UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

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.

SECTION – I

Q.1.

a. Obtain the eigen values of energy and normalized wave function for a particle in a one dimensional infinite potential of side 'a' for n = 1,2,3. (6.5)

b. Define bloch function and discuss its significance, also write down its expression in terms of Fourier series. (3)

c. Suppose we have two specimens A and B. A has large residual resistivity as compared to B, at constant temperature which sample is said to be more pure. (3)

Q.2.

a. Given the central equation.

$$(\lambda - E)\,C(k) + \sum_{G} U_G\,C(k-G) = 0 \; where \; \lambda_k = \frac{h^2k^2}{2m}$$

Determine analytically the splitting of energy levels of free electrons near the zone boundary. (6.5)

b. Define and draw Fermi sphere (3)

c. Explain the impact of temperature on mobility of semiconductor. (3)

Q.3.

a. Discuss the formation of allowed and forbidden energy bands on the basis of Kronig Penny model. Discuss the extreme conditions when the energy levels are either discrete or continuous. Is this model supports energy band theory of solids or not? (9.5)

b. Explain the difference between direct and indirect band gap materials. (3)

Q.4.

a. What are the principal sources of the magnetic moment of a free atom? (6.5)

b. Derive Langevin's expression for the paramagnetic susceptibility of a material and relate it to Curie Law. (6)

SECTION – II

Q.5.

a. Derive an expression for intrinsic carries concentration in a semiconductor. (6.5)

b. Prove that $E_F = E_G/2$ for intrinsic semiconductors. (6)

Q.6.

a. Calculate ionization energy for N-type semiconductor and Bohr radius of donor electron. (3)

b. Derive expressions for the built in potential and the depletion width of an $P-N$ in thermal equilibrium. What is the effect of doping on the depletion width? (9.5)

Q.7. Write Notes on the following.

a. Motion in magnetic field (6)

b. Heat capacity of the electron gas. (6.5)

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

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) State and Prove the "Liouville's Theorem" **(6.5)**
(b) Provide a detail comparison of different ensembles. **(6)**

Q. No. 2: (a) Define the conditions for equilibrium and discuss Thermal, Mechanical, and Particle equilibrium briefly. **(7)**
(b) If the volume of a perfect gas of N-atoms is increased by three times, while keeping energy constant. Then, what will be the change in entropy.? **(5.5)**

Q. No. 3: (a) State and explain the important properties of entropy implied by its definition in statistical physics . **(7.5)**
(b) Using thermodynamic relations, show that for an ideal gas, $C_p - C_v = R$. **(5)**

Q. No. 4: (a) Using Canonical ensemble, discuss the Maxwell's velocity distribution. **(8.5)**
(b) Provide the discrepancies of specific heat in classical theory. **(4)**

SECTION-II

Q. No. 5: (a) Prove that $C_v \propto T^3$. **(6.5)**
(b) Discuss that why the Einstein model failed to explain heat capacity at low temperature and also describe the high temperature case. **(6)**

Q. No. 6: (a) Define fermions and drive a relation for Fermi-Dirac statistics. **(6)**
(b) How is the equation of symmetry of wave functions related to basic distinction between Fermi-Dirac and Bose-Einstein systems? **(3)**
(c) The total energy of electron gas is given by $E = 3/5(NE_F)$ at 0K. Using this results, derive a relation between pressure and volume of electron gas. **(3.5)**

Q. No. 7: (a) Derive a formula for the density of states $G(v)$ and hence find an expression for total number of photons in terms of frequency v for a photon gas enclosed in a volume V and in equilibrium at temperature T. What value of chemical potential is used in this calculation and why? **(6)**
(b) Derive Stefan Boltzmann law from Planck's law of radiation. **(3)**
(b) If the universe is an impenetrable spherical cavity of radius 1228 *cm* with inside temperature 3*K*, estimate the total number of photons in the universe. **(3.5)**

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ……………..

Subject: Physics **Paper: III (Relativity & Cosmology)** **Time: 3 Hrs.** **Marks: 50**

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

Section-I

Q1.(a) Find Lorentz transformation laws for the components of velocity and acceleration. [6½]

(b) A rod of length 'l' is held in a vertical xy – plane, x being in the horizontal direction. The rod makes an angle θ with the x – axis and is held in this position during its entire motion. If the rod is given with a velocity $0.5c$ in the x – direction, what will be the length of the rod as seen by a stationary observer? [6]

Q2.(a) State and prove the law of composition of velocities for objects moving with relativistic speeds. [6½]

(b) If at time $t = \acute{t} = 0$, the origions of inertial systems S and $\acute{S}$ moving with relative velocity v and are in standard configuration just coincide and a spherical pulse of light is produced at the common origin. Show that the speed of propagation of the spherical wavefront is the same in both systems. [6]

Q3.(a) Starting from the electromagnetic field tensor, find covariant form of four Maxwell equations. [6 ½]

(b) Discuss the following with reference to special relativity

(i) Mass variation (ii) Energy-momentum relation [6]

Section-II

Q4. (a) Define the following terms:

(i) Differentiable Manifold (ii) Coordinate transformations (iii) Contravariant Vector [6]

(b) What is index free interpretation of a vector field? Show that the expression $X = X^\mu \partial_\mu$ remain invariant under coordinate transformation. [6 ½]

Q5. (a) Find the Christoffel symbols of the 2-sphere of radius 'a' with the metric:

$$ds^2 = a^2 d\theta^2 + a^2 \sin^2\theta \, d\varphi^2$$ [5]

(b) For the Christoffel symbol of second kind, show that

$$\Gamma^a_{bc} = \frac{1}{2} g^{ad}\left(\partial_a g_{bd} + \partial_b g_{cd} - \partial_d g_{bc}\right)$$ [7½]

Q6.(a) If $\Gamma^\mu_{\nu\lambda} = 0$ at point p, then show that: $R^\mu_{\nu[\sigma\rho:\lambda]} = 0$, where $R^\mu_{\nu\sigma\rho}$ is Riemann Tensor. [6½]

(b) If $G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$ is the Einstein tensor. Show that the contraction of the Bianchi identity implies $\nabla_\mu G^\mu_\nu = 0$. [6]

Q7. Write notes on following: [6+6 ½]

(i) Cosmological Red Shift (ii) FRW metric and Hubble's Law

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. …………….

Subject: Physics **Paper: IV (Computational Physics)** **Time: 3 Hrs.** **Marks: 50**

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

	Section-I	
Q.1. (A)	Write a C^{++} program for the Decay of Current in a simple RL-circuit using Euler's Method with initial conditions: r=10Ω, L=5H, initial time 0, time step 0.1, maximum time 2.5sec., initial current 5A and voltage v=0 volts. Print current against time values.	8 ½+4
(B)	Write C^{++} program to calculate and print equivalent resistance of seven resistors connected in series.	
Q.2. (A)	Write C^{++} program to evaluate the $\int_1^6 \sqrt{3x^3 - 5x + 9}\, dx$ by trapezoidal rule. (Use n=6).	7+5 ½
(B)	Write C^{++} program to print the following series and sum of the series: $S = \sum_{n=1}^{15} \frac{x^{n/2}}{n(n+1)}$ Ask user to input value of x.	
Q.3. (A)	Find the roots of the equation **5x – cos x – 9** using simple iterative method using $x_o = 0.5$. Write C^{++} program to implement the method correct to 2dp.	8+4 ½
(B)	Write C^{++} program with function to calculate range of projectile motion ($R = \frac{v^2 sin2\theta}{g}$). Implement for three iterations.	
	Section-II	
Q.4. (A)	The acceleration of a spherical body experiencing air drag is given by **a = g – k v²** where **k = c π ρ r² / 2 m** with the conditions: **g = 9.8 m/sec², c=0.46** (drag constant), **ρ= 1.2 kg/m³, r=1m, v=0 m/sec, h= 0.1 sec** and **tmax=2.5sec.** Write MATLAB program to plot and print time, position, velocity and acceleration values. Also draw estimate output graphs with proper curve labels, x & y labels and title.	8 +4½

(B) Write MATLAB program to plot time (t) against sin(t), 5sin(t) and 3cos(t) curves on the same graph with different colors. Use t = [0 4π] where step size =0.5

Q.5. — Marks: 6½+6

(A) The temperature values per day for two cities A and B are given in the table. Write MATLAB program to determine: (i) number of times the temperature of A is less than that of B with day (ii) temp. of A & B > 48 with days (iii) find out the day with two temperatures are very close or apart from each other and (iv) find average temperature per day and per week.

Day	1	2	3	4	5	6
A	30	43.2	51	38	41	46
B	37	33	44.2	31.3	41	49

(B) Write down the MATLAB syntax with example for: expand(), diff(), and factor().

Q.6. — Marks: 8+4 ½

(A) A mass m is suspended by three cables with tensions T1, T2 and T3, which are related by the following equations:

$$T_1/\sqrt{35} - 3T_2\sqrt{34} + T_3/\sqrt{42} = 0$$

$$3T_1/\sqrt{35} - 4T_3/\sqrt{42} = 0$$

$$T_1/\sqrt{35} - 3T_2\sqrt{34} + T_3/\sqrt{42} = mg$$

Write MATLAB program to solve for the tensions using three methods due to options 1, 2 or 3 using selection structure.

(B) Calculate the radius r of a sphere that has a volume of $350 m^3$. Once **r** is determined, use this **r** to calculate surface area of sphere using MATLAB program.

Q.7. — Marks: 8+4 ½

(A) Write MATLAB program to show the curves for the half-wave rectifier circuit. How you can change the program to implement full-wave rectifier circuit?

Such that: For half wave rectification:

$V_s(t)=\sin(\pi t)$

$0 \le t \le 10$

$$v_L = \begin{cases} v_S & if \quad v_s > 0 \\ 0 & \text{if} \quad v_s \le 0 \end{cases}$$

(B) Create a matrix M in MATLAB expression such that

$$M = \begin{matrix} 11 & 13 & 15 & 17 & 19 & 21 & 23 \\ 13 & 11 & 29 & 7 & 5 & 2 & 3 \\ 1 & 2 & 4 & 9 & 15 & 32 & 71 \end{matrix}$$

Sort data in M. Also find the maximum and mean value of M.

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ……………

Subject: Physics **Paper: XIII (opt-iv) / IX-1 (Advance Electronics)** **Time: 3 Hrs.** **Marks: 100**

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

Q 1. **Draw the internal structure of an operational amplifier. Design the operational amplifier as integrator, differentiator and summing amplifier. (5,15)**

Q 2. Describe the construction, working and characteristics of the magnetron tube. (20)

Q 3. Design the RS, D and JK flip flops by using discrete components. Also discuss the application of master slave flip flop.(15,5)

Q 4. What are shift registers counters? Describe the working of 5 bit- ring counter. Also draw the truth table and timing diagram. (5,15)

Q 5. a. Design the MOD 10 up and down synchronous counter. (10)

b. Design 4-bit asynchronous counter. (10)

Q 6. a. What is parity? Design 4-bit even parity generator circuit.? (10)

b. Draw the combinational logic circuit for Excess-3 to BCD code converter. (10)

Q 7. a. Design the Radio Broadcasting Transmitters. (10)

b. Define the term in short note FM, AM, PM, GSM and CDMA. (10)

Q 8.a. Differentiate between DRAM and SRAM memory cell structure. (5,5)

b. Draw the tree analysis of RAM family and discuss its features. (10)

Q 9. a. What is the basic role of Execution unit and Bus interface in microprocessor. (10)

b. Differentiate the main features of microprocessor and microcontrollers. (5,5)

Q 10. Write the note ant two of the followings.

a. PAL vs GAL.
b. 8 to 1 line MUX.
c. Solar cell vs photo conductor.

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

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) What do you understand by an electric dipole? *(3 Marks)*

(b) Find potential produced by a specified charged distribution in terms of its dipole moments using multipole expansion of electric fields. *(17 Marks)*

Q.2. (a) Describe method of images. What are the main advantages of using the method of images to solve Electrostatic boundary value problems? *(5 Marks)*

(b) Two spherical conducting shells of radii r_a and r_b are arranged concentrically and charged to the potentials φ_a and $\varphi_b$respectively. If $r_b > r_a$, find the potential at points between the shells and at points $r > r_b$. *(15 Marks)*

Q.3. (a) What do you understand by "electric susceptibility" and "dielectric constant". *(5 Marks)*

(b) 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. *(15 Marks)*

Q.4. (a) How would you define energy density of electrostatic field? *(3 Marks)*

(b) Show that the magnetic induction due to a magnetized distribution of matter may be expressed as

$$\boldsymbol{B}(\boldsymbol{r}) = -\mu_o \nabla\varphi^*(\boldsymbol{r}) + \mu_o \boldsymbol{M}(\boldsymbol{r})$$

where $\varphi^*(\boldsymbol{r})$ is the magnetic scalar potential and $\boldsymbol{M}(\boldsymbol{r})$ is the magnetization. *(17 marks)*

Q.5. (a) What do you understand by magnetization current and magnetization current density *(5 Marks)*

(b) How discrepancy in Ampere's law was removed by the concept of displacement current? Discuss in detail. *(15 Marks)*

Q.6. Calculate reflection and refraction for the EM plane wave with oblique incidence at the boundary of two non-conducting media. *(20 Marks)*

Q.7. (a) What is poynting theorem. *(3 Marks)*

(b) Derive the equations of electromagnetic wave propagation for **E** and **H** in a linear and charge free medium. *(17 Marks)*

Q.8. (a) What is plasma? Why it is called a fourth state of matter? *(4 Marks)*

(b) What is Debye shielding in a plasma? How is Debye length calculated? *(16 Marks)*

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

(a) Lorentz gauge and the coulomb gauge (b) Faraday's law of electromagnetic induction (c) polarizations of EM waves (d) Magnetic mirror

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ....

Subject: Physics **Paper: VI (Nuclear Physics)** **Time: 3 Hrs.** **Marks: 100**

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

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

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? [12]

(b) Let's suppose we can form ^3He or ^3H by adding a proton or a neutron to ^2H, which has spin equal to 1 and even parity. Let l be the orbital angular momentum of the added nucleon relative to the ^2H center of mass. What are the possible values of the total angular momentum of ^3H or ^3He? [8]

(c) What is the magnetic dipole moment of a nucleon in an orbital with angular momentum quantum number $l = 2$? [5]

2. (a) Explain the working principle of a gas detector. What kind of gas would be most suitable for the use in a gas detector? What are its limitations? [10]

(b) Explain the structure and working principle of a synchrocyclotron? [10]

(c) What is the basic difference between a betatron and a cyclotron? [05]

SECTION – II

3. (a) How do nuclei with magic number of protons/neutrons differ with those having non-magic number nucleons? [07]

(b) Derive a relation for the magnetic dipole moment of odd-A nuclei using shell model.To what extent the single-particle shell model can explain the nuclear magnetic dipole moment? [12]

(c) Give the expected ground state spin parity of $^{34}_{15}P$, $^{16}_{7}N$, and $^{12}_{5}B$. [06]

4. (a) What is the difference between β^+ emission and electron capture? Can both processes have non-zero probability for a given nucleus? [10]

(b) What factors determine the spectrum of beta particles? Derive the expression for the spectrum of beta particles in the allowed approximation. [10]

(c) Defining the Q value as $(m_i - m_f)c^2$, compute the range of neutrino energies in the solar fusion reaction $p + p \rightarrow d + e^+ + \nu$. Assume the initial protons to have negligible kinetic energies. [05]

SECTION – III

5. (a) Explain the physical meanings of the reaction cross-section. [06]

   (b) What is the difference between compound nucleus reactions and direct reactions? Explain with examples. [12]

   (c) It is desired to study the first excited state of ^{16}O, which is at an energy of 6.049 MeV. Using the (α, n) reaction on a target of ^{13}C, what is the minimum energy of incident alphas which will populate the excited state? [07]

6. (a) Why do nuclei fission? Use liquid drop model to derive the condition for the spontaneous fission of a nucleus. [12]

   (b) 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? [08]

   (c) Explain the fission isomers.[05]

7. (a) Explain in detail how could we have a sustained fission reaction in the sample of natural Uranium (0.72% ^{235}U and 99.28% ^{238}U). What would be the size of such a sample? [15]

   (b) What is nuclear fusion? What factors determine the fusion rate in a large sample of nuclei at very high temperature? Explain proton-proton fusion cycle in sun. [10]

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ……………

Subject: Physics **Paper: VII (Solid State Physics-I)** **Time: 3 Hrs.** **Marks: 100**

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

Q. 1 (a) Derive Harhee Fock equation using variation principles, for independent electrons and apply to free electron gas to find the expression for energy. (13)

(b) What is Bom Oppen Heimer approximation? Describe briefly how the dynamics of electrons and ions in solids can be decoupled based on this approximation. (12)

Q. 2 (a) Describe the concept of Pseudo potentials. Discuss in detail Orthogonalised plane wave method with regards to energy band structures in solids. What is the muffin tin potential? (13)

(b) Discuss about tight binding approximation and evaluate the eigen energy of electron using nearest neighbour interactions by following tight binding approximation. (12)

Q. 3 (a) State Block Theorem and obtain the energy spectrum of an electron in a one-dimensional periodic potential. Show that in the limiting case of vanishing potential barrier leads to the results obtained in a free electron model. (13)

(b) What is Meisener effect in superconductors. Enumerate the properties of type I and type II superconductors. (12)

Q. 4 (a) What is meant by Raman Effect? Discuss Quantum theory of Raman Effect in detail. Show with the help of schematic figure about transition in this process regarding the Stokes and Anti-Stokes line? (13)

(b) Explain about basic difference between Rayleigh and Raman scattering. At what angle will a diffracted beam emerge from the (111) plane of a face centered cubic (fcc) cubic crystal of unit cell length of 0.4 nm? Assume diffraction occurs in the first order and the incident X-Ray wavelength is 0.3 nm. (5+7=12)

Q. 5 (a) How do you differentiate between diplacive, order and disorder ferroelectrics? Explain comprehensively the phenomenon of polarization catastrophe with regard to displacive ferroelectrics. (13)

(b) Give a comprehensive description of three different sources of polarizability in materials. Also draw polarizability against frequency and label appropriately to mark three different polarizabilities. (12)

Q. 6 Write note about following: (5 x 5)

i. Wannier Mott and Frenkel Excitons
ii. Augmented plane wave method.
iii. Born-Oppenheimer approximation
iv. Effective Mass of an electron in a solid
v. Meissner Effect

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ……………..

Subject: Physics **Paper: VIII (Solid State Physics-II) (Opt.)** **Time: 3 Hrs.** **Marks: 100**

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

Q.1 (a) Give a basic principle and construction of magnetic force microscopy (MFM).
(b) Discuss details of De Haas-Van Alphen effect.
(c) Deduce Madelung energy term from the total lattice energy of an ionic crystal.
(5+10+10)

Q.2 (a) How does the nuclear quadrupole resonance occur without any static magnetic field?
(b) Derive Boltzmann transport equation in relaxation time approximation.
(c) What is Motional Narrowing effect? How does it affect the NMR line width?
(5+10+10)

Q.3 (a) Discuss three level Maser system.
(b) Find an expression for the resonance frequency of uniaxial antiferromagnet.
(c) Explain the importance of the screening of electron-phonon interaction.
(5+10+10)

Q.4 (a) Explain nuclear quadrupole moment
(b) What is Hubbard model? How can it be used to differentiate metallic and insulating limits?
(c) Give details about the microscopic theory of frequency dependent dielectric constant.
(5+10+10)

Q.5 (a) Briefly describe Geomagnetism and Biomagnetism.
(b) Describe various optical properties of semiconductors
(c) Give details of hyperfine interactions. **(5+10+10)**

Q.6 (a) Define Neel temperature, Curie temperature, Mean field Approximation, Bloch wall and superparamagnetism.
(b) Show that fractional change in magnetization due to quantized spin waves by the temperature variation leads to the Bloch $T^{3/2}$ law.
(b) Derive an expression for the total magnetic response of a paramagnetic metal to external magnetic field. **(5+10+10)**

Q.7 Write explanatory notes on any two of the followings. **(25)**
(a) The Einstein model for heat capacity
(b) Neutron diffraction
(c) The quantum Hall effect

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ....

Subject: Physics | Paper: IX / VIII-1 (Particle Physics-I) | Time: 3 Hrs. | Marks: 100

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

Question 1: $(13 + 12 = 25)$

(a): QED and QCD are theories to describe electromagnetic and strong interactions, respectively. Narrate at least 4 differences in QED and QCD. Also explain why α_s shows different behavior than α_e?

(b): Use three quarks (u, d, s) and their antiquarks $(\bar{u}, \bar{d}, \bar{s})$ to make all possible combinations of 3 quarks (baryons), 3 antiquarks (antibaryons) and quak-antiquark pairs (mesons). Also write down the values of resulting charge and strangeness and possible hadron for these quark contents.

Question 2: $(12 + 8 + 5 = 25)$

(a): Give some examples of strange particles. Also explain, why are they called strange particles? In strangeness changing weak interactions, a strange quarks changes into an up-quark. Give an example of such reaction and explain how the theory of weak interactions was modified to incorporate such reactions?

(b): Show that homogeneity of space leads to the conservation of linear momentum.

(c): Which of the following processes are allowed and which are forbidden in nature and why?

$$\begin{aligned} p &\to n + e^+ + \bar{\nu}_e \\ \mu^- &\to e^- + \gamma \\ \pi^- + p^+ &\to K^+ + \Sigma^- \\ \Lambda &\to p^+ + \pi^- \\ K^- &\to \pi^- + \pi^+ + \pi^- \end{aligned}$$

SECTION – II

Question 3: $(10 + 10 + 5 = 25)$

(a): Consider a proton-antiproton system $(p\bar{p})$ in a state of definite orbital angular momentum, l, and spin, s. Show that the state vector of $(p\bar{p})$ system is an eigen state of charge conjugation operator with an eigen value $(-1)^{l+s}$.

(b): Considering the capture of negative pions into deuterium explain in detail how its intrinsic parity was measured?

(c): Write down the relation for μ^- decay and draw the corresponding Feynman diagram. Also comment on which type of process is this?

Question 4: (10 + 7 + 8 = 25)

(a): Using Isospin symmetry prove the following result.

$$\frac{\Gamma(\Delta^+ \to p\pi^0)}{\Gamma(\Delta^+ \to n\pi^+)} = 2$$

(b): Define helicity. How does helicity of neutrino implies parity violation in weak interactions?

(c): Show that

$$J_\pm|j,m>= [j(j+1) - m(m \pm 1)]^{1/2}|j,m \pm 1>$$

where $|j,m>$ are eigen-states of J^2 and J_z with eigen values $j(j+1)$ and m, respectively.

SECTION – III

Question 5: (10 + 10 + 5 = 25)

(a): Using the non-relativistic perturbation theory show that the transition amplitude T_{fi} is given by

$$T_{fi} = -i \int dx^4 \phi_f^*(x) V(x) \phi_i(x)$$

where $\phi_i(x)$ and $\phi_f(x)$ are initial and final states of the system and $V(x)$ is the interaction potential.

(b): Develop Klein Gordon equation using relativistic expression of energy. Derive the corresponding expressions for the probability and current density. Also find the values of ρ and $\mathbf{j}$ for a free particle of energy E and momentum $\mathbf{p}$.

(c): What kind of particles do obey Dirac equation? How did Dirac interpret negative energy solutions in his Hole theory?

Question 6: (10 + 10 + 5 = 25)

(a): Discuss the rules for scattering amplitudes in the Feynman-Stuckelberg approach. Check that the rules satisfy the conservation of energy for (a) e^-e^+ pair creation and (b), e^-e^+ annihilation.

(b): What are Lorentz transformations? Show that Schroedinger wave equation is not invariant under Lorentz transformations.

(c): Write down the Dirac equation and derive its adjoint form.

Question 7: (10 + 10 + 5 = 25)

(a): Derive the completeness relations for Dirac spinors.

(b): Working in the Dirac-Pauli representation of γ matrices show that

$$\gamma^5 u^{(s)} \simeq \begin{pmatrix} \sigma \cdot \hat{\mathbf{p}} & 0 \\ 0 & \sigma \cdot \hat{\mathbf{p}} \end{pmatrix} u^{(s)}$$

where $u^{(s)}$ is the electron spinor. How would you interpret this result?

(c): Show that $[\sigma^{\alpha\beta}, \gamma^\mu] = 2\, i(\gamma^\alpha g^{\beta\mu} - \gamma^\beta g^{\mu\alpha})$

UNIVERSITY OF THE PUNJAB

M.A./M.Sc. Part – II Annual Examination – 2022

Roll No. ....

Subject: Physics **Paper: X / VIII-2 (Particle Physics-II)** **Time: 3 Hrs. Marks: 100**

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

SECTION – I

Q1. Explain the general process of scattering. Discuss the wave forms which we obtain for incident and scattered waves. Also, write down the general expression for incident and reflected waves. (20)

Q2. Define Mandelstam variables. Show that for electron-positron scattering in s-channel in center of mass frame (20)

$$s = 4(K^2 + m^2)$$
$$t = -2K^2(1 - \cos\theta)$$
$$u = -2K^2(1 + \cos\theta)$$

Where θ is the center of mass scattering angle and $K = |K_i| = |K_f|$, where K_i and K_f are the momenta of incident & scattered electron. (20)

Q3. State and prove optical theorem for scattering theory. (20)

SECTION – II

Q4. What are fundamental particles. Name two fundamental and two non-fundamental particles. Discuss Quark model in detail. Briefly explain the classification of particles in Quark model. (20)

Q5. Find the transition amplitude and transition current for a spinless electron moving in an electromagnetic field. Define Fermi – Golden Rule. (20)

Q6. (a) . Define the generators of the group SU (3) . What are structure constants.

(b) Solve the following commutators

$[T_1, T_2]$

$[T_2, T_5]$ (12 +8)

SECTION – III

Q7. Prove the following

i. $Tr(\not{a}\not{b}) = 4\, a.b$

ii. $Tr(\gamma_5 \not{a}\not{b}) = 0$

iii. $Tr(\gamma_5) = 0$

iv. $Tr(\gamma^k) = 0$,k = 1,2,3 (20)

Q8. Show that for a Dirac particle (20)

$$\overline{U_f}\ \gamma^\mu U_i = \frac{1}{2m}\overline{U_f}\left[\left(P_i + P_f\right)^\mu + i\sigma^{\mu\nu}\left(P_f - P_i\right)_\nu\right]U_i$$

Where , $\sigma^{\mu\nu} = \frac{i}{2}(\gamma^\mu\gamma^\nu - \gamma^\nu\gamma^\mu)$

Q9. (a) Draw Feynman diagrams for $e^- e^+$ scattering.

(b) Show that for $e^- e^+$ at very high energies.

$$\sigma = \frac{4\pi\alpha^2}{3s}$$ (8+12)