (B)

Section – 3 (Matching List Type)

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. 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. $-y$

(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

Answer (A)

18. 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

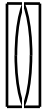
P.



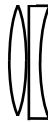
Q.



R.



S.



List II

1. $2r$

2. $r/2$

3. $-r$

4. r

Choices:

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

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

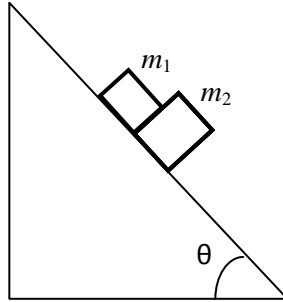
(C) P-4, Q-1, R-2, S-3

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

Answer (B)

19. 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 θ . Various values of θ 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. $\mu (m_1 + m_2) g \cos \theta$

Choices:

(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

Answer (D)

20. 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 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 list.

List I

P. Lift is accelerating vertically up.

Q. Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.

R. Lift is moving vertically up with constant speed.

S. Lift is falling freely.

List II

1. $d = 1.2\text{ m}$

2. $d > 1.2\text{ m}$

3. $d < 1.2\text{ m}$

4. No water leaks out of the jar

(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

Answer (C)

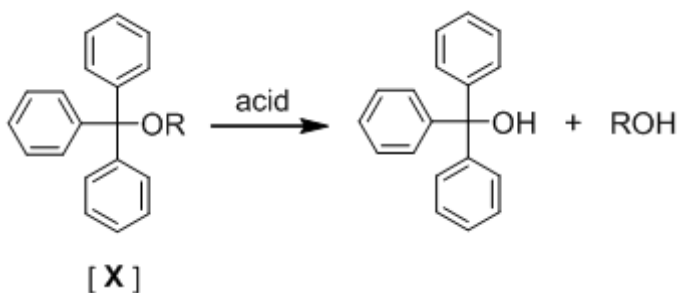
PART-2 CHEMISTRY

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

[Figure]

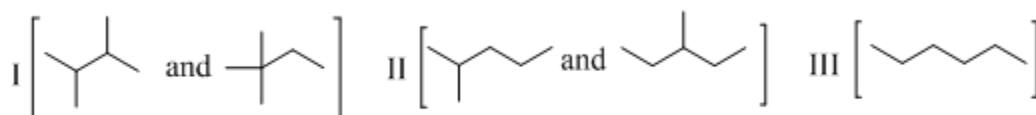


- (A) one phenyl group is replaced by a methyl group.
- (B) one phenyl group is replaced by a *para*-methoxyphenyl group.
- (C) two phenyl groups are replaced by two *para*-methoxyphenyl groups.
- (D) no structural change is made to **X**.

Answer (C)

22. 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

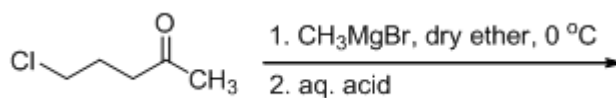
(C) II > III > I

(D) III > I > II

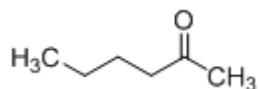
Answer (B)

23. The major product in the following reaction is

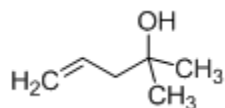
[Figure]



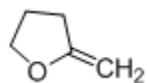
(A)



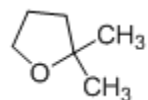
(B)



(C)



(D)



Answer (D)

24. Hydrogen peroxide in its reaction with KIO_4 and NH_2OH 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

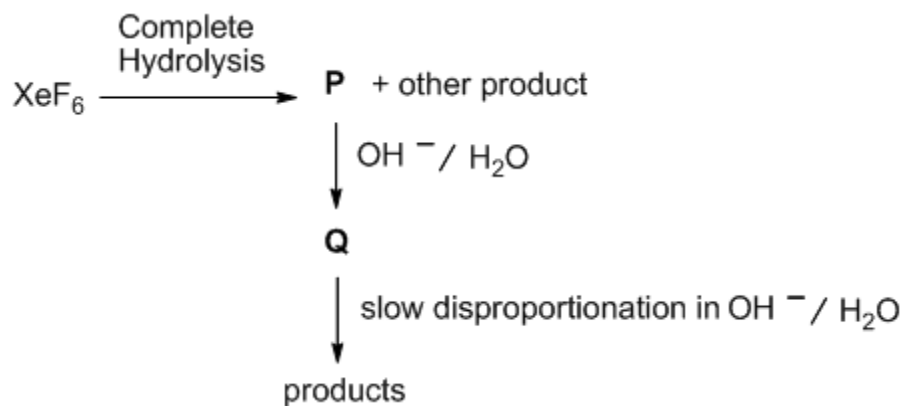
Answer (A)

25. The product formed in the reaction of SOCl_2 with white phosphorous is

- (A) PCl_3
- (B) SO_2Cl_2
- (C) SCl_2
- (D) POCl_3

Answer (A)

26. 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

Answer (C)

27. For the identification of β -naphthol using dye test, it is necessary to use

(A) dichloromethane solution of β -naphthol.

(B) acidic solution of β -naphthol.

(C) neutral solution of β -naphthol.

(D) alkaline solution of β -naphthol.

Answer (D)

28. For the elementary reaction $\mathbf{M} \rightarrow \mathbf{N}$, the rate of disappearance of \mathbf{M} increases by a factor of 8 upon doubling the concentration of \mathbf{M} . The order of the reaction with respect to \mathbf{M} is

(A) 4

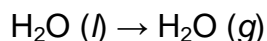
(B) 3

(C) 2

(D) 1

Answer (B)

29. For the process



at $T = 100^\circ\text{C}$ and 1 atmosphere pressure, the correct choice is

(A) $\Delta S_{\text{system}} > 0$ and $\Delta S_{\text{surroundings}} > 0$

(B) $\Delta S_{\text{system}} > 0$ and $\Delta S_{\text{surroundings}} < 0$

(C) $\Delta S_{\text{system}} < 0$ and $\Delta S_{\text{surroundings}} > 0$

(D) $\Delta S_{\text{system}} < 0$ and $\Delta S_{\text{surroundings}} < 0$

Answer (B)

30. 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

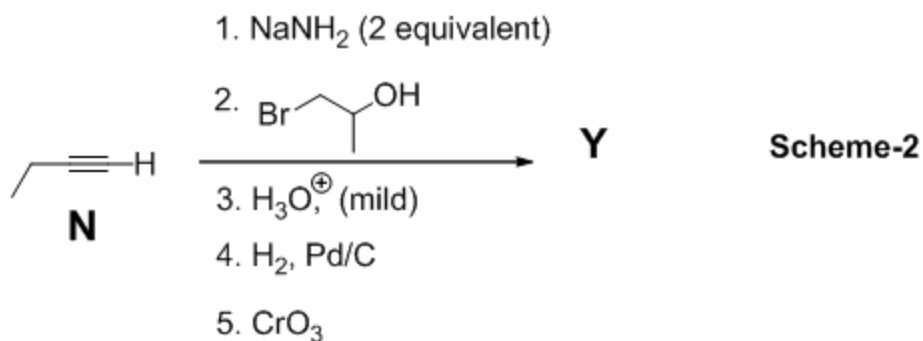
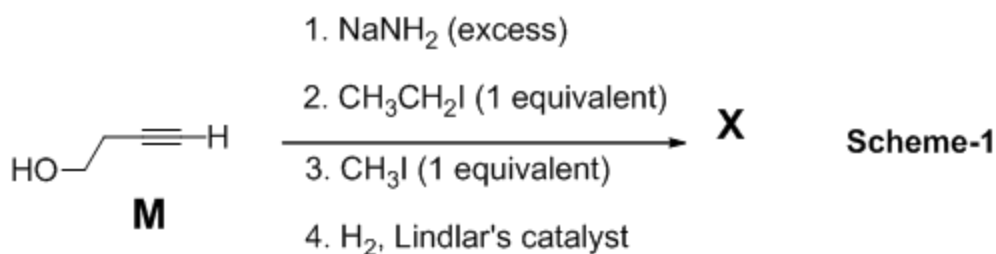
Answer (C)

Section -2 Comprehension Type

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).

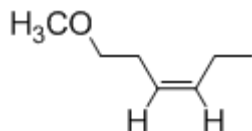
Paragraph For Question 31 and 32

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.

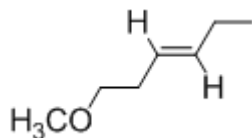


31. The product **X** is

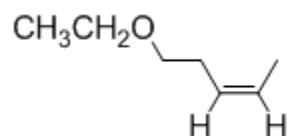
(A)



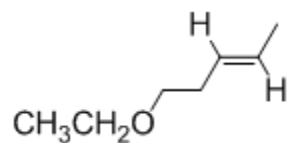
(B)



(C)



(D)



Answer (A)

32. The correct statement with respect to product **Y** is

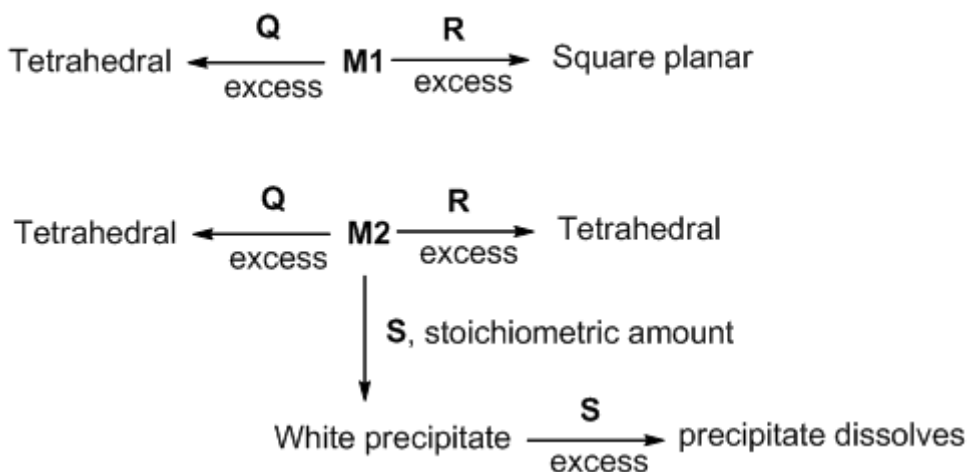
- (A) It gives a positive Tollens test and is a functional isomer of **X**.
- (B) It gives a positive Tollens test and is a geometrical isomer of **X**.
- (C) It gives a positive iodoform test and is a functional isomer of **X**.
- (D) It gives a positive iodoform test and is a geometrical isomer of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

Answer (C)

Paragraph For Question 33 and 34

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:



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

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

Answer (B)

34. Reagent **S** is

(A) $\text{K}_4[\text{Fe}(\text{CN})_6]$

(B) Na_2HPO_4

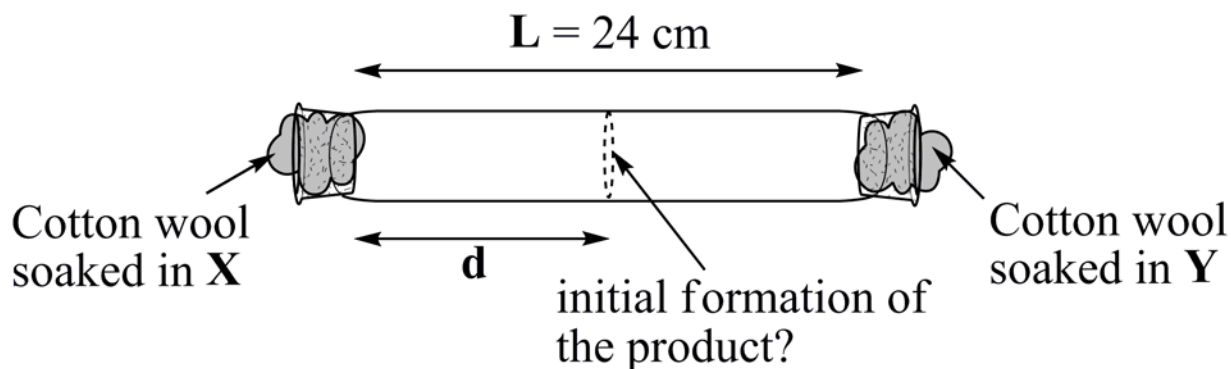
(C) K_2CrO_4

(D) KOH

Answer (D)

Paragraph For Question 35 and 36

X and **Y** are two volatile liquids with molar weights of 10 g mol^{-1} and 40 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** 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.



35. 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

Answer (C)

36. The experimental value of λ is found to be smaller than the estimate obtained using Graham's law. This is due to

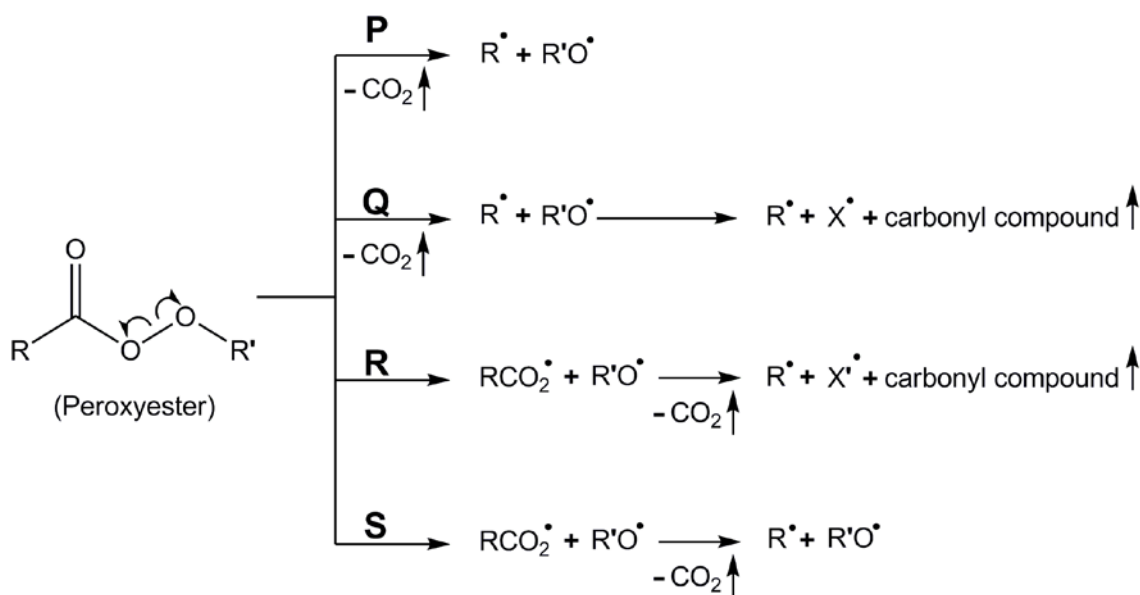
- (A) larger mean free path for **X** as compared to that of **Y**.
- (B) larger mean free path for **Y** as compared to that of **X**.
- (C) increased collision frequency of **Y** with the inert gas as compared to that of **X** with the inert gas.
- (D) increased collision frequency of **X** with the inert gas as compared to that of **Y** with the inert gas.

Answer (D)

Section – 3 (Matching List Type)

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. 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

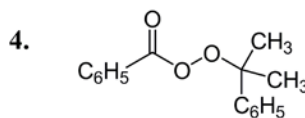
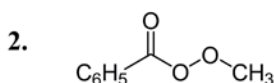
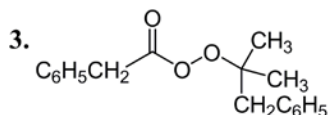
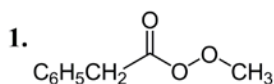
P. Pathway P

Q. Pathway Q

R. Pathway R

s. Pathway S

List-II



Codes:

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

Answer (A)

38. 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	
(P)	$\text{H}-\text{C}\equiv\text{C}-\text{H}$	1. Scheme I	
(Q)		(i) KMnO_4 , HO^\ominus , heat (ii) H^\oplus , H_2O (iii) SOCl_2 (iv) NH_3	$\text{C}_7\text{H}_6\text{N}_2\text{O}_3$
(R)		2. Scheme II	
(S)		(i) Sn/HCl (ii) CH_3COCl (iii) conc. H_2SO_4 (iv) HNO_3 (v) dil. H_2SO_4 , heat (vi) HO^\ominus	$\text{C}_6\text{H}_6\text{N}_2\text{O}_2$
		3. Scheme III	
		(i) red hot iron, 873 K (ii) fuming HNO_3 , H_2SO_4 , heat (iii) $\text{H}_2\text{S}.\text{NH}_3$ (iv) NaNO_2 , H_2SO_4 (v) hydrolysis	$\text{C}_6\text{H}_5\text{NO}_3$
		4. Scheme IV	
		(i) conc. H_2SO_4 , 60 °C (ii) conc. HNO_3 , conc. H_2SO_4 (iii) dil. H_2SO_4 , heat	$\text{C}_6\text{H}_5\text{NO}_4$

Codes:

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

Answer (C)

39. 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 = $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$; atomic numbers: Ti = 22; Cr = 24; Co = 27; Pt = 78}



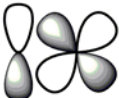

List-I	List-II
P. $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$	1. Paramagnetic and exhibits ionisation isomerism
Q. $[\text{Ti}(\text{H}_2\text{O})_5\text{Cl}](\text{NO}_3)_2$	2. Diamagnetic and exhibits <i>cis-trans</i> isomerism
R. $[\text{Pt}(\text{en})(\text{NH}_3)\text{Cl}]\text{NO}_3$	3. Paramagnetic and exhibits <i>cis-trans</i> isomerism
S. $[\text{Co}(\text{NH}_3)_4(\text{NO}_3)_2]\text{NO}_3$	4. Diamagnetic and exhibits ionisation isomerism

Codes:

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

Answer (B)

40. 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

Codes:

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

Answer (C)

PART-3 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. The function $y = f(x)$ is the solution of the differential equation

$$\frac{dy}{dx} + \frac{xy}{x^2 - 1} = \frac{x^4 + 2x}{\sqrt{1 - x^2}}$$

in $(-1, 1)$ satisfying $f(0) = 0$. Then

$$\int_{-\frac{\sqrt{3}}{2}}^{\frac{\sqrt{3}}{2}} f(x) \, dx$$

is

(A) $\frac{\pi}{3} - \frac{\sqrt{3}}{2}$

(B) $\frac{\pi}{3} - \frac{\sqrt{3}}{4}$

(C) $\frac{\pi}{6} - \frac{\sqrt{3}}{4}$

(D) $\frac{\pi}{6} - \frac{\sqrt{3}}{2}$

Answer (B)

42. The following integral

$$\int_{\frac{\pi}{4}}^{\frac{\pi}{2}} (2 \operatorname{cosec} x)^{17} \, dx$$

is equal to

(A) $\int_0^{\log(1+\sqrt{2})} 2(e^u + e^{-u})^{16} \, du$

(B) $\int_0^{\log(1+\sqrt{2})} (e^u + e^{-u})^{17} \, du$

(C) $\int_0^{\log(1+\sqrt{2})} (e^u - e^{-u})^{17} \, du$

(D) $\int_0^{\log(1+\sqrt{2})} 2(e^u - e^{-u})^{16} \, du$

Answer (A)

43. Coefficient of x^{11} in the expansion of $(1 + x^2)^4 (1 + x^3)^7 (1 + x^4)^{12}$ is

- (A) 1051
- (B) 1106
- (C) 1113
- (D) 1120

Answer (C)

44. Let $f: [0, 2] \rightarrow \mathbb{R}$ be a function which is continuous on $[0, 2]$ and is differentiable on $(0, 2)$ with $f(0) = 1$. Let

$$F(x) = \int_0^{x^2} f(\sqrt{t}) dt$$

for $x \in [0, 2]$. If $F'(x) = f'(x)$ for all $x \in (0, 2)$, then $F(2)$ equals

- (A) $e^2 - 1$
- (B) $e^4 - 1$
- (C) $e - 1$
- (D) e^4

Answer (B)

45. 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

Answer (D)

46. For $x \in (0, \pi)$, the equation $\sin x + 2 \sin 2x - \sin 3x = 3$ has

- (A) infinitely many solutions
- (B) three solutions
- (C) one solution
- (D) no solution

Answer (D)

47. 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) $\frac{3y}{4c(x+c)}$

Answer (B)

48. 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

Answer (C)

49. 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) $\frac{3}{4}$

Answer (A)

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

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

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

Answer (D)

Section -2 Comprehension Type

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

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 $(2a, 0)$.

51. The value of r is

Choices:

(A) $-\frac{1}{t}$

(B) $\frac{t^2+1}{t}$

(C) $\frac{1}{t}$

(D) $\frac{t^2-1}{t}$

Answer (D)

52. 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) $\frac{a(t^2+2)^2}{t^3}$

Answer (B)

Paragraph For Question 53 and 54

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

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

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

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

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

Answer (A)

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

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

Answer (D)

Paragraph For Questions 55 and 56

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, $i = 1, 2, 3$.

55. 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) $\frac{1}{2}$

Answer (B)

56. 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) $\frac{7}{105}$

Answer (C)

Section – 3 (Matching List Type)

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. 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. True

Q. There exists a $k \in \{1, 2, \dots, 9\}$ such that $z_1 \cdot z =$

2. False

z_k has no solution z in the set of complex numbers.

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

(B) 2 1 3 4

(C) 1 2 3 4

(D) 2 1 4 3

Answer (C)

58.

List I

List II

P. The number of polynomials $f(x)$ with non-negative integer coefficients of degree ≤ 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. $\frac{\left(\int_{-\frac{1}{2}}^{\frac{1}{2}} \cos 2x \log\left(\frac{1+x}{1-x}\right) dx\right)}{\left(\int_0^{\frac{1}{2}} \cos 2x \log\left(\frac{1+x}{1-x}\right) dx\right)}$ equals

4. 0

P Q R S

(A) 3 2 4 1

(B) 2 3 4 1

(C) 3 2 1 4

(D) 2 3 1 4

Answer (D)

59.

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 $\frac{1}{y(x)} \left\{ (x^2 - \right.$

1. 1

1) $\frac{d^2 y(x)}{dx^2} + x \frac{dy(x)}{dx} \}$ equals

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

4. 9

$$\tan^{-1} \left(\frac{1}{2x+1} \right) + \tan^{-1} \left(\frac{1}{4x+1} \right) = \tan^{-1} \left(\frac{2}{x^2} \right) \text{ is}$$

P Q R S

(A) 4 3 2 1

(B) 2 4 3 1

(C) 4 3 1 2

(D) 2 4 1 3

Answer (A)

60. 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

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

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

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

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 II

P. f_4 is

Q. f_3 is

R. $f_2 \circ f_1$ is

S. f_2 is

P Q R S

(A) 3 1 4 2

(B) 1 3 4 2

(C) 3 1 2 4

(D) 1 3 2 4

List I

1. onto but not one-one

2. neither continuous nor one-one

3. differentiable but not one-one

4. continuous and one-one

Answer (D)

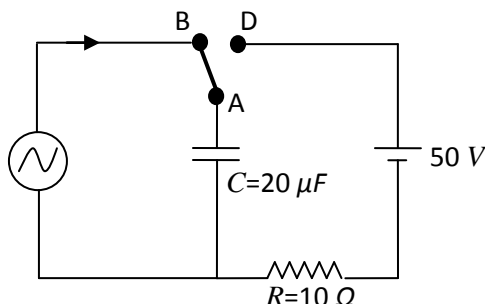
Questions with Answers

PART – 1 PHYSICS

SECTION – 1 (One or More Than One Options Correct Type)

This section contains 10 multiple choice type questions. Each question has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

1. At time $t = 0$, terminal A in the circuit shown in the figure is connected to B by a key and an alternating current $I(t) = I_0 \cos(\omega t)$, with $I_0 = 1\text{A}$ and $\omega = 500 \text{ rad s}^{-1}$ starts flowing in it with the initial direction shown in the figure. At $t = \frac{7\pi}{6\omega}$, the key is switched from B to D. Now onwards only A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If $C = 20\mu\text{F}$, $R = 10\Omega$ and the battery is ideal with *emf* of 50V , identify the correct statement (s).



- (A) Magnitude of the maximum charge on the capacitor before $t = \frac{7\pi}{6\omega}$ is $1 \times 10^{-3}\text{C}$.
 (B) The current in the left part of the circuit just before $t = \frac{7\pi}{6\omega}$ is clockwise.
 (C) Immediately after A is connected to D, the current in R is 10A .
 (D) $Q = 2 \times 10^{-3}\text{C}$.

Answer (C) and (D)

2. A light source, which emits two wavelengths $\lambda_1 = 400 \text{ nm}$ and $\lambda_2 = 600 \text{ nm}$, is used in a Young's double slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 © number of fringes for them within a distance y on one side of the central maximum are m_1 and m_2 , respectively, then

(A) $\beta_2 > \beta_1$

(B) $m_1 > m_2$

(C) From the central maximum, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1

(D) The angular separation of fringes for λ_1 is greater than λ_2

Answer: (A), (B) and (C)

3. One end of a taut string of length 3m along the x axis is fixed at $x=0$. The speed of the waves in the string is 100 ms^{-1} . The other end of the string is vibrating in the y direction so that stationary waves are set up in the string. The possible waveform(s) of these stationary waves is(are)

(A) $y(t) = A \sin \frac{\pi x}{6} \cos \frac{50\pi t}{3}$

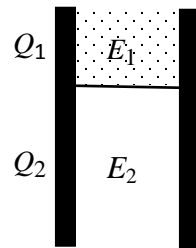
(B) $y(t) = A \sin \frac{\pi x}{3} \cos \frac{100\pi t}{3}$

(C) $y(t) = A \sin \frac{5\pi x}{6} \cos \frac{250\pi t}{3}$

(D) $y(t) = A \sin \frac{5\pi x}{2} \cos 250\pi t$

Answer: (A) , (C) and (D)

4. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers $1/3$ of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1 . When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2 . The electric field in the dielectric is E_1 and that in the other portion is E_2 . Choose the correct option/options, ignoring edge effects.



(A) $\frac{E_1}{E_2} = 1$

(B) $\frac{E_1}{E_2} = \frac{1}{K}$

(C) $\frac{Q_1}{Q_2} = \frac{3}{K}$

(D) $\frac{C}{C_1} = \frac{2+K}{K}$

Answer: (A) and (D)

5. Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric fields at a distance r from a point charge Q , an infinitely long wire with constant linear charge density λ , and an infinite plane with uniform surface charge density σ . If $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0 , then

(A) $Q = 4\sigma\pi r_0^2$

(B) $r_0 = \frac{\lambda}{2\pi\sigma}$

(C) $E_1(r_0/2) = 2E_2(r_0/2)$

(D) $E_2(r_0/2) = 4E_3(r_0/2)$

Answer: (C)

6. A student is performing an experiment using a resonance column and a tuning fork of frequency 244s^{-1} . He is told that the air in the tube has been replaced by another gas (assume that the column remains filled with the gas). If the minimum height at which resonance occurs is $(0.350 \pm 0.005)\text{ m}$, the gas in the tube is

(Useful information: $\sqrt{167RT} = 640\text{ J}^{1/2}\text{mole}^{-1/2}$; $\sqrt{140RT} = 590\text{ J}^{1/2}\text{mole}^{-1/2}$. The molar masses M in grams are given in the options. Take the values of $\sqrt{\frac{10}{M}}$ for each gas as given there.)

(A) Neon ($M = 20, \sqrt{\frac{10}{20}} = \frac{7}{10}$)

(B) Nitrogen ($M = 28, \sqrt{\frac{10}{28}} = \frac{3}{5}$)

(C) Oxygen ($M = 32, \sqrt{\frac{10}{32}} = \frac{9}{16}$)

(D) Argon ($M = 36, \sqrt{\frac{10}{36}} = \frac{17}{32}$)

Answer: (D)

7. Heater of an electric kettle is made of a wire of length L and diameter d . It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K . This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K ?

(A) 4 if wires are in parallel

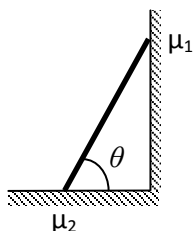
(B) 2 if wires are in series

(C) 1 if wires are in series

(D) 0.5 if wires are in parallel

Answer : (B) and (D)

8. In the figure, a ladder of mass m is shown leaning against a wall. It is in static equilibrium making an angle θ with the horizontal floor. The coefficient of friction between the wall and the ladder is μ_1 and that between the floor and the ladder is μ_2 . The normal reaction of the wall on the ladder is N_1 and that of the floor is N_2 . If the ladder is about to slip, then



(A) $\mu_1 = 0 \quad \mu_2 \neq 0$ and $N_2 \tan \theta = \frac{mg}{2}$

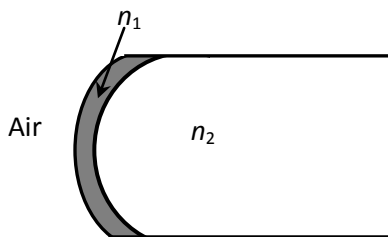
(B) $\mu_1 \neq 0 \quad \mu_2 = 0$ and $N_1 \tan \theta = \frac{mg}{2}$

(C) $\mu_1 \neq 0 \quad \mu_2 \neq 0$ and $N_2 = \frac{mg}{1 + \mu_1 \mu_2}$

(D) $\mu_1 = 0 \quad \mu_2 \neq 0$ and $N_1 \tan \theta = \frac{mg}{2}$

Answer: (C) and (D)

9. A transparent thin film of uniform thickness and refractive index $n_1 = 1.4$ is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index $n_2 = 1.5$, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film. Then



(A) $|f_1| = 3R$

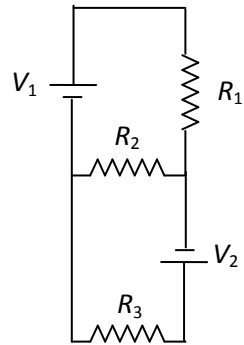
(B) $|f_1| = 2.8R$

(C) $|f_2| = 2R$

(D) $|f_2| = 1.4R$

Answer: (A) and (C)

10. Two ideal batteries of $emf V_1$ and V_2 and three resistances R_1 , R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if



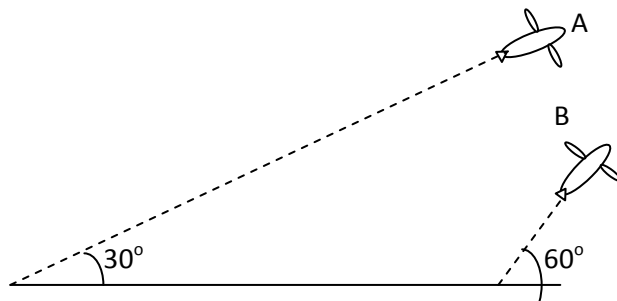
- (A) $V_1 = V_2$ and $R_1 = R_2 = R_3$
- (B) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
- (C) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$
- (D) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

Answer: (A), (B) and (D)

SECTION – 2 (One Integer Value Correct Type)

This section contains 10 questions. Each question, when worked out will result in one integer from 0 to 9 (both inclusive).

11. Airplanes A and B are flying with constant velocity in the same vertical plane at angles 30° and 60° with respect to the horizontal respectively as shown in figure. The speed of A is $100\sqrt{3} \text{ ms}^{-1}$. At time $t = 0 \text{ s}$, an observer in A finds B at a distance of 500 m . This observer sees B moving with a constant velocity perpendicular to the line of motion of A. If at $t = t_0$, A just escapes being hit by B, t_0 in seconds is

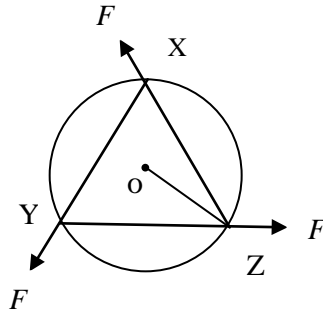


Answer: 5

12. During Searle's experiment, zero of the Vernier scale lies between $3.20 \times 10^{-2} \text{ m}$ and $3.25 \times 10^{-2} \text{ m}$ of the main scale. The 20^{th} division of the Vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between $3.20 \times 10^{-2} \text{ m}$ and $3.25 \times 10^{-2} \text{ m}$ of the main scale but now the 45^{th} division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is $8 \times 10^{-7} \text{ m}^2$. The least count of the Vernier scale is $1.0 \times 10^{-5} \text{ m}$. The maximum percentage error in the Young's modulus of the wire is

Answer: 4

13. A uniform circular disc of mass 1.5 kg and radius 0.5 m is initially at rest on a horizontal frictionless surface. Three forces of equal magnitude $F = 0.5 \text{ N}$ are applied simultaneously along the three sides of an equilateral triangle XYZ with its vertices on the perimeter of the disc (see figure). One second after applying the forces, the angular speed of the disc in rads^{-1} is



Answer: 2

14. Two parallel wires in the plane of the paper are distance X_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance X_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1 . In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2 . If $\frac{X_0}{X_1} = 3$, the value of $\frac{R_1}{R_2}$ is

Answer: 3

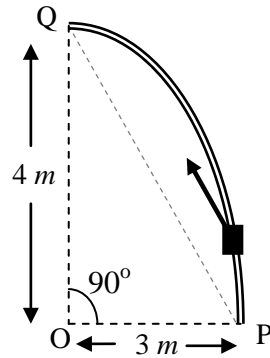
15. To find the distance d over which a signal can be seen clearly in foggy conditions, a railways engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) S of the light from the signal and its frequency f . The engineer finds that $d \propto S^{1/n}$. The value of n is

Answer: 3

16. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990Ω resistance, it can be converted into a voltmeter of range $0 - 30 \text{ V}$. If connected to a $\frac{2n}{249} \Omega$ resistance, it becomes an ammeter of range $0 - 1.5 \text{ A}$. The value of n is

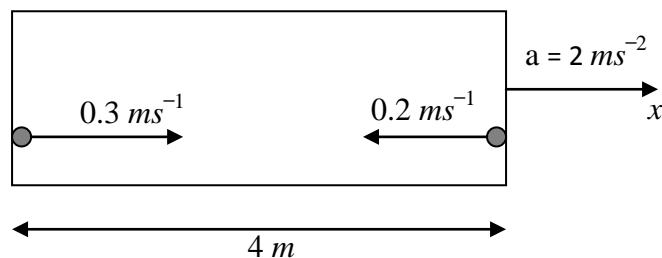
Answer: 5

17. Consider an elliptically shaped rail PQ in the vertical plane with $OP = 3\text{ m}$ and $OQ = 4\text{ m}$. A block of mass 1 kg is pulled along the rail from P to Q with a force of 18 N , which is always parallel to line PQ (see the figure given). Assuming no frictional losses, the kinetic energy of the block when it reaches Q is $(n \times 10)\text{ Joules}$. The value of n is (take acceleration due to gravity $= 10\text{ ms}^{-2}$)



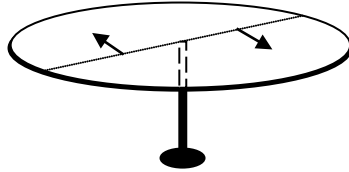
Answer : 5

18. A rocket is moving in a gravity free space with a constant acceleration of 2 ms^{-2} along $+x$ direction (see figure). The length of a chamber inside the rocket is 4 m . A ball is thrown from the left end of the chamber in $+x$ direction with a speed of 0.3 ms^{-1} relative to the rocket. At the same time, another ball is thrown in $-x$ direction with a speed of 0.2 ms^{-1} from its right end relative to the rocket. The time in seconds when the two balls hit each other is



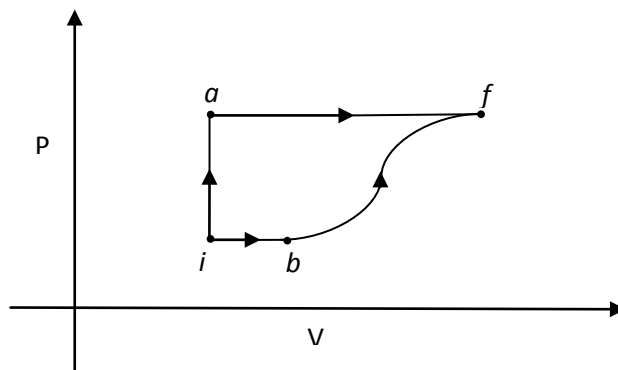
Answer : 2 OR 8

19. A horizontal circular platform of radius 0.5 m and mass 0.45 kg is free to rotate about its axis. Two massless spring toy-guns, each carrying a steel ball of mass 0.05 kg are attached to the platform at a distance 0.25 m from the centre on its either sides along its diameter (see figure). Each gun simultaneously fires the balls horizontally and perpendicular to the diameter in opposite directions. After leaving the platform, the balls have horizontal speed of 9 ms^{-1} with respect to the ground. The rotational speed of the platform in rads^{-1} after the balls leave the platform is



Answer: 4

20. A thermodynamic system is taken from an initial state i with internal energy $U_i = 100\text{ J}$ to the final state f along two different paths iaf and ibf , as schematically shown in the figure. The work done by the system along the paths af , ib and bf are $W_{af} = 200\text{ J}$, $W_{ib} = 50\text{ J}$ and $W_{bf} = 100\text{ J}$ respectively. The heat supplied to the system along the path iaf , ib and bf are Q_{iaf} , Q_{ib} and Q_{bf} respectively. If the internal energy of the system in the state b is $U_b = 200\text{ J}$ and $Q_{iaf} = 500\text{ J}$, the ratio Q_{bf}/Q_{ib} is



Answer : 2

PART – 2 CHEMISTRY

SECTION – 1 (One or More Than One Options Correct Type)

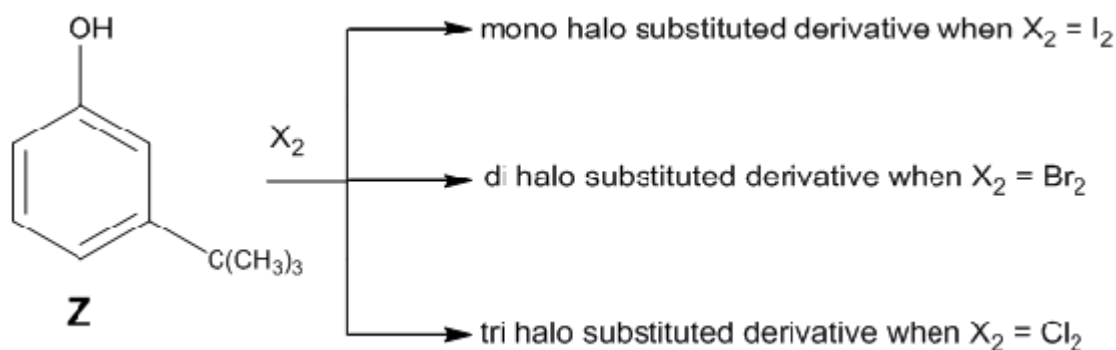
This section contains 10 multiple choice type questions. Each question has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

21. The correct combination of names for isomeric alcohols with molecular formula $C_4H_{10}O$ is/are

- (A) *tert*-butanol and 2-methylpropan-2-ol
- (B) *tert*-butanol and 1, 1-dimethylethan-1-ol
- (C) *n*-butanol and butan-1-ol
- (D) isobutyl alcohol and 2-methylpropan-1-ol

Answer: (A), (C) and (D)

22. The reactivity of compound **Z** with different halogens under appropriate conditions is given below:

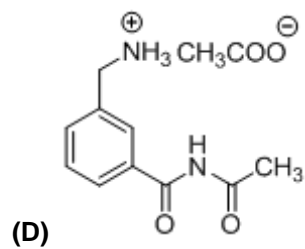
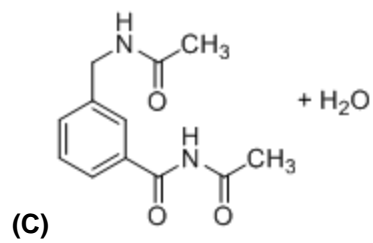
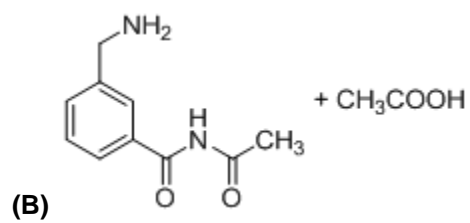
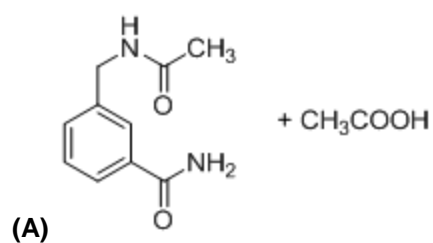
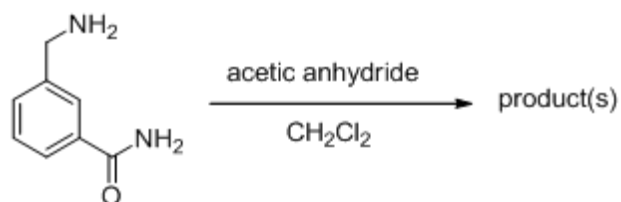


The observed pattern of electrophilic substitution can be explained by

- (A) the steric effect of the halogen
- (B) the steric effect of the *tert*-butyl group
- (C) the electronic effect of the phenolic group
- (D) the electronic effect of the *tert*-butyl group

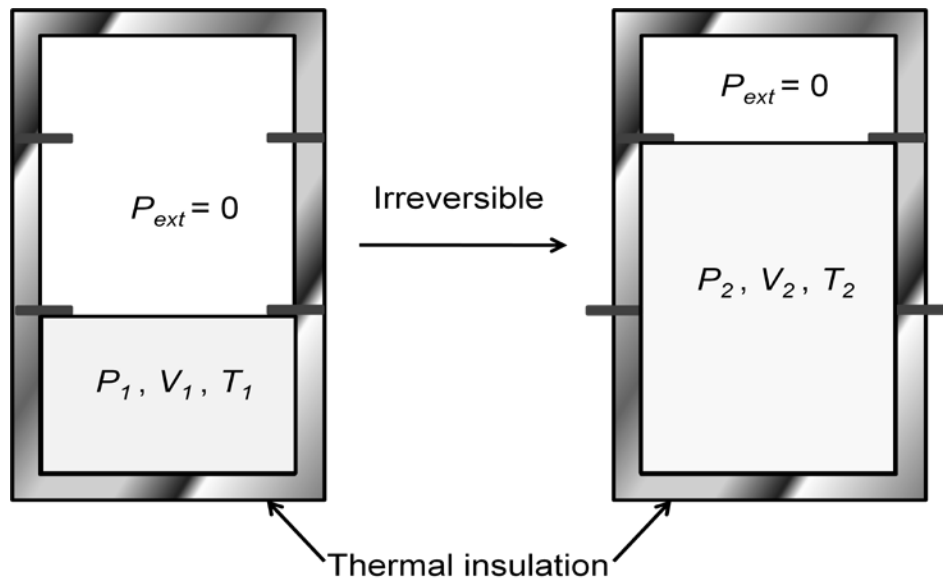
Answer: (A), (B) and (C)

23. In the reaction shown below, the major product(s) formed is/are



Answer : (A)

24. An ideal gas in a thermally insulated vessel at internal pressure = P_1 , volume = V_1 and absolute temperature = T_1 expands irreversibly against zero external pressure, as shown in the diagram. The final internal pressure, volume and absolute temperature of the gas are P_2 , V_2 and T_2 , respectively. For this expansion,



- (A) $q = 0$
- (B) $T_2 = T_1$
- (C) $P_2 V_2 = P_1 V_1$
- (D) $P_2 V_2^\gamma = P_1 V_1^\gamma$

Answer (A), (B) and (C)

25. Hydrogen bonding plays a central role in the following phenomena:

- (A) Ice floats in water.
- (B) Higher Lewis basicity of primary amines than tertiary amines in aqueous solutions.
- (C) Formic acid is more acidic than acetic acid.
- (D) Dimerisation of acetic acid in benzene.

Answer : (A), (B) and (D)

26. In a galvanic cell, the salt bridge

- (A) does not participate chemically in the cell reaction.
- (B) stops the diffusion of ions from one electrode to another.
- (C) is necessary for the occurrence of the cell reaction.
- (D) ensures mixing of the two electrolytic solutions.

Answer: (A) and (C) or only (A)

27. Upon heating with Cu_2S , the reagent(s) that give copper metal is/are

- (A) CuFeS_2
- (B) CuO
- (C) Cu_2O
- (D) CuSO_4

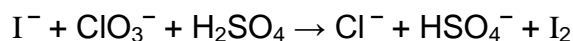
Answer: (B), (C) and (D)

28. The correct statement(s) for orthoboric acid is/are

- (A) It behaves as a weak acid in water due to self ionization.
- (B) Acidity of its aqueous solution increases upon addition of ethylene glycol.
- (C) It has a three dimensional structure due to hydrogen bonding.
- (D) It is a weak electrolyte in water.

Answer: (B) and (D)

29. For the reaction:



The correct statement(s) in the balanced equation is/are:

- (A) Stoichiometric coefficient of HSO_4^- is 6.
- (B) Iodide is oxidized.
- (C) Sulphur is reduced.
- (D) H_2O is one of the products.

Answer: (A), (B) and (D) OR (A) and (D)*

**- Due to a minor error in option (B) in the Hindi Version, Answer (A) and (D) will also be accepted as correct.*

30. The pair(s) of reagents that yield paramagnetic species is/are

- (A) Na and excess of NH_3
- (B) K and excess of O_2
- (C) Cu and dilute HNO_3
- (D) O_2 and 2-ethylantraquinol

Answer : (A), (B) and (C)

31. Consider all possible isomeric ketones, including stereoisomers, of MW = 100. All these isomers are independently reacted with NaBH_4 (**NOTE**: stereoisomers are also reacted separately). The total number of ketones that give a racemic product(s) is/are

Answer: 5

32. A list of species having the formula XZ_4 is given below.

XeF_4 , SF_4 , SiF_4 , BF_4^- , BrF_4^- , $[\text{Cu}(\text{NH}_3)_4]^{2+}$, $[\text{FeCl}_4]^{2-}$, $[\text{CoCl}_4]^{2-}$ and $[\text{PtCl}_4]^{2-}$.

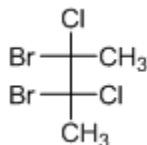
Defining shape on the basis of the location of X and Z atoms, the total number of species having a square planar shape is

Answer: 4

33. Among PbS , CuS , HgS , MnS , Ag_2S , NiS , CoS , Bi_2S_3 and SnS_2 , the total number of **BLACK** coloured sulfides is

Answer: 6 OR 7

34. The total number(s) of **stable** conformers with **non-zero** dipole moment for the following compound is (are)



Answer: 3

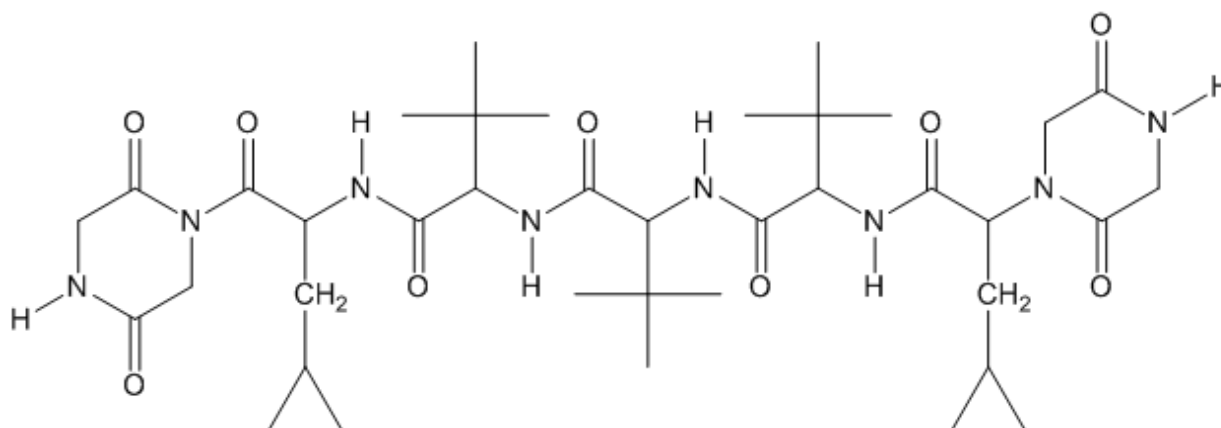
35. Consider the following list of reagents:

Acidified $\text{K}_2\text{Cr}_2\text{O}_7$, alkaline KMnO_4 , CuSO_4 , H_2O_2 , Cl_2 , O_3 , FeCl_3 , HNO_3 and $\text{Na}_2\text{S}_2\text{O}_3$.

The total number of reagents that can oxidise aqueous iodide to iodine is

Answer: 7

36. The total number of distinct naturally occurring amino acids obtained by complete acidic hydrolysis of the peptide shown below is



Answer: 1

37. In an atom, the total number of electrons having quantum numbers $n = 4$, $|m_l| = 1$ and $m_s = -1/2$ is

Answer: 6

38. If the value of Avogadro number is $6.023 \times 10^{23} \text{ mol}^{-1}$ and the value of Boltzmann constant is $1.380 \times 10^{-23} \text{ J K}^{-1}$, then the number of significant digits in the calculated value of the universal gas constant is

Answer: 4

39. A compound H_2X with molar weight of 80 g is dissolved in a solvent having density of 0.4 g ml^{-1} . Assuming no change in volume upon dissolution, the **molality** of a 3.2 molar solution is

Answer: 8

40. MX_2 dissociates into M^{2+} and X^- ions in an aqueous solution, with a degree of dissociation (α) of 0.5. The ratio of the observed depression of freezing point of the aqueous solution to the value of the depression of freezing point in the absence of ionic dissociation is

Answer: 2

PART – 3 MATHEMATICS

SECTION – 1 (One or More Than One Options Correct Type)

This section contains 10 multiple choice type questions. Each question has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

41. Let M and N be two 3×3 matrices such that $MN = NM$. Further, if $M \neq N^2$ and $M^2 = N^4$, then

- (A) determinant of $(M^2 + MN^2)$ is 0
- (B) there is a 3×3 non-zero matrix U such that $(M^2 + MN^2)U$ is the zero matrix
- (C) determinant of $(M^2 + MN^2) \geq 1$
- (D) for a 3×3 matrix U , if $(M^2 + MN^2)U$ equals the zero matrix then U is the zero matrix

Answer: (A), (B)

42. For every pair of continuous functions $f, g: [0, 1] \rightarrow \mathbb{R}$ such that

$$\max \{f(x): x \in [0, 1]\} = \max \{g(x): x \in [0, 1]\},$$

the correct statement(s) is(are) :

- (A) $(f(c))^2 + 3f(c) = (g(c))^2 + 3g(c)$ for some $c \in [0, 1]$
- (B) $(f(c))^2 + f(c) = (g(c))^2 + 3g(c)$ for some $c \in [0, 1]$
- (C) $(f(c))^2 + 3f(c) = (g(c))^2 + g(c)$ for some $c \in [0, 1]$
- (D) $(f(c))^2 = (g(c))^2$ for some $c \in [0, 1]$

Answer: (A), (D)

43. Let $f: (0, \infty) \rightarrow \mathbb{R}$ be given by

$$f(x) = \int_{\frac{1}{x}}^x e^{-(t+\frac{1}{t})} \frac{dt}{t}.$$

Then

- (A) $f(x)$ is monotonically increasing on $[1, \infty)$
- (B) $f(x)$ is monotonically decreasing on $(0, 1)$
- (C) $f(x) + f\left(\frac{1}{x}\right) = 0$, for all $x \in (0, \infty)$
- (D) $f(2^x)$ is an odd function of x on \mathbb{R}

Answer: (A), (C), (D)

44. Let $a \in \mathbb{R}$ and let $f: \mathbb{R} \rightarrow \mathbb{R}$ be given by

$$f(x) = x^5 - 5x + a.$$

Then

- (A) $f(x)$ has three real roots if $a > 4$
- (B) $f(x)$ has only one real root if $a > 4$
- (C) $f(x)$ has three real roots if $a < -4$
- (D) $f(x)$ has three real roots if $-4 < a < 4$

Answer: (B), (D)

45. Let $f: [a, b] \rightarrow [1, \infty)$ be a continuous function and let $g: \mathbb{R} \rightarrow \mathbb{R}$ be defined as

$$g(x) = \begin{cases} 0 & \text{if } x < a, \\ \int_a^x f(t)dt & \text{if } a \leq x \leq b, \\ \int_a^b f(t)dt & \text{if } x > b. \end{cases}$$

Then

- (A) $g(x)$ is continuous but not differentiable at a
- (B) $g(x)$ is differentiable on \mathbb{R}
- (C) $g(x)$ is continuous but not differentiable at b
- (D) $g(x)$ is continuous and differentiable at either a or b but not both

Answer: (A), (C)

46. Let $f: (-\frac{\pi}{2}, \frac{\pi}{2}) \rightarrow \mathbb{R}$ be given by

$$f(x) = (\log(\sec x + \tan x))^3.$$

Then

- (A) $f(x)$ is an odd function
- (B) $f(x)$ is a one-one function
- (C) $f(x)$ is an onto function
- (D) $f(x)$ is an even function

Answer: (A), (B) and (C)

47. From a point $P(\lambda, \lambda, \lambda)$, perpendiculars PQ and PR are drawn respectively on the lines $y = x, z = 1$ and $y = -x, z = -1$. If P is such that $\angle QPR$ is a right angle, then the possible value(s) of λ is(are)

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

Answer: (C)

48. Let \vec{x}, \vec{y} and \vec{z} be three vectors each of magnitude $\sqrt{2}$ and the angle between each pair of them is $\frac{\pi}{3}$. If \vec{a} is a nonzero vector perpendicular to \vec{x} and $\vec{y} \times \vec{z}$ and \vec{b} is a nonzero vector perpendicular to \vec{y} and $\vec{z} \times \vec{x}$, then

- (A) $\vec{b} = (\vec{b} \cdot \vec{z})(\vec{z} - \vec{x})$
- (B) $\vec{a} = (\vec{a} \cdot \vec{y})(\vec{y} - \vec{z})$
- (C) $\vec{a} \cdot \vec{b} = -(\vec{a} \cdot \vec{y})(\vec{b} \cdot \vec{z})$
- (D) $\vec{a} = (\vec{a} \cdot \vec{y})(\vec{z} - \vec{y})$

Answer: (A), (B) and (C)

49. A circle S passes through the point $(0, 1)$ and is orthogonal to the circles $(x - 1)^2 + y^2 = 16$ and $x^2 + y^2 = 1$. Then

- (A) radius of S is 8
- (B) radius of S is 7
- (C) centre of S is $(-7, 1)$
- (D) centre of S is $(-8, 1)$

Answer: (B), (C)

50. Let M be a 2×2 symmetric matrix with integer entries. Then M is invertible if

- (A) the first column of M is the transpose of the second row of M
- (B) the second row of M is the transpose of the first column of M
- (C) M is a diagonal matrix with nonzero entries in the main diagonal
- (D) the product of entries in the main diagonal of M is not the square of an integer

Answer: (C), (D)

51. Let a, b, c be positive integers such that $\frac{b}{a}$ is an integer. If a, b, c are in geometric progression and the arithmetic mean of a, b, c is $b + 2$, then the value of

$$\frac{a^2 + a - 14}{a + 1}$$

is

Answer: 4

52. Let $n \geq 2$ be an integer. Take n distinct points on a circle and join each pair of points by a line segment. Colour the line segment joining every pair of adjacent points by blue and the rest by red. If the number of red and blue line segments are equal, then the value of n is

Answer: 5

53. Let $n_1 < n_2 < n_3 < n_4 < n_5$ be positive integers such that $n_1 + n_2 + n_3 + n_4 + n_5 = 20$. Then the number of such distinct arrangements $(n_1, n_2, n_3, n_4, n_5)$ is

Answer: 7

54. Let $f: \mathbb{R} \rightarrow \mathbb{R}$ and $g: \mathbb{R} \rightarrow \mathbb{R}$ be respectively given by $f(x) = |x| + 1$ and $g(x) = x^2 + 1$. Define $h: \mathbb{R} \rightarrow \mathbb{R}$ by

$$h(x) = \begin{cases} \max \{f(x), g(x)\} & \text{if } x \leq 0, \\ \min \{f(x), g(x)\} & \text{if } x > 0. \end{cases}$$

The number of points at which $h(x)$ is not differentiable is

Answer: 3

55. The value of

$$\int_0^1 4x^3 \left\{ \frac{d^2}{dx^2} (1 - x^2)^5 \right\} dx$$

is

Answer: 2

56. The slope of the tangent to the curve $(y - x^5)^2 = x(1 + x^2)^2$ at the point $(1, 3)$ is

Answer: 8

57. The largest value of the nonnegative integer a for which

$$\lim_{x \rightarrow 1} \left\{ \frac{-ax + \sin(x - 1) + a}{x + \sin(x - 1) - 1} \right\}^{\frac{1-x}{1-\sqrt{x}}} = \frac{1}{4}$$

is

Answer: 0 (zero)

58. Let $f: [0, 4\pi] \rightarrow [0, \pi]$ be defined by $f(x) = \cos^{-1}(\cos x)$. The number of points $x \in [0, 4\pi]$ satisfying the equation

$$f(x) = \frac{10 - x}{10}$$

is

Answer: 3

59. For a point P in the plane, let $d_1(P)$ and $d_2(P)$ be the distances of the point P from the lines $x - y = 0$ and $x + y = 0$ respectively. The area of the region R consisting of all points P lying in the first quadrant of the plane and satisfying $2 \leq d_1(P) + d_2(P) \leq 4$, is

Answer: 6

60. Let \vec{a} , \vec{b} , and \vec{c} be three non-coplanar unit vectors such that the angle between every pair of them is $\frac{\pi}{3}$. If $\vec{a} \times \vec{b} + \vec{b} \times \vec{c} = p\vec{a} + q\vec{b} + r\vec{c}$, where p, q and r are scalars, then the value of $\frac{p^2 + 2q^2 + r^2}{q^2}$ is

Answer: 4