Diamond Harbour Women's University

M. Sc 2nd Year 3rd Semester Examination 2021

Subject: Physics

Paper: PHY/Th/3S/301

(Condensed Matter Physics)

Time: 2 Hours Full Marks: 40

(The figures in the margin indicate full marks.)

Candidates are required to write their answers in their own words as far as practicable.

Group-A

Answer any two questions from this group

1. a) What is Euler construction? Find the angle (A) between a 2 fold and a 3 fold symmetry axis.

b) State and explain Braggs law of diffraction.

c) NaCl crystallizes in an face-centered cubic lattice with a basis of Na and Cl ions separated by half the body diagonal of the cube. The atomic numbers of Na and Cl are 11 and 17 respectively.

i) Determine which x-ray reflections will be observed (indexed for the conventional cubic unit cell).

ii) Of these which group will be strong and which group will be weak?

d) Explain space group symmetry. Draw a stereographic projection of P_{2_1} and find out its equivalent points. 2+2+ (2+2)+2=10

2. a) In Aluminium $v_l = 6.32 * 10^3 m/s$ and $v_t = 3.1 * 10^3 m/s$. The density of Aluminium is $2.7*10^3$ kg/m^3 and its atomic weight is 26.97.

i) Calculate the Debye temperature.

ii) The Debye temperature for Al, obtained from specific heat measurement, is found to be 375K, find the Debye frequency.

b) State Dulong and Petit's law. Discuss the Debye model of heat capacity. What is Debye T^3 law? 2.5+2.5+(1+3+1)=10

3. a) Define Fermi sphere.

b) The atomic radius of Sodium is 1.86 Å Calculate the Fermi energy at 0 Kelvin.

c) Explain Bloch's theorem?

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d) What is meant by effective mass? Show that the effective mass of a free electron is identical to its original mass. 1+4+2+(2+1)=10

Group-B

Answer any two questions from this group

4. (a) What is Schottky defect? How does it differ from Frenkel defect?
(b) The concentration of Schottky defects in an fcc crystal is 1 in 10^{10} at a temperature of 300K. Estimate the average separation between the defects in terms of the lattice spacing at 300K and calculate the expected concentration of Schottky defects at 1000K.
(c) Show that Pauli spin paramagnetism of a free electron metal is given by

$$\chi_p = \frac{3n\mu_0\mu_B^2}{2k_BT_F},$$

where the symbols have their usual meanings. 2+4+4=10

5. (a) Consider a typical magnetic field of 10^4 Gauss and compare the magnetic potential energy of an electron spin dipole moment with k_BT at room temperature. Comment on this result.

(b) For a paramagnetic gas of N atoms/cc and with L=0, S= 1/ 2, by calculating the number of atoms in the two levels at temperature T and in a magnetic field of strength H, prove that the resultant magnetization is,

$M = \frac{1}{2}Ng\mu_B \tanh\left(\frac{g\mu_B H}{2k_BT}\right)$. Here all the symbols have their usual meanings.

(c) Estimate the order of diamagnetic susceptibility of copper by assuming that only one electron per atom makes the contribution given that the radius of a copper atom is 1 A^0 and the lattice parameter is 3.608 A^0. 2+5+3=10

6.(a) How do specific heat and thermal conductivity vary with temperature for a superconductor?

(b) Discuss the two component model of a superconductor. Deduce the London equations and hence explain the Meissner effect.

(c) The penetration depth of mercury at 3.5K is about 750A^0. Estimate the penetration depth at 0K. Also calculate the superconducting electron density. (Given molecular weight of Hg is 200.6 and density 13.55 x 10^3 kg/m^3) 2+ (1.5+3+1.5)+2=10

Sujit Das

Diamond Harbour Women's University

M. Sc.(2nd Year)3rdSemester Examination 2021

Subject: Physics

Paper: PHY/Th/3S/302

(Nuclear and Particle Physics)

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

(The figures in the margin indicate full marks.)

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

Candidates are required to write their answers in their own words as far as practicable.

Group-A

Answer any <u>two</u> questions

1. a) a). Establish the relation $A \cong 2Z$ for light nuclei using the semiempirical 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. Here symbols have their usual meaning..

b) To study the nuclear size, shape and density distribution one employs electrons, protons and neutrons as probes.

(i) What are the criteria for selecting the probe? Explain.

(ii) Compare the advantages and disadvantages of the probes mentioned above.

iii) What is your opinion about using photons for this purpose?

c) To penetrate the Coulomb barrier of a light nucleus, a proton must have a minimum energy of the order of (i) 1 GeV, (ii) 1 MeV, (iii) 1 KeV?

d) The greatest binding energy per nucleon occurs near 56Fe and is much less for 238U. Explain this in terms of the semiempirical nuclear binding theory. State the semiempirical binding energy formula (you need not specify the values of the various coefficients).

2+(1+1+1)+2+3= 10

2. a) In Gamow's Theory of Alpha Decay show that the half-life ($t_{\frac{1}{2}}$) and alpha disintegration energy (Q) are inversely related.

b). Explain why at low energy (1 MeV) no excited states exist in the case of n-p scattering.

c). What is the difference between allowed Gamow-Teller transition and allowed Fermi Transition?

d) Describe the attenuation coefficient in γ decay process. **4+2+2+2=10**

3. a) Obtain an estimate of the potential depth of the nuclear force by considering a nucleus in a central force field.

b) Show that the ground state of deuteron is an admixture of l=0 and l=2 states.

c) Are there any excited states for a deuteron nucleus? Explain your answer.

4+4+2=10

Sig Pen

Group-B

Answer any <u>two</u> questions

4. a) A neutron star consists of only neutrons. The gravitational potential energy $-\frac{3}{5}\frac{Gm^2}{r}$ plays a major role in giving the star stability by making the binding energy positive. Find the minimum number of neutrons expected in a neutron star based on a suitably modified semi empirical mass formula.

b) Assume a single particle central potential to describe the shell structure of nuclei. An addition of a term $V_{SO}\vec{L}\cdot\vec{S}$ gives the correct shell closing. Suppose $V_{SO} = -1.0\ MeV/h^2$. Find the change in the energy of $1f$ state as the state becomes (i) $1f_{7/2}$ (ii)$1f_{5/2}$.

c) What are the spin-parity values of the vibrational state of an even-even nucleus corresponding to one octupole phonon excitation? **5+3+2=10**

5.a) The ground state rotational band of ^{238}Pu is as follows; $0^+:0,\ 2^+:44.11\ KeV,$ $4^+:146\ KeV,\ 6^+:303.7\ KeV,\ 8^+:514\ KeV$. Calculate the moment of inertia of the nucleus from this data. What is the moment of inertia of this nucleus if it is assumed to be a rigid sphere? Find the ratio of these two values.

b) The weak force is thought to originate from the exchange of particles of mass 80 GeV. Calculate the range of the interaction?

c) State whether the following interactions are allowed or forbidden. If allowed, state the nature of the interaction involved.

i) $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$

ii) $K^- + p \rightarrow \Xi^- + K^+$

4+2+4=10

3.a) Deuterons of energy 1.51 MeV are used to produce the reaction $^{16}O(d,\alpha)^{14}N$. The α particles emitted at 90° are found to have an energy of 3.427 MeV. Calculate the Q-value of the reaction and check the same from the masses of the nuclei. [Given: $M(^4He) = 4.002603\ u, M(^2H) = 2.014102\ u, M(^{16}O) = 15.994915\ u, M(^{14}N) = 14.0067\ u$ and $1u = 931.5\ MeV$].

b) Suppose a hypothetical particle X is discovered with strangeness, $S = -2$ and charge 0. Is it a baryon or a meson? Explain. Write down the quark content of the particle. What is the value of I_3 (3rd component of isospin) for the particle X? Identify the particle.

c) An experiment in a gold mine in South Dakota has been carried out to detect solar neutrinos having $E_\nu > 0.82\ MeV$ using the reaction $\nu + Cl^{37} \rightarrow Ar^{37} + e^-$. How can the sensitivity of detection of neutrinos be improved in this experiment? **5+4+1=10**

DHWU
M.Sc. (2nd Year) 3rd Semester Examination, 2021
Subject: Physics
Paper: PHY/Th/3S/303
(Atomic and Molecular Physics)

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

*(Use **separate** answer script for each group)*
Candidates are required to write their answers in their own words as far as practicable.

Group-A
Answer any <u>two</u> questions

1.(a) In the presence of a weak magnetic field atomic hydrogen undergoes the transition, $^2P_{1/2} \rightarrow {}^1S_{1/2}$, by emission of radiation. Draw the distinct spectral lines that are observed in the resultant Zeeman spectra.

(b) Check whether the following transitions are possible or not:

(i) $2f_{5/2} \rightarrow 2d_{5/2}$ (ii) $2d_{3/2} \rightarrow 2p_{1/2}$

(iii) $2d_{3/2} \rightarrow 2s_{1/2}$ (iv) $2p_{1/2} \rightarrow 2s_{1/2}$.

(c) What is meant by Doppler broadening of spectral lines? Show that the probability for transition at frequency ω is Gaussian.

(d) Obtain the ratio of rates of spontaneous and stimulated emission of a two level system at room temperature. 2+2+ (1+3)+2=10

2.(a) Distinguish between spontaneous emission and stimulated emission.

(b) Explain what is meant by atomic absorption co-efficient? Why is it called atomic cross section?

(c) Mention some characteristics of a laser beam. 3+ (2+2)+3=10

3.(a) Draw and briefly discuss the origin of the energy level shift for n=1 and n=2 levels of H atom according to Bohr model, fine structure, Lamb shift and hyperfine structure. State the principle of detailed balancing. 4+1=5

(b) What is Raman effect? State the selection rules for Raman scattering. Write down the energy expression for every vibrational mode of Raman spectra and explain each parameter in it and also state the selection rule. (1+1)+ (1+1+1) =5

PTO

Group-B

Answer any <u>two</u> questions

4.(a) For an anharmonic oscillator of appropriate potential (Morse potential) find an expression for the vibrational wave number. Show that the 1st overtone band of a vibrating diatomic molecule has a frequency approximately 2 times that of the fundamental band.

(b) Obtain the L-S coupled ground state of the C-atom. Why do homonuclear molecules not show any rotational spectra?

(2+2)+ (5+1)=10

5.(a) Write down the ground and the first excited state level ($^{2S+1}L_J$) of the Ne^{10} atom. Explain why removal of an electron from an O_2 molecule increases the dissociation energy?

(b) For H_2^+ system, use the LCAO method, to obtain the energy eigenvalues for bonding and anti-bonding cases. Write down in order of increasing energy: $^1D_2$, $^3F_{3/2}$, $^3D_2$, $^3F_2$.

(2+2)+ (5+1)=10

6.(a) Write down the electronic configuration and the ground state of F_2 molecule. What is the importance of the exchange term in the energy expression of Hartee-Fock theory?

(b) For a diatomic vibrating-rotator, obtain the general expression of the wave number of P and R branches. What asymmetry is found with the experimental spectra?

(2+2)+ (5+1)=10
