NATIONAL INSTITUTE OF TECHNOLOGY, PATNA
END SEMESTER EXAMINATION- December 2023

Program: BT-MT (DD) Semester: 3 Department: Physics
Course Code: PH38103 Course Name: Materials Science
Full Marks: 60 Duration of Examination: 3 hours

Attempt all questions. Please assume missing data suitably, if any.

Q.1. (a) Discuss the Laue method for the crystal structure determination. 15
(b) X-ray of wavelength 1.4 Å is found to be Bragg reflected from the (111) plane of a FCC structure. If the lattice parameter of the crystal is 5Å. Find the angle at which the X-ray is incident on (111) plane of the crystal.
(c) Electrons accelerated from the state of rest by 120 V are reflected from a FCC crystal. The reflection maximum is observed at 22°. Determine the lattice parameter if the Bragg reflection occurs from the (1 1 1) plane. (Given h = 6.6×10^{-34} J-s, mass of electron = 9.1×10^{-31} Kg).

Q.2. (a) What is the Hall effect? The R_H of a specimen is 3.66×10^{-4} m^3C^{-1}. Its resistivity is 8.93×10^{-3} Ω-m. Find carrier concentration (n) and mobility (μ_e). 15
(b) For intrinsic gallium arsenide, the room-temperature electrical conductivity is 10^{-6} $(ohm\text{-}m)^{-1}$; the electron and hole mobilities are, respectively 0.85 and 0.04 $m^2/V\text{-}s$. Compute the intrinsic carrier concentration n_i at room temperature.
(c) Describe different types of polarization in dielectrics. Discuss the behaviour of a dielectric in an alternating field.

Q.3. (a) Describe briefly ferromagnetic, anti-ferromagnetic and ferrimagnetic materials by giving suitable example. 15
(b) Explain the Meissner effect in superconductors. What is isotopic effect in superconductor? The critical temperature T_c for Hg with isotopic mass 199.5 is 4.185K. What will be its critical temperature when its isotopic mass increased to 203.4?
(c) What are the magnetic domains? Discuss the formation of hysteresis loop in ferromagnetic materials.

Q.4. (a) A superconducting tin has a critical temperature of 3.7K at zero magnetic field and a critical field of 0.0306 Tesla at 0 K. Find the critical field at 2K. 15
(b) What is optical fibre? Discuss its application briefly.
(c) Discuss briefly (i) Thermal expansion and (ii) Thermal conductivity in solid.

NATIONAL INSTITUTE OF TECHNOLOGY PATNA

Department of Mathematics

End-Semester Examination : December, 2023

Subject: Complex Variables and PDEs **Code: MA38101/OE38101**

Time: 3 hours **Maximum Marks:** $6 \times 10 = 60$

Symbols and notations have their usual meaning

Answer ~~any~~ **All** questions

1. (a) Prove that the function $u(x, y) = 3x^2y + 2x^2 - y^3 - 2y^2$ is harmonic. Find the conjugate harmonic function v and express $u + iv$ as an analytic function of z.

   (b) Show that e^{z^2} has an essential singularity at infinity.

2. (a) State and prove the Cauchy's theorem.

   (b) Find the residue of the function $f(z) = e^z \operatorname{cosec}^2 z$ at all its poles.

3. (a) If $f(z)$ and $g(z)$ are analytic inside and on a simple closed curve C and if $|g(z)| < |f(z)|$ on C, then $f(z) + g(z)$ and $f(z)$ have the same number of zeros inside C.

   (b) Prove that all the roots of $z^7 - 5z^3 + 12 = 0$ lie between the circles $|z| = 1$ and $|z| = 2$.

4. (a) Find the Laurent series of the function $f(z) = (z - 3)\sin\left(\dfrac{1}{z+3}\right)$ about the point $z = -2$.

   (b) If $|f(z)| \leq M/R^k$ for $z = Re^{i\theta}$ where $k > 1$ and M are constants, prove that

$$\lim_{R\to\infty} \int_{\Gamma} f(z)dz = 0$$

   where Γ is the semicircular arc of radius R.

5. Evaluate $\displaystyle\int_0^{\infty} \frac{dx}{x^6 + 1}$.

6. Eliminate the arbitrary function and hence obtain the partial differential equation

   (a) $f(x + y + z, x^2 + y^2 - z^2) = 0$

   (b) $y = f(x + at) + xg(x + at)$.

7. Find a complete integral of $p^2x + q^2y = z$.

8. Reduce the equations $\dfrac{\partial^2 z}{\partial x^2} + \dfrac{\partial^2 z}{\partial x \partial y} + \dfrac{\partial^2 z}{\partial y^2} = 0$ to its canonical form.

9. Solve the boundary value problem $\dfrac{\partial^2 u}{\partial x^2} = \dfrac{1}{k}\dfrac{\partial u}{\partial t}$ satisfying the boundary condition $u(0, t) = u(l, t) = 0$ and initial condition $u(x, 0) = lx - x^2$.

10. Solve the wave equation $\dfrac{\partial^2 u}{\partial t^2} = c^2 \dfrac{\partial^2 u}{\partial x^2}$ subject to the boundary condition $u(0, t) = u(1, t) = 0$ and initial condition $u(x, 0) = A \sin \pi x$ and $\left.\dfrac{\partial u}{\partial t}\right|_{t=0} = 0$.

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National Institute of Technology Patna

End Semester Examination Dec. 2023

Time allotted: 3 Hours ***Full Marks: 60***

Subject: Physics of Materials ***Subject code: PH38102***

The figures in the margin indicates full marks

Attempt all questions. All questions carry equal marks

1. Considering a one dimensional ionic crystal, describe a clear understanding on why thermal expansion occurs. Describe direct current conductivity measurement using four probe methods. [7+5]

2. (a) State the advantages of the four probe method over the two probe method. [5]

   (b) Consider a sample of length 4cm, cross-sectional area $2cm^2$ and resistance 5Ω. Calculate its electrical conductivity. [3]

   (c) What is the percentage error in the DC two probe measurements, where the constant resistance is 0.2 ohm and the sample resistance is 0.02 ohm? [4]

3. Differentiate between truly free electrons, nearly free electrons and bound electrons. Show that the extents of confinement of nearly free electrons and bound electrons with the help of E-r plot. Show that on the basis of a string analogy (tied at both ends) confinement of the string leads to quantization. [4+4+4]

NATIONAL INSTITUTE OF TECHNOLOGY, PATNA

END SEMESTER EXAMINATION, December 2023

Program: B.Tech. + M.Tech. (MSE) **Semester: 3rd** **Department: Physics**

Course Code: PH38101 **Course Name: Physics of semiconductor devices**

Full Marks: 60 **Duration of Examination: 3 Hours**

Answer all the questions :(Symbols have their usual meanings)

Q.1 Discuss the concept of allowed and forbidden energy bands in a single crystal both qualitatively and more rigorously from the results of using the Kronig-Penney model. **[10]**

Q. 2 (a) State the definition of effective mass from the E versus K diagram and discuss its meaning in terms of the movement of a particle in a crystal. **[6]**

(b) Qualitatively, in terms of energy bands, discuss the difference between a metal, an insulator, and semiconductor. **[4]**

Q.3 What is fermi energy level? The Fermi energy for copper at T = 300 K is 7.0 eV. The electrons in copper follow the Fermi–Dirac distribution function. Find the probability of an energy level at 7.15 eV being occupied by an electron. **[10]**

Q 4 Derive an expression for carrier concentration in intrinsic semiconductor. Calculate the intrinsic concentration of charge carriers at 300 K, given that $m_e = 0.12m_o$, $m_h = 0.28m_o$ and the value of band gap = 0.67 eV. The value of $m_o = 9.1 \times 10^{-31}$ Kg. **[10]**

Q 5. Explain the electrical conductivity variation with respect to temperature in intrinsic and extrinsic semiconductors. **[10]**

Q.6 **(a)** What is pn junction diode? Derive a relation to calculate the built-in potential barrier in the pn-junction diode. **[6]**

(b) Calculate the built-in potential of a silicon pn-junction at room temperature with doping densities of $N_a = 1\times10^{18}$ cm^{-3} and $N_d = 1\times10^{15}$cm^{-3}. Assume that $n_i = 1.5 \times 10^{10}$ cm^{-3}. **[4]**