2017

PHYSICS — HONOURS

Sixth Paper

Full Marks – 100

The figures in the margin indicate full marks

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

Answer ***Question No. 1*** and ***four*** each from **Unit–11** and **Unit–12**

1. Answer ***any ten*** of the following : 2×10

(a) A hadron has a quark content ddu. Find the charge and strangeness of this hadron.

(b) What is velocity selector in a mass spectrometer ? Explain with sketch.

(c) What are nuclear isomers ?

(d) The average nuclear binding energy in the range $30<A<170$ is almost constant. Explain why this is so.

(e) What is Kurie plot ?

(f) The maximum energy encountered in β- particle emission from radioactive nuclides is about 4 MeV. What is the shortest length of the waves associated with β particles ?

(g) Sketch the specific heat of a superconductor and normal metal as a function of temperature. (Indicate the critical transition temperature in the graph.)

(h) Find the Miller indices for planes with the following sets of intercepts :

(i) $(6\vec{a}, 2\vec{b}, 3\vec{c})$

(ii) $(\vec{a}, 2\vec{b}, \infty)$

where $\vec{a}, \vec{b}, \vec{c}$ are lattice vectors.

(i) How does a measurement of the potential difference between two points of contact in a metallic sheet in presence of a known magnetic field determines the sign of the charge carriers and their concentration ?

(j) The Fermi energy (E_F) of silver is 5.5 eV. Calculate the fraction of free electrons at room temperature ($\approx$300 K) located within a width of K_BT on either side of E_F.

(k) The relative permittivity of argon at $0^{\circ}C$ and one atmospheric pressure is 1.000435. Calculate the electronic polarizability of the argon atom.

(l) Starting from the dispersion relation $\omega=\omega_m \sin\left(\frac{Ka}{2}\right)$ for linear monatomic chain of length L (= N.a, N is the no. of atoms), obtain and sketch the density of states as a function of ω.

Unit – 11

(Nuclear and Particle Physics)

2. (a) Show that an electron confined to a box of nuclear dimension must have an energy more than 20 MeV. What will be the order of magnitude of the minimum energy for protons in the above situation ? 2+1

(b) A flux of 10^{12} neutrons/m^2 emerges each second from a port in a nuclear reactor. If these neutrons have a Maxwell-Boltzmann energy distribution corresponding to T = 300 K;

(i) calculate the average velocity of a neutron. 3

(ii) calculate the density of neutrons in the beam. 4

3. (a) Explain the origin of asymmetry energy in liquid drop model. 3

(b) Show that the law of conservation of angular momentum is not violated in β-decay if the intrinsic spin of the neutrino is $\frac{1}{2}\hbar$. 2

(c) What is the implication of Geiger-Nuttal law in relation with α-decay ?

Given that the range in standard air of the α-particles from radium (half life = 1622 years) is 3.36 cm,whereas from polonium (half life = 138 days) this range is 3.85 cm. Calculate the half life of RaC' for which the α -particle range is 6.97 cm. 2+3

4. (a) Polonium–212 emits α particles whose kinetic energy is 10.54 MeV. Determine the α-disintegration energy. 3

(b) Find out the spin-parity of the nucleus $^{25}_{13}X$ using extreme single particle shell model. 2

(c) The capture cross-section of ^{59}Co for thermal neutrons is 37b.

(i) What percentage of a beam of thermal neutrons will penetrate a 1.0 mm sheet of ^{59}Co ? The density of ^{59}Co is 8.9×10^3 kg/m^3.

(ii) What is the mean free path of thermal neutrons in ^{59}Co ? 2+2

(d) How one can detect the presence of an excited state of nuclei ? 1

5. (a) (i) Using liquid drop model of the nucleus, find the condition for spontaneous fission to occur.

(ii) Explain why a free proton cannot decay through —

$$p \rightarrow n + e^+ + \gamma_e$$ 3+1

(b) Find the minimum kinetic energy in the laboratory system needed by an alpha particle to cause the reaction ^{14}N (α, p) ^{17}O. The masses of ^{14}N, ^4He, ^1H and ^{17}O are respectively 14.00307 amu, 4.00260 amu, 1.00783 amu and 16.99913 amu. 3

(c) Explain the phenomenon of pair production. 3

6. (a) Explain briefly why the cyclotron principle is not used to accelerate protons and the heavier ions to very high energies. 3

(b) An organic quenched GM tube operates at 1 KV and has a wire of diameter of 0.2 mm. The radius of the cathode is 20 mm and the tube has a waranteed life time of 10^9 counts. What is the maximum radial field ? How long will the counter last if it is used on the average for 30 hours per week at 3000 counts per minute ? 2+2

(c) What do you mean by the recovery time in GM tube ? 1

(d) How is the CNO cycle in stars different from the pp chain ? 2

7. (a) Which of the following reactions can occur ? State the conservation principles violated by the others.

(i) $p+p \rightarrow n+p+\pi^+$, (ii) $p+p \rightarrow n+\pi^0$,

(iii) $\pi^+ + p \rightarrow \pi^+ + p + \pi^- + \pi^0$. 3

(b) What is color hypothesis ? Which type of interaction is supported by this hypothesis ? 2+1

(c) Find the missing particles in the following interactions : 3

(i) $\mu^- \rightarrow e^- + \gamma_c^- + \_\_$, (ii) $\gamma_c + n \rightarrow p + \_\_$, (iii) $e^+ + e^- \rightarrow \mu^- + \_\_$.

(d) All resonance particles have very short lifetimes. Why does this suggest they must be hadrons ? 1

Unit – 12

(Solid State Physics)

8. (a) Show that the reciprocal lattice corresponding to a simple cubic lattice is another simple cubic lattice. Find the relation between volumes of the unit cells of the two lattices. 3

(b) Write down Bragg's equation and hence, argue-greater is the angle of diffraction, greater is the accuracy in determining the lattice parameter. 1+2

(c) A diffractometer data of a crystal of an element show peaks at 2θ angles of 44.46 Å, 64.7 Å, 82 Å and 93.22 Å. If the wavelength of X-rays used is 1.543 Å, assign Miller indices to the peaks and determine the lattice constant. Can you identify the crystal structure ? 2+1+1

9. (a) Explain the origin of non-zero value of average energy of degenerate free electrons at T = 0K. 2

(b) What is meant by mean free path of free electrons in metal ? Calculate the electrical conductivity with mean free path Λ for a metal with 6×10^{22} conduction electrons per cc in unit of Λ ohm^{-1} cm^{-1}. 1+3

(c) A uniform copper wire of length 0.5 m and diameter 0.3 mm has a resistance of 0.12 Ω at 293 K. If the thermal conductivity of the specimen at the same temperature is 390 $Wm^{-1}K^{-1}$, calculate the Lorentz number. Compare this value with the theoretical value based on free electron theory. 3+1

10. (a) Mention the different types of bondings in crystalline solids. Describe their properties briefly. 1+2

(b) The potential energy of a system of two atoms is given by

$$U = -\frac{A}{r^6} + \frac{B}{r^{12}}.$$

The atoms form a stable bond having bond length 3Å and bond- energy 1.8 eV. Calculate the force required to break the molecule and the critical interatomic distance for which it occurs. 3+1

(c) Find the minimum distance of the Na^+ and Cl^- ions in NaCl crystal. The crystal has FCC interpenetrating lattice structure.

Given : atomic wt. of Na and Cl are 23 and 35.5, density of NaCl is 2.17 gm/cm^3. 3

11. (a) State Bloch's theorem in periodic crystals. 2

(b) In the Krönig-Penney model, the following equation is obtained after simplification :

$$\frac{P}{\alpha a}\sin\alpha a + \cos\alpha a = \cos ka \; ; \; \alpha = \sqrt{\frac{2mE}{\hbar^2}} \; ; \; P = \frac{mV_0 ab}{\hbar^2}$$

(i) Obtain the energy band gap at $k = \pi/a$ in the limit $V_0 ab << \frac{\hbar^2}{m}$.

(ii) What is the energy of the lowest band at k = 0 in the limit P<<1 ? 2+2

(c) Find the expression for effective mass of an electron in a lattice. What happens to this mass close to the edges of the Brillouin zones and why ? 2+2

12. (a) Suppose a paramagnetic atom having permanent moment $\vec{\mu}$ with a given resultant quantum number $\vec{J}$, is placed in a uniform magnetic field $\vec{B}$. Obtain an expression of the magnetization as a function of $\vec{B}$ and temperature T. Hence, obtain Curie's law in the appropriate limit. 4+2

(b) Sketch the spontaneous magnetization of a ferromagnet as a function of temperature. Indicate the universal feature associated with the graph. 1+1

(c) Atomic weight and density of iron are 55.847 and 7.87×10^3 kg/m^3 respectively. If iron has a magnetic moment of 2.2 Bohr magneton, determine its spontaneous magnetization. 2

13. (a) Explain briefly the Meissner effect with a suitable diagram. 2+1

(b) Calculate the wavelength of the photon which will be required to destroy the superconductivity in Aluminium having critical transition temperature 1.2K. In which region of electromagnetic spectrum does it belong ? 1+1

(c) What are the main assumptions in Debye model ? How does it differ from Einstein's model ? Find the expression for number of modes of vibrations in the range γ to $\gamma + d\gamma$ in a cubic solid having N atoms. 1+1+3