Department of Physics

PHL120: Physics of Materials

Max. Marks: 40 Max. Time: 2 hour. Note: Answer *ALL* Questions.

1.a. Justify why presence of a nucleus is essential for pair production.

b. Estimate de Broglie wavelength of an electron revolving around an ionized donor in silicon. (*take the dielectric constant of Si as 12 and effective mass of electron as* $0.2m_e$) (2 + 2)

2. In a region of space, a particle has a wavefunction given by $\psi(x) = A \exp(-x^2/2L^2)$ and energy $E = h^2/8\pi^2mL^2$. Find potential and kinetic energies of the particle. (4)

3.a. An electron is in n=5 state in a one-dimensional infinite square potential well of length L (extending from x = 0 to x = L). What is the probability of finding the electron between x = 0.2L and x = 0.4L?

b. What will be the expectation value of position between x=0 and x=L of the electron if it is in the n=3 state? (2 + 2)

4. Five identical, non-interacting particles are placed in an infinite square potential well.
(a) When the particles are Fermions, obtain the two lowest total energies of the system (expressed in terms of ground state energy taken as E_1)?

(b) Obtain the two lowest total energies of the system, if the particles are Bosons? (2 + 2)

5. a Using 2D Brillouin zone-fermi energy contour, explain the hole conduction nature of Zn metal.

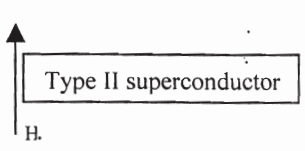
b. Sketch first and second Brillouin zones for a rectangular lattice of edge lengths x = a and y = 2a. (2 + 2)

6.a. Si and GaN have bandgaps of 1.1 eV and 3.3 eV, respectively. Explain which of the two semiconductors will be transparent when light of wavelength 600 nm is incident on them.

b. What is the difference between the energy gap in a superconductor and that for a semiconductor? (1 + 1)

7.a. Draw energy band diagrams and I-V characteristics for (i) gold/n-Si and (ii) cobalt/n-Si junctions. (***Useful data***: work function of gold = 4.8 eV, work function of cobalt = 3.9 eV, electron affinity of silicon= 4.05 eV.

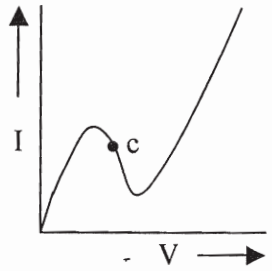
b. A magnetic field H_a is applied to a circular disk of type II superconductor maintained at $T<T_c$ (see figure). Draw magnetic flux lines for two values of the applied field (i) $H_a<H_{c1}$ and (ii) $H_{c1}<H_a<H_{c2}$. (4+2)



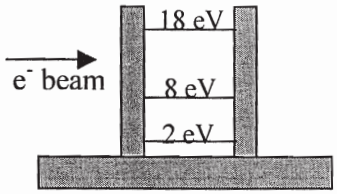
8. Two metals Sn (T_c = 3.7 K) and Nb (T_c = 7.2 K) are separated by an ultrathin insulating barrier. Draw I-V characteristics when the junction is maintained at (i) 2 K (ii) 5 K and (ii) 10 K. (3)

9. a. Why are the drift currents in a p-n junction not dependent on bias voltage but depend on operating temperature?

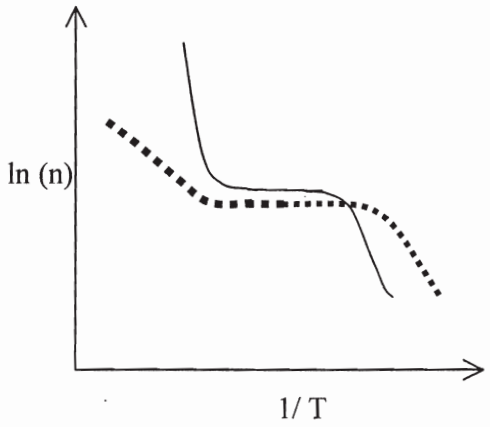
b. Draw energy band diagram corresponding to point C on the I-V characteristics of a p^+-n^+ junction (see figure). (2 + 2)



10. An electron beam is incident on a double barrier shown in figure below. Draw transmission coefficient as a function of incident electron energy when it is varied from 0 to 10 eV. (2)



11. The temperature variation of carrier concentration, n of two extrinsic semiconductors doped with unknown number of donors is shown in figure. Identify (a) relative doping concentrations (b) relative band gaps of the semiconductors and (c) relative ionization energies of the respective donors. (3)



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