(1) Explain type 1 & type 2 Superconductors? (2)

There is a certain minimum value of magnetic field $B_c(T)$ below which there is complete expelsion of magnetic flux. At this value the the flux abbruptly penetrates perfectly into the entire speciman. Reverting the speciman into its normal state. The ~~sc~~ material that show this behaviour is called type-1 superconductor.

There is no penetration of magnetic field below a certain lower critical field $B_{c_1}(T)$ and the penetration begins at this value & grows further till an upper critical field $B_{c_2}(T)$ is reached. And the penetration is complete. In the region of partial penetration from $B_{c_1}(T)$ to $B_{c_2}(T)$ the speciman assumes a complecated mixture of normal & superconducting states. The speciman is said to be in a mixed state commonly known as vortex state. Superconductors with these features are called type-2 superconductors.

(2) Explain Meissner effect? (2)

The expulsion for the magnetic flux from a interial of sc material as the material undergo transition to sc phase is known as Meissner effect.

(3) Explain Josephson effect? (2)

If both materials are superconductor. Josephson predicted that in addition to normal tunneling of single e^-s, the cooper pair not only can tunnel through the insulting tunnel from one sc to another without dissociation, even at zero potential across the junction but also there wave function on both sides, would be highly corelated. This is known as Josephson effect.

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(4) A superconducting material has critical temperature of 3.722 K at zero magnetic field and a critical field of 0.0305 T at zero K. Find critical field at 2K. (4)

$T_c = 3.722\,K$. when, $B = 0\,T$

$B_c(0) = 0.0305\,T$

$T = 2K$.

$$B_c(T) = B_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$= 0.0305\left[1 - \left(\frac{2}{3.722}\right)^2\right]$$

$$B_c(T) = 0.0217\,T$$

(5) Superconductivity show perfect diamagnetism. Explain (2)

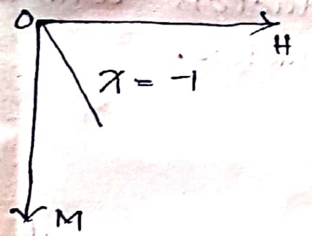
The magnetic induction inside the substance is,

$$B = \mu_0 (H + M) = \mu_0 (1 + \chi) H$$

where,

$H \rightarrow$ External applied field

$M \rightarrow$ magnetization.



According to Meissner effect inside the material,

$$B = 0$$

$$M = -H$$

Or $\chi = -1$

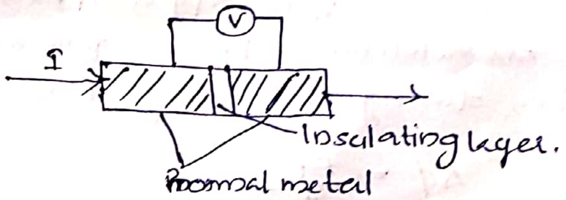
Therefore, the superconducting materials are perfectly diamagnetic.

(6) What is meant by superconductivity? (1)

When we cool certain metals & alloys to sufficiently low temperature they are exhibit almost zero electric resistivity. This phenomenon is known as superconductivity.

Q) What is Josephson effect? discuss both dc and ac Josephson effect applications?

When a thin insulating layer is sandwitch between two metals it act as a potential barrier as far as the flow of conduction e^- is conserved. But by quantum mechanics e's can tunnel across the barrier when a potential is applied. Thus current-voltage relation across the tunneling junction is observed to obey ohm's law.

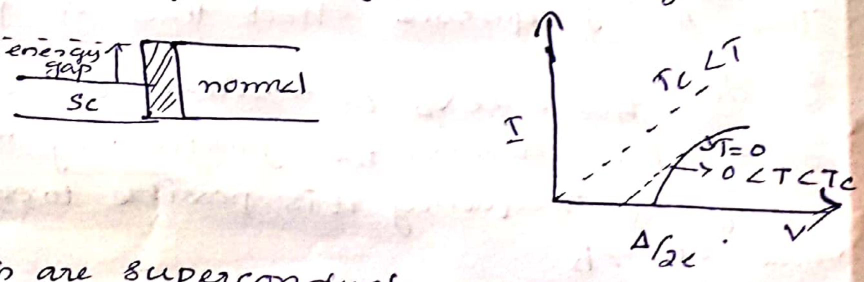


If one metal is super conductor no current is observed through flow across the junction until the potential reaches a threshold value,

$$eV = \Delta/2$$

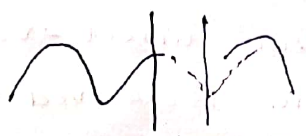
where Δ is the bandgap energy.

It is because the energy states lying horizontally below E_f in the normal metals are occupai. As the temp. increases towards T_c the threshold voltage decreases. This consequently indecates a decrease in energy gap itself. The above discussed tunneling is called normal tunneling or single e^- tunneling.



If both are superconductor Joseph predicted that in addition to normal tunneling of single e's, the cooper pair not only can tunnel through the insulating tunnel from one sc to another without dissociate even at zero potential across the junction but also the wave function on both sides, would be highly coreleted. This is know as Josephson effect.

He showed that the effect of insulating layer is just to introduce a phase difference $\delta\phi$ b/w the two parts of the wave function on opposite sides of the junction. He showed that the tunneling current $I = I_0 \sin\phi_0$, I_0 is the max. current that without ~~an~~ no-applied voltage a dc current will flow across the junction with a value between I_0 & $-I_0$. According to the phase difference $\phi_0 = \phi_2 - \phi_1$



If a static potential V_0 is applied across a junction due to which an additional phase will be introduced by the cooper pair, during tunneling across the junction.

$$\Delta\phi = \frac{Et}{\hbar}$$

$E \rightarrow$ total energy of the system

$E = (2e) V_0$

$$\therefore \quad \Delta\phi = \frac{2eV_0t}{\hbar}$$

then,

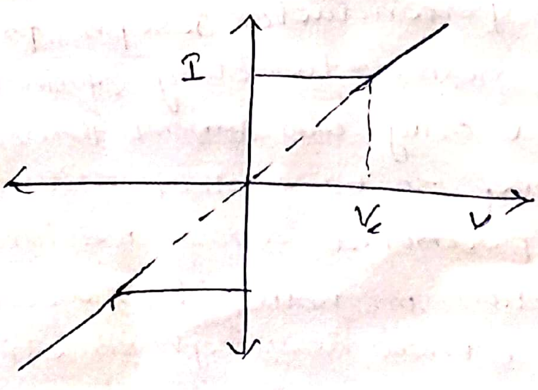
$$I = I_0 \sin(\phi_0 + \Delta\phi)$$

$$= I_0 \sin\left(\phi_0 + \frac{2eV_0t}{\hbar}\right)$$

This equation represents an alternating current with an angular frequency,

$$\frac{2eV_0}{\hbar}$$

This AC Josephsons effect thus a photon of energy, $\hbar\omega = 2eV_0$ is emitted or absorbed when a e^- pair across the junction. By measuring the voltage & frequency it is possible to obtain precise value of $e/\hbar$



8) Explain properties exhibited by materials in super conductivity states. What are type1 & type 2 super conductors. Explain how BCS theory describe super conductivity.

Bcs theory

The theory of sc was put forward by Bardeen, cooper & shrifer, & named as BCS theory. They theorised that the electrons in sc operates in pairs called cooper pair. which has opposite spin & oposite spin vector. As a result a pair of particle operates as though they have zero spin & have no net wave vector. Particle that have integer spins belongs to the cls of particles called boson. In the case of sc the e's which are normally fermions pair up & behave like bosons. In view or zero wave vector of superpair they do not suffer from typical scattering effect that normals e's experienced.

The theory of sc requires a net attractive interaction b/w a pair of e's in the neighbourhood of fermi surface. This is possible only if the interaction b/w the e's will taking coulomb interaction b/w them always produces a repulsion.

Consider an e⁻ passing through the packing of +ve lattice ion. Because it is -vely charged it is attracted by the neighbouring +ve ions & gets screened by them. The screening greatly reduces the effective charge of this e⁻, in fact the ion core may produce a net +ve charge on this assembly. At the same time due to attraction b/w the e's & the ion core, the lattice gets defomed on local state.

Thus the 2 e's form a bound state and there motions are corelated. Cooper pairs can have a significant distance b/w them of the order of several nanometer & still maintained the interaction b/w them. This is accomblished using lattice waves or exchange of phonons.

As a result of formation of cooper pairs

an energy gas occures an this energy gap is highest at low temp but vanishes at low temperature.

BCS theory gives the relationship at OT an T_c as

$\Delta(T=0) = 3.52\, k T_c$.
