PhysicsByAaryan

CSIR NET . GATE . JEST . BARC - Physics

CSIR NET Physics - Dec 2023 - Full Paper

Complete question paper with answer key

75 questions . Answer key included

www.physicsbyaaryan.com . www.csirnetphysics.com
Contact: 9501976811

Q1. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

In how many ways can a menu be made from 5 dishes, if the menu contains either 3 or 4 dishes?

1. 2
2. 3
3. 7
4. 15

Q2. [Dec 2023] . 2.0 marks

General Aptitude > Reasoning

CSIR NET	2023 Dec	2 M

All the four entries in column A must be matched with all those in column B. Each correctly matched option gets one mark and no mark is awarded otherwise. Which of the following mark(s) CANNOT be scored?

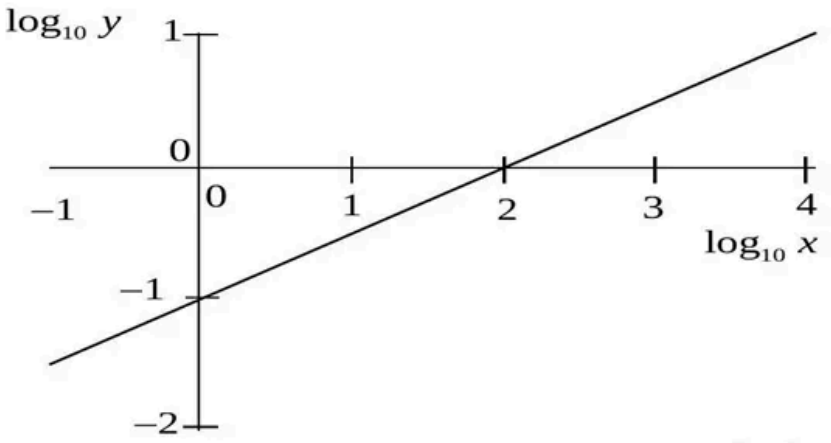
1. 3
2. 1
3. 2
4. 4

Q3. [Dec 2023] . 2.0 marks

General Aptitude > Data Analysis

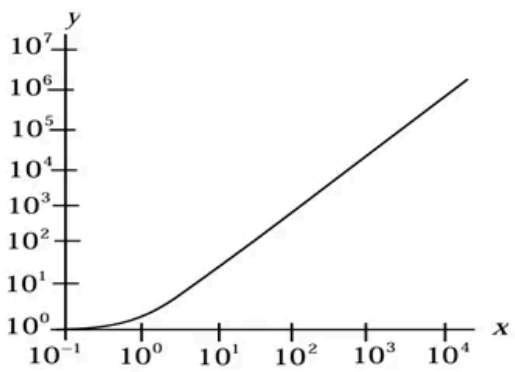
CSIR NET	2023 Dec	2 M

In the figure $\log_{10} y$ is plotted against $\log_{10} x$



When y is plotted against x, then the plot in the provided range is

1.



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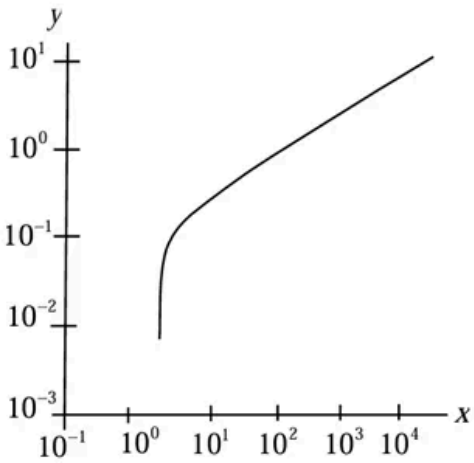

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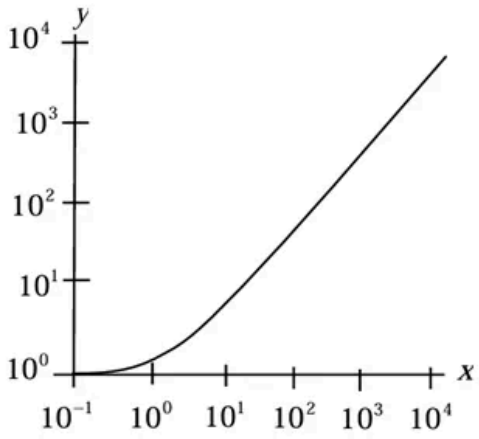

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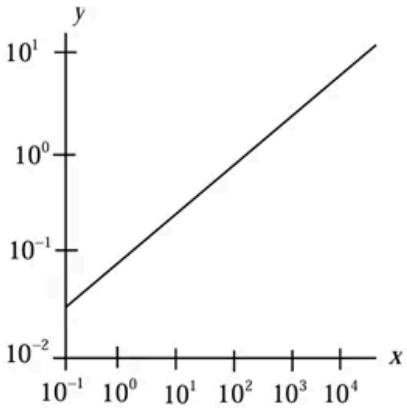


Q4. [Dec 2023] . 2.0 marks

General Aptitude > Reasoning

CSIR NET	2023 Dec	2 M

Four children had 27 apples among them. No child had less than 5 apples. If no two children had the same number of apples, then which of the following could NOT be the number of apples a child had?

1. 5
2. 6
3. 8
4. 9

Q5. [Dec 2023] . 2.0 marks

General Aptitude > Reasoning

CSIR NET	2023 Dec	2 M

In 1979, Ramesh's age was the sum of the digits of his year of birth. In 2017, on his birthday, what was his age?

1. 49
2. 57
3. 60
4. 64

Q6. [Dec 2023] . 2.0 marks

General Aptitude > Reasoning

CSIR NET	2023 Dec	2 M

What is the minimum number of pourings needed to get 4 litre of milk from a fully filled 8 litre can, using ungraduated empty 5 and 3 litre cans? No milk should be wasted.

1. 4
2. 5
3. 6
4. 8

Q7. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

Radius of sphere is measured with 5% uncertainty. What is the uncertainty in the volume, determined from this radius?

1. 5%
2. 6.6%
3. 125%
4. 15%

Q8. [Dec 2023] . 2.0 marks

General Aptitude > Basic Physics

CSIR NET	2023 Dec	2 M

A truck from a post office is sent to collect post from a plane as per schedule. The plane lands ahead of schedule, therefore its contents are transported by a rickshaw. The rickshaw meets the truck 30 minutes after the arrival of plane, and the post is transferred. The truck returns to the post office 20 minutes early. How early did the plane arrive? (Assume all transactions are instantaneous).

1. 10 minutes
2. 20 minutes
3. 30 minutes
4. 40 minutes

Q9. [Dec 2023] . 2.0 marks

General Aptitude > Data Analysis

CSIR NET	2023 Dec	2 M

A person's viral load measured in some unit was 15,25,50,200,300,150 and 30 on days 1 to 7, respectively. The maximum relative change took place between

1. day 3 to day 4
2. day 4 to day 5
3. day 5 to day 6
4. day 6 to day 7

Q10. [Dec 2023] . 2.0 marks

General Aptitude > Basic Physics

CSIR NET	2023 Dec	2 M

The time seen in a mirror placed opposite a numberless analog (with hands) wall clock is 4 h 55 min . What approximately is the correct time?

1. 4 h 55 min
2. 5 h 05 min
3. 7 h 05 min
4. 1 h 35 min

Q11. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

For every 5 chocolates that Ramesh gets, Suresh gets 3 chocolates. Geeta gets 3 chocolates for every 2 chocolates that Suresh gets. If Geeta has 18 chocolates, then the sum of chocolates with Ramesh and Suresh is

1. 16
2. 30
3. 32
4. 38

Q12. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

In a market, you can buy a mango for Rs. 10, a lemon for Re. 1 and 8 chillies for Re.1. How many of these items do you need to buy to get a mix of 100 items for exactly Rs. 100?

1. 6 mangoes, 22 lemons, 72 chillis
2. 7 mangoes, 21 lemons, 72 chillis
3. 1 mango, 9 lemons, 80 chillis
4. 8 mangoes, 12 lemons, 80 chillis

Q13. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

The sum of the two positive integers is 14 . Then their product CANNOT be divisible by

1. 12
2. 13
3. 14
4. 49

Q14. [Dec 2023] . 2.0 marks

General Aptitude > Basic Physics

CSIR NET	2023 Dec	2 M

A bird keeps flying continuously between two trains, that are following each other on a straight track. The train behind is slower than the one ahead by $1.5\ \mathrm{km/h}$. If the speed of the bird is $20\ \mathrm{km/h}$, what distance would the bird cover in an hour?

1. 20 km
2. 30 km
3. 50 km
4. 60 km

Q15. [Dec 2023] . 2.0 marks

General Aptitude > Reasoning

CSIR NET	2023 Dec	2 M

SCRIPT : DIRECTOR :: ?? : CHEF

Choose the most appropriate option from the following to fill the blank

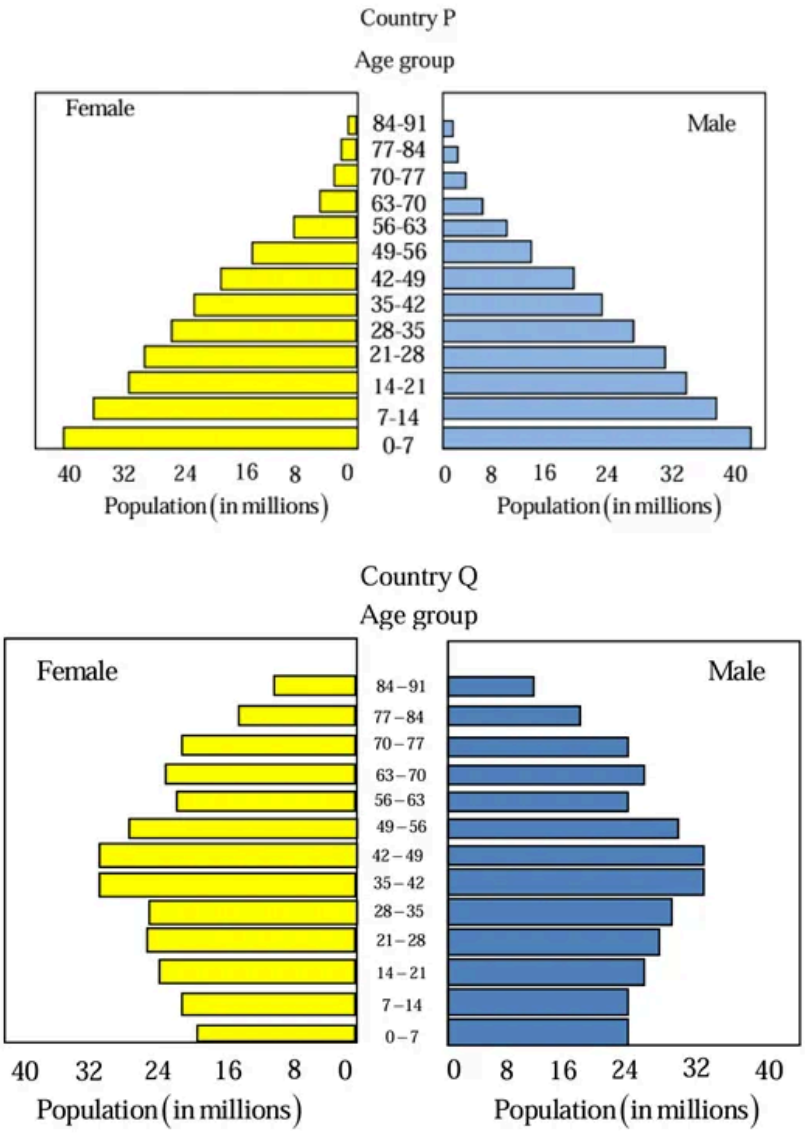
1. MENU
2. RECIPE
3. RESTAURANT
4. MEAL

Q16. [Dec 2023] . 2.0 marks

General Aptitude > Data Analysis

CSIR NET	2023 Dec	2 M

The figure shows age-wise bar graph of male and female population of two countries. Which one of the following is likely to be true?

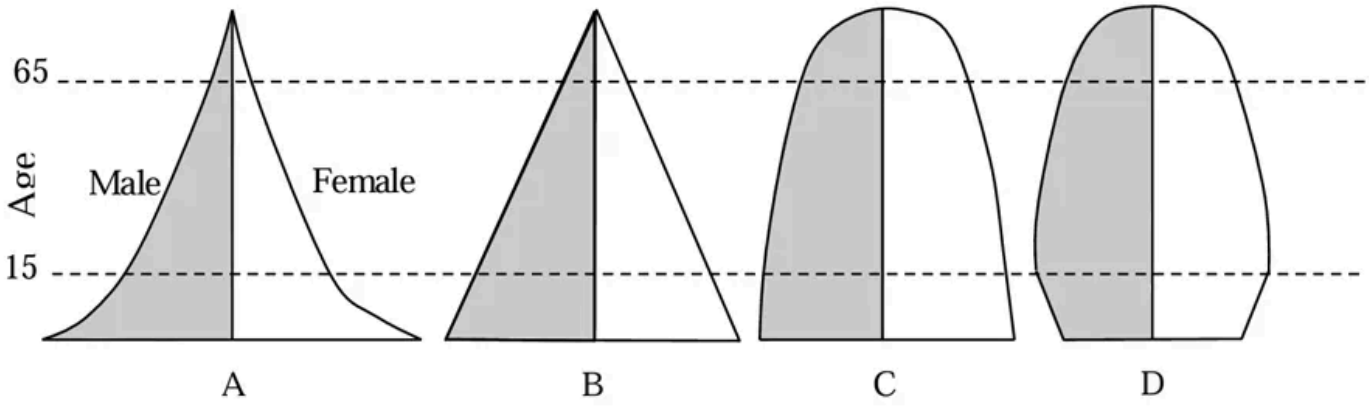


1. Country Q has higher life expectancy
2. Country P has higher per-capita income
3. The population of country P is decreasing more rapidly than Q
4. Country P has better health facilities

Q17. [Dec 2023] . 2.0 marks

General Aptitude > Data Analysis

CSIR NET	2023 Dec	2 M



The above figures show population pyramids to four countries A, B, C and D . The country showing the most stable population is

1. C
2. A
3. B
4. D

Q18. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

What is the value of x in the given magic square, (i.e, a square grid in which the sum of the numbers in rows, columns and diagonals is the same)?

x	$x-5$	8
$x+1$	y	$y-2$
2	9	4

1. 6
2. 4
3. 3
4. 1

Q19. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

If $a < x < b$, then for which of the following relations does $0 < y < 1$ always hold?

1. $y = \frac{a-x}{b+a}$

2. $y = \frac{x-a}{b-a}$

3. $y = \frac{x-b}{b-a}$

4. $y = \frac{b-x}{a+b}$

Q20. [Dec 2023] . 2.0 marks

General Aptitude > Mathematical Analysis

CSIR NET	2023 Dec	2 M

A letter is drawn at random from the following string of letters.

RAMUKYAJNAS

What is the probability that it is NOT a vowel?

1. 1/2
2. 6/11
3. 7/11
4. 8/11

Q21. [Dec 2023] . 3.5 marks

Classical Mechanics > Central forces

CSIR NET	2023 Dec	3.5 M

A particle of mass m is moving in a stable circular orbit or radius r_0 with angular momentum L. For a potential energy $V(r) = \beta r^k (\beta > 0 \text{ and } k > 0)$, which of the following options is correct?

1. $k = 3, r_0 = \left(\frac{3L^2}{5m\beta}\right)^{1/5}$

2. $k = 2, r_0 = \left(\frac{L^2}{2m\beta}\right)^{1/4}$

3. $k = 2, r_0 = \left(\frac{L^2}{4m\beta}\right)^{1/4}$

4. $k = 3, r_0 = \left(\frac{5L^2}{3m\beta}\right)^{1/5}$

Q22. [Dec 2023] . 3.5 marks

Classical Mechanics > Lagrangian and Hamiltonian

CSIR NET	2023 Dec	3.5 M

The 1-dimensional Hamiltonian of a classical particle of mass m is

$$H = \frac{P^2}{2m} e^{-x/a} + V(x)$$

where a is a constant with appropriate dimensions. The corresponding Lagrangian is,

1. $\frac{m}{2}\left(\frac{dx}{dt}\right)^2 e^{x/a} - V(x)$
2. $\frac{m}{2}\left(\frac{dx}{dt}\right)^2 e^{-x/a} - V(x)$
3. $\frac{3m}{2}\left(\frac{dx}{dt}\right)^2 e^{x/a} - V(x)$
4. $\frac{3m}{2}\left(\frac{dx}{dt}\right)^2 e^{-x/a} - V(x)$

Q23. [Dec 2023] . 3.5 marks

Classical Mechanics > Oscillations

CSIR NET	2023 Dec	3.5 M

A particle of unit mass subjected to the 1-dimensional potential

$$V(x) = \frac{2\alpha}{x^3} - \frac{3\beta}{x^2}$$

executes small oscillations about its equilibrium position, where α and β are positive constants with appropriate dimensions. The time period of small oscillations is

1. $\frac{\pi\alpha^2}{\sqrt{6\beta^5}}$
2. $\frac{\pi\alpha^2}{\sqrt{3\beta^5}}$
3. $\frac{2\pi\alpha^2}{\sqrt{3\beta^5}}$
4. $\frac{2\pi\alpha^2}{\sqrt{6\beta^5}}$

Q24. [Dec 2023] . 3.5 marks

Classical Mechanics > Special theory of relativity

CSIR NET	2023 Dec	3.5 M

The coordinates of the following events in an observer's inertial frame of reference are as follows:

Event 1: $t_1 = 0, x_1 = 0$: A rocket with uniform velocity $0.5c$ crosses the observer at origin along x axis

Event 2: $t_2 = T, x_2 = 0$: The observer sends a light pulse towards the rocket

Event 3: t_3, x_3 : The rocket receives the light pulse

The values of t_3, x_3 respectively are

1. $2T, cT$
2. $2T, \frac{c}{2}T$
3. $\frac{\sqrt{3}}{2}T, \frac{2}{\sqrt{3}}cT$
4. $\frac{2}{\sqrt{3}}T, \frac{\sqrt{3}}{2}cT$

Q25. [Dec 2023] . 3.5 marks

Classical Mechanics > Central forces

CSIR NET	2023 Dec	3.5 M

A particle moves in a circular orbit under a force field given by $\vec{F}(\vec{r}) = -\frac{k}{r^2}\hat{r}$, where k is a positive constant. If the force changes suddenly to $\vec{F}(\vec{r}) = -\frac{k}{2r^2}\hat{r}$, the shape of the new orbit would be

1. parabolic
2. circular
3. elliptical
4. hyperbolic

Q26. [Dec 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 Dec	3.5 M

The Schrodinger wave function for a stationary state of an atom in spherical polar coordinates (r, θ, ϕ) is

$$\psi = Af(r)\sin\theta\cos\theta e^{i\phi}$$

where A is the normalization constant. The eigenvalue of $\hat{L}_z$ for this state is

1. $2\hbar$
2. $\hbar$
3. $-2\hbar$
4. $-\hbar$

Q27. [Dec 2023] . 3.5 marks

Quantum Mechanics > Orbital angular Momentum and Hydrogen atom

CSIR NET	2023 Dec	3.5 M

The Hamiltonian for two particles with angular momentum quantum numbers $l_1 = l_2 = 1$, is

$$\hat{H} = \frac{\epsilon}{\hbar^2}\left[(\hat{L}_1 + \hat{L}_2)\cdot\hat{L}_2 - (\hat{L}_{1z} + \hat{L}_{2z})^2\right]$$

If the operator for the total angular momentum is given by $\hat{L} = \hat{L}_1 + \hat{L}_2$, then the possible energy eigenvalues for states with $l = 2$, (where the eigenvalues of $\hat{L}^2$ are $l(l+1)h^2$) are

1. $3\in, 2\in, -\in$
2. $6\in, 5\in, 2\in$
3. $3\in, 2\in, \in$
4. $-3\in, -2\in, \in$

Q28. [Dec 2023] . 3.5 marks

Quantum Mechanics > Spin Angular momentum

CSIR NET	2023 Dec	3.5 M

The normalized wave function of an electron is

$$\psi(\vec{r}) = R(r)\left[\sqrt{\frac{3}{8}}Y_1^0(\theta,\varphi)\chi_- + \sqrt{\frac{5}{8}}Y_1^1(\theta,\varphi)\chi_+\right]$$

where Y_l^m are the normalized spherical harmonics and $\chi_\pm$ denote the wavefunction for the two spin states with eigenvalues $\pm\frac{1}{2}\hbar$. The expectation value of the z component of the total angular momentum in the above state is

1. $-\frac{3}{4}\hbar$
2. $\frac{3}{4}\hbar$
3. $-\frac{9}{8}\hbar$
4. $\frac{9}{8}\hbar$

Q29. [Dec 2023] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2023 Dec	3.5 M

A quantum system is described by the Hamiltonian

$$H = JS_z + \lambda S_x$$

where $S_i = \frac{\hbar}{2}\sigma_i$ and $\sigma_i (i = x, y, z)$ are the Pauli matrices. If $0 < \lambda \ll J$, then the leading correction in λ to the partition function of the system at temperature T is

1. $\frac{\hbar\lambda^2}{2Jk_BT} \coth\left(\frac{J\hbar}{2k_BT}\right)$
2. $\frac{\hbar\lambda^2}{2Jk_BT} \tanh\left(\frac{J\hbar}{2k_BT}\right)$
3. $\frac{\hbar\lambda^2}{2Jk_BT} \cosh\left(\frac{J\hbar}{2k_BT}\right)$
4. $\frac{\hbar\lambda^2}{2Jk_BT} \sinh\left(\frac{J\hbar}{2k_BT}\right)$

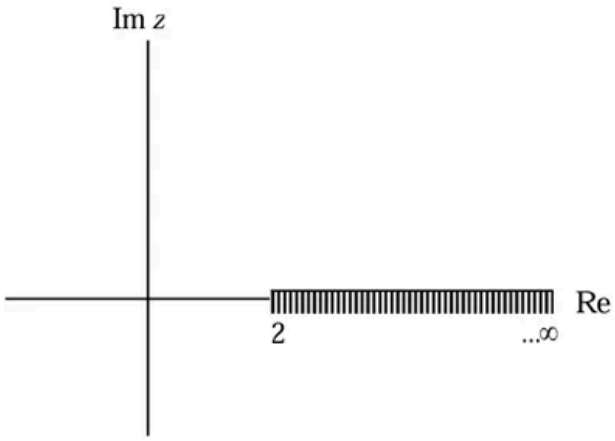
Q30. [Dec 2023] . 3.5 marks

Mathematical Physics > Complex analysis

CSIR NET	2023 Dec	3.5 M

The branch line for the function $f(z) = \sqrt{\frac{z^2-5z+6}{z^2+2z+1}}$ is

1.



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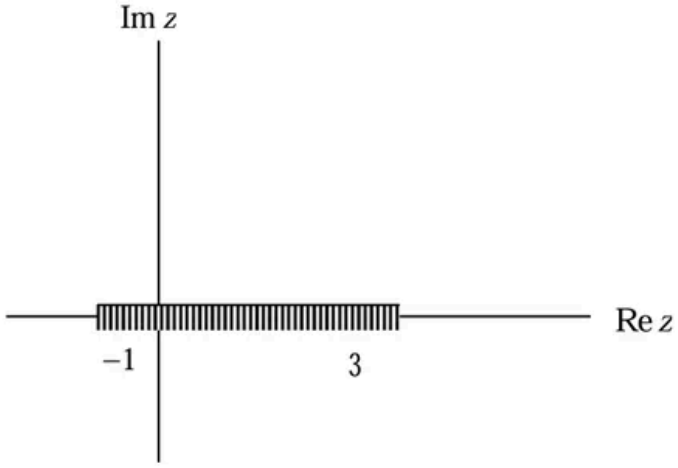

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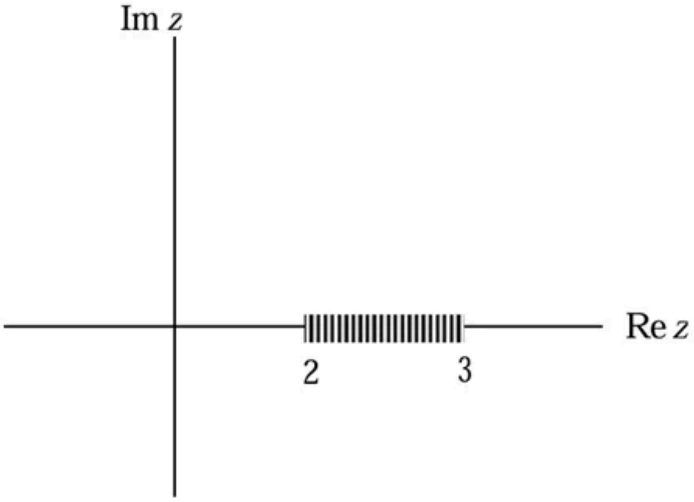

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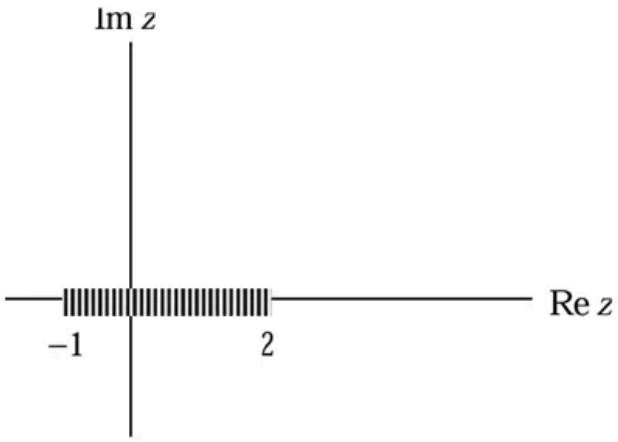


Q31. [Dec 2023] . 3.5 marks

Mathematical Physics > Gamma and beta functions

CSIR NET	2023 Dec	3.5 M

The Beta function is defined as

$$B(x,y) = \int_0^1 t^{x-1}(1-t)^{y-1}dt.$$

Then $B(x, y+1) + B(x+1, y)$ can be expressed as

1. $B(x, y-1)$
2. $B(x+y, 1)$
3. $B(x+y, x-y)$
4. $B(x, y)$

Q32. [Dec 2023] . 3.5 marks

Mathematical Physics > Complex analysis

CSIR NET	2023 Dec	3.5 M

If z is a complex number, which among the following sets is neither open nor closed?

1. $\{z|0 \leq |z-1| \leq 2\}$
2. $\{z||z| \leq 1\}$
3. $\{z \mid z \in (\mathbf{C} - \{3\}) \text{ and } |z| \leq 100\}$
4. $\left\{z \mid z = re^{i\theta}, 0 \leq \theta \leq \frac{\pi}{4}\right\}$

Q33. [Dec 2023] . 3.5 marks

Mathematical Physics > Matrices and Linear Algebra

CSIR NET	2023 Dec	3.5 M

Let M be a 3×3 real matrix such that

$$e^{M\theta} = \begin{vmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{vmatrix}$$ where θ is a real parameter. Then M is given by

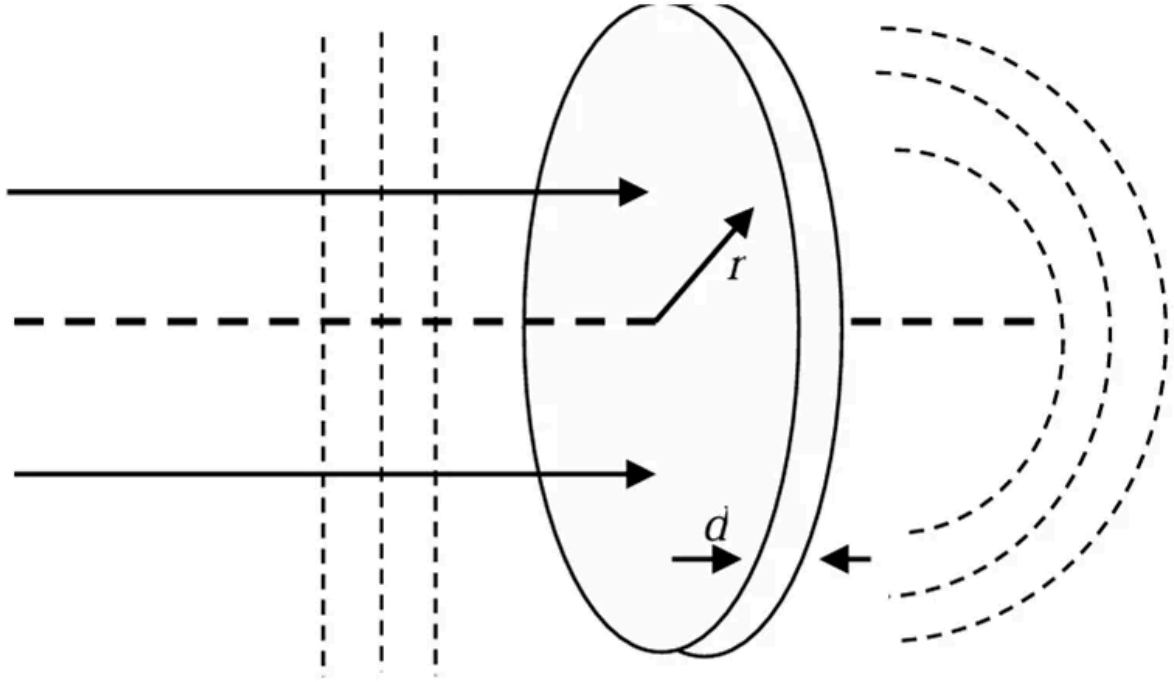
1. $\begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$
2. $\begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$
3. $\begin{bmatrix} 0 & 0 & 1 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$
4. $\begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Q34. [Dec 2023] . 3.5 marks

Optics > Interference and diffraction

CSIR NET	2023 Dec	3.5 M

For a flat circular glass plate of thickness d, the refractive index $n(r)$ varies radially, where r is the radial distance from the centre of the plate. A coherent plane wavefront is normally incident on this plate as shown in the figure below.



If the emergent wavefront is spherical and centered on the axis of the plate, then $n(r) - n(0)$ should be proportional to

1. $r^{1/2}$
2. r
3. r^2
4. $r^{3/2}$

Q35. [Dec 2023] . 3.5 marks

Electromagnetism > Magetostatics

CSIR NET	2023 Dec	3.5 M

A small bar magnet is placed in a magnetic field $B(\vec{r}) = B(x)\hat{z}$. The magnet is initially at rest with its magnetic moment along $\hat{y}$. At later times, it will undergo

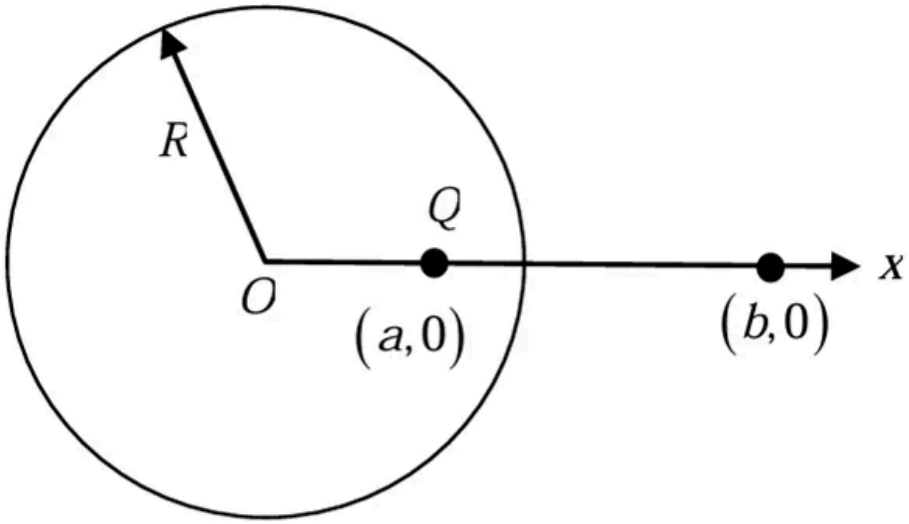
1. angular motion in the yz plane and translational motion along $\hat{y}$
2. angular motion in the yz plane and translational motion along $\hat{x}$
3. angular motion in the zx plane and translational motion along $\hat{z}$
4. angular motion in the xy plane and translational motion along $\hat{z}$

Q36. [Dec 2023] . 3.5 marks

Electromagnetism > Electrostatics

CSIR NET	2023 Dec	3.5 M

A conducting shell of radius R is placed with its centre at the origin as shown below. A point charge Q is placed inside the shell at a distance a along the x-axis from the centre.



The electric field at a distance $b > R$ along the x-axis from the centre is

1. $\frac{Q}{4\pi\varepsilon_0 b^2}\hat{x}$
2. $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{(b-a)^2}-\frac{aR}{(ab-R^2)^2}\right]\hat{x}$
3. $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{(b-a)^2}+\frac{aR}{(ab-R^2)^2}\right]\hat{x}$
4. $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{b^2}-\frac{R^2}{a^2b^2}\right]\hat{x}$

Q37. [Dec 2023] . 3.5 marks

Electromagnetism > Electrostatics

CSIR NET	2023 Dec	3.5 M

A one dimensional infinite long wire with uniform linear charge density λ is placed along the z-axis. The potential difference $\delta V = V(\rho + a) - V(\rho)$, between two points at radial distances $\rho + a$ and ρ from the z-axis, where $a \ll \rho$, is closest to

1. $-\frac{\lambda}{2\pi\varepsilon_0}\frac{a^2}{\rho^2}$
2. $-\frac{\lambda}{2\pi\varepsilon_0}\frac{a}{\rho}$
3. $\frac{\lambda}{2\pi\varepsilon_0}\frac{a}{\rho}$
4. $\frac{\lambda}{2\pi\varepsilon_0}\frac{a^2}{\rho^2}$

Q38. [Dec 2023] . 3.5 marks

Thermodynamics > Laws of thermodynamics

CSIR NET	2023 Dec	3.5 M

A classical ideal gas is subjected to a reversible process in which its molar specific heat changes with temperature T as $C(T) = C_V + R\frac{T}{T_0}$. If the initial temperature and volume are T_0 and V_0 respectively, and the final volume is $2V_0$, then the final temperature is

1. $T_0/\ln 2$
2. $2T_0$
3. $T_0/[1 - \ln 2]$
4. $T_0[1 + \ln 2]$

Q39. [Dec 2023] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 Dec	3.5 M

Each allowed energy level of a system of non-interacting fermions has a degeneracy M. If there are N fermions and R is the remainder upon dividing N by M , then the degeneracy of the ground state is

1. R^M
2. 1
3. M
4. ${}^{M}C_{R}$

Q40. [Dec 2023] . 3.5 marks

Statistical Mechanics > Microstates and Macrostates

CSIR NET	2023 Dec	3.5 M

Four distinguishable particle fill up energy levels $0, \in, 2 \in$. The number of available microstates for the total energy $4 \in$ is

1. 20
2. 24
3. 11
4. 19

Q41. [Dec 2023] . 3.5 marks

Statistical Mechanics > Canonical Ensemble

CSIR NET	2023 Dec	3.5 M

A system of N non-interacting classical spins, where each spin can take values $\sigma = -1,0,1$, is placed in a magnetic field h. The single spin Hamiltonian is given by

$$H = -\mu_B h\sigma + \Delta(1-\sigma^2),$$

where μ_B, Δ are positive constants with appropriate dimensions. If M is the magnetization, the zero-field magnetic susceptibility per spin $\frac{1}{N}\frac{\partial M}{\partial h}\Big|_{h\to 0}$, at a temperature $T = 1/\beta k_B$ is given by

1. $\beta\mu_B^2$
2. $\frac{2\beta\mu_B^2}{2+e^{-\beta\Delta}}$
3. $\beta\mu_B^2 e - \beta\Delta$
4. $\frac{\beta\mu_B^2}{1+e^{-\beta\Delta}}$

Q42. [Dec 2023] . 3.5 marks

Electronics > "Errors , curve fitting and data analysis"

CSIR NET	2023 Dec	3.5 M

In the measurement of a radioactive sample, the measured counts with and without the sample for equal time intervals are $C = 500$ and $B = 100$, respectively. The errors in the measurements of C and B are $|\Delta C| = 20$ and $|\Delta B| = 10$, respectively. The net error $|\Delta Y|$ in the measured counts from the sample $Y = C - B$, is closet to

1. 22
2. 10
3. 30
4. 43

Q43. [Dec 2023] . 3.5 marks

Electronics > Digital Electronics

CSIR NET	2023 Dec	3.5 M

For three inputs A, B and C , the minimum number of 2 -input NAND gates required to generate the output $Y = \overline{A + B} + \bar{C}$ is

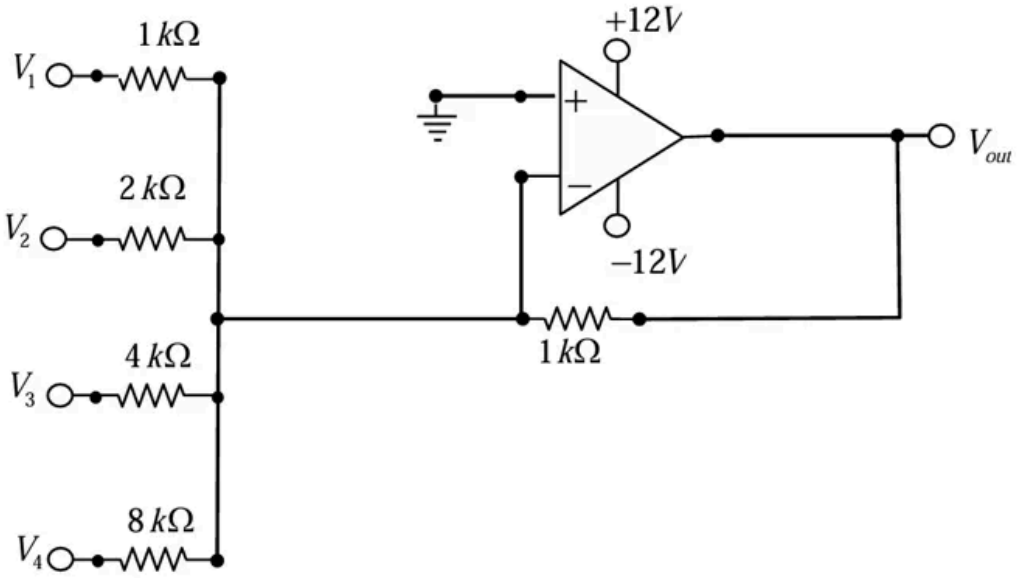
1. 3
2. 4
3. 7
4. 6

Q44. [Dec 2023] . 3.5 marks

Electronics > OPAMP

CSIR NET	2023 Dec	3.5 M

In the circuit shown below using an ideal opamp, inputs $V_j (j = 1,2,3,4)$ may either be open or connected to a -5 V battery.



The minimum measurement range of a voltmeter to measure all possible values of V_{out} is

1. 10 V
2. 30 V
3. 3 V
4. 1 V

Q45. [Dec 2023] . 3.5 marks

Electronics > Diodes

CSIR NET	2023 Dec	3.5 M

The light incident on a solar cell has a uniform photon flux in the energy range of 1 eV to 2 eV and is zero elsewhere. The active layer of the cell has a bandgap of 1.5 eV and absorbs 80% of the photons with energies above the bandgap. Ignoring non-radiative losses, the power conversion efficiency (ratio of the output power to the input power) is closest to

1. 47%
2. 70%
3. 23%
4. 35%

Q46. [Dec 2023] . 5.0 marks

Classical Mechanics > Central forces

CSIR NET	2023 Dec	5 M

A particle of mass m is moving in a 3-dimensional potential

$$\phi(r) = -\frac{k}{r} - \frac{k'}{3r^3}, k, k' > 0$$

For the particle with angular momentum l, the necessary condition to have a stable circular orbit is

1. $kk' < \frac{l^4}{4m^2}$
2. $kk' > \frac{l^4}{4m^2}$
3. $kk' < \frac{l^4}{m^2}$
4. $kk' > \frac{l^4}{m^2}$

Q47. [Dec 2023] . 5.0 marks

Classical Mechanics > Canonical transformations

CSIR NET	2023 Dec	5 M

A canonical transformation from the phase space coordinates (q, p) to (Q, P) is generated by the function

$$\psi(p, Q) = \frac{p^2}{2\omega} \tan 2\pi Q,$$

where ω is a positive constant. The function $\psi(p, Q)$ is related to $F(q, Q)$ by the Legendre transform $\psi = pq - F$, where F is defined by $dF = pdq - PdQ$. If the solution for (P, Q) is

$$P(t) = \frac{\omega}{4\pi} t^2, Q(t) = Q_0 = \text{constant}$$

where t is time, then the solution for (p, q) variables can be written as

1. $p = \frac{\omega t}{2\pi} \cos 2\pi Q_0, q = \frac{t}{2\pi} \sin 2\pi Q_0$
2. $p = -\frac{\omega t}{2\pi} \cos 2\pi Q_0, q = \frac{t}{2\pi} \sin 2\pi Q_0$
3. $p = \frac{\omega t}{2\pi} \sin 2\pi Q_0, q = \frac{t}{2\pi} \cos 2\pi Q_0$
4. $p = -\frac{\omega t}{2\pi} \sin 2\pi Q_0, q = \frac{t}{2\pi} \cos 2\pi Q_0$

Q48. [Dec 2023] . 5.0 marks

Classical Mechanics > Lagrangian and Hamiltonian

CSIR NET	2023 Dec	5 M

A Lagrangian is given by

$$L = \frac{1}{2}m(\dot{x}^2 + \dot{y}\dot{z} + \dot{z}^2) - \alpha(2x + 3y + z)$$

The conserved momentum is

1. $m[2\dot{x} + \dot{z}]$
2. $m[2\dot{x} + \dot{y} + \dot{z}]$
3. $m\left[\dot{x} + \frac{3}{2}\dot{y} + \frac{1}{2}\dot{z}\right]$
4. $m[2\dot{x} + 3\dot{z}]$

Q49. [Dec 2023] . 5.0 marks

Quantum Mechanics > Scattering theory

CSIR NET	2023 Dec	5 M

An incident plane wave with wavenumber k is scattered by a spherically symmetric soft potential. The scattering occurs only in S - and P-waves. The approximate scattering amplitude an angles $\theta = \frac{\pi}{3}$ and $\theta = \frac{\pi}{2}$ are

$$f\left(\theta = \frac{\pi}{3}\right) \approx \frac{1}{2k}\left(\frac{5}{2} + 3i\right) \text{ and } f\left(\theta = \frac{\pi}{2}\right) \approx \frac{1}{2k}\left(1 + \frac{3i}{2}\right)$$

Then the total scattering cross-section is closest to

1. $\frac{37\pi}{4k^2}$
2. $\frac{10\pi}{k^2}$
3. $\frac{35\pi}{4k^2}$
4. $\frac{9\pi}{k^2}$

Q50. [Dec 2023] . 5.0 marks

Quantum Mechanics > Basic Quantum Mechanics

CSIR NET	2023 Dec	5 M

In a quantum harmonic oscillator problem, $\hat{a}$ and $\hat{N}$ are the annihilation operator and the number operator, respectively. The operator $e^{\hat{N}}\hat{a}e^{-\hat{N}}$ is

1. $\hat{a}$
2. $e^{-1}\hat{a}$
3. $e^{-(\hat{I}+\hat{a})}$
4. $e^{\hat{a}}$

(where $\hat{I}$ is the identity operator)

Q51. [Dec 2023] . 5.0 marks

Quantum Mechanics > Dirac delta potential

CSIR NET	2023 Dec	5 M

A quantum particle of mass m is moving in a one dimensional potential

$$V(x) = V_0\theta(x) - \lambda\delta(x)$$

where V_0 and λ are positive constants, $\theta(x)$ is the Heaviside step function and $\delta(x)$ is the Dirac delta function. The leading contribution to the reflection coefficient for the particle incident from the left with energy $E \gg V_0 > \lambda$ and $\sqrt{2mE} \gg \frac{V_0\hbar}{\lambda}$ is

1. $\frac{V_0^2}{4E^2}$
2. $\frac{V_0^2}{8E^2}$
3. $\frac{m\lambda^2}{2E\hbar^2}$
4. $\frac{m\lambda^2}{4E\hbar^2}$

Q52. [Dec 2023] . 5.0 marks

Quantum Mechanics > Pertubation theory

CSIR NET	2023 Dec	5 M

A quantum system is described by the Hamiltonian

$$H = -J\sigma_z + \lambda(t)\sigma_x,$$

where $\sigma_i (i = x, y, z)$ are Pauli matrices, J and λ are positive constants $(J \gg \lambda)$ and

$$\lambda(t) = \begin{cases} 0 \text{ for } t < 0 \\ \lambda \text{ for } 0 < t < T \\ 0 \text{ for } t > T \end{cases}$$

At $t < 0$, the system is in the ground state. The probability of finding the system in the excited state at $t \gg T$, in the leading order in λ is

1. $\frac{\lambda^2}{8J^2} \sin^2 \frac{JT}{\hbar}$
2. $\frac{\lambda^2}{J^2} \sin^2 \frac{JT}{\hbar}$
3. $\frac{\lambda^2}{4J^2} \sin^2 \frac{JT}{\hbar}$
4. $\frac{\lambda^2}{16J^2} \sin^2 \frac{JT}{\hbar}$

Q53. [Dec 2023] . 5.0 marks

Mathematical Physics > Group Theory

CSIR NET	2023 Dec	5 M

The regular representation of two nonidentity elements of the group of order 3 are given by

1. $\begin{pmatrix}0&1&0\\1&0&0\\0&0&1\end{pmatrix}, \begin{pmatrix}0&0&1\\0&1&0\\1&0&0\end{pmatrix}$
2. $\begin{pmatrix}1&0&0\\0&0&1\\0&1&0\end{pmatrix}, \begin{pmatrix}0&1&0\\1&0&0\\0&0&1\end{pmatrix}$
3. $\begin{pmatrix}0&0&1\\1&0&0\\0&1&0\end{pmatrix}, \begin{pmatrix}0&1&0\\0&0&1\\1&0&0\end{pmatrix}$
4. $\begin{pmatrix}0&0&1\\0&1&0\\1&0&0\end{pmatrix}, \begin{pmatrix}0&0&1\\1&0&0\\0&1&0\end{pmatrix}$

Q54. [Dec 2023] . 5.0 marks

Mathematical Physics > Numerical Methods

CSIR NET	2023 Dec	5 M

Given the date points

x	1	3	5
y	4	28	92

Using Lagrange's method of interpolation, the value of y at $x = 4$ is closest to

1. 54
2. 55
3. 53
4. 56

Q55. [Dec 2023] . 5.0 marks

Mathematical Physics > Complex analysis

CSIR NET	2023 Dec	5 M

The function $f(z) = \frac{1}{(z+1)(z+3)}$ is defined on the complex plane. The coefficient of the $(z - z_0)^2$ term of the Laurent series of $f(z)$ about $z_0 = 1$ is

1. $\frac{7}{64}$
2. $\frac{7}{128}$
3. $\frac{9}{64}$
4. $\frac{9}{128}$

Q56. [Dec 2023] . 5.0 marks

Mathematical Physics > Ordinary Differential Equations

CSIR NET	2023 Dec	5 M

The solution $y(x)$ of the differential equation $y'' + \frac{y}{4} = \frac{x}{2}$, where $0 \leq x \leq \pi$, together with the boundary conditions $y(0) = y(\pi) = 0$ is

1. $\frac{2}{\pi}\sum_{n=1}^{\infty} (-1)^n \frac{\pi}{n} \frac{\sin nx}{\frac{1}{4}-n^2}$
2. $\frac{2}{\pi}\sum_{n=1}^{\infty} (-1)^n \frac{\pi}{2n} \frac{\sin nx}{\frac{1}{4}-n^2}$
3. $\frac{2}{\pi}\sum_{n=1}^{\infty} (-1)^{n+1} \frac{\pi}{n} \frac{\sin nx}{\frac{1}{4}-n^2}$
4. $\frac{2}{\pi}\sum_{n=1}^{\infty} (-1)^{n+1} \frac{\pi}{2n} \frac{\sin nx}{\frac{1}{4}-n^2}$

Q57. [Dec 2023] . 5.0 marks

Electromagnetism > Waveguides

CSIR NET	2023 Dec	5 M

A transmission line has the characteristic impedance of $(50 + 1j)\Omega$ and is terminated in a load resistance of $(70 - 7j)\Omega$ (where $j^2 = -1$). The magnitude of the reflection coefficient will be closest to

1. $\frac{5}{7}$
2. $\frac{1}{2}$
3. $\frac{1}{6}$
4. $\frac{1}{7}$

Q58. [Dec 2023] . 5.0 marks

Electromagnetism > Plasma

CSIR NET	2023 Dec	5 M

The permittivity of a medium $\varepsilon(\vec{k}, \omega)$, where ω and $\vec{k}$ are the frequency and wavevector, respectively, has no imaginary part. For a longitudinal wave, $\vec{k}$ is parallel to the electric field such that $\vec{k} \times \vec{E} = 0$, while for a transverse wave $\vec{k} \cdot \vec{E} = 0$. In the absence of free charges and free currents, the medium can sustain

1. longitudinal waves with $\vec{k}$ and ω when $\varepsilon(\vec{k}, \omega) > 0$
2. transverse waves with $\vec{k}$ and ω when $\varepsilon(\vec{k}, \omega) < 0$
3. longitudinal waves with $\vec{k}$ and ω when $\varepsilon(\vec{k}, \omega) = 0$
4. both longitudinal and transverse waves with $\vec{k}$ and ω when $\varepsilon(\vec{k}, \omega) > 0$

Q59. [Dec 2023] . 5.0 marks

Electromagnetism > Radiations

CSIR NET	2023 Dec	5 M

The radius of a sphere oscillates as a function of time as $R + a\cos\omega t$, with $a < R$. It carries a charge Q uniformly distributed on its surface at all times. If P is the time averaged radiated power through a sphere of radius r, such that $r \gg R + a$ and $r \gg \frac{c}{\omega}$, then

1. $P \propto \frac{Q^2\omega^4 a^2}{c^3}$
2. $P \propto \frac{Q^2\omega^4}{c}$
3. $P = 0$
4. $P \propto \frac{Q^2\omega^6 a^4}{c^5}$

Q60. [Dec 2023] . 5.0 marks

Electromagnetism > Waveguides

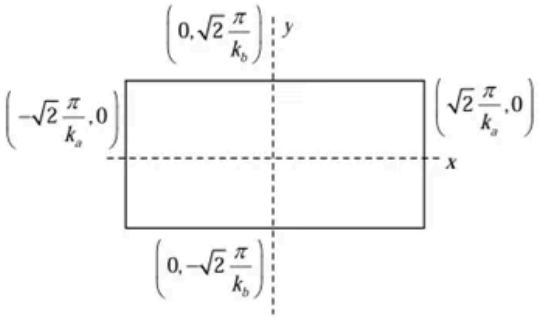
CSIR NET	2023 Dec	5 M

A 2-dimensioanl resonant cavity supports a TM mode built from a function

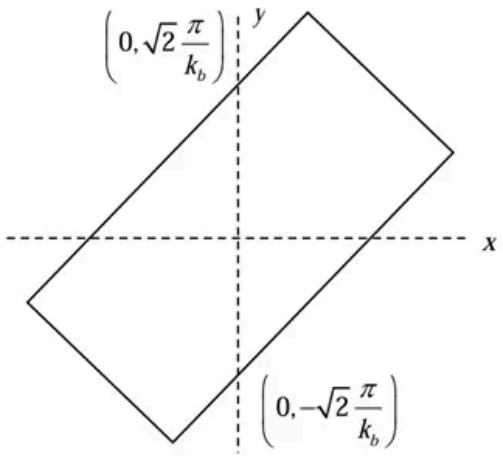
$$\psi(x,y,t) = \sin(\vec{k}_a \cdot \vec{r} - \omega t) + \sin(\vec{k}_b \cdot \vec{r} - \omega t) + \sin(\vec{k}_a \cdot \vec{r} + \omega t) + \sin(\vec{k}_b \cdot \vec{r} + \omega t)$$

where $\vec{k}_a$ and $\vec{k}_b$ lie in the xy-plane and make angles $\frac{\pi}{4}$ and $\frac{3\pi}{4}$ with the x-axis, respectively. If $0 < |\vec{k}_a| < |\vec{k}_b|$, then which of the following closely describes the outline of the cavity?

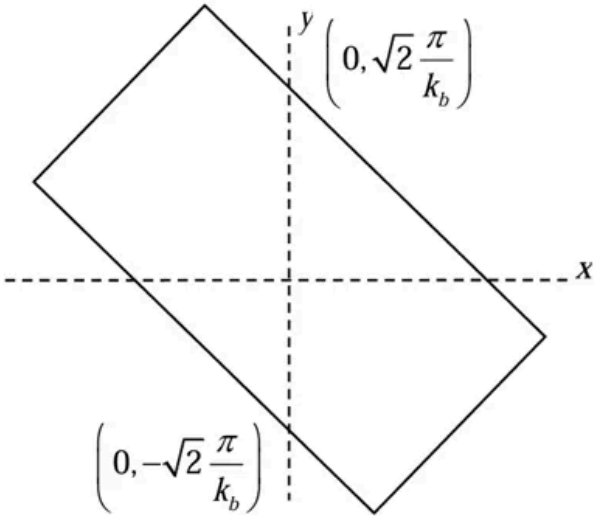
1.



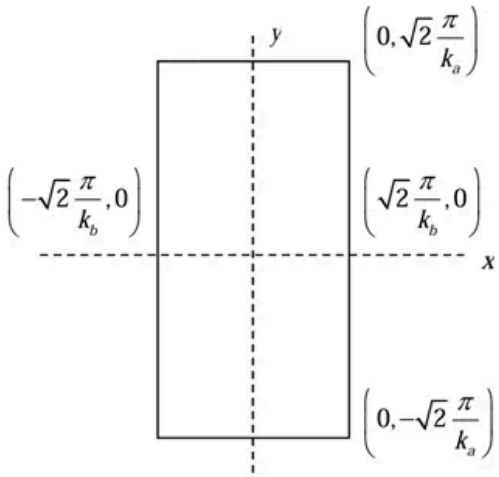
2.



3.



4.



Q61. [Dec 2023] . 5.0 marks

Statistical Mechanics > Quantum Statistical Mechanics

CSIR NET	2023 Dec	5 M

A system of non-relativistic and non-interacting bosons of mass m in two dimensions has a density n. The Bose-Einstein condensation temperature T_c is

1. $\frac{12n\hbar^2}{\pi m k_B}$
2. $\frac{3n\hbar^2}{\pi m k_B}$
3. $\frac{6n\hbar^2}{\pi m k_B}$
4. 0

Q62. [Dec 2023] . 5.0 marks

Thermodynamics > Phase transitions

CSIR NET	2023 Dec	5 M

The work done on a material to change its magnetization M in an external field H is $dW = HdM$. Its Gibbs free energy is

$$G(T,H) = -\left(\gamma T + \frac{aH^2}{2T}\right)$$

where $\gamma, a > 0$ are constants. The material is in equilibrium at a temperature $T = T_0$ and in an external field $H = H_0$. If the field is decreased to $\frac{H_0}{2}$ adiabatically and reversibly, the temperature changes to

1. $2T_0$
2. $\frac{T_0}{2}$
3. $\left(\frac{a}{2\gamma}\right)^{\frac{1}{4}}\sqrt{H_0T_0}$
4. $\left(\frac{a}{\gamma}\right)^{\frac{1}{4}}\sqrt{H_0T_0}$

Q63. [Dec 2023] . 5.0 marks

Statistical Mechanics > Random Walk/Brownian motion/Diffusion

CSIR NET	2023 Dec	5 M

A photon inside the sun executes a random walk process. Given the radius of the sun $\approx 7 \times 10^8$ km and mean free path of a photon $\approx 10^{-3}$ m, the time taken by the photon to travel from the centre to the surface of the sun is closest to

1. 10^6sec
2. 10^{24}sec
3. 10^{12}sec
4. 10^{18}sec

Q64. [Dec 2023] . 5.0 marks

Electronics > "Errors , curve fitting and data analysis"

CSIR NET	2023 Dec	5 M

Gauge factor of a strain gauge is defined as the ratio of the fractional change in resistance $\left(\frac{\Delta R}{R}\right)$ to the fractional change in length $\left(\frac{\Delta L}{L}\right)$. A metallic strain gauge with a gauge factor 2 has a resistance of 100Ω under unstrained condition. An aluminum foil with Young's modulus $Y = 70GN/m^2$ is installed on the metallic gauge. Keeping the foil within its elastic limit, a stress of $0.2GN/m^2$ is applied on the foil. The change in the resistance of the gauge will be closest to

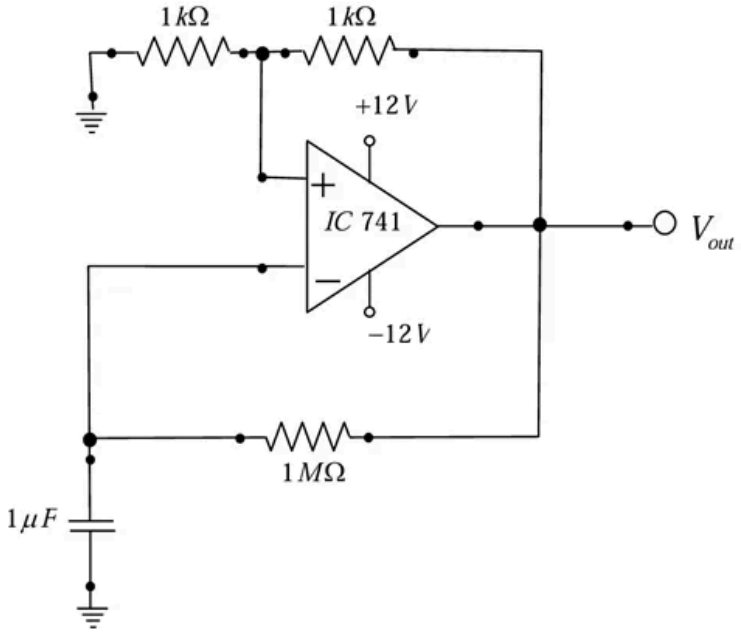
1. 0.14Ω
2. 1.23Ω
3. 0.28Ω
4. 0.56Ω

Q65. [Dec 2023] . 5.0 marks

Electronics > OPAMP

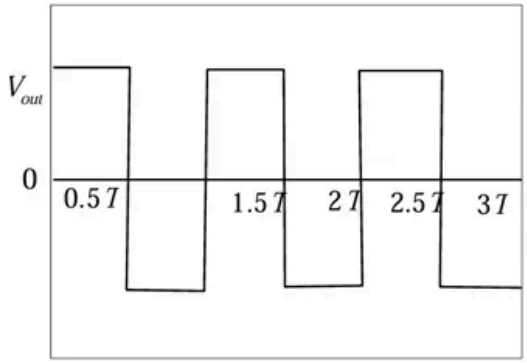
CSIR NET	2023 Dec	5 M

A circuit with operational amplifier is shown in the figure below.

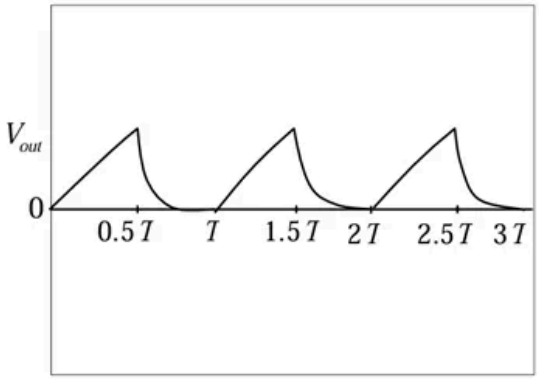


The output voltage waveform V_{out} will be closest to

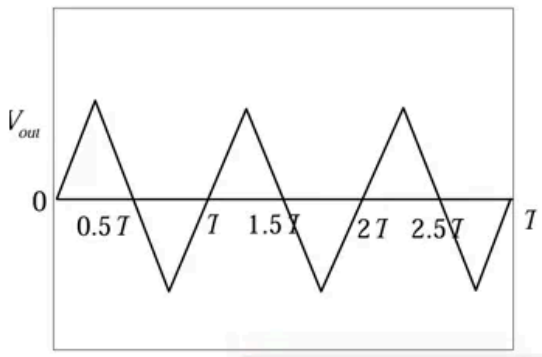
1.



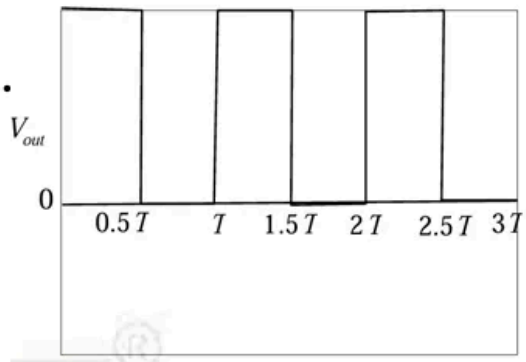
2.



3.



4.

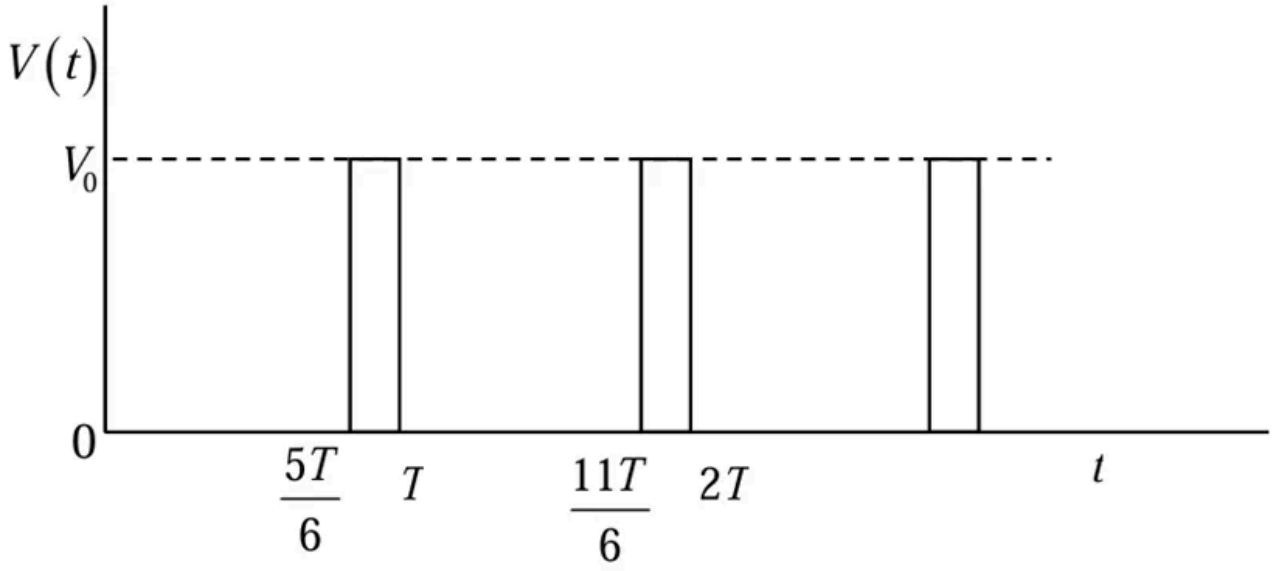


Q66. [Dec 2023] . 5.0 marks

Electronics > Instruments

CSIR NET	2023 Dec	5 M

An infinite waveform $V(t)$ varies as shown in the figure below



The lowest harmonic that vanishes in the Fourier series of $V(t)$ is

1. 2
2. 3
3. 6
4. None

Q67. [Dec 2023] . 5.0 marks

Solid State Physics > Free electron theory

CSIR NET	2023 Dec	5 M

The lattice constant of the bcc structure of sodium metal is 4.22Å. Assuming the mass of the electron inside the metal to be the same as free electron mass, the free electron Fermi energy is closest to

1. 3.2 eV
2. 2.9 eV
3. 3.5 eV
4. 2.5 eV

Q68. [Dec 2023] . 5.0 marks

Solid State Physics > Free electron theory

CSIR NET	2023 Dec	5 M

The collision time of the electrons in a metal in the Drude model is τ and their plasma frequency is ω_p. If this metal is placed between the plates of a capacitor, the time constant associated with the decay of the electric field inside the metal is

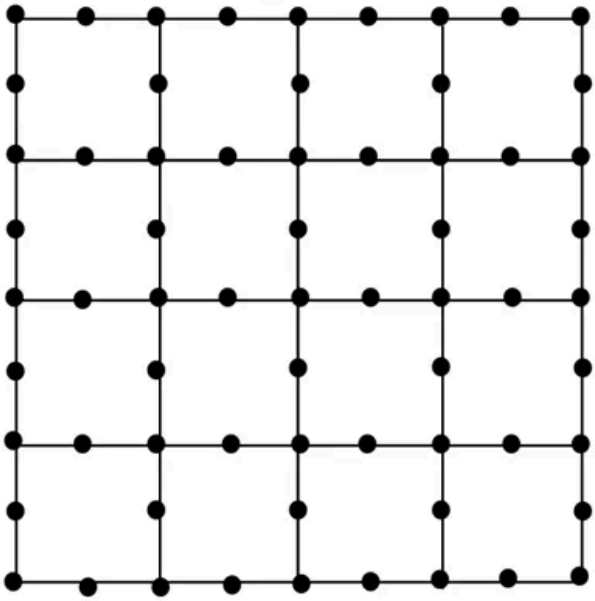
1. $\tau + \frac{1}{\omega_p}$
2. $\omega_p \tau^2$
3. $\frac{1}{\omega_p^2 \tau}$
4. $\frac{\tau}{1+\omega_p \tau}$

Q69. [Dec 2023] . 5.0 marks

Solid State Physics > Crystallography

CSIR NET	2023 Dec	5 M

In the section of an infinite lattice shown in the figure below, all sites are occupied by identical hard circular discs so that the resulting structure is tightly packed.



The packing fraction is

1. $\frac{3\pi}{4}$
2. $\frac{\pi}{4}$
3. $\frac{3\pi}{16}$
4. $\frac{9\pi}{16}$

Q70. [Dec 2023] . 5.0 marks

Atomic and Molecular Physics > Bohar Model and h-atom model

CSIR NET	2023 Dec	5 M

The ionization potential of hydrogen atom is 13.6 eV and λ_H and λ_D denote longest wavelengths in Balmer spectrum of hydrogen and deuterium atoms, respectively. Ignoring the fine and hyperfine structures, the percentage difference $y = \frac{\lambda_H - \lambda_D}{\lambda_H} \times 100$, is closest to

1. 1.0003%
2. -0.03%
3. 0.03%
4. -1.0003%

Q71. [Dec 2023] . 5.0 marks

Atomic and Molecular Physics > Zeeman effect

CSIR NET	2023 Dec	5 M

A solar probe mission detects a fractional wavelength shift $(\Delta\lambda/\lambda)$ of the spectral line $\lambda = 630\ \text{nm}$ within a sunspot to be of the order of 10^{-5}. Assuming this shift is caused by the normal Zeeman effect (i.e., neglecting other physical effects), the estimated magnetic field (in tesla) within the observed sunspot is closest to

1. 3×10^{-5}
2. 300
3. 0.3
4. 3×10^{5}

Q72. [Dec 2023] . 5.0 marks

Atomic and Molecular Physics > Molecular physics

CSIR NET	2023 Dec	5 M

In the rotational-vibrational spectrum of an idealized carbon monoxide (CO) molecule, ignoring rotational-vibrational coupling, two transitions between adjacent vibrational levels with wavelength λ_1 and λ_2, correspond to the rotational transition from $J' = 0$ to $J'' = 1$ and $J' = 1$ to $J'' = 0$, respectively. Given that the reduced mass of CO is $1.2 \times^{-26}$ kg, equilibrium bond length of CO is 0.12 nm and vibrational frequency is 5×10^{13} Hz, the ratio of $\frac{\lambda_1}{\lambda_2}$ is closest to

1. 0.9963
2. 0.0963
3. 1.002
4. 1.203

Q73. [Dec 2023] . 5.0 marks

Nuclear and Particle Physics > Particle physics

CSIR NET	2023 Dec	5 M

Atmospheric neutrinos are produced from the cascading decays of cosmic pions ($\pi^{\pm}$) to stable particles. Ignoring all other neutrino sources, the ratio of muon neutrino $(\nu_\mu + \bar{\nu}_\mu)$ flux to electron neutrino $(\nu_e + \bar{\nu}_e)$ flux in atmosphere is expected to be closest to

1. 2:3
2. 1: 1
3. 1: 2
4. 2: 1

Q74. [Dec 2023] . 5.0 marks

Nuclear and Particle Physics > Radioactivity

CSIR NET	2023 Dec	5 M

The ground state of $^{207}_{82}\text{Pb}$ nucleus has spin-parity $J^{\pi} = \left(\frac{1}{2}\right)^{-}$, while first excited state has $J^{\pi} = \left(\frac{5}{2}\right)^{-}$. For the transition from the first excited state to the ground state, possible multipolarities of emitted electromagnetic radiation are

1. E2, E3
2. M2, M3
3. M2, E3
4. E2, M3

Q75. [Dec 2023] . 5.0 marks

Nuclear and Particle Physics > Shell model

CSIR NET	2023 Dec	5 M

In a shell model description, neglecting Coulomb effects, which of the following statements for the energy and spin-parity is correct for the first excited state of $A = 12$ isobars $^{12}_{5}B$, $^{12}_{6}C$, $^{12}_{7}N$?

1. same for $^{12}_{5}B$, $^{12}_{6}C$ and $^{12}_{7}N$
2. different for each $^{12}_{5}\text{B}$, $^{12}_{6}\text{C}$ and $^{12}_{7}\text{N}$
3. same for $^{12}_{6}C$ and $^{12}_{7}N$, but different for $^{12}_{5}B$
4. same for $^{12}_{5}B$ and $^{12}_{7}N$ but different for $^{12}_{6}C$

Answer Key

75 questions . Subject and topic for quick revision

Q. No	Subject	Topic	Answer
Q1	General Aptitude	Mathematical Analysis	**4**
Q2	General Aptitude	Reasoning	**1**
Q3	General Aptitude	Data Analysis	**4**
Q4	General Aptitude	Reasoning	**3**
Q5	General Aptitude	Reasoning	**3**
Q6	General Aptitude	Reasoning	**3**
Q7	General Aptitude	Mathematical Analysis	**4**
Q8	General Aptitude	Basic Physics	**4**
Q9	General Aptitude	Data Analysis	**1**
Q10	General Aptitude	Basic Physics	**3**
Q11	General Aptitude	Mathematical Analysis	**3**
Q12	General Aptitude	Mathematical Analysis	**2**
Q13	General Aptitude	Mathematical Analysis	**3**
Q14	General Aptitude	Basic Physics	**1**
Q15	General Aptitude	Reasoning	**2**
Q16	General Aptitude	Data Analysis	**1**
Q17	General Aptitude	Data Analysis	**1**
Q18	General Aptitude	Mathematical Analysis	**1**
Q19	General Aptitude	Mathematical Analysis	**2**
Q20	General Aptitude	Mathematical Analysis	**3**
Q21	Classical Mechanics	Central forces	**2**
Q22	Classical Mechanics	Lagrangian and Hamiltonian	**1**
Q23	Classical Mechanics	Oscillations	**4**
Q24	Classical Mechanics	Special theory of relativity	**1**
Q25	Classical Mechanics	Central forces	**1**
Q26	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**2**
Q27	Quantum Mechanics	Orbital angular Momentum and Hydrogen atom	**1**
Q28	Quantum Mechanics	Spin Angular momentum	**2**
Q29	Statistical Mechanics	Canonical Ensemble	**4**
Q30	Mathematical Physics	Complex analysis	**3**
Q31	Mathematical Physics	Gamma and beta functions	**4**
Q32	Mathematical Physics	Complex analysis	**3**
Q33	Mathematical Physics	Matrices and Linear Algebra	**2**
Q34	Optics	Interference and diffraction	**3**
Q35	Electromagnetism	Magetostatics	**2**
Q36	Electromagnetism	Electrostatics	**1**
Q37	Electromagnetism	Electrostatics	**2**
Q38	Thermodynamics	Laws of thermodynamics	**4**
Q39	Statistical Mechanics	Microstates and Macrostates	**4**
Q40	Statistical Mechanics	Microstates and Macrostates	**4**

Answer Key (cont.)

Q. No	Subject	Topic	Answer
Q41	Statistical Mechanics	Canonical Ensemble	**2**
Q42	Electronics	"Errors , curve fitting and data analysis"	**1**
Q43	Electronics	Digital Electronics	**2**
Q44	Electronics	OPAMP	**1**
Q45	Electronics	Diodes	**1**
Q46	Classical Mechanics	Central forces	**1**
Q47	Classical Mechanics	Canonical transformations	**1**
Q48	Classical Mechanics	Lagrangian and Hamiltonian	**2**
Q49	Quantum Mechanics	Scattering theory	**1**
Q50	Quantum Mechanics	Basic Quantum Mechanics	**2**
Q51	Quantum Mechanics	Dirac delta potential	**3**
Q52	Quantum Mechanics	Pertubation theory	**2**
Q53	Mathematical Physics	Group Theory	**3**
Q54	Mathematical Physics	Numerical Methods	**2**
Q55	Mathematical Physics	Complex analysis	**2**
Q56	Mathematical Physics	Ordinary Differential Equations	**4**
Q57	Electromagnetism	Waveguides	**3**
Q58	Electromagnetism	Plasma	**3**
Q59	Electromagnetism	Radiations	**3**
Q60	Electromagnetism	Waveguides	**2**
Q61	Statistical Mechanics	Quantum Statistical Mechanics	**4**
Q62	Thermodynamics	Phase transitions	**2**
Q63	Statistical Mechanics	Random Walk/Brownian motion/Diffusion	**4**
Q64	Electronics	"Errors , curve fitting and data analysis"	**4**
Q65	Electronics	OPAMP	**1**
Q66	Electronics	Instruments	**3**
Q67	Solid State Physics	Free electron theory	**1**
Q68	Solid State Physics	Free electron theory	**3**
Q69	Solid State Physics	Crystallography	**3**
Q70	Atomic and Molecular Physics	Bohar Model and h-atom model	**3**
Q71	Atomic and Molecular Physics	Zeeman effect	**3**
Q72	Atomic and Molecular Physics	Molecular physics	**Drop**
Q73	Nuclear and Particle Physics	Particle physics	**4**
Q74	Nuclear and Particle Physics	Radioactivity	**4**
Q75	Nuclear and Particle Physics	Shell model	**4**

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