Quiz 2_22: TOPICS IN NANOSCIENCES

TIME: 45 min

MAX. MARKS: 45

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Q1. Why are the size effects often observed at much larger sizes in semiconductors than in metals? (3)

Q2. Consider an electron having kinetic energy 5 eV.

(a) Calculate the de Broglie wavelength of the electron.

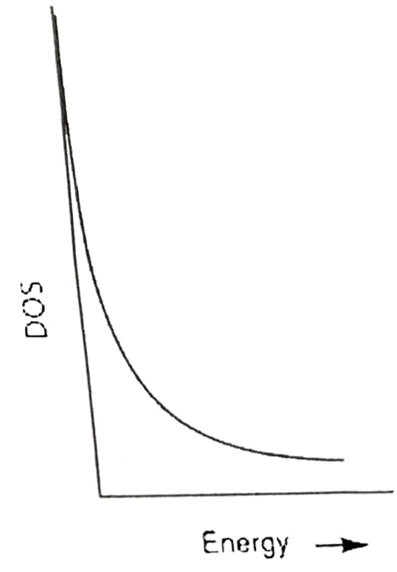
(b) If the electron is confined to a quantum dot of size L x L x L, discuss how big the dot should be for the electron's energy levels to be well quantized. (4+4)

Q3. Consider an electron in a room of size 10 x 10 x 10 m^3. Assume that within the room, potential energy is zero, and that the walls and ceilings of the room are perfect (so that the electron cannot escape from the room). If the electron's energy is approximately 5 eV, what is the state index $n^2 = n_x^2 + n_y^2 + n_z^2$? What is the approximate energy difference $E_{2.1.1} - E_{1.1.1}$? (4+4)

Q4. In the band theory of solids, there are an infinite number of bands. If, at T = 0 K, the uppermost band to contain electrons is partially filled, and the gap between that band and the next lowest band is 0.8 eV, is the material a metal, an insulator, or a semiconductor? (2)

Q5. In the band theory of solids, if, at T = 0 K, the uppermost band to have electrons is completely filled, and the gap between that band and the next lowest band is 8 eV, is the material a metal, an insulator or a semiconductor? What if the gap is 0.8 eV? (2+2)

Q6. A graphical plot of the density of states (DOS) function vs. energy is shown here. The plot corresponds to which of the following cases: bulk, quantum well, quantum wire, or quantum dot? (2)



Q7. Mention two classical material property that becomes quantized in some nanomaterials.

(2)

Q8. Write two differences between bosons and fermions.

(4)

Q9. (a) Mention two advantages of single-electron-transistors (SET). (b) Name the property (effect) of the nanometer-scale materials that is exploited for the operating principle of the SET.

(2+2)

Q10. What is the critical size (say, in terms of radius r) of a sphere-shaped quantum dot that would show single electron charging behavior at room temperature?

(4)

Q11. Give an expression (in terms of e, C and n, the number of electrons) for the voltage (V) required to inject the n-th electron in a quantum dot?

(4)

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Δr

$G = \frac{\Delta I}{\Delta V}$

$\Delta V =$

$\Delta E = \Delta V \cdot \Delta Q$

$\Delta I = n \cdot$

$t =$

$V = \frac{d}{t}$

$\Delta I = \frac{\Delta Q \cdot}{t} = \frac{ne}{\frac{L}{V}}$

$t = \frac{L}{V}$

$$\boxed{\Delta I = \frac{Vne}{L}}$$