



UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Supply – 2020 & Annual – 2021

Roll No.

Subject: Physics

Paper: I (Solid State Physics-II)

Time: 3 Hrs. Marks: 50

NOTE: Attempt any FOUR questions, in all by selecting at least ONE question from each section.

Q.1.

- Explain the quantum free-electron model of metals in terms of Pauli's exclusion principle
(6)
- Metallic silver is an excellent conductor. It has 5.86×10^{26} conduction electrons per cubic meter. (i) Calculate its Fermi energy. (ii) Compare this energy to the thermal energy $k_B T$ of the electrons at a room temperature of 300K.
(4.5)
- What is the cause of failure of free electron theory? (2)

Q.2.

- Calculate the heat capacity of the electron gas by using Fermi Dirac distribution. Explain why experimental results do not agree with the results obtained by using classical statistics.
(6)
- Explain Fermi Dirac distribution function. Show that Fermi curve at room temperature shows a little change from that at 0K. (6.5)

Q.3.

- What is the reason and origin of the energy band formation in solids? (6.5)
- In a solid, consider the energy level lying 0.01eV below fermi level. What was is the probability of this level not being occupied by an electron. (3)
- What do you mean by Bloch theorem and state its significance in Physics? (3)

Q.4.

- Differentiate between paramagnetic, ferromagnetic and diamagnetic materials (3)
- Describe the quantum theory of paramagnetic susceptibility of a substance in an external magnetic field B_z under the following conditions.
(9.5)
 - B_z is week and temperature is high
 - B_z is very strong and temperature is very low

Section-II

Q.5.

- How the carrier concentration in intrinsic semiconductor varies as a function of temperature? (6.5)
- What is the primary difference between an n-type and a p-type semiconductor? (2)
- Prove that Fermi level lies in the middle of the forbidden gap in case of intrinsic semiconductors. (4)

Q.6.

- How is P-N junction formed? (3)
- Derive expressions for the built-in potential and the depletion width of a P-N junction in thermal equilibrium. What is the effect of doping on the depletion width?
(9.5)

Q.7.

Write notes on the following:

- Effective Mass (6.5)
- Electrical resistivity of metals (6)



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Roll No.

Subject: Physics

Paper: II (Statistical Physics)

Time: 3 Hrs. Marks: 50

NOTE: Attempt FOUR questions, in all by selecting at least ONE question from each section. Try to be focused and give only precise answers, of the asked questions.

SECTION-I

- Q. No. 1:** (a) Define Phase, Mu (μ), and Gamma (Γ) space for N-particle systems. Describe the density distribution in Phase space in detail. (3, 5)
(b) Explain the Ensemble average for a set of N-points and for a set of systems. (4.5)
- Q. No. 2:** (a) Prove that time rate of change of density of a fluid (P) along the flow line is zero. (7)
(b) By considering an ideal gas of N-non-interacting particles enclosed in a cubical box, illustrate the use of a micro- canonical ensemble in order to calculate the energy of the system. (5.5)
- Q. No. 3:** (a) Describe the Entropy in Statistical mechanics explicitly. (7.5)
(b) If the volume of a perfect gas of N-atoms is doubled, while keeping energy constant. Then, what will be the change in entropy? (5)
- Q. No. 4:** (a) Write a detail note on the principle of equipartition of energy for mono- and diatomic gases along with its discrepancies. (8.5)
(b) Explain the thermodynamic functions for canonical ensemble. (4)

SECTION-II

- Q. No. 5:** (a) Discuss briefly the thermal wavelength by considering three different cases in quantum statistics. (7.5)
(b) State and prove the Fermi-Distribution law, which provides average no. of particles in a state j. (5)
- Q. No. 6:** (a) Drive a relation for Bose-Einstein statistics and discuss it at a finite temperature. (7.5)
(b) Write a note on the Bose-Einstein condensation. (5)
- Q. No. 7:** (a) By using Plank's law of radiation, prove the Stephen-Boltzman law categorically. (7)
(b) State and Explain the Pauli Exclusion Principle along with significance. (5.5)



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Subject: Physics

Paper: III (Relativity & Cosmology)

Roll No.

Time: 3 Hrs. Marks: 50

NOTE: Attempt FOUR questions selecting at least ONE from each section.

Section-I

Q1. (a) Show that the wave equation $\nabla^2 u - \frac{1}{c^2} \frac{\partial^2 u}{\partial t^2} = 0$ is invariant under the Lorentz transformation but not invariant under Galilean transformations. [9½]

(b) Differentiate between proper and improper Lorentz transformations. [3]

Q2. (a) Find Lorentz transformation laws for the components of velocity and acceleration. [7 ½]

(b) Two inertial frames S and S' are moving with velocity v relative to each other. A particle as observed by an observer in S' describes a circle:

$$x'^2 + y'^2 = a^2, \quad z' = 0$$

with constant speed. Show that as observed from S , the particle describes an ellipse. Find the center of the ellipse and draw it for S . [5]

Q3. (a) Find the components of four force and four momentum. [6 ½]

(b) Starting from the orthogonality of four force and four velocity, show that the total energy of a particle is the sum of its kinetic energy and the rest mass energy. [6]

Section-II

Q4. (a) Show that the covariant derivative of a contravariant vector field X^a is

$$\nabla_c X^a = \partial_c X^a + \Gamma_{bc}^a X^b \quad [7\frac{1}{2}]$$

(b) If $T_{\alpha\beta\gamma\delta}$ is a tensor of rank 4, then show that

$$T_{\alpha[\beta\gamma\delta]} = T_{\alpha[\beta\gamma\delta]} \quad [5]$$

Q5. (a) Show that the divergence of Ricci tensor is non-zero but divergence of Einstein tensor is zero. [8½]

(b) Using equation of geodesic, describe the spacetime in the following cases:

(i) Motion with gravity

(ii) Motion without gravity [4]

Q6. (a) What is gravitational red shift? Derive the quantitative relation showing that it depends upon gravitational acceleration. [6 ½]

(b) Discuss the cosmic microwave background. [6]

Q7. Write notes on the following:

(i) Principle of Equivalence

(ii) Friedmann's model [6½, 6]



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Subject: Physics

Paper: IV (Computational Physics)

Roll No.

Time: 3 Hrs. Marks: 50

NOTE: Attempt FOUR questions selecting at least ONE from each section.

Section-I		
Q.1. (A)	Write C++ program which reads in a number as decimal number and convert it into a binary equivalent number or as binary number and convert it into a decimal equivalent number due to option 1 or 2. Implement your program for 4 iterations.	8 ½+4
(B)	Write C++ program to calculate electric field ($E=Kq/r^2$) at certain point due to charge; ask user to input values of charge and corresponding distance; $K= 9 \times 10^9 \text{ Nm}^2.\text{C}^{-2}$. Implement for five iterations.	
Q.2. (A)	Write C++ program to evaluate the $\int_1^6 \frac{\sqrt{x}+4}{11} dx$ by trapezoidal rule. (Use n=6).	7+5 ½
(B)	Write C++ program to print the following series and sum of the series: $S = \sum_{n=1}^{20} \frac{x^{n/4}}{4}$ Ask user to input value of x.	
Q.3. (A)	Find the roots of the equation $3x - \cos x - 1$ using Newton-Raphson method using $x_0 = 0.5$. Write C++ program to implement the method (i) correct to 2dp. (ii) How can you change same program to implement the method correct to 3dp?	8+4 ½
(B)	Write C++ program to calculate time period of simple pendulum ($T=2\pi \sqrt{\frac{l}{g}}$) using functions. Ask user to input value of l .	
Section-II		
Q.4. (A)	Write MATLAB program to print time against the growth of Current and the decay of current values on a single graph in the RL-circuit using Euler's Method with initial conditions: $r=10\Omega$, $L=5H$,	8 +4½

	initial time 0sec, time step 0.1sec, maximum time 2.5sec., initial current 0A and voltage v=4 volts. Also plot point of intersection of two curves. Draw estimate graphs with proper labels. How you can get the coordinates of the interaction point?	
(B)	Write MATLAB to plot 'x' against f(x) values using subplot such that: $x = [0 \ 4\pi]$, $y(x) = \sin(n*x)$ and $n=1,2,3,4$	
Q.5. (A)	Suppose A and B be 3x3 matrices. Write MATLAB program which reads in entries of the matrices and calculate (i) $C=10A-5B$, (ii) $D=3Ax4B$ (iii) sum and average of the matrix C and D elements	6½+6
(B)	Write down the MATLAB syntax with example for: polyder(), polyint(), and polyval().	
Q.6. (A)	Write general syntax for user define function in MATLAB. Write a program to implement to calculate volume of a sphere of radius r, such that $r = [5 \ 15]$; [Hint: $V = \frac{4}{3} \pi r^3$]	6+ 6 ½
(B)	Write MATLAB program to solve the system of linear algebraic equations using following methods: (i) Left division method. (ii) Cramer rule. (iii) Matrix inverse method. $\begin{aligned} 3x + 2y - 4z &= 6 \\ -3x - 4y + 3z &= -20 \\ 9x + 6y + 2z &= 12 \end{aligned}$	
Q.7. (A)	A parallel plate capacitor is constructed from two or more parallel conducting plates such that its capacitance C can be computed from the formula $C = (n-1) \epsilon A / d$ Where n is number of plates, $\epsilon = 8.85 \times 10^{-12}$ farad/meter is dielectric constant, $A = 15 \text{ cm}^2$ is the area of each plate separated by distance $d = 2 \text{ mm}$. Write MATLAB program to construct a table to print number of plates against capacitance values for a maximum of 5 plates.	8+4 ½
(B)	Write MATLAB program using arrays for conversions of (i) temperature from Celsius to Kelvin where $\text{Kelvin} = \text{Celsius} + 273.15$ (ii) length from Meter to Yards where $1 \text{ meter} = 1.0936 \text{ yards}$	



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Roll No.

Subject: Physics

Paper: V (Classical Electrodynamics)

Time: 3 Hrs. Marks: 100

NOTE: Attempt any FIVE questions. All questions carry equal marks.

Q.1. (a) State Gauss's law in dielectrics. How do you calculate total charge, volume and surface charge densities for a point charge in a dielectric fluid. (13 Marks)

(b) Two dielectric media with dielectric constants K_1 and K_2 are separated by a plane Interface. There is no external charge on the interface. Find a relationship between θ_1 and θ_2 , where these are the angles that an arbitrary line of displacement makes with normal to the interface. (7 Marks)

Q.2. (a) Show that torque on a complete circuit, for uniform magnetic field, is given by $\tau = IA \times B$, where $m = IA$ is the magnetic dipole moment of the circuit. (10 Marks)

(b) When the conducting system is suddenly isolated from applied electric fields, explain how the equilibrium state is approached exponentially. (10 Marks)

Q.3. (a) Describe briefly method of images. (4 Mark)

(b) Calculate electrostatic energy of an arbitrary distribution of charge. (16 Marks)

Q.4. Find the following expression of potential for the conducting sphere in a uniform electric field:

$$\phi(r, \theta) = -E_0 r \cos\theta + E_0 (a^3/r^2) \cos\theta \quad (20 \text{ Marks})$$

Q.5. (a) what do you understand by "magnetic susceptibility" and "permeability". (4 Marks)

(b) What is significance of Lorentz and coulomb gauges? By imposing the Lorentz condition, show that scalar and vector potentials satisfy the inhomogeneous wave equations of similar forms. (16 Marks)

Q.6. (a) What is magnetization current density J_M ? Also prove that $J_M = \nabla \times M$ where M is the Magnetization. (12 Marks)

(b) If a current density J in a wire of circular cross section with radius R is proportional to the distance from the axis. Find an expression for the total current in the wire. (8 Marks)

Q.7. (a) Define Phase velocity and group velocity. (3 Marks)

(b) What is skin depth and its significance? Calculate the skin depth in the case of plane monochromatic waves travelling through a conducting media. (17 Marks)

Q.8. (a) What is difference between neutral gas and a plasma? (4 Marks)

(b) What does a uniform magnetic field (B) do to a charged particle in a plasma? (16 Marks)

Q.9. Discuss only two topics from the following: (10+10 Marks)

(a) Faraday's law (b) Magnetic mirror (c) linear and circular polarizations (d) Ohm's law and conductivity



NOTE: Attempt any FOUR questions selecting at least ONE from each section. All questions carry equal marks. Please read question carefully and answer accordingly.

SECTION – I

1. (a) The empirical binding energy for a nucleus with Z protons and A total number of nucleons is given by

$$B = a_v A - a_s A^{2/3} - a_c Z(Z - 1)A^{-1/3} - a_{sym} \frac{(A - 2Z)^2}{A} + \delta,$$

where pairing energy is

$$\begin{aligned} \delta &= +a_p A^{-3/4} && \text{even } Z \text{ \& even } N, \\ &= -a_p A^{-3/4} && \text{odd } Z \text{ \& odd } N, \\ &= 0 && \text{odd } A. \end{aligned}$$

One suitable choice gives $a_v = 15.5$ MeV, $a_s = 16.8$ MeV, $a_c = 0.72$ MeV, $a_{sym} = 23$ MeV, and $a_p = 34$ MeV. Use this relation to get empirical mass of the nucleus. How many protons in a nucleus with mass number A give most tightly bound structure? [10]

- (b) What is nuclear binding energy? Use the semiempirical formula to compute the total binding energy and the binding energy per nucleon for (a) ${}^7\text{Li}$; (b) ${}^{20}\text{Ne}$; (c) ${}^{56}\text{Fe}$; (d) ${}^{235}\text{U}$. What percentage of the binding energy is a contribution from pairing energy? [10]
- (c) What physical information do we get from the magnetic dipole moment of a neutron. [05]
2. (a) Explain the structure and working principle of a betatron? What are its limitations? [10]
- (b) In a scintillation detector why do we need a scintillator which is blind to its own radiation? How could we accomplish this? [10]
- (c) What is the basic difference between a cyclotron and synchrocyclotron? [05]

SECTION – II

3. (a) What evidences do we have for the shell structure of nuclei? Propose a reasonable potential function for shell model and justify it. Why do we need spin-orbit interaction to get the observed shell closure numbers? [10]
- (b) Show that spin-orbit splitting for an orbital is directly proportional to its orbital angular momentum. [08]
- (c) Give the expected shell-model spin and parity assignments for the ground states of (a) ${}^7_3\text{Li}$; (b) ${}^{11}_5\text{B}$; (c) ${}^{15}_6\text{C}$; (d) ${}^{17}_9\text{F}$; (e) ${}^{31}_{15}\text{P}$. [07]
4. (a) Why do we have a continuous energy distribution of electrons (positrons) emitted in a β decay? Use allowed approximation to derive an expression for the decay rate such that it can explain the energy spectrum of the particles emitted in β decay. [10]
- (b) The decay of ${}^{253}\text{Es}(I = \frac{7}{2}, \pi = +)$ leads to a sequence of negative-parity states in ${}^{249}\text{Bk}$ with $I = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}, \frac{9}{2}, \frac{11}{2}, \frac{13}{2}$. For each state, find the permitted values of l_α . [10]

- (c) Let's consider the decay of a nucleus of mass M at rest, from an initial excited state E_i to a final state E_f . What would be the energy of the photon emitted in this transition? [05]

SECTION – III

5. (a) What is compound nucleus theory for nuclear reactions? Explain with one example. How do compound nucleus reactions differ with direct nuclear reactions? [10]
- (b) It is desired to study the low-lying excited states of ^{35}Cl (1.219, 1.763, 2.646, 2.694, 3.003, 3.163 MeV) through the $^{32}\text{S}(\alpha, p)$ reaction. With incident α particles of 5.000 MeV, which of these excited states can be reached? [$m(^{35}\text{Cl}) = 32573.5565\text{MeV}/c^2$, $m(^{32}\text{S}) = 29783.7583\text{MeV}/c^2$, $m(\alpha) = 3727.409\text{MeV}/c^2$, $m_p = 938.280\text{MeV}/c^2$]. [10]
- (c) What are the physical meanings of reaction cross section? [05]
6. (a) Why do heavy nuclei release large amount of energy in fission? Use liquid drop model to find the condition for spontaneous fission of a nucleus. [10]
- (b) How much energy would be released if a ^{238}U nucleus is split into two equal mass fragments? Why do the fission fragments undergo several β -decay steps to transform into a stable nucleus? [10]
- (c) In ^{239}Pu , the thermal fission cross section is 742 b, while the cross section for other (nonfission) absorptive processes is 267 b. Each fission produces, on the average, 2.86 fast neutrons. What is the mean number of fission neutrons produced by ^{239}Pu per thermal neutron? [05]
7. (a) Why does fusion of light nuclei results in large energy release? [05]
- (b) The sun is a natural thermonuclear reactor where protons are combined to get helium nuclei. Explain the proton-proton cycle in the solar fusion. [10]
- (c) Consider the fusion reaction ${}^6_6\text{C} + {}^{12}_6\text{C} \rightarrow {}^{18}_6\text{C}$. What is the height of the coulomb barrier which needs to be penetrated for the fusion. If one wants to make this reaction occur thermally what is the required temperature? [10]