PHYSICS - II (PHYS 2001)

Time Alloted: 3 Hours

Full Marks: 70

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

# GROUP - A (Multiple Choice Type Questions)

- 1. Choose the correct alternatives for the following: [10×1=10]
  - i) The Lagrangian of a system is given in terms of the coordinates r,  $\theta$ ,  $\phi$  and the corresponding velocities as

 $L = \frac{1}{2}\alpha\dot{\theta}^2 + \frac{1}{2}r^2\dot{\phi}^2 + \frac{1}{2}\beta\dot{\gamma}^2, \ \alpha \ \text{and} \ \beta \ \text{are constants. The}$ 

cyclic coordinates are

(a)  $\gamma$  and  $\theta$ 

(b) y and  $\phi$ 

(c) θ and φ

(d)  $\gamma$ ,  $\theta$ , and  $\phi$ 

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The total polarization of a polyatomic gas is

(a) 
$$\vec{P} = N(\alpha_e + \alpha_i)\vec{E}$$

(a) 
$$\vec{P} = N(\alpha_e + \alpha_i)\vec{E}$$
 (b)  $\vec{P} = N(\alpha_e + \alpha_i + \frac{\mu}{KT})\vec{E}$ 

(c) 
$$\vec{P} = N(\alpha_e + \alpha_i + \frac{\mu^2}{3KT})\vec{E}$$
 (d)  $\vec{P} = N\frac{\mu}{KT}\vec{E}$ 

iii) For four distinguishable particles for macrostates (3,1) the number of possible arrangements are

(a) 2

(b) 3

.(c) 4

(d) 9

iv) The average energy of a free electron in a metal (with Fermi level E<sub>F</sub>) at T. = 0 K is given by

(a) zero

(b) = EF

(c) 3 E<sub>F</sub>

(d) E\_

Which of the following particles is NOT a Fermion?

(a) Proton

(b) Alpha-particle

(c) Neutron

(d) Electron.

vi) Given  $\phi = C_1\phi_1 + C_2\phi_2$ , where  $\phi_1$  and  $\phi_2$  are orthonormal energy eigen states of a system corresponding to energies  $E_1$  and  $E_2$ . If  $\phi$  is normalised and  $C_1 = \sqrt{3}$ then C, is

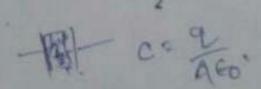
(a)  $\frac{1}{\sqrt{3}}$ 

(b)  $\frac{2}{\sqrt{3}}$ 

(c)  $\sqrt{\frac{2}{3}}$ 

(d)  $\sqrt{\frac{3}{3}}$ 

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[Turn over]

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

  - (a) Scleronomic (b) Conservative
  - (c) Bilateral

- (d) Holonomic
- viii) Dielectrics are substances which are
  - (a) semiconductors (b) conductor
  - (c) insulators

3,1)

- (d) none of these
- ix) In an intrinsic semiconductor, the donor level is
  - (a) near the valence band edge
  - (b) near the conduction band edge
  - (c) about halfway between the valence and conduction band edges
  - (d) none of the above
- A superconductor below its transition temperature behaves like a
  - (a) paramagnetic material
  - (b) diamagnetic material
  - (c) antiferromagnetic material
  - (d) ferromagnetic material

#### GROUP - B

2. (a) Write down the Lagrangian function and Langrangian equation of motion of a freely falling body falling from a height 'h'.

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[Turn over]

(b) For a free particle moving with relativistic speed, has mass  $m = \frac{m_0}{r}$  where  $m_0$  is the rest mass, v is the

mass m = 
$$\frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$
 where  $m_0$  is the rest mass,  $v$  is the

generalised velocity and c is the speed of light in vacuum. Assuming the langrangian of the system to be

 $L = -m_0c^2\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$ , obtain momentum of the particle.

- (c) Verify that the quantum mechanical operators x and p<sub>x</sub> satisfy the equation  $x p_x p_x x = i \bar{n}$ . Hence show that  $[x, p_x^n] = n i \bar{n} p_x^{n-1}$ .
- (d) Write down the expression for energy eigein value for three dimensional potential well. Hence show that the first excited state has three fold degeneracy.

$$(1+2)+2+(2+3)+(1+1) = 12$$

- 3. (a) What are the necessary conditions for Hamiltonian H to represent the total energy of the system?
  - (b) Obtain the Hamiltonian function from its Lagrangian for a particle of mass m and undergoing simple harmonic equation. Hence obtain corresponding Hamiltonian

Show that the probability current density for free particle is proportional to its velocity.

A normalised wave function is given by,  $\psi(x) = \left(\frac{1}{\sigma\sqrt{\pi}}\right)^2 e^{\frac{x^2}{2\sigma^2}}$ Phys 2001

Phys 2001

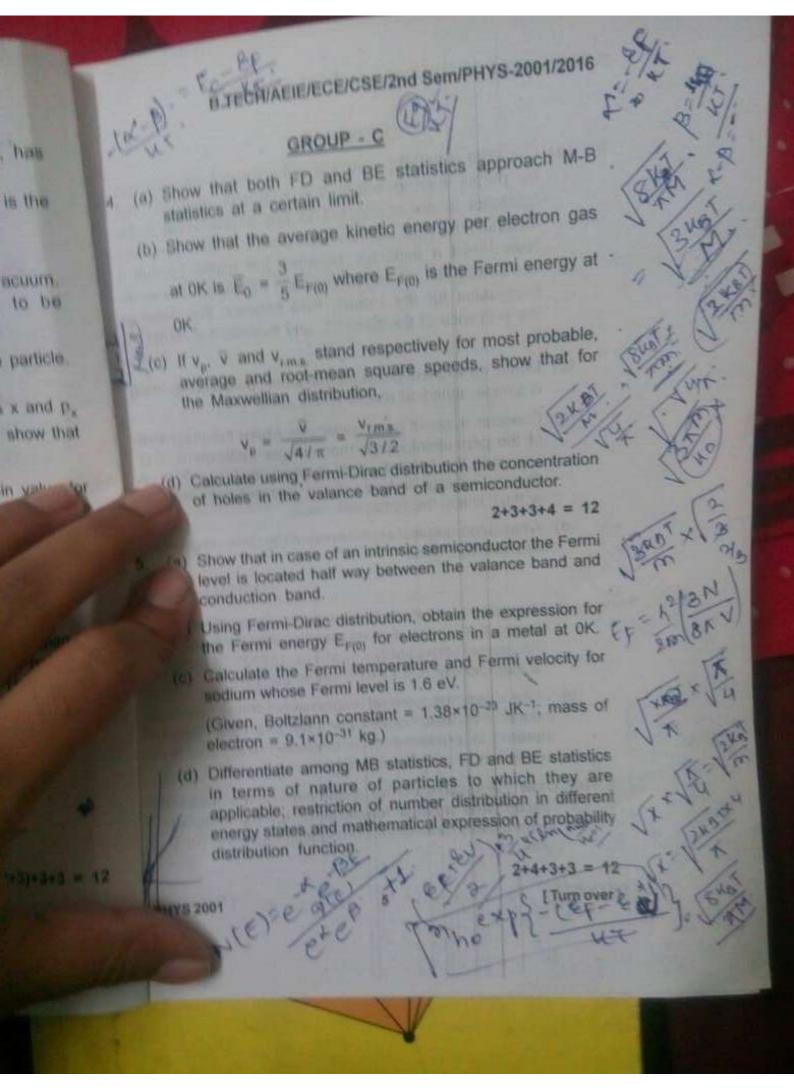
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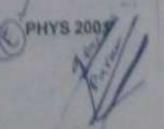
#### Group - D

- 6. (a) Consider a parallel plate capacitor without dielectric with its plates having equal and opposite charges. The capacitor is not connected to any circuit. What is the electric field (E<sub>0</sub>) between the plates of the capacitor? Now insert a dielectric between the plates so that it completely fills the region between the plates. Derive an expression for the electric field between the plates in the presence of the dielectric and express it in terms of E<sub>0</sub>.
  - (b) Derive an expression for the electronic polarizability using a simple spherical model of an atom.
  - (c) Consider a gas of polar molecules where the magnitude of the permanent dipole moment per molecule is 1 D. Calculate the field strength required at T = 297 K so that the average induced dipole moment per molecule is 0.07 times the saturation value.
  - (d) What is the physical significance of the Bohr magneton? Estimate its value.

(1+3)+4+2+2=12

- 7. (a) Calculate the induced dipole moment per unit volume of He gas if it is placed in an electric field of 6000 V/cm. The atomic polarizability of He is 0.18×10<sup>-40</sup> F-m<sup>2</sup> and the gas density is 2.6×10<sup>25</sup> atoms per m<sup>3</sup>
  - (b) Write down the general expression for the average induced magnetic moment per atom in a paramagnetic material in presence of a magnetic field. Use this expression to derive Curie's Law.

Draw the graphs of the reciprocals of the magnetic susceptibility against temperature for paramagnetic, ferromagnetic and antiferromagnetic materials in the same plot.



Fon 2 0 m3 N m2 : [Turn over]

#### B.TECH/AEIE/ECE/CSE/2nd Sem/PHYS-2001/2016 (d) The magnetic susceptibility of Ge is -0.8×10-5. Given that the applied magnetic field intensity is 5×10<sup>4</sup> Amp/m, calculate the magnetization in Ge and also the magnetic electric with larges. The field induction. What is the (e) Draw the hysteresis loops of a soft and a hard magnetic e capacitor? material in the same plot. is so that it 2+(1+4)+2+2+1 = 12 Derive an the plates in It in terms of GROUP - E (a) State and explain Bloch's theorem. anzability using (b) The energy-wave vector dispersion relation for a onedimensional crystal of lattice constant a is given by the magnitude $E(k) = E_0 - \alpha - 2\beta \cos k\alpha$ , where $E_0$ , $\alpha$ , $\beta$ are constants. decute is 1 D. (I) Find the expression for the velocity of the electron C = 297 K so as a function of k. For what value of k the velocity t per molecule is maximum? (ii) Find the difference between the top and the bottom ohr magneton? of the energy band. (iii) Find the expression for the effective mass of the 3)+4+2+2 = 12 electron as a function of k. What are its values at the top and the bottom of the energy band? unit volume of of 8000 V/cm. (c) What is the Meissner effect? Illustrate your answer with All E-m2 and an appropriate diagram. 3+(2+2+2)+(1+2) = 12 4 N.m2 = Nm2 MAGE s of the mater ersture for paramagnetic, magnatic materials in the man [Tumover] [Turn over]

9. (a) An electron is moving in one dimension in a region

where the potential is given by  $V(x) = V_0 \left[ 1 + \cos\left(\frac{2\pi x}{a}\right) \right]$ 

where  $V_0$  and a are constants. Show that if  $\psi(x)$  is an eigenfunction of the Hamiltonian then  $\psi(x+a)$  is also an eigenfunction of the Hamiltonian with the same energy.

- (b) Write a short note on Type 1 and Type 2 superconductors explaining their difference.
- (c) What is the London penetration depth? Write down its expression as a function of temperature.
- (d) Calculate the number density of electrons in a material for which London penetration depth at zero K is  $0.5\times10^{-8}$  m. ( $\mu_0=4\pi\times10^{-7}$  N/A<sup>2</sup>).

3+3+(1+2)+3 = 12

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