Magnetic Properties of Superconductors.

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In macroscopic superconductors Meissner discovered that the induction $B$ is always equal to zero, therefore since

$$B = H + 4\pi M,$$

where $M$ is the magnetic moment per unit volume, we conclude that

$$M = -\frac{H}{4\pi}.$$

Because of the demagnetizing field associated with any finite magnetic specimen immersed in an external field, $H_e$, we have to put

$$H = H_e - NM,$$

where $N$ is the demagnetizing coefficient and $H_e$ is the uniform external field which exists before the specimen is brought into the field.

Solving $M$ as a function of $H_e$, we get

$$M = -\frac{H_e}{4\pi - N}.$$

For a very long needle-shaped specimen parallel to $H_e$, $N = 0$, so that in this case

$$M = -\frac{H_e}{4\pi},$$
and the specimen has an apparent volume susceptibility of $\chi = M / H_x = -1/4\pi$. The free enthalphy/unit volume is

$$G = u - TS - H_x M,$$

so that

$$\frac{\partial G}{\partial H_x} = -M,$$

and integrating this equation we get

$$G = G_{H_x=0} + \frac{1}{2} \frac{B_x^2}{4\pi}.$$

In Fig. 1 we show the three quantities $B$, $M$ and $G$ as functions of the external field for the case of an infinitely long cylinder with its axis parallel to the field ($N = 0$), and for an infinitely long circular cylinder with its axis perpendicular to the field ($N = 2\pi$).

So far we have only discussed the behaviour of a superconducting specimen for small fields. We shall discuss what happens in larger fields after discussing the caloric behaviour of superconductors.