Superconductors

Shane Wilton, Julia Taylor, Amelia French

April 20, 2011

1 Problems

1.1 London Penetration Depth

In superconductors, the Meissner effect requires that a magnetic field decays to zero as it penetrates a superconductor. The London penetration depth is defined as the distance required for the field to decrease to $\frac{1}{e}$ multiplied by its original strength. The London penetration depth is given by $\lambda_L = \sqrt{\frac{\epsilon_0 m_s c^2}{n_s e_s^2}}$ Here, m_s is the mass of an electron, $e_s$is the charge of an electron, $n_s$is the number density of the superconductor, and $\epsilon_0$is the vacuum permittivity constant. If you have a sample of superconducting tin, with a number density of $1.1 * 10^{22} cm^{-3}$, and the vacuum permeability constant is equal to $8.854 * 10^{-12} F \cdot m^{-1}$, then what is the superconductor's London penetration depth in meters? If you have trouble with the units, keep in mind that your solution should be a length.

1.2 Internal Field Strength

Using the same superconductor from problem 1.1, determine the intensity of a magnetic field which penetrates 250nm into the superconductor. At the point where the magnetic field meets the surface of the superconductor, the field intensity, generated by a strong ferrite magnet, is 0.1T. The field intensive is given by $B(x) = B(0)e^{\frac{-x}{\lambda}}$ Where x is the depth, in meters, that the field penetratres the superconductor, $\lambda$is the London penetration depth, and B(0) is the magnetic field strength at the surface of the superconductor.

2 Solutions

2.1 London Penetration Depth

$m_s = 9.109 * 10^{-31} kg$

$e_s = -1.602 * 10^{-19} C$

$\epsilon_0 = 8.854 * 10^{-12} F \cdot m^{-1}$

$c = 2.998 * 10^8 \frac{m}{s}$

$n_s = 1.1 * 10^{22} cm^{-3} = 1.1 * 10^{28} m^{-3}$

$\lambda_L = \sqrt{\frac{\epsilon_0 m_s c^2}{n_s e_s^2}}$

$\lambda_L = \sqrt{\frac{(8.854*10^{-12} F \cdot m^{-1})(9.109*10^{-31} kg)(2.998*10^8 \frac{m}{s})^2}{(1.1*10^{28} m^{-3})(-1.602*10^{-19} C)^2}}$

$\lambda_L \approx 5.067 * 10^{-8} m$

Therefore, the London penetration depth is approximately $5.067 * 10^{-8} m$.

2.2 Internal Field Strength

$\lambda \approx 5.067 * 10^{-8} m$

$B(0) = 0.1T$

$x = 250nm = 2.5 * 10^{-7} m$

$B(x) = B(0) e^{\frac{-x}{\lambda}}$

$B(2.5 * 10^{-7}) = 0.1T * e^{\frac{-2.5*10^{-7} m}{5.067*10^{-8} m}}$

$B(2.5 * 10^{-7}) \approx 7.2 * 10^{-4} T$

Therefore, the magnetic field intensity drops to approximately $7.2 * 10^{-4} T$ as the field penetrates 250nm into the superconductor.