4/EH–24 (iv) (Syllabus–2015)

2017

(April)

PHYSICS

(Elective/Honours)

(Atomic, Nuclear and Solid-State Physics)

PHY 04(T)

Marks : 56

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** and *any* **four** from the rest

1. *(a)* State the limitations of Aston's mass spectrograph. In a mass spectrometer, a singly charged positive ion is accelerated through a uniform magnetic field of 0·1 tesla and is deflected into a circular path 18·2 cm in radius. Find *(i)* the speed of the ion, *(ii)* the mass of the ion in kg and a.m.u., and *(iii)* the mass number of the ion. 1+3=4

(b) Define the term 'half-life' of a radioactive material. A radioactive sample has its half-life equal to 60 days. Calculate *(i)* its decay constant, *(ii)* its average life and *(iii)* the time required for $\frac{2}{3}$ of the original number of atoms to disintegrate. 1+3=4

(c) Explain what you understand by Miller indices of a lattice plane. In a crystal, a plane cuts intercepts $2a$, $3b$ and c along the crystallographic axes. Determine the Miller indices of the plane. 2+2=4

2. (a) Describe Millikan's oil drop method for the determination of electronic charge. What corrections did Millikan apply to Stokes' formula and why? 3+1+1=5

(b) State Pauli's exclusion principle and use it to show that at any state of principal quantum number n, the maximum number of electrons which can be accommodated, is $2n^2$. 3

(c) Calculate the ionization potential of *(i)* H-atom and *(ii)* He-atom in the ground state. 1½+1½=3

3. (a) What is Compton effect? Obtain an expression for the Compton shift using non-relativistic mechanics only. 1+4=5

(b) State Moseley's law. Show that this law can be deduced from the modified Bohr's theory of hydrogen spectra. 1+2=3

(c) What is population inversion? Explain why laser action cannot occur without population inversion between atomic levels. 1+2=3

4. (a) Describe with a neat sketch the principle of operation of a cyclotron. Explain what is meant by 'resonance condition' in a cyclotron. Derive an expression for the maximum energy produced in this machine. 3+1+2=6

(b) Describe a GM-counter and explain its operation. What is meant by dead time of a GM-counter? 4+1=5

5. (a) Distinguish between nuclear fission and nuclear fusion. Explain the energy released in these two processes from the graph showing the variation of binding energy per nucleon as a function of mass number. Why does ^{235}U and not ^{238}U nucleus undergo fission with thermal neutrons? 2+2+1=5

(b) Define nuclear reactions. What are the quantities that are conserved in a nuclear reactions? Discuss the significance of Q-factor in this context. 1+1+2=4

(c) Calculate the binding energy in MeV of ^4He from the following data : 2

Mass of $^4He = 4 \cdot 003875$ a.m.u.

Mass of $^1H = 1 \cdot 008145$ a.m.u.

Mass of neutron $= 1 \cdot 008986$ a.m.u.

6. (a) What are cosmic rays? What is the effect of the earth's magnetic field on them? Discuss the nature of the hard and soft components of cosmic rays. 1+3+2=6

(b) What are elementary particles? How are the elementary particles classified on the basis of their masses, interaction or statistics? 1+2=3

(c) A μ^- meson decays into an electron e^- and a pair of neutrinos. Calculate the maximum available energy for the process and the average electron energy. 2

7. (a) Define coordination number. Write down the same for simple cubic, b.c.c. and f.c.c. lattices. Also prove that the distances between nearest neighbours are a, $\frac{a\sqrt{3}}{2}$ and $\frac{a}{\sqrt{2}}$ respectively. 1+2+2=5

(b) What are reciprocal lattice vectors? Write down Laue's equations representing the conditions of X-ray diffraction by crystal and hence obtain Bragg's law. 1+1½+3½=6

8. (a) Distinguish between dia-, para- and ferro-magnetic materials. 3

(b) What are magnetic susceptibility and Meissner's effect? Calculate the penetration depth of lead at 5·2 K if the London penetration depth at 0 K is 37 nm. The critical temperature of lead is 7·193 K. 1+1+2=4

(c) Define Fermi energy E_F. Explain the classification of solids into conductors, semiconductors and insulators on the basis of band theory. 1+3=4

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1. *(a)* A monochromatic X-ray beam of frequency $1 \cdot 95 \times 10^{18}$ Hz undergoes Compton scattering from a carbon block, find the wavelength of X-rays scattered at angle of 180°. [Given Planck's constant $(h) = 6 \cdot 62 \times 10^{-34}$ Js, rest mass of electron $(m_e) = 9 \cdot 11 \times 10^{-31}$ kg, velocity of electromagnetic wave in vacuum $(c) = 3 \times 10^{8}$ m/s] 4

(b) A ray of ultraviolet light of wavelength 3000 Å falling on the surface of a material whose work function is 2·28 eV, ejects an electron. What will be the kinetic energy and velocity of the emitted electron? [Given Planck's constant $(h) = 6 \cdot 62 \times 10^{-34}$ Js, mass of electron $(m_e) = 9 \cdot 11 \times 10^{-31}$ kg] 4

(c) If the magnetization and flux density of a magnetic material be 3200 A/m and 0·005 Wb/m^2, calculate the susceptibility and relative permeability of the material. 4

2. (a) Discuss the mobility of ions moving through a gas under an electric field E. 3

(b) Describe Thomson's method for the determination of e/m of an electron. 6

(c) Discuss the basic principle of a cathode ray oscilloscope. 2

3. (a) State the fundamental postulates of Bohr's theory of hydrogen atom. What interpretation do you give to the negative sign of the energy value? 2+1=3

(b) What are characteristic X-rays? Distinguish between continuous X-radiations and characteristic X-ray emission spectra. 1+3=4

(c) Describe the construction and principle of operation of a He-Ne laser. 4

4. (a) Describe one method of measuring ionization current. 4

(b) Explain why the Thomson's parabola does not extend to the vertex. What important results have been obtained from positive ray analysis? 1+2=3

(c) What do you understand by mean life of a radioactive substance? Show that the mean life of a radioactive substance $\overline{T} = \frac{1}{\lambda}$, where λ is the decay constant. 1+3=4

5. (a) What is meant by pair production? What is the minimum energy requirement of the agent causing the phenomenon? 1+1=2

(b) Discuss the working principle of linear accelerator and hence deduce the drift tube length of the accelerator. 2+2=4

(c) Explain the principle of action of scintillation counter. Describe their usefulness in the study of nuclear radiations. 2+1=3

(d) Describe briefly about the discovery of a neutron. 2

6. (a) What is controlled nuclear chain reaction? Describe how this can be achieved in a nuclear reactor indicating the function of each part of the reactor. 1+4=5

(b) Explain briefly the important features of the collective model of nuclei. How does the collective model help in understanding the nuclear fission? 2+2=4

(c) Discuss the origin of cosmic rays. 2

7. (a) What do you understand by packing fraction of a crystal? Calculate the packing fraction for a face-centred cubic (f.c.c.) structure. 1+3=4

(b) Derive the expression for the interplanar spacing of the set of (hkl) planes of a cubic lattice. 4

(c) Show that a five-fold rotation axis is not compatible in crystals. 3

8. (a) Discuss the experimental evidence on the occurrence of superconductivity in metals and alloys. 3

(b) Discuss the breakdown of classical theory of electrical conductivity with special reference to mean free path of electrons and molar specific heat of metals. 2½+2½=5

(c) Distinguish between type-I and type-II superconductors. 3

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