Q.1) What is superconductivity and illustrate the effect of magnetic field on the superconductor materials with drawing.

**Superconductivity** is the phenomenon of losing resistivity when sufficiently cooled to a very low temperature (below a certain critical temperature).

**The Effect of Magnetic Field**

- An important characteristic of all superconductors is that the superconductivity is "quenched" when the material is exposed to a sufficiently high magnetic field.
- This magnetic field, $B_c$, is called the critical field.
- **Critical magnetic field ($H_C$)**: Minimum magnetic field required to destroy the superconducting property at any temperature and obeys a parabolic law of the form:
  
  $$H_c = H_0 \left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

  Where $H_0$ – Critical field at 0K
  $T$ – Temperature below $T_C$
  $T_C$ – Transition Temperature

- the figure, show:
  1- The value of ($H_C = 0$) when $(T = T_C)$.
  2- Increase ($H_C$) gradually whenever decrease ($T$) of superconductor material from $T_C$.
  3- at $T = 0$ K, $H_C = Max.$ value

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Q.2) To generate of X – rays for X – ray Diffraction (XRD), suppose an electron accelerated at 5000 V strikes a copper target. Will $K_\alpha$, $K_\beta$, or $L_\alpha$ X – rays be emitted from the copper target? The wave length of $K_\alpha$, $K_\beta$, and $L_\alpha$ X – ray for copper are 1.542 Å, 1.392 Å and 13.357 Å, respectively.

The electron must possess enough energy to excite an electron to a higher level, or its wavelength must be less than that corresponding to the energy difference between the shells:

$$E_g = (5000 \text{ eV}) \left(1.6 \times 10^{-19} \text{ J/ eV}\right) = 8 \times 10^{-16} \text{ J}$$

$$\lambda = \frac{h c}{E_g} = \frac{(6.62 \times 10^{-34} \text{ J} \cdot \text{s})(3 \times 10^{16} \text{ cm/s})}{(8 \times 10^{-16} \text{ J})} = 2.48 \times 10^{-8} \text{ cm} = 2.48 \text{ Å}$$

Thus, when compare the calculation $\lambda$ with that in the example, find the $L_\alpha$ peak may be produced, but $K_\alpha$ and $K_\beta$ will not.

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Q.3) Give short answer for following questions; (chose 5 points) (25 degree)

a) Radiation "waves" divided into two major categories are **ionizing** and **non-ionizing**.

b) Wave represents (or defines) by **wavelength ($\lambda$)**, **amplitude (A)** and **frequency (f)**.

c) The resistivity of some materials approach to zero.

As the temperature drops below the critical point, $T_c$, resistivity rapidly drops to zero and current can flow freely without any resistance, then the material will be superconductor.

d) The (HTS) ceramics have technological disadvantages, what are they?

The HTS ceramics have two technological disadvantages:
1- They are brittle and 2- They degrade under common environmental influences 

e) What are the types of SQUID?

There are two main types of SQUID:

1) RF SQUIDs have only one Josephson junction

2) DC SQUIDs have two or more junctions.

• f) The principle of Josephson device persistent current in d.c. voltage.

Q.4) After finding the electrical conductivity of cobalt at 0°C, we decide we would like to double that conductivity. To what temperature must we cool the metal? Hence the resistivity at room temperature 6.24*10^{-6} Ω.cm and α = 0.006 Ω.cm/°C.

1) at T = 0°C 
\[ \rho = \rho_{RF} \left(1 + \alpha_R(T - T_0)\right) \rightarrow \rho_{zero} = (6.24 \times 10^{-6})[1 + 0.006(0 - 25)] \]
\[ = 5.304 \times 10^{-6} [\text{ohm.cm}] \]

Since the conductivity is double, or halve the resistivity to 2.652 × 10^{-6} ohm.cm. the required temperature is:
\[ 2.652 \times 10^{-6} = (6.24 \times 10^{-6})[1 + 0.006(T - 25)] \]
\[ -0.575 = 0.006(T - 25) \rightarrow T = -70.8°C \]

Q.5) Nb₃Sn and GaV₃ are candidates for a superconductive application at the same critical magnetic field. Find the lower temperature for GaV₃ in order to be superconductive. Hence, GaV₃ (H₀ = 350,000 oersted, T_C = 16.8 K), Nb₃Sn (H₀= 250,000 oersted, T =11.42 K, T_C= 18.05 K).

\[ H_c = H_o \left[1 - \left(\frac{T}{T_C}\right)^2\right] \]

\[ H_c(Nb₃Sn) = 250,000 \left[1 - \left(\frac{11.42}{18.05}\right)^2\right] = (250,000)(0.5997) = 149926 \equiv 150,000 \text{ oersted} \]

Since the two materials are superconductive at the same critical magnetic field. So

\[ H_c(GaV₃) = 150,000 = 350,000 \left[1 - \left(\frac{T}{16.8}\right)^2\right] \]
\[ \frac{150,000}{350,000} = 1 - \left(\frac{T}{16.8}\right)^2 \rightarrow 0.428 - 1 = - \left(\frac{T}{16.8}\right)^2 \rightarrow 0.572 = \left(\frac{T}{16.8}\right)^2 \]
\[ \sqrt[2]{0.572} = \frac{T}{16.8} \rightarrow T = (0.7563)(16.8) = 12.7 K \]