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Lecture for M. Sc. Physics IV Semester students

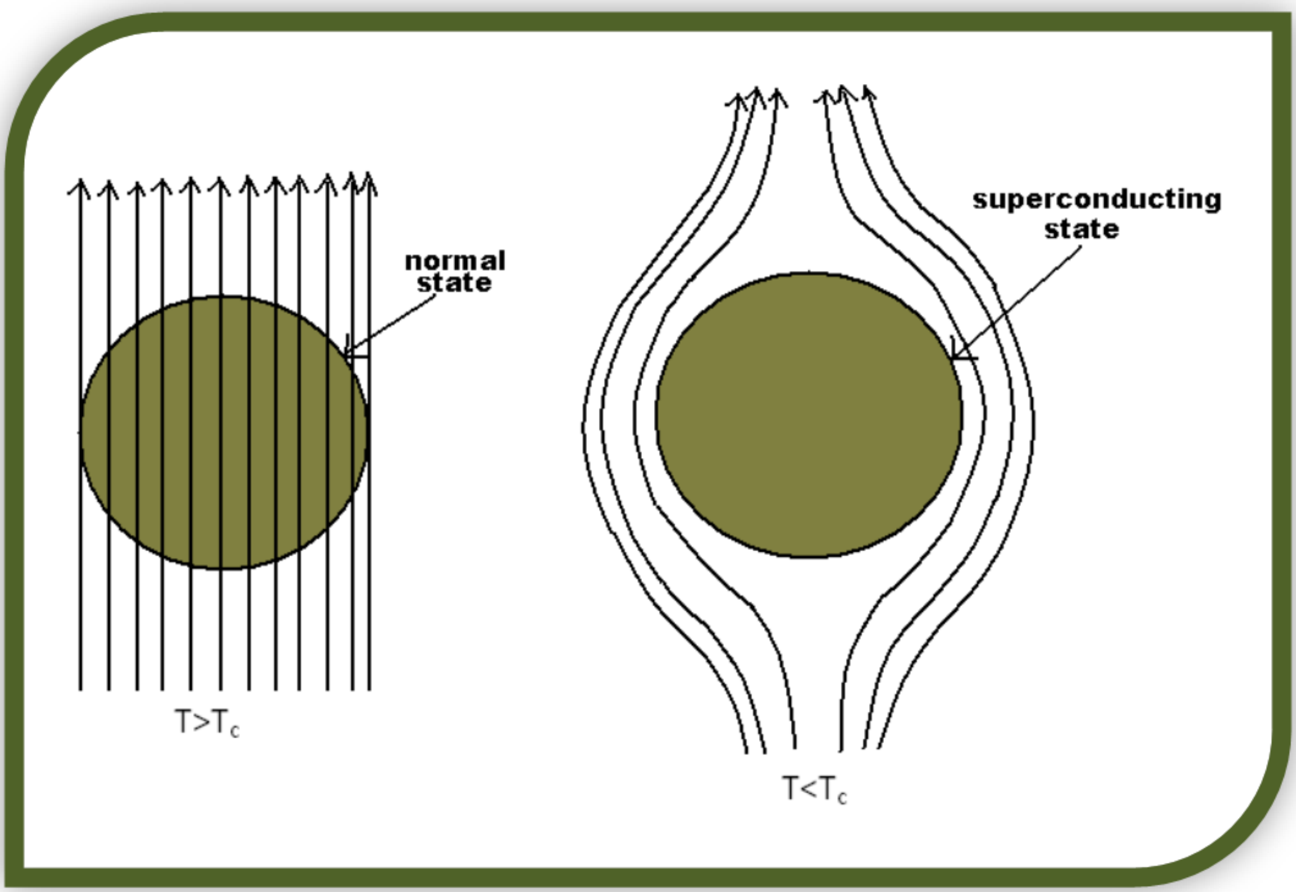
Paper-I: Condensed Matter Physics

Unit 4-: Superconductivity

<u>**Meissner Effect of Flux Exclusion**</u>

In 1933, Meissner and Ochsenfeld observed that a superconductor expels magnetic flux completely, a phenomenon known as the **Meissner effect**.

In a series of experiments on superconducting cylinders, they demonstrated that, as the temperature is lowered to T_c , the flux **is suddenly and completely** expelled as the specimen becomes superconducting as shown below. The flux exclusion continues for all $T < T_c$.



They established this by carefully measuring the magnetic field in the neighborhood of the specimen. Furthermore they established that this effect is REVERSIBLE.

When the temperature is raised from below T_c the flux suddenly penetrates the specimen after it reaches T_c and the substance is in the normal state.

The magnetic induction inside the substance is

$$\vec{B} = \mu_0(\vec{H} + \vec{M}) = \mu_0(1 + \chi)\vec{H} \qquad \text{……….} \ (1)$$

Where $\vec{H}$ is the external intensity of magnetic field,

$\vec{M}$ - Magnetization in the medium

χ - Magnetic susceptibility = $\frac{\vec{M}}{\vec{H}}$

Since $\vec{B}$=0 in the superconducting state, it follows that

$$\vec{M} = -\vec{H} \qquad \text{……….} \ (2)$$

Meaning that magnetization is equal to and opposed to $\vec{H}$. The medium is therefore diamagnetic and the susceptibility is

$$\chi = -1 \qquad \text{……….} \ (3)$$

Such a condition – in which magnetization cancels the external intensity exactly – is referred to as **perfect diamagnetism**.

Compare this behavior with that of normal metal. The metal is also diamagnetic – if a spin susceptibility is ignored – but in that case $\chi \approx -10^{-5}$ which is much smaller than that given by eq(3). It follows that some new mechanism operates in superconducting states in order to give such an enormous diamagnetism.

The Meissner effect is particularly interesting because it contradicts classical laws.