

West Bengal State University
B.A./B.Sc./B.Com (Honours, Major, General) Examinations, 2015

PART - III

PHYSICS — HONOURS

Paper - VI

Duration : 4 Hours]

[Full Marks : 100

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

The figures in the margin indicate full marks.

1. Answer any ten questions from the following : 10 × 2 = 20
- a) What are magic numbers ? What is their significance ?
 - b) What is meant by cross-section of a nuclear reaction ? What is its unit ?
 - c) What is pair production ? Find the threshold energy for this process.
 - d) A beam of monochromatic γ -rays is incident on an Al sheet of thickness 10 cm. The sheet reduces the intensity of the beam to 21% of the original. Calculate the linear and mass absorption coefficients, given the density of Al = 2700 kg/m³.
 - e) Calculate the binding energy in MeV of ⁴He from the following data :
 Mass of ⁴He = 4.002603 u;
 Mass of ¹H = 1.007825 u;
 Mass of neutron = 1.008665 u.
 - f) Which of the following reactions is allowed by conservation of charge, spin and strangeness ?
 (i) $K^- + p \rightarrow K^0 + n$; (ii) $\pi^- + p \rightarrow \Sigma^0 + n$.
 - g) What are the basic differences between a cyclotron and a synchrotron ?
 - h) What is the basic principle of a Pirani Gauge ?
 - i) The potential energy of a diatomic molecule is given by $U(r) = -\frac{a}{r^2} + \frac{b}{r^{10}}$, where r is the interatomic distance. Determine the equilibrium spacing in terms of a and b . ($a > 0$, $b > 0$)
 - j) What are the Miller indices for a crystal ? Explain with a diagram.
 - k) How does the Lattice contribution to the specific heat of a crystal vary with temperatures ? Show using a schematic plot. Clearly specify the temperature-dependence at low temperatures.

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[Turn over

- l) Write down the Clausius-Mosotti relation and explain its physical significance.
- m) Find the reciprocal lattice of a cubic lattice of side a .
- n) Define mobility of a charge carrier. Which one has a greater mobility — an electron or a hole in an intrinsic semiconductor?
- o) What is meant by a metastable state? Give an example.
- p) What is the essential difference between a 'step index' and a 'graded index' type optical fibres?

UNIT - I

Group - A

Answer any three questions.

 $3 \times 10 = 30$

2. a) Why does ${}_{92}^{235}\text{U}$, but not ${}_{92}^{238}\text{U}$ nucleus undergo fission with thermal neutrons? 3
- b) The equation representing a nuclear reaction is given as : $x + X \rightarrow C^* \rightarrow Y + y + Q$. Prove that for the endoenergetic reaction the threshold energy (E_{th}) is given by $E_{th} = -Q \left(1 + \frac{m_x}{M_X} \right)$. In case of photo-disintegration, show that $E_{th} = -Q$. 4 + 1
- c) On the basis of extreme single particle shell model, find ground state spin and parity of ${}^{13}\text{C}_6$. 2
3. a) To what minimum distance will an α particle with kinetic energy 0.4 MeV approach a stationary ${}_{82}^{208}\text{Pb}$ nucleus in a head on collision? 3
- b) Explain with the help of energy level diagram the fine structure of α -spectrum. 3
- c) Prove that the Coulomb potential energy of a nucleus of charge $+Ze$ and radius R is given by $E_c = -\frac{3}{5} \frac{(Ze)^2}{4\pi\epsilon_0 R}$. 4
4. a) The semi-empirical mass formula contains five parameters. Write down this formula that comes from the 'liquid-drop model' of the nucleus and discuss the significance of various terms. 2 + 5
- b) Using the semi-empirical nuclear binding energy formula, calculate the atomic number of the most stable nucleus for mass numbers $A = 27$, $A = 75$. Given the Coulomb energy term $a_{coul} = 0.70$ MeV and the asymmetry term $a_{asym} = 23.0$ MeV. 3

5. a) What are the four basic interactions in nature ? 2
 b) What are quarks ? How can we account for the electric charges of a neutron and a proton using their quark structures ? 2 + 2
 c) Explain the formation of the Baryon and the Meson octets on the basis of the quark hypothesis. 4

Group - B

Answer any *one* question. 1 × 10 = 10

6. a) Write down the basic principle of a linear accelerator. 2
 b) Describe briefly the apparatus and how it works. Obtain the condition of synchronization. 2 + 2
 c) What are the advantages of this accelerator ? Why is it not possible to accelerate electrons to very high energies in such a machine ? 2 + 2
 7. a) Give the basic working principle of a Penning gauge. 4
 b) A vacuum pump has a pumping speed of 15 lit/sec. It is connected to a vessel of volume 20 litres with a tube of conductance 1 lit/sec. After what time the pressure in the vessel will be reduced from 760 Torr to 0.2 Torr ? 4
 c) Mention two major types of leak detectors used in vacuum technology. 2

UNIT - II**Group - C**

Answer any *three* questions. 3 × 10 = 30

8. a) What is the difference between a crystal and an amorphous solid ? 2
 b) Define a unit cell. Is any unit cell necessarily a primitive cell ? Justify. 1 + 1
 c) What do you mean by coordination number ? What is its value for a *bcc* crystal ? 1 + 1
 d) In Bragg's experiment with a KCl crystal, strong reflections from the sets of planes (1, 0, 0), (1, 1, 0) and (1, 1, 1) were obtained at the same order for angles 5°23' , 7°35' and 9°25' respectively. From these observations one concludes that KCl has a simple cubic structure. Justify this conclusion from the above-mentioned data. 4
 9. a) Give Einstein's theory of specific heat of an insulating solid. Show that at high temperatures it gives results consistent with Dulong and Petit's law. 4 + 1
 b) What are the deficiencies of the above theory ? Discuss in brief how these deficiencies are overcome in the Debye's theory of specific heat. 2 + 3

10. a) Describe Langevin's theory of diamagnetism and hence show that the diamagnetic susceptibility of an element is independent of temperature. 5
 b) Describe a very simple experiment by which you can distinguish a paramagnetic, a ferromagnetic and a diamagnetic substance. 3
 c) What do you mean by atomic polarizability? What is its dimension? 1 + 1
11. a) Consider a free electron moving in one dimension. Write down its stationary state wavefunction. Draw a schematic graph show its dispersion relation i.e. the dependence of its energy on its wavevector. 1 + 1
 b) Now consider that the electron is subjected to a periodic potential having period a . How would its wavefunction look like now? Show that the electronic charge density would obey the periodicity of the potential. 1 + 1
 c) Considering the case in part (b) explain qualitatively the formation of energy bands in a crystalline solid (you can consider one-dimensional case for convenience). Hence distinguish between metals, insulators and intrinsic semiconductors. Using this picture, explain why the resistivity of an intrinsic semiconductor starts decreasing with increasing temperature. 1 + 2 + 1
 d) Will the Hall coefficient change sign if one reverses the direction of the applied magnetic field? Explain briefly. 2

Group - DAnswer any *one* question.

1 × 10 = 10

12. a) What is meant by 'population inversion'? Mention briefly a method for achieving this. 2 + 1
 b) Why four-level laser scheme is more advantageous than three-level laser action? 2
 c) At what temperature are the rates of spontaneous and stimulated emissions equal? Assume $\lambda = 5000 \text{ \AA}$. 3
 d) What is holography? 2
13. a) What is an optical fibre? An optical fibre of length 150 m has input power of $10 \mu\text{W}$ and an output power of $9 \mu\text{W}$. Compute the loss in decibels per kilometre. 1 + 2
 b) What is a multimode step index optical fibre? What are its advantages and disadvantages? 2 + 2
 c) The radial distribution of refractive index is given by $n(r) = 1.53 - 2r^2$ in a graded index fibre. In the expression r is given in mm and the relation is valid up to $r = 0.2 \text{ mm}$. Calculate the acceptance angle and the numerical aperture of the fibre. 3