DHWU

M.Sc. 4TH SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/Th/4S/401-A

Advanced Electronics

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.

*Answer **two** questions from each group*

*(Use **separate** answer script for each group)*

Group – A

1. a) State the law of mass action in semiconductor. Deduce an expression for the concentration of electrons in conduction band of an intrinsic semiconductor at temperature T.(You may assume the formula for the density of states of free electrons)

b) Establish the continuity equation of carriers in semiconductor. Write down the importance of Shockley-Haynes experiment.

c) Draw the variation of logarithmic resistivity of a semiconductor with temperature. How do you calculate the band gap of a semiconductor from this graph? (1+3)+(3+1)+(1+1)=10

2. a) Does the gain of a BJT have any dependence on the collector current? Explain your views.

b) Is it possible to use transistor as a switch? Explain.

c) A transistor is operating in CE mode, draws a constant current $I_B = 30\ \mu A$. The collector current I_C is found to change from 3.5 mA to 3.7 mA when the collector emitter voltage V_{CE} changes from 7.5 V to 12.5 V. Calculate the output resistance and β at $V_{CE} = 12.5$ V. What is the value of α. 4+3+3=10

3. a) What are metal-semiconductor ohmic and Schottky contacts?

b) Write down the linearized Boltzmann transport equation in presence of uniform electric and magnetic field. Find the solution.

c) Using the above solution, derive an expression for the Hall co-efficient of a material for weak magnetic field by the concept of two-band model. 2+(1+3)+4=10

Group – B

4. a) Define the pinch off voltage of a field effect transistor. Show its dependence with depletion width.

b) For a certain MOSFET, $I_{DSS} = 18$ mA and $V_{GS}(off) = +10$ V.

i) Is this a p-type or n type channel?

ii) Calculate I_D at $V_{GS} = +4$ V.

c) Show that the tunneling current of a Tunnel diode depends on the band gap of the material. (1+3)+3+3=10

5. a) Prove that the negative resistance arises in an IMPATT diode due to the phase lag between the current and voltage.

b) Two photodiodes, each with an effective area of 10 cm^2, are exposed to bichromatic radiation having power densities of 500W/m^2, in narrow bands one around 430 THz and the other, around 600 THz. One diode has a bandgap energy of 1 eV, the other has 2 eV. When diode is reverse biased (in the dark), the saturation current is 10 nA. The diodes operate at 300 K. What are the short-circuit photo currents? And what is the open-circuit voltage of each diode?

c) What is a photodetector? How do you explain the efficiency of a photodetector? What are the limiting factors of the output efficiency of a photodetector? 3+3+(1+1+2)=10

6. a) Discuss the current voltage characteristics of a BARITT diode.

b) "In a Gunn diode the negative resistance originates from negative mobility". Does the statement is true? Explain.

c) A typical GeAs Gunn diode has the following parameters:

Threshold field (E_{th}) = 2800 V/cm, applied field (E) = 3200 V/cm, Device Length (L) = 10 μm, Doping Concentration (n_0) = 2×10^{14} cm^{-3}, Operating Frequency (f) = 10 GHz,

i) Compute the electron drift velocity.

ii) Calculate the current density.

iii) Estimate the negative electron mobility. 3+4+3=10

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M.Sc. 4TH SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/Th/4S/401-B

Advanced Condensed Matter Physics

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.

Answer two questions from each group

(*Use **separate** answer script for each group*)

Group – A

1. a) Calculate the temperature dependence of Debye Weller factor assuming that all atoms vibrate as independent oscillators of frequency ω.

b) Using the Kroing Penney model show that for P <<1 the energy of the lowest energy band is $E=\frac{\hbar^2 P}{ma^2}$ Symbols have their usual meaning. ($P=\frac{mu_0 ba}{\hbar}$, where u_0 is the height of the periodic potential, (a+b) is the periodicity of the crystal.

c) Calculate the cyclotron frequency. 4+4+2=10

2. a) Mention the properties symmetric and anti-symmetric wave function. Name two particles for each type of wave function followed by. Write down the determinantal wave function for a N particle system. Show how this follows the Pauli principle.

b) Apply Hartree-Fock method to calculate the total energy of Na-metal containing N numbers of atoms. What will be the difference if Hartree method is applied in this system? What is Fermi hole? (1+1+1+1)+(4+1+1)=10

3. a) When the magnetic moment of a pure metal crystal oscillates as the intensity of an applied magnetic field B is increased, then show that the oscillation period is inversely proportional to the Fermi Surface in the direction of the applied field.

b) Prove that orthogonalized plane waves are not orthogonal to each other.

c) Discuss the basic features of Korringa-Khon-Rostoker method for to calculate the band structure of a crystalline solid. 5+3+2=10

Group – B

4. a) What is meant by a local field in a dielectric? Derive the Debye equation expressing the relationship between dielectric constant and atomic polarizability.

b) Define dielectric relaxation.

c) Derive Ginzberg-Landau equation of superconducting phase transition. Hence obtain the value of order parameter deep inside the superconductor. (1+3)+1+(4+1)=10

5. a) i) Derive the expression $\varepsilon(\omega)=1-\frac{\omega_p^2}{\omega^2}, \omega_p^2=\frac{ne^2}{\varepsilon_0 m}$ for the dielectric constant as a function of ω for a free electron gas of number density n.

ii) Show clearly that metals are opaque to light for which ω is less than ω_p.

iii) Calculate the wavelength cut-off for Na metal if the volume of a primitive unit cell in Na is $35X10^{-30}$ m^3.

b) What is cooper pair?

c) Explain DC Josephson effect. Show that the supercurrent of superconducting pairs across the junction depends on the phase difference. (2+1+1)+1+(1+4)=10

6. a) What is photoluminescence? Discuss its mechanism.

b) Show that the Photoconductivity of a pure crystal is given by $\sigma= n_0 e \sqrt{L}$ where L is the number of photons incident on the crystal per unit volume and n_0 is the number of charge carriers at equilibrium.

What is trap center? How the above expression for photoconductivity (σ) is modified due to the introduction of N number of trap center into the crystal? (1+2)+(3+1+3)=10

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M.Sc. 4TH SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/ThE/4S/402

High Energy Physics - Elective

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.
Answer two questions from each Group
(*Use **separate** answer script for each group*)

Group – A

Answer any two questions :

1. a) Estimate the range of weak interaction. (Hint : Use $M_Z = 90GeV$)

   b) Draw the Feynman diagram for the process : $e^- + e^- \rightarrow e^- + e^-$. Hence, find an expression for its amplitude.

   c) Write down the Gell-Mann/Okubo mass formula relating to the masses of the baryon octet. Ignore the small differences between p and n; Σ^+, Σ^- and Σ^0; and Ξ^0 and Ξ^- and use m_N for masses of nucleons (average of masses of p and n), m_Σ (average of all 3 Σ's) and m_Ξ (average of Ξ's). Predict the mass of Λ from the above relation. [Given $m_N = 939$, $m_\Sigma = 1179$, $m_\Xi = 1327$; masses are in GeV] 2+(2+4)+2=10

2. a) Using Young tableaux method for $SU(3)$ group, show that $3 \otimes 3 \otimes 3 = 10 \otimes 8 \otimes \overline{8} \otimes 1$.

   b) Find the dimension of the adjoint representation of the gauge group : $SU(N)$

   c) How many gauge bosons are needed as mediation particles for the gauge group - $SU(5)$?

   d) Show that isospin invariance leads to equality of masses of proton and neutron. 4+2+1+3=10

3. a) Why was Color degrees of freedom introduced in QCD?

   b) Show that Charge conjugation operator is hermitian.

   c) Show that $|K^0>$ and $|\overline{K^0}>$ are not eigen states of the operator - CP. Construct the eigen states of CP by linear superposition of $|K^0>$ and $|\overline{K^0}>$. Hence, find the eigen values of CP.

   Comment on 2π and 3π decay modes of K-mesons. (Notations have their usual meaning) 2+2+(2+2+2)=10

Group – B

Answer any two questions :

4. The Lagrangian for free Dirac field is given by : $\mathcal{L} = \overline{\psi}(i\gamma^\mu \partial_\mu - m)\psi$

a) Show that under global gauge transformation, $U(\theta)=e^{i\alpha\theta}$, $\mathcal{L}$ remains invariant. (α is the parameter and θ is the variable independent of space coordinates and both are real)

b) Assuming $U(\theta)$ to be local gauge transformation (i.e., θ depends on x), show that local gauge invariance introduces the electromagnetic field A_μ which transforms as :

$A'_\mu \rightarrow A_\mu + \partial_\mu \theta$. Define covariant derivative.

c) Hence, explain the Spontaneous Symmetry Breaking for $U(1)$ local gauge symmetry assuming scalar field theory. 2+(3+1)+4=10

5. a) Why is electron a good probe for revealing the sybstructure of proton?

b) Consider the elastic scattering process : $e(p_1)+p(p_2)->e(p_3)+p(p_4)$ and assume the leptonic current, $L^{\mu\nu}=2[p_1^{\mu}\cdot p_3^{\nu}+p_1^{\nu}\cdot p_3^{\mu}+g^{\mu\nu}(m^2-p_1\cdot p_3)]$.

i. Write down an expression for hadronic current, $K_{\mu\nu}$ explaining all terms.

ii. Using the condition $q^{\mu}K_{\mu\nu}=0$, obtain an expression for $K_{\mu\nu}$ in terms of structure constants K_1 and K_2. Here, q^{μ} four momenta transfer function.

iii. Comparing this expression with $K^{\mu\nu}$ for Dirac proton show that $K_1=-q^2$ and $K_2=4M^2$, where M is mass of the proton 2+(2+3+3)=10

6. a) Write down the generic term for Yukawa interaction for a femion f. Hence, find an expression for the mass of that fermion.

b) What is the problem in giving mass to u quark in the SM? How is it resolved in the SM?

c) The running coupling constant in QCD is given by :

$$\alpha_S(|q^2|)=\frac{\alpha_S(\mu^2)}{1+\left(\frac{\alpha_S(\mu^2)}{12\pi}\right)(11n-2f)\ln(|q^2|/\mu^2)} \quad (|q^2|>>\mu^2).$$

where, n is the number of colors and f is the number of flavors.

i. Discuss the condition for which antiscreening will dominate.

ii. How is the concept of asymptotic freedom emerged from this expression?

iii. Why did we choose $\alpha_S(\mu^2)$ instead of $\alpha_S(0)$? (1+2)+(1+2)+(1+2+1)=10

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M.Sc. 4TH SEMESTER EXAMINATION 2018

Subject : Physics

Paper : Phy/ThE/4S/403

Nuclear Physics (Elective)

Time : 2 Hours **Full Marks : 40**

The figures in the margin indicate full marks.

Answer any three questions from Group A and any one from Group B

(*Use **separate** answer script for each group*)

Group – A

1. a) The Hamiltonian of a vibrating nucleus is defined as

$$H_l = \frac{1}{2}\sum_{l,m} D_l \left|\frac{da_{lm}(t)}{dt}\right|^2 + \frac{1}{2}\sum_{l,m} C_l |a_{lm}(t)|^2$$

where the symbols carry their usual meanings. Show that the shape parameter (a_{lm}) undergoes harmonic oscillation with frequency $\omega_l = \sqrt{C_l/D_l}$. What are the energy eigenvalues of this system?

b) If the isospin raising and lowering operators are defined as

$$\tau_{\pm} = \frac{1}{2}(\tau_1 \pm i\tau_2),$$

where $$\tau_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \& \tau_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix};$$

then find the followings,

(i) $\langle p|(\tau_+\tau_-)^q|p\rangle$,
(ii) $\langle n|(\tau_+\tau_-)^q|n\rangle$,
(iii) $\langle p|(\tau_-\tau_+)^q|p\rangle$,
(iv) $\langle n|(\tau_-\tau_+)^q|n\rangle$,

where q is any nonzero positive integer and $|p\rangle$ & $|n\rangle$ are the states of proton and neutron respectively. (5+1)+(1+1+1+1)=10

2. a) Show that the quadrupole moment for a homogeneous ellipsoid nucleus with semi axes a, b and b is given by

$$Q = \frac{2}{5} Ze(a^2 - b^2)$$

where Z = number of charge present in the nucleus and e is the electronic charge.

b) Lets define the radius of a spherical nucleus (with mass M_0) as follows

$$R = R_0\{1 + a_{lm} Y_{lm}(\theta, \phi)\}$$

where the symbols carry their usual meanings. What can you infer about the nuclear shape and density for $l=0, m=0$ state with $a_{00} = \sqrt{\pi/8}$? [Given : $2Y_{00}(\theta, \phi) = \sqrt{1/\pi}$] 7+3=10

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3. a) Defining the *Gamow Teller* operator as

$$O_{GT} = G_A \sum_{j=1}^{A} \sigma(j)\tau_+(j)$$

show that the transition strength between an initial ($|i>$) and final ($|f>$) state of a nucleus can be expressed as

$$S_+ = G_A^{-2} \sum <i|O_{GT}^{\dagger} O_{GT}|i>$$

where the symbols carry their usual meanings. Henceforth, also show that

$$S_- - S_+ = 3(N - Z),$$

where N and Z are the total number of neutrons and protons present in the said nucleus. 8+2=10

4. a) What do you mean by *Coulomb* excitation?

b) A recent model treats the collective nuclear states in terms of interacting bosons. Now, for a series of states that can be described in principle of symmetric superposition of S and D bosons (i.e. of spins 0 and 2 respectively), what are the spins of the states having $N_D = 0, 1, 2$ and 3 bosons? If the energy of the S boson is E_S and the energy of the D boson is E_D, and if there is a residual interaction between the pairs of D bosons of constant strength α, then what is the energy spectrum of the states with $N_S + N_D = 3$ bosons?

c) Lets take two nucleus, named 'A' and 'B'; with the former having the electronic charge as much as twice than that of the latter, are at rest. Lets now assume that two particles (both having five protons and four neutrons each) are approaching towards both the rest nuclei, separately, with *Sommerfeld* coefficients $\eta_A = 3\eta_B$. Compare the velocities of the two approaching particles. 2+(3+3)+2=10

5. Write a short note about any two of the following :

a) Breathing Mode

b) Compound nucleus formation

c) Deformed single particle shell model 5+5=10

Group – B

6. a) Why is the non-central nature of two-nucleon force come into account? Obtain an expression for the scattering amplitude f(θ) for the pp-scattering in the presence of a central nuclear potential and a Coulomb potential.

b) For pure Coulombic potential, obtain Mott Scattering formula. Show that at the scattering angle $\theta = 90^{\circ}$ in CM-frame and low proton energy, Mott formula gives a cross-section which is half of that be obtained if the effect of quantum mechanical indistinguishibility is not taken into account. (1+4)+(3+2)=10

7. a) Find the allowed isospin-triplet states of a pp-system. Obtain an expression of nuclear scattering amplitude $f_N(\theta)$ in presence Coulomb potential for a pp-scattering process.

b) Give a graphical variation of relative contribution of attenuation of the different process of γ-ray absorption with incident energy for a given absorber and just mention their dependence on impact parameter. What is the Dirac's explanation of pair production? (2+4)+(2+2)=10