Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(EE-NEW/EEE-NEW/EIE-NEW/ICE-NEW)/ SEM-4/PH(EE)-401/2012

2012

PHYSICS - II

Time Allotted : 3 Hours Full Marks : 70

The figures in the margin indicate full marks.

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

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

i) He^3 and muon are

a) fermions

b) bosons

c) fermions & bosons respectively

d) bosons & fermions respectively.

ii) The degrees of freedom for a system of N particles with K constraint relations is given by

a) N – K b) N – 3K

c) 3N – K d) 3K – N.

iii) The coordination number for FCC structure is

a) 6 b) 8

c) 12 d) 5.

iv) The dielectric constant of a conductor is

a) 0 b) 1

c) – 1 d) infinity.

v) Fermi-Dirac distribution approaches Maxwell-Boltzmann distribution at

a) low temperature & high density

b) high temperature & low density

c) low temperature & low density

d) high temperature & high density.

vi) If E_1 is the energy of the ground state of a one-dimensional potential box of length l and E_2 be the energy of the ground state when the length of the box is halved, then

a) $E_2 = 2E_1$ b) $E_2 = E_1$

c) $E_2 = 4E_1$ d) $E_2 = 3E_1$.

vii) The reciprocal lattice of a body centered cubic (*bcc*) lattice is

a) *bcc* b) *fcc*

c) *sc* d) *hcp*.

viii) The wave function of a particle is $\Psi = A \cos^2 x$ for $-\frac{\pi}{2} < x < \frac{\pi}{2}$. Then, the value of A is

a) $\sqrt{\frac{8}{3\pi}}$ b) $\sqrt{\frac{3}{8\pi}}$

c) $\sqrt{\frac{1}{2\pi}}$ d) $\sqrt{\frac{3}{2\pi}}$.

ix) The density of free electron states in a metal varies with energy E as

a) $\sqrt{E}$ b) E^2

c) E^0 d) $\frac{1}{E}$.

x) Curie-Weiss law is obeyed by

a) paramagnetic materials

b) anti-ferromagnetic materials

c) ferromagnetic materials above the Curie temperature

d) ferromagnetic materials below the Curie temperature.

xi) The Miller indices of a plane parallel to XY plane is

a) (100) b) (010)

c) (001) d) (110) .

xii) If σ and k be the electrical and thermal conductivities in a solid, then according to Widemann-Franz law,

a) $\frac{\sigma}{kT}$ = const. b) $\frac{k\sigma}{T}$ = const.

c) $\frac{k}{\sigma T}$ = const. d) σkT = const.

(where T is the temperature)

xiii) The product of generalized force (Q_i) and generalized displacement (δq_j) must have the dimension of

a) force b) work

c) power d) length.

xiv) The spacing between the nth energy state and next energy state in a one-dimensional potential box increases by

a) $2n - 1$ b) $2n + 1$

c) $n - 1$ d) $n + 1$.

xv) In an n-type semiconductor, donor level

a) is nearer to conduction band

b) is at the middle between valence and conduction bands

c) is nearer to valence band

d) is not formed at all.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. a) Describe briefly micro-state and macro-state with suitable examples.

b) Show that the average energy of electrons at $T = 0K$ is given by $\frac{3}{5} E_F$ (where E_F is the Fermi energy) . 2 + 3

3. a) What do you mean by cyclic coordinate ? Explain with an example.

b) Show that if a given coordinate is cyclic in Lagrangian, it will also be cyclic in Hamiltonian. 2 + 3

4. a) Define atomic polarizability. Establish a relation between polarization and atomic polarizability.

b) Calculate the induced dipole moment per unit volume of He gas if it is placed in an electric field of 6000 V cm^{-1} . The atomic polarizability of He is $0{\cdot}18 \times 10^{-40}$ Fm^2 and density of He is $2{\cdot}6 \times 10^{25}$ atoms per m^3 . 3 + 2

5. a) Derive Curie's law of paramagnetism in the framework of Langevin's theory.

   b) Are all orientations of the magnetic dipoles possible in quantum theory ? Explain. 4 + 1

6. a) Explain what you mean by degeneracy of an eigenstate with an example.

   b) The eigenvalue equation for the momentum operator is $\left(\frac{\hbar}{i}\right)\left(\frac{\partial \Psi}{\partial x}\right) = \lambda\Psi$.

   Solve the above equation and hence show that for Ψ to be a physically admissible eigenstate, the eigenvalue λ must be real. 2 + 3

7. Derive the Bragg's law of *X*-ray diffraction from Laue equation and deduce the vector form of Bragg's law of *X*-ray diffraction in reciprocal space. 2 + 3

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

8. a) A free particle of mass *m* is confined within $x = 0$ and $x = L$.

   i) Write down Schrö dinger time-independent equation for such a system.

   ii) Solve the equation to find out the normalized eigenfunctions.

   iii) Show that the eigenfunctions corresponding to two different eigenvalues are orthogonal. 1 + 4 + 3

b) If $\hat{P}$ and $\hat{L}$ be the momentum and angular momentum operators, find the values of $[\hat{L}_x, \hat{x}]$ and $[\hat{L}_x, \hat{y}]$. 2 + 2

c) Find the expectation value of x for the wave function given by $\Psi(x) = Ae^{-bx^2}$. 3

9. a) The energy wave vector dispersion relation for a one-dimensional crystal of lattice constant a is given by $E(k) = E_o - \alpha - 2\beta \cos ka$, where E_o, α, β are constants.

i) Find the value of k at which the velocity of an electron is a maximum.

ii) Find the difference between the top and the bottom of the energy band.

iii) Obtain the effective mass m^* of the electron at the bottom and at the top of the band. 2 + 2 + 2

b) What do you mean by density of states ? Show that the density of states of free electrons vary with energy (E) as $\sqrt{E}$. 1 + 4

c) In sodium metals, the free electron density is $2{\cdot}5 \times 10^{28}$ m^{-3}. Calculate the Fermi energy and the dermi temperature. 2 + 2

10. a) Define Hamiltonian of a dynamical system. When does it represent the total energy of the system ? Explain. 2 + 3

b) The Lagrangian of a particle of mass m in one dimension is given by

$$L = \frac{1}{2} m(\dot{x}^2 - \omega^2 x^2) e^{bt}$$

Obtain the canonical momentum and equation of motion. Is the Hamiltonian constant of motion ? 3 + 3

c) Deduce D'Alembert's principle from the principle of virtual work. 4

11. a) What do you mean by symmetric and anti-symmetric wave function ? How does Fermi-Dirac (FD) statistics differ from Bose-Einstein (BE) statistics ? 2

b) Explain graphically the Fermi distribution at zero and non-zero temperature. 3

c) Derive Planck's radiation law from BE statistics. State clearly the assumptions made in the theory. 3 + 2

d) Compute the specific heat of a free electron gas using classical statistics. Using FD statistics, argue that the specific heat of electrons should vary linearly with temperature (T). 2 + 3

12. a) What is Larmor frequency ? 2

b) With the help of Weiss molecular field theory of ferromagnetism, derive the Curie-Weiss law. 5

c) Draw the B-H curve for a ferromagnetic material and identify the retentivity and the coercive field on the curve. What is the energy loss per cycle ? 3 + 1

d) Explain the reason behind the negative susceptibility of diamagnetic material. 2

e) Calculate the effective Bohr magneton for Gd^{+3} . The electronic configuration for Gd^{+3} is $4f^7\ 5s^2\ 5p^6$ .2