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**QUESTION PAPER**

**Name of the Examination: WINTER 2022-2023 – FAT**

**Course Code: PHY 1008** | **Course Title: Modern Physics**

**Set number: 01** | **Date of Exam:** 16/06/2023(AN)(A

**Duration: 120 minutes** | **Total Marks: 60**

**Instructions:**

1. Assume data wherever necessary.
2. Any assumptions made should be clearly stated.
3. Use the following values, $h = 6.63 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg, $m_n = 1.67 \times 10^{-27}$ kg, $m_p = 1.67 \times 10^{-27}$ kg $c = 3 \times 10^8$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, $k_B = 1.38 \times 10^{-23}$ J K$^{-1}$ $= 8.617 \times 10^{-5}$ eV K$^{-1}$, $\mu_0 = 4\pi \times 10^{-7}$ H/m, Avogadro Number $(N_A) = 6.023 \times 10^{23}$/mol, Bohr Magneton ($\mu_B$ or $\beta$) $= 9.27 \times 10^{-24}$ A m$^2$, wherever required.

**Q1.** A particle is in the ground state of an infinite square well potential, which extends from $x = 0$ to $x = L$. Determine the probability that the particle is confined within a length of $x = 0$ and $x = L/4$.

**(10 marks)**

**Q2.** A certain intrinsic germanium rod is 1 cm long, 1 mm wide and 1mm thick. The rod carries current along its length. The intrinsic carrier density at 300 K is $2.5 \times 10^{19}$ m$^{-3}$ and the mobilities of electron and hole are 0.39 and 0.19 m$^2$V$^{-1}$s$^{-1}$, respectively.

Find the resistance of the rod at 300 K.

**(10 marks)**

**Q3.** Consider silicon at $T = 300$ K, having a band gap energy of 1.12 eV, with $N_c = 2.8 \times 10^{19}$ cm$^{-3}$ and $N_V = 1.04 \times 10^{19}$ cm$^{-3}$. If the Fermi energy is 0.25 eV below the conduction band, find the thermal equilibrium concentration of electrons and holes. Take $k = 8.6 \times 10^{-5}$ eV/K as the Boltzmann constant.

**(10 marks)**

**Q4.** The energy of a photon in Sodium light of wavelength $\lambda = 589$ nm, equals the band-gap energy ($E_g$) of a semiconducting material.

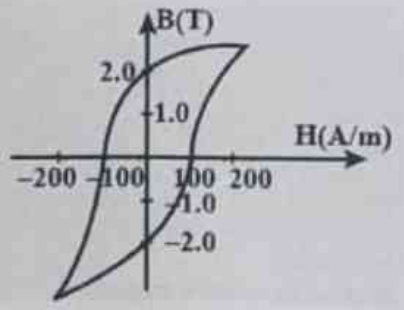
(a) Find the minimum energy required to create an electron-hole pair.
(b) Find the value of $E_g/kT$, at $T = 300$ K, where $T$ is the absolute temperature. From this value, could you say if it is easier to generate an electron-hole pair thermally, or by irradiation with Sodium light?

Here $k = 8.6 \times 10^{-5}$ eV/K is the Boltzmann constant.

**(10 marks)**

**Q5.** The magnetic flux density within a bar of some material is 0.63 Tesla at an external field of $5 \times 10^5$ A/m. Compute the magnetic permeability, and magnetic susceptibility for this material. Justify as to what type of magnetism is being displayed by the material.
**(10 marks)**

**Q6.** The B-H curve for a certain ferromagnetic material is as below:




From the curve identify the values of retentivity and coercivity.

Draw the M-H plots for a paramagnetic and diamagnetic material.

**(10 marks)**

**QP MAPPING**

| Q. No. | Module Number | CO Mapped | PO Mapped | PEO Mapped | PSO Mapped | Marks |
|---|---|---|---|---|---|---|
| Q1 | 3 | 2 | 1,2,3,4,5,6,7 | - | - | 10 |
| Q2 | 4 | 3,5 | 1,2,3,4,5,6,7 | - | - | 10 |
| Q3 | 4 | 3,5 | 1,2,3,4,5,6,7 | - | - | 10 |
| Q4 | 4 | 3,5 | 1,2,3,4,5,6,7 | - | - | 10 |
| Q5 | 5 | 4,5 | 1,2,3,4,5,6,7 | - | - | 10 |
| Q6 | 5 | 1,5 | 1,2,3,4,5,6,7 | - | - | 10 |

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**QUESTION PAPER**

**Name of the Examination: WINTER 2022-2023 – FAT**

| | | | |
|---|---|---|---|
| **Course Code** | : PHY1008 | **Course Title** | : Modern Physics |
| **Set number** | : 04 | **Date of Exam** | : 20/06/2023 (FN)(D1) |
| **Duration** | : 120 Minutes | **Total Marks** | : 60 Marks |

**Instructions:**

1. Assume data wherever necessary.
2. Any assumptions made should be clearly stated.
3. Use the following values, $h = 6.63 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg, $m_n = 1.67 \times 10^{-27}$ kg, $m_p = 1.67 \times 10^{-27}$ kg $c = 3 \times 10^{8}$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, $k_B = 1.38 \times 10^{-23}$ J K$^{-1}$ $= 8.617 \times 10^{-5}$ eV K$^{-1}$, $\mu_0 = 4\pi \times 10^{-7}$ H/m, Avogadro Number $(N_A) = 6.023 \times 10^{23}$/mol, Bohr Magneton $(\mu_B \text{ or } \beta) = 9.27 \times 10^{-24}$ A m$^2$ , wherever required.

**Q1.** The normalized wave function of a particle trapped in a one-dimensional box of length L is given by $\psi = \sqrt{2/L}\ \sin(n\pi x/L)$. Compute the probability that the particle can be found between 0.45 L and 0.55 L in the first excited state. **(10 Marks)**

**Q2.** Calculate the intrinsic concentration in silicon at (a) T = 200 K and (b) T = 450 K. The values of effective density of states function in the conduction band and valence band for silicon at 300 K are $N_c = 2.8 \times 10^{19}$ cm$^{-3}$ and $N_v = 1.04 \times 10^{19}$ cm$^{-3}$, respectively. Both $N_c$ and $N_v$, vary as $T^{3/2}$. Assume the band gap of silicon as 1.12 eV and does not vary over this temperature range. **(10 Marks)**

Q3. Determine the position of the intrinsic Fermi level at T = 300 K with respect to the center of the band gap for (a) GaAs and (b) Ge. The effective carrier masses (electron $(m_e^*)$ and hole $(m_h^*)$ in GaAs and Ge at 300 K are given as follows. For GaAs, $m_e^* = 0.067\, m_0$ & $m_h^* = 0.48\, m_0$ and for Ge, $m_e^* = 0.55\, m_0$ *and* $m_h^* = 0.37\, m_0$. **(10 Marks)**

**Q4.** (a) An n-type semiconductor is known to have an electron concentration of $1.0 \times 10^{18}\ m^{-3}$. If the electron drift velocity is 60 m/s in an electric field of 300 V/m, calculate the conductivity of the material. **(5 Marks)**

(b) A sample of intrinsic silicon at room temperature has a carrier concentration of $2.5 \times 10^{19}\ m^{-3}$. It is doped with arsenic at a rate of one arsenic atom per million atoms of silicon. If the concentration of the silicon atoms is $5.0 \times 10^{28}\ m^{-3}$. Determine the hole concentration. **(5 Marks)**

Q5. When a magnetic field (H) of 150 A/m is applied to some metal alloy, the magnetization in the alloy is $1.7 \times 10^6$ A/m. Determine the following (a) magnetic susceptibility (b) permeability (c) magnetic flux density within this material (d) identify the type of magnetism present in the metal alloy.
**(10 Marks)**

Q6. (a) An iron bar magnet having a coercivity of 4000 A/m is to be demagnetized. If the bar is inserted within a cylindrical wire coil (a solenoid) 25 cm long and having 150 turns, what electric current is required to generate the necessary magnetic field? **(5 Marks)**

(b) The retentivity and coercive field of a ferromagnetic material are 1.25 T and 9000 A/m, respectively. The saturation magnetization is achieved when the magnetic field intensity is 15,000 A/m and the corresponding magnetic flux density is 1.5 T. From the given data, draw the complete hysteresis curve in the range H = −15,000 to +15,000 A/m. Correctly indicate the scale and label both coordinate axes. **(5 Marks)**

**QP MAPPING**

| Q. No. | Module Number | CO Mapped | PO Mapped | PEO Mapped | PSO Mapped | Marks |
|---|---|---|---|---|---|---|
| Q1 | 3 | 2 | 1, 2, 3, 4 & 5 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |
| Q2 | 4 | 3 | 1, 2, 3, 4, 5, 6 & 7 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |
| Q3 | 4 | 3 | 1, 2, 3, 4, 5, 6 & 7 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |
| Q4 | 4 | 5 | 1, 2, 3, 4, 5, 6 & 7 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |
| Q5 | 5 | 4 | 1, 2, 3, 4, 5, 6 & 7 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |
| Q5 | 5 | 4 | 1, 2, 3, 4, 5, 6 & 7 | 1, 2, 3 & 4 | 1, 2 & 3 | 10 |

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## QUESTION PAPER

**Name of the Examination: WIN SEM 2022-2023 - FAT**

**Course Code: PHY1008** | **Course Title: Modern Physics**

**Set number: 07** | **Date of Exam: 20/06/2023 (AN)**

**Duration: 120 Min** | **Total Marks: 60 Marks**

**Instructions:**

1. Assume data wherever necessary.
2. Any assumptions made should be clearly stated.
3. Use the following values, $h = 6.63 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg, $m_n = 1.67 \times 10^{-27}$ kg, $m_p = 1.67 \times 10^{-27}$ kg $c = 3 \times 10^8$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, $k_B = 1.38 \times 10^{-23}$ J K$^{-1}$ $= 8.617 \times 10^{-5}$ eV K$^{-1}$, $\mu_0 = 4\pi \times 10^{-7}$ H/m, Avogadro Number $(N_A) = 6.023 \times 10^{23}$/mol, Bohr Magneton ($\mu_B$ or $\beta$) $= 9.27 \times 10^{-24}$ A m$^2$, wherever required.

**Q 1.** A particle is trapped in an infinite one-dimensional potential well of width 'L'. Find the probability of finding the particle between x=0 and x=L/2 in its first excited state. **(10 M)**

**Q 2.** The high-purity Silicon is added with $1.5 \times 10^{23}$ m$^{-3}$ Boron atoms. (i) Is this materials p-type or n-type? (ii) Calculate the electrical conductivity of this material at room temperature. Assume the mobility of the charge carriers is 0.042 m$^2$ / V-s at room temperature. **(10 M)**

**Q 3.** Find the intrinsic carrier concentration of Silicon at 27 °C and 77 °C whose band gap is 1.12 eV. Given that the effective mass of electron and hole are $0.28m_o$ and $0.15m_o$ respectively. **(10 M)**

**Q 4a.** A thermistor which is made of intrinsic silicon has a resistance of 450 Ω at 300 K. Estimate its approximate resistance at 350 K, assuming a gap energy of silicon of 1.05 eV and that the carrier mobilities do not vary appreciably over this range of temperatures. **(5 M)**

**Q 4b.** The solar insolation on a rectangular module (2.5 m x 3.5 m) of a photovoltaic cell is 950 W/m$^2$. If the efficiency of the cells is 11.5 %, find the power that can be generated with photovoltaic module? **(5 M)**

**Q 5.** Calculate the saturation magnetization and saturation flux density of Ni. Given the net magnetic moment per atom of 0.60 Bohr magnetons for Ni and a density of 8.90 g/cm$^3$. Given the atomic mass of the Fe is 58.69 g/mol. **(10 M)**

**Q 6.** The B-H curve of an iron–silicon alloy is shown below and is kept within a coil of wire producing a magnetic field strength of having the B–H behaviour shown below is inserted within a coil of wire producing a magnetic field strength of 5 A/m. **(10 M)**