Total No. of Questions : 7] [Total No. of Pages : 2

**P703**

# [3922] - 101
## M.Sc. (Sem. - I)
## PHYSICS
## PHY UTN - 501 : Classical Mechanics
## (2008 Pattern) (New Course)

*Time : 3 Hours]* *[Max. Marks :80*

***Instructions to the candidates:***

1) *Question No. 1 is compulsory and solve any four questions from the remaining.*
2) *Draw neat diagrams wherever necessary.*
3) *Figures to the right indicate full marks.*
4) *Use of logarithmic table and electronic pocket calculator is allowed.*

***Q1)*** Attempt <u>any four</u> of the following:

a) Show that the constraints acting in the case of rigid body are conservative. **[4]**

b) What is a cyclic coordinate? Illustrate with examples. **[4]**

c) For scleronomic systems, show that the kinetic energy is homogeneous quadratic function of generalized velocities. **[4]**

d) Prove the invariance of Lagrange equations under Galilean transformations. **[4]**

e) Prove that a coordinate cyclic in Lagrangian is also cyclic in Hamiltonian. **[4]**

f) Show that

$q = \sqrt{2\mathrm{P}}\sin \mathrm{Q}$

$p = \sqrt{2\mathrm{Q}}\cos \mathrm{Q}$ is canonical transformation. **[4]**

***Q2)*** a) What is generalized potential? Set up Lagrangian for a charged particle moving in electromagnetic field. **[8]**

b) A particle of mass *m* moves in a force field due to ordinary potential V depending on position. Set up the Hamiltonian and obtain equation of motion in spherical coordinates. **[8]**

***Q3)*** a) A particle of mass *m*, moves on a plane in the field of force given by $\vec{\mathrm{F}} = -\mathrm{K}r\cos\theta\,\hat{r}$ where K is a constant and $\hat{r}$ is radial unit vector. Will the angular momentum of the particle about origin be conserved? Obtain differential equation of the orbit of the particle. **[8]**

*P.T.O.*

b) State and prove Virial theorem. When the force is derivable from a potential $V \alpha r^{n+1}$, show that the average kinetic energy equals $\left(\frac{n+1}{2}\right)$ times the average potential energy. **[8]**

***Q4)*** a) For a relativistic particle moving in a conservative potential field $V(\vec{r})$ show that the Hamiltonian is given by

$$H(\vec{r}, \vec{p}) = \sqrt{p^2C^2 + m_0^2C^4} + V(\vec{r})$$ **[8]**

b) Discuss the stability of orbits under central force. Hence show that the circular orbit is stable if $(n + 3) > 0$ where '$n$' is integer. **[8]**

***Q5)*** a) What is Focault's pendulum? Obtain an equation of motion for such a pendulum. **[8]**

b) Explain variational principle. A particle is moving under constant conservative force field. Apply variational principle to find the path of the particle along which its time of transit will be minimum. **[8]**

***Q6)*** a) Obtain an expression for Corioli's acceleration for rotating coordinate system. **[8]**

b) The transformation equations between two sets of coordinates are

$$Q = \log\left(1 + 9^{1/2} \cos p\right)$$

$$P = 2\left(1 + 9^{1/2} \cos p\right) 9^{1/2} \sin p$$

Show that the transformation is canonical. **[8]**

***Q7)*** a) If the generating function has the form $F(q_k, p_k, t)$ then show that $p_k = \frac{\partial F}{\partial q_k}$ and $Q_k = \frac{\partial F}{\partial P_k}$ **[4]**

b) What are holonomic and nonholonomic constraints. Give examples. **[4]**

c) Show that the Poisson Bracket of two dynamical variables remain invariant under canonical transformation. **[8]**

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Total No. of Questions : 7]                                                                 [Total No. of Pages : 2

**P705**

# [3922] - 103
# M.Sc.
# PHYSICS
## PHY UTN - 503 : Mathematical Methods of Physics
## (New Course) (Sem. - I) (2008 Pattern)

*Time : 3 Hours]*                                                                 *[Max. Marks :80*

***Instructions to the candidates:***

1) *Question No. 1 is compulsory attempt any four questions from the remaining.*
2) *Draw neat diagrams wherever necessary.*
3) *Figures to the right indicate full marks.*
4) *Use of logarithmic tables and calculator is allowed.*

***Q1)*** Attempt any four of the following:

a) Find the Laplace transform of sin$at$. **[4]**

b) Let a linear transformation T : $V_2 \to V_1$ be defined by $T(x_1, x_2) = (x_1 + x_2, 2x_1 - x_2, 7x_2)$ and if $B_1 = (e_1, e_2)$ and $B_2 = (f_1, f_2, f_3)$ are the standard bases of $V_2$ and $V_3$ respectively then find the matrix of T relative to $B_1$ and $B_2$. **[4]**

c) What is Dirichlet's condition in Fourier series? State the monotonic and bounded conditions. **[4]**

d) Show the graphical representation of the following function for period = 10.

$$f(x)=\begin{cases} 3 & 0<x<5 \\ -3 & -5<x<0 \end{cases}$$ **[4]**

e) Prove, $|z_1 + z_2| \le |z_1| + |z_2|$ **[4]**

f) Prove the following recurrence relation for the Legendre polynomials $P_n(-x) = (-1)^n P_n(x)$ **[4]**

***Q2)*** a) Give the general definition of the inner product in vector space and prove Schwartz Inequality $|u.\vartheta| \le \|u\|\|\vartheta\|$. **[8]**

b) Find the Fourier series for the periodic function $f(x)$ by

$$f(x) = -\pi \text{ if } -\pi < x < 0$$
$$= x \text{ if } 0 < x < \pi$$ **[8]**

*P.T.O.*

*Q3)* a) Find the residue of $\frac{z^2}{z^2+a^2}$ at $z = ia$. **[8]**

b) Find $L^{-1}\left\{\frac{s+1}{s^2+6s+25}\right\}$ **[8]**

*Q4)* a) State and prove Laurent's theorem. **[8]**

b) Prove the following recurrence relations for Laguerre polynomials.

i) $L_{n+1}(x) + (x - 2n - 1)L_n(x) + nL_{n-1}(x) = 0$

ii) $L'_n(x) - nL'_{n-1}(x) - nL_{n-1}(x) = 0$ **[8]**

*Q5)* a) Prove the orthogonality condition for Hermite polynomials

$\int_{-\infty}^{+\infty} e^{-x^2} H_m(x) H_n(x)\, dx = 2^n n! \sqrt{\pi}\, \delta_{m,n}$ where,

$\delta_{m,n} = 0$ when $m \neq n$

$= 1$ when $m = n$. **[8]**

b) Expand the function

$f(x) = 1$ when $0 \leq x < 1$

$= 0$ when $|x| > 1$

as a fourier integral. Hence evaluate $\int_0^{\infty} \frac{\sin\lambda \cos\lambda x}{\lambda}\, d\lambda$ **[8]**

*Q6)* a) State and prove Parseval's identity for fourier series. **[8]**

b) Prove Taylor's theorem. **[8]**

*Q7)* a) Prove that set {(1, 1, 1), (1, –1, 1), (0, 1, 1)} is a basis for $V_3$. **[4]**

b) Define spherical harmonic $Y_n^m(\theta, \phi)$ and write the orthogonal integral for $y_n^m(\theta, \phi)$. **[4]**

c) Show that eigen values of matrix are unchanged under similarity transformation. **[4]**

d) Prove the shifting property of Laplace transform. **[4]**

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Total No. of Questions : 7]

[Total No. of Pages : 2

**P706**

# [3922] - 104
# M.Sc.
# PHYSICS
## PHY UTN - 504 : Quantum Mechanics - I
## (New Course) (Sem. - I)

*Time : 3 Hours]* *[Max. Marks :80*

***Instructions to the candidates:***

1) *Question No. 1 is compulsory and Solve any four questions from the remaining.*
2) *Draw neat diagrams wherever necessary.*
3) *Figures to the right indicate full marks.*
4) *Use of logarithmic table and electronic pocket calculator is allowed.*

***Q1)*** Attempt any four of the following:

a) A 1 eV electron is inside the surface of metal. If the potential barrier 4 eV having width 2 A.U., then calculate the probability of it's transmission. (Given : $\hbar$ = 1.053 x $10^{-34}$ Jxs; $m_e$ = 9.1 x $10^{-31}$ kg and 1 eV = 1.6 x $10^{-19}$ J) **[4]**

b) For the ground state of a linear harmonic oscillator, the wave function is

$$\phi_0(x) = \left(\frac{mw}{\pi\hbar}\right)^{1/4} e^{-mwx^2/2\hbar}$$. Show that the uncertainty product is

$\Delta\times\Delta P_x = \frac{\hbar}{2}$. (Given $\langle x\rangle = \langle P_x\rangle = 0$). **[4]**

c) In three dimension, the ground state of H-atom is $\psi(r) = \left(\frac{1}{\pi a_0^3}\right)^{\frac{1}{2}} e^{-r/a_0}$

where a0 = radius of fir **[4]**

d) Show the graphical representation of the following function for period = 10.

$$f(x) = \begin{cases} 3 & 0 < x < 5 \\ -3 & -5 < x < 0 \end{cases}$$ **[4]**

e) Prove, $|z_1 + z_2| \leq |z_1| + |z_2|$ **[4]**

f) Prove the following recurrence relation for the Legendre polynomials $P_n(-x) = (-1)^n P_n(x)$ **[4]**

*P.T.O.*

*Q2)* a) Give the general definition of the inner product in vector space and prove Schwartz Inequality $|u.v| = \|u\| \|v\|$. **[8]**

b) Find the Fourier series for the periodic function $f(x)$ by

$$f(x) = -\pi \text{ if } -\pi < x < 0$$
$$= x \text{ if } 0 < x < \pi$$ **[8]**

*Q3)* a) Find the residue of $\frac{z^2}{z^2 + a^2}$ at $z = ia$. **[8]**

b) Find $L^{-1}\left\{\frac{s+1}{s^2+6s+25}\right\}$ **[8]**

*Q4)* a) State and prove Laurent's theorem. **[8]**

b) Prove the following recurrence relations for Laguerre polynomials.

i) $L_{n+1}(x) + (x - 2n - 1)L_n(x) + nL_{n-1}(x) = 0$

ii) $L'_n(x) - nL'_{n-1}(x) - nL_{n-1}(x) = 0$ **[8]**

*Q5)* a) Prove the orthogonality condition for Hermite polynomials

$$\int_{-\infty}^{\infty} e^{-x^2} H_m(x) H_n(x)\, dx = 2^n n! \sqrt{\pi}\, \delta_{m,n} \text{ where,}$$

$$\delta_{m,n} = 0 \text{ when } m \neq n$$
$$= 1 \text{ when } m = n.$$ **[8]**

b) Expand the function

$$f(x) = 1 \text{ when } 0 \le x < 1$$
$$= 0 \text{ when } |x| > 1$$

as a fourier integral. Hence evaluate $\int_0^{\infty} \frac{\sin\lambda \cos\lambda x}{\lambda} d\lambda$ **[8]**

*Q6)* a) State and prove Parseval's identity for fourier series. **[8]**

b) Prove Taylor's theorem. **[8]**

*Q7)* a) Prove that set {(1, 1, 1), (1, –1, 1), (0, 1, 1)} is a basis for $V_3$. **[4]**

b) Define spherical harmonic $Y_n^m(\theta, \phi)$ and write the orthogonal integral for $y_n^m(\theta, \phi)$. **[4]**

c) Show that eigen values of matrix are unchanged under similarity transformation. **[4]**

d) Prove the shifting property of Laplace transform. **[4]**

**Total No. of Questions : 7]** **[Total No. of Pages : 3**

**P706**

# [3922] - 104

## M.Sc.

## PHYSICS

## PHY UTN - 504 : Quantum Mechanics - I

## (Sem. - I) (New Course) (2008 Pattern)

*Time : 3 Hours]* *[Max. Marks : 80*

***Instructions to the candidates:***

1) *Question No. 1 is Compulsory. Attempt any four from the remaining.*
2) *Draw neat diagrams wherever necessary.*
3) *Figures to the right indicates full marks.*
4) *Use of logarithmic tables and calculator is allowed.*

***Q1)*** Attempt <u>any four</u> of the following :

a) A 1 eV electron is inside the surface of metal. If the potential barrier 4 eV having width 2 A.U., then calculate the probability of it's transmission.

(Given : $\hbar$ = $1.053 \times 10^{-34}$J×s; $m_e = 9.1 \times 10^{-31}$ kg & 1 eV = $1.6 \times 10^{-19}$ J) **[4]**

b) For the ground state of a linear harmonic oscillator, the wave function is

$$\phi_0(x) = \left(\frac{mw}{\pi\hbar}\right)^{1/4} e^{-mwx^2/2\hbar}.$$

Show that the uncertainty product is $\Delta X \Delta P_x = \frac{\hbar}{2}$.

(Given : $<X> = <P_x> = 0$). **[4]**

c) In three dimension, the ground state of H-atom is $\Psi(r) = \left(\frac{1}{\pi a_0^3}\right)^{1/2} e^{-r/a_0}$,

where $a_0$ = radius of first Bohr orbit. Show that the probability amplitude

is $C(p) = \frac{1}{\pi}\left(\frac{2a_0}{\hbar}\right)^{\frac{3}{2}} \frac{1}{\left[\frac{P^2 a_0^2}{\hbar^2} + 1\right]^2}$. **[4]**

*P.T.O.*

d) If operators A and B are hermitian, then show that $i$[A, B] is also hermitian. **[4]**

e) Explain projection operator. Why it is called unit operator. **[4]**

f) For $j = ½$; obtain matrices for $J_x$ and $J_y$. **[4]**

***Q2)*** a) Obtain eigen values and eigen functions of simple harmonic oscillator by abstract operator method. **[10]**

b) What are observable? Use expansion postulate to show that

i) Eigen-functions belonging to discrete eigen values are normalizable &

ii) Eigen-functions belonging to continuous eigen values are of infinite norm. **[6]**

***Q3)*** a) The square-well potential for finite walls are defined as :

$V(X) = V_0$ for $x < -a$ and $x > a$

$= 0$ for $-a < x < a$

For a particle having energy $E < V_0$; discuss the bound states. **[8]**

b) Explain the terms :

i) State vector and Dirac notations.

ii) Norm and scalar product.

iii) Hibert space and basis in it for any arbitrary $|\Psi\rangle$. **[8]**

***Q4)*** a) Define adjoint and self adjointness of operator. Show that i) the eigen values of hermitian operator are real and ii) any two eigen-functions of hermitian operator belongs to distinct (unequal) eigen-values are orthogonal. **[8]**

b) Obtain the Clebsch-Gorden coefficients matrix equation for a system having $j_1 = ½$ and $j_2 = ½$. **[8]**

***Q5)*** a) When a set of functions $\{\phi_a\}$ will be orthonormal and complete? Hence obtain closure relation $\sum_a \phi_a(X)\phi_a^*(X') = \delta(x \cdot x')$. **[6]**

b) Obtain eigen value spectrum of $J^2$ and $J_z$ operators. **[10]**

*Q6)* a) Describe Schroedinger and Heigenberg pictures during the evolution of system with time. **[8]**

b) Show that i) $\left(\frac{L_z}{\hbar}\right)$ plays role of the generator of infinitesimal rotations and ii) For finite rotations through an angle $\theta$, when $N \rightarrow \infty$ then $\psi'(x) = e^{i\theta\hat{n}\cdot\bar{L}/\hbar}|\psi(x)\rangle$, where N = number of infinitesimal rotations and $\hat{n}$ is unit vector about an arbitrary axis of rotation. **[8]**

*Q7)* a) What is spin angular momentum? i) State the commutation relations satisfied by $S_x$, $S_y$, $S_z$. ii) Write down eigen-value equations for simultaneous eigen states $|s, m_s\rangle$ of $S^2$ and $s_z$. **[4]**

b) Write down equation defining Pauli-matrices $\sigma$ interms of $\bar{s}$ for spin ½ particle and show that

i) $\lfloor\sigma_x, \sigma_y\rfloor = 2i\sigma_z$ and ii) $\sigma_x \sigma_y \sigma_z = i$. **[4]**

c) Show that operator $\hat{L}_z = -i\hbar\frac{\partial}{\partial\phi}$ is self-adjoint. **[4]**

d) If $H = \frac{1}{2}m\dot{q}^2 + v(q)$ then the equation $(qH - Hq) = i\hbar\dot{q}$ is satisfied when $qp - pq = i\hbar$ where $\dot{q} = \frac{dq}{dt}$. **[4]**

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Total No. of Questions : 7] [Total No. of Pages : 3

**P707**

# [3922] - 201

## M.Sc.

## PHYSICS

## PHY UTN - 601 : Electrodynamics

## (New Course) (2008 Pattern) (Sem. - II)

*Time : 3 Hours*] [*Max. Marks : 80*

***Instructions to the candidates:***

1) *Q. No. 1 is Compulsory and solve any four questions from the remaining.*
2) *Draw neat labelled diagrams wherever necessary.*
3) *Figures to the right indicate full marks.*
4) *Use of logarithmic tables and pocket calculator is allowed.*

***Q1)*** Attempt <u>any four</u> of the following :

a) Find the ratio of skin-depth in copper at 1 KHz to 100 MHz. **[4]**

b) An electron is accelerated from rest to a speed of 0.9995 C in a particle accelerator. Determine the total energy of electron, if it's rest mass energy is $8.2 \times 10^{-14}$ J. **[4]**

c) Compute the electric field associated with a LASER beam having energy per unit volume as 100 J/m$^3$. **[4]**

d) Calculate the magnitude of Poynting's vector at the surface of the sun. Give that the power radiated by sun is equal to $3.8 \times 10^{26}$ Watt and radius of the sun is equal to $7 \times 10^8$ m. **[4]**

e) Calculate the wave impedance of an e.m. wave travelling through free-space. **[4]**

Given : for free - space

$$\mu = \mu_0 = 4\pi \times 10^{-7} \frac{Wb}{A-m} \text{ and } \in = \in_o = 8.85 \times 10^{-12} \frac{c^2}{N-m^2}.$$

f) Describe magnetic interaction between the two current loops. **[4]**

*P.T.O.*

*Q2)* a) What is a linear quadrupole? Derive an expression for potential at a distant point due to a small linear quadrupole. **[8]**

b) Show that $C^2B^2–E^2$ and $\vec{E}\cdot\vec{B}$ are invariant under Lorentz transformations. **[8]**

*Q3)* a) The magnetic field intensity $\vec{B}$ at a point is given by $\vec{B}=\left(\frac{\mu_0}{4\pi}\right)\int\frac{\vec{j}\times\vec{r}}{r^3}d\tau$.

Show that Curl $\vec{B}=\mu_0\vec{j}$. **[8]**

b) What is an oscillating electric dipole? Derive the expression for electric and magnetic field radiations, when the length of the dipole is extremely small as compared with the wavelength of radiation. Hence explain 'radiation resistance'. **[8]**

*Q4)* a) Explain the term electromagnetic field tensor. Hence obtain an expression for e.m. field tensor $F_{\mu\upsilon}$. **[8]**

b) What is Hertz potential? Show that the electric and magnetic fields can be expressed in terms of Hertz potential as $\vec{E}=\vec{\nabla}\times\left(\vec{\nabla}\times\vec{Z}\right)$ and $\vec{B}=\frac{1}{C^2}\frac{\partial}{\partial t}\left(\vec{\nabla}\times\vec{Z}\right)$, where $\vec{Z}$ is the Hertz potential. **[8]**

*Q5)* a) Show that the Maxwell's equations in a charge free region lead to :

$$\nabla^2\vec{E}-\frac{k\,k_m}{C^2}\frac{\partial^2\vec{E}}{\partial t^2}-\mu\sigma\frac{\partial\vec{E}}{\partial t}=0$$

Explain which term can be ignored in a nonconducting medium. **[8]**

b) Prove that the space interval $x^2 + y^2 + z^2$ is not invariant under Lorentz transformations, while the combined space - time interval $x^2 + y^2 + z^2 - c^2t^2$ is Lorentz invariant. **[8]**

*Q6)* a) If a medium is moving with a velocity $\vec{u}$, then show that the Faraday's law has the form $\vec{\nabla}\times\left(\vec{E}'-\vec{u}\times\vec{B}\right)=-\frac{\partial\vec{B}}{\partial t}$. **[8]**

b) A plane e.m. wave is incident obliquely on an interface between the two non-conducting dielectric media. Obtain expressions for Fresnel's equations if the electric field vectors are perpendicular to the plane of incidence. **[8]**

***Q7)*** a) Explain the term 'four vector potential'. **[4]**

b) Write Mexwell's equations in differential and integral forms. **[4]**

c) Given the e.m. wave : **[4]**

$\vec{E} = \hat{i} E_0 Cos\, W\left(\sqrt{\in \mu}\, Z - t\right) + \hat{j} E_0\, Sin\, W\left(\sqrt{\in \mu}\, Z - t\right)$, where $E_0$ is constant. Find the corresponding magnetic field.

d) Find the phase velocity of a plane e.m. wave at a frequency of 10 GHz in Polyethelene material.

Given : $\mu \simeq \mu_0 = 4\pi \times 10^{-7} \dfrac{Wb}{A-m}, \in_r = 2.3, \in_0 = 8.85 \times 10^{-12} \dfrac{c^2}{N-m^2}$ and

$\sigma = 2.56 \times 10^{-4} \dfrac{mho}{m}$ . **[4]**

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Total No. of Questions : 7] [Total No. of Pages : 3

**P709**

# [3922] - 203

## M.Sc.

## PHYSICS

## PHY UTN - 603 : Statistical Mechanics

## (New Course) (2008 Pattern) (Sem. - II)

*Time : 3 Hours*] [*Max. Marks : 80*

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory. Attempt any four of the remaining questions.***
2) ***Draw neat diagrams wherever necessary.***
3) ***Figures to the right indicate full marks.***
4) ***Use of logarithmic tables and electronic calculators is allowed.***

***Q1)*** Attempt any four of the following : **[4]**

a) A system with two energy levels in thermal equilibrium with a heat reservoir at temperature 608 K. The energy gap between the levels is 0.1 eV. Find the probability that the system is in the higher energy level.

b) Considering the system consisting of N weakly interacting particles each of spin ½ and magnetic moment μ, located in an external magnetic field H. Suppose that the system is in thermal contact with a heat reservoir at absolute temperature T. Calculate mean energy $\overline{E}$ as a function of T and H. **[4]**

c) Prove the following relation $S = -k\sum_{r} p_r \ln p_r$ . **[4]**

d) Determine wether the electron gas in copper at room temperature is degenerate or non-degenerate (concentration of electrons in copper is $8.5 \times 10^{28}\ cm^{-3}$). **[4]**

e) State and explain the postulate of equal a priori probability. **[4]**

f) Using Maxwell's law of velocity distribution, prove that the mean value of $V_x^2$ is

$$\overline{V_x^2} = \frac{kT}{m}$$ **[4]**

*P.T.O.*

*Q2)* a) Show that when T << $\theta_r$,

$$(C_v)_{rot} = 12\,\mathrm{NK}\left(\frac{\theta_r}{\mathrm{T}}\right)^2 e^{-\frac{2\theta_r}{\mathrm{T}}}.$$

Where, $\theta_r$ = The rotational characteristic temperature in the lowest approximation. **[8]**

b) What is Gibb's paradox? How it is resolved? **[8]**

*Q3)* a) What are classical limits? Explain, how quantum distribution laws are reduced to classical Maxwell – Boltzmann distribution. Hence, show that

$$\overline{\mathrm{n}\cdot s} = \mathrm{N}\frac{e^{-\beta\epsilon_s}}{\sum_s e^{-\beta\epsilon_s}}.$$ **[8]**

b) Using canonical distribution, obtain the law of atmosphere. **[8]**

*Q4)* a) For Debye's model of specific heat of solids, show that,

$$C_v = \frac{12}{5}\pi^4\,\mathrm{NK}\left(\frac{\mathrm{T}}{\theta_\mathrm{D}}\right)^3.$$ **[8]**

b) State and prove Liouville's theorem. **[8]**

*Q5)* a) Considering Eienstein's idea about system of oscillators and radiations in equilibrium in an isothermal enclosure, derive Plank's law. **[8]**

b) Describe the formation and evolution process of white Dwarf star. **[8]**

*Q6)* a) Derive an expression for classical partition function for an ideal monoatomic gas and obtain various thermodynamic quantities. **[8]**

b) Show that the value of the single particle momentum corresponding to the Fermi energy which is referred as Fermi momentum is given by

$$P_f = \frac{\hbar}{l}\cdot\left[\frac{6\mathrm{N}\pi^2}{(2s+1)\mathrm{V}}\right]^{1/3}.$$ **[8]**

***Q7)*** a) Discuss the distribution of energy between two systems in thermal contact and obtain the condition at thermal equilibrium. **[8]**

b) State and prove equipartion theorem. **[8]**

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Total No. of Questions : 7] [Total No. of Pages : 3

**P711**

# [3922] - 301

## M.Sc. (Semester - III)

## PHYSICS

## PHY UTN - 701 : Solid State Physics

## (New Course) (2008 Pattern)

*Time : 3 Hours*] [*Max. Marks : 80*

***Instructions to the candidates:***

1) ***Q. No. 1 is Compulsory and solve any four questions from the remaining.***
2) ***Figures to the right indicate full marks.***
3) ***Draw neat labelled diagram wherever necessary.***
4) ***Use of logarithmic table and pocket calculator is allowed.***

***Given :-***

| | | |
|---|---|---|
| *Rest mass of electron* | = | $9.109 \times 10^{-31}$ *Kg.* |
| *Charge of electron* | = | $1.6021 \times 10^{-19}$ *C.* |
| *Planck's constant* | = | $6.626 \times 10^{-34}$ *J–S.* |
| *Boltzmann constant* | = | $1.3805 \times 10^{-23}$ $JK^{-1}$. |
| *Avogadro's number* | = | $6.0225 \times 10^{26}$ $(Kilomole)^{-1}$. |
| *Bohr magneton* | = | $9.27 \times 10^{-24}$ $A\text{–}m^2$. |
| *Permeability of free-space* | = | $4\pi \times 10^{-7}$ *Henry/m.* |
| *Permittivity of free-space* | = | $8.85 \times 10^{-12}$ $C^2/N\text{-}m^2$. |

***Q1)*** Attempt any four of the following : **[16]**

a) Calculate the number of energy states lying in an energy interval of 0.02 eV above $E_F$ for Sodium crystal of unit volume. $E_F = 3.22$ eV.

b) Determine the energy to which electrons are excited at 200 K. Given : $F(E) = 0.1$ and $E_F = 3$ eV.

c) Show that for Kronig-Penny potential with P << 1, the energy of the lowest energy band at K = 0 is $E = \frac{\hbar^2 P}{ma^2}$.

***P.T.O.***

d) A paramagnetic material is subjected to a homogeneous field of $10^6$ A/m at 37°C. Calculate the average magnetic moment along the field direction per spin in Bohr magneton.

e) A superconducting material has a critical temperature of 3.7 K in zero magnetic field and a critical field of 0.0306 Tesla at zero K. Find the critical field at 2 K.

f) Calculate the critical current which can flow through a long thin superconducting wire of Al of diameter 1 mm. The critical magnetic field for Al is $8 \times 10^3$ A/m.

***Q2)*** a) What are longitudinal plasma oscillations? Derive expression for the frequency of these oscillations. Draw necessary diagrams. **[8]**

b) Explain with the help of neat diagrams reduced, periodic and extended zone schemes. **[8]**

***Q3)*** a) Describe motion of electron in one dimensional periodic potential. Explain the concept of effective mass m*. Draw E–K, V–K and m*–K diagrams. **[8]**

b) Explain origin of band-gap using nearly free electron model. **[8]**

***Q4)*** a) Derive London equation for superconducting state and obtain an expression for the superconducting penetration depth. **[8]**

b) Explain Langevin's classical theory of paramagnetism. Hence obtain an expression for paramagnetic susceptibility. **[8]**

***Q5)*** a) Distinguish between ferromagnetism, ferrimagnetism and antiferromagnetism. **[8]**

b) Explain thermodynamics of superconductivity with special reference to the stabilization energy. **[8]**

***Q6)*** a) Describe the Weiss molecular field theory of ferromagnetism with reference to Curie point. Hence derive the relation for Curie-Weiss law. **[8]**

b) Explain Meissner effect in superconductivity. **[4]**

c) Describe Josephson superconducting tunneling. **[4]**

*Q7)* a) Write the expression for F-D statistics and explain how the distribution changes with temperature. **[4]**

b) Write an expression for Bloch function and discuss it's properties. **[4]**

c) The Curie temperature of Iron is 1043K. Assume that Iron atoms when in the metallic form have moments of two Bohr magneton per atom. Iron is bcc and edge of the cube is 2.86 $\mathring{A}$. Calculate the saturation magnetization. **[4]**

d) Explain the application of a superconductor based on IR property. **[4]**

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Total No. of Questions : 7] [Total No. of Pages : 2

**P712**

# [3922] - 401
# M.Sc.
# PHYSICS
## PHY UTN - 801 : Nuclear Physics
## (New Course) (2008 Pattern) (Sem. - IV)

***Time : 3 Hours]*** ***[Max. Marks :80***

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory. Attempt any four of the remaining.***
2) ***Draw neat diagrams wherever necessary.***
3) ***Figures to the right indicate full marks.***
4) ***Use of logarithmic tables and pocket calculator is allowed.***

***Q1)*** Attempt any four of the following: **[16]**

a) Find the energy released if two, ${}_1H^2$ nuclei can fuse together to form ${}_2He^4$ nucleus.

Given that Binding energy per nucleon of ${}_1H^2$ & ${}_2He^4$ is 1.1 MeV & 7.00 MeV respectively.

b) Calculate the maximum energy of the compton recoil is from the absorption in Al of 2.19 MeV $\gamma$ rays.

Given $m_0 = 4.109 \times 10^{-31}$ kg.

c) For energy fitters in mass spectrometers, show that $\frac{1}{2}mV^2 = \frac{n_e VR_0}{2d}$

where the symbols have usual meanings.

d) In a mass spectrometer a single charged positive ion is accelerated through a potential difference of 1000 volts. It then travels through a uniform magnetic field at 1000 Gauss and is deflected in a circular path of radius 18.2 cm. Find

i) Speed of the ion.

ii) Mass of the ion.

e) Calculate the total cross section for n-p scattering of neutrons having energy 2 MeV

given :

$a_t = 5.38$ F $\quad$ $a_s = 23.4$ F

$r_{ot} = 1.70$ F $\quad$ $r_{os} = 2.40$ F

f) Calculate the radius of $Cl^{33}$ nucleus from the information that it delays by position emission with a maximum energy of 4.8 MeV.

***P.T.O.***

*Q2)* a) What is Compton effect? Derive the expression for Compton cross-section in case of a Linearly polarized, plane electro magnetic wave. **[8]**

b) Describe the shape independent effective range scattering theory and obtain the expression for cross-section in terms of effective range. **[8]**

*Q3)* a) Explain the magnetic dipole moment. Show that, for the nucleus of mass number A the magnetic dipole moment is

$$\vec{\mu}=\frac{\mu_0 e}{2m}\left[\sum_{k=1}^{\mathbf{A}} g_s \vec{S}_k + \sum_{k=1}^{\mathbf{Z}} g_l \vec{l}_k\right]$$ **[8]**

b) What are quarks? Explain how quarks are treated as a building blocks of hadrons and mesons. **[8]**

*Q4)* a) What is a struggling? Derive the formula for struggling when a charged particle is moving through the matter. **[8]**

b) Show that for low energy n-p scattering $\sigma_0 = \frac{4\pi}{k^2}\sin^2\delta_0$ where the symbols have usual meaning. **[8]**

*Q5)* a) Discuss the theory of Microtron. Show that increase in energy after each orbit is given by $\Delta E = \frac{E_0\gamma}{\mu-\gamma}$ where symbols have their usual meaning. **[8]**

b) Explain the multiple radiation in case of $\gamma$ decay. State the selection rules. **[8]**

*Q6)* a) Derive Bethe's formula for 'Stopping Power' of charged particles moving through matter. Write the expression for relativistic effects. **[8]**

b) Write a short note on pair production. **[4]**

c) By considering the conservation of strangeness, conservation of baryon number and conservation of charge, verify the following reaction and state whether reaction is allowed or forbidden $\pi^+ + n \rightarrow \wedge^o + k^+$. **[4]**

*Q7)* a) Explain the principle, construction and working of Bainbridge mass spectrograph. Explain its merits and demerits. **[8]**

b) Explain the concept of Isospin associated with elementary particles. **[4]**

c) Explain why experimentally the study of p-p scattering is capable of much higher accuracy than n-p scattering. **[4]**

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**Total No. of Questions : 7]** **[Total No. of Pages : 2**

**P712**

# [3922] - 401
# M.Sc.
# PHYSICS
## PHY UTN - 801 : Nuclear Physics
## (Old Course) (2005 Pattern) (Sem. - IV)

***Time : 3 Hours]*** ***[Max. Marks :80***

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory.***
2) ***Attempt any four from the remaining questions.***
3) ***Figures to the right indicate full marks.***
4) ***Use of mathematical tables and electronic pocket calculator is allowed.***

***Q1)*** Attempt any four of the following: **[16]**

a) Write the shell configuration and predict the spin and parity of the following nuclei on the basis of single particle shell model

i) ${}_{6}C^{12}$

ii) ${}_{8}O^{17}$

b) Derive the expression for nuclear magnetic moment of proton.

c) In an absorption experiment with 1.14 MeV - $\gamma$ radiation from $Z_n^{65}$, it is found that 25 cm of aluminium reduce the beam intensity to 2%. Calculate the half-life value thickness and the mass absorption coefficient of Aluminium $P_{Al} = 2700$ kg/m$^3$.

d) In a Bainbridge and Jordon mass-spectrograph singly ionized atoms of Neon 20 pass into the deflection chamber with a velocity of $10^5$ m/sec. If they are deflected by a magnetic field of flux density 0.08 tesla, calculate the radius of their path. If the initial velocity of Neon-22 is same as that of Neon 20, find the radius of Neon-22.

Given : Mass of proton = 1.67 x $10^{-27}$ kg.

e) What are ortho and para hydrogen molecules? Show that if spin of neutron is assumed to be 3/2 then $\frac{\sigma_{\text{ortho}}}{\sigma_{\text{para}}} \simeq 2$.

f) Calculate the scattering lengths $a_t$ and $a_s$. Given that $\sigma_{\text{para}} = 4.19$ and $\sigma_{\text{ortho}} = 128$ bars.

***P.T.O.***

*Q2)* a) Describe the working of Bainbridge mass spectrograph state its advantages and disadvantages. **[8]**

b) Explain significance of variation of binding energy per nucleon as a function of mass number. **[8]**

*Q3)* a) Discuss mass parabola for odd A and even A nucleus, on the basis of liquid drop model of the nucleus. **[8]**

b) Discuss effective range theory of n-p scattering. Hence obtain expression for scattering length and effective range. **[8]**

*Q4)* a) Describe the high energy electron scattering method to determine the size of a nucleus. **[8]**

b) Calculate the electric quadrapole moment of a charge of magnitude $Z_e$, over a ring of radius R and with axis along Z axis. **[8]**

*Q5)* a) Find the angular momentum and parity for the ground state of ${}_{16}S^{33}$ nucleus from the single particle shell model. **[4]**

b) Derive the expression for Nuclear magnetic moment of proton. **[4]**

c) Discuss coherent scattering of slow neutrons. **[8]**

*Q6)* a) Write a note on nuclear reactors in India. **[8]**

b) Discuss the properties, production and decay modes of muons and pions. **[8]**

*Q7)* a) Discuss the theory of Microtron. Show that increase in energy after each orbit is given by

$$\Delta E = \frac{E_0 \gamma}{\mu - \gamma}$$

Where symbols have their usual meaning. **[8]**

b) Write a note on quark theory. **[8]**

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**Total No. of Questions : 7]** **[Total No. of Pages :2**

# P704

## [3922] - 102
## M.Sc.
## PHYSICS
### PHY UTN 502 : Electronics
### (New Course) (Sem. - I) (2008 Pattern)

*Time : 3 Hours]* *[Max. Marks :80*

***Instructions to the candidates:***

1) *Question No. 1 is compulsory. Attempt any four questions from the remaining.*
2) *Figures to the right indicate maximum marks.*
3) *Draw neat diagrams wherever necessary.*
4) *Use of logarithmic tables and calculators is allowed.*

***Q1)*** Attempt any four of the following:

a) Sketch a circuit diagram of a notch filter. State the formula for the notch frequency. Explain its frequency response. **[4]**

b) Design a second order low-pass filter with a cutoff frequency of 4kHz and a passband gain of 2. Sketch the circuit diagram and frequency response. **[4]**

c) Sketch the functional block diagram of IC 8038. Design a function generator using IC 8038 to provide an output frequency of 5 kHz. **[4]**

d) Explain the working of a sample and hold circuit. **[4]**

e) Design a regulated supply which is variable from +5V to +25 V using LM 317. Sketch the circuit diagram. **[4]**

f) Explain the use of a PLL as a frequency multiplier. **[4]**

***Q2)*** a) Sketch the circuit diagram and explain the working of a step-down switching regulator. **[8]**

b) Sketch a functional block diagram of IC 566 and explain its working. Design a VCO using IC 566 for a nominal output frequency of 2kHz. **[8]**

***Q3)*** a) Explain the working of foldback current limiting using IC 723 and external components. **[8]**

b) Discuss the working of an Instrumentation Amplifier. **[8]**

*Q4)* a) Explain the working of a Dual-slope type ADC. **[8]**

b) Sketch a diagram of a full wave precision rectifier and explain its working. **[8]**

*Q5)* a) Explain the working of a PLL. Determine the free running frequency, capture range and lock range for an IC 565. Given $V_{cc} = \pm 12$ V $R_1 = 10$ kΩ, $C_1 = 0.04$ 7μF, $C_2$ =10μF. **[8]**

b) Show how a Karnaugh map can be used to realize a four input logic circuit where the output is to be high if at least two inputs are HIGH. **[6]**

c) State four logic Identities. **[2]**

*Q6)* a) What is a shift register? How is it used? Explain the working of two types of shift registers. **[8]**

b) What is a monostable multivibrator? Explain the working of IC 555 as a monostable multivibrator. Design a monostable multivibrator using IC 555 for an output pulse width of 20 ms. **[8]**

*Q7)* Write short notes on any FOUR of the following: **[16]**

a) Optical fibre communication

b) PLA's

c) UPS

d) Satellite communication

e) DAC

f) Up-Down counters

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Total No. of Questions : 7] [Total No. of Pages :2

**P708**

# [3922] - 202
# M.Sc.
# PHYSICS
## PHY UTN - 602 : Atoms, Molecules and Solids
## (New Course) (2008 Pattern) (Sem.- II)

*Time : 3 Hours]* *[Max. Marks :80*

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory. Solve any four questions of the remaining.***
2) ***Draw neat diagrams wherever necessary.***
3) ***Figures to the right indicate full marks.***
4) ***Use of logarithmic tables and electronic pocket calculator is allowed.***

Given :

| | |
|---|---|
| Rest mass of electron | $= 9.109 \times 10^{-31}$ kg. |
| Charge on electron | $= 1.6021 \times 10^{-19}$ coulomb. |
| Plank's constant | $= 6.626 \times 10^{-34}$ J.s. |
| Boltzmann constant | $= 1.38054 \times 10^{-23}$ $JK^{-1}$. |
| Avogadro's number | $= 6.02252 \times 10^{26}$ $(k\ mole)^{-1}$. |
| Bohr magneton | $= 9.27 \times 10^{-24}$ amp.-$m^2$. |
| 1eV | $= 1.6021 \times 10^{-19}$ J. |

***Q1)*** Attempt any four of the following. **[16]**

a) If the Debye temperature of a solid is 2000 K, what will be its specific heat at temperature 27°C.

b) The vibrational structure of the absorption spectrum of $O_2$ becomes a continuum at 56,876 $cm^{-1}$. If the upper electronic state dissociates into one ground state atom and one excited atom with excitation energy 15,875 $cm^{-1}$, estimate the dissociation energy of the ground state in $cm^{-1}$ and kJ/mole.

c) The ground state of chlorine is $^2P_{3/2}$. Find the magnetic moment of chlorine.

d) Find the maximum radius of interstitial sphere that can just sit into the void at $\left(\frac{1}{2},\frac{1}{2},\frac{1}{2}\right)$ between the body centred atom of bcc structure in terms of radius of atom.

*P.T.O.*

e) Find the minimum magnetic field needed for Zeeman effect to be observed in a spectral line of 400 nm wavelength, when a spectrometer of resolution 0.01 nm is used.

f) Calculate the magnetic field required to get a transition frequency 60 MHz for fluorine.
<u>Given</u> : $g_N = 5.255$, $\mu_N = 5.051 \times 10^{-27}$ $JT^{-1}$.

***Q2)*** a) Define dissociation energy for a diatomic molecule. Obtain an expression for $\upsilon_{max}$ corresponding to the dissociation energy. **[8]**

b) Draw a block diagram of simple ESR spectrometer. Explain the working and state different applications of ESR. **[8]**

***Q3)*** a) What is anamolous Zeeman effect? Derive the formula for $\Delta\upsilon$ in this case. Explain importance of Lande's $g$ factor. **[8]**

b) What are P,Q and R branches in the context of rotational fine structure of electronic vibration spectra. Hence define band head and band origin. Draw necessary diagrams. **[8]**

***Q4)*** a) Explain the Paschen-Back effect for 2s - 2p transition. **[8]**

b) Derive the expression for geometrical structure factor for a bcc structure.**[8]**

***Q5)*** a) What are the assumptions of Einstein model of specific heat? Derive an expression for the same. **[8]**

b) Obtain an expression for the temperature dependance of concentration of vacancies in metal. **[8]**

***Q6)*** a) Derive the relation between W & K for vibrational modes in one-dimensional mono-atomic lattice of identical atoms. **[8]**

b) Explain concept of phonon with reference to quantization of elastic waves in solids. **[4]**

c) What is the difference between edge and screw dislocation? **[4]**

***Q7)*** a) Write a note on colour centers. **[4]**

b) Explain with diagrams what do you mean by Umklapp processes and normal processes. **[4]**

c) Define and explain configurational entropy. **[4]**

d) The value of $x_e$ for lower and upper states of $C_2$ are 0.00711 & 0.00919 respectively. Find the no. of levels in the upper and lower states. **[4]**

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Total No. of Questions : 7] [Total No. of Pages :2

**P710**

# [3922] - 204
# M.Sc.
# PHYSICS
## PHY UTN 604 : Quantum Mechanics - II
## (New Course) (2008 Pattern) (Sem.- II)

*Time : 3 Hours]* *[Max. Marks :80*

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory. Attempt any four from the remaining.***
2) ***Figures to the right indicate full marks.***
3) ***Draw neat diagrams wherever necessary.***
4) ***Use of mathematical tables and calculator is allowed.***

***Q1)*** Attempt any four of the following. **[16]**

a) Show that the variation method gives an upper bound to the ground state energy.

b) Using time independent perturbation theory, explain splitting of the $1p \rightarrow 1s$ zeeman transition of an atom placed in magnetic field B along z direction.

c) Discuss the conditions of validity of WKB approximation.

d) What is Born approximation? Show that the scattering amplitude is the fourier transform of the scattering potential.

e) Obtain an expression for phase-shift and total scattering cross-section for s-wave scattering ($l = 1$) by the potential

$$\upsilon(r) = \infty \text{ for } 0 \leq r \leq a$$
$$= 0 \text{ for } r > a.$$

f) Explain the term

i) identical particles and

ii) symmetric and antisymmetric wave functions.

***Q2)*** a) Explain time independent perturbation theory and obtain first and second order correction equations. Hence for stationary and nondegenarate case obtain the expressions for first and second order correction to the energy. **[10]**

b) Obtain slatter determinant for a system of N-electrons. **[6]**

***P.T.O.***

*Q3)* a) Obtain the expression for scattering amplitude by using Green's function. **[8]**

b) Explain stark effect. Explain the energy correction for the first excited level of the hydrogen atom. **[8]**

*Q4)* a) State and prove Fermi Golden rule for the rate of transition induced by a constant perturbation. **[8]**

b) Using variation method, obtain ground state energy of hydrogen atom by using a trial wave function $\psi(r) = Ae^{-\alpha r}$ where $\alpha$ is variation parameter. **[8]**

*Q5)* a) Explain the partial wave analysis of scattering obtain the expression for scattering Amplitude in terms of phase - shifts : Hence obtain the total cross-section. **[8]**

b) Define exchange operator in case of system of identical particles 1 and 2. Find the eigen values of the operator. Hence i) explain symmetric and antisymmetric wave functions ii) show that it commutes with the Hamiltonian operator. **[8]**

*Q6)* a) Calculate the differential cross-section and total cross-section in the Born approximation for yukawa potential $v(r) = v_o \frac{e^{-\alpha r}}{r}$, where $V_o$ and $\alpha$ are constants. **[8]**

b) Use perturbation theory to obtain the first order correction to $n^{th}$ energy level of an anharmonic oscillator with Hamiltonian $H = \frac{p^2}{2m} + \frac{m}{2}\omega^2 x^2 + \lambda x^4$, for a very small value of $\lambda$. **[8]**

*Q7)* a) Discuss validity conditions of Born approximation. **[4]**

b) Explain selection rules for electric dipole transitions. **[4]**

c) Using WKB approximation, explain $\alpha$-particle emission by nuclei. **[4]**

d) Discuss scattering event in laboratory frame and center of mass frame and obtain relation : $\tan\theta_o = \frac{\sin\theta}{(m_1/m_2) + \cos\theta}$. where $\theta_0$ and $\theta$ are scattering angles in lab and CM frames respectively. **[4]**

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**Total No. of Questions : 7]** **[Total No. of Pages :2**

# P711

# [3922] - 301
# M.Sc.
# PHYSICS
## PHY UTN 701 : Solid State Physics
## (New Course) (Sem.- III)

***Time : 3 Hours]*** ***[Max. Marks :80***

***Instructions to the candidates:***

1) ***Question No. 1 is compulsory. and solve any four questions from the remaining.***
2) ***Figures to the right indicate full marks.***
3) ***Draw neat labelled diagrams wherever necessary.***
4) ***Use of logarithmic tables and pocket calculator is allowed.***

Given:

| | |
|---|---|
| Rest mass of electron | $= 9.109 \times 10^{-31}$ kg. |
| Charge of electron | $= 1.6021 \times 10^{-19}$ coulomb. |
| Planck's constant | $= 6.626 \times 10^{-34}$ J-s. |
| Boltzmann constant | $= 1.3805 \times 10^{-23}$ $JK^{-1}$. |
| Avogadro's number | $= 6.0225 \times 10^{26}$ $(\text{kilo mole})^{-1}$. |
| Bohr magneton | $= 9.27 \times 10^{-24}$ $A\text{-}m^2$. |
| Permeability of free space | $= 4\pi \times 10^{-7}$ Henry/m. |
| Permittivity of free space | $= 8.85 \times 10^{-12}$ $C^2/N\text{-}m^2$. |

***Q1)*** Attempt any four of the following. **[16]**

a) Calculate the number of energy states lying in an energy interval of 0.02 eV above $E_F$ for sodium crystal of unit valume. $E_F = 3.22$ eV.

b) The momentum of electron at the boundary of first Brillouin zone is $1.1 \times 10^{-24}$ kg m/s. Calculate the lattice constant of the crystal using this data.

c) The band gap of a semiconductor is 2 eV. Calculate the wavelength of the emitted radiation when electron and hole recombine.

d) A magnetic material has a magnetization of 3300 A/m and magnetic flux density of $4.4 \times 10^{-3}$ T. Calculate the magnetizing force.

e) The London penetration depths for Lead at 3K and 7.1K are 39.6 nm and 173 nm respectively. Calculate it's transition temperature.

f) The Curie temperature of Iron is 1043K. Assume that Iron atoms when in the metallic form have moments of two Bohr magneton per atom. Iron is bcc and edge of the cube is 2.86 Å. Calculate the saturation magnetization.

*Q2)* a) Derive the expression for local electric field $E_{local}$ at an atom placed at general lattice site. Explain each term in the expression. **[8]**

b) Explain the formation of energy gap on the basis of nearly free electron model. **[8]**

*Q3)* a) Draw neat diagrams showing construction of 2-D Fermi surfaces in first, second and third Brillouin zones. Explain and interpret these diagrams. **[8]**

b) Derive the expression for energy levels of free electron in 1-D box of length L. What is Fermi energy? **[8]**

*Q4)* a) Explain the origin of diamagnetism in a free atom. Derive Langevin's diamagnetism equation for the diamagnetic susceptibility. **[8]**

b) Distinguish between ferromagnetism, antiferromagnetism and ferrimagnetism. **[8]**

*Q5)* a) Derive London equation for superconducting state and obtain an expression for the penetration depth. **[8]**

b) Give an account of Weiss theory of ferromagnetism and show from the plot of Langevin's function, spontaneous magnetization exists below the Curie temperature and vanishes above the Curie temperature. **[8]**

*Q6)* a) Explain BCS theory of superconductivity. **[8]**

b) What is meant by hysteresis in magnetic materials? **[4]**

c) Explain Meissner effect in superconductivity. **[4]**

*Q7)* a) Hole is a fictious particle. Comment. **[4]**

b) The relative permittivity of Ar at zero °C and 1 atmosphere is 1.000435. Calculate the polarizability. **[4]**

c) The magnetic field strength in silicon is 1000 A/m. If the magnetic susceptibility is $-(0.3 \times 10^{-5})$, calculate the magnetization and flux density in Silicon. **[4]**

d) Describe Josephson superconducting tunneling. **[4]**

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