DHWU

M.Sc. (2nd Year) 4th Semester Examination, 2019

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 scripts for each group**)*

Group-A

Question 1 is compulsory and answer any two from the remaining three questions

1. a) It is possible to use transistor as a switch ? Explain.
   b) Show that the excess hole or electron concentration dies out exponentially with distance due to recombination and the diffusion. 2+2=4
2. a) What is photoconductivity ? How conductivity of a semiconductor changes due to the absorption of photon ?
   b) What is a thin film ? Write down different techniques for producing it ?
   c) Show that for a p-type semiconductor the average life time of an electron in the conduction band is equal to the time constant. (1+2)+(1+2)+2=8
3. a) Establish a differential equation of carriers in semiconductor due to diffusion, drift and recombination processes.
   b) What is Schottky diode ? Can we use a Schottky diode as contact ?
   c) Distinguish between p-n junction diode and Schottky diode. 4+(1+1)+2=8
4. a) Find the relation between collector current and the width of base region (w) in case of a BJT in CB configuration.
   b) A transister in CE mode, draws constant base current I_B =30 μA. The collector current I_C is found to change 3.5 mA to 3.7 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}=12.5V. What is the value of α. 4+(1+3)=8

Group-B

Question 6 is compulsory and answer any two from the remaining three questions

5. a) What is BRAITT diode ?
   b) Why negative resistance occur in a Gunn diode ? 2+2=4

P.T.O.

6. a) Explain three major loss mechanism of a LED. To what kind of precautions are taken to overcome these losses.

   b) A GaAs LED radiates at 900 nm. If the forward current in the LED is 20 mA. Calculate the power output, assuming an internal quantum efficiency of 2%. (3+1)+4=8

7. a) What do you mean by a tunnel diode ? Draw an ideal *I-V* characteristics of tunnel diode and explain its characteristics.

   b) What is an IMPATT diode. Discuss the origui of it's negative resistance. (1+3)+(3+1)=8

8. a) A step index fiber has a core index of reflection 1.425., the cutoff angle for light entering the fiber from are is found to be 8.50^0.

      i) What is the numerical aperture ?

      ii) What is the refractive index of cladding ?

      iii) If the fiber is immersed into water what will be the value of new numerical aperture?

   b) An n-channel Si JFET has a donor concentration of 10^{21} m^{-3} and a channel width of about 4μm. If the dielectric constant of Si is 11.8 estimate the pinch off voltage. Use this value to calculate the saturation drain current for V_{GS}= –2 V and I_{DSS} =12mA. The symbols have utter usual meaning. 4+4=8

DHWU

M.Sc. (2nd Year) 4th Semester Examination, 2019

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

Group-A

(Answer Question No. 1 and any two from the rest)

1. a) Discuss the basic features of Korringa-Khon-Rostoker method for a calculate the band structure of a crystalline solid.

   b) In a monovalent metal show that the interaction energy of electron with ions is $-3e^2/2r$ (where r is the radius of an ion) 2+2=4

2. a) Calculate the density of states of a gas of fermions by Hartree-Fock method. Compare it with that obtained by Sommerfeld and Hartree method. Explain with diagrams.

   b) Show that the average energy per electron obtained by Hartree Fock method is.

   $$-\frac{3e^2}{4}\left(\frac{9}{4\pi^2}\right)\frac{1}{r_s}$$ (3+2+1)+2=8

3. a) What are the Brillouin zones ? How are they related to the energy of an electron in a metal ?

   b) What are the limitations of the tight-binding model ? What is the basic idea of using the orthogonalized plane wave method in calculating energy eigen values ?

   c) Using the Krong 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 potential, (a+b) is the periodictiy of the crystal. (1+2)+(2+1)+2=8

4. a) In neutron scattering on which factors does the scattering amplitude depend ? Calculate the atomic scattering factro Ø and hence atomic structure factor. 1+4+3=8

Group-B

(Answer Question no. 5 and any two from the rest)

5. a) The penetration depth for mercury at 3.5K is about 750Å. Estimate the penetration depth at OK. Also calculate the superconducting electron density.

   (Given Molecular weight of mercury 200.6 and density $13.55 \times 10^3 kg/m^3$.)

P.T.O.

b) Explain how the dielectric constant of a ferroelectric crystal varies with temperature ?

2+2=4

6. a) What is meant by a local field in a dielectric ? Find the expression for local field for cubic structure of a crystal. Hence obtain the Clausius-Mossotti relation expressing the relationship between dielectric constant and atomic polarizability.

b) The electronic polarisability of Ar atom is 1.7×10^{-40} F/m^2. What is the static dielectric constant of solid Ar if its density is 1.8gm/cm^3?

(1+3+2)+2=8

7. a) Explain AC Josephon effect. Show that the supercurrent of superconducing pairs across the junction oscillates will frequency $\omega = \left(\frac{2eV}{\hbar}\right)$.

b) Consider a CsCl crystal which has the CsCl nit cell crystal structure (One Cs^+-Cl^- pair per unit cell) with a lattice parameter 'a' of 0.412 nm. The electronic polarizability of Cs+ and Cl- ions are 3.35×10^{-40} F/m^2 and 3.40×10^{-40} F/m^2 respectively and the mean ionic polarizability per ion pair is 6.00×10^{-40} F/m^2. Find the electric constant.

(1+4)+3=8

8. a) Derive the Ginzberg-Landau equation for the suerconducting phase transition. Hence obtain the value of the order parameter deep inside the superconductor.

b) Give a schematic sketch of the variation of total polarizability of a crystal as a function of frequency, explaining the physical origin of the various contribution and the relevant frequency ranges.

(3+2)+3=8

DHWU

M.Sc. (2nd Year) 4th Semester Examination, 2019

Subject : Physics

Paper : Phy/Th/4S/402

(High Energy Physics-Elective)

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

The figures in the margin indicate full marks

(Use separate Answer Script for each Group)

Group-A

(Answer Questions No. 1 and any two from the rest)

1. a) The decay mode $\omega \to \pi^0 + \gamma$ is allowed but $\omega \to \pi^0 + 2\gamma$ is forbidden. Explain. 2

   b) Assuming isospin inariance show that

   $$\sigma_a(p + p \to d + \pi^+) : \sigma_b(p + n \to d + \pi^0) = 2 : 1$$

   where, d stands for deuteron and others have their usual meaning. 2

2. a) Express the dimension of universal gravitational constant G in natural unit system.

   b) Draw the Feynman diagram for Compton scattering and find an expression for its amplitude.

   c) Using Young tableaux method for SU (3) group, show that $3 \otimes \bar{3} = 8 \oplus 1$. 2+4+2=8

3. a) Prove that the eigen value of a charge conjugation operator for a fermin-antifermion bound state is $(-1)^{\ell+S}$. Symbols have their usual meaning.

   b) At t=0, a pure beam of υ_e starts its journey from a source and after travelling a distance L in time t transforms into υ_μ. Assuming mass eigen states of the neutrions to be υ_1 and υ_2 with masses m_1 and m_2 respectively, show that the probability of finding υ_μ at time t is :

   $$P_{\nu_e \to \nu_\mu}(\nu_e, 0;\ \nu_\mu, t) = sin^2 2\theta\ sin^2\left[\frac{\Delta m^2{}_{12}}{4E} \times L\right],$$

   where notations have their usual meaning. (Consider ultra-relativistic limit for neutrions). 3+5=8

4. a) Show that invariance of CPT summetry leads to equality of masses of particle and antiparticle.

   b) Consider the production of Higgs boson (m_h = 125 GeV) at the threshold at the Large Hadron Collider (LHC). What are the energy required for fixed-target experiment and for colliding-beam machine ?

P.T.O.

er a New physics model having gauge group $SU(2)_L \otimes SU(2)_R \otimes U(1)_Y$. How
auge bosons as mediating particuls does the model have ?

Group-B

(Answer Question no. 5 and any two from the rest)

5. he Dirac mass term like $m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ is not invariant under
$_L \otimes U(1)_Y$ gauge transformation in the SM? 2
ing m_{π^+} and 140 *MeV* and $m_{\mu^\pm}$ ~100 *MeV* estimate the energy of muon produced
ecay of π^+ at rest. 2

6. the spontaneous symmetry breaking considering a complex scalar field under
lobal gauge transformation. Check that the mass term comes out with correct
re and also find the mass of the corresponding field.

Higgs mechanism by promoting $U(1)$ global gauge symmetry to the local one
bove case. Why is this mechanism so important ? $(3+1)+(3+1)=8$

7. own the gauge group of the Standard Mode. Which gauge symmetry remains
en in the SM ? Prove it.
own the term which generates masses of the electroweak gauge bosons in the
gian of the Standard Model. Obtain expressions for masses of electroweak
osons in terms of gauge couplings and vacuum expectation value of the Higgs
$2+1+5=8$

8. the consequence of Bjorken scaling in determining the substructure of proton ?
cture functions for scattering of a quark flavor i are :

$$\frac{Q_i^2}{2m_i}\delta(x_i - 1) \quad \text{and} \quad W_2^i = -\frac{2m_i Q_i^2}{q^2}\delta(x_i - 1)$$

m_i is the mass of quark flavor i and $x_i = -\frac{q^2}{2q\cdot p_i}$

p and $m_i = z_i M$, where M is mass of the proton and p is the mome
nd p_i is the fraction of momentum of proton carried by quark flavor i, s

$$\frac{Q_i^2}{2M}\delta(x - z_i) \quad \text{and} \quad W_2^i = -\frac{2z_i^2 M Q_i^2}{q^2}\delta(x - z_i) \quad \text{, Where } x =$$

h the Callan-Gross relation : $F_2(x) = 2xF_1(x)$)assuming
$F_1(x)$ and $-\frac{q^2}{2Mx}W_2 \equiv F_2(x)$

ference can be drawn from the above relation ?

c) Consider a New physics model having gauge group $SU(2)_L \otimes SU(2)_R \otimes U(1)_Y$ How many gauge bosons as mediating particuls does the model have ? 2+4+2=8

Group-B

(Answer Question no. 5 and any two from the rest)

5. a) Why the Dirac mass term like $m(\bar{\psi}_L\psi_R + \bar{\psi}_R\psi_L)$ is not invariant under $SU(2)_L \otimes U(1)_Y$ gauge transformation in the SM? 2

b) Assuming $m_{\pi^\pm}$ and 140 MeV and $m_{\mu^\pm} \approx 100\,MeV$ estimate the energy of muon produced in the decay of π^+ at rest. 2

6. a) Discuss the spontaneous symmetry breaking considering a complex scalar field under $U(1)$ global gauge transformation. Check that the mass term comes out with correct signature and also find the mass of the corresponding field.

b) Discuss Higgs mechanism by promoting $U(1)$ global gauge symmetry to the local one in the above case. Why is this mechanism so important ? (3+1)+(3+1)=8

7. a) Write down the gauge group of the Standard Mode. Which gauge symmetry remains unbroken in the SM ? Prove it.

b) Write down the term which generates masses of the electroweak gauge bosons in the Lagrangian of the Standard Model. Obtain expressions for masses of electroweak gauge bosons in terms of gauge couplings and vacuum expectation value of the Higgs field. 2+1+5=8

8. a) What is the consequence of Bjorken scaling in determining the substructure of proton ?

b) The structure functions for scattering of a quark flavor i *are :*

$$W_1^i = \frac{Q_i^2}{2m_i}\delta(x_i - 1) \quad \text{and} \quad W_2^i = -\frac{2m_iQ_i^2}{q^2}\delta(x_i - 1)$$

where, m_i is the mass of quark flavor i and $x_i = -\frac{q^2}{2q\cdot p_i}$.

i) If $pi=Z_ip$ and $m_i = z_iM$, where M is mass of the proton and p is the momentum of proton and p_i is the fraction of momentum of proton carried by quark flavor i, show that

$$W_1^i = \frac{Q_i^2}{2M}\delta(x - z_i) \quad \text{and} \quad W_2^i = -\frac{2z_i^2 M\, Q_i^2}{q^2}\delta(x - z_i) \quad \text{, Where } x = \frac{q^2}{2qp}$$

ii) Establish the Callan - Gross relation : $F_2(x) = 2xF_1(x)$ assuming

$MW_1 \equiv F_1(x)$ and $-\frac{q^2}{2Mx}W_2 \equiv F_2(x)$

iii) What inference can be drawn from the above relation ? 2+(2+3+1)=8

DHWU

M.Sc. (2nd Year) 4th Semester Examination, 2019

Subject : Physics

Paper : Phy/Th/4S/403

(Nuclear Physics Elective Course)

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

The figures in the margin indicate full marks

(Use separate Answer Script for each Group)

Group-A

(Answer Questions No. 1 and any two from the rest)

1. a) Show that the electric dipole moment of a nucleus at its ground state vanishes.

   b) What do you mean by form factor ? Show that the form factor for a symmetric charge distributions is : $F(q^2)=1-(q^2<a^2>)/6$, where symbols have their usual meanings. 2x8=16

2. a) Approximate the potential energy of a deuteron nucleus by a spherical square well $V(r) = -V_0 \quad r < a$ and $V(r) = 0, r > a$. Calculate the value of V_0 in MeV given that m_p=938.2 MeV, m_n = 939.5 *MeV*, a =1.5 fm and the binding energy E_b = 2.226 *MeV* [Note that the solution of zcotz=−0.3471 is z=1.765] 4+4=8

   b) Discuss the possibility of the existence of excited states of deuteron.

3. a) Obtain an expression for the magnetic dipole moment μ_d of deuteron. Calculate $\mu_d(^3S_1)$ given that $\mu_p = 2.79281\mu_N$ and $\mu_n = -1.913148\mu_N$ where the symbols have their usual significance. Explain how the observed discrepancy with the experimental value of the magnetic dipole moment of deuteron is accounted for.

   b) Calculate the electric quadrupole moment of a uniform charge distribution assuming that the equation of the surface of the ellipsoid is

   $$R = R_0\,[1 + \beta Y_{20}(\theta, \phi)] \text{ where } Y_{20}(\theta, \phi) = \sqrt{\frac{5}{16\pi}}\,(3\cos^2\theta - 1).$$

   Express your result only up to the first-order in β 5+3=8

4. a) Calculate the nuclear form factor for the following exponential charge distribution.

   $$\rho(r) = \frac{b^3}{8\pi} e^{-br}$$

   b) Show that the total cross-section for n-p scattering of S-wave phase shifts is given by

   $$\sigma \cong \frac{4\pi\hbar^2}{2\mu} \frac{1}{T + |E_B|}$$

   where the symbols have their usual meanings. How does this value compare with the observed experimental results ? 3+5=8

P.T.O.

Group-B

Answer question No. 5 and any two from the rest

5. a) Calculate the range of a 10 *MeV* α Particle in aluminium, if the relative stopping power of aluminium is 1700.

   b) Using the uncertainty principle, estimate the kinetic energy of a nucleon where the radius of the nucleus is 5×10^{-13}cm. Given that $\hbar c = 197\ MeV\text{-}fm$, $h = 6.6 \times 10^{-34}\ J\text{-}s$, $m_n \simeq m_p \simeq 940\ MeV/c^2$ and $m_e = 0.5\ MeV/c^2$ 2+2=4

6. Show that a 3-D, isotropic harmonic oscillator model for the nucleus can only predict the first three magic numbers correctly. Thereafter, show that the total energy of the nucleus is proportional to $A^{-1/3}$, where A is the total number of nucleons present in the nucleus. 4+4=8

7. a) The Slater determinant for a two nucleon system is given by.

$$\psi_{SD} = \frac{1}{\sqrt{2}} \begin{vmatrix} \chi_1(1) & \chi_1(2) \\ \chi_2(1) & \chi_2(2) \end{vmatrix},$$

   Where χ_1 and χ_2 correspond to the spin orbitals. If we interchange the coordinates of those two nucleons then the resulting Slater determinant takes the form :

$$\psi_{SD(interchanged)} = \frac{1}{\sqrt{2}} \begin{vmatrix} \chi_1(2) & \chi_1(1) \\ \chi_2(2) & \chi_2(1) \end{vmatrix}.$$

   What can you infer about the spins of the nuclons ? Give proper justifications for your answer.

   b) If the coupling between the intrinsic spin $(\vec{s})$ of a nucleon to its orbital angular momentum $(\vec{l})$ is incorporated into the Hamiltonian for a 3-D, isotropic harmonic oscillator model for the nucleus with the coupling strength 'x' then evaluate the energy eigenvalues for $l = 0$ and 1.

   c) What is Cerenkov radiation ? Explain briefly. 2.5+3+2.5=8

8. a) The semi empirical single prticle Hamiltonian for a nucleus can be assumed as

$$h(r) = h_0 + h_\delta + a\vec{l} \cdot \vec{s} + bl^2,$$

   where h_0 is the unperturbed Hamiltonian for a 3 – D isotropic harmonic oscillator,

   $h_\delta = -\left(\frac{1}{3}\right) \delta_{osc} \mu \omega_0^2 r^2 \sqrt{\frac{16\pi}{5}} Y_{20}(\theta, \varphi)$, is the deformation potential originating to the due quadrupole field with δ_{osc} is being the deformation parameter. The coefficients a, and b are the strengths of the $\vec{l}.\vec{s}$ and $\vec{l}\,\vec{l}$ couplings respectively. Now

introducing the Nilsson states configuration with the assumption of having the body fixed symmetry axis along z, compute the angular frequencies along the three axes and show that the total energy of the nucleus remains conserved under the assumption of

$$\omega_3^2 = \omega_0^2\left(1 - \frac{4}{3}\delta_{osc}\right), \text{ and}$$

$$\omega_\perp^2 = \omega_0^2\left(1 + \frac{2}{3}\delta_{osc}\right).$$

Here ω_0 is the normal mode frequency of the 3 – D harmonic oscillator and the rest of the symbols carry their usual meanings.

b) What do you mean by direct and compound nuclear reaction ? Briefly discuss with appropriate example. 5+3=8