JEE Advanced 2024
Sample Paper - 4

Time Allowed: 3 hours **Maximum Marks: 180**

General Instructions:

This question paper has THREE main sections and four sub-sections as below.

MRQ

- Each question has FOUR options (A), (B), (C) and (D). ONE OR MORE THAN ONE of these four option(s) is(are) the correct answer(s).
- You will get +4 marks for the correct response and -2 for the incorrect response.
- You will also get 1-3 marks for a partially correct response.

MCQ

- Each question has FOUR options (A), (B), (C) and (D). ONLY ONE of these four options is the correct answer.
- You will get +3 marks for the correct response and -1 for the incorrect response.

NUM

- The answer to each question is a NON-NEGATIVE INTEGER.
- You will get +4 marks for the correct response and 0 marks for the incorrect response.

MATCH

- FOUR options are given in each Multiple Choice Question based on List-I and List-II and ONLY ONE of these four options satisfies the condition asked in the Multiple Choice Question.
- You will get +3 marks for the correct response and -1 for the incorrect response.

Mathematics (MRQ)

1. Tangents are drawn to the hyperbola $\frac{x^2}{9} - \frac{y^2}{4}$ = 1, parallel to the straight line 2x - y = 1. The points of contact of the tangents on the hyperbola are **[4]**

a) $(3\sqrt{3}, -2\sqrt{2})$

b) $\left(-\frac{9}{2\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$

c) $(-3\sqrt{3}, 2\sqrt{2})$

d) $\left(\frac{9}{2\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$

2. Let a, b $\in$ R and f : R $\rightarrow$ R be defined by f(x) = a cos ($|x^3$ -x|) + b |x| sin ($|x^3$ + x|). Then f is **[4]**

a) NOT differentiable at x = 0 if a = 1 b = 0

b) NOT differentiable at x = 1 if a = 1 and b = 1

c) differentiable at x = 0 if a = 0 and b = 1

d) differentiable at x = 1 if a = 1 and b = 0

3. Let f : R $\Rightarrow$ (0, 1) be a continuous function. Then, which of the following function(s) has(have) the value zero at some point in the interval (0, 1)? **[4]**

a) $x^9 - f(x)$

b) $e^x - \int_0^x f(t) \sin t\,dt$

c) $x - \int_0^{\frac{\pi}{2}-x} f(t)\cos t dt$

d) $f(x) + \int_0^{\frac{\pi}{2}} f(t)\sin t dt$

Mathematics (MCQ)

4. If ${}^{n-1}C_r = (k^2 - 3)\, {}^{n}C_{r+1}$, then k belongs to **[3]**

a) $[2, \infty)$

b) $(-\infty, -2]$

c) $(\sqrt{3}, 2]$

d) $[-\sqrt{3}, \sqrt{3}]$

5. The total number of local maxima and local minima of the function f(x) = $\begin{cases} (2+x)^3, & -3 < x \leq -1 \\ x^{2/3}, & -1 < x < 2 \end{cases}$ is **[3]**

a) 1

b) 3

c) 2

d) 0

6. The points $\left(0, \frac{8}{3}\right), (1, 3)$ and (82, 30) are vertices of **[3]**

a) A right angled triangle

b) An obtuse angled triangle

c) None of these

d) An acute angled triangle

7. Let $f'(x) = \frac{x}{(1+x^n)^{1/n}}$ for n $\geq$ 2 and $g(x) = \underbrace{(\text{fofo...of})}_{f \text{ occurs } n \text{ times}}(x)$. Then $\int x^{n-2}$g(x)dx equals. **[3]**

a) $\frac{1}{n(n+1)}(1+nx^n)^{1+\frac{1}{n}} + K$

b) $\frac{1}{n(n-1)}(1+nx^n)^{1-\frac{1}{n}} + K$

c) $\frac{1}{n+1}(1+nx^n)^{1+\frac{1}{n}} + K$

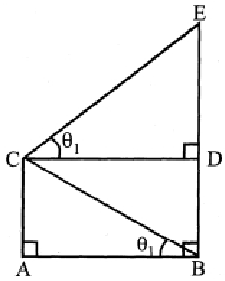
d) $\frac{1}{n-1}(1+nx^n)^{1-\frac{1}{n}} + K$

Mathematics (NUM)

8. Let AP(a; d) denote the set of all the terms of an infinite arithmetic progression with first term a and common difference d > 0. If AP (1; 3) AP (2; 5) AP (3; 7) = AP (a; d) then a + d equals _______. **[4]**

9. Let the mirror image of a circle $c_1 : x^2 + y^2 - 2x - 6y + \alpha = 0$ in line y = x + 1 be $c_2 : 5x^2 + 5y^2 + 10gx + 10fy + 38 = 0$. If r is the radius of circle c_2, then $\alpha + 6r^2$ is equal to _______. **[4]**

10. In the figure, $\theta_1 + \theta_2 = \frac{\pi}{2}$ and $\sqrt{3}(\mathrm{BE}) = 4(\mathrm{AB})$. If the area of $\triangle\mathrm{CAB}$ is $2\sqrt{3} - 3$ unit^2, when $\frac{\theta_2}{\theta_1}$ is the largest, then the perimeter (in unit) of $\triangle\mathrm{CED}$ is equal to _______. **[4]**



11. Consider the set of eight vectors V = $\{a\hat{i} + \hat{j} + c\hat{k} : a, b, c \in \{-1, 1\}\}$. Three non-coplanar vectors can be chosen from V in 2^p ways. Then p is: **[4]**

12. Let $f_1 : (0, \infty) \to \mathbb{R}$ and $f_2 : (0, \infty) \to \mathbb{R}$ be defined by $f_1(x) = \int\limits_0^x \prod_{j=1}^{21} (t - j)^j dt, x > 0$ and **[4]**

$f_2(x) = 98 (x - 1)^{50} - 600(x - 1)^{49} + 2450, x > 0$, where for any positive integer n and real numbers $a_1, a_2, \ldots a_n$, $\Pi_{i=1}^n a_i$ denotes the product of $a_1, a_2, \ldots a_n$, Let m_i and n_i, respectively, denote the number of points of local minima and the number of points of local maxima of function f_i, i = 1, 2, in the interval $(0, \infty)$

The value of $6m_2 + 4n_2 + 8m_2n_2$ is _______.

13. The number of all possible values of θ where $0 < \theta < \pi$, for which the system of equations **[4]**

$(y + z) \cos 3\theta = (xyz) \sin 3\theta$

$x \sin 3\theta = \frac{2 \cos 3\theta}{y} + \frac{2 \sin 3\theta}{z}$

$(xyz) \sin 3\theta = (y + 2z) \cos 3\theta + y \sin 3\theta$ have a solution (x_0, y_0, z_0) with $y_0 z_0 \neq 0$, is

Mathematics (MATCH)

14. Let $z_k = \cos\left(\frac{2k\pi}{10}\right) + i \sin\left(\frac{2k\pi}{10}\right)$; k = 1, 2, ..., 9. **[3]**

List-I	List-II
(P) For each z_k there exists as z_j such that $z_k.z_j = 1$	(1) True
(Q) There exists a $k \in \{1, 2, ..., 9\}$ such that $z_1.z = z_k$ has no solution z in the set of complex numbers	(2) False
(R) $\frac{\|1-z_1\|\|1-z_2\|\ldots\|1-z_9\|}{10}$ equal	(3) 1
(S) $1 - \sum\limits_{k=1}^{9} \cos\left(\frac{2k\pi}{10}\right)$ equal	(4) 2

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

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

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

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

15. Let H: $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$, here a > b > 0, be a hyperbola in the xy-plane whose conjugate axis LM subtends an angle of 60^o at one of its vertices N. Let the area of the triangle LMN be $4\sqrt{3}$. **[3]**

List I	List II
P. The length of the conjugate axis of H is	1. 8

List I	List II
Q. The eccentricity of H is	2. $\frac{4}{\sqrt{3}}$
R. The distance between the foci of H is	3. $\frac{2}{\sqrt{3}}$
S. The length of the latus rectum of H is	4. 4

a) P $\rightarrow$ 4; Q $\rightarrow$ 3; R $\rightarrow$ 1; S $\rightarrow$ 2

b) P $\rightarrow$ 4; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 3

c) P $\rightarrow$ 4; Q $\rightarrow$ 1; R $\rightarrow$ 3; S $\rightarrow$ 2

d) P $\rightarrow$ 3; Q $\rightarrow$ 4; R $\rightarrow$ 2; S $\rightarrow$ 1

16. Let p, q, r be nonzero real numbers that are, respectively, the 10^{th}, 100^{th} and 1000^{th} terms of a harmonic progression. Consider the system of linear equations **[3]**
x + y + z = 1
10x + 100y + 1000z = 0
qr x + pr y + pq z = 0.

List-I	List-II
(I) If $\frac{q}{r}$ = 10, then the system of linear equations has	(P) x = 0, y = $\frac{10}{9}$, z = $-\frac{1}{9}$ as a solution
(II) If $\frac{p}{r} \neq$ 100, then the system of linear equations has	(Q) x = $\frac{10}{9}$, y = $-\frac{1}{9}$, z = 0 solution
(III) If $\frac{p}{q} \neq$ 10, then the system of linear equations has	(R) infinitely many solutions
(IV) If $\frac{p}{q}$ = 10, then the system of linear equations has	(S) no solution
	(T) at least one solution

a) (I) $\rightarrow$ (Q); (II) $\rightarrow$ (S); (III) $\rightarrow$ (S); (IV) $\rightarrow$ (R)

b) (I) $\rightarrow$ (Q); (II) $\rightarrow$ (R); (III) $\rightarrow$ (P); (IV) $\rightarrow$ (R)

c) (I) $\rightarrow$ (T); (II) $\rightarrow$ (R); (III) $\rightarrow$ (S); (IV) $\rightarrow$ (T)

d) (I) $\rightarrow$ (T); (II) $\rightarrow$ (S); (III) $\rightarrow$ (P); (IV) $\rightarrow$ (T)

17. Let ℓ_1 and ℓ_2 be the lines $\vec{r}_1 = \lambda(\hat{i} + \hat{j} + \hat{k})$ and $\vec{r}_2 = (\hat{j} - \hat{k}) + \mu(\hat{i} + \hat{k})$, respectively. Let X be the set of all the planes H that contain the line ℓ_1. For a plane H, let d(H) denote the smallest possible distance between the points of ℓ_2 and H. Let H_0 be a plane in X for which d(H_0) is the maximum value of d(H) as H varies over all planes in X. **[3]**
Match each entry in List-I to the correct entries in List-II.

List - I	List - II
(P) The value of d(H_0) is	(1) $\sqrt{3}$
(Q) The distance of the point (0, 1, 2) from H_0 is	(2) $\frac{1}{\sqrt{3}}$
(R) The distance of origin from H_0 is	(3) 0

(S) The distance of origin from the point of intersection of planes y = z, x = 1 and H_0 is	(4) $\sqrt{2}$
	(5) $\frac{1}{\sqrt{2}}$

a) (P) → (5), (Q) → (1), (R) → (4), (S) → (2)

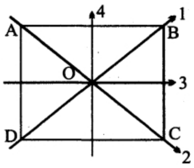
b) (P) → (5), (Q) → (4), (R) → (3), (S) → (1)

c) (P) → (2), (Q) → (1), (R) → (3), (S) → (2)

d) (P) → (2), (Q) → (4), (R) → (5), (S) → (1)

Physics (MRQ)

18. The moment of inertia of a thin square plate ABCD, Fig., of uniform thickness about an axis passing through the centre O and perpendicular to the plane of the plate is **[4]**



where I_1, I_2, I_3 and I_4 are respectively the moments of intertial about axis 1, 2, 3 and 4 which are in the plane of the plate.

a) $I_1 + I_3$

b) $I_3 + I_4$

c) $I_1 + I_2$

d) $I_1 + I_2 + I_3 + I_4$

19. A horizontal stretched string, fixed at two ends, is vibrating in its fifth harmonic according to the equation, y(x, t) = (0.01 m) sin [(62.8 m^{-1})x] cos[(628 s^{-1})t]. Assuming n =3.14, the correct statement(s) is (are) **[4]**

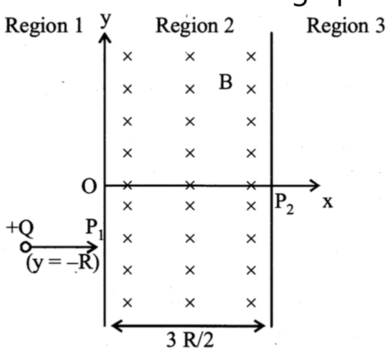
a) The maximum displacement of the midpoint of the string, from its equilibrium position is 0.01 m

b) The fundamental frequency is 100 Hz

c) The length of the string is 0.25 m

d) The number of nodes is 5

20. A uniform magnetic field B exists in the region between x = 0 and x = $\frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge +Q and momentum p directed along x-axis enters region 2 from region 1 at point P_1 (y = -R). Which of the following option(s) is/are correct? **[4]**



a) For a fixed B, particles of same charge Q and same velocity v, the distance between the point P_1 and the point of re -entry into region 1 is inversely proportional to the mass of the particle

b) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point P_1 and the farthest point from y-axis is $\frac{p}{\sqrt{2}}$

c) For B = $\frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x - axis.

d) For B > $\frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1

Physics (MCQ)

21. If force (F), length (L) and time (T) are taken as the fundamental quantities. Then what will be the dimension of density: **[3]**

a) $[FL^{-5}T^{2}]$

b) $[FL^{-3}T^{3}]$

c) $[FL^{-4}T^{2}]$

d) $[FL^{-3}T^{2}]$

22. A block of mass 0.1 kg is held against a wall applying a horizontal force of 5 N on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is **[3]**

a) 0.98 N

b) 4.9 N

c) 0.49 N

d) 2.5 N

23. The escape velocity of a body on the surface of the earth is 11.2 km/sec. If the earth’s mass increases to twice its present value and radius of the earth become half, the escape velocity becomes: **[3]**

a) 11.2 km/s

b) 5.6 km/s

c) 44.8 km/s

d) 22.4 km/s

24. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times 10^{5}\mathrm{Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} ms^{-1}. Given g = 9.8 ms^{-1}, viscosity of the air = 1.8×10^{-5} Ns m^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is **[3]**

a) 1.6×10^{-19} C

b) 4.8×10^{-19} C

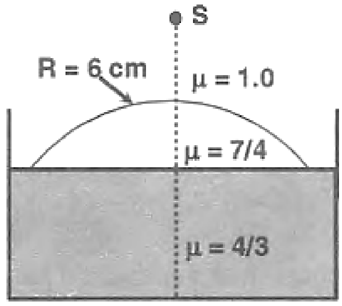
c) 8.0×10^{-19} C

d) 3.2×10^{-19} C

Physics (NUM)

25. Water (with refractive index = $\frac{4}{3}$) in a tank is 18 cm deep. Oil of refractive index $\frac{7}{4}$ lies on water making a convex surface of radius of curvature **R = 6 cm** as shown. Consider oil to act as a thin lens. An object **S** is placed 24 cm above water surface. The location of its **[4]**

image is at **x** cm above the bottom of the tank. Then **x** is:

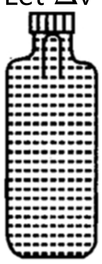


26. 300 grams of water at 25 ^{O}C is added to 100 grams of ice at 0 ^{O}C. The final temperature of the mixture is _______ ^{O}C. **[4]**

27. Four solid spheres each of diameter $\sqrt{5}$ cm and mass 0.5 kg are placed with their centres at the comers of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is N $\times$ 10^{-4} kg-m^{2}, then N is **[4]**

28. A soft plastic bottle, filled with water of density 1 gm/cc, carries an inverted glass test-tube with some air (ideal gas) trapped as shown in the figure. The test-tube has a mass of 5 gm, and it is made of a thick glass of density 2.5 gm/cc. Initially the bottle is sealed at atmospheric pressure p_0 = 10^5 Pa so that the volume of the trapped air is v_0 = 3.3 cc. When the bottle is squeezed from outside at constant temperature, the pressure inside rises and the volume of the trapped air reduces. It is found that the test tube begins to sink at pressure P_0 + Δp without changing its orientation. At this pressure, the volume of the trapped air is v_0 - Δv. **[4]**

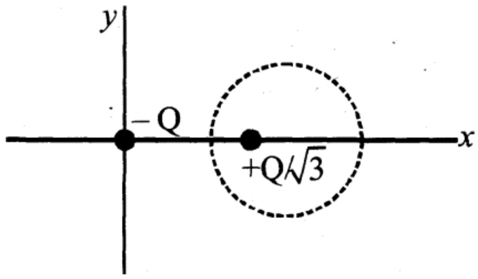
Let Δv = X cc and Δp = Y $\times$ 10^3 Pa.



The value of X is _______.

29. A Hydrogen-like atom has atomic number Z. Photons emitted in the electronic transitions from level n = 4 to level n = 3 in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of Z is _______. **[4]**
[Given: hc = 1240 eV-nm and Rhc = 13.6 eV, where R is the Rydberg constant, h is the Planck's constant and c is the speed of light in vacuum]

30. Two point charges -Q and $+\frac{Q}{\sqrt{3}}$ are placed in the xy-plane at the origin (0, 0) and a point (2, 0), respectively, as shown in the figure. This results in an equipotential circle of radius R and potential V = 0 in the xy-plane with its center at (b, 0). All lengths are measured in meters. **[4]**



The value of b is ________ meter.

Physics (MATCH)

31. List I describes thermodynamic processes in four different systems. List II gives the magnitudes (either exactly or as a close approximation) of possible changes in the internal energy of the system due to the process. **[3]**

List-I	List-II
(I) 10^{-3} kg of water at 100°C is converted to steam at the same temperature, at a pressure of 10^5 Pa. The volume of the system changes from 10^{-6} m^3 to 10^{-3} m^3 in the process. Latent heat of water = 2250 kJ/kg.	(P) 2 kJ
(II) 0.2 moles of a rigid diatomic ideal gas with volume V at temperature 500 K undergoes an isobaric expansion to volume 3 V. Assume R = 8.0 $Jmol^{-1}$ K^{-1}.	(Q) 7 kJ
(III) One mole of a monatomic ideal gas is compressed adiabatically from volume $V = \frac{1}{3}m^3$ and pressure 2 kPa to volume $\frac{V}{8}$.	(R) 4 kJ
(IV) Three moles of a diatomic ideal gas whose molecules can vibrate, is given 9 kJ of heat and undergoes isobaric expansion.	(S) 5 kJ
	(T) 3 kJ

Which one of the following options is correct?

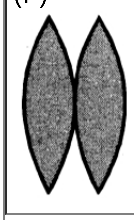
a) (I) $\rightarrow$ (P); (II) $\rightarrow$ (R); (III) $\rightarrow$ (T); (IV) $\rightarrow$ (Q)

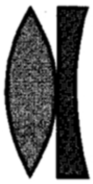
b) (I) $\rightarrow$ (S); (II) $\rightarrow$ (P); (III) $\rightarrow$ (T); (IV) $\rightarrow$ (P)

c) (I) $\rightarrow$ (T); (II) $\rightarrow$ (R); (III) $\rightarrow$ (S); (IV) $\rightarrow$ (Q)

d) (I) $\rightarrow$ (Q); (II) $\rightarrow$ (R); (III) $\rightarrow$ (S); (IV) $\rightarrow$ (T)

32. 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. **[3]**

List-I	List-II
(P) 	(1) 2r

(Q) 	(2) $\frac{r}{2}$
(R) 	(3) -r
(S) 	(4) r

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

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

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

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

33. Match List I of the nuclear processes with List II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the lists: **[3]**

List I	List II
P. Alpha decay	1. ${}^{15}_{8}\mathrm{O} \rightarrow {}^{15}_{7}\mathrm{O} + \ldots$
Q. $\beta +$ decay	2. ${}^{138}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + \ldots$
R. Fission	3. ${}^{185}_{83}\mathrm{Bi} \rightarrow {}^{184}_{82}\mathrm{Pb} + \ldots$
S. Proton emission	4. ${}^{239}_{94}\mathrm{Pu} \rightarrow {}^{140}_{57}\mathrm{La} + \ldots$

a) (P) - (2); (Q) - (1); (R) - (4); (S) - (3)

b) (P) - (4); (Q) - (3); (R) - (2); (S) - (1)

c) (P) - (4); (Q) - (2); (R) - (1); (S) - (3)

d) (P) - (1); (Q) - (3); (R) - (2); (S) - (4)

34. A musical instrument is made using four different metal strings 1,2,3 and 4 with mass per unit length μ, 2μ, 3μ and 4μ respectively. The instrument is played by vibrating the strings by varying the free length in between the range L_0 and $2L_0$. It is found that in string-1 (μ) at free length L_0 and tension T_0 the fundamental mode frequency is f_0. List - I gives the above four strings while list - II lists the magnitude of some quantity. **[3]**

List-I	List-II
(I) String - 1 (μ)	(P) 1
(II) String - 2 (2μ)	(Q) $\frac{1}{2}$
(III) String - 3 (3μ)	(R) $\frac{1}{\sqrt{2}}$

List-I	List-II
(IV) String - 4 (4μ)	(S) $\frac{1}{\sqrt{3}}$
	(T) $\frac{3}{16}$
	(U) $\frac{1}{16}$

If the tension in each string is T_0, the correct match for the highest fundamental frequency in f_0 units will be,

a) (I) $\rightarrow$ (P), (II)$\rightarrow$ (Q), (III)$\rightarrow$ (T), (IV)$\rightarrow$ (S)

b) (I) $\rightarrow$ (Q), (II)$\rightarrow$ (P), (III)$\rightarrow$ (R), (IV)$\rightarrow$ (T)

c) (I) $\rightarrow$ (Q), (II)$\rightarrow$ (S), (III)$\rightarrow$ (R), (IV)$\rightarrow$ (P)

d) (I) $\rightarrow$ (P), (II)$\rightarrow$ (R), (III)$\rightarrow$ (S), (IV)$\rightarrow$ (Q)

Chemistry (MRQ)

35. Which of the following compounds will give a yellow precipitate with iodine and alkali? **[4]**

a) 2-Hydroxypropane

b) acetophenone

c) methyl acetate

d) acetamide

36. A catalyst: **[4]**

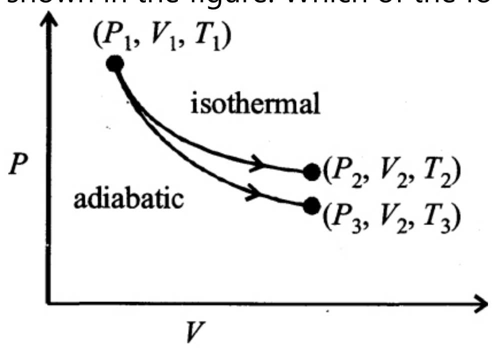
a) decreases the activation energy

b) alters the reaction mechanism

c) increases the frequency of collisions of reacting species

d) increases the average kinetic energy ofreacting molecules

37. The reversible expansion of an ideal gas under adiabatic and isothermal conditions is shown in the figure. Which of the following statement(s) is (are) correct? **[4]**



a) $W_{isothermal} > W_{adiabatic}$

b) $T_3 > T_1$

c) $T_1 = T_2$

d) $\Delta U_{isothermal} > \Delta U_{adiabatic}$

Chemistry (MCQ)

38. The isoelectronic set of ions is **[3]**

a) F^-, Li^+, Na^+ and Mg^{2+}

b) N^{3-}, O^{2-}, F^- and Na^+

c) Li^+, Na^+, O^{2-} and F^- d) N^{3-}, Li^+, Mg^{2+} and O^{2-}

39. Which one is more acidic in aqueous solution? **[3]**

a) $FeCl_3$ b) $BeCl_2$

c) $AlCl_3$ d) $NiCl_2$

40. A solution when diluted with H_2O and boiled, it gives a white precipitate. On the addition of excess NH_4Cl/NH_4OH, the volume of precipitate decreases leaving behind a white gelatinous precipitate. Identify the precipitate which dissolves in NH_4OH/NH_4Cl. **[3]**

a) $Al(OH)_3$ b) $Mg(OH)_2$

c) $Ca(OH)_2$ d) $Zn(OH)_2$

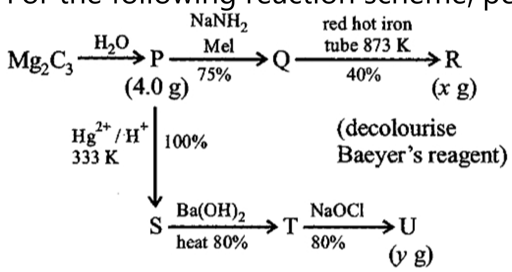
41. Which of the following acids has the smallest dissociation constant? **[3]**

a) $CH_3CHFCOOH$ b) FCH_2CH_2COOH

c) $BrCH_2CH_2COOH$ d) $CH_3CHBrCOOH$

Chemistry (NUM)

42. For the following reaction scheme, percentage yields are given along the arrow: **[4]**



x g and y g are mass of R and U, respectively.

(Use: Molar mass (in g mol^{-1}) of H, C and O as 1, 12 and 16, respectively)

The value of y is ________.

43. The vapour pressure of pure benzene at a certain temperature is 640 mm of Hg. A non-volatile non-electrolyte solid weighing 2.175 g is added to 39.0 g of benzene. The vapour pressure of the solution is 600 mm Hg. The molar mass of solid substance is ________ g mol^{-1}. **[4]**

44. For the reaction, $2CO + O_2 \longrightarrow 2CO_2$; ΔH = -560kJ. **[4]**

Two moles of CO and one mole of O_2 are taken in a container of volume 1 L. They completely form two moles of CO_2, the gases deviate appreciably from ideal behaviour. If the pressure in the vessel changes from 70 to 40 atm, find the magnitude (absolute value) of ΔU at 500 K. (1 atm = 0.1 kJ)

45. The work function (ϕ) of some metals is listed below. The number of metals that will show a photoelectric effect when the light of 300 nm wavelength falls on the metal is ________ eV. **[4]**

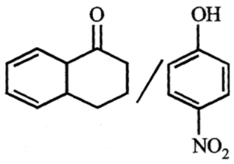
Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
Φ(eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

46. Consider the following reversible reaction, **[4]**
A(g) + B(g) $\leftrightharpoons$ AB(g)
The activation energy of the backward reaction exceeds that of the forward reaction by 2RT (in J mol^{-1}). If the pre-exponential factor of the forward reaction is 4 times that of the reverse reaction, the absolute value of ΔG° (in J mol^{-1}) for the reaction at 300 K is ________.
(Given; ln(2) = 0.7 RT = 2500 J mol^{-1} at 300 K and G is the Gibbs energy)

47. The total number of cyclic isomers possible for a hydrocarbon with the molecular formula C_4H_6 is **[4]**

Chemistry (MATCH)

48. Match items of column I and II **[3]**

Column I (Mixture of compounds)	**Column II (Separation Technique)**
(A) $\frac{H_2O}{CH_2Cl_2}$	(i) Crystallization
(B) 	(ii) Differential solvent extraction
(C) Kerosene/Naphthalene	(iii) Column chromatography
(D) $\frac{C_6H_{12}O_6}{NaCl}$	(iv) Fractional Distillation

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

49. Match each set of hybrid orbitals from LIST-I with complex(es) given in LIST-II **[3]**

List-I	List-II
(A) dsp^2	(p) $[FeF_6]^4$
(B) sp^3	(q) $[Ti(H_2O)_3Cl_3]$
(C) $sp^3\ d^2$	(r) $[Cr(NH_3)_6]^{3+}$
(D) d^2sp^3	(s) $[FeCl_4]^{2-}$
	(t) $[Ni(CO)_4]$
	(w) $[Ni(CN)_4]^{2-}$

a) A - t; B - s, w; C - q, r; D - p
b) A - t, w; B - s; C - q; D - p, q
c) A - w; B - s, t ; C - p; D - q, r
d) A - s, w; B - t, w; C - p, q; D - r

50. The standard reduction potential data at 25^{o}C is given below: **[3]**

$E^{o}(Fe^{3+}, Fe^{2+})$ = + 0.77 V; $E^{o}(Fe^{2+}, Fe)$ = - 0.44 V; $E^{o}(Cu^{2+}, Cu)$ = + 0.34 V; $E^{o}(Cu^{+}, Cu)$ = + 0.52 V

$E^{o}[O_2(g) + 4H^{+} + 4e^{-} \rightarrow 2H_2O]$ = +1.23 V; $E^{o}[O_2(g) + 2H_2O + 4e^{-} \rightarrow 4OH^{-}]$ = + 0.40 V

$E^{o}(Cr^{3+}, Cr)$ = -0.74 V; $E^{o}(Cr^{2+}, Cr)$ = -0.91 V

Match E^{o} of the redox pair in List I with the values given in List II and select the correct answer using the code given below the lists:

List I	List II
(P) $E^{o}(Fe^{3+}, Fe)$	(1) - 0.18 V
(Q) $E^{o}(4H_2O \rightleftharpoons 4H^{+} + 4OH^{-})$	(2) -0.8 V
(R) $E^{o}(Cu^{2+} + Cu \rightarrow 2Cu^{+})$	(3) -0.04 V
(S) $E^{o}(Cr^{3+}, Cr^{2+})$	(4) -0.83 V

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

51. Match the reactions (in the given stoichiometry of the reactants) in List-I with one of their products given in List-II and choose the correct option. **[3]**

List- I	List- II
(P) $P_2O_3 + 3H_2O \rightarrow$	(1) $P(O)(OCH_3)Cl_2$
(Q) $P_4 + 3NaOH + 3H_2O \rightarrow$	(2) H_3PO_3
(R) $PCl_5 + CH_3COOH \rightarrow$	(3) PH_3
(S) $H_3PO_2 + 2H_2O + 4AgNO_3 \rightarrow$	(4) $POCl_3$
	(5) H_3PO_4

a) P $\rightarrow$ 2; Q $\rightarrow$ 3; R $\rightarrow$ 1; S $\rightarrow$ 5
b) P $\rightarrow$ 2; Q $\rightarrow$ 3; R $\rightarrow$ 4; S $\rightarrow$ 5
c) P $\rightarrow$ 3; Q $\rightarrow$ 5; R $\rightarrow$ 4; S $\rightarrow$ 2
d) P $\rightarrow$ 5; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 3

JEE Advanced 2024
Sample Paper - 4
Solution

Mathematics (MRQ)

1. **(b)** $\left(-\frac{9}{2\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$

   (d) $\left(\frac{9}{2\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$

   Explanation: If slope of tangents to hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2}$ = 1 is m, then equations of tangent to the hyperbola is y = $mx \pm \sqrt{a^2m^2 - b^2}$ with the points of contact $\left(\frac{\pm a^2m}{\sqrt{a^2m^2-b^2}}, \frac{\pm b^2}{\sqrt{a\frac{m^2-b^2}{}}}\right)$

   ∵ Tangent to hyperbola $\frac{x^2}{9} - \frac{y^2}{4}$ = 1 is parallel to 2x - y = 1,

   ∴ Slope of tangent = 2

   ∴ Points of contact are $\left(\frac{\pm 9\times 2}{\sqrt{9\times 4-4}}, \frac{\pm 4}{\sqrt{9\times 4-4}}\right)$

   i.e. $\left(\frac{9}{2\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$ and $\left(\frac{-9}{2\sqrt{2}}, \frac{-1}{\sqrt{2}}\right)$

2. **(c)** differentiable at x = 0 if a = 0 and b = 1

   (d) differentiable at x = 1 if a = 1 and b = 0

   Explanation: f(x) = a cos ($|x^3$ - x|) + b |x| sin ($|x^3$ + x|)

   a. If a = 0, b = 1

      ⇒ f(x) = |x| sin $|x^3$ + x|

      = x sin (x^3 + x)

      Which is differentiable every where.

   b. (c) If a = 1, b = 0 ⇒ f(x) = cos ($|x^3$ - x|) = cos (x^3 - x)

      Which is differentiable every where.

   c. When a = 1, b = 1, f(x) = cos (x^3 - x) + x sin (x^3 + x)

      Which is differentiable at x = 1

   Hence only options (differentiable at x = 0 if a = 0 and b = 1) and (differentiable at x = 1 if a= 1 and b = 0) are the correct options.

3. **(a)** $\mathrm{x}^9 - \mathrm{f(x)}$

   (c) $x - \int\limits_0^{\frac{\pi}{2}-x} f(t)\cos t dt$

   Explanation: Let us check the given options one by one.

   i. Let g(x) = x^9- f(x)

      ⇒ g(0) = -f(0) < 0 [∵ f(x) ∈ (0, 1)]

      And g(1) = 1 - f(1) > 0

      ∴ x^9 - f(x) = 0 for some x ∈ (0, 1)

   ii. Let $\mathrm{h(x)} = \mathrm{x} - \int\limits_0^{\frac{\pi}{2}-\mathrm{x}} \mathrm{f(t)}\cos \mathrm{t}\, d\mathrm{t}$

      h(0) = -$\int\limits_0^{\frac{\pi}{2}} f(t)\cos t dt$ < 0

      and h(1)= $1 - \int\limits_0^{\frac{\pi}{2}-1} f(t)\cos t dt > 0$

$\therefore$ h(0) < 0 and h(1) > 0 $\Rightarrow \mathrm{h}(\mathrm{x})=0$ at some x $\in$ (0, 1)

$\therefore \mathrm{h}(\mathrm{x})=\mathrm{x}-\int_0^{\frac{\pi}{2}-\mathrm{x}} \mathrm{f}(\mathrm{t}) \cos \mathrm{t} d\mathrm{t}=0$

at some $\mathrm{x} \in$ (0, 1)

iii. $e^{\mathrm{x}}-\int_0^{\mathrm{x}} \mathrm{f}(\mathrm{t}) \sin \mathrm{t} d\mathrm{t}$

$\because \mathrm{x} \in(0,1) \Rightarrow \mathrm{e}^{\mathrm{x}} \in(1, \mathrm{e})$

and 0 < f(t) < 1 and 0 < sin t < 1, ∀ x ∈ (0, 1)

$\therefore 0<\int_0^{\mathrm{x}} \mathrm{f}(\mathrm{t}) \sin \mathrm{t} d\mathrm{t}<1$

$\therefore e^x-\int_0^x f(t) \sin t d t \neq 0$ for any x ∈ (0, 1)

iv. $\mathrm{f}(\mathrm{x})+\int_0^{\frac{\pi}{2}} \mathrm{f}(\mathrm{t}) \sin \mathrm{t} d\mathrm{t}$ is always positive $\forall \mathrm{x} \in(0,1)$

Mathematics (MCQ)

4.

(c) $(\sqrt{3}, 2]$

Explanation: Given, ${}^{n-1}C_r = (k^2 - 3)\, {}^{n}C_{r+1}$

$\Rightarrow \quad {}^{n-1}C_r=\left(k^2-3\right) \frac{n}{r+1}{}^{n-1}C_r$

$\Rightarrow \quad k^2-3=\frac{r+1}{n}$ [since, $n \geq r \Rightarrow \frac{r+1}{n} \leq 1$ and n, r > 0]

$\Rightarrow \quad 0<k^2-3 \leq 1 \Rightarrow 3<k^2 \leq 4$

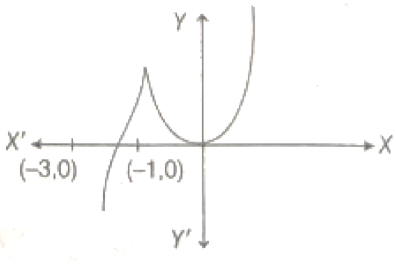
$\Rightarrow \quad k \in[-2,-\sqrt{3}) \cup(\sqrt{3}, 2]$

5.

(c) 2

Explanation: Given, $f(x)=\begin{cases}(2+x)^3, & \text{if } -3<x \leq-1 \\ x^{2/3}, & \text{if } -1<x<2\end{cases}$

$\Rightarrow \quad f'(x)=\begin{cases}3(x+2)^2, & \text{if } -3<x \leq-1 \\ \frac{2}{3} x^{\frac{1}{3}}, & \text{if } -1<x<2\end{cases}$



Clearly, f'(x) changes its sign at x = -1 from +ve to -ve and so f(x) has local maxima at x = -1.

Also, f'(0) does not exist but $f'(0^-) < 0$ and $f'(0^+) < 0$.

It can only be inferred that f(x) has a possibility of a minima at x = 0. Hence, the given function has one local maxima at x = -1 and one local minima at x = 0.

6.

(c) None of these

Explanation: Since, vertices of a triangle are $(0, \frac{8}{3})$, (1, 3) and (82, 30)

Now, $\frac{1}{2}\begin{vmatrix}0 & \frac{8}{3} & 1 \\ 1 & 3 & 1 \\ 82 & 30 & 1\end{vmatrix}$

$= \frac{1}{2}\left[-\frac{8}{3}(1-82)+1(30-246)\right]$

$= \frac{1}{2}$ [216 - 216] = 0

$\therefore$ Points are collinear.

7.

(b) $\frac{1}{n(n-1)}(1+nx^n)^{1-\frac{1}{n}}+K$

Explanation: Given: $f(x)=\frac{x}{(1+x^n)^{1/n}}$ for $n \geq 2$

$\Rightarrow fof(x) = f[f(x)] = f\left[\frac{x}{(1+x^n)^{1/n}}\right]$

$= \frac{\frac{x}{(1+x^n)^{1/n}}}{\left[1+\frac{x^n}{1+x^n}\right]^{1/n}} = \frac{x}{(1+2x^n)^{1/n}}$

Similarly, f o f o f(x) $= \frac{x}{(1+3x^n)^{1/n}}$

Proceeding in the same way, we get

g(x) = f o f o f .... o f(x) $= \frac{x}{(1+nx^n)^{1/n}}$ (f occurs n times)

Now, $\mathrm{I} = \int x^{n-2} g(x) dx = \int \frac{x^{n-1}}{(1+nx^n)^{1/n}} dx$

Let 1 + nx^n = t $\Rightarrow$ n^2x^{n-1}dx = dt

$\therefore I = \frac{1}{n^2}\int t^{-1/n} dt = \frac{1}{n^2} \cdot \frac{t^{-\frac{1}{n}+1}}{-\frac{1}{n}+1} + K$

$= \frac{1}{n} \cdot \frac{t^{1-1/n}}{n-1} + K = \frac{(1+nx^n)^{1-1/n}}{n(n-1)} + K$

Mathematics (NUM)

8. 157

Explanation:

AP (1, 3); 1, 4, 7, 10, 13 ...

AP (2, 5): 2, 7, 12, 17, 22 ...

AP (3, 7): 3, 10, 17, 24, 31 ...

For AP (1, 3) ∩ AP (2, 5) ∩ AP (3, 7)

first term will be the minimum common value of a term

$\therefore$ we need to find that minimum number which when divided by 7 leaves remainder 3 (7m + 3)

and when divided by 5 leaves remainder 2 (5p + 2)

and when divided by 3 leaves remainder 1 (3q +1)

By hit and trial 52 is such number (7 $\times$ 7 + 3)

$\therefore$ first term 'a' of intersection AP = 52

Also common difference 'd' of intersection AP

= LCM (7, 5, 3) = 105

$\therefore$ a + d = 52 + 105 = 157

9. 12.0

Explanation:

Image of centre $c_1 \equiv (1, 3)$ in x - y + 1 = 0 is given by

$\frac{x_1-1}{1} = \frac{y_1-3}{-1} = \frac{-2(1-3+1)}{1^2+1^2}$

$\Rightarrow x_1 = 2, y_1 = 2$

$\therefore$ Centre of circle $c_2 \equiv (2, 2)$

$\therefore$ Equation of c_2 be $x^2 + y^2 - 4x - 4y + \frac{38}{5} = 0$

Now radius of c_2 is $\sqrt{4+4-\frac{38}{5}}$ $r_2 = \sqrt{\frac{2}{5}}$

(radius of $C_1)^2$ = (radius of $c_2)^2$

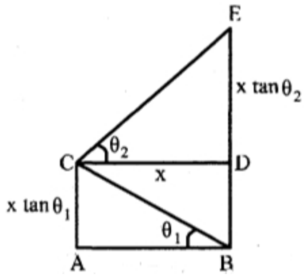
$\Rightarrow 10 - \alpha = \frac{2}{5} \Rightarrow \alpha = \frac{48}{5} \therefore \alpha + 6r^2 = \frac{48}{5} + \frac{12}{5} = 12$

10. 6.0

Explanation:

$\sqrt{3}BE = 4AB$

$\mathrm{Ar}(\triangle CAB) = 2\sqrt{3} - 3$



$\frac{1}{2}x^2 \cdot \tan\theta_1 = 2\sqrt{3} - 3$

$\mathrm{BE} = \mathrm{BD} + \mathrm{DE}$

$= x(\tan\theta_1 + \tan\theta_2)$

$\mathrm{BE} = \mathrm{AB}(\tan\theta_1 + \cot\theta_1)$ [$\because \sqrt{3}$BE = 4 AB]

$\frac{4}{\sqrt{3}} = (\tan\theta_1 + \cot\theta_1) \Rightarrow \tan\theta_1 = \sqrt{3}, \frac{1}{\sqrt{3}}$

$\theta_1 = \frac{\pi}{6}, \quad \theta_2 = \frac{\pi}{3}$ or $\theta_1 = \frac{\pi}{3}, \quad \theta_2 = \frac{\pi}{6}$,

As $\frac{\theta_2}{\theta_1}$ is largest $\therefore \theta_1 = \frac{\pi}{6}; \quad \theta_2 = \frac{\pi}{3}$

$\therefore x^2 = \frac{(2\sqrt{3}-3)\times 2}{\tan\theta_1} = \frac{\sqrt{3}(2-\sqrt{3})\times 2}{\tan\frac{\pi}{6}}$ [In (i)]

$\Rightarrow x^2 = 12 - 6\sqrt{3} = (3-\sqrt{3})^2 \Rightarrow x = 3 - \sqrt{3}$

Now perimeter of $\triangle \mathrm{CED} = \mathrm{CD} + \mathrm{DE} + \mathrm{CE}$

$= 3\sqrt{3} + (3-\sqrt{3})\sqrt{3} + (3-\sqrt{3}) \times 2 = 6$

11. 5

Explanation:

Given 8 vectors are

(1, 1, 1), (-1, -1, -1); (-1, 1, 1), (1, -1, -1); (1, -1, 1), (-1, 1, -1); (1, 1, -1), (-1, -1, 1)

These are the 4 diagonals of a cube and their opposites.

For 3 non-coplanar vectors first, we select 3 groups of diagonals and their opposite in ${}^4C_3$ ways. Then one vector from each group can be selected in 2 × 2 × 2 ways.

$\therefore$ Total ways = ${}^4C_3 \times 2 \times 2 \times 2 = 32 = 2^5$

$\therefore$ p = 5

12. 6.0

Explanation:

$f_2(x) = 98(x-1)^{50} - 600(x-1)^{49} + 2450$

$\Rightarrow f_2(x) = 2 \times 49 \times 50(x-1)^{49} - 50 \times 12 \times 49(x-1)^{48}$

$= 50 \times 49 \times 2(x-1)^{48}(x - 1 - 6)$

$= 50 \times 49 \times 2(x-1)^{48}(x-7)$

f_2 (x) has local minimum at x = 7 and no local maxima

$\Rightarrow m_2 = 1, n_2 = 0$

= 6 m_2 + 4n_2 + 8 $m_2 n_2$

= 6 ×1 + 4 × 0 + 8 × 1 = 6

13. 3

Explanation:

Given equations are

xyzsin 3θ = (y + z)cos3θ ...(i)

xyzsin3θ = 2zcos3θ + 2y sin 3θ ...(ii)

xyz sin3θ = (y + 2z)cos3θ + y sin3θ ...(iii)

On subtracting eq. (ii) from (i), we get

(cos3θ -2 sin θ)y - (cos3θ)z = 0 ...(iv)

On subtracting eq. (i) from (iii), we get

sin 3θ y + (cos3θ)z = 0 ...(v)

Eq. (iv) and (v) from the homogeneous system of linear equation.

But y $\neq$ 0, z $\neq$ 0

$\frac{\cos 3\theta - 2\sin 3\theta}{\sin 3\theta} = -\frac{\cos 3\theta}{\cos 3\theta} \Rightarrow \cos 3\theta = \sin 3\theta$

$\Rightarrow \tan 3\theta = 1 \Rightarrow 3\theta = n\pi + \frac{\pi}{4} \Rightarrow \theta = (4n+1)\frac{\pi}{12}, n \in Z$

For $\theta \in (0, \pi) \Rightarrow \theta = \frac{\pi}{12}, \frac{5\pi}{12}, \frac{3\pi}{4}$

$\therefore$ Three such solutions are possible.

Mathematics (MATCH)

14. **(a)** (P) - (1), (Q) - (2), (R) - (3), (S) - (4)

Explanation: (P) $\rightarrow$ (1) : z_k = cos$\frac{2k\pi}{10} + i\sin\frac{2k\pi}{10}$, k = 1 to 9

$\therefore z_k = e^{i\frac{2k\pi}{10}}$

Now $z_k z_j = 1 \Rightarrow z_j = \frac{1}{z_k} = e^{-i\frac{2k\pi}{10}} = \overline{z_k}$

We know if z_k is 10th root of unity so will be $\bar{z}_k$.

$\therefore$ For every z_k, there exist z_i = $\bar{z}_k$

Such that $z_k \cdot z_j = z_k \cdot \bar{z}_k$ = 1

Hence the statement is true.

(Q) $\rightarrow$ (2) z_1= z_k $\Rightarrow z = \frac{z_k}{z_1}$ for $z_1 \neq 0$

$\therefore$ We can always find a solution of z_1.z = z_k

Hence the statement is false.

(R) $\rightarrow$ (3): We know z^{10} -1 = (z - 1)(z - z_1)...(z - z_9)

$\Rightarrow$ (z - z_1) (z - z_2)...(z - z_9) $= \frac{z^{10}-1}{z-1}$

= 1 + z + z^2 + ...z^9

For z = 1, we get (1 - z_1) (1 - z_2)...(1 - z_9) = 10

$\therefore \frac{|1-z_1||1-z_2|\ldots|1-z_9|}{10}$ = 1

(S) $\rightarrow$ (4): 1, Z_1, Z_2, ..., Z_9 are 10th roots of unity.

$\therefore Z^{10}$ - 1 = 0

From equation 1 + Z_1 + Z_2 +...+ Z_9 = 0,

Re(1) + Re(Z_1) + Re(Z_2) +...+ Re(Z_9) = 0

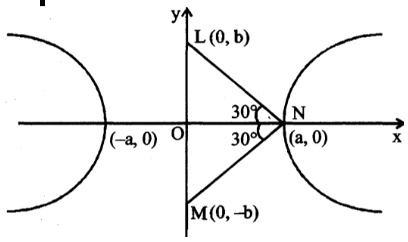
$\Rightarrow$ Re(Z_1) + Re(Z_2) + ... Re(Z_9) = -1

$\Rightarrow \sum_{K=1}^{9} \cos\frac{2k\pi}{10} = -1 \Rightarrow 1 - \sum_{K=1}^{9} \cos\frac{2k\pi}{10}$ = 2

Hence ((P) - (1), (Q) - (2), (R) - (3), (S) - (4)) is the correct option.

15. **(a)** P $\rightarrow$ 4; Q $\rightarrow$ 3; R $\rightarrow$ 1; S $\rightarrow$ 2

Explanation: Area of $\triangle$LMN = $4\sqrt{3}$ (given)



$\Rightarrow \frac{1}{2} \times$ LM $\times$ ON = $4\sqrt{3} \Rightarrow \frac{1}{2}$(2b)($\sqrt{3}b$) = $4\sqrt{3}$

$\therefore$ b^2 = 4 $\Rightarrow$ b = 2

So, length of the conjugate axis of hyperbola = 2b = 4

Now tan 30^{o} = $\frac{OL}{ON} = \frac{a}{b} \Rightarrow$ a = $\sqrt{3}b \Rightarrow$ a = $2\sqrt{3}$

$\therefore$ b^2 = a^2 (e^2 - 1) $\Rightarrow$ 4 = 12(e^2 - 1) $\Rightarrow$ e^2 = 1 + $\frac{1}{3}$ = $\frac{4}{3}$

$\therefore$ The eccentricity of hyperbola = e = $\frac{2}{\sqrt{3}}$ and

The distance between the foci of hyperbola = 2ae

= 2 $\times$ $2\sqrt{3}$ $\times = \frac{2}{\sqrt{3}}$ = 8

And length of latus ractum of hyperbola

= $\frac{2b^2}{a} = \frac{2\times4}{2\sqrt{3}} = \frac{4}{\sqrt{3}}$

16. **(a)** (I) $\rightarrow$ (Q); (II) $\rightarrow$ (S); (III) $\rightarrow$ (S); (IV) $\rightarrow$ (R)

Explanation: We have system of linear equations

x + y + z = 1 ...(i)

10x + 100y + 1000z = 0

x + 10y + 100z = 0 ...(ii)

qrx + pry + pqz = 0 ...(iii)

$\Rightarrow \frac{x}{p} + \frac{y}{q} + \frac{z}{r}$ = 0 ($\because$ p, q, r $\neq$ 0)

Let p = $\frac{1}{a+9d}$, q = $\frac{1}{a+99d}$, r = $\frac{1}{a+999d}$

Now, equation (iii) is

(a + 9d)x + (a + 99d)y + (a + 999d)z = 0

$$\Delta = \begin{vmatrix} 1 & 1 & 1 \\ 1 & 10 & 100 \\ a+9d & a+99d & a+999d \end{vmatrix} = 0$$

$$\Delta_x = \begin{vmatrix} 1 & 1 & 1 \\ 0 & 10 & 100 \\ 0 & a+99d & a+999d \end{vmatrix} = 900(d - a)$$

$$\Delta_y = \begin{vmatrix} 1 & 1 & 1 \\ 1 & 0 & 100 \\ a+9d & 0 & a+999d \end{vmatrix} = 990(a - d)$$

$$\Delta_z = \begin{vmatrix} 1 & 1 & 1 \\ 1 & 10 & 0 \\ a+9d & a+99d & 0 \end{vmatrix} = 90(d - a)$$

Let option I: If $\frac{q}{r}$ = 10 $\Rightarrow$ a = d

Δ = Δ_x = Δ_y = Δ_z = 0

Since eq. (i) and eq. (ii) represents non-parallel planes and eq. (ii) and eq. (iii) represents same plane

$\Rightarrow$ Infinitely many solutions
So, option I $\rightarrow$ P, Q, R, T
Option II: $\frac{p}{r} \neq 100 \Rightarrow a \neq d$
$\Delta = 0, \Delta_x, \Delta_y, \Delta_z \neq 0$
No solution
So, option II $\rightarrow$ S
Option III: $\frac{p}{q} \neq 10 \Rightarrow a \neq d$
No solution
So, option III $\rightarrow$ S
Option IV: If $\frac{p}{q} = 10 \Rightarrow a = d$
Infinitely many solution
Hence, IV $\rightarrow$ P, Q , R , T

17.
(b) (P) $\rightarrow$ (5), (Q) $\rightarrow$ (4), (R) $\rightarrow$ (3), (S) $\rightarrow$ (1)
Explanation: For largest possible distance between plane H_0 and l_2, the line l_2 must be parallel to plane H_0.
$\therefore H_0$ will be the plane containing the line l_1 and parallel to l_2

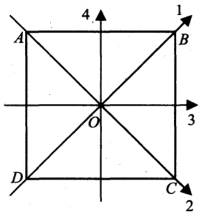
Normal vector $\overrightarrow{\mathbf{n}} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & 1 \\ 1 & 0 & 1 \end{vmatrix} = \hat{i} - \hat{k}$

$\therefore H_0 : x - z = \frac{c}{(0,0,0)} \Rightarrow c = 0$
$\therefore H_0 : x - z = 0$
(P) Distance of point (0,1, -1) from H_0.
$d(H_0) = \left|\frac{0-(1)}{\sqrt{2}}\right| = \frac{1}{\sqrt{2}}$
(Q) The distance of the point (0, 1, 2) from $H_0 = \left|\frac{0-2}{\sqrt{2}}\right| = \sqrt{2}$
(R) The distance of origin from $\mathrm{H}_0 = \left|\frac{0}{\sqrt{2}}\right| = 0$
(S) Point of intersection of planes y = z, x = 1 and H_0 is (1, 1, 1).
Distance $= \sqrt{1+1+1} = \sqrt{3}$.

Physics (MRQ)

18. **(a)** $I_1 + I_3$
(b) $I_3 + I_4$
(c) $I_1 + I_2$
Explanation: Since, ABCD is a square lamina hence by symmetry $I_1 = I_2$ and $I_3 = I_4$
From perpendicular axes theorem,
Moment of inertia about an axis perpendicular to square plate and passing from centre, O
$I_O = I_1 + I_2 = I_3 + I_4$
or $I_O = 2I_2 = 2I_3 \therefore I_2 = I_3$
$I_1 = I_2 = I_3 = I_4$
Therefore, I_O can be obtained by adding any two
i.e., $I_O = I_1 + I_2 = I_1 + I_3$
$= I_1 + I_4 = I_2 + I_3$

= $I_2 + I_4 = I_3 + I_4$



19. **(a)** The maximum displacement of the midpoint of the string, from its equilibrium position is 0.01 m

(c) The length of the string is 0.25 m

Explanation: y = [0.01 sin (62.8x)] cos (6281). [Given]

From the given equation, k $= \frac{2\pi}{\lambda} = 62.8 \therefore \lambda = \frac{2\pi}{62.8} = 0.1 \text{ m}$

Length of string, l $= 5 \times \frac{\lambda}{2} = 5 \times \frac{1}{20} = 0.25 \text{ m}$

The midpoint M is an antinode and has the maximum displacement = 0.01 m

The fundamental frequency, v = $\frac{v}{2l} = \frac{\frac{\omega}{k}}{2l} = \frac{628}{2\times0.25\times62.8} = 20 \text{ Hz}$

20. **(c)** For B = $\frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x - axis.

(d) For B > $\frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1

Explanation:

a. For the charge +Q to return region 1.

$\frac{mv^2}{\left(\frac{3R}{2}\right)}$ = QvB ⇒ $\frac{2p}{3R}$ = QB [Here, radius $r = \frac{3}{2}R$]

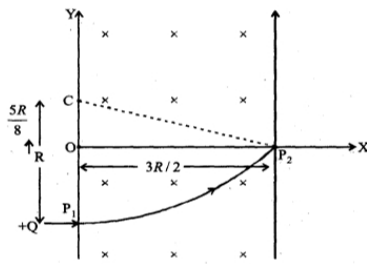
∴ B = $\frac{2p}{3QR}$

Therefore for B $\geq \frac{2p}{2QR}$, the particle will re-enter region 1.

b. When B = $\frac{8p}{13QR}$

$\frac{mv^2}{r}$ = Qv$\left(\frac{8p}{13QR}\right)$ ∴ r = $\frac{13R}{8}$

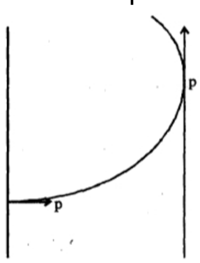
Thus 'C' is the of the centre of circular path of radius $\frac{13R}{8}$



Also $CP_2 = \sqrt{CO^2 + OP_2^2}\ \sqrt{\left(\frac{5R}{8}\right)^2 + \left(\frac{3R}{2}\right)^2}$

∴ $CP_2 = \frac{13R}{8}$

Thus the particle will enter region 3 through the point P_1 on X - axis



c. Change in momentum = $\sqrt{2}$ p

d. Further $\frac{mv^2}{r}$ = qvB ∴ r ∝ m

i.e., Distance is directly proportional to mass.

Physics (MCQ)

21.

(c) $[FL^{-4} T^2]$

Explanation: As, density =

$[F]^a[L^b][T^c]$

$[ML^{-3}] = [MLT^{-2}]^a[L]^b[T]^c$

$[ML^{-3}] = [M^aL^aT^{-2a}L^bT^c]$

$[M^1L^{-3}] = [M^aL^{a+b}T^{-2a+c}]$

On comparing

a = 1, a + b = -3, 1 + b = -3, b = -4

-2a + c = 0 ⇒ c = 2a

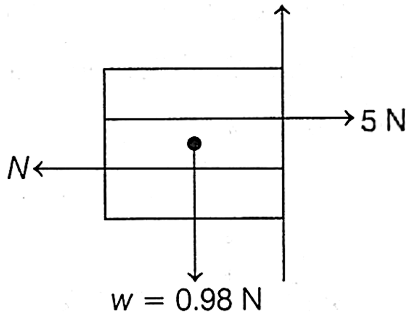
c = 2 ∴ Density = $[F^1L^{-4}T^2]$

22. **(a)** 0.98 N

Explanation:

N = 5N

$(f)_{max} = \mu N = (0.5)(5) = 2.5$ N



For vertical equilibrium of the block,

f = mg = 0.98 N < $(f)_{max}$

23.

(d) 22.4 km/s

Explanation: Escape velocity, $v_e = \sqrt{\frac{2GM_e}{R_e}} = 11.2\text{km/s}$

For $R' = \frac{R_e}{2} M'$ = $2M_e$

$v_e' = \sqrt{\frac{2G(2M_e)}{\frac{R_e}{2}}}$ = $2v_e$ = 22.4km/s

24.

(c) 8.0×10^{-19} C

Explanation: qE = mg ...(i)

$6\pi\eta\, rv = mg$

$\frac{4}{3}\pi r^3 \rho g = mg$ ...(ii)

$\therefore \quad r = \left(\frac{3mg}{4\pi\rho g}\right)^{1/3}$

Substituting the value of r in Eq. (ii) we get,

$6\pi\eta v\left(\frac{3mg}{4\pi\rho g}\right)^{1/3} = mg$

or $(6\pi\eta v)^3 \left(\frac{3mg}{4\pi\rho g}\right) = (mg)^3$

Again substituting mg = qE we get,

$(qE)^2 = \left(\frac{3}{4\pi\rho g}\right)(6\pi r v)^3$

or $qE = \left(\frac{3}{4\pi\rho g}\right)^{1/2}(6\pi r/v)^{3/2}$

$\therefore \quad q = \frac{1}{E}\left(\frac{3}{4\pi\rho g}\right)^{1/2}(6\pi r v)^{3/2}$

Substituting the values we get ,

$q = \frac{7}{81\pi\times10^5}\sqrt{\frac{3}{4\pi\times900\times9.8}\times216\pi^3}\times\sqrt{\left(18\times10^{-5}\times2\times10^{-3}\right)^3}$

= 8.0 $\times$ 10^{-19} C

Physics (NUM)

25. 2

Explanation:

For the convex spherical refracting surface i.e., air-oil interface

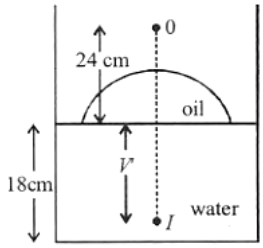
u = -24 cm, v = ?, u_1 = 1, $\mu_2 = \frac{7}{4}$ and R = 6 cm

$\frac{-\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2-\mu_1}{R}$

$\therefore \frac{-1}{(-24)} + \frac{\frac{7}{4}}{v} = \frac{\frac{7}{4}-1}{6}$

$\therefore$ v = 21 cm

This image will not as object for the water-oil interface



u = 21 cm, v = v', $\mu_1 = \frac{7}{4}$, $\mu_2 = \frac{4}{3}$ anf R = ∞

$\frac{\frac{-7}{4}}{+21} + \frac{\frac{4}{3}}{V'}$ = 0

$\therefore v'$ = 16 cm

Therefore the distance of the image from the bottom of the tank = 18 - 16 = 2 cm

26. 0

Explanation:

The heat required for 100 g of ice at 0° C to change into water at 0° C = mL = 100 $\times$ 80 $\times$ 4.2 = 33,600 J

The heat released by 300 g of water at 25° C to change its temperature to 0° C = mcΔT = 300 $\times$ 4.2 $\times$ 25 = 31,500 J

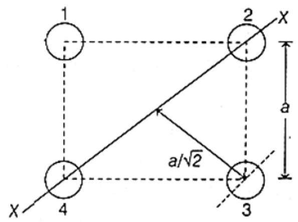
Hence complete ice will not melt, so the final temperature of the mixture will be 0°C.

27. 9

Explanation:

r = $\frac{d}{2} = \frac{\sqrt{5}}{2}$ cm = $\frac{\sqrt{5}}{2}\times10^{-2}$ m $\Rightarrow$ m = 0.5 kg

a = 4 cm = 4 $\times$ 10^{-2} m



$I_{XX} = I_1 + I_2 + I_3 + I_4$

$= \left[\frac{2}{5}mr^2 + m\left(\frac{a}{\sqrt{2}}\right)^2\right] + \frac{2}{5}mr^2 + \left[\frac{2}{5}mr^2 + m\left(\frac{a}{\sqrt{2}}\right)^2\right] + \frac{2}{5}mr^2$

Substituting the values, we get

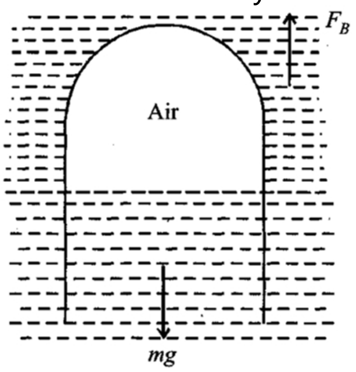
$I_{XX} = 9 \times 10^{-4}$ kg m^2

$\therefore$ N = 9

28. 0.3

Explanation:

When tube + air system starts sinking



$F_B = mg$

$\Rightarrow \rho_0(V_{\text{glass}} + V_{\text{gas}}) = m$

$1(2 + V_{gas}) = 5$

$\Rightarrow V_{gas} = 3cc$

Hence $\Delta V = V_0 - V_{gas}$

= 3.3 cc - 3cc = 0.3 cc.

$\therefore x = \Delta V = 0.3$

29. 3.0

Explanation:

$K_{max} = E - W \Rightarrow E_4 \rightarrow 3 = K_{max} + W = 1.95 + \frac{hc}{\lambda}$

$= 1.95 + \frac{1240}{310} = 5.95$ eV

$13.6\ Z^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 5.95$

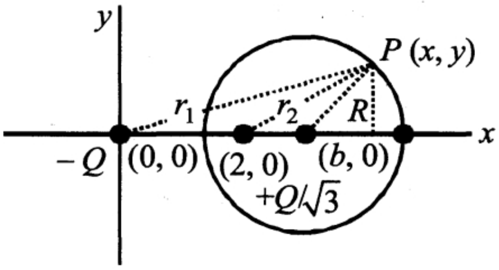
$13.6\ Z^2\left(\frac{7}{9\times16}\right) = 5.95 \Rightarrow Z^2 = \frac{5.95\times9\times16}{13.6\times7} = 9$

$\therefore Z = 3$

30. 3.0

Explanation:

let us consider a point P on the circle



$V_P = 0 = \frac{k(-Q)}{r_1} + \frac{\frac{kQ}{\sqrt{3}}}{r_2} \Rightarrow \frac{kQ}{r_1} = \frac{\frac{kQ}{\sqrt{3}}}{r_2}$

$\Rightarrow \frac{1}{\sqrt{x^2+y^2}}$ - $\frac{1}{\sqrt{3}\sqrt{(x-2)^2+y^2}}$

$\Rightarrow 3(x-2)^2 + 3y^2 = x^2 + y^2$

$\Rightarrow 3(x^2 + 4 - 4x) - x^2 + 2y^2 = 0 \Rightarrow 2x^2 + 12 - 12x + 2y^2 = 0$

$\Rightarrow x^2 + 6 - 6x + y^2 = 0 \Rightarrow (x-3)^2 + y^2 = (\sqrt{3})^2$

or $(x-b)^2 + y^2 = (\sqrt{3})^2 = R^2$

$\therefore$ R = $\sqrt{3}$ = 1.73 and b = 3

Physics (MATCH)

31. **(a)** (I) $\rightarrow$ (P); (II) $\rightarrow$ (R); (III) $\rightarrow$ (T); (IV) $\rightarrow$ (Q)

Explanation:

I. By first law of thermodynamics.

$\Delta U = \Delta Q - \Delta W$

$= ML_V - P\Delta V$

$= 10^{-3} \times 2250 \times 10^3 - 10^5 \times (10^{-3} - 10^{-6})$

= 2250 - 100 = 2150 J

= 2.15 kJ. So, (I) $\rightarrow$ (P)

II. $P = \frac{nRT}{V} = \frac{0.2 \times 8 \times 500}{V} = \frac{800}{V}$ Pa

$\Delta U = \frac{f}{2} P\Delta V = \frac{5}{2} \times \frac{800}{V} \times 2$ V = 4000 J = 4 kJ

So (II) $\rightarrow$ (R)

III. $PV^\gamma =$ const $\Rightarrow P_1 V_1^\gamma = P_2 V_2^\gamma$

$\Rightarrow 2 V^\gamma = P_2 \left(\frac{V}{8}\right)^\gamma \Rightarrow P_2 = 2 \times 8^\gamma = 2 \times 8^{5/3}$ = 64 kPa

So, $\Delta U = \frac{f}{2}(P_2 V_2 - P_1 V_1)$

$= \frac{3}{2}\left(64 \times \frac{1}{24} - 2 \times \frac{1}{3}\right) \times 10^3$ = 3 kJ

So, (III) $\rightarrow$ (T)

IV. Here f = 7

So, $\Delta U = nC_V \Delta T = \frac{t}{2} nR\Delta T = \frac{7}{2} nR\Delta T$

and, $\Delta Q = nC_V \Delta T = \left(\frac{f}{2} + 1\right) nR\Delta T = \frac{9}{2} nR\Delta T = \frac{9}{2} \times \frac{2}{7}\ \Delta U = \frac{9}{7}\Delta U$

So, $\Delta U = \frac{7}{9}\Delta Q = \frac{7}{9} \times 9$ = 7 kJ. So (IV) $\rightarrow$ (Q)

32.

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

Explanation: For double convex lens, (P) $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

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

$\frac{1}{F_{eq.}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{r} + \frac{1}{r} = \frac{2}{r}$

$\therefore F_{eq} = \frac{r}{2}$

For (Q) plano-convex lens $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

= (1.5 - 1)$\left[\frac{1}{\infty}-\frac{1}{-r}\right]$ = $\frac{0.5}{r}$ = $\frac{1}{2r}$ $\therefore$ f = 2r

$\frac{1}{F_{eq.}}$ = $\frac{1}{f_1}+\frac{1}{f_2}$ = $\frac{1}{2r}+\frac{1}{2r}$ = $\frac{2}{2r}$ = $\frac{1}{r}$ $\therefore$ $F_{eq.}$ = r

For (R) plano-concave lens

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

$\frac{1}{F_{eq.}}$ = $\frac{1}{f}+\frac{1}{f}$ = $\frac{1}{-2r}+\frac{1}{-2r}$ $\Rightarrow$ $F_{eq.}$ = -r

For (S) combination of one double convex and one planoconcave lens

$\frac{1}{F_{eq.}}$ = $\frac{1}{r}+\frac{1}{-2r}$ = $\frac{1}{2r}$ $\Rightarrow$ $F_{eq.}$ = 2r

33. **(a)** (P) - (2); (Q) - (1); (R) - (4); (S) - (3)

Explanation: In B^{+}- decay mass number (Z) decreases by 1 and mass number (A) remains unchanged.

$^{15}_{8}\mathrm{O} \longrightarrow {}^{15}_{7}\mathrm{N} + {}^{0}_{1}\beta$

In α-decay mass number (A) decreases by 4 unit and atomic number (Z) by 2 unit.

$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + \underset{2-\text{ particle}}{4}\mathrm{He}$

In proton $\left({}^{1}_{1}\mathrm{H}\right)$ emission both (A) and (Z) decreases by 1 .

$^{185}_{83}\mathrm{Bi} \longrightarrow {}^{184}_{82}\mathrm{Pb} + {}^{1}_{1}\mathrm{H}$

In fission process heavier nucleus breaks into two fragments.

$^{239}_{94}\mathrm{Pu} \longrightarrow {}^{140}_{57}\mathrm{La} + {}^{99}_{37}\mathrm{X}$

34.

(d) (I) $\rightarrow$ (P), (II)$\rightarrow$ (R), (III)$\rightarrow$ (S), (IV)$\rightarrow$ (Q)

Explanation: Frequency, v = $\frac{1}{2\ell}\sqrt{\frac{\mathrm{T}}{\mathrm{m}}}$ for first mode of vibration

For 'v' to be maximum, 'l' should be minimum.

String - 1 $\mathrm{f}_0=\frac{1}{2\,\mathrm{L}_0}\sqrt{\frac{\mathrm{T}_0}{\mu}}$

String - 2 $\mathrm{f}_2=\frac{1}{2\,\mathrm{L}_0}\sqrt{\frac{\mathrm{T}_0}{2\mu}}=\frac{\mathrm{f}_0}{\sqrt{2}}$

String - 3 $f_3=\frac{1}{2L_0}\sqrt{\frac{T_0}{4\mu}}=\frac{f_0}{\sqrt{3}}$

String - 4 $\mathrm{f}_4=\frac{1}{2\,\mathrm{L}_0}\sqrt{\frac{\mathrm{T}_0}{4\mu}}=\frac{\mathrm{f}_0}{2}$

Chemistry (MRQ)

35. **(a)** 2-Hydroxypropane

(b) acetophenone

Explanation: Iodoform reaction is given by the compounds containing - $COCH_3$, -$CH(OH)CH_3$ group and also CH_3CH_2OH and CH_3CHO.

2-Hydroxypropane ($CH_3CHOHCH_3$) contains the grouping CH_3CHOH - and acetophenone ($C_6H_5COCH_3$) contains the grouping CH_3CO -.

36. **(a)** decreases the activation energy

(b) alters the reaction mechanism

Explanation: A catalyst provides a new path of lower activation energy. The catalyst reacts with the reactants to form an activated complex of low activation energy. The activated complex then decomposes to form the products along with regeneration of catalyst. Thus, the reaction mechanism changes completely.

37. **(a)** $W_{isothermal} > W_{adiabatic}$

(c) T_1 = T_2

(d) $\Delta U_{isothermal} > \Delta U_{adiabatic}$

Explanation: T_1 = T_2 because process is isothermal.

Work done in adiabatic process is less than in isothermal process because area covered by isothermal curve is more than the area covered by the adiabatic curve.
In adiabatic process expansion occurs by using internal energy, hence, it decreases while in isothermal process temperature remains constant, that's why no change in internal energy.

Chemistry (MCQ)

38.

(b) N^{3-}, O^{2-}, F^- and Na^+

Explanation: The species with its atomic number and number of electrons are as follows:

Species (ions)	At. no. (Z)	No. of electrons
N^{3-}	7	7 + 3 = 10
O^{2-}	8	8 + 2 = 10
F^-	9	9 + 1 = 10
Na^+	11	11 - 1 = 10
Li^+	3	3 - 1 = 2
Mg^{2+}	12	12 - 2 = 10

Thus, option (N^{3-}, O^{2-}, F^- and Na^+) contains isoelectronic set of ions.

39.

(c) $AlCl_3$

Explanation: $AlCl_3$ is more acidic in aqueous solution as on hydrolysis, it gives weak base and strong acid.

$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$

40.

(d) $Zn(OH)_2$

Explanation: $\mathrm{Zn}^{2+} + 2\mathrm{H}_2\mathrm{O} \longrightarrow \underset{\text{White}}{\mathrm{Zn(OH)}_2} \downarrow + 2\mathrm{H}^+$

41.

(c) $BrCH_2CH_2COOH$

Explanation:

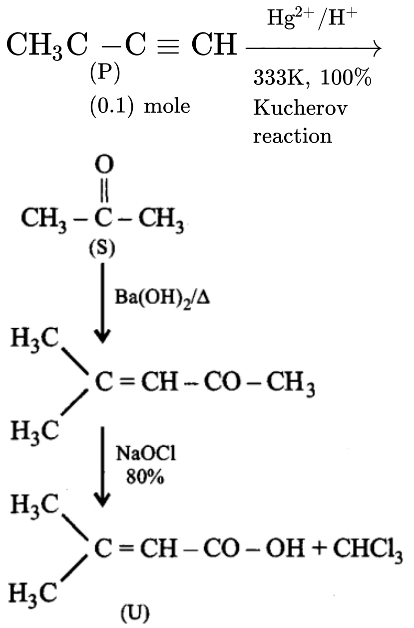
i. The acidity increases with the increase in electronegativity of the halogen present.
ii. The inductive effect decreases with increase in distance of halogen atom from the carboxylic group and hence, the strength of acid proportionally decreases.

Smallest dissociation constant means weakest acid, which is $BrCH_2$ CH_2COOH because here Br (less electronegative than F) is two carbon atoms away from - COOH.

Chemistry (NUM)

42. 3.2

Explanation:



From 0.1 mol of P, 0.032 mol of U is produced.
So, the value of y = 0.032 × 100 = 3.2 g

43. 65.25

Explanation:

Given, P^0 = 640 mm, P_S = 600mm.

w = 2.175g, W = 390g, $M_{C_\theta H_6} = 78$

$\because \quad \frac{(P^0 - P_S)}{P_S} = \frac{(w \times M)}{(m \times W)}$

$\therefore \frac{(640-600)}{600} = \frac{(2.175 \times 78)}{(m \times 39)}$

$\therefore$ m = 65.25g mol^{-1}

44. 557

Explanation:

ΔH = ΔU + Δ(PV) = ΔU + VΔP ($\because$ ΔV = 0)

or ΔU = ΔH - VΔP = -560 -[1(40 - 70) × 0.1]

= -560 + 3 = -557 kJ mol^{-1}

So, the magnitude is 557 kJ mol^{-1}

45. 4.14

Explanation:

Energy of Photon

$= \frac{hc}{\lambda}\mathbf{J} = \frac{hc}{e\lambda}\text{eV} = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9} \times 1.602 \times 10^{-19}}$ = 4.14 eV

For the photoelectric effect to occur, the energy of incident photons must be greater than the work function of the metal. Hence, only Li, Na, K, and Mg have work functions less than 4.14 V.

46. -8500

Explanation:

For the reaction,

A(g) + B(g) $\leftrightharpoons$ AB(g)

Given E_{ab} = E_{af} + 2RT or E_{ab} - E_{af} = 2RT

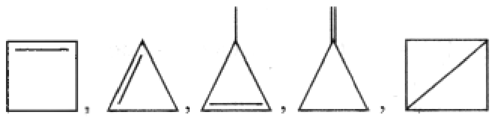
Further

A_f = $4A_b$ or $\frac{A_f}{A_b}$ = 4

Now, the rate constant for forward reaction,

$k_f = A_f e^{-E_{af}/RT}$
Likewise, rate constant for backward reaction,
$k_b = A_b e^{-E_{ab}/RT}$
At equilibrium, Rate of forward reaction = Rate of backward reaction
i.e, $k_f = k_b$ or $\frac{k_f}{k_h} = k_{eq}$
so k_{eq} = $\frac{A_f e^{-E_{af}/RT}}{A_b e^{-E_{ab}/RT}} = \frac{A_f}{A_b} e^{-\left(E_{a_f} - E_{a_b}\right)/RT}$
After putting the given values
$k_{eq} = 4e^2$ (as $E_{ab} - E_{af}$ = 2RT and $\frac{A_f}{A_b}$ = 4)
Now, $\Delta G^\circ = -RT \ln K_{\text{eq}}$ = -2500 ln $(4e^2)$
= -25000 (ln 4 + ln e^2) = -2500 (1.4 + 2)
= -2500 × 3.4 = -8500 J/mol
Absolute value = -8500 J/mol

47. 5
Explanation:

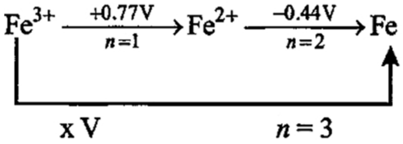


Chemistry (MATCH)

48. **(a)** A - (ii), B - (iii), C - (iv), D - (i)
Explanation: Density of CH_2Cl_2 is greater than H_2O. Therefore they can be separated by differential solvent extraction. Due to H-bonding in p-nitrophenol it can be separated from other component by column chromatography.
Due to different boiling point of kerosene and Naphthalene, it can be separated by fractional distillation. NaCl (ionic compound) and $C_6H_{12}O_3$ can be separated by crystallisation.

49.
(c) A - w; B - s, t ; C - p; D - q, r
Explanation: (p) $[\mathrm{FeF_6}]^{4-}, \mathrm{Fe}^{2+}$ = $3d^6$ and F^- is weak field ligand
∴ Hybridization is sp^3d^2 (high spin complex)
(q) $[\mathrm{Ti(H_2O)_3Cl_3}]$, Ti^{3+} = $3d^1$ (No effect of ligand field strength)
∴ Hybridization is d^2sp^3
(r) $[\mathrm{Cr(NH_3)_6}]^{3+}, \mathrm{Cr}^{3+}$ = $3d^3$ (No effect of ligand field strength)
∴ Hybridization is d^2sp^3
(s) $[\mathrm{FeCl_4}]^{2-}, 3d^6$ and Cl^- is weak field ligand
∴ Hybridization is sp^3
(t) $[\mathrm{Ni(CO)_4}]$, Ni = $3d^{10}$ and CO is strong field ligand
∴ Hybridization is sp^3
(w) $[\mathrm{Ni(CN)_4}]^{2-}, \mathrm{Ni}^{2+}$ = $3d^8$ and CN is strong field ligand
∴ Hybridization is dsp^2

50. **(a)** (P) - (3), (Q) - (4), (R) - (1), (S) - (2)
Explanation:

p. 

$$\Delta G^{o}_{Fe^{3+}/Fe} = \Delta G^{o}_{Fe^{3+}/Fe^{2+}} + \Delta G^{0}_{Fe^{2+}/Fe}$$

$$\Rightarrow -3 \times FE^{o}_{(Fe^{+3}/Fe)} = -1 \times FE^{o}_{(Fe^{+3}/Fe^{+2})} + \left(-2 \times FE^{o}_{Fe^{+2}/Fe}\right)$$

$\Rightarrow 3 \times x = 1 \times 0.77 + 2 \times (-0.44)$

$\Rightarrow x = -\frac{0.11}{3} V \simeq -0.04$ V.

q.

$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$ $\quad E^\circ = -1.23\,V$

$4e + O_2 + 2H_2O \longrightarrow 4OH^-$ $\quad E^\circ = +0.40\,V$

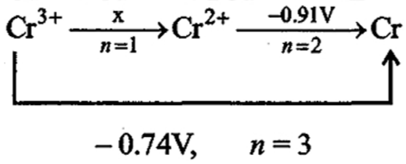
$4H_2O \longrightarrow 4H^+ + 4OH^-$ $\quad E^\circ = -0.83\,V$

r.

$Cu^{2+} + 2e \longrightarrow Cu$ $\quad E^\circ = +0.34\,V$

$2Cu \longrightarrow 2Cu^+ + 2e$ $\quad E^\circ = -0.52\,V$

$Cu^{2+} + Cu \longrightarrow 2Cu^+$ $\quad E^\circ = -0.18\,V$

s. 

$x \times 1 + 2 \times (-0.91) = 3 \times (-0.74)$

$x - 1.82 = -2.22 \Rightarrow x = -0.4$ V

51.

(b) P → 2; Q → 3; R → 4; S → 5

Explanation: (P) $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$

(Q) $P_4 + 3NaOH + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$

(R) $PCl_5 + CH_3COOH \rightarrow CH_3COCl + POCl_3 + HCl$

(S) $H_3PO_2 + 2H_2O + 4AgNO_3 \rightarrow 4Ag + 4HNO_3 + H_3PO_4$