Interview and Entrance Questions for PhD in Physics

Compiled by MSc Physics Students of 2007-09 Batch

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1 DISCLAIMER

The interview questions included here are from the memory of students. The question papers included here (those of HRI and IIT Kanpur) are from those actual question papers which were returned to the students after the written examinations were over. We do not guarantee the correctness of all the questions based on memory. For the written test question papers it is recommended that you see the original question papers. We have tried for a faithful representation only, so as to enable the students to get all the questions at one place.

This compilation is intended for use by students only.

Every care has been taken to reduce mistakes of anytype: typological and conceptual. But there might be some errors too. So students are requested to follow each question carefully.

We hope this question collection will be helpful to other students.

2 Harish-Chandra Research Institute, Allahabad

2.1 Interview Questions asked to Dibyakrupa Sahoo (HRI)

1. Find out the path joining two points a and b (both present on a plane) for which the time of travel from a to b would be least, when there is a gravitational field present.

   Let us find out the answer to a simpler question. How would you calculate the time taken by a particle to fall through a distance, say d, from rest in a gravitational field?

2. Given

$$\psi(x,t) = A \exp i(ax + bt) \tag{1}$$

   (a) What does this wavefunction represent? How do you know that?

   (b) Find out $\langle p \rangle$.

   (c) Find the force on the particle. Any physical significance of the force being zero?

   (d) How can you find Hamiltonian of a system, given the wavefunction?

3. Write down the Maxwell's Equations in Electrodynamics. What is the physical significance of $\vec{J}$ in Maxwell's Equations?

4. Write down the Hamiltonian for a particle of mass m moving in an electromagnetic field.

5. What is Fermi Energy? Given a two Fermion system, how many states are possible if only two energy levels are available?

2.2 Interview Questions asked to Chandan Setty (HRI)

1. Given a square-well potential (See Figure 1, page 5). A wavefunction is given by:

$$\psi(x) = A\, x\, (x - a) \tag{2}$$

   (a) Is the wavefunction a valid one?

   (b) Plot it.

   (c) Is it an eigenstate?

   (d) What is the solution (eigenfunction) to the above problem?

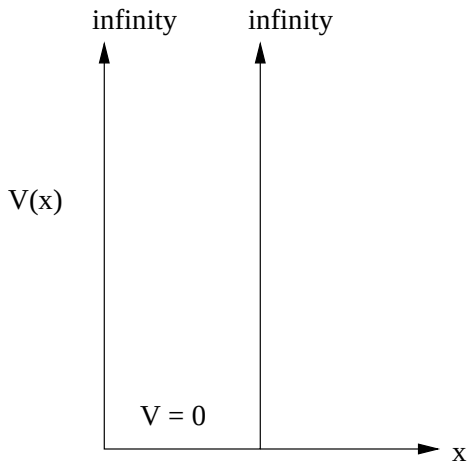

Figure 1: Square-well Potential.

(e) What is the average value of momentum for the above problem?

(f) Why is it zero?

(g) What is the physical significance of it being zero?

(h) Can you redraw the eigenfunction to make it have a nonzero momentum?

(i) Give eigenvalue of the momentum eigenfunction.

(j) Normalize it.

(k) Why not normalizable? What is the physical significance?

(l) Write time evolution of $\psi(x)$. How do you determine the eigenvalues to be inserted into the time evolution factor?

(m) How can you normalize (suggest a method) the momentum eigenfunction suggested by you?

2. Mathematical Physics:

(a) Find $\nabla\cdot\left(\frac{\hat{r}}{r^2}\right)$.

(b) Show it to be equal to $4\,\pi\,\delta^3(\vec{r})$.

(c) Given

$$f(r) = \frac{\exp\left(-\alpha\, r\right)}{r}. \tag{3}$$

Determine what is $\nabla^2\, f - \alpha\, f =?$

(d) Write down all the properties of Dirac delta.

3. Stastical Mechanics:

   For a stastical system of two identical particles at temperature T where each particle can be in one of two possible quantum states: one with energy eigenvalue 0 and the other with energy eigenvalue E, explain why does the average energy $\bar{E}$ follows the pattern: $\bar{E}_{Fermi-Dirac} > \bar{E}_{Maxwell-Boltzmann} > \bar{E}_{Bose-Einstein}$

2.3 Interview Questions asked to Swarup Kundu (HRI)

1. Given that a particle has to loop-a-loop. It is released from a height h. The radius of the circular loop is r. Find the minimun height from which if we release the particle it will just be able to loop-the-loop. Derive everything you use. (See Figure 2, page 6)

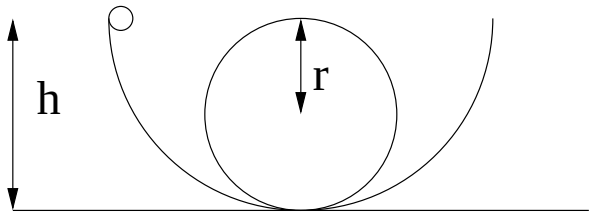

Figure 2: Problem of looping the loop.

2. Statistical Mechanics:

   (a) What are the differences among the three statisics (MB, FD, BE)?

   (b) Suppose you have two particles with two energy eigenstates 0 and E. Then what are the possible microstates for the three statistics?

   (c) Find out the number of microstates following MB statistics for N number of particles and with three energy eigenstates 0, E, $2E$.

   (d) If the total energy in the above case is $1000E$, find out the value of N.

3. Solid State Physics:

   (a) How do you distinguish Metals, Semiconductors and Insulators?

   (b) Show the band diagrams for them.

   (c) Why are the curvatures of Valence Band (VB) and Conduction Band (CB) different?

   (d) What are the differences between direct band gap semiconductor and indirect band gap semiconductor?

2.4 Written Test For Physics Research Admissions (HRI)

1. Take a statistical system of two identical particles at temperature T where each particle can be in one of two possible quantum states: one with energy eigenvalue 0 and the other with energy eigenvalue E. Calculate the average energy of the system as a function of the temperature if the particles obey (i) Bose statistics, (ii) Fermi statistics, and (iii) Boltzmann statistics. You can assume that the particles do not interact with each other.

   Can you tell which system (of the three) will have the highest average energy and which system will have the lowest average energy at a given temperature.

2. Suppose a spaceship of mass m_0 and cross-sectional area A is moving with a velocity v_0 when it encounters a stationary dust cloud of density ρ. Solve for subsequent motion of the spacecraft assuming that the dust sticks to its surface and that A is constant over time.

3. (a) A particle (mass m) in a one dimensional harmonic oscillator potential (angular frequency ω) has the initial wave function:

$$\psi(x,0) = A\left[\psi_0(x) + \psi_1(x)\right], \tag{4}$$

   where A is normalization constant. ψ_0 and ψ_1 are the ground and first excited state wave functions of the harmonic oscillator problem.

   i. Find $\psi(x,t)$ and $|\psi(x,t)|^2$.

   ii. Find the expectation value of x as a function of time.

   (b) Two non-interacting spinless Fermions are put together in this harmonic oscillator potential. Write down the two particle ground state wavefunction $\psi(x_1, x_2; 0)$, where x_1 and x_2 are the coordinates of the two particles.

   Useful information:
   (i) $\psi_n(x) = \left(\frac{m\omega}{\pi\hbar}\right)^{1/4} \frac{1}{\sqrt{2^n\, n!}}\, H_n(\xi)\, e^{-\xi^2/2}$, (ii) $\xi = \sqrt{\frac{m\omega}{\hbar}}\, x$,
   (iii) $H_0(\xi) = 1$, and $H_1(\xi) = 2\,\xi$, (iv) $\displaystyle\int_0^\infty x^{2n}\, e^{-x^2/a^2}\, dx = \sqrt{\pi}\, \frac{(2n)!}{n!} \left(\frac{\alpha}{2}\right)^{2n+1}$.

4. Consider a horizontal sheet of dimension (length, width) l, w which is uniformly charged with surface charge density σ. Find out the electric field at point P which is at a vertical distance d above the center of the sheet. Calculate the electric field if the length of the sheet becomes infinity.

5. Let

$$f(x_1, x_2, x_3) = \sum\nolimits_{n\,=\,1}^{4} \left[(x_n - x_{n-1})^2 - \alpha^2 (x_n + x_{n-1})^2\right] \tag{5}$$

with $x_0 = x_4 = 0$ and $0 < \alpha < 1$ is real.

(a) Express the above as $X^T AX$ where X is a column vector with elements x_1, x_2 and x_3 and T denotes the transpose and find the matrix A.

Go to a different basis where A can be written as $Y^T A_D Y$ where A_D is diagonalized form of A.

(b) Find the matrix A_D.

(c) Evaluate the integral $\int_{-\infty}^{\infty} dy_1\, dy_2\, dy_3\, e^{-Y^T A_D Y}$

3 Saha Institute of Nuclear Physics, Kolkata

3.1 Interview Questions asked to Dibyakrupa Sahoo (SINP)

1. How do you classify elementary particles? Explain how many types of Leptons and Hadrons are there and their classification. Is the following process: $\mu^- \longrightarrow e^- + \nu$, allowed or not? Why? What is the allowed process? What are the conservation laws that must be followed here?

2. What is the time taken by a particle to travel a displacement d in a gravitational field? What kind of trajectories are allowed in a central force field where force varies inversely as the square of the distance? Solve the equation of motion in such a case.

3. Given only half of the Harmonic Oscillator Potential (in the 1st Quadrant).(See the Figure 7 on Page 24.) Write down the wavefunction describing the system? Draw the wavefunctions. Why only odd harmonics are allowed? Give a physical explanation. Where are the zeros of the wavefunction? What is the physical significance of the wavefunction being zero at infinity?

4. What are the Pauli sigma matrices? What is $\sigma_x^{25} = ?$ What is $(\sigma_x + \sigma_y)^{25} = ?$

5. If we consider the absorption spectrum, them we know that it arises due to transition of electron to excited states. However, the electron does come back to the original (or ground) state from the excited state through spontaneous emission. Then should we not expect the dark lines of the absorption spectrum to be bright indeed?

3.2 Interview Questions asked to Shuvendu Jena (SINP)

1. Write the general uncertainty relation.

2. Find Δp and Δx?

3. What is the difference between $|\langle \cdots \rangle|$ and $\langle | \cdots | \rangle$? Why don't we write $\langle | \cdots | \rangle$?

4. How can we apply uncertainty relation to Nano-particles?

5. Write Poisson's equation, Laplace equation and their solutions.

6. Why do you choose $\nabla^2 \left(\frac{1}{r}\right) = 4\,\pi\,\delta(r)$ instead of $\nabla^2 \left(\frac{1}{r}\right) = 0$? What is its physical significance?

7. There are two identical boxes sharing a common wall, one filled with Bosons and one with Fermions. Number of Bosons = Number of Fermions. Which particles will exert more pressure on the common wall?

8. What is the Band theory for Solids?

9. Distinguish Metals, Insulators and Semiconductors through band structure.

10. Draw the above band structures at absolute zero and at room temperature.

11. What is the variation of resistance of semiconductor with temperature? Plot the relevant graph.

12. How carrier concentration is related with band gap?

13. Plot $x \ln x$.

3.3 Interview Questions Asked to Atul Charan Sahoo (SINP)

1. Suppose you know Bohr's 1st Principle. If an electron travelling along X-direction experiences a magnetic field in a direction perpendicular to X-direction, find its ground state energy.

2. How do you find the magnetic dipole moment of an electron?

3. What is $\vec{E}$ at any point due to a point charge? What is the value of $\vec{E}$ if there were 10 charges?

4. Why superposition principle is applied here? When can you use superposition principle?

5. Write Gauss law. Suppose Gauss law is not known. If $\vec{\nabla} \cdot \left(|\vec{E}|^n \vec{E} \right) = \frac{\rho}{\epsilon_0}$, then what is the value of n?

6. How vacuum is created? What is the necessity of vacuum in particle physics experiments? What is the name of the motor creating vacuum?

4 The Institute of Mathematical Sciences, Chennai

4.1 Interview Questions asked to Dibyakrupa Sahoo (IMSc)

1. Given a rectangular loop of wire with a portion inside a constant magnetic field. A constant current I flows through the circuit. (See Figure 3, page 11.)

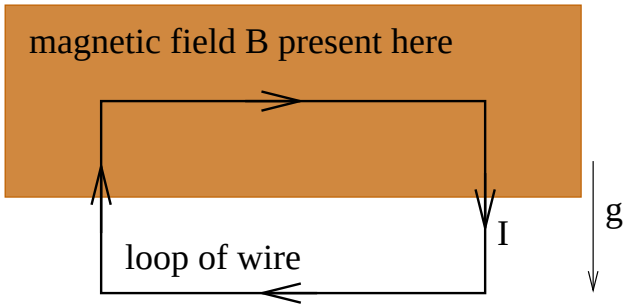

Figure 3: Rectangular wire carrying current I and present inside a magnetic field $\vec{B}$.

   (a) Describe in detail what will happen to the loop.

   (b) What will happen if the loop is massive and there is gravitational field present?

   (c) How does the flux linked with the loop vary with time?

   (d) Does the variation of flux imply anything?

   (e) Do you need an external source to keep current at constant value?

2. Particle Physics

   (a) Draw the Feynman diagrams for electron-electron scattering (Möller scattering).

   (b) Write down the Feynman amplitude for the above process.

   (c) Write down the formula for scattering cross-section.

   (d) What is phase space? What is phase space volume? How do you determine the number of states?

   (e) What is the importance of each term in the scattering cross-section formula? Give experimental relevance.

   (f) When is phase space analysis more important?

   (g) What is charge conjugation symmetry? Given the decay: $\pi^0 \longrightarrow e^+ + e^-$, and with a detector which can detect both electron and positron, what would charge conjugation symmetry imply?

3. Given an one-particle system with two allowed energy levels: $+E$ and -E.

(a) What is the average energy of the system?

(b) What is the probability of finding the particle in $+E$ energy state and in -E energy state?

(c) How do you normalize the probability?

(d) What do you call the term: $e^{E/kT} + e^{-E/kT}$?

4. Solve the differential equation: $y'' + 3\,y' + 2\,y = e^x$.

4.2 Interview Questions asked to Archana Mishra (IMSc)

1. A cart is moving with acceleration $\vec{a}$ which keeps on increasing with time. A cubical block of sides s is placed on the cart. The surface of the cart is rough. (Do not consider the rolling of wheels of the cart. See Figure 4, page 12.)

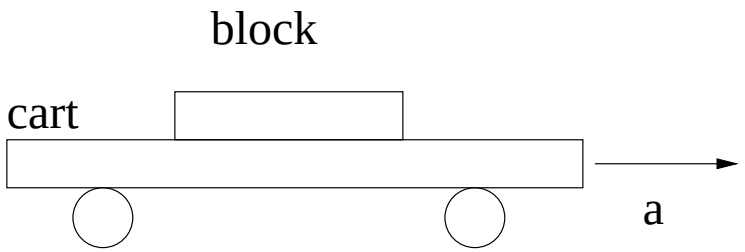

Figure 4: Problem of cart and block.

(a) Show all the forces with their directions, acting on the cart.

(b) Write down the equation of motion for the system using the datas given.

2. About Summer Project

(a) Describe your project.

(b) What is the difference between Seyfert-I and Seyfert-II galaxies?

(c) How is X-ray produced in AGNs (Active Galactic Nuclies)?

(d) Draw the spectrums corresponding to the Seyfert-I and Seyfert-II galaxies.

(e) What other types of AGNs are there?

(f) How is red-shift related to distance?

(g) What are the typical red-shift values for Seyfert I and II galaxies, and pulsars?

3. Solid State

(a) Draw the energy band.

(b) How is energy band formed?

(c) How is diffraction condition applicable to e^- ?

(d) Why Bragg's reflection takes place for only certain values of $\vec{k}$?

(e) In some $\epsilon \sim \vec{k}$ diagrams, all the bands are drawn in the first Brillouin zone. What is it?

(f) What are different zone schemes and what are their uses?

(g) How to create a band gap at $\pi/2a$ or at any other point in the $\epsilon \sim \vec{k}$ diagram?

4. Particle Physics

(a) How can we estimate the mass of proton?

(b) How to estimate the mass of proton from Avogadro's Number N_A ?

(c) Write the β^- decay equation.

(d) Can proton decay?

(e) How does β^+ dacay occur?

5. Mathematical Methods

(a) Given $y = \sqrt{x} - \ln_2 x$.Plot sign of y.

(b) What happens at $x = 4$. What is the sign of y at this point?

(c) What type of function does the graph look like?

(d) What is its derivative?

5 Physical Research Laboratory, Ahmedabad

5.1 Interview Questions asked to Dibyakrupa Sahoo (PRL)

1. Given a Harmonic oscillator potential.

   (a) Write down the Hamiltonian for the system.

   (b) Write down the creation and annihilation operators.

   (c) Write down the Hamiltonian in terms of the creation and annihilation operators. ($a^\dagger$= creation operator, a = annihilation operator)

   (d) Prove that:

   $$a|n\rangle = \sqrt{n}\,|n-1\rangle \tag{6}$$

   $$a^\dagger|n\rangle = \sqrt{n+1}\,|n+1\rangle \tag{7}$$

   (e) Prove that:

   $$H|n\rangle = \left(n + \frac{1}{2}\right)\hbar\,\omega|n\rangle \tag{8}$$

   (f) Find out the solution for wavefunction.

   (g) Explain how creation and annihilation operators are used in Particle Physics.

2. What is the procedure to accelerate charged particles? What is the role of electric field and magnetic field in the process of acceleration? Does magnetic field spend any energy on the charged particles?

3. Given a box of neutral atoms in gaseous state.

   (a) How can you form a plasma out of it?

   (b) What is the temperature at which we shall get the plasma?

   (c) How does the distribution of energy amongst electrons and ions look like? Explain the distribution curve. State which type of statistics is obeyed by the plasma? Why?

   (d) How do you incorporate relativistic effects in the above case?

4. Particle Physics Experiment:

   (a) Explain how a scintillation detector works. What is the use of photomultiplier tube? Explain its action. Does a photomultiplier tube multiply photons? If yes, how; if no, why is it then called a photomultiplier tube?

(b) Explain how a semiconductor detector works. Which one of the detectors:

i. scintillation detector and

ii. semiconductor detector,

is better and why? Explain physically.

(c) Draw a typical γ-ray spectrum and explain the various peaks.

5. Are neutrinos really massless? can we measure the energy of neutrinos directly? How do you experimentally determine the mass of neutrinos?

6. Given a simple pendulum of mass m and length l.

(a) Write down the Lagrangian and Hamiltonian for the system.

(b) Find out the equation of motion in terms of l and θ.

(c) Solve the equation of motion for small θ. Find out the time period of oscillation.

(d) Solve the equation of motion for large θ. Find out the time period of oscillation.

5.2 Interview Questions asked to Archana Mishra (PRL)

1. Project

(a) Explain your project.

(b) What are Active Galactic Nuclei (AGNs)?

(c) How do you know that there is a black hole at the center of the AGNs?

(d) How is X-ray emitted from AGNs?

(e) What kind of lines (spectral) do you get in AGNs's spectrum?

(f) To which wavelengths do they correspond to?

(g) What is the difference between Seyfert galaxies and Quasars?

(h) How to determine luminosity?

2. Solve the equation for force $F = -w\,x$. Now if electric field $E = E_0 \cos(\omega t)$ is applied, solve the equation.

3. Write the equation for β-deacy.

4. How is energy produced in the Sun?

5. Write the reaction for energy production via nuclear fission that is going on in Sun.

6. How much energy is produced in Sun by nuclear fusion?

7. How do protons combine to form heavier nuclei despite electromagnetic force of repulsion existing between them?

8. If the energy of protons is less than the Coulomb barrier, can two protons combine?

9. What is the tunnelling process?

10. What is radio-active Carbon?

11. Describe carbon dating?

12. What are the different models for nucleus? describe them.

13. Explain the Standard Model of Particle Physics.

14. Explain Compton Scattering.

15. If you don't remember the Compton Scattering formula, how would you verify physically whether $\lambda_C\,(1-\cos\phi)$ or $\lambda_C\,(1+\cos\phi)$ is the right one. Do not derive or calculate, just give a physical argument.

5.3 Interview Questions asked to Preeti Manjari Mishra (PRL)

1. Dirac Equation

   (a) Write down the Time-Independent Dirac Equation.

   (b) Write down the Time-Dependent Dirac Equation.

   (c) Write down the Relativistic Time-Dependent Dirac equation.

   (d) Find out the energy eigenvalues of Dirac Equation.

   (e) What is the range of energy for Fermions?

2. What is the divergence of a radial function?

3. Particle Physics

   (a) What are the outcomes of Neutrino Oscillation experiment?

   (b) Which experiment shows that Neutrinos have slight mass?

(c) What is the relation between symmetries and conservation principles in Particle Physics and prove it?

(d) What are solar neutrinos?

4. What is the mechanism by which the energy from the Sun comes to the Earth?

5. Find out the turning point in the SHO Potential $\sim$ position curve. Does existence of particle possible beyond turning point?

6. What is the graph for e^{-x^2}?

7. Do ceramics act as superconductors? If yes, how?

6 Indian Institute of Technology Kanpur

6.1 Questions of the Written Test for PhD in Physics

1. A bead of mass m can slide along a smooth rod which is rotating in a vertical plane about its end O with constant angular velocity ω. The bead is connected to a light spring (spring constant k, natural length r_0) whose other end is attached to the rod at O. (See Figure 5, page 18.) Obtain the Lagrangian for the bead and thus its equation of motion.

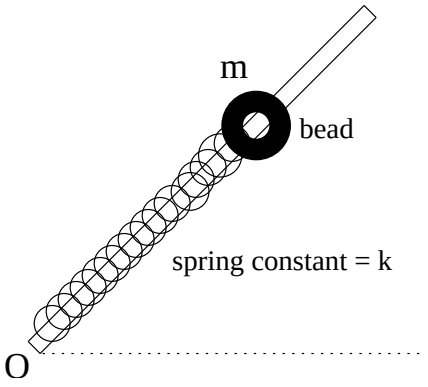

Figure 5: The Bead Spring problem.

2. An resulting sphere of radius R carries a volume charge density $\rho(r) = (k/\pi)r$ (where k is a constant and r the radial distance), and also a uniform surface charge density $\sigma = -kR^2/4\pi$ pasted on its surface. Obtain the electric field $\vec{E}(r)$ for (i) $r < R$ and (ii) $r > R$.

3. A parallel plate capacitor with large circular plates (radius $R \gg$ plate separation d) is connected to a low-frequency ($\omega R/c \ll 1$) ac-voltage source, so that the electric field in the region between the two plates is approximately spatially uniform and varies with time as $\vec{E} = \hat{z}E_0 \sin\omega t$. Obtain the resulting magnetic field vector $\vec{B}(r)$ between the plates at a distance r from the central (z) axis (r <R).

4. The magnetc field in a certain region of space is changing with time. The electric field induced consequently is approximately given (in cylindrical coordinates r, ϕ, z) by:

   (a) $E_z = E_0 \cos(\omega t) \ln(a/b) \quad (r < a)$

   (b) $E_z = E_0 \cos(\omega t) \ln(r/b) \quad (a < r < b)$

   (c) $E_z = 0 \quad (r > b)$

   The other components E_r, E_ϕ are zero everywhere. From the appropriate Maxwell equation, obtain the magnetic field vector (magnitude and direction) in the three given regions. Explain how such a

magnetic field can be produced from currents (using wires/rods/pipes/solenoids/sheets).

5. For one dimensional motion in a finite potential well extending from $x = -a$ to $x = a$, the ground state energy (E) for a quantum particle of mass m is exactly half of the well height ($V = 2E$). Obtain E in terms of a and m.

6. The amplitude for an electron (in the usual basis) are evolving with time as:

$$\begin{pmatrix} c_1 \\ c_2 \end{pmatrix} = \begin{pmatrix} \cos\theta\, e^{-i\omega t} \\ \sin\theta\, e^{i\omega t} \end{pmatrix} \tag{9}$$

   Evaluate the expectation values $\langle S_x \rangle$, $\langle S_y \rangle$, $\langle S_z \rangle$ of the components of electron spin operator. What is the corresponding physical situation?

7. For a d-orbital electron in an effective one-electron (alkali) atom, obtain all possible expectation values of the (perturbation) operator $\vec{L} \cdot \vec{S}$.

8. Consider a solid in which each atom has two possible energy states with energies 0 and ϵ. The solid is in thermal equilibrium at temperature T.

   (a) Determine the average energy $\langle E \rangle$ per atom.

   (b) Make a plot of $\langle E \rangle$ with temperature, clearly showing the "low temperature" and "high temperature" limiting behaviours.

   (c) Make a plot showing the variation of the specific heat of the solid with temperature.

9. (a) Using contour integration, evaluate the following integral (a is real and positive)

$$\int_{-\infty}^{\infty} \frac{e^{-ix}}{x^2 + a^2}\, dx \tag{10}$$

   (b) Express a matrix $[A]$ in terms of its eigenvalues λ_n and eigenvectors $|n\rangle$. Thus express the matrix $\exp[A]$ in terms of the eigenvalues and eigenvectors of $[A]$.

10. A sine wave input of amplitude 2V and frequency 50Hz is fed to the input of the three circuits shown in the figure below. Plot the output of the circuits in your answer book in the format shown. (See Figure 6, page 20.) Assume that the opamps are operating from +15V and -15V supplies.

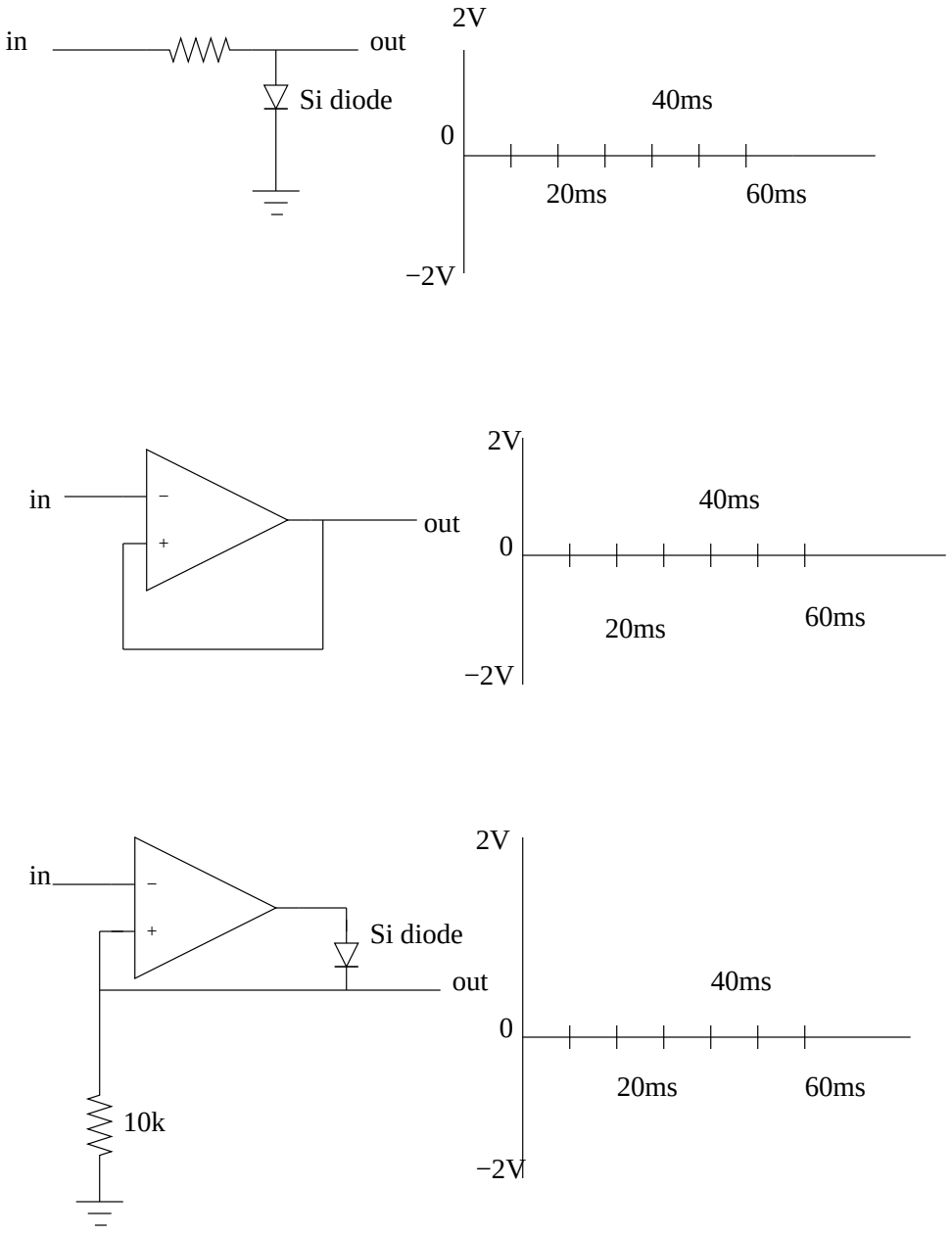

Figure 6: Electronic circuits of the problem.

Useful Information:

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},\ \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix},\ \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \tag{11}$$

In cylindrical coordinates:

$$\vec{\nabla} \times \vec{E} = \left[\frac{1}{r}\frac{\partial E_z}{\partial \phi} - \frac{\partial E_\phi}{\partial z}\right]\hat{r} + \left[\frac{\partial E_r}{\partial z} - \frac{\partial E_z}{\partial r}\right]\hat{\phi} + \frac{1}{r}\left[\frac{\partial}{\partial r}(rE_\phi) - \frac{\partial E_r}{\partial \phi}\right]\hat{z} \tag{12}$$

6.2 Interview Questions asked to Archana Mishra (IITK)

1. Summer Project: "Study of X-ray spectra of AGNs" done at IUCAA, Pune

   (a) How is X-ray produced?

   (b) Describe the process.

   (c) What type of process is seen in AGNs?

   (d) What is the energy of X-rays produced in AGNs?

   (e) How can you find out the energy of X-rays if wavelength of X-ray, and wavelength and energy of Visible radiation is known?

   (f) Is the above method simpler than calculating energy of X-rays from their wavelengths alone?

2. Solid State Physics:

   (a) What is superconductivity and what are superconductors?

   (b) Draw the $\rho \sim T$ graph depicting metal and superconductor stage.

   (c) Explain Meisner effect.

   (d) Describe how magnetic flux lines are associated with metals and superconductors.

   (e) What is the magnitude of χ in superconductors?

   (f) How does current flow in a superconductor?

   (g) Why do superconductors show diamagnetism?

7 Bhabha Atomic Research Center

7.1 Interview Questions asked to Shuvendu Jena (BARC)

1. How can you determine experimentally the Transition Temperature (T_c) of a Ferro-magnetic material?

2. How can you determine Polarisation? How can you get Electrical Susceptibility χ_e?

3. What are the differences between free electron and nearly free electron model and its consequences?

4. What is the origin of band gap? (Explain.)

5. Draw $E \sim \vec{k}$ diagram for Free Electron Model and Nearly Free Electron Model. Draw it in Reduced Periodic Zone Scheme.

6. How can you reduce 2nd zone and 3rd zone?

7. What is Bloch's Theorem and what does it mean?

8. Given two basis vectors U_1 and U_2 with eigenvalues $\lambda_1 = 1$ and $\lambda_2 = 2$:

$$\hat{A}\,U_1 = \lambda_1\,U_1\ ,\hat{A}\,U_2 = \lambda_2\,U_2 \tag{13}$$

$$U_1 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}\ ,\ U_2 = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \tag{14}$$

Find out what is $\hat{A}$? Now let us change the basis to V_1 and V_2:

$$V_1 = \begin{pmatrix} 1 \\ 1 \end{pmatrix} = U_1 + U_2\ , V_2 = \begin{pmatrix} 1 \\ -1 \end{pmatrix} = U_1 - U_2 \tag{15}$$

so that again:

$$\hat{A}\,V_1 = \lambda_1^{'}\,V_1\ ,\hat{A}\,V_2 = \lambda_{2'}^{'}\,V_2\ . \tag{16}$$

Find out what are $\lambda_1^{'},\ \lambda_2^{'}$?

9. Can an electron come out from a metal? If it can, how and if it cannot, why not? What are the different processes by which electrons can come out of a metal? (Suggest different processes.)

10. What is Secondary Emission?

11. What are α,β,γ radiations?

12. What is β decay?

13. Draw the energy spectrum of β decay. Why is it continuous while for α it is discrete?

7.2 Interview Questions asked to Atul Charan Sahoo (BARC)

1. Free Particle:

   (a) Write the Hamiltonian of a free particle and its equation of motion in differential form.

   (b) Write the Schrödinger's Equation for a free particle.

   (c) What is the solution of this equation? Write the solution in general form.

   (d) Does the particle have definite energy? Definite momentum? How can you know that it has definite momentum or not?

2. Simple Harmonic Oscillator

   (a) Write Schrödinger's Equation for 1-D SHO.

   (b) Write the ground state wave function (ψ_0).

   (c) Draw the $V(x) \sim x$ for SHO.

   (d) Draw $\psi_0(x) \sim x$ for SHO.

   (e) Draw the Probability density $\sim x$ for SHO.

   (f) Differentiate between a particle in Simple Harmonic Oscillator Classically as well as Quantum Mechanically.

   (g) Where is the probability of finding the particle maximum; consider the case both Classically and Quantum Mechanically?

   (h) What are the boundary conditions used to solve SHO problem?

   (i) Given the SHO potential in 1st quadrant only. (See Figure 7, page 24). What is its ground state wave function? Write down the ground state energy in this case. What are the boundary conditions used to solve this problem? Why do you select only the odd ns from the equation $E_n = \left(n + \frac{1}{2}\right) \hbar\,\omega$?

3. Draw the graph for $x\,e^{-x^2} \sim x$.

4. Nuclear Physics

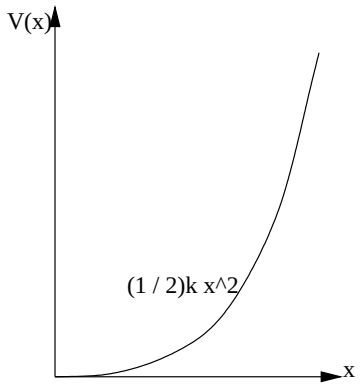

Figure 7: Half of the SHO Potential

(a) What are the propeties of a nucleus?

(b) What is the charge of a nucleus?

(c) Does it have dipole moment? Does it have quadrupole moment? What is quadrupole moment?

(d) Is the nucleus compressible or incompressible?

(e) Explain the spherical, prolate, oblate shape of the nuclei. (From dipole moment and quadrupole moment points of view.)

(f) What is the dipole moment for the configuration given in Figure 8, Page 24.

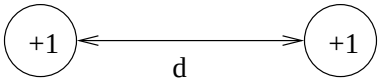

Figure 8: Find out dipole moment for this configuration.

(g) For a spherical charge distribution draw (i) Potential $\sim$ r, (ii) Field $\sim$ r.

(h) What is fission? Why it occurs?

(i) Draw $\frac{B.E.}{A} \sim A$ and $B.E. \sim A$ graphs.

(j) How can you explain fission? Which models can explain peaks in $\frac{B.E.}{A} \sim A$ graph?

(k) Explain B. E. in terms of semi-empirical mass formula.

5. Complex Analysis

(a) Find (i) $\oint \frac{d\,z}{z+2}\,, |z| = 3$, (ii) $\int \frac{d\,z}{z^2-4}\,, |z| = 3$.

(b) Find $\int_{SC} z^2\,dz$ in the semi-circular contour given in Figure 9, Page 25

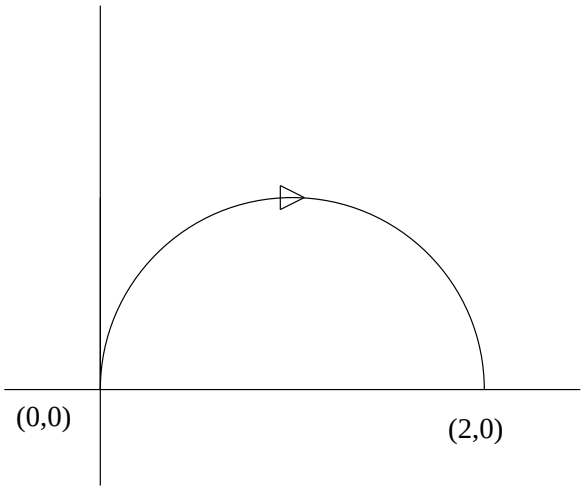

Figure 9: Semi-circular Contour.

6. If a body falls from a height h and then rebounds by the surface and reaches a height $\frac{h}{2}$ and this process goes on repeating each time the body hits the surface, (see Figure 10, page 25) calculate the total distance covered by the body. How much time does the body take to come to rest?

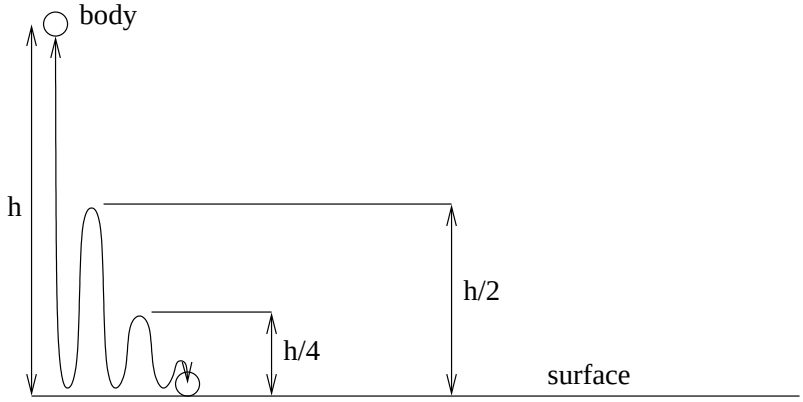

Figure 10: Body bouncing off the surface.

7. What is the function $x - \frac{x^3}{3!} + \frac{x^5}{5!} - ... = ?$

8. What are the values of J to which transitions can take place from $J = 0$? Why?

9. Physically without any calculation, how can you explain why $J = 0$ to $J = 0$ is forbidden?

10. See the figure 11 on page 26.

    Does the potential has any effect on the velocity of the particle moving with velocity v? How is it affected for all regions: AB, BC, CD and beyond D?

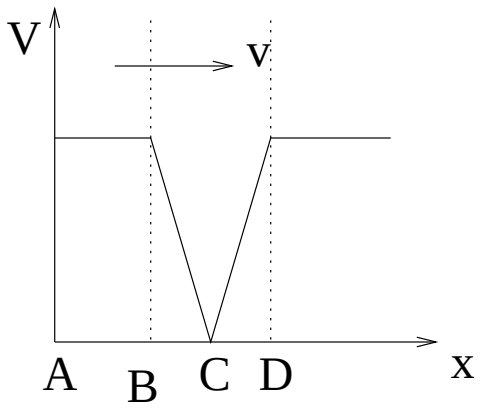

Figure 11: An Arbitrary Given Potential.

7.3 Interview Questions asked to Minakshi Nayak (BARC)

1. Classify the elementary particles.
2. Write the heaviest lepton and its mass.
3. Which method is easy to collide two particles: when the two particles are moving towards each other or when one particle at rest and the other moving towards it?
4. If we separate two quarks what will happen?
5. What type of potential we take in Shell Model?
6. Electrons are arranged in different orbits around nucleus. Write how neutrons and protons are arranged inside nucleus.
7. How do we get γ-ray?
8. When a radio-isotope decays emitting α-particles what are the final products?
9. for a given matrix how do we find eigenfunctions and eigenvalues? Prove that $A - \lambda I = 0$.

7.4 Interview Questions asked to Madhusmita Baral (BARC)

1. A particle is represented by a wave function $\psi(x)$. How do you find the position of the particle? Suppose the wave function is like given in Figure 12, page 27. How can you find the position of the particle here? Are the expectation value and Most-probable value the same?
2. Write down the ground state energy and wavefunction of 2-D SHO, considering the Harmonic Oscillator to be isotropic.

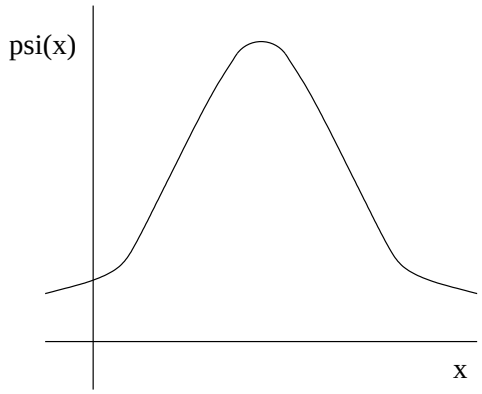

Figure 12: The given Wavefunction.

3. Given the Hamiltonian $H(x) = \frac{p_x^2}{2m} + \frac{p_y^2}{2m} + \frac{1}{2}\,m\,\omega^2\,x^2 + \frac{1}{2}\,m\,\omega^2\,y^2 + \alpha\,x^4$. What is the energy now?

4. Suppose the energy is $2\hbar\omega$, instead of $\hbar\omega$. How do you find out the Energy for the Hamiltonian above? can you apply same procedure for finding the energy (perturbed) for both case?

5. What is nuclear fission? How does the energy distribution amongst various fission products look like?

6. How do you convert nuclear energy from nuclear fission to electrical energy?

7. Plot Binding energy per nucleon curve and explain each term in binding energy formula. Why the term $Z(Z-1)$ comes in the Coulomb energy term?

8. What will be the curve for binding energy $\sim$ mass number? Does it start from origin?

9. How does the nuclear density vary with distance? Whether it is isotropic, anisotropic or homogeneous?

10. Suppose a nucleus is placed at origin and a proton is at some distance, what is the variation of potential? (See Figure 13, page 27)

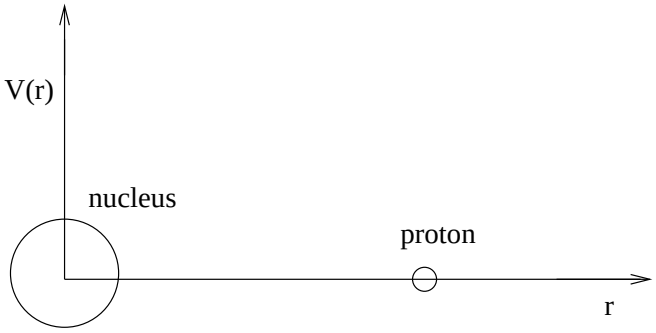

Figure 13: Nucleus and proton problem.

11. Plot and write down the verification of potential and also what is the force on charge particle due to hollow sphere as shown in Figure 14, Page 28

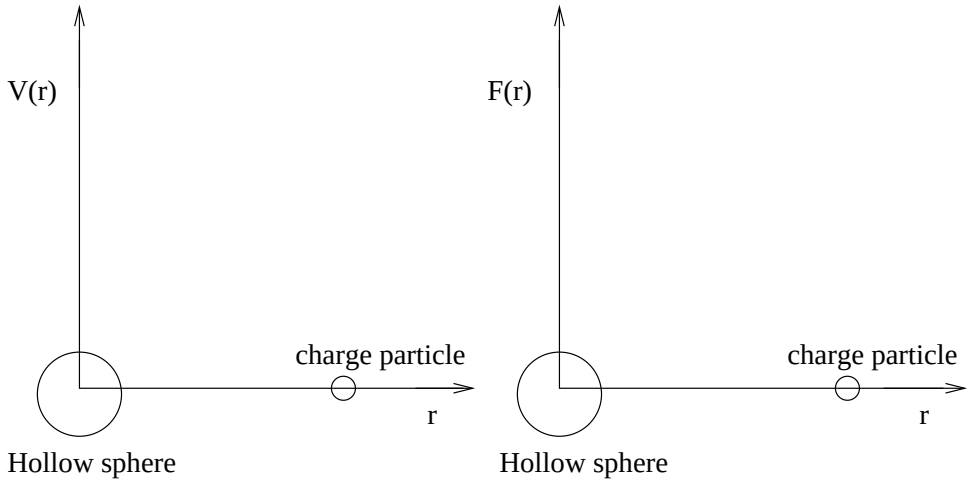

Figure 14: Hollow sphere and charge problem.

12. What is the electric field of an infinite charged conducting sheet having surface charge density σ?

13. How do you find the resistance of unknown resistors?

14. Given that $\vec{u} = A\,\vec{w}$, $\vec{u} = B\,\vec{x}$, $\vec{w} = C\,\vec{x}$. What is C?

8 Indian Institute of Technology Madras, Chennai

8.1 Questions asked to Madhusmita Baral (IITM)

1. What are the different generations of Quarks? What are the quantum numbers associated with Quarks? Which ones are more important? How color quantum number came into picture?
2. What is the kind of potential inside the nucleus?
3. What is asymptotic freedom?
4. What is the ground state energy and wavefunction for 1-D harmonic oscillator? Plot the energy spectra and the wavefunction.
5. Write down the Hamiltonian for Harmonic Oscillator using ladder operator starting from classical mechanics?
6. What is $\{a, a^\dagger\}$, $\{a^2, a^\dagger\}$, and $\{H, a\}$?

8.2 Interview Questions asked to Minakshi Nayak (IITM)

1. Write down Hamiltonian for a free particle in presence of electric and magnetic fields.
2. What is the corresponding equation of motion ?
3. Draw the ground state wavefunction for Hydrogen atom.
4. Draw Fermi-Dirac distribution function at absolute zero temperature.
5. What is the probability of finding the Hydrogen atom in its fourth excited state?
6. How does an atom go from its ground state to its first excited state?
7. Write down the selection rule for dipole-dipole transition.
8. What is Fermi's Golden Rule?

9 Indian Institute of Technology Guwahati, Guwahati

9.1 Interview Questions asked to Atul Charan Sahoo (IITG)

1. Interference:
   (a) Draw double slit interference interference pattern if intensity of photon decreases.
   (b) Draw the pattern for one photon.
   (c) What happens to the interference pattern if we consider one electron?
   (d) If a beam of bullets are fired, will we be able to observe the interference pattern?
2. Mathematical Methods:
   (a) Indicate the branch points for: $f(z) = \sqrt{z^2 + 1}$.
   (b) What is singularity?
   (c) What is an analytic function?
   (d) Show that the above function has singularities at branch points.
   (e) Is this one: $e^{i\,(3\,x\,+\,5\,y\,-\,\omega\,t)}$ a spherical or plane wave solution?
3. Solid State: Draw energy band for semiconductor, conductor and insulator. What are their order of energy gaps?
4. Draw electromagnetic wave in a conductor.
5. What is the density of water?
6. If you are cooling water and stop cooling while the thermometer reads 0^o, then what will be the state of matter. Explain.