Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH/ECE/PWE/NEW/SEM-4/PH-401/2013

2013

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) If the constraint relations can be made independent of velocity, then the constraints are called

a) Sclerenomic b) Bilateral

c) Holonomic d) Conservative.

ii) If a system had f degrees of freedom, then the number of Lagrange's equation for the system is

a) 3 b) f

c) $2f$ d) $f/2$.

iii) The physical interpretation of $\vec{\nabla} \cdot \vec{B} = 0$ is

a) magnetic monopole does not exist

b) magnetic field is irrotational

c) magnetic field is conservative

d) magnetic lines of force are open curves.

iv) The velocity of electromagnetic wave in free space is

a) equal to velocity of light

b) greater than the velocity of light

c) less than the velocity of light

d) zero.

v) Dielectrics are substances which are

a) semiconductor b) conductor

c) insulator d) none of these.

vi) Ampere's circuital law is applicable when the current density is

a) constant over space

b) time independent

c) solenoidal

d) irrotational.

vii) The waves representing a free particle in three dimensions are

a) standing waves b) progressive waves

c) transverse waves d) polarized waves.

viii) In an electromagnetic wave in free space, the electric and magnetic fields are

a) parallel to each other

b) perpendicular to each other

c) inclined at an angle

d) inclined at an obtuse angle.

ix) A moving charge produces

a) electric field only

b) magnetic field only

c) both of them

d) static electric field only.

x) When the Hamiltonian operator operates on a wave function $\psi(r)$, then the corresponding eigenvalue is

a) potential energy of the system

b) kinetic energy of the system

c) total energy of the system

d) none of these.

xi) The value of probability of an event cannot be

a) 1 b) negative

c) zero d) positive.

xii) If a wave packet is described by

$\varphi(x) = A\, exp\left(-\frac{x^2}{2\sigma^2}\right)$ then the normalization constant is

a) 2σ b) σ

c) $\frac{\pi\sigma}{2}$ d) none of these.

xiii) He^3 and muon are

a) Fermions

b) Bosons

c) Fermions & Bosons respectively

d) classical particles.

xiv) The spin angular momentum of photon is

a) h b) $h/8$

c) 0 d) $2h$.

xv) The maximum energy that can be occupied by an electron at $T = 0$ K is known as

a) band gap energy

b) Fermi energy

c) radiation energy

d) potential energy.

GROUP – B

(Short Answer Type Questions)

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

2. a) If the vectors A and B be irrotational, then show that the vector $A \times B$ is solenoidal.

   b) Prove that

   $$i \times (j \times k) = j \times (k \times i) = k \times (i \times j) = 0.$$

   $2\frac{1}{2} + 2\frac{1}{2}$

3. a) Write down Laplace's equation. Show that the potential function $x^2 - y^2 + z$ satisfies Laplace's equation.

   $1 + 2$

   b) Show that when a dielectric is placed in an electric field, the field within the dielectric becomes weaker than the original field. 2

4. a) Calculate the magnetic field along the axis of the current carrying circular coil. 4

   b) What is the value of magnetic field at the centre of the coil ? 1

5. a) What do you mean by commutator ? Prove that

   $\left[x,\ P_x \right] = i\hbar$. $1 + 2$

   b) Write the basic postulates of wave mechanics. 2

6. a) Show that the average energy of an electron in a metal at 0 K is given by $3/5\ E_F$, where E_F is the Fermi energy. 3

   b) Show that both *FD* and *BE* statistics approach *MB* statistics at a certain limit. When does that happen ? 2

GROUP – C

(Long Answer Type Questions)

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

7. a) If in a region of space electric field is always in the x-direction then prove that

   i) the potential is independent of y and z coordinates and

   ii) if the field is constant, there is no free charge in that region. 2 + 1

   b) Write down the differential form of Gauss' law. Suppose that electric field in some region is found to be $\vec{E} = \alpha r^3 \hat{r}$ in spherical coordinates (α is a constant). Find the electric charge density. 1 + 3

   c) A very long cylindrical object carries charge distribution proportional to the distance from the axis (r). If the cylinder is of radius a, then find the electric field both at $r > a$ and $r < a$, by the application of Gauss' law in electrostatics. 4

   d) What is Electric Displacement vector ? Establish the relation $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$ where symbols have their usual meanings. 1 + 3

8. a) State Biot-Savart's law and obtain the magnetic field induction due to a wire carrying current I at a point P situated at a distance R from it. 2 + 3

   b) Find the magnetic field at a point (1, 1, 1) if vector potential at that position is

   $$\vec{A} = \left(10x^2 + y^2 - z^2 \right) \hat{j}.$$ 3

   c) Obtain the magnetic field induction $\vec{B}$ at a point on the axis of a current circular conductor (loop) with n turns. 7

9. a) State Poynting theorem. 2

b) Prove that $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$. 3

c) A conducting wire in the shape of an equilateral triangle of each side *a* carries a current *I*. Calculate the magnetic field at its centroid. 3

d) If ϕ is a scalar potential associated with the electric field $\vec{E}$ and $\vec{A}$ is the vector potential associated with the magnetic induction $\vec{B}$, show that they must satisfy the equation $\nabla^2 \phi + \frac{\partial}{\partial t}\left(\vec{\nabla} \cdot \vec{A}\right) = -\frac{\rho}{\varepsilon_0}$. 5

e) A long solenoid of 40 cm length has 300 turns. If the solenoid carries a current of 3·5 A, find the magnetic field at one end of the solenoid. 2

10. a) Calculate total number of particles in a Fermionic gas in terms of the Fermi level at absolute zero temperature. 4

b) Apply *B-E* statistics to a photon and deduce Planck's law of spectral energy density of black body radiation. 3

c) Define Microstates and Macrostates with suitable examples. 3

d) A box contains 5 red balls and 3 white balls. The balls except their colours, are identical. What is the probability that, on two independent draws, 1 ball is red and 1 ball is white ? 3

e) What do you mean by Macro-canonical and Micro-canonical ensemble ? 2

11. a) If a system has two eigenstates ψ_1 and ψ_2 with eigenvalues E_1 and E_2, under what condition will linear combination $(\psi = a\,\psi_1 + b\,\psi_2)$ be also an eigenstate ? 2

b) If the wave function $\psi(x)$ of quantum mechanical particle is given by

$$\psi(x) = a \sin\left(\frac{\pi x}{L}\right) \text{ for } 0 \le x \le L$$

$$= 0, \text{ otherwise,}$$

then determine the value of a. Also determine the value of x where probability of finding the particle is maximum. 5

c) Write down Schrödinger equation for one-dimensional motion of a free particle in a one-dimensional potential box. Find its eigenfunction and eigenenergy. 5

d) Prove that the first excited energy state of a free particle in a cubical box has three fold degeneracy. 3