DHWU

M.Sc. (2^{nd} Year) 3^{rd} SEMESTER EXAMINATION 2019

Subject : Physics

Paper: Phy/Th/3S/301

Condensed Matter Physics

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

The figures in the margin indicate full marks
*(**Use separate answer scripts for each group**)*

Group-A

*Answer question **No.1** which is compulsory and **any two** from the rest.*

1. (i) Draw the stereographic projection $\bar{3}$. 2

(ii) Find the equivalent points of C_{2_1}. 2

2. (a) Show that 5-fold symmetry does not exist in Nature. 3

(b) While sitting in front of a colour T V with 25kV picture potential you have an excellent chance of being irradiated with X-rays.

(i) What process produces most of the X-ray flux? 1

(ii) For the resulting continuous distribution calculate the shortest wavelength (maximum energy) X-ray where $\hbar = 6.6 \times 10^{-34} Js$, $c = 3 \times 10^8 m/s$ and $1eV = 1.6 \times 10^{-19} J$. 2

(iii) For rock salt (NaCl) crystal placed in front of the tube calculate the Bragg's angle for the first order reflection maxima at $\lambda = 0.5\mathring{A}$, $\rho_{NaCl} = 2.165\ g/cm^3$ and $M = 58.45\ g/mol$. 2

3. (a) A one dimensional diatomic chain of masses m_1 and m_2 are formed by placing them alternately. A spring of spring constant k couples a mass to its nearest neighbours on either side.

(i) Write the equations of motion obeyed by the masses. 1

(ii) Obtain the dispersion relation. 2

(iii) Show schematically the appearance of the optical and acoustic branches of the normal mode vibration. 1

(b) Compute the cut-off frequency for a linear monoatomic lattice if the velocity of sound and the interatomic spacing in the lattice are $3 \times 10^3\ m/s$ and $3 \times 10^{-10}\ m$ respectively. 4

4.(a) Define Fermi sphere. 2

(b)The atomic radius of Sodium is $1.86\mathring{A}$. Calculate the Fermi energy at $K = 0$. 4

(c) Are Bloch functions eigenfunctions of the momentum operator? Explain. 2

Group-B

Answer question ***No. 5*** *which is compulsory and* ***any two*** *from the rest.*

5. (i) Calculate the diamagnetic susceptibility of an atomic hydrogen in the ground state at S.T.P using the wave function 2

$$\psi(r) = \frac{1}{\sqrt{\pi a_0^3}} \exp\left(-\frac{r}{a_0}\right) \quad \text{where } a_0(= 0.46\mathring{A}) \text{ is the atomic radius.}$$

(ii) The penetration depth of mercury at $3.5K$ is about $750\mathring{A}$. Estimate the penetration depth at $0K$. Also calculate the superconducting electron density. (Given molecular weight of Hg is 200.6 and density $13.55 \times 10^3\ kg/m^3$). 2

6. (a) Show that the paramagnetic susceptibility of conduction electrons (metals) is independent of temperature and can be expressed as $\chi_p = \frac{3n\mu_0\mu_B^2}{2k_BT_F}$, where the terms have their usual meanings. 4

(b) What is adiabatic demagnetization? Explain how low temperatures can be attained by the process of adiabatic demagnetization? (1+3)

7. (a)A type-II semiconducting material with superconducting transition temperature T_C is placed in a magnetic field. What is the material state (normal or superconducting or mixed) for
i) $T < T_C,\ H > H_{C2}$
ii) $T > T_C,\ H < H_{C1}$
iii)$T < T_C,\ H_{C1} < H < H_{C2}$
iv) $T < T_C,\ H < H_{C1}$
v) $T > T_C,\ H > H_{C2}$
where H_{C1} and H_{C2} are the lower and upper critical fields for a type-II superconductor. 2.5

(b) Define Néel temperature of an antiferromagnetic material. Explain the variation of susceptibility with temperature for an antiferromagnetic material. (1+2)

(c) What is a Cooper pair? How are Cooper pairs formed in superconductors? (0.5+2)

8.(a) What is Paramagnetic relaxation? 1

(b) Derive the Bloch equation for a paramagnetic system placed in an oscillating magnetic field. Hence obtained the total power absorbed by the magnetic system from the oscillating magnetic field. (2+5)

DHWU
M. Sc (2^{nd} Year) 3^{rd} Semester Examination, 2019
Subject: Physics
(Phy/Th/3S/302)
Nuclear & Particle Physics

Time: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.

(Use Separate answer scripts for each group)

Group-A

*Answer **question no. 1** which is compulsory and **any two** from the rest.*

1. a) What do you mean by Packing fraction of a nucleus? 2

   b) Write down the expression for binding energy following the semi empirical mass formula. Mention the origin of each individual component. 2

2. a) Establish the relation $A \cong 2Z$ for light nuclei using semi empirical mass formula. Given $a_c = 0.71\ MeV$, $a_n = 22.7\ MeV$, $M(^1_1H) = 1.0078\ amu$, $M_n = 1.0086\ amu$ respectively. Where symbols have their usual meaning. 4

   b) Assuming the nuclear radius to be given by $R = r_0 A^{\frac{1}{3}}$ with $r_0 = 1.2 \times 10^{-15} m$. Show that the neutron and proton densities in a nucleus with $N = Z$ are 0.069 nucleons/fm^3 for each. 4

3. a) Show that the ground state of deuteron is admixture of l=0 and l=2 state. 4

   b) Show that the Q value in β decay process, differs by the factor $2m_e$ when compare with β^+ decay and β^- (where m_e= electron rest mass energy). 4

4. a) What is nuclear magneton? Find out its relationship with Bohr magneton. 1+2

   b) Argue why electrons can not exist inside a nucleus? 2

   c) From mass parabola find the condition for most stable nuclei of a given isobar. 3

Group-B

*Answer **question no. 5** which is compulsory and **any two** from the rest.*

5. a) A deformed nucleus $(150 < A < 190)$has the first excited state at 90 KeV with parity 2^+. What is the expected energy, spin and parity for the next excited state? 2

   c) Given that ρ^0 has a decay width of $158\frac{MeV}{c^2}$. How would you classify the interaction from its decay? 2

6. a) A neutron star consists of only neutrons. Account for the stability of the neutron star. Hence, find the minimum number of neutrons expected in a neutron star based on properly modified semi empirical mass formula. Values of parameters of semi empirical mass formula are, $a_V = 15.6MeV; a_s = 16.7\ MeV;\ \ a_c = 0.72\ MeV$ and $a_{asym} = 23.5\ MeV$. Symbols carry their usual meaning. 4

   b) Consider the nuclear reaction ${}^{16}_{8}O + d \rightarrow p + {}^{17}_{8}O^*$. Estimate the energy level of ${}^{17}_{8}O^*$ corresponding to the protons with kinetic energy 8.58 MeV obtained in the detector placed at an angle 25^0 with respect to the direction of the incident beam. Comment on your result. (Given the kinetic energy of incident deuteron is 10 MeV and Q-value of the reaction is 1.96 MeV. Consider mass numbers of the given nuclei to be the approximate masses of the corresponding nuclei.) 4

7. a) A nucleus ${}^{A}_{Z}X$ in its ground state is subjected to an external magnetic field applied along z-direction. Obtain an expression for the magnetic moment of an odd A nucleus corresponding to $j = = l + \frac{1}{2}$ state, where j denotes total angular momentum and l denotes orbital angular momentum quantum number. 3

   b) What are the appropriate isospin assignments,(I, I_3) for the antiquarks $\bar{u}$, $\bar{d}$ and $\bar{s}$? Check that your assignments are consistent with Gell-Mann-Nishijima formula. How would this formula be modified if charm quark is taken into account? 4+1

8. a) Find the dimension of universal gravitational constant in natural system of units. 2

   b) Draw the Feynman diagram of $n \rightarrow p + e^- + \bar{\nu}_e$. Comment on the type of interaction. 3

   c) Why was color quantum number introduc[illegible] particle physics? Can a bound state of four quarks (no antiquark!) exist in nature? Explain. 2+1

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M.Sc. (2^{nd} Year) 3^{rd} SEMESTER EXAMINATION 2019

Subject : Physics

Paper: Phy/Th/3S/303

Atomic and Molecular Physics

Time : 2 Hours

Full Marks : 40

The figures in the margin indicate full marks

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

Group-A

Answer question ***No.*** *1 which is compulsory and* ***any two*** *from the rest.*

1. (i) Explain the principle of a two level MASER. 2

(ii) The ground state of hydrogen atom is 1*s*. When examined very closely it is found that the level splits into two levels. Explain why this splitting takes place. 2

2. (a) Explain how the phenomenon of electron spin resonance (ESR) occurs in a material. What are the conditions necessary for ESR? Name two such materials.

(b) How is population inversion obtained in a two level LASER system? (2+1)+5=8

3. (a) Explain how population inversion can be achieved for a two level system.

(b) (i) What is the origin of spectral line when one-electron atom interact with electromagnetic radiation?

(ii) Calculate the transition probability amplitude of the system and hence define the emission and absorption. 3+(1+4)=8

4. (a) What is Stark effect? Show that the ground state energy is not perturbed by the application of an electric field (up to first order).

(b) Show that the second-order correction is proportional to the square of the electric field.

(c) An atom in the state $3P_2$ is placed in a weak and strong magnetic field. How many sub-states will be splitted for both cases? Show the splitting in a diagram. 1+2+(3+2)=8

Group-B

Answer question **No. 5** *which is compulsory and* **any two** *from the rest.*

5. (i) Why do homonuclear molecules, even though they do not show rotational spectra, exhibit electronic spectra? 2

(ii) An atom is in the state whose multiplicity is 3 and the total mechanical moment is $(6\hbar^2)^{1/2}$. Obtain the ground state of the atom. 2

6. (a) Obtain the $L-S$ coupled ground state of the C-atom.

(b) Discuss the He_2^+ system using LCAO method - obtain energy eigenvalues for the bonding and anti-bonding cases. 4+4=8

7. (a) For an anharmonic oscillator of appropriate potential (Morse Potential) find an expression for the vibrational wave number.

(b) For a diatomic vibrating-rotator obtain the general expression for the wave number of P and R branches. Why is some asymmetry found with experimental spectra? 3 +(4+1)=8

8. (a) Among the following diffuse series of alkali atom which one is the strongest in intensity?

$$^2F_{5/2} \longleftarrow {}^2D_{5/2}\ (I_1),\ {}^2F_{7/2} \longleftarrow {}^2D_{5/2}\ (I_2),\ \text{and}\ {}^2F_{5/2} \longleftarrow {}^2D_{3/2}\ (I_3).$$

(b) Show that the 1^{st} and 2^{nd} overtone bands of a vibrating diatomic molecule have frequency approximately 2 and 3 times that of the fundamental band. State Frank-Condon principle. 3 +(4+1)=8

DHWU

M.Sc. (2^{nd} Year) 3^{rd} SEMESTER EXAMINATION 2019

Subject : Physics

Paper:Phy/ThE/3S/304

Astrophysics

Time : 2 Hours

Full Marks : 40

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

Group-A

Answer Question ***No.1*** *which is compulsory and* ***any two*** *from the rest.*

1. (i) At Diamond Harbour (latitude $22^0 22'$ N), a star is observed to cross the meridian at $44^0 4'$ H (south) of Zenith. Find its declination. 2

(ii) Compare the free fall times for a Neutron star and the Sun with densities $10^{15}\ gm\ cm^{-3}$ and $1.4 \times 10^3\ kg\ m^{-3}$ respectively. 2

2. (a) Establish the virial theorem for an astrophysical system with N particles under the influence of mutual gravitational force and an external mechanical force.

(b) What are the Solar Neutrinos? Why is there a huge discrepancy between the number of neutrinos observed experimentally and predicted theoretically?

(c) What are circumpolar stars? 5+(1+1)+1=8

3. (a) What is a *Celestial sphere*? Draw a neat diagram of a celestial sphere and label the following: *Zenith, Nadir, Celestial Poles, Prime meridian and Equator*

(b) Write a short note on any one of the following: (i) The formation of Stars, (ii) Neutron Stars. (2+2)+4=8

4. (a) Derive the *Lane-Emden* equation for a system with polytropic index n. What can you infer about the system characteristics for $n = 0$?

(b) What is the basic criterion to have a collapsing star with respect to its mass? Is there any critical limit regarding the stability criterion of the said star? (5+1)+(1+1)=8

Group-B

Answer Question **No. 5** *which is compulsory and* **any two** *from the rest.*

5. (i) Find the metric tensor in 3-D *Euclidean* space for the coordinates: $3x = u+2v, 3y = u-v$ and $z = w$. 2

(ii) Let us assume that there are two containers of plasma and each of them is filled with the same number of electrons with electron equilibrium temperatures $900K$ and $1024K$ respectively. Compare the screening lengths of the plasmas placed inside the two containers? 2

6. (a) What is deacceleration parameter $[q(t)]$ in cosmology? Assuming an equation of state $P_i = w_i \rho_i c^2$ for the different constituents of the universe, express the deacceleration parameter $q(t)$ in terms of w_i and the cosmological parameter Ω_{i0}, where the energy density ρ_i for different constituents is expressed as $\rho_i = \rho_{i0} a^{-3(1+w_i)}$. The notations carry their usual meanings.

(b) What are *Cepheid* variables? Discuss about the applications of those variables in cosmology? 6+(1+1)=8

7. (a) What do you mean by "*gravitational time dilation*"? Show that the clock of any observer 'A' at earth runs slower than the clock of another observer 'B' placed at an orbit of height h from the earth.

(b) What is a *black hole*? What would be the dynamics of an observer if he/she is - (i) outside the event horizon and (ii) inside the event horizon?

(c) What is *magnetic viscosity*? (1+3)+(1+1)+2=8

8. (a) What do you mean by '*plasma*'? Can any ionized gas be termed as '*plasma*'?

(b) Derive an expression for the electron plasma frequency (ω_p). (1+1)+6=8