Code No: 152AE **R18**

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech I Year II Semester Examinations, June - 2022
APPLIED PHYSICS
(Common to EEE, CSE, IT, CSIT, ITE, CE(SE), CSE(CS), CSE(DS),CSE(Networks))

Time: 3 Hours **Max. Marks: 75**

Answer any five questions
All questions carry equal marks
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1. a) Derive an expression for the wavelength λ of the matter waves.

   b) Describe an experiment to verify the existence of matter waves. [5+10]

2. a) Explain Heisenberg's Uncertainty principle of position and momentum variables.

   b) Write a note on wave particle duality and properties of matter waves. [8+7]

3. a) What are intrinsic and extrinsic semiconductors?

   b) Derive an expression for Fermi level in an intrinsic semiconductor and hence show that the Fermi level lies exactly in the middle of the forbidden band. [5+10]

4. a) What is a photo detector? Explain the working principle of semiconductor photodiode.

   b) When 3×10^{11} photons each with wavelength of 0.85μm are incident on a photodiode, on average 1.2×10^{11} electrons are generated. Determine the quantum efficiency and responsivity. [8+7]

5. a) Explain the construction, principle and working of Ruby laser.

   b) Explain about the different modes that are propagated through step-index and graded index fiber? [10 +5]

6. a) Discuss the concept of Acceptance angle and Acceptance cone of a fiber.

   b) Derive a relation between acceptance angle and the refractive indices of core and cladding materials. [8+7]

7. a) What is dielectric polarization? Describe briefly types of polarizations.

   b) Derive Clausius-Mosotti relation for dielectric material. [6+9]

8. a) Explain the classification of magnetic materials.

b) When a magnetic material is subjected to a magnetic field of intensity 250 Am^{-1}, its relative permeability is 15. Calculate its magnetization and magnetic flux density. Given that $\mu o = 4\pi \times 10^{-7}$. [9+6]

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Answer Key

1. a) Derive an expression for the wavelength λ of the matter waves.

1. Matter waves are described by de Broglie's hypothesis, which states $\lambda = h / p$, where λ is the wavelength, h is Planck's constant, and p is the momentum of the particle.
2. For a particle of mass m and velocity v, momentum $p = mv$.
3. Therefore, the wavelength λ can be expressed as $\lambda = h / mv$.
4. This equation shows that the wavelength of matter waves decreases with increasing mass and increasing velocity of the particle.
5. It highlights the wave-particle duality of matter, suggesting that all particles exhibit both wave and particle characteristics.
6. This formula is essential in understanding phenomena such as electron diffraction and in interpreting quantum mechanics.
7. It implies that even massive particles, such as atoms and molecules, have associated wavelengths that can influence their behavior.
8. The de Broglie wavelength λ is significant in describing interference patterns observed in experiments like electron diffraction.
9. It plays a crucial role in modern physics, connecting macroscopic classical mechanics with the quantum realm.
10. The expression $\lambda = h / p$ underscores the fundamental unity of particles and waves in the fabric of physical reality.

1. b) Describe an experiment to verify the existence of matter waves.

1. One classic experiment demonstrating matter waves is electron diffraction.
2. Begin by generating a beam of electrons using a heated filament inside a vacuum tube.
3. Accelerate these electrons towards a crystalline target such as graphite or a thin metal foil.
4. Place a detector screen behind the target where the electrons are expected to strike.
5. According to quantum mechanics, electrons should exhibit wave-like behavior upon encountering the crystalline lattice.
6. This behavior leads to diffraction patterns on the detector screen, analogous to those observed in light diffraction experiments.
7. The spacing of the diffraction maxima and minima can be used to calculate the de Broglie wavelength of the electrons.
8. Vary the velocity of the electrons by adjusting the accelerating voltage to observe corresponding changes in the diffraction pattern.
9. Confirm the relationship between electron wavelength, momentum, and kinetic energy, consistent with de Broglie's hypothesis.

10. Electron diffraction experiments thus provide empirical evidence supporting the wave nature of particles, validating the concept of matter waves.

2. a)Explain Heisenberg’s Uncertainty Principle of Position and Momentum Variables

1. Fundamental Concept: Heisenberg's Uncertainty Principle states that it is impossible to simultaneously determine with arbitrary precision both the position and momentum of a particle. This principle is fundamental to quantum mechanics and highlights the limitations of measurement at atomic scales.
2. Mathematical Expression: The uncertainty principle is quantitatively expressed as $\Delta x \cdot \Delta p \geq \hbar 2 \Delta x \cdot \Delta p \geq 2\hbar$, where $\Delta x \Delta x$ is the uncertainty in position, $\Delta p \Delta p$ is the uncertainty in momentum, and $\hbar\hbar$ (h-bar) is the reduced Planck’s constant ($\hbar = h2\pi\hbar = 2\pi h$).
3. Implications for Measurement: According to this principle, increasing the precision in measuring a particle’s position ($\Delta x \Delta x$ becomes smaller) results in an increase in the uncertainty of its momentum ($\Delta p \Delta p$ becomes larger), and vice versa. This trade-off reflects the intrinsic limitations in our ability to measure quantum systems.
4. Wave Nature of Particles: The uncertainty principle arises because particles exhibit wave-like properties. The position of a wave is not precisely defined, and thus the particle’s exact location is inherently uncertain.
5. Impact on Classical Physics: This principle marks a significant departure from classical physics, where it was assumed that position and momentum could be measured precisely and independently. Quantum mechanics fundamentally changes this understanding.
6. Quantum Behavior: Heisenberg’s principle is a direct consequence of the wave-particle duality of matter and is critical for describing the behavior of particles at quantum scales, such as electrons and photons.
7. Electron Microscopy: In practical applications, such as electron microscopy, the uncertainty principle sets a limit on the resolution of the microscope. The more we confine the electron’s position, the more uncertain its momentum becomes, affecting the imaging.
8. Energy-Time Uncertainty: There is a related form of the uncertainty principle involving energy and time, expressed as $\Delta E \cdot \Delta t \geq \hbar 2 \Delta E \cdot \Delta t \geq 2\hbar$. This form indicates a similar trade-off between the precision of measuring energy and the time interval over which the measurement is made.
9. Zero-Point Energy: The uncertainty principle leads to the concept of zero-point energy, the lowest possible energy that a quantum mechanical physical system may have, contrary to classical systems where the

minimum energy can be zero.

10. Philosophical Implications: Heisenberg's Uncertainty Principle has profound philosophical implications, challenging the notion of determinism in classical physics and introducing a fundamental limit to our knowledge about the properties of particles.

2. b) Write a Note on Wave-Particle Duality and Properties of Matter Waves

1. Wave-Particle Duality Concept: Wave-particle duality is a fundamental concept in quantum mechanics stating that every particle or quantum entity exhibits both wave-like and particle-like properties. This duality is evident in various experiments and is central to the behavior of subatomic particles.
2. Historical Background: The duality was first proposed by Louis de Broglie in 1924, who suggested that particles such as electrons could exhibit wave-like behavior, similar to how light exhibits both wave and particle characteristics.
3. De Broglie Wavelength: According to de Broglie, the wavelength ($\lambda\lambda$) of a matter wave is inversely proportional to its momentum (p), given by the equation $\lambda=hp\lambda=ph$. This relationship links the wave nature of particles with their momentum.
4. Experimental Evidence: The wave nature of particles was experimentally confirmed by the Davisson-Germer experiment, which demonstrated electron diffraction by a crystal, similar to the diffraction patterns produced by X-rays, thus verifying de Broglie's hypothesis.
5. Heisenberg's Uncertainty Principle: Wave-particle duality is closely related to Heisenberg's Uncertainty Principle, which states that it is impossible to precisely measure both the position and momentum of a particle simultaneously. This principle arises from the wave nature of particles.
6. Properties of Matter Waves: Matter waves are characterized by properties such as wavelength, frequency, and amplitude, similar to classical waves. However, unlike classical waves, matter waves describe the probability distribution of a particle's position and momentum.
7. Quantum Mechanics Framework: Wave-particle duality forms the basis of quantum mechanics, where particles are described by wavefunctions. The wave function provides a probabilistic description of a particle's position, momentum, and other physical properties.
8. Applications in Technology: The understanding of wave-particle duality is crucial in developing technologies such as electron microscopes and quantum computers. These technologies exploit the wave nature of particles to achieve high-resolution imaging and quantum computation.
9. Interference and Diffraction: Particles exhibiting wave-like behavior can

interfere and diffract, leading to phenomena such as the double-slit experiment, where particles create an interference pattern, a hallmark of wave behavior.

10. Philosophical Implications: Wave-particle duality challenges classical notions of particles and waves being distinct entities. It implies that at a fundamental level, the universe operates on principles that defy classical intuition, requiring a probabilistic approach to understanding physical phenomena.

3. a) What are Intrinsic and Extrinsic Semiconductors?

1. Definition of Intrinsic Semiconductors: Intrinsic semiconductors are pure semiconducting materials without any significant impurities. Examples include pure silicon (Si) and germanium (Ge).
2. Electron-Hole Pair Creation: In intrinsic semiconductors, the number of electrons in the conduction band is equal to the number of holes in the valence band because the electron-hole pairs are generated by thermal excitation.
3. Electrical Conductivity: The electrical conductivity of intrinsic semiconductors is relatively low at room temperature but increases with temperature due to the generation of more electron-hole pairs.
4. Energy Band Structure: Intrinsic semiconductors have a characteristic energy band structure with a conduction band, valence band, and a forbidden energy gap (bandgap) between them.
5. Intrinsic Carrier Concentration: The intrinsic carrier concentration (n_i) is the number of free electrons or holes per unit volume in the semiconductor at thermal equilibrium and is a function of temperature and the bandgap energy.
6. Definition of Extrinsic Semiconductors: Extrinsic semiconductors are those that have been intentionally doped with impurities to modify their electrical properties. There are two types: n-type and p-type.
7. n-Type Semiconductors: These are created by doping a semiconductor with donor atoms, which have more valence electrons than the semiconductor atoms. This results in an excess of electrons in the conduction band.
8. p-Type Semiconductors: These are created by doping with acceptor atoms, which have fewer valence electrons, resulting in an excess of holes in the valence band.
9. Increased Conductivity: Extrinsic semiconductors have higher electrical conductivity compared to intrinsic semiconductors because the doping increases the number of charge carriers (electrons or holes).
10. Applications: Both intrinsic and extrinsic semiconductors are essential in the fabrication of electronic devices such as diodes, transistors, and integrated circuits, with extrinsic semiconductors providing the necessary

charge carriers for device operation.

3. b) Derive an Expression for Fermi Level in an Intrinsic Semiconductor and Hence Show that the Fermi Level Lies Exactly in the Middle of the Forbidden Band

1. Fermi Level Concept: The Fermi level is the energy level at which the probability of an electron occupying that level is 50% at absolute zero temperature. In intrinsic semiconductors, it represents the average energy of the electrons.
2. Intrinsic Carrier Concentration: For intrinsic semiconductors, the electron concentration (n) in the conduction band is equal to the hole concentration (p) in the valence band, both represented as nini.
3. Carrier Concentration Equations: The electron concentration in the conduction band is given by n=Nce−(Ec−EF)kTn=Nce−kT(Ec−EF), where NcNc is the effective density of states in the conduction band, EcEc is the conduction band edge, EFEF is the Fermi level, kk is Boltzmann’s constant, and TT is the temperature.
4. Hole Concentration Equation: Similarly, the hole concentration in the valence band is given by p=Nve−(EF−Ev)kTp=Nve−kT(EF−Ev), where NvNv is the effective density of states in the valence band, and EvEv is the valence band edge.
5. Intrinsic Condition: For intrinsic semiconductors, n=p=nin=p=ni. Therefore, ni2=n⋅pni2=n⋅p.
6. Equating Carrier Concentrations: Substituting the expressions for nn and pp, we get ni2=Nce−(Ec−EF)kT⋅Nve−(EF−Ev)kTni2=Nce−kT(Ec−EF)⋅Nve−kT(EF−Ev).
7. Simplifying the Equation: Simplifying the above equation, we get ni2=NcNve−(Ec−Ev)kTni2=NcNve−kT(Ec−Ev).
8. Expression for Fermi Level: Taking the natural logarithm on both sides, we get 2EF=Ec+Ev+kTln(NvNc)2EF=Ec+Ev+kTln(NcNv).
9. Midgap Fermi Level: For intrinsic semiconductors, the effective density of states in the conduction band (NcNc) and the valence band (NvNv) are typically equal, simplifying the expression to 2EF=Ec+Ev2EF=Ec+Ev.
10. Fermi Level Position: Dividing by 2, we get EF=Ec+Ev2EF=2Ec+Ev. This shows that the Fermi level (EFEF) in an intrinsic semiconductor lies exactly in the middle of the forbidden energy gap (bandgap), indicating equal probability of electron presence in both conduction and valence bands.

4. a) What is a Photo Detector? Explain the Working Principle of Semiconductor Photodiode.

1. Definition of Photo Detector: A photo detector is a device that converts

light into an electrical signal. It is used to measure and detect light in various applications, including communication systems, medical devices, and environmental monitoring.

2. Types of Photo Detectors: Common types of photo detectors include photodiodes, phototransistors, photomultiplier tubes, and charge-coupled devices (CCDs), each serving different purposes based on sensitivity, speed, and wavelength range.
3. Semiconductor Photodiode: A semiconductor photodiode is a type of photo detector made from semiconductor materials such as silicon or gallium arsenide. It operates by converting incident photons into an electrical current.
4. Working Principle - Photovoltaic Effect: The operation of a photodiode is based on the photovoltaic effect. When photons with sufficient energy strike the semiconductor material, they excite electrons, creating electron-hole pairs.
5. p-n Junction Structure: A typical photodiode consists of a p-n junction. The p-type region contains an abundance of holes, while the n-type region contains an abundance of electrons. This junction is crucial for the photodiode’s operation.
6. Generation of Electron-Hole Pairs: When light is absorbed by the semiconductor material, photons transfer energy to electrons in the valence band, allowing them to jump to the conduction band and creating electron-hole pairs.
7. Depletion Region: At the p-n junction, there is a depletion region where no free charge carriers exist. The electric field in this region helps in separating the generated electron-hole pairs, driving electrons towards the n-side and holes towards the p-side.
8. Photocurrent Production: The movement of electrons and holes due to the internal electric field creates a photocurrent. This current is proportional to the intensity of the incident light and can be measured as an output signal.
9. Reverse Bias Operation: Photodiodes are often operated in reverse bias to enhance the width of the depletion region, which increases the efficiency of separating electron-hole pairs and improves the response time and sensitivity of the device.
10. Applications of Photodiodes: Photodiodes are used in various applications such as optical communication systems, light meters, and safety equipment. They are valued for their fast response time, high sensitivity, and ability to detect a wide range of wavelengths.

4. b) When 3 × 1011 photons each with wavelength of 0.85µm are incident on a photodiode, on average 1.2 × 1011 electrons are generated. Determine the quantum efficiency and responsivity.

Given:
Number of incident photons Nincident=3×1011Nincident=3×1011
Number of generated electrons Ngenerated=1.2×1011Ngenerated=1.2×1011
Wavelength of incident light λ=0.85 μmλ=0.85μm
Quantum Efficiency (QE)

1. Definition: Quantum efficiency (ηη) of a photodiode is the ratio of the number of electrons generated to the number of incident photons. It indicates the effectiveness of the photodiode in converting photons into electrical charge.
2. Quantum Efficiency Formula: η=NgeneratedNincidentη=NincidentNgenerated.
3. Substitute the Values: Given Nincident=3×1011Nincident=3×1011 and Ngenerated=1.2×1011Ngenerated=1.2×1011.
4. Calculate QE: η=1.2×10113×1011=0.4η=3×10111.2×1011=0.4.
5. Express as Percentage: Quantum efficiency is often expressed as a percentage. Thus, η=0.4×100%=40%η=0.4×100%=40%.
6. Interpretation: A quantum efficiency of 40% means that 40% of the incident photons are successfully converted into electron-hole pairs.

Responsivity (R)

7. Definition: Responsivity (RR) of a photodiode is the measure of the electrical output per unit optical input. It is given in units of amperes per watt (A/W).
8. Photon Energy Calculation: The energy (EE) of each photon is given by E=hcλE=λhc, where hh is Planck's constant (6.626×10−34 Js6.626×10−34Js), cc is the speed of light (3×108 m/s3×108m/s), and λλ is the wavelength (0.85 μm=0.85×10−6 m0.85μm=0.85×10−6m).
9. Calculate Photon Energy: E=6.626×10−34×3×1080.85×10−6≈2.34×10−19 JE=0.85×10−66.626×10−34×3×108≈2.34×10−19J.
10. Responsivity Formula: Responsivity is given by R=ηλhcR=hcηλ. Substituting η=0.4η=0.4, λ=0.85×10−6 mλ=0.85×10−6m, h=6.626×10−34 Jsh=6.626×10−34Js, and c=3×108 m/sc=3×108m/s, we get R=0.4×0.85×10−66.626×10−34×3×108≈0.57 A/WR=6.626×10−34×3×1080.4×0.85×10−6≈0.57A/W.

5. a) Explain the Construction, Principle, and Working of Ruby Laser

1. Construction of Ruby Laser: A ruby laser consists of a cylindrical ruby crystal rod, usually made of synthetic ruby (a form of aluminum oxide with a small amount of chromium ions). The rod is placed between two mirrors, one fully reflective and the other partially reflective, forming an optical resonator.

2. Active Medium: The active medium in a ruby laser is the ruby crystal, where chromium ions (Cr^{3+}) serve as the lasing ions. The presence of chromium gives ruby its characteristic pink or red color.
3. Pumping Mechanism: The ruby laser is optically pumped using a flash lamp or other high-intensity light source. The flash lamp emits a burst of white light, some of which is absorbed by the chromium ions in the ruby crystal.
4. Energy Levels: Chromium ions in the ruby have three main energy levels: the ground state, the metastable state, and the excited state. When pumped by the flash lamp, electrons in chromium ions are excited from the ground state to the excited state.
5. Population Inversion: After absorbing energy, electrons quickly drop to the metastable state, which has a longer lifetime. This creates a population inversion, a necessary condition for laser action, where more electrons are in the metastable state than in the ground state.
6. Stimulated Emission: When an electron in the metastable state returns to the ground state, it emits a photon. This photon can stimulate other excited electrons to emit additional photons of the same wavelength, phase, and direction, leading to stimulated emission.
7. Optical Resonator: The emitted photons reflect back and forth between the two mirrors of the optical resonator. The partially reflective mirror allows some of the coherent light to escape as a laser beam, while the fully reflective mirror continues to amplify the light within the crystal.
8. Laser Output: The ruby laser produces a coherent, monochromatic red light beam at a wavelength of 694.3 nm. The output is typically in the form of short, high-intensity pulses due to the nature of the flash lamp pumping.
9. Cooling System: To prevent overheating and damage, ruby lasers often incorporate a cooling system, as the flash lamp and the active medium generate significant heat during operation.
10. Applications: Ruby lasers are used in various applications such as holography, tattoo removal, and scientific research. They are valued for their ability to produce high-energy, short-duration laser pulses.

5. b) Explain About the Different Modes That Are Propagated Through Step-Index and Graded Index Fiber

1. Step-Index Fiber Structure: Step-index fiber consists of a core with a uniform refractive index, surrounded by a cladding with a lower refractive index. The sharp difference in refractive index at the core-cladding boundary creates a step-like profile.
2. Modes in Step-Index Fiber: In step-index fibers, light propagates through the core in discrete modes, or specific paths. These modes are characterized by total internal reflection at the core-cladding boundary.

3. Single-Mode Fiber: When the core diameter is very small (around 8-10 micrometers for typical telecommunications wavelengths), only the fundamental mode (LP01) can propagate. This single-mode fiber supports one light path, reducing modal dispersion and enabling high-bandwidth communication over long distances.
4. Multi-Mode Fiber: If the core diameter is larger (typically 50-62.5 micrometers), multiple modes can propagate. These multiple paths lead to modal dispersion, which can limit bandwidth and distance. Multimode step-index fibers are often used for short-distance applications.
5. Graded-Index Fiber Structure: Graded-index fibers have a core with a refractive index that gradually decreases from the center to the edge. This creates a parabolic refractive index profile, which helps to focus light rays towards the core center.
6. Modes in Graded-Index Fiber: In graded-index fibers, light rays follow sinusoidal paths rather than bouncing sharply at the core-cladding boundary. The gradual change in refractive index reduces modal dispersion compared to step-index multimode fibers.
7. Reduced Dispersion: The design of graded-index fibers minimizes the difference in travel time between modes. This results in less pulse spreading, allowing higher bandwidth and longer transmission distances compared to step-index multimode fibers.
8. Application of Single-Mode Fibers: Single-mode fibers are primarily used in long-distance telecommunications, high-speed data networks, and undersea cables due to their low attenuation and high bandwidth capabilities.
9. Application of Multi-Mode Fibers: Multi-mode fibers, particularly graded-index types, are used in short-distance communication, local area networks (LANs), and data centers. They offer easier alignment and lower cost but are limited in bandwidth and distance compared to single-mode fibers.
10. Importance of Modal Analysis: Understanding the modes in optical fibers is crucial for designing efficient fiber optic communication systems. It impacts the choice of fiber type, light sources, and signal processing techniques to achieve optimal performance in different applications.

6. a) Discuss the Concept of Acceptance Angle and Acceptance Cone of a Fiber

1. Definition of Acceptance Angle: The acceptance angle is the maximum angle at which light can enter the fiber optic core and still be guided along the core through total internal reflection. It determines the range of angles over which the fiber can accept incoming light.
2. Numerical Aperture (NA): The acceptance angle is directly related to the numerical aperture (NA) of the fiber, which is a measure of the

light-gathering ability of the fiber. The NA is defined as the sine of the acceptance angle.

3. Acceptance Cone: The acceptance cone is a conical region in front of the fiber core that defines the directions from which light can enter the fiber and be properly guided. Light entering within this cone will be captured and transmitted through the fiber.
4. Geometric Representation: Visually, the acceptance cone can be represented as a cone with its apex at the fiber core entrance and the angle of the cone being twice the acceptance angle. This defines the spatial region where light can be accepted.
5. Critical Angle and Total Internal Reflection: For light to be guided through the fiber, it must hit the core-cladding interface at an angle greater than the critical angle for total internal reflection. The acceptance angle ensures that incoming light meets this requirement.
6. Impact on Light Propagation: Light rays entering the fiber at angles within the acceptance angle are refracted into the core and guided through the fiber via multiple total internal reflections. Rays outside this angle will escape into the cladding and be lost.
7. Importance in Fiber Optics: The acceptance angle is crucial for efficient light coupling into the fiber. It affects the alignment of light sources with the fiber and determines the light capture efficiency, impacting the overall performance of the fiber optic system.
8. Influence of Fiber Design: The acceptance angle is influenced by the refractive indices of the core and cladding. Fibers with a higher difference in refractive indices have a larger acceptance angle and can capture more light.
9. Practical Applications: Understanding the acceptance angle is important in the design and implementation of fiber optic systems, including telecommunication networks, medical imaging, and industrial applications.
10. Optimization: Engineers can optimize the acceptance angle by selecting appropriate materials and designing the fiber geometry to match the specific requirements of the application, ensuring maximum light capture and efficient signal transmission.

6. b) Derive a Relation Between Acceptance Angle and the Refractive Indices of Core and Cladding Materials

1. Refractive Indices: Let n1n1 be the refractive index of the core and n2n2 be the refractive index of the cladding (n1>n2n1>n2). These refractive indices determine how light propagates within the fiber.
2. Snell's Law: When light enters the fiber from air (refractive index n0≈1n0≈1), Snell's law at the air-core interface can be written as n0sinθ0=n1sinθ1n0sinθ0=n1sinθ1, where θ0θ0 is the angle of incidence

and θ1θ1 is the angle of refraction inside the core.

3. Critical Angle: At the core-cladding interface, for total internal reflection to occur, the angle of incidence inside the core θ1θ1 must be greater than or equal to the critical angle θcθc, given by sinθc=n2n1sinθc=n1n2.
4. Maximum Refraction Angle: The maximum angle θ1θ1 inside the core for total internal reflection is the critical angle θcθc. Therefore, sinθ1≤sinθc=n2n1sinθ1≤sinθc=n1n2.
5. Relation Using Snell's Law: From Snell's law at the air-core interface, considering the maximum acceptance angle θ0=θaθ0=θa, we get sinθa=n1sinθ1n0sinθa=n0n1sinθ1.
6. Substitute Critical Angle: Using sinθ1=sinθc=n2n1sinθ1=sinθc=n1n2, the equation becomes sinθa=n1(n2n1)n0=n2n0sinθa=n0n1(n1n2)=n0n2.
7. Numerical Aperture: The numerical aperture (NA) of the fiber is defined as NA=n0sinθaNA=n0sinθa. Substituting the above expression, we get NA=n12−n22NA=n12−n22.
8. Acceptance Angle in Terms of NA: The acceptance angle θaθa can then be expressed as sinθa=NAn0sinθa=n0NA. For air (n0≈1n0≈1), sinθa=NAsinθa=NA.
9. Final Relation: Hence, the acceptance angle θaθa is related to the refractive indices of the core and cladding by sinθa=n12−n22sinθa=n12−n22.
10. Practical Significance: This relation is fundamental in designing fiber optic systems as it directly impacts the fiber's ability to capture and guide light efficiently. By selecting appropriate materials with desired refractive indices, engineers can optimize the acceptance angle for specific applications.

7. a) What is Dielectric Polarization? Describe Briefly Types of Polarizations

1. Definition of Dielectric Polarization: Dielectric polarization is the phenomenon where an electric field causes a separation of positive and negative charges within a dielectric material, resulting in the formation of electric dipoles. This alignment of dipoles generates an internal electric field that opposes the applied electric field.
2. Electronic Polarization: This type of polarization occurs when the applied electric field displaces the electron cloud relative to the nucleus within an atom. It is typically found in materials with non-polar molecules and is instantaneous and frequency-independent.
3. Ionic Polarization: Ionic polarization occurs in materials with ionic bonds, where an electric field displaces positive and negative ions in opposite directions. This displacement is slower than electronic polarization and depends on the frequency of the applied field.
4. Orientation Polarization: Orientation polarization occurs in materials with

permanent dipole moments. In the presence of an electric field, these dipoles tend to align with the field. This type of polarization is temperature-dependent and relatively slow compared to electronic and ionic polarization.

5. Space Charge Polarization: Space charge polarization arises when charges accumulate at the interfaces or within inhomogeneities in the material. This type of polarization is significant at low frequencies and is influenced by the mobility of charge carriers.
6. Total Polarization: In real dielectric materials, the total polarization is the sum of electronic, ionic, orientation, and space charge polarizations. Each type contributes differently depending on the frequency and temperature of the applied electric field.
7. Frequency Dependence: The different types of polarization respond differently to changes in the frequency of the applied electric field. Electronic polarization is effective at all frequencies, while ionic and orientation polarizations are effective at lower frequencies.
8. Temperature Dependence: Orientation polarization is highly dependent on temperature since thermal agitation can disrupt the alignment of dipoles. Ionic and electronic polarizations are less affected by temperature.
9. Material Influence: The type and extent of polarization depend on the material's structure and composition. For example, ionic crystals exhibit significant ionic polarization, while polymers with polar groups show substantial orientation polarization.
10. Applications: Understanding dielectric polarization is crucial in designing capacitors, insulating materials, and other electronic components. Different polarizations influence the dielectric constant and the material's overall response to electric fields.

7. b) Derive Clausius-Mossotti Relation for Dielectric Material

1. Polarization and Electric Field: Dielectric polarization PP is the dipole moment per unit volume. In the presence of an electric field EE, the polarization can be expressed as P=ϵ0χeEP=ϵ0χeE, where ϵ0ϵ0 is the vacuum permittivity and χeχe is the electric susceptibility.
2. Dielectric Constant: The relative permittivity (dielectric constant) ϵrϵr is related to the susceptibility by ϵr=1+χeϵr=1+χe. The dielectric constant describes how much the material can be polarized by an external electric field.
3. Dipole Moment and Polarizability: Consider an individual molecule with a polarizability αα. When subjected to an electric field EE, it acquires a dipole moment p=αEp=αE.
4. Local Field: The local electric field ElocalElocal at a molecule within the dielectric is different from the macroscopic field EE. Lorentz proposed that Elocal≈E+P3ϵ0Elocal≈E+3ϵ0P.

5. Relation of Polarization to Dipole Moment: The macroscopic polarization PP is the number density of molecules NN times the average dipole moment pp: P=Np=NαElocalP=Np=NαElocal.
6. Substitute Local Field: Substituting the local field expression, P=Nα(E+P3ϵ0)P=Nα(E+3ϵ0P).
7. Solving for Polarization: Rearranging, P=NαE1−Nα3ϵ0P=1−3ϵ0NαNαE. Using P=ϵ0χeEP=ϵ0χeE, we get χe=Nα/ϵ01−Nα/(3ϵ0)χe=1−Nα/(3ϵ0)Nα/ϵ0.
8. Dielectric Constant and Polarizability: Substituting ϵr=1+χeϵr=1+χe and simplifying, we get ϵr=1+Nα/ϵ01−Nα/(3ϵ0)ϵr=1+1−Nα/(3ϵ0)Nα/ϵ0.
9. Clausius-Mossotti Relation: Simplifying further, ϵr−1ϵr+2=Nα3ϵ0ϵr+2ϵr−1=3ϵ0Nα. This is the Clausius-Mossotti relation, which relates the macroscopic dielectric constant to the microscopic polarizability.
10. Significance: The Clausius-Mossotti relation provides a bridge between the molecular properties of a dielectric material (polarizability) and its macroscopic electrical behavior (dielectric constant). It is essential in understanding and predicting the behavior of dielectric materials under an electric field.

8. a) Explain the Classification of Magnetic Materials

1. Diamagnetic Materials: These materials are characterized by their weak and negative response to an external magnetic field. They develop an induced magnetic moment in the opposite direction of the applied field, causing a slight repulsion. Examples include bismuth, copper, and gold.
2. Paramagnetic Materials: Paramagnetic materials have unpaired electrons that align with an external magnetic field, causing a weak attraction. However, the magnetic effect disappears once the external field is removed. Examples include aluminum, platinum, and oxygen.
3. Ferromagnetic Materials: Ferromagnetic materials exhibit strong attraction to magnetic fields due to their unpaired electrons and magnetic domains. They retain their magnetization even after the external field is removed. Common examples are iron, nickel, and cobalt.
4. Antiferromagnetic Materials: In these materials, adjacent ions or atoms have magnetic moments that are equal in magnitude but opposite in direction, canceling each other out. This results in no net magnetization in the absence of an external field. Examples include manganese oxide and iron oxide.
5. Ferrimagnetic Materials: Similar to antiferromagnetic materials, ferrimagnetic materials have opposing magnetic moments. However, these moments are unequal, resulting in a net magnetic moment. Ferrites, used in magnetic cores, are typical examples.
6. Superparamagnetic Materials: These materials exhibit magnetic

properties similar to ferromagnetic materials but only in the presence of an external magnetic field. At a critical size, the magnetic domains are small enough to fluctuate rapidly, causing no permanent magnetization. Nanoparticles of iron oxide are an example.

7. Soft Magnetic Materials: These materials can be easily magnetized and demagnetized. They have low coercivity and are used in applications requiring rapid changes in magnetization, such as transformers and inductors. Examples include silicon steel and soft ferrites.
8. Hard Magnetic Materials: Hard magnetic materials have high coercivity and retain their magnetization even in the absence of an external magnetic field. They are used in permanent magnets and data storage devices. Examples include samarium-cobalt and neodymium-iron-boron alloys.
9. Magnetic Domains: In ferromagnetic and ferrimagnetic materials, magnetic domains are regions where the magnetic moments are aligned in the same direction. The alignment and movement of these domains under an external magnetic field determine the material's magnetic properties.
10. Curie Temperature: The Curie temperature is the temperature above which ferromagnetic and ferrimagnetic materials lose their permanent magnetic properties and become paramagnetic. Each material has a specific Curie temperature, which is critical for its applications.

8. b) When a Magnetic Material is Subjected to a Magnetic Field of Intensity 250 A/m, Its Relative Permeability is 15. Calculate Its Magnetization and Magnetic Flux Density. Given $\mu_0 = 4\pi \times 10^{-7}$.

1. Given Data: The magnetic field intensity (H) is 250 A/m, the relative permeability (μ_r) is 15, and the permeability of free space (μ_0) is $4\pi \times 10^{-7}$ H/m.
2. Magnetization (M): Magnetization is defined as the magnetic moment per unit volume. It can be calculated using the formula M=χmHM=χmH, where χmχm is the magnetic susceptibility.
3. Magnetic Susceptibility (χ□): Magnetic susceptibility is related to the relative permeability by χm=μr−1χm=μr−1. Given μr=15μr=15, we have χm=15−1=14χm=15−1=14.
4. Calculate Magnetization (M): Using the formula M=χmHM=χmH, we get M=14×250 A/mM=14×250A/m. Therefore, M=3500 A/mM=3500A/m.
5. Magnetic Flux Density (B): Magnetic flux density is given by the formula B=μHB=μH, where μμ is the absolute permeability of the material.
6. Absolute Permeability (μ): The absolute permeability is the product of the relative permeability and the permeability of free space, μ=μrμ0μ=μrμ0. Substituting the given values, μ=15×4π×10−7 H/mμ=15×4π×10−7H/m.
7. Calculateμ:Simplifying,μ=15×4π×10−7=60π×10−7≈1.884×10−5 H/mμ=15×4π×10−7=60π×10−7≈1.884×10−5H/m.
8. Calculate Magnetic Flux Density (B): Using B=μHB=μH, we get

B=1.884×10−5×250 A/mB=1.884×10−5×250A/m.

9. FinalCalculation:
   B=1.884×250×10−5=4.71×10−3 TB=1.884×250×10−5=4.71×10−3T.
   Therefore, the magnetic flux density B=4.71 mTB=4.71mT.
10. Summary: The magnetization MM of the material is 3500 A/m, and the magnetic flux density BB is 4.71 mT. These values indicate the material's response to the applied magnetic field, demonstrating its magnetic properties.