Registration Number:

Date & session:

ST JOSEPH'S UNIVERSITY, BENGALURU -27

M.Sc (Physics) – IV SEMESTER

SEMESTER EXAMINATION: APRIL 2024

(Examination conducted in May / June 2024)

PHDE0522: MATERIAL SICENCE

(For current batch students only)

Time: 2 Hours **Max Marks: 50**

This paper contains TWO printed pages and TWO parts

PART-A

Answer any FIVE questions. Each question carries SEVEN Marks.

[5 x 7 = 35]

1. Discuss about the construction and working of Dutta-Das Spin Field Effect Transistors (SPINFETs).
2. (a). Describe how the RKKY interaction explain the interaction between the magnetic moments and the itinerant electrons in rare-earth metal compounds.
   (b). Demonstrate the multiple quantum-well structure through a band diagram. [5+2]
3. Using the Vander Pauw method, derive expressions for both vertical and horizontal resistances, and subsequently obtain the equation of resistivity.
4. (a). Explain the absorption, fluorescence, and phosphorescence processes using Jablonski diagram. How can fluorescence and phosphorescence be confirmed through emission spectra?
   (b). Describe the operational mechanism of a light-emitting diode (LED) using a double heterostructure. [3+4]
5. Describe the time-temperature transformation (TTT) diagram and analyze its impact on phase transformation and microstructural changes in the Iron-Carbon system during the following heat treatment processes: (a) annealing, (b) normalizing, and (c) quenching. [3+2+2]
6. a) Explain with diagram, what happens when sunlight falls on the p-n junction in a solar cell and hence, explain its working.
   b) What are the different types of thin film solar cells. Explain. [3+4]
7. a) Draw a comparative study between Nickel-Cadmium and Li-ion batteries.
   b) Explain the principle of Compressed Air Energy storage (CAES).
   c). Describe the Hall effect with a suitable diagram. [3+2+2]

PART-B

Answer any THREE questions. Each question carries FIVE Marks.

[3 x 5 = 15]

8. Calculate the change in resistance(ΔR) of a spin-valve device when the magnetization of the two ferromagnetic layers switches from being parallel to being antiparallel, given the following parameters:
   (i) Thickness of the spacer layer(d) = 5 nm
   (ii) Resistivity of the spacer layer (ρ) = 100 μΩ. cm
   (iii) Area of the device(A) = 1 μm^2
   (iv) Saturation magnetization (Ms) for both ferromagnetic layers = 800 emu/cm^3
   (v) Spin polarization (P) for both layers = 0.6

9. A semiconductor cone with a refractive index of 2.5 is interfaced with air. Calculate the reflectivity of the interface for light incident at an angle of 30 degrees with respect to the normal.

10. Consider a scenario where a proton is enclosed within a box with a width of 12.5 nm, which is approximately the size of a typical nuclear radius. What energy levels characterize the ground and first excited states in this confinement? Furthermore, if the proton undergoes a transition from its first excited state back to the ground state, what would be the energy and frequency of the resulting emitted photon?

$$E_1 = \frac{\pi^2 \hbar^2}{2mL^2}$$

If we assume that the proton confined in the nucleus can be modelled as a quantum particle in a box, all we need to do is to use energy equation to find its energies E_1 and E_2. The mass of a proton is $m = 1.76 \times 10^{-27}$. The emitted photon carries away the energy difference $\Delta E = E_2 - E_1$. We can use the relation $E = h\vartheta$ to find its frequency.

11. Given that a solar cell has open-circuit voltage V_{OC} = 4.2V, short circuit current I_{SC} = 45mA, and fill-factor FF=60%, what is the efficiency? The light used during the measurement has an intensity of $1000W/m^2$ and the area of the cell is $50cm^2$.