47 JEE ADVANCED

YEARS (2024 TO 1978)

CHAPTER-WISE & TOPIC-WISE SOLVED PAPERS

FIRST TIME EVER!

Analyse the question-wise difficulty level in real-time with Correct (C), Wrong (W) and Unattempted (UA) questions response tagging provided by IIT-JEE

MATHEMATICS

ANSWER KEY VERIFIED FROM OFFICIAL WEBSITE OF JEE ADVANCED

JEE ADVANCED 2024 Paper Analysis

Paper 1

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	Matrix Type Questions	4	3	–1	12
	Total Questions per subject	17			60

Paper 2

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	(Numerical Value Based Questions)	4	3	–1	12
	Total Questions per subject	17			60

Total No. of Questions in Part 1 = 51 Questions

Total No. of Questions in Part 2 = 51 Questions

Each Subject Carries = 60 Marks

Total Marks = 180

Paper Analysis

Paper Difficulty Compared to Last Year	Easier Compared to 2023 Paper
Overall Difficulty Level of JEE 2024	
Easy	18%
Moderate	49%
Difficult	33%

Mathematics Topics	Paper 1 Difficulty Level	Paper 2 Difficulty Level	Remarks
Basic maths	1 moderate question from basic mathematics	no question from this topic in paper 2	
Functions & Relations	1 easy question from this topic	Total 5 topics from Functions & relations out of which, 1 is difficult, 2 questions are easy and 2 questions are moderate	
Algebra - Matrix, trigonometry, sets, complex number, quadratic, inverse trigonometry	1 easy question from trigonometry, 1 tough question from complex number, 1 moderate question from Quadratic & complex number, 2 moderate question from Matrix & determinant, 2 question from Permutation & combination,	1 Easy Question from inverse trigonometry	
Coordinate geometry	1 moderate question from Ellipse, 1 tough question from Straight line, 1 easy question from circles	2 moderate questions from conic sections	

CONTENTS

HINTS AND SOLUTIONS

2024

JEE ADVANCED SOLVED PAPER

Mathematics Paper-1

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If **ONLY** the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : –1 In all other cases.

1. Let $f(x)$ be a continuously differentiable function on the interval $(0, \infty)$ such that $f(1) = 2$ and $\lim\limits_{t \to x} \frac{t^{10} f(x) - x^{10} f(t)}{t^9 - x^9} = 1$ for each $x > 0$. Then, for all $x > 0$, $f(x)$ is equal to

(*a*) $\frac{31}{11x} - \frac{9}{11}x^{10}$ (*b*) $\frac{9}{11x} + \frac{13}{11}x^{10}$

(*c*) $\frac{-9}{11x} + \frac{31}{11}x^{10}$ (*d*) $\frac{13}{11x} + \frac{9}{11}x^{10}$

2. A student appears for a quiz consisting of only true-false type questions and answers all the questions. The student knows the answers of some questions and guesses the answers for the remaining questions. Whenever the student knows the answer of a question, he gives the correct answer. Assume that the probability of the student giving the correct answer for a question, given that he has guessed it, is $\frac{1}{2}$. Also assume that the probability of the answer for a question being guessed, given that the student's answer is correct, is $\frac{1}{6}$. Then the probability that the student knows the answer of a randomly chosen question is

(*a*) $\frac{1}{12}$ (*b*) $\frac{1}{7}$ (*c*) $\frac{5}{7}$ (*d*) $\frac{5}{12}$

3. Let $\frac{\pi}{2} < x < \pi$ be such that $\cot x = \frac{-5}{\sqrt{11}}$. Then

$\left(\sin\frac{11x}{2}\right)(\sin 6x - \cos 6x) + \left(\cos\frac{11x}{2}\right)(\sin 6x + \cos 6x)$ is equal to

(*a*) $\frac{\sqrt{11}-1}{2\sqrt{3}}$ (*b*) $\frac{\sqrt{11}+1}{2\sqrt{3}}$ (*c*) $\frac{\sqrt{11}+1}{3\sqrt{2}}$ (*d*) $\frac{\sqrt{11}-1}{3\sqrt{2}}$

4. Consider the ellipse $\frac{x^2}{9} + \frac{y^2}{4} = 1$. Let $S(p, q)$ be a point in the first quadrant such that $\frac{p^2}{9} + \frac{q^2}{4} > 1$. Two tangents are drawn from S to the ellipse, of which one meets the ellipse at one end point of the minor axis and the other meets the ellipse at a point T in the fourth quadrant. Let R be the vertex of the ellipse with positive x-coordinate and O be the center of the ellipse. If the area of the triangle ΔORT is $\frac{3}{2}$, then which of the following options is correct?

(*a*) $q = 2, p = 3\sqrt{3}$ (*b*) $q = 2, p = 4\sqrt{3}$

(*c*) $q = 1, p = 5\sqrt{3}$ (*d*) $q = 1, p = 6\sqrt{3}$

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;
Partial Marks : +3 If all the four options are correct but **ONLY** three options are chosen;
Partial Marks : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;
Partial Marks : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks: –2 In all other cases.

- For example, in a question, if (*a*), (*b*) and (*d*) are the **ONLY** three options corresponding to correct answers, then
choosing ONLY (*a*), (*b*) and (*d*) will get +4 marks;
choosing ONLY (*a*) and (*b*) will get +2 marks;
choosing ONLY (*a*) and (*d*) will get +2 marks;
choosing ONLY (*b*) and (*d*) will get +2 marks;
choosing ONLY (*a*) will get +1 mark;
choosing ONLY (*b*) will get +1 mark;
choosing ONLY (*d*) will get +1 mark;
choosing no option (i.e. the question is unanswered) will get 0 marks; and
choosing any other combination of options will get –2 marks.

2 COMPLEX NUMBERS

JEE-Advanced

Definition Based

Single Correct

1. If $x+iy=\begin{vmatrix}6i & 3i & 1\\ 4 & 3i & -1\\ 20 & 3 & i\end{vmatrix}$, find x and y. **[IIT-JEE 1998]**

(a) $x = 3, y = 1$ (b) $x = 1, y = 1$

(c) $x = 0, y = 3$ (d) $x = 0, y = 0$

2. The value of sum $\sum_{n=1}^{13}\left(i^n+i^{n+1}\right)$, where $i=\sqrt{-1}$, equals **[IIT-JEE 1998]**

(a) i (b) $i-1$

(c) $-i$ (d) 0

3. For positive integers n_1, n_2 the value of expression $(1 + i)^{n_1} + (1 + i^3)^{n_1} + (1 + i^5)^{n_2} + (1 + i^7)^{n_2}$, here $i=\sqrt{-1}$ is a real number, if and only if **[IIT-JEE 1996]**

(a) $n_1 = n_2 + 1$ (b) $n_1 = n_2 - 1$

(c) $n_1 = n_2$ (d) $n_1 > 0, n_2 > 0$

4. The smallest positive integer n for which $\left(\frac{1+i}{1-i}\right)^n=1$, is **[IIT-JEE 1980]**

(a) 8 (b) 16

(c) 12 (d) None of these

Numerical/Integer Types

5. Let $A=\left\{\frac{1967+1686i\sin\theta}{7-3i\cos\theta}:\theta\in\mathbb{R}\right\}$. If A contains exactly one positive integer n, then the value of n is

C-10.77 W-57.72 UA-31.51 **[JEE Adv. 2023]**

Properties of Conjugate and Modulus

Single Correct

6. Let complex numbers α and $1/\bar{\alpha}$ lies on circles $(x-x_0)^2+(y-y_0)^2=r^2$ and $(x-x_0)^2+(y-y_0)^2=4r^2$, respectively. If $z_0=x_0+iy_0$ satisfies the equation $2|z_0|^2=r^2+2$ then $|\alpha|$ is equal to

C-26.76 W 63.3 UA-9.94 **[JEE Adv. 2013]**

(a) $\frac{1}{\sqrt{2}}$ (b) $\frac{1}{2}$

(c) $\frac{1}{\sqrt{7}}$ (d) $\frac{1}{3}$

7. Let z be a complex number such that the imaginary part of z is non-zero and $a = z^2 + z + 1$ is real. Then, a cannot take the value

C-14.09 W-45.71 UA-40.19 **[IIT-JEE 2012]**

(a) -1 (b) $\frac{1}{3}$

(c) $\frac{1}{2}$ (d) $\frac{3}{4}$

8. Let $z = x + iy$ be a complex number where, x and y are integers. Then, the area of the rectangle whose vertices are the root of the equation $z\bar{z}^3 + \bar{z}z^3 = 350$, is **[IIT-JEE 2009]**

(a) 48 (b) 32

(c) 40 (d) 80

9. If $w = \alpha + i\beta$, where $\beta \neq 0$ and $z \neq 1$, satisfies the condition that $\left(\frac{w-\bar{w}z}{1-z}\right)$ is purely real, then the set of values of z is **[IIT-JEE 2006]**

(a) $|z| = 1, z \neq 2$ (b) $|z| = 1$ and $z \neq 1$

(c) $z = \bar{z}$ (d) None of these

10. If $|z| = 1$ and $w=\frac{z-1}{z+1}$ (where, $z \neq -1$), then $Re(w)$ is **[IIT-JEE 2003]**

(a) 0 (b) $\frac{1}{|z+1|^2}$

(c) $\left|\frac{1}{z+1}\right|\cdot\frac{1}{|z+1|^2}$ (d) $\frac{\sqrt{2}}{|z+1|^2}$

11. If z_1, z_2 and z_3 are complex numbers such that $|z_1|=|z_2|=|z_3|=\left|\frac{1}{z_1}+\frac{1}{z_2}+\frac{1}{z_3}\right|1,$, then $|z_1 + z_2 + z_3|$ is **[IIT-JEE 2000]**

(a) equal to 1 (b) less than 1

(c) greater than 3 (d) equal to 3

12. The complex numbers numbers $\sin x + i \cos 2x$ and $\cos x - i \sin 2x$ are conjugate to each other, for **[IIT-JEE 1988]**

(a) $x = n\pi$ (b) $x = 0$

(c) $x = (n + 1/2)\pi$ (d) no value of x

13. If $z = x + iy$ and $w = (1 - iz)/(z - i)$, then $|w| = 1$ implies that, in the complex plane **[IIT-JEE 1989]**

(*a*) z lies on the imaginary axis

(*b*) z lies on the real axis

(*c*) z lies on the unit circle

(*d*) None of these

Multiple Correct

14. Lei $\bar{z}$ denote the complex conjugate of a complex number z. If z is a non-zero complex number for which both real and imaginary parts of $(\bar{z})^2 + \frac{1}{z^2}$ are integers, then which of the following is/are possible value(s) of $|z|$? C-2.14 W-26.93 UA-70.92 **[JEE Adv. 2022]**

(*a*) $\left(\frac{43+3\sqrt{205}}{2}\right)^{\frac{1}{4}}$ (*b*) $\left(\frac{7+\sqrt{33}}{4}\right)^{\frac{1}{4}}$

(*c*) $\left(\frac{9+\sqrt{65}}{4}\right)^{\frac{1}{4}}$ (*d*) $\left(\frac{7+\sqrt{13}}{6}\right)^{\frac{1}{4}}$

15. Let S be the set of all complex numbers z satisfying $|z^2 + z + 1| = 1$. Then which of the following statements is/are true?

C-8.01 W-31.31 UA-49.59 PC-11.09 **[JEE Adv. 2020]**

(*a*) $\left|z+\frac{1}{2}\right| \le \frac{1}{2}$ fall all $z \in S$

(*b*) $|z| \le 2$ for all $z \in S$

(*c*) $\left|z+\frac{1}{2}\right| \ge \frac{1}{2}$ fall all $z \in S$

(*d*) The set S has exactly four elements

16. Let s,t,r be non-zero complex numbers and L be the set of solutions $z = x + iy\left(x, y \in R, i = \sqrt{-1}\right)$ of the equation $sz + t\bar{z} + r = 0$, where $\bar{z} = x - iy$. Then, which of the following statement(s) is (are) TRUE?

C-1.18 W-27.03 UA-56.41 PC-15.38 **[JEE Adv. 2018]**

(*a*) If L has exactly one element, then $|s| \neq |t|$

(*b*) If $|s| = |t|$, then L has infinitely many elements

(*c*) The number of elements in $L \cap \{z : |z - 1 + i| = 5\}$ is at most 2

(*d*) If L has more than one element, then L has infinitely many elements

17. Let a,b,x and y be real numbers such that $a - b = 1$ and $y \neq 0$. If the complex number $z = x + iy$ satisfies $Im\left(\frac{az+b}{z+1}\right) = y$, then which of the following is(are) possible value(s) of x ?

C-31.5 W-13.18 UA-49.89 **[JEE Adv. 2017]**

(*a*) $1-\sqrt{1+y^2}$ (*b*) $-1-\sqrt{1-y^2}$

(*c*) $1+\sqrt{1+y^2}$ (*d*) $-1+\sqrt{1-y^2}$

18. Let z_1 and z_2 be complex numbers such that $z_1 \neq z_2$ and $|z_1| = |z_2|$. If z_1 has positive real part and z_2 has negative imaginary part, then $\frac{z_1+z_2}{z_1-z_2}$ may be **[IIT-JEE 1986]**

(*a*) zero (*b*) real and positive

(*c*) real and negative (*d*) purely imaginary

19. If $z_1 = a + ib$ and $z_2 = c + id$ are complex numbers such that $|z_1| = |z_2| = 1$ and $Re(z_1\bar{z}_2) = 0$, then the pair of complex numbers $w_1 = a + ic$ and $w_2 = b + id$ satisfies **[IIT-JEE 1985]**

(*a*) $|w_1| = 1$ (*b*) $|w_2| = 1$

(*c*) $Re(w_1\bar{w}_2) = 0$ (*d*) None of these

Match the Column

20. Let z be complex number satisfying $|z|^{\beta} + 2z^2 + 4\bar{z} - 8 = 0$ where $\bar{z}$ denotes the complex conjugate of z. Let the imaginary part of z be non zero. C-13.5 W-32.06 UA-54.44 **[JEE Adv. 2023]**

Match List-I with List-II:

List-I		List-I	
A.	$\|z\|^2$ is equal to	I.	12
B.	$\|z-\bar{z}\|^2$ is equal to	II.	4
C.	$\|z\|^2 + \|z+\bar{z}\|^2$ is equal to	III.	8
D.	$\|z+1\|^2$ is equal to	IV.	10
		V.	7

Choose the correct answer from the options given below:

(*a*) A → I; B → III; C → V; D → IV

(*b*) A → II; B → I; C → III; D → V

(*c*) A → II; B → IV; C → V; D → I

(*d*) A → II; B → III; C → V; D → IV

21. Match the statements of Column-I with those of Column-II. Here, z takes values in the complex plane and *Im* (z) and *Re* (z) denote respectively, the imaging part and real part of z *i* **[IIT-JEE 2010]**

Column-I	Column-II
(A) The set of points z satisfying $\|z - i\|z\|\| = \|z + i\|z\|\|$ is contained in or equal to	(p) an ellipse with eccentricity 4/5
(B) The set of points z satisfying $\|z+4\|+\|z-4\|=10$ is contained in or equal to	(q) the set of points z satisfying $Im\ z = 0$
(C) If $\|w\| = 2$, then the set of points $z = w - 1$ w is contained in or equal to	(r) the set of points z satisfying $\|Imz\| \le 1$
(D) If $\|w\| = 1$, then the set of points $z = w + 1$, w is contained in or equal to	(s) the set of points z satisfying $\|Rez\| < 2$
	(t) the set of point z satisfying $\|z\| \le 3$

Numerical/Integer Types

22. Let z be a complex number with non-zero imaginary part. If $\frac{2+3z+4z^2}{2-3z+4z^2}$ is a real number, then the value of $|z|^2$ is_____.

C-7.05 W-56.77 UA-36.18 **[JEE Adv. 2022]**

23. Let z denote the complex conjugate of a complex number z and let $i = \sqrt{-1}$ in the set of complex numbers, the number of distinct roots of the equation $\bar{z} - z^2 = i(\bar{z} + z^2)$ is_____

C-10.03 W-59.83 UA-30.14 **[JEE Adv. 2022]**

24. If z is any complex number satisfying $|z - 3 - 2i| \le 2$, then the minimum value of $|2z - 6 + 5i|$ is ..... **[IIT-JEE 2011]**

Fill in the Blanks

25. If α,β,γ are the cube roots of p, $p<0$, then for any x,y and z then $\frac{x\alpha+y\beta+z\gamma}{x\beta+y\gamma+z\alpha}=\ldots$ **[IIT-JEE 1990]**

26. For any two complex numbers z_1, z_2 and any real numbers a and b, $|az_1-bz_2|^2+|bz_1+az_2|^2=\ldots$ **[IIT-JEE 1988]**

27. If the expression $\frac{\left[\sin\left(\frac{x}{2}\right)+\cos\left(\frac{x}{2}\right)-i\tan(x)\right]}{\left[1+2i\sin\left(\frac{x}{2}\right)\right]}$ is real, then the set of all possible values of x is .... **[IIT-JEE 1978]**

True/False

28. For complex numbers $z_1=x_1+iy_1$ and $z_2=x_2+iy_2$ we write $z_1\cap z_2$, if $x_1\le x_2$ and $y_1\le y_2$. Then, for all complex numbers z with $1\cap z$, we have $\frac{1-z}{1+z}\cap 0$. **[IIT-JEE 1981]**

Subjective

29. Prove that there exists no complex number z such that $|z|<1/3$ and $\sum_{r=1}^{n}a_r z^r=1$, where $|a_r|<2$. **[IIT-JEE 2003]**

30. If z_1 and z_2 are two complex numbers such that $|z_1|<1<|z_2|$, then prove that $\left|\frac{1-z_1\bar{z}_2}{z_1-z_2}\right|<1$ **[IIT-JEE 2003]**

31. For complex numbers z and w, prove that $|z|^2w-|w|^2z=z-w$, if and only if $z=w$ or $z\bar{w}=1$. **[IIT-JEE 1999]**

32. Find all non-zero complex numbers z satisfying $\bar{z}=iz^2$. **[IIT-JEE 1996]**

33. If $iz^3+z^2-z+i=0$, then show that $|z|=1$. **[IIT-JEE 1995]**

34. A relation R on the set of complex numbers is defined by z_1Rz_2, if and only if $\frac{z_1-z_2}{z_1+z_2}$ is real. Show that R is an equivalence relation. **[IIT-JEE 1982]**

35. Find the real values of x and y for which the following equation is satisfied $\frac{(1+i)x-2i}{3+i}+\frac{(2-3i)y+i}{3-i}=i$. **[IIT-JEE 1980]**

36. Express $\frac{1}{(1-\cos\theta)+2i\sin\theta}$ in the form A + iB. **[IIT-JEE 1979]**

37. If $x+iy=\sqrt{\frac{a+ib}{c+id}}$, prove that $\left(x^2+y^2\right)^2=\frac{a^2+b^2}{c^2+d^2}$ **[IIT-JEE 1978]**

Properties of Amplitude

Single Correct

38. Let z and w be two non-zero complex numbers such that $|z|=|w|$ and $arg\,(z)+arg\,(w)=\pi$, then z equals **[IIT-JEE 1995]**

(a) w (b) $-w$

(c) $\bar{w}$ (d) $-\bar{w}$

39. If z_1 and z_2 are two non-zero complex numbers such that $|z_1+z_2|=|z_1|+|z_2|$, then $arg(z_1)-arg(z_2)$ is equal to **[IIT-JEE 1987]**

(a) $-\pi$ (b) $-\pi/2$

(c) 0 (d) $\pi/2$

Match the Column

40. Match the conditions/expressions in Column-I with statement in Column-II ($z\neq 0$ is a complex number) **[IIT-JEE 1992]**

Column-I		Column-II	
A.	$Re(z)=0$	p.	$p.\ Re(z^2)=0$
B.	$\arg(z)=\pi/4$	q.	$q.\ Im(z^2)=0$
		r.	$r.\ Re(z^2)=Im(z^2)$

Subjective

41. $|z|\le 1$, $|w|\le 1$, then show that $|z-w|^2\le(|z|-|w|)^2+(arg\,z-arg\,w)^2$ **[IIT-JEE 1995]**

Complex Number-Geometry

Single Correct

42. Let $\theta_1,\theta_2,\ldots,\theta_{10}$ be positive valued angles (in radian) such that $\theta_1+\theta_2+\ldots+\theta_{10}=2\pi$.
Define the complex numbers $z_1=e^{i\theta_1}$, $z_k=z_{k-1}e^{i\theta_k}$ for $k=2,3,\ldots,10$, where $i=\sqrt{-1}$. Consider the statements P and Q given below:

$P:\left|z_2-z_1\right|+\left|z_3-z_2\right|+\ldots+\left|z_{10}-z_9\right|+\left|z_1-z_{10}\right|\le 2\pi$

$Q:\left|z_2^2-z_1^2\right|+\left|z_3^2-z_2^2\right|+\ldots.+\left|z_{10}^2-z_9^2\right|+\left|z_1^2-z_{10}^2\right|\le 4\pi$

Then, C-16.06 W-18.26 UA-65.69 **[JEE Adv. 2021]**

(a) P is **TRUE** and Q is **FALSE**

(b) Q is **TRUE** and P is **FALSE**

(c) Both P and Q are **TRUE**

(d) Both P and Q are **FALSE**

43. Let S be the set of all complex numbers z satisfying $|z-2+i|\ge\sqrt{5}$. If the complex number z_0 is such that $\frac{1}{|z_0-1|}$ is the maximum of the set $\left\{\frac{1}{|z-1|}:z\in S\right\}$ then the principal argument of $\frac{4-z_0-\bar{z}_0}{z_0-\bar{z}_0+2i}$ is

C-15.22 W-26.59 UA-58.19 **[JEE Adv. 2019]**

(a) $\pi/4$ (b) $3\pi/4$

(c) $-\pi/2$ (d) $\pi/2$

44. For all complex numbers z_1,z_2 satisfying $|z_1|=12$ and $|z_2-3-4i|=5$, the minimum value of $|z_1-z_2|$ is **[IIT-JEE 2002]**

(a) 0 (b) 2

(c) 7 (d) 17

45. Let z and w be two complex numbers such that $|z|\le 1$, $|w|\le 1$ and $|z+iw|=|z-i\bar{w}|=2$, then z equals **[IIT-JEE 1995]**

(a) 1 or i (b) i or $-i$

(c) 1 or -1 (d) i or -1

46. If a,b,c and u,v,w are the complex numbers representing the vertices of two triangles such that $c=(1-r)a+rb$ and $w=(1-r)u+rv$, where r is a complex number, then the two triangles **[IIT-JEE 1985]**

(a) have the same area (b) are similar

(c) are congruent (d) None of these

Rotation Theorem

Single Correct

61. A particle P starts from the point $z_0 = 1 + 2i$, where $i = \sqrt{-1}$. It moves first horizontally away from origin by 5 units and then vertically away from origin by 3 units to reach a point z_1. From z_1 the particle moves $\sqrt{2}$ units in the direction of the vector $\hat{i} + \hat{j}$ and then it moves through an angle $\frac{\pi}{2}$ in anti-clockwise direction on a circle with center at origin, to reach a point z_2. The point z_2 is given by **[IIT-JEE 2008]**

(*a*) $6 + 7i$ (*b*) $-7 + 6i$

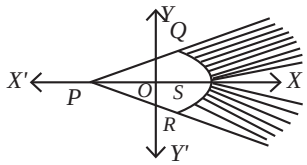
(*c*) $7 + 6i$ (*d*) $-6 + 7i$

62. A man walks a distance of 3 units from the origin towards the North-East (N45°E) direction. From there, he walks a distance of 4 units towards the North-West (N45°W) direction to reach a point P. Then, the position of P in the Argand plane **[IIT-JEE 2007]**

(*a*) $3e^{i\pi/4} + 4i$ (*b*) $(3-4i)e^{\pi/4}$

(*c*) $(4+3i)e^{j\pi/4}$ (*d*) $(3+4i)e^{i\pi/4}$

63. The shaded region, where $P=(-1,0), Q=\left(-1+\sqrt{2},\sqrt{2}\right)$ $R=\left(-1+\sqrt{2},-\sqrt{2}\right), S(1,0)$ is represented by **[IIT-JEE 2005]**



(*a*) $|z+1|>2, |arg(z+1)|<\frac{\pi}{4}$

(*b*) $|z+1|<2,\ \arg(z+1)<\frac{\pi}{2}$

(*c*) $|z+1|>2, |arg(z+1)|>\frac{\pi}{4}$

(*d*) $|z-1|>2, |arg(z+1)|>\frac{\pi}{4}$

64. If $0<\alpha<\frac{\pi}{2}$ is a fixed angle. If P = (cosθ, sinθ) and $Q=\left\{cos\left(\alpha\frac{2}{\theta}\right), sin(\alpha-\theta)\right\}$, then Q is obtained from P by **[IIT-JEE 2002]**

(*a*) clockwise rotation around origin through an angle α

(*b*) anti-clockwise rotation around origin through an angle α

(*c*) reflection in the line through origin with slope tanα

(*d*) reflection in the line through origin with slope $tan\frac{\alpha}{2}$

65. The complex numbers z_1, z_2 and z_3 satisfying $\frac{z_1-z_3}{z_2-z_3}=\frac{1-i\sqrt{3}}{2}$ are the vertices of a triangle which is **[IIT-JEE 2001]**

(*a*) of area zero (*b*) right angled isosceles

(*c*) equilateral (*d*) obtuse angled isosceles

Fill in the Blanks

66. Suppose z_1, z_2, z_3 are the vertices of an equilateral triangle inscribed in the circle $|z| = 2$. If $z_1 = 1+i\sqrt{3}$, then z_2 = ..., z_3 = ... **[IIT-JEE 1994]**

67. *ABCD* is a rhombus. Its diagonals *AC* and *BD* intersect at the point *M* and satisfy *BD* = 2*AC*. If the points *D* and *M* represent the complex numbers 1 + *i* and 2 – *i* respectively, then *A* represents the complex number ...or... **[IIT-JEE 1993]**

68. If *a* and *b* are real numbers between 0 and 1 such that the points $z_1 = a + i$, $z_2 = 1 + bi$ and $z_3 = 0$ form an equilateral triangle, then *a* = ... and *b* = ... **[IIT-JEE 1990]**

Subjective

69. If one of the vertices of the square circumscribing the circle $|z-1|=\sqrt{2}$ is $2+\sqrt{3}$. Find the other vertices of the square **[IIT-JEE 2005]**

70. Let $\bar{b}\,z + b\,\bar{z} = c$, $b \neq 0$, be a line in the complex plane, where $\bar{b}$ is the complex conjugate of *b*. If a point z_1 is the reflection of the point z_2 through the line, then show that $c = \bar{z}_1 b + z_2 \bar{b}$. **[IIT-JEE 1997]**

71. Let z_1 and z_2 be the roots of the equation $z^2 + pz + q = 0$, where the coefficients *p* and *q* may be complex numbers. Let *A* and *B* represent z_1 and z_2 in the complex plane. If $\angle AOB = \alpha \neq 0$ and *OA* = *OB*, where *O* is the origin prove that $p^2 = 4qcos^2\left(\frac{\alpha}{2}\right)$. **[IIT-JEE 1997]**

72. Complex numbers z_1, z_2, z_3 are the vertices *A*,*B*,*C* respectively of an isosceles right angled triangle with right angle at C. Show that **[IIT-JEE 1986]**

$$(z_1 - z_2)^2 = 2(z_1 - z_3)(z_3 - z_2)$$

73. Show that the area of the triangle on the argand diagram formed by the complex number z, *iz* and z + *iz* is $\frac{1}{2}|z|^2$. **[IIT-JEE 1986]**

74. Prove that the complex numbers z_1, z_2 and the origin form an equilateral triangle only if $z_1^2 + z_2^2 - z_1 x_2 = 0$. **[IIT-JEE 1983]**

75. Let the complex numbers z_1, z_2 and z_3 be the vertices of an equilateral triangle. Let z_0 be the circumcentre of the triangle. Then, prove that $z_1^2 + z_2^2 + z_3^2 = 3z_0^2$. **[IIT-JEE 1981]**

Demoivre's Theorem, Cube Root of Unity, Nth Roots of Unity

Single Correct

76. Let z = cosθ + *i*sinθ. Then, the value of $\sum_{m=1}^{15} Im\left(z^{2m-1}\right)$ at θ = 2° is **[IIT-JEE 2009]**

(*a*) $\frac{1}{sin2^\circ}$ (*b*) $\frac{1}{3sin2^\circ}$

(*c*) $\frac{1}{2sin2^a}$ (*d*) $\frac{1}{4sin2^\circ}$

Fill in the Blanks

93. The value of the expression $1(2-\omega)(2-\omega^2)+2(3-\omega)(3-\omega^2)+....+(n-1).(n-\omega)(n-\omega^2)$, where, ω is an imaginary cube root of unity, is _____. **[IIT-JEE 1996]**

True/False

94. The cube roots of unity where represented on Argand diagram form the vertices of an equilateral triangle. **[IIT-JEE 1988]**

Subjective

95. Let $\omega = e^{i\pi/3}$ and a, b, c, x, y, z be non-zero complex numbers such that $a+b+c=x$, $a+b\omega+c\omega^2=y$, $a+b\omega^2+c\omega=z$.

Then, the value of $\frac{|x|^2+|y|^2+|z|^2}{|a|^2+|b|^2+|c|^2}$ is..... **[IIT-JEE 2011]**

96. Let a complex number α, $\alpha \neq 1$, be a root of the equation $z^{p+q}-z^p-z^q+1=0$ where, p and q are distinct primes. Show that either $1+\alpha+\alpha^2+....+\alpha^{p-1}=0$ or $1+\alpha+\alpha^2+....+\alpha^{q-1}=0$ but not both together. **[IIT-JEE 2002]**

97. If $1, a_1, a_2, ..., a_{n-1}$ are the n roots of unity, then show that $(1-a_1)(1-a_2)(1-a_3)...(1-a_{n-1})=n$ **[IIT-JEE 1984]**

98. It is given that n is an odd integer greater than 3, but n is not a multiple of 3. Prove that x^3+x+x is a factor of $(x+1)^n-x^n-1$ **[IIT-JEE 1980]**

99. If $x=a+b$, $y=a\alpha=b\beta$, $z=a\beta+b\alpha$, where α,β are complex cube roots of unity, then show that $xyz=a^3+b^3$. **[IIT-JEE 1979]**

ANSWER KEY

1. (*d*)	**2.** (*b*)	**3.** (*d*)	**4.** (*c*)	**5.** [281]	**6.** (*c*)	**7.** (*d*)	**8.** (*a*)	**9.** (*b*)	**10.** (*a*)
11. (*a*)	**12.** (*d*)	**13.** (*b*)	**14.** (*a*)	**15.** (*b, c*)	**16.** (*a, c, d*)	**17.** (*b*)	**18.** (*a, d*)	**19.** (*a, b, c*)	**20.** (*b*)
21. [(A)→(q)(r),(B)→(p),(C)→(p), (D)→(q), (r)]				**22.** [0.5]	**23.** [4]	**24.** [5]	**25.** [w^2]	**26.** [$k\in(1,2)$]	**27.** [$2n\pi$]
28. [True]	**38.** (*d*)	**39.** (*c*)	**40.** [A → q, B→ p]		**42.** (*c*)	**43.** (*c*)	**44.** (*b*)	**45.** (*c*)	**46.** (*b*)
47. (*b*)	**48.** (*d*)	**49.** (*a*)	**50.** (*b, d*)	**51.** (*a*)	**52.** (*a*)	**53.** (*a, c ,d*)	**54.** (*c*)	**55.** (*b*)	**56.** [8]
57. [False]	**58.** [True]	**61.** (*d*)	**62.** (*d*)	**63.** (*a*)	**64.** (*d*)	**65.** (*c*)	**66.** [$z_2=-2$, $z_3=1-i\sqrt{3}$]		
67. $\left[z=1-\frac{3}{2}i \text{ or } z=3-\frac{1}{2}i\right]$	**68.** [$a=b=2-\sqrt{3}$]			**76.** (*d*)	**77.** (*d*)	**78.** (*b*)	**79.** (*c*)	**80.** (*d*)	**81.** (*c*)
82. (*d*)	**83.** (*d*)	**84.** (*b*)	**85.** (*b*)	**86.** (*d*)	**87.** (*c, d*)	**88.** (*c*)	**89.** [3]	**90.** [4]	**91.** [512]
92. [1]	**93.** $\left[\left[\frac{n(n+1)}{2}\right]^2-n\right]$		**94.** [True]						

1 QUADRATIC EQUATIONS

1. (*d*) $x^2 + 20x - 2020 = 0$ has two roots $a, b \in R$
$x^2 - 20x + 2020 = 0$ has two roots $c, d \in$ complex
$ac(a-c) + ad(a-d) + bc(b-c) + bd(b-d)$
$= a^2c - ac^2 + a^2d - ad^2 + b^2c - bc^2 + b^2d - bd^2$
$= a^2(c+d) + b^2(c+d) - c^2(a+b) - d^2(a+b)$
$= (c+d)(a^2+b^2) - (a+b)(c^2+d^2)$
$= (c+d)((a+b)^2 - 2ab) - (a+b)$
$((c+d)^2 - 2cd)$
$= 20[(20)^2 + 4040] + 20[(20)^2 - 4040]$
$= 20[(20)^2 + 4040 + (20)^2 - 4040]$
$= 20 \times 800 = 16000$

2. (*c*) Using the quadratic formula for the equation $x^2 - 2x\sec\theta + 1 = 0$,

$$x = \frac{2\sec\theta \pm \sqrt{4\sec^2\theta - 4}}{2}$$

$$= \frac{2\sec\theta \pm 2\sqrt{\sec^2\theta - 1}}{2} = \sec\theta \pm \tan\theta$$

According to the given conditions,

$\left(\because \alpha_1 > \beta_1 \text{ and } -\frac{\pi}{6} < \theta < -\frac{\pi}{12}\right)$

$\sec\theta$ is always positive in the negative range of θ and $\tan\theta$ will always be negative in the negative range of θ

Hence,

$\alpha_1 = \sec\theta - \tan\theta$

$\beta_1 = \sec\theta + \tan\theta$

Similarly, for $x^2 + 2x\tan\theta - 1 = 0$

$$x = \frac{-2\tan\theta \pm \sqrt{4\tan^2\theta + 4}}{2}$$

$$= \frac{-2\tan\theta \pm 2\sqrt{\tan^2\theta + 1}}{2}$$

$$= -\tan\theta \pm \sec\theta$$

Again, according to the given conditions,

$\alpha_2 = \sec\theta - \tan\theta, \beta_2 = -\sec\theta - \tan\theta$

Hence

$\alpha_1 + \beta_2 = \sec\theta - \tan\theta - \sec\theta - \tan\theta$

$\alpha_1 + \beta_2 = -2\tan\theta$

3. (*d*) For a quadratic equation to have purely imaginary roots the condition is, $b = 0$
hence, $ax^2 + c = 0$

Let $p(x) = x^2 + 1 = 0$

Now, $p(p(x)) = (x^2+1)^2 + 1$

$= \left(x^4 + 1 + 2x^2 + 1\right)$

$= \left(x^4 + 2x^2 + 2\right)$

Let $x^2 = t$

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

$D = (2)^2 - 4(1)(2) < 0$

Hence,

x^2 is imaginary and hence x is also imaginary.

Therefore, all the roots of $p(p(x))$ are imaginary but they are not purely imaginary rather they are in the form $\sqrt{a+ib}$

We conclude that $p(p(x))$ has neither real nor purely imaginary roots

4. (*b*) The equations with roots α and β,

$x^2 - (\alpha+\beta)x + \alpha\beta = 0$

Given the roots $\frac{\alpha}{\beta}$ and $\frac{\beta}{\alpha}$

$$x^2 - \left(\frac{(\alpha^2+\beta^2)}{\alpha\beta}\right)x + \frac{\alpha}{\beta}\cdot\frac{\beta}{\alpha} = x^2 - \frac{(\alpha^2+\beta^2)}{\alpha\beta}x + 1 = 0$$

Now, $\alpha^3 + \beta^3 = (\alpha+\beta)\left((\alpha+\beta)^2 - 3\alpha\beta\right) = q$

$-p\left(p^2 - 3\alpha\beta\right) = q$

$p^2 - 3\alpha\beta = -\frac{q}{p}$

$p^2 + \frac{q}{p} = 3\alpha\beta$

$\frac{(p^3+q)}{3p} = \alpha\beta$

Putting the values,

$$x^2 - \frac{(\alpha^2+\beta^2)}{\alpha\beta}x + 1 = x^2 - \frac{\left((\alpha+\beta)^2 - 2\alpha\beta\right)}{\alpha\beta}x + 1 = 0$$

$$x^2 - \frac{\left(p^2 - \frac{2(p^3+q)}{3p}\right)}{\frac{p^3+q}{3p}}x + 1 = x^2 - \frac{(p^3-2q)x}{p^3+q} + 1 = 0$$

Final Equation,

$(p^3+q)x^2 - (p^3-2q)x + (p^3+q) = 0$

5. (*d*) For the equation

$x^2 - px + r = 0$

$$\alpha + \beta = -\frac{(\text{coefficient of } x)}{\text{coefficient of } x^2} = p$$

$$\alpha\beta = -\frac{\text{coefficient of } x^0}{\text{coefficient of } x^2} = r$$

For the equation

$x^2 - qx + r = 0$

Sum of roots

$$= -\frac{\text{coefficient of } x}{\text{coefficient of } x^2}$$

Products of roots $\alpha\beta = \frac{\text{coefficient of } x^0}{\text{coefficient of } x^2} = r$

Solving the equations

$\alpha + \beta = p \Rightarrow \beta = p - \alpha$

$$= \frac{\alpha}{2} + 2\beta \Rightarrow \frac{\alpha}{2} + 2(p-\alpha) = q$$

$$\Rightarrow -3\frac{\alpha}{2} + 2p = q$$

$$\Rightarrow \frac{3\alpha}{2} = 2p - q$$

$$\Rightarrow \alpha = \frac{2}{3}(2p-q)$$

$\beta = p - \frac{2}{3}(2p-q)$ $[\because \beta = p - \alpha]$

$= \frac{2q-p}{3}$

$r = \alpha\beta = \frac{2}{9}(2p-q)(2q-p)$

6. (*a*) As roots are real then the discriminant is $D \geq 0$

$4(a+b+c)^2 - 12\lambda(ab+bc+ca) \geq 0$

$(a+b+c)^2 \geq 3\lambda(ab+bc+ca)$

$a^2+b^2+c^2 \geq (3\lambda - 2)(ab+bc+ca)$

$\frac{a^2+b^2+c^2}{ab+bc+ca} + 2 \geq 3\lambda$

a, b, c are sides of triangle

$|a-c| < b$

Squaring on both sides

$a^2 + c^2 - 2ac < b^2$

$b^2 + c^2 - 2bc < a^2$

$b^2 + a^2 - 2bc < c^2$

Adding all the above inequations

$(a^2+b^2+c^2) - 2(ab+bc+ca) < 0$

$\frac{a^2+b^2+c^2}{ab+bc+ca} < 2$

So, $2 + 2 > 3\lambda$

$\lambda < \frac{4}{3}$

7. (*a*) Let the roots of $x^2 + px + q = 0$ be α and α^2.

Sum of the roots $= -\left(\frac{\text{coefficient of } x}{\text{coefficient of } x^2}\right)$

Products of roots $= \frac{\text{constant}}{\text{coefficient of } x^2}$

$\alpha + \alpha^2 = -p$

$\alpha \cdot \alpha^2 = q$

$\Rightarrow \alpha^3 = q$

So, $\alpha(1+\alpha) = -p$

Cubing on both side

$\alpha^3(1+\alpha)^3 = -p^3$

$q\left(1 + \alpha^3 + 3\alpha(1+\alpha)\right) = -p^3$

$q(1+q-3p) = -p^3$

$p^3 - (3p-1)q + q^2 = 0$

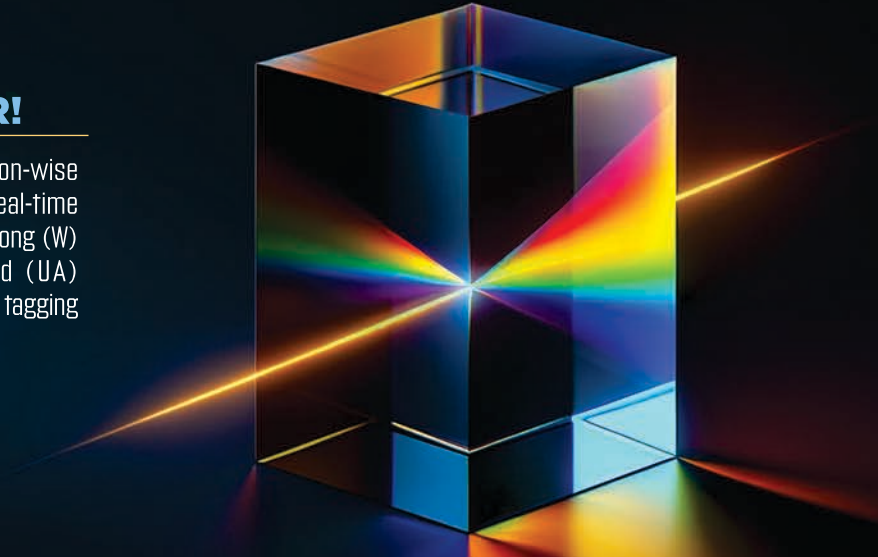
47 JEE ADVANCED

YEARS (2024 TO 1978)

CHAPTER-WISE & TOPIC-WISE SOLVED PAPERS

FIRST TIME EVER!

Analyse the question-wise difficulty level in real-time with Correct (C), Wrong (W) and Unattempted (UA) questions response tagging provided by IIT-JEE



PHYSICS

ANSWER KEY VERIFIED FROM OFFICIAL WEBSITE OF JEE ADVANCED

JEE ADVANCED 2024 Paper Analysis

Paper 1

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	Matrix Type Questions	4	3	–1	12
	Total Questions per subject	17			60

Paper 2

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	(Numerical Value Based Questions)	4	3	–1	12
	Total Questions per subject	17			60

Total No. of Questions in Part 1 = 51 Questions
Total No. of Questions in Part 2 = 51 Questions
Each Subject Carries = 60 Marks
Total Marks = 180

Paper Analysis

Paper Difficulty Compared to Last Year	Easier Compared to 2023 Paper
Overall Difficulty Level of JEE 2024	
Easy	18%
Moderate	49%
Difficult	33%

Physics Topics	Paper 1 Difficulty Level	Paper 2 Difficulty Level
Mechanics	Total 3 questions in paper 1 from Mechanics out which 1 question from fluid mechanics was difficult 1 question from Rotational mechanics was easy and 1 moderate level question from rotational mechanics	Total 3 questions in paper 2 were asked from Mechanics out which all of them where moderate level
Thermodynamics	Total 2 questions where asked from thermodynamics in paper 1 one question was easy and the other was moderate	No questions asked in paper 2
Electrodynamics	3 Moderate level Questions	Total 6 questions were asked out of which 1 Question from EMI was difficult and rest were moderate level. Rest were moderate
Optics	3 moderate level question from optics out which 2 were from Ray optics and 1 was from wave optics	3 moderate level question in paper 2 out which 2 were from wave optics and 1 was from ray optics
Modern Physics	1 moderate level question	1 easy level question from x rays
Oscillations & waves	Total 3 moderate level question out of which 2 question from waves and 1 question from shm	1 Question from SHM was difficult
Mathematical tools, Errors & measurement	1 question from mathematical tools were asked in paper 1	1 question from error was asked in paper. Level of question was easy

Overall Analysis

Paper Difficulty Compared to Last Year

- Paper was overall moderate
- 6 Questions were easy, 3 Questions were Difficult and rest were moderate
- Compared to the other topic, Electrodynamics has the maximum weightage
- Weightage of 12th was slightly more compared to 11th topics
- In paper 1, 8 out of 17 questions were from 11th topics and 9 out of 17 questions were from 12th
- In paper 2, 7 out of 17 were from 11th and 10 out of 17 were from 12th.
- Total questions from mechanics - 6
- Total questions from thermodynamics - 2
- Total questions from Electrodynamics - 9
- Total questions frpm Optics - 6
- Total questions from Waves & oscillations - 4
- Total questions from mathematical tools, errors and measurement - 2
- Questions were based on fundamental concepts
- Language of questions was on tougher side
- Questions were not lengthy.

CONTENTS

HINTS AND SOLUTIONS

2024

JEE ADVANCED SOLVED PAPER

Physics Paper-1

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If **ONLY** the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : –1 In all other cases.

1. A dimensionless quantity is constructed in terms of electronic charge e, permittivity of free space ε_0, Planck's constant h, and speed of light c. If the dimensionless quantity is written as $e^{\alpha}\varepsilon_0{}^{\beta}h^{\gamma}c^{\delta}$ and n is a non-zero integer, then $(\alpha, \beta, \gamma, \delta)$ is given by

(*a*) $(2n, -n, -n, -n)$ (*b*) $(n, -n, -2n, -n)$
(*c*) $(n, -n, -n, -2n)$ (*d*) $(2n, -n, -2n, -2n)$

2. An infinitely long wire, located on the z-axis, carries a current I along the +z-direction and produces the magnetic field $\vec{B}$. The magnitude of the line integral $\int \vec{B}\cdot\vec{dl}$ along a straight line from the point $(-\sqrt{3}a, a, 0)$ to $(a, a, 0)$ is given by

[μ_0 is the magnetic permeability of free space.]

(*a*) $7\mu_0 I/24$ (*b*) $7\mu_0 I/12$
(*c*) $\mu_0 I/8$ (*d*) $\mu_0 I/6$

3. Two beads, each with charge q and mass m, are on a horizontal, frictionless, non-conducting, circular hoop of radius R. One of the beads is glued to the hoop at some point, while the other one performs small oscillations about its equilibrium position along the hoop. The square of the angular frequency of the small oscillations is given by [ε_0 is the permittivity of free space.]

(*a*) $q^2/(4\pi\varepsilon_0 R^3 m)$ (*b*) $q^2/(32\pi\varepsilon_0 R^3 m)$
(*c*) $q^2/(8\pi\varepsilon_0 R^3 m)$ (*d*) $q^2/(16\pi\varepsilon_0 R^3 m)$

4. A block of mass 5 kg moves along the x-direction subject to the force $F = (-20x + 10)$N, with the value of x in metre. At time $t = 0$s, it is at rest at position $x = 1$ m. The position and momentum of the block at $t = (\pi\backslash 4)$s are

(*a*) –0.5 m, 5 kg m/s (*b*) 0.5 m, 0 kg m/s
(*c*) 0.5 m, –5 kg m/s (*d*) –1 m, 5 kg m/s

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;
Partial Marks : +3 If all the four options are correct but **ONLY** three options are chosen;
Partial Marks : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;
Partial Marks : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks: –2 In all other cases.

- For example, in a question, if (*a*), (*b*) and (*d*) are the **ONLY** three options corresponding to correct answers, then
choosing ONLY (*a*), (*b*) and (*d*) will get +4 marks;
choosing ONLY (*a*) and (*b*) will get +2 marks;
choosing ONLY (*a*) and (*d*) will get +2 marks;
choosing ONLY (*b*) and (*d*) will get +2 marks;
choosing ONLY (*a*) will get +1 mark;
choosing ONLY (*b*) will get +1 mark;
choosing ONLY (*d*) will get +1 mark;
choosing no option (i.e. the question is unanswered) will get 0 marks; and choosing any other combination of options will get –2 marks.

5. A particle of mass m is moving in a circular orbit under the influence of the central force $F(r) = -kr$, corresponding to the potential energy $V(r) = kr^2/2$, where k is a positive force constant and r is the radial distance from the origin. According to the Bohr's quantization rule, the angular momentum of the particle is given by $L = n\hbar$, where $\hbar = h/(2\pi)$, h is the Planck's constant, and n a positive integer. If v and E are the speed and total energy of the particle, respectively, then which of the following expression(s) is(are) correct?

(*a*) $r^2 = n\hbar\sqrt{\dfrac{1}{mk}}$ (*b*) $v^2 = n\hbar\sqrt{\dfrac{k}{m^3}}$
(*c*) $\dfrac{L}{mr^2} = \sqrt{\dfrac{k}{m}}$ (*d*) $E = \dfrac{n\hbar}{2}\sqrt{\dfrac{k}{m}}$

1 GENERAL PHYSICS

JEE-Advanced

UNITS, SYSTEM OF UNITS

Single Correct

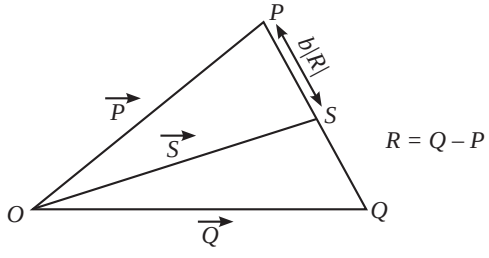
1. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{p}\frac{dp}{dt}\right)$ is constant. The velocity v of any point of the surface of the expanding sphere is proportional to

C-26.78 W-30.86 UA-42.37 **(JEE Adv. 2017)**

(*a*) R (*b*) $\frac{1}{R}$ (*c*) R^3 (*d*) $R^{\frac{2}{3}}$

2. Three vectors P, Q and R are shown in the figure. Let S be any point on the vector R. The distance between the points P and S is $b[R]$. The general relation among vectors P, Q and S is

C-46.13 W-17.08 UA-36.79 **(JEE Adv. 2017)**



$R = Q - P$

(*a*) $S = (1 - b^2)P + bQ$ (*b*) $S = (b - 1)P + bQ$

(*c*) $S = (1 - b)P + bQ$ (*d*) $S = (1 - b)P + b^2Q$

3. A cube has a side of length 1.2×10^{-2} m. Calculate its volume.

(IIT-JEE 2003)

(*a*) 1.7×10^{-6} m^3 (*b*) 1.73×10^{-6} m^3

(*c*) 1.70×10^{-6} m^3 (*d*) 1.732×10^{-6} m^3

Subjective

4. Write the dimensions of the following in terms of mass, time, length and charge. **(IIT-JEE 1982)**

A. Magnetic flux B. Rigidity modulus

5. Give the MKS units for each of the following quantities.

(IIT-JEE 1980)

1. Young's modulus 2. Magnetic induction
3. Power of a lens

Multiple Correct

6. A physical quantity $\vec{S}$ is defined as $\vec{S} = (\vec{E} \times \vec{B})/\mu_0$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity (ies)?

C-40.2 W-27.78 UA-22.17 PC-9.84 **(JEE Adv. 2021)**

(*a*) $\frac{\text{Energy}}{\text{Charge} \times \text{Current}}$ (*b*) $\frac{\text{Force}}{\text{Length} \times \text{Time}}$

(*c*) $\frac{\text{Energy}}{\text{Volume}}$ (*d*) $\frac{\text{Power}}{\text{Area}}$

7. The SI unit of the inductance, the henry can by written as

(IIT-JEE 1998)

(*a*) weber/ampere (*b*) volt-second/ampere

(*c*) joule/(ampere)^2 (*d*) ohm-second

Match the Column

8. Some physical quantities are given in Column-I and some possible SI units in which these quantities may be expressed are given in Column-II. Match the physical quantities in Column-I with the units in Column-II. **(IIT-JEE 2007)**

	Column-I		Column-II
A.	GM_eM_sG - universal gravitational constant, M_e - mass of the earth, M_s - mass of the sun,	p.	(volt) (coulomb) (meter)
B.	$\frac{3RT}{M}$ R - universal gas constant, T - absolute temperature, M - molar mass,	q.	(kilogram) (meter)^3 (second)$^{-2}$
C.	$\frac{F^2}{q^2B^2}$ F - force, q - charge, B - magnetic field,	r.	(meter)^2 (second)$^{-2}$
D.	$\frac{GM_e}{R_e}$ G - universal gravitational constant, M_e - mass of the earth, R_e - radius of the earth,	s.	(farad) (volt)^2 (kg)$^{-1}$

*C – Correct, W – Wrong, UA – Unattempted, PC – Partial Correct, real time response in percentage are given

9. Column-I gives three physical quantities. Select the appropriate units for the choices given in Column-II. Some of the physical quantities may have more than one choice. **(IIT-JEE 1990)**

Column-I	Column-II
Capacitance	ohm-second
Inductance	Coulomb^2-joule^{-1}
Magnetic induction	Coulomb (volt)$^{-1}$
	Newton (ampere metre)$^{-1}$
	volt-second (ampere)$^{-1}$

Fill in the Blanks

10. Two vectors A and B are defined as $A = a\,\hat{i}$ and $B = a(\cos \omega t\,\hat{i} + \sin \omega t\,\hat{j})$, where a is a constant and $\omega = \pi/6$ rad s^{-1}. If $|A + B| = \sqrt{3}\,|A - B|$ at time $t = \tau$ for the first time, the value of τ, in seconds, is ..... . **C-35.57 W-49.68 UA-14.75 (JEE Adv.2018)**

DIMENSION, FINDING DIMENSIONAL FORMULA

Single Correct

11. Which of the following sets have different dimensions? **(IIT-JEE 2005)**

(*a*) Pressure, Young's modulus, Stress

(*b*) Emf, Potential difference, Electric potential

(*c*) Heat, Work done, Energy

(*d*) Dipole moment, Electric flux, Electric field

12. In the relation, $p = \frac{\alpha}{\beta} e^{-\left(\frac{\alpha z}{k\theta}\right)}$ is pressure, z is distance, k is Boltzmann's constant and θ is the temperature. The dimensional formula of β will be **(IIT-JEE 2004)**

(*a*) $[M^0L^2T^0]$ (*b*) $[ML^2T]$ (*c*) $[ML^0T^{-1}]$ (*d*) $[M^0L^2T^{-1}]$

13. A quantity X is given by $\varepsilon_0 L\frac{\Delta V}{\Delta t}$, where ε_0 is the permittivity of free space, L is a length, ΔV is a potential difference and Δt is a time interval. The dimensional formula for X is the same as that of **(IIT-JEE 2001)**

(*a*) Resistance (*b*) Charge (*c*) Voltage (*d*) Current

14. The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E : electric field) is: **(IIT-JEE 2001)**

(*a*) $[MLT]$ (*b*) $[ML^2T^{-2}]$ (*c*) $[ML^{-1}T^{-2}]$ (*d*) $[ML^2T^{-1}]$

15. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of vacuum. If M = mass, L = length, T = Time and A = electric current, then **(IIT-JEE 1998)**

(*a*) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (*b*) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(*c*) $[\varepsilon_0] = [M^{-2}L^2T^{-1}A^{-2}]$ (*d*) $[\varepsilon_0] = [M^{-1}L^2T^{-1}A^2]$

Multiple Correct

16. A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann's constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles and the charge (q) carried by each of the particles. Which of the following expression(s) for l is (are) dimensionally correct?

C-17.85 W-20.89 UA-49.13 PC-12.13 (JEE Adv. 2016)

(*a*) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (*b*) $l = \sqrt{\left(\frac{Ek_E T}{nq^2}\right)}$

(*c*) $l = \sqrt{\left(\frac{q^2}{\varepsilon h^{2/3} k_B T}\right)}$ (*d*) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

17. Planck's constant h, speed of light c and gravitational constant G are used to form a unit of length L and a unit of mass M. Then, the correct options is/are **(JEE Adv. 2015)**

(*a*) $M \propto \sqrt{c}$ (*b*) $M \propto \sqrt{G}$

(*c*) $L \propto \sqrt{h}$ (*d*) $L \propto \sqrt{G}$

18. In terms of potential difference V, electric current I, permittivity ε_0, permeability μ_0 and speed of light c the dimensionally correct equations is/are **(JEE Adv. 2015)**

(*a*) $\mu_0 I^2 = E_0 V^2$ (*b*) $\varepsilon_0 I = \mu_d V$

(*c*) $I = E_0 cV$ (*d*) $\mu_0 cI = \varepsilon_0 V$

19. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum and $[\mu_0]$ that of the permeability of the vacuum. If M = mass, L = length, T = time and I = electric current. Then, **(IIT-JEE1998)**

(*a*) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (*b*) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(*c*) $[\mu_0] = [MLT^{-2}A^{-2}]$ (*d*) $[\mu_0] = [ML^2T^{-1}I]$

20. The pairs of physical quantities that have the same dimensions is (are) **(IIT-JEE 1995)**

(*a*) Reynolds number and coefficient of friction

(*b*) Curie and frequency of a light wave

(*c*) Latent heat and gravitational potential

(*d*) Planck's constant and torque

21. The dimensions of the quantities in one (or more) of the following pairs are the same. Identify the pair (*s*). **(IIT-JEE 1986)**

(*a*) Torque and work

(*b*) Angular momentum and work

(*c*) Energy and Young's modulus

(*d*) Light year and wavelength

22. L, C and R represent the physical quantities inductance, capacitance and resistance, respectively. The combinations which have the dimensions of frequency are **(IIT-JEE 1984)**

(*a*) $\frac{1}{RC}$ (*b*) $\frac{R}{L}$ (*c*) $\frac{1}{\sqrt{LC}}$ (*d*) $\frac{C}{L}$

Match the Column

23. Match the physical quantities given in Column-I with dimensions expressed in terms of mass (M), length (L), time (T) and charge (Q) given in Column-II and write the correct answer against the matched quantity in a tabular form in your answer book. **(IIT-JEE 1990)**

Column-I		Column-II	
A.	Angular momentum	p.	$[ML^2T^{-2}]$
B.	Latent heat	q.	$[ML^2Q^{-2}]$
C.	Torque	r.	$[ML^2T^{-1}]$
D.	Capacitance	s.	$[ML^3T^{-1}Q^{-2}]$
E.	Inductance	t.	$[M^{-1}L^{-2}T^2Q^2]$
F.	Resistivity	u.	$[L^2T^{-2}]$

Subjective

24. Planck's constant has dimensions: **(IIT-JEE 1985)**

55. The edge of a cube is measured using a vernier caliper. (9 divisions of the main scale is equal to 10 divisions of vernier scale and 1 main scale division is 1 mm). The main scale division reading is 10 and 1 division of vernier scale was found to be coinciding with the main scale. The mass of the cube is 2.736 g. Calculate the density in g/cm^3 upto correct significant figures. **(IIT-JEE 2005)**

56. The pitch of a screw gauge is 1 mm and there are 100 divisions on the circular scale. While measuring the diameter of a wire, the linear scale reads 1 mm and 47th division on the circular scale coincides with the reference line. The length of the wire is 5.6 cm. Find the curved surface area (in cm^2) of the wire in appropriate number of significant figures **(IIT-JEE 2004)**

Subjective

57. N divisions on the main scale of a vernier calipers coincide with $(N + 1)$ divisions on the vernier scale. If each division on the main scale is of a units, determine the least count of instruments. **(IIT-JEE 2003)**

FUNCTION, DIFFERENTIATION AS A RATE MEASUREMENT

Numerical Types/Integer Types

58. A person of height 1.6 m is walking away from a lamp post of height 4 m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is 60 cm s^{-1}, the speed of the tip of the person's shadow on the ground with respect to the person is _____ cm s^{-1}.

C-12.69 W-65.37 UA-21.94 (JEE Adv. 2023)

ANSWER KEY

1. (*a*)	**2.** (*c*)	**3.** (*a*)	**6.** (*b,d*)	**7.** (*a,c,d*)	**8.** A-p,q B-r,s C-r,s D-r,s	**11.** (*d*)	**12.** (*a*)	**13.** (*d*)	
14. (*c*)	**15.** (*b*)	**16.** (*b,d*)	**17.** (*a, c, d*)	**18.** (*a,c*)	**19.** (*b,c*)	**20.** (*a, b, c*)	**21.** (*a, d*)	**22.** (*a, b, c*)	
23. A-(r), B-(u), C-(p), D-(t), E-(q), F-(s)			**27.** (*a*)	**28.** (*c*)	**29.** (*d*)	**30.** (*c*)	**31.** (*b*)	**32.** (*a, b*)	**33.** (*a,b,d*)
34. [3]	**35.** [4]	**36.** (*a*)	**37.** (*a*)	**38.** (*a*)	**39.** (*c*)	**40.** (*a,c*)	**41.** (*b*)	**42.** (*d*)	**43.** (*d*)
44. (*b*)	**45.** (*c*)	**47.** (*c*)	**48.** (*b*)	**49.** (*b*)	**50.** (*b*)	**51.** (*d*)	**52.** (*d*)	**53.** (b,c)	**54.** [4]
55. [2.66]	**56.** [2.6]	**58.** [40]							

1 GENERAL PHYSICS

1. (*a*) The velocity v any point of the surface of the expanding sphere is proportional to R.

The density is given as

$$\rho = \frac{\text{Mass}}{\text{Volume}}$$

Mass = $\rho \times$ volume = constant

On differentiating,

$$\Rightarrow V\frac{d\rho}{dt} + \rho\frac{dV}{dt} = 0$$

$$\Rightarrow \frac{4}{3}\pi R^3 \times \frac{d\rho}{dt} + \rho \times \frac{d}{dt}\left(\frac{4}{3}\pi R^3\right) = 0$$

$$\Rightarrow \frac{1}{\rho}\frac{d\rho}{dt} = \frac{-3}{R}\frac{dR}{dt}$$

$$\Rightarrow R^3(-3R^{-4})\frac{dR}{dt} = \text{constant}$$

$$\frac{dR}{dt} \propto R$$

2. (*c*) The general relation among vectors P, Q and S is $S = (1 - b)P + bQ$.

From triangular law of vector addition, we get $\overrightarrow{OP} + \overrightarrow{PS} = \overrightarrow{OS}$

$$\therefore \vec{P} + b\left|\vec{R}\right|\frac{\vec{R}}{\left|\vec{R}\right|} = \vec{S}$$

$$\vec{P} + b\vec{R} = \vec{S}$$

But $\vec{R} = \vec{Q} - \vec{P}$ (Given)

$$\vec{P} + b\left(\vec{Q} - \vec{P}\right) = \vec{S}$$

$$\Rightarrow \vec{S} = (1-b)\vec{P} + b\vec{Q}$$

3. (*a*) **Given:** Length of the cube,

$L = 1.2 \times 10^{-2}$ m

We know, Volume of the cube,

$V = L^3 = (1.2 \times 10^{-2}) \times (1.2 \times 10^{-2}) \times (1.2 \times 10^{-2})$ m^3

$\Rightarrow V = 1.728 \times 10^{-6}$ m^3

But as the length contains only 2 significant digits, the volume must also contain 2 significant digits. Hence, volume of the cube is 1.7×10^{-6} m^3.

4. (A) The dimensions of the magnetic flux and rigidity modulus in terms of mass, length, time and charge are $[\phi] = [M^1L^2T^{-1}Q^{-1}]$ and $[n] = ML^{-1}T^{-2}$.

Dimension of magnetic field, $[B] = [M^1L^0Q^{-1}]$ and Dimension of surface Area, $[A] = [L^2]$.

The magnetic flux is given as the product of the magnetic field and surface area; $\phi = B.A$.

The dimension of magnetic flux in term of mass, time, length and charge,

$[\phi] = [M^1L^2T^{-1}Q^{-1}]$

(B) Shear stress = η (Shear strain),

where, η = modulus of rigidity

According to the formula, we get the dimensions of 'η' same as that of pressure as of shear strain is dimensionless.

$\therefore [\eta] = ML^{-1}T^{-2}$

5.

1. Young's modulus = Nm^{-2} = Newton per meter^2
2. Magnetic induction = $W \cdot m^{-2}$ = Tesla
3. Power of lens = m^{-1} = diopter

6. (*b*,*d*)

$$\vec{S} = [\vec{E} \times \vec{B}]\frac{1}{\mu_0}$$

$\vec{S}$ is pointing vector denotes flow of energy per unit area per unit time

$$\vec{S} = \frac{\text{watt}}{m^2}$$

7. (*a*,*c*,*d*)

Using the formula of emf;

$$e = \frac{d\phi}{dt} = L\frac{dI}{dt}$$

$$\Rightarrow [\text{volt}] = \frac{[\text{weber}]}{[\text{second}]} = [L]\frac{[\text{ampere}]}{[\text{second}]}$$

And Energy dissipated (E) = VIt

Putting the units of all the above values,

$\Rightarrow$ [Joule] = [volt][Ampere][second]

$$\Rightarrow [\text{volt} - \text{second}] = \frac{[\text{Joule}]}{[\text{Ampere}]}$$

Thus, we can now evaluate the unit of self inductance, units of self inductance L is,

$$[L] = \frac{\text{weber}}{\text{Ampere}} = \frac{\text{volt} - \text{second}}{\text{Ampere}} = \frac{\text{Joule}}{\text{Ampere}^2}$$

d also correct

$$\frac{1}{2}Li^2 = i^2Rt \Rightarrow [L] = [Rt] = Ohm - \text{sec}$$

8. A-p,q B-r,s C-r,s D-r,s

Given: G is the universal gravitational constant, R is the universal gas constant, T is the absolute temperature and B is the magnetic field.

(A) GM_eM_x where, M_e is the mass of the earth and M_x is the mass of the Sun.

From the Gravitational force formula,

$GM_eM_s = Fr^2$

Taking the units of each value and deriving its dimensions:

SI unit of Force is (kilogram) (metre) s^{-2}.

SI unit of r^2 is m^2.

$$= Nm^2\, kg\frac{m}{s^2} \times m^2 = kgm^3\, s^{-2}$$

Also, (volt) (coulomb) (meter) has the same dimensions.

(Joule) (meter)

$$= kg\left(\frac{m}{s^2}\right)\cdot m \cdot m \Rightarrow \frac{dn}{N} = -td$$

$$= \left(1 - \frac{9}{10}\right) \times 1mm = \text{kg m}^3\, \text{s}^{-2}$$

(B) $\frac{3RT}{M}$ where, R is the universal gas constant, T is the absolute temperature.

Taking root mean square velocity formula:

$$v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms}^2 = \frac{3RT}{M}$$

Unit of $\frac{3RT}{M}$ is m^2s^{-2}

Also, (farad) (volt)^2 (kg)$^{-1}$ has the same dimensions.

(farad) (volt)^2 (kg)$^{-1}$

= (Joule) (kg)$^{-1}$

$$= \text{kg}\left(\frac{m}{s^2}\right)\cdot \text{m (kg)}^{-1}$$

= m^2 5^{-2}

(C) $\frac{F^2}{q^2B^2}$

Force in the magnetic field;

$$F = qvB \Rightarrow v^2 = \frac{F^2}{q^2B^2}$$

unit of v^2 is m^2s^{-2} which is also equal to $FVkg^{-1}$.

Hence, (farad) (volt)^2 (kg)$^{-1}$ has the same dimensions.

(D) $\frac{GM_e}{R_e}$

We know, Escape velocity,

$$V_e = \sqrt{\frac{2GM}{R}} \Rightarrow V_e^2 = \frac{2GM}{R}$$

So the unit of $\frac{GM}{R}$ is m^2s^{-2}

9. Let us first derive Capacitance, Inductance and Magnetic Induction in terms of given units.

Capacitance is the charge per unit volt. And we know, Volt has unit of work per unit charge.

So capacitance has units of charge square per unit energy.

Inductance is defined as volt per unit rate of change of current and voltage per unit current is resistance, so inductance is ohm second.

Magnetic Induction is defined as the property of the material by which it gets magnetized by an external magnetic field.

Equation for magnetic induction:

47 JEE ADVANCED

YEARS (2024 TO 1978)

CHAPTER-WISE & TOPIC-WISE SOLVED PAPERS

FIRST TIME EVER!

Analyse the question-wise difficulty level in real-time with Correct (C), Wrong (W) and Unattempted (UA) questions response tagging provided by IIT-JEE

CHEMISTRY

ANSWER KEY VERIFIED FROM OFFICIAL WEBSITE OF JEE ADVANCED

JEE ADVANCED 2024 Paper Analysis

Paper 1

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	Matrix Type Questions	4	3	–1	12
	Total Questions per subject	17			60

Paper 2

Section	Question Type	No. of Questions	Marks per Question	Negative marks per question	Total Marks (Section wise)
1	Single Correct MCQs	4	3	–1	12
2	More than One Correct MCQs	3	4	–2	12
3	Non Negative Integer Type Questions	6	4	0	24
4	(Numerical Value Based Questions)	4	3	–1	12
	Total Questions per subject	17			60

Total No. of Questions in Part 1 = 51 Questions
Total No. of Questions in Part 2 = 51 Questions
Each Subject Carries = 60 Marks
Total Marks = 180

Paper Analysis

Paper Difficulty Compared to Last Year	Easier Compared to 2023 Paper
Overall Difficulty Level of JEE 2024	
Easy	18%
Moderate	49%
Difficult	33%

Chemistry Topics	Paper 1 Difficulty Level	Paper 2 Difficulty Level	Comments/Remarks	
Physical	Paper 1 easier compared to last year	Paper2 easy to moderate compared to last year		No question from Ionic equilibrium question from every topic
Inorganic	Same	Slightly Tougher		No question from metallurgy
Organic	Overall Tougher	Tougher to moderate	No Questions from GOC, sterio-isomerism, nomenclature	1 Easy level question from combined chemistry in every day life and Biomolecule. Questions based on Name reaction + Polymer, Alkyl halide

Overall Analysis

Paper Difficulty Compared to Last Year
- Easy to moderate - Equal distribution among Physical, Organic, inorganic - in paper 1, slightly more Questions from organic - in paper 2, slightly more Questions from physical - 3 questions were difficult and out of the box - 1 question from paper1 from organic chemistry was out of the box - 2 question in paper 2 was out of the box - 5 questions from Paper 1 and 4 Question from paper 2 was very easy - Rest of the questions were moderate - Chemistry will decide the rank

CONTENTS

HINTS AND SOLUTIONS

2024

JEE ADVANCED SOLVED PAPER

Chemistry Paper-1

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated <u>according to the following marking scheme:</u>

Full Marks : +3 If **ONLY** the correct option is chosen;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

Negative Marks : –1 In all other cases.

1. A closed vessel contains 10 g of an ideal gas **X** at 300 K, which exerts 2 atm pressure. At the same temperature, 80 g of another ideal gas **Y** is added to it and the pressure becomes 6 atm. The ratio of root mean square velocities of **X** and **Y** at 300 K is

(*a*) $2\sqrt{2}:\sqrt{3}$ (*b*) $2\sqrt{2}:1$

(*c*) 1 : 2 (*d*) 2 : 1

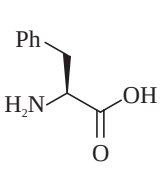
2. At room temperature, disproportionation of an aqueous solution of *in situ* generated nitrous acid (HNO_2) gives the species

(*a*) H_3O^+, NO_3^- and NO (*b*) H_3O^+, NO_3^- and NO_2

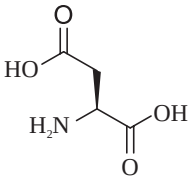
(*c*) H_3O^+, NO^- and NO_2 (*d*) H_3O^+, NO_3^- and N_2O

3. Aspartame, an artificial sweetener, is a dipeptide aspartyl phenylalanine methyl ester. The structure of aspartame is

Structures of phenylalanine and aspartic acid are given below.

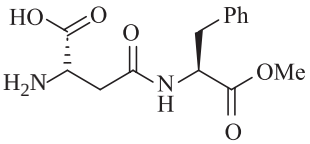


Phenylalanine

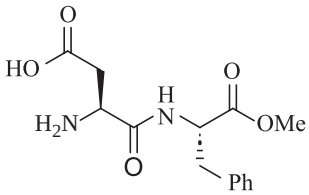


Aspartic acid

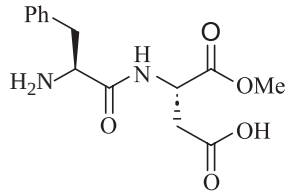
(*a*)



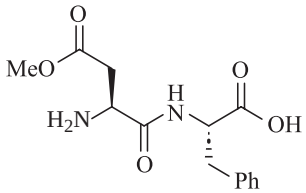
(*b*)



(*c*)



(*d*)



4. Among the following options, select the option in which each complex in **Set-I** shows geometrical isomerism and the two complexes in **Set-II** are ionization isomers of each other.

[en = $H_2NCH_2CH_2NH_2$]

(*a*) **Set-I:** $[Ni(CO)_4]$ and $[PdCl_2(PPh_3)_2]$
Set-II: $[Co(NH_3)_5Cl]SO_4$ and $[Co(NH_3)_5(SO_4)]Cl$

(*b*) **Set-I:** $[Co(en)(NH_3)_2Cl_2]$ and $[PdCl_2(PPh_3)_2]$
Set-II: $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$

(*c*) **Set-I:** $[Co(NH_3)_3(NO_2)_3]$ and $[Co(en)_2Cl_2]$
Set-II: $[Co(NH_3)_5Cl]SO_4$ and $[Co(NH_3)_5(SO_4)]Cl$

(*d*) **Set-I:** $[Cr(NH_3)_5Cl]Cl_2$ and $[Co(en)(NH_3)_2Cl_2]$
Set-II: $[Cr(H_2O)_6]Cl_3$ and $[Cr(H_2O)_5Cl]Cl_2{\cdot}H_2O$

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated <u>according to the following marking scheme</u>:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

2 ATOMIC STRUCTURE

JEE-Advanced

Subatomic Particles and Atomic Models

Single Correct

1. Rutherford's experiment, which established the nuclear model of the atom, used a beam of **(IIT JEE 2002)**

(*a*) β-particles, which impinged on a metal foil and got absorbed
(*b*) γ-rays, which impinged on a metal foil and got scattered
(*c*) helium atoms, which impinged on a metal foil and got scattered
(*d*) helium nuclei, which impinged on a metal foil and got scattered

2. Rutherford's alpha particle scattering experiment eventually led to the conclusion that **(IIT JEE 1986)**

(*a*) mass and energy are related
(*b*) electrons occupy space around the nucleus
(*c*) neutrons are buried deep in the nucleus
(*d*) the point of impact with matter can be precisely determined

3. The radius of an atomic nucleus is of the order of **(IIT JEE 1985)**

(*a*) 10^{-10} cm (*b*) 10^{-13} cm
(*c*) 10^{-15} cm (*d*) 10^{-18} cm

4. The increasing order (lowest first) for the values of e/m (charge/mass) for electron (e), proton (p), neutron (n) and alpha particle (α) is **(IIT JEE 1984)**

(*a*) e, p, n, α (*b*) n, p, e, α
(*c*) n, p, α, e (*d*) n, α, p, e

5. Rutherford's scattering experiment is related to the size of the **(IIT JEE 1983)**

(*a*) nucleus (*b*) atom (*c*) electron (*d*) neutron

6. Rutherford's experiment on scattering of α-particles showed for the first time that the atom has **(IIT JEE 1981)**

(*a*) electrons (*b*) protons (*c*) nucleus (*d*) neutrons

Multiple Correct

7. The atomic nucleus contains **(IIT JEE 1988)**

(*a*) protons (*b*) neutrons
(*c*) electrons (*d*) photons

8. The sum of the number of neutrons and proton in the isotope of hydrogen is **(IIT JEE 1986)**

(*a*) 6 (*b*) 5 (*c*) 4 (*d*) 3

9. When alpha particles are sent through a thin metal foil, most of them go straight through the foil, because **(IIT JEE 1984)**

(*a*) alpha particles are much heavier than electrons
(*b*) alpha particles are positively charged
(*c*) most part of the atom is empty space
(*d*) alpha particles move with high velocity

10. Many elements have non-integral atomic masses, because **(IIT JEE 1984)**

(*a*) they have isotopes
(*b*) their isotopes have non-integral masses
(*c*) their isotopes have different masses
(*d*) the constituents, neutrons, protons and electrons, combine to give fractional masses

11. An isotone of $^{76}_{32}Ge$ **(IIT JEE 1984)**

(*a*) $^{77}_{32}Ge$ (*b*) $^{77}_{33}As$ (*c*) $^{77}_{34}Se$ (*d*) $^{78}_{34}Se$

Fill in the Blanks

12. Elements of the same mass number but of different atomic numbers are known as ..... **(IIT JEE 1983)**

13. The mass of a hydrogen is ..... kg. **(IIT JEE 1982)**

14. Isotopes of an element differ in the number of ..... in their nuclei. **(IIT JEE 1982)**

True/False

15. In a given electric field, β-particles are deflected more than α-particles in spite of α-particles having larger charge. **(IIT JEE 1993)**

Developments Leading to the Bohr's Model of Atom

Single Correct

16. The first use of quantum theory to explain the structure of atom was made by **(IIT JEE 1997)**

(*a*) Heisenberg (*b*) Bohr
(*c*) Planck (*d*) Einstein

17. Which of the following relates to photons both as wave motion and as a stream of particles? **(IIT JEE 1992)**

(*a*) Interference (*b*) $E = mc^2$
(*c*) Diffraction (*d*) $E = hv$

Fill in the Blanks

53. The uncertainty principle and the concept of wave nature of matter were proposed by ..... and ..... respectively

(IIT JEE 1988)

Subjective

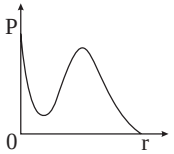
54. An electron beam can undergo diffraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.54Å. **(IIT JEE 1997)**

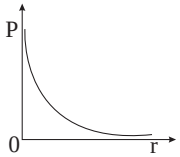
Quantum Mechanical Model of the Atom

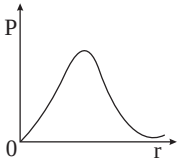
Single Correct

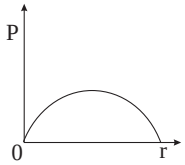
55. P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness, dr, at a distance r from the nucleus. The volume of this shell is $4\pi r^2$ dr. The qualitative sketch of the dependence of P on r is

C-37.22 W-37.41 UA-25.38 (JEE Adv. 2016)

(*a*) 

(*b*) 

(*c*) 

(*d*) 

56. The number of radial nodes in 3s and 2p respectively are

(IIT JEE 2005)

(*a*) 2 and 0 (*b*) 0 and 2 (*c*) 1 and 2 (*d*) 2 and 1

57. If the nitrogen atom had electronic configuration $1s^7$, it would have energy lower than that of the normal ground state configuration $1s^2 2s^2 2p^3$, because the electrons would be closer to the nucleus, yet $1s^7$ is not observed, because it violates **(IIT JEE 2002)**

(*a*) Heisenberg uncertainty principle

(*b*) Hund's rule

(*c*) Pauli exclusion principle

(*d*) Bohr postulate of stationary orbits

58. The quantum numbers $+\frac{1}{2}$ and $-\frac{1}{2}$ for the electron spin represent **(IIT JEE 2001)**

(*a*) rotation of the electron in clockwise and anti-clockwise direction respectively

(*b*) rotation of the electron in anti-clockwise and clockwise direction respectively

(*c*) magnetic moment of the electron pointing up and down respectively

(*d*) two quantum mechanical spin states which have no classical analogue

59. The number of nodal planes in a p_x orbital is **(IIT JEE 2001)**

(*a*) one (*b*) two (*c*) three (*d*) zero

60. The electronic configuration of an element is $1s^2$, $2s^2 2p^6$, $3s^2 3p^6 3d^5$, $4s^1$. This represents its **(IIT JEE 2000)**

(*a*) excited state (*b*) ground state

(*c*) cationic form (*d*) anionic form

61. The electrons, identified by quantum numbers n and *l*, (i) $n = 4$, $l = 1$, (ii) n = 4, $l = 0$, (iii) n = 3, $l = 2$, (iv) n = 3, $l = 1$ can be placed in order of increasing energy, from the lowest to highest, as

(IIT JEE 1999)

(*a*) (iv) < (ii) < (iii) < (i) (*b*) (ii) < (iv) < (i) < (iii)

(*c*) (i) < (iii) < (ii) < (iv) (*d*) (iii) < (i) < (iv) < (ii)

62. For a d-electron, the orbital angular momentum is

(IIT JEE 1997)

(*a*) $\sqrt{6}\left(\frac{h}{2\pi}\right)$ (*b*) $\sqrt{2}\left(\frac{h}{2\pi}\right)$

(*c*) $\left(\frac{h}{2\pi}\right)$ (*d*) $2\left(\frac{h}{2\pi}\right)$

63. The orbital angular momentum of an electron in 2*s*-orbital is

(IIT JEE 1996)

(*a*) $+\frac{1}{2}\cdot\frac{h}{2\pi}$ (*b*) zero

(*c*) $\frac{h}{2\pi}$ (*d*) $\sqrt{2}\cdot\frac{h}{2\pi}$

64. The outermost electronic configuration of the most electronegative element is **(IIT JEE 1990)**

(*a*) $ns^2\, np^3$ (*b*) $ns^2\, np^4$

(*c*) $ns^2\, np^5$ (*d*) $ns^2\, np^6$

65. The correct set of quantum numbers for the unpaired electron of chlorine atom is **(IIT JEE 1989)**

(*a*) n = 2, l = 1, m = 0 (*b*) n = 2, l = 1, m = 1

(*c*) n = 3, l = 1, m = 1 (*d*) n = 3, l = 0, m = 0

66. The correct ground state electronic configuration of chromium atom is **(IIT JEE 1989)**

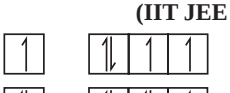
(*a*) $[Ar]3d^5 4s^1$ (*b*) $[Ar]3d^4 4s^2$

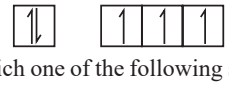
(*c*) $[Ar]3d^6 4s^0$ (*d*) $[Ar]4d^5 4s^1$

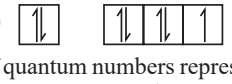
67. The orbital diagram in which the Aufbau principle is violated

(IIT JEE 1988)

(*a*) 

(*b*) 

(*c*) 

(*d*) 

68. Which one of the following sets of quantum numbers represents an impossible arrangement? for n, l, m, s **(IIT JEE 1986)**

(*a*) $\left(3, 2, -2, \frac{1}{2}\right)$ (*b*) $4, 0, 0, \frac{1}{2}$

(*c*) $3, 2, -3, \frac{1}{2}$ (*d*) $5, 3, 0, -\frac{1}{2}$

69. Correct set of four quantum numbers for the valence (outermost) electron of rubidium ($Z = 37$) is **(IIT JEE 1984)**

(*a*) $5, 0, 0, +\frac{1}{2}$ (*b*) $5, 0, 1, +\frac{1}{2}$

(*c*) $5, 1, 1, +\frac{1}{2}$ (*d*) $6, 0, 0, +\frac{1}{2}$

70. The principal quantum number of an atom is related to the

(IIT JEE 1983)

(*a*) size of the orbital

(*b*) spin angular momentum

(*c*) orientation of the orbital in space

(*d*) orbital angular momentum

71. Any *p*-orbital can accommodate upto **(IIT JEE 1983)**

(*a*) four electrons

(*b*) six electrons

(*c*) two electrons with parallel spins

(*d*) two electrons with opposite spins

Fill in the Blanks

85. The outermost electronic configuration of Cr is _____.
(IIT JEE 1994)

86. Wave functions of electrons in atoms and molecules are called _____.
(IIT JEE 1993)

87. The $2p_x$, $2p_y$ and $2p_z$ orbitals of atom have identical shapes but differ in their _____.
(IIT JEE 1993)

88. When there are two electrons in the same orbital, they have _____ spins
(IIT JEE 1983)

True/False

89. The electron density in the *XY*-plane in $3d_{x^2-y^2}$ orbital zero.
(IIT JEE 1986)

90. The energy of the electron in the 3d-orbital is less than that in the 4*s* orbital in the hydrogen atom.
(IIT JEE 1983)

91. The outer electronic configuration of the ground state chromium atom is $3d^44S^2$.
(IIT JEE 1982)

Subjective

92. The Schrodinger wave equation for hydrogen atom is

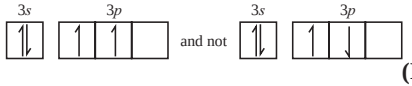
$$\psi_{2s} = \frac{1}{4(2\pi)^{1/2}}\left(\frac{1}{a_0}\right)^{3/2}\left(2-\frac{r}{a_0}\right)e^{-r/2a_0}$$

where, a_0 is Bohr's radius. Let the radial node in 2s be at r_0. Then, find r in terms of a_0.

(*b*) A base ball having mass 100 g moves with velocity 100 m/s. Find out the value of wavelength of baseball.
(IIT JEE 2004)

93. What is the maximum number of electrons that may be present in all the atomic orbitals with principal quantum number 3 and azimuthal quantum number 2?
(IIT JEE 1985)

94. Give reason why the ground state outermost electronic configuration of silicon is



(IIT JEE 1985)

ANSWER KEY

1. (*d*)	**2.** (*b*)	**3.** (*b*)	**4.** (*d*)	**5.** (*a*)	**6.** (*c*)	**7.** (*a*, *b*)	**8.** (*a*)	**9.** (*a*, *c*)	**10.** (*a*,*c*)
11. (*b*, *d*)	**12.** Isobar	**13.** 1.66×10^{-24} kg		**14.** Neutrons	**15.** TRUE	**16.** (*b*)	**17.** (*d*)	**18.** (*c*)	**19.** (*d*)
20. (*b*)	**21.** (*b*)	**22.** [5]	**23.** [4]	**24.** Photons	**25.** FALSE	**29.** (*c*)	**30.** (*b*)	**31.** (*a*)	**32.** (*c*)
33. (*d*)	**34.** (*c*)	**35.** (*d*)	**36.** A→(r); B→(q); C→(p); D→(s)			**37.** [30]	**38.** [–5242.4192]		**39.** [1:16]
51. (*c*)	**52.** [30]	**53.** Heisenberg and De-Broglie			**55.** (*c*)	**56.** (*a*)	**57.** (*c*)	**58.** (*d*)	**59.** (*a*)
60. (*b*)	**61.** (*a*)	**62.** (*a*)	**63.** (*b*)	**64.** (*c*)	**65.** (*c*)	**66.** (*a*)	**67.** (*b*)	**68.** (*c*)	**69.** (*a*)
70. (*a*)	**71.** (*d*)	**72.** (*a*, c)	**73.** (*a*, *d*)	**74.** (*a*, *b*, *c*)	**75.** (*c*)	**76.** (*b*)	**77.** (*c*)	**78.** (*b*)	**79.** (*c*)
80. (*a*)	**81.** (*d*)	**82.** [3]	**83.** [6]	**84.** [9]	**85.** $[Ar]3d^54s^1$		**86.** Orbital	**87.** Orientation in space	
88. opposite	**89.** FALSE	**90.** TRUE	**91.** FALSE						

1 SOME BASIC CONCEPTS OF CHEMISTRY

1. (*a*) The molecular weight of oxalic acid dihydrate ($C_2H_2O_4 \cdot 2H_2O$) is g/mol. It is a dibasic acid.

Its equivalent weight is $\frac{126}{2} = 63$.

Its normality is

$$\frac{\text{weight}}{\text{equivalent weight}} \times \frac{1000}{\text{Volume in}} = \frac{6.3 \times 1000}{63 \times 250} = 0.4\text{N}$$

But $N_1V_1 = N_2V_2$,

Hence, $0.1\ V_1 = 0.4 \times 10$

Thus, the volume of 0.1 N NaOH required to completely neutralize 10 mL of this solution is 40 mL.

2. (*d*) From given question we have Molarity (M) = 0.3M and we know that the relation between normality (N) and molarity(M). Then, we have

Normality (N) = Molarity × basicity (basicity of H_3PO_3 is 2

So, N = 0.3 × 2 = 0.6N

3. (*d*) Molarity depends on temperature.

$$M\alpha\frac{1}{V}\alpha\frac{1}{T}$$

V = Volume, T = Temperature

Normality = Molarity $\times n_{factor}$.

So, it depends upon temperature.

Formality

$$\frac{\text{No. of gram formula masses dissolved}}{\text{Volumes (Litres)}}$$

So, Formality also depends on temperature.

$V \propto T$

Molality is the one which depends upon the mass of the solute and the solvent.

The mass is independent of temperature.

Thus, molality is independent of temperature.

4. (*b*) Volume strength of hydrogen peroxide is defined as the term which is used to express the concentration of H_2O_2 with respect to the volumes of oxygen gas based on its decomposition to form water and oxygen.

Normality (N) = 1.5

Equivalent weight of H_2O_2 is 17

Strength of H_2O_2 = (Normality) (Equivalent weight)

= 1.5 × 17 = 25.5

$2H_2O_2 \rightarrow 2H_2O + O_2$

(2) (34 g) (22.4 L)

Since 68 grams of H_2O_2 produces 22.4 liters of oxygen at NTP,

Therefore, 25.5 grams of H_2O_2 will produce = (22.4/68) 25.5 = 8.4 liter of oxygen

Thus, volume strength of given H_2O_2 solution is 8.4.

5. (*a*) According to molality (m) definition,

Molality is the number of moles of solute dissolved in 1000 grams of solvent. So 1 molal solution contains one mole of solute in 1000 grams of solvent.

Hence option (*a*) is correct.

6. (*d*) Chemical Reaction:

$3BaCl_2 + 2Na_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6NaCl$

2 mol of $Na_3PO_4 \Rightarrow 3$ mol of $BaCl_2$

0.2 mol of $Na_3PO_4 \Rightarrow 0.3$ mol of $BaCl_2$

$\therefore$ Na_3PO_4 is the limiting reagent.

Thus, 2 mol of $Na_3PO_4 \Rightarrow 1$ mol of $Ba_3(PO_4)_2$

0.2 mol of $Na_3PO_4 \Rightarrow 0.1$ mol of $Ba_3(PO_4)_2$

7. (*a*) We know that, Atomic number = $n_p = n_e$

In case of carbon dioxide,

C has atomic number 6 so it has 6 electrons

oxygen has atomic no. 8, i.e., 16 electrons.

So total electrons present are in one mole of carbon dioxide (CO_2), 2 will be subscript of O = 16 + 6 = 22 electrons.

8. [6.15] Aluminium reacts with sulphuric acid to form aluminium sulphate and hydrogen.

$$\underset{\left(\frac{5.4}{27}=0.2\text{mol}\right)}{2\text{Al}} + \underset{\left(\frac{50\times5}{1000}=0.25\text{ mol}\right)}{3H_2SO_4} \rightarrow Al_2(SO_4)_3 + + 3H_2$$

H_2SO_4 is limiting reagent and moles of H_2(g) produced = 0.25 mol

Using ideal gas equation,

pV = nRT

$$\Rightarrow V = \frac{0.25 \times 0.082 \times 300}{1\text{atm}} \Rightarrow 6.15\text{ L}$$

9. [2.98 or 2.99]

$$X_{urea} = 0.05 = \frac{n}{n+50}$$

19n = 50

n = 2.6315

$$V_{sol} = \frac{(2.6315 \times 60 + 900)}{1.2} = 881.5789\text{ ml}$$

$$\text{Molarity} = \frac{2.6315 \times 1000}{881.5789} = 2.9849$$

Molarity = 2.98M

10. [9] Molecular weight of solute be = M_1

Molecular weight of solvent be M_2

Fraction of solute = 0.1

Let solution be litre

mass of solution = 2000 g

mass of solute = x mass of solvent = 2000 × x · g

$$\text{Molarity} = \frac{x}{M_1}/1\text{ litre} = \frac{x}{M_1}$$

$$\text{Molarity} = \frac{x}{M_1}/(2000 - x) \times 10^{-3}$$

$$= \frac{1000x}{(2000 - x)M_1}$$

Molarity = Molarity

$$\frac{x}{M_1} = \frac{1000x}{(2000 - x)M_1} = 2000 - x = 1000;\ x = 1000\text{ gM}$$

$$\frac{\frac{1000}{M_1}}{\frac{1000}{M_1} + \frac{1000}{M_2}} \Rightarrow \frac{M_2}{M_1 + M_2} = 0.1$$

$M_2 = 0.1M_1 + 0.1\ M_2$

$0.9\ M_2 = 0.1\ M_1$

$M_1/M_2 = 0.9/0.1 = 9$

11. [8] According to given question

$$M_{(H_2X)} = 80\,\text{gmol}^{-1}$$

$$d_{solvent} = 0.4\,\text{gmol}^{-1}$$

$$M = 3.2 = \frac{n_B}{V_{solution}}$$

$V_{solvent} = V_{solution} = 1000$ ml (given in question)

$W_{Solvent} = 0.4 \times 1000 = 400\text{g} = W_A$

3.2 moles of H_2X in 1000 ml of Solution

n_B = 3.2 moles

$$\text{molality} = \frac{n_B}{W_A} \times 1000 = \frac{3.2 \times 1000}{400} = 8\text{ m}$$

12. [8] Given data

100 g solution contains 29.2g HCl and molecular weight of HCl = 36.5 g/mol

$$\text{Volume of solution} = \frac{\text{Mass}}{\text{density}} = \frac{100}{1.25} = 80\text{ ml}$$

Molarity

$$= \frac{\text{Mass of solute}}{\text{Mol.wt. of solute} \times \text{Volume (in ml)}} \times 1000$$

$$= \frac{29.2}{36.5 \times 80} \times 1000 = 10\text{ M}$$

Let V ml of this HCl are used to prepare 200 ml of 0.4M HCl, then

milli-mole of conc. HCl = milli-mole of dil. HCl

(milli-mole does not change on dilution)

$V \times 10 = 200 \times 0.4 \Rightarrow V = 8$ ml

13. (0.4) The expression for the molality of the solution is

Molality (m)

$$= \frac{\text{mass of salt}}{\text{molar mass of salt}} \times \frac{1}{\text{mass of water}}$$

Substituting values in the above expression, we get kg

$$m = \frac{3}{30} \times \frac{1}{250} \times 1000 = 0.4\text{m}$$

The molality of the solution is 0.4 m.

14. (6.023×10^{24}) Number of electron in one molecule of H_2O is 2 + 8 = 10.

Density = 1 g/ml

$\therefore$ 18 ml means 18 g

$$\text{Moles} = \frac{18}{18} = 1$$

Electrons = $6.023 \times 10^{23} \times 10 = 6.023 \times 10^{24}$

15. Given that for absorbed N_2 on surface sites,

$P(N_2) = 0.001\text{ atm}, V = 2.46\text{ cm}^3 = 2.46 \times 10^{-3}\text{ l}$, T = 298

KEY FEATURES

- Chapter-wise & topic-wise solved papers of the past 47 years
- Exam Analysis based on different parameters
- Realtime Question-wise difficulty level analysis with Correct (C), Wrong(W) and Unattempted (UA) questions response tagging provided by IIT-JEE
- Answer key verified from the official website of JEE Advanced

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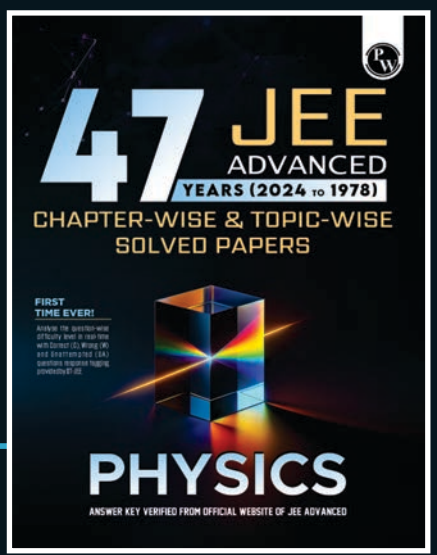

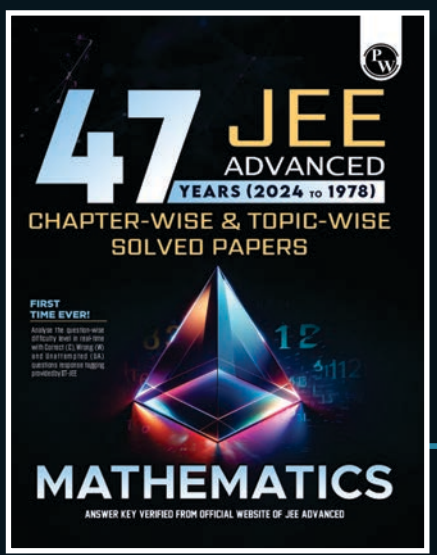

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