APPLIED PHYSICS – II

Paper Code: BS-106 L T C
Paper : APPLIED PHYSICS – II 2 1 3
INSTRUCTIONS TO PAPER SETTERS: MAXIMUM MARKS: 75

1. Question No. 1 should be compulsory and cover the entire syllabus. This question should have objective or short answer type questions. It should be of 25 marks.
2. Apart from Question No. 1, rest of the paper shall consist of four units as per the syllabus. Every unit should have two questions. However, student may be asked to attempt only 1 question from each unit. Each question should be of 12.5 marks.

Objective: The objective of the paper is to facilitate the student with the basics of Applied Physics aspects that are required for his understanding of basic physics.

UNIT I

Quantum Mechanics: Introduction; wave particle duality**,** de-Broglie waves, The experiment of Davisson Germer, electron diffraction, physical interpretation of Wave function, properties, The Wave Packet, Phase and group velocities, Uncertainty principle, Schrodinger wave equation (1D) for free particle, Eigen vales and eigen function, Expectation values, Simple eigen value problems- Solution of Schrodinger equation for free particle, Infinite well, Finite well, Tunnelling effect, Scanning electron microscope, quantum simple harmonic oscillator, Zero point energy

[T1], [T2][No. of Hrs. 8]

UNIT II

Statistical Physics: The need for statistics, statistical distribution: Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics and their comparison, Fermions and bosons, Applications of quantum statistics (1) Molecular speed and energies in an ideal gas (2) Black body spectrum, the failure of classical statistics to give the correct explanation-Bose Einstein statistics applied to the black body radiation spectrum. Fermi-Dirac distribution, free electron theory, electronic specific heat, Fermi energy and average energy, dying star

[T1][T2][No. of Hrs. 8]

UNIT III

Crystal Structure: Types of solids, Unit cell, Types of crystals, Translation vectors, Lattice planes, Miller indices, Simple crystal structures, Interplanar spacing, Crystal structure analysis: Bragg's law, Laue method, Point defects: Schottky and Frankel defects.

[T1], [T2][No. of Hrs. 8]

UNIT IV

Band Theory of Solids: Origin of energy bands in solids, Motion of electron in periodic potential-Kronig-Penney model(qualitative), Brillouin zones, Effective mass, Metals, semiconductors and Insulators and their energy band structures, Extrinsic and Intrinsic semiconductors, doping – Fermi energy for doped and undoped semiconductors, pn junction (energy band diagram with fermi energy), the unbiased diode, forward and reversed biased diode- Tunnel diode, Zener diode, photo diode, its characteristics, LED

[T1][T2][No. of Hrs. 8]

Text Books:

[T1]. Arthur Beiser 'Concepts of Modern Physics', [McGraw-Hill], 6th Edition 2009.
[T2]. A. S.Vasudeva, 'Modern Engineering Physics', S. Chand, 6th Edition, 2013.

Reference Books

[R1]. Richard Wolfson 'Essential University Physics' Pearson, Ist edition, 2009.
[R2]. H.K. Malik & A. K. Singh 'Engineering Physics' [McGraw-Hill], Ist Edition, 2009.
[R3]. C. Kittle, 'Mechanics', Berkeley Physics Course, Vol.- I. Latest Edition.
[R4]. Irving Kaplan 'Nuclear Physics' Latest Edition.

[R5]. John R. Taylor, Chris D. Zafirator and Michael A. Dubson, ‘Modern Physics For Scientists and
Engineers’, PHI, 2nd Edition.
[R6]. D.J. Griffith, ‘Introduction to Electrodynamics’, Prentice Hall, Latest Edition.

APPLIED PHYSICS LAB – II

Paper Code: BS-152 P C
Paper: Applied Physics Lab – II 2 1
LIST OF EXPERIMENTS

1. To determine the e/m ratio of an electron by J.J. Thomson method.
2. To measure the frequency of a sine-wave voltage obtained from signal generator and to obtain lissajous pattern on the CRO screen by feeding two sine wave signals from two signal generators.
3. To determine the frequency of A.C. mains by using Sonometer .
4. To determine the frequency of electrically maintained tuning fork by Melde’s method.
5. Computer simulation (simple application of Monte Carlo): Brownian motion, charging & discharging of a capacitor.
6. To study the charging and discharging of a capacitor and to find out the time constant.
7. To study the Hall effect.
8. To verify Stefan’s law.
9. To determine the energy band gap of a semiconductor by four probe method/or by measuring the variation of reverse saturation current with temperature.
10. To study the I-V characteristics of Zener diode.
11. To find the thermal conductivity of a poor conductor by Lee’s disk method.
12. To study the thermo emf using thermocouple and resistance using Pt. Resistance thermometer.

Suggested Books:

[T1] C. L. Arora ‘B. Sc. Practical Physics’ S. Chand, Latest edition.

Note: Any 8-10 experiments out of the list may be chosen. Proper error – analysis must be carried out with all the experiments

Question bank

UNIT I

Quantum Mechanics:

Q 1. **Explain expectation value. Calculate the expectation value of x for a particle in a 1-D box.**

Q 2. **Calculate the De-Broglie wavelength of basket ball of mass 1 kg moving at a speed of 10 m/s. Discuss the reason, why we can't observe its wave nature?**

Q 3. **What is quantum mechanical tunnelling?**

Q 4. **An electron is constrained to move in a 1-D box of length 0.1 nm. Find the first three energy Eigen values and the corresponding De-Broglie wavelength.**

Q 5. **Find the probability that the particle trapped in a box "L" wide can be found between 0.45 L and 0.55 L for the first excited state.**

Q 6. **Explain postulates of quantum mechanics.**

Q 7. **What do you mean by the dual nature of matter and wave? Describe an experiment to support it.**

Q 8. **State Heisenberg's uncertainty principle and explain its validity by any thought experiment.**

Q 9. **Set up the Schrodinger equation for a particle in an infinite well (1-D). Solve it for Eigen values and Eigen functions. Plot the first three Eigen functions and also plots its probability.**

Q 10. **The wave function Ψ of a particle is given by**

$\Psi = N\, e^{-\left(\frac{x^2}{2\beta}\right)}$ **for** $-\infty < x < \infty$**. Find N.**

UNIT II

Quantum Statistics:

Q 1. **Differentiate between MB, BE and FD statistics.**

Q 2. **What are black body radiation? Establish Plank's radiation law using BE statistics.**

Q 3. **Show that Rayleigh Jeans law and Wien's law are special cases of Plank's radiation formula.**

Q 4. **Write the distribution function of MB, BE and FD statistics. Show the energy variation of all these on the graph.**

Q 5. **State Rayleigh Jeans law. Show how its drawbacks can be overcome using Plank's radiation law.**

Q 6. **Which type of statistics shall be applicable for a gas of photon. Justify your answer.**

Q 7. **Distinguish between Bosons and Fermions.**

Q 8. **What is ultra-violet catastrophe of classical physics.**

Q 9. **Explain the terms:**

(a) Position space (b) Momentum space (c) Phase space

Q 10. **Define Fermi energy. Discuss in brief its physical significance.**

Q 11. **Write a short note on dying star.**

UNIT III

Crystal Structure:

Q 1. **What are the essential conditions for a unit cell to be called a primitive unit cell?**

Q 2. **Draw the (100) and (111) plane in the simple cubic crystal.**

Q 3. **What are the differences between Frankel and Schottky defects?**

Q 4. **Derive the expression for the inter planner spacing between two parallel plane with Miler indices (hkl) in a cubic crystal of side a.**

Q 5. **Explain and deduce Bragg's law in X-ray diffraction. Give a brief account of Laue method for crystal structure analysis.**

Q 6. **Deduce the Miller indices of a set of parallel planes, which make intercepts in the ratio of a:2b on the x and y-axis are parallel to z- axis, a, b, c being primitive vectors of lattice. Also calculate the inter-planner distance d of the plane taking the lattice to be cube with a=b=c=5 Å.**

Q 7. **In a simple cubic crystal (a) Find the ratio of intercepts of three axis by (123) plane and (b) Find the ratio of spacing of (110) and (111) plane.**

Q 8. **An electron initially at rest accelerated through a potential difference of 5000 V, calculate (a) Momentum, (b) De-Broglie wavelength and (c) Wave number. Also calculate the Bragg angle for first order reflection from (111) planes which are 0.2 nm apart.**

Q 9. **Define the terms: Lattice, Basis, Crystal structure and unit cell. What are Miller indices? How are they determined?**

Q 10. **Deduce atomic radius, coordination number and packing fraction of body cantered cubic and closed packed structure.**

UNIT IV

Band Theory of Solids:

Q 1. **Explain Kronig-Penney model for the motion of electron in a periodic potential. What do you mean by negative mass? Explain.**

Q 2. **At what temperature we can expect a 10 % probability that electron and silver have an energy which is 1 % above the Fermi energy? The Fermi energy of Silver is 5.5 eV.**

Q 3. **Discuss how the process of avalanche breakdown occurs in pn junction diode?**

How is it different from Zener break down?

Q 4. **Mark the Fermi level for (a) An intrinsic semiconductor (b) n-type semiconductor (c) p-type semiconductor. Describe the behaviour and properties of conductors, insulators and semiconductors on the basis of band theory.**

Q 5. **Using Kronig-Penney model show that the energy spectrum of electron consisting of number of allowed energy bands separated by forbidden bands.**

Q 6. **Derive expression for electron and hole concentration in conduction and valence band respectively of an intrinsic semiconductors. Describe their temperature dependence.**

Q 7. **What are E-k diagrams? Explain the origin of forbidden gaps in solids with the help of E-k diagram.**

Q 8. **What do you mean by effective mass of an electron? Can it be negative?**

Q 9. **What are Brillouin zones? Draw the Brillouin zones for a one dimensional lattice of side a.**

Q 10. **Explain the effect of temperature on the Fermi level of (a) n-type semiconductors (b) p-type semiconductors.**

Assignment

UNIT I

Quantum Mechanics:

Q 1. **Calculate the De-Broglie wavelength of (a) a particle accelerated by a potential difference of 30,000 V and (b) an electron moving with a velocity of 0.01 c where c is the speed of light.**

Q 2. **Show that the group velocity of a wave packet is same as the particle velocity.**

Q 3. **Show that the phase velocity is half of the group velocity for a non-relativistic free particle.**

Q 4. **We cannot know future because we cannot know present. Justify the statement using uncertainty principle.**

Q 5. **Give physical interpretation of a wave function and what are the conditions for a wave function to be physically acceptable.**

Q 6. **A state of a particle of mass m is given by $e^{-\alpha x^2}$. Normalise the wave function and calculate the expectation value of kinetic energy and momentum of the particle.**

Q 7. **Write the physical significance of zero-point energy.**

Q 8. **An operator $\frac{d^2}{dx^2}$ has Eigen function $\psi = e^{\alpha x}$. Calculate the Eigen value.**

Q 9. **Resolve the Schrodinger wave equation into a space dependent equation and a time dependent equation.**

Q 10. **What do you mean by Eigen value and Eigen function.**

Q 11. **The energy of a linear harmonic oscillator in third excited state is 0.1 eV. Find the frequency of vibration.**

Q 12. **An electron in metal encounters a barrier layer of height 6 eV and thickness 0.5 nm. If the electron energy is 5 eV, what is the probability of tunnelling through the barrier.**

UNIT II

Quantum Statistics:

Q 1. **Differentiate between classical and quantum mechanics.**

Q 2. **Which type of statistics shall be applicable for a gas of photon? justify your answer.**

Q 3. **Plot Fermi distribution function f(E) vs. energy E for the temperature T=0 K, T>0 K and T>> 0 K.**

Q 4. **Using exchange symmetry of wave function, show that bosons do not obey Pauli exclusion principle.**

Q 5. **Distribute two particles in the three energy levels according to MB, BE and FD distribution functions.**

Q 6. **Make a comparison of statistical distribution functions f(E) for BE and FD system of identical particles.**

Q 7. **Show that the Pauli exclusion principal follows directly from the distribution function of FD statistics.**

Q 8. **A certain spectral line has a wavelength of 4000 Å. Calculate the energy of the photon in eV.**

Q 9. **A 10 kV radio transmitter operates at a frequency 880 KHz. How many photons per second does it emit.**

Q 10. **Explain Wien's and Rayleigh-Jeans laws. Mention their drawbacks.**

UNIT III

Crystal Structure:

Q 1. **Calculate the glancing angle of the (111) plane of simple cubic structure (atomic radius =1.404 Å) corresponding to second order diffraction maxima for X-rays of wavelength 1 Å.**

Q 2. **In a crystal whose primitives are 1.2 Å, 1.8 Å and 2.0 Å, a plane (231) cuts an intercepts 1.2 Å on the x-axis. Find the corresponding intercepts on y and z-axis.**

Q 3. **Show that the number of Frenkel defect in equilibrium at a given temperature is proportional to $(NN_i)^{1/2}$, where N and N_i are the number of atoms and interstitials atom respectively.**

Q 4. **Calculate the inter-planar spacing for a (321) plane in a simple cubic lattice whose lattice constant is 4.2×10^{-8} cm.**

Q 5. **Fe forms a bcc crystal with a = 2.86 Å. The mass of Fe atom is 9.$^{27x10-}$27 kg. Calculate mass density of Fe crystal.**

Q 6. **Calculate the lattice constant of KBr from following data.: Density = 2.7 g/cm^2 , molecular weight = 119.**

Q 7. **Calculate the volume of unit cell for a hexagonal close packed structure in which the atom occupying the lattice point has radius of 1.6 Å.**

Q 8. **Chromium has bcc structure its atomic radius is 0.1249 nm. Calculate the free volume per unit cell.**

Q 9. **Distinguish between crystalline and amorphous solids.**

Q 10. **Draw the following planes inside the unit cell of a cubic crystal: (a) $(\bar{1}0\bar{1})$ (b) (111) (c) $(\bar{1}\bar{1}1)$ (d) (231) (e) (001) (f) $(\bar{1}\bar{1}\bar{1})$**

UNIT IV

Band Theory of Solids:

Q 1. **Write a short note on: Zener diode, pn junction diode, LED, Tunnel diode, photodiode.**

Q 2. **For an intrinsic semiconductor having band gap Eg = 0.7 eV, calculate the density of holes and electrons at room temperature (=27^0 C).**

Q 3. **Show the change in position of the Fermi level when germanium is doped with gallium.**

Q 4. **Consider two- dimensional square lattice of side 3 Å. At what electron momentum value, do the sides of first Brilliouin zone appears? What is the energy of free electron with this momentum?**

Q 5. **In a n-type semiconductor the Fermi level lies 0.3 eV below the conduction band at 300 K. If the temperature is increased to 330 K, find the new position of Fermi level.**

Q 6. **Fermi energy of intrinsic semiconductor is 0.6 V. The lower lying energy level in conduction band is 0.2 eV above the Fermi level. Calculate the probability of occupation of this level by an electron at room temperature.**

Q 7. **Consider a slab of Cu, 0.1mm thick, 1.0 mm wide and 10.0mm long : (a) If we derive a current of 1 Å down the length of slab, what is the current density? (b)**

If we then put the slab in the magnetic field of 1 T with the field perpendicular to the 1 mm x 10 mm face, What is the hall field produced, if the hall coefficient is 0.55 x 10^{-10} m^3/C. (c) What hall voltage will be observed across the slab?

Q 8. **Calculate the position of Fermi level at 300 K for germanium crystal containing 5x 10^{22} arsenic atom per m^3.**

Q 9. **For intrinsic semiconductor with gap width Eg = 0.7 eV, determine the density of holes and electrons at 300 K.**

Q 10. **The energy near the valance band edge of a crystal is given by E= -10^{-39} $k^2 Jm^2$. An electron with wave vector 10^{10} $\widehat{k_x}$/m is removed from an orbital in the completely filled valance band. Determine effective mass and momentum.**

Lecture Plan

UNIT I

Quantum Mechanics

1	Introduction; wave particle duality, de-Broglie waves, The experiment of Davisson Germer, electron diffraction	1	2
2	Physical interpretation of Wave function, properties, The Wave Packet, Phase and group velocities, Uncertainty principle	1	
3	Schrodinger wave equation (1D) for free particle, Eigen vales and eigen function, Expectation values	1	
4	Simple eigen value problems- Solution of Schrodinger equation for free particle	1	
5	Infinite well	1	2
6	Finite well	1	
7	Tunnelling effect, Scanning electron microscope,	1	
8	Quantum simple harmonic oscillator, Zero point energy	1	

UNIT II

Quantum Statistics

9	The need for statistics, statistical distribution: Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics and their comparison, Fermions and bosons	1	2
10	Applications of quantum statistics (1) Molecular speed and energies in an ideal gas	1	
11	(2) Black body spectrum, the failure of classical statistics to give the correct explanation	1	
12	Bose Einstein statistics applied to the black body radiation spectrum.	1	
13	Fermi-Dirac distribution, free electron theory	1	2
14	electronic specific heat	1	
15	Fermi energy and average energy	1	
16	Dying star	1	

UNIT III

Crystal Structure

18	Types of solids, unit cell, types of crystal	1	2
19	Translational vectors, lattice planes, Miler indices	1	

20	**Simple crystal structures, Interplanar spacing, crystal structure analysis**	**2**	
21	**Bragg's law, Laue Method, Numerical problems**	**2**	**2**
22	**Point defects: Schottky and Frankel defects**	**2**	

UNIT IV

<u>Band Theory of Solids</u>

23	**Origin of energy bands in solids, Motion of electron in periodic potential-Kronig-Penney model(qualitative)**	**2**	**2**
24	**Brillouin zones, Effective mass**	**1**	
25	**Metals, semiconductors and Insulators and their energy band structures**	**1**	
26	**Extrinsic and Intrinsic semiconductors, doping – Fermi energy for doped and undoped semiconductors**	**1**	**2**
27	**pn junction (energy band diagram with fermi energy), the unbiased diode**	**1**	
28	**forward and reversed biased diode- Tunnel diode, Zener diode, photo diode, its characteristics, LED**	**2**	