

Ques A superconducting tin has a critical temperature of 3.7 K at zero magnetic field and a critical field of 0.0306 Tesla at 0 K. Find the critical field at 2 K.

Solution:

Given data:

Critical temperature $T_c = 3.7 \text{ K}$
 Critical field $H_c = 0.0306 \text{ Tesla}$
 Temperature $T = 2 \text{ K}$
 The critical magnetic field

magnetic field intensity is represented by H.
 Magnetic flux density is represented by B.
 Here magnetic field means B. Unit is Tesla.
 This formula is applicable for H and B.

$$H_c = H_0 \left[1 - \left[\frac{T^2}{T_c^2} \right] \right]$$

$$B_c = B_0 \left[1 - \frac{T^2}{T_c^2} \right]$$

$$= 0.0306 \left[1 - \left[\frac{2}{3.7} \right]^2 \right] = 0.0216 \text{ Tesla}$$

The critical magnetic field $H_c = 0.0216 \text{ Tesla}$.

7. Calculate the critical current and current density for a wire of a lead having a diameter of 1 mm at 4.2 K. The critical temperature for lead is 7.18 K and $H = 6.5 \times 10^4 \text{ A m}^{-1}$.

Solution:

Given data:

Critical temperature $T_c = 7.18 \text{ K}$
 Critical field $H_0 = 6.5 \times 10^4 \text{ A m}^{-1}$
 Temperature $T = 4.2 \text{ K}$
 Radius of the wire $r = 0.5 \times 10^{-3} \text{ m}$

$$\text{The critical magnetic field } H_c = H_0 \left[1 - \left[\frac{T^2}{T_c^2} \right] \right]$$

$$= 6.5 \times 10^4 \left[1 - \left[\frac{4.2}{7.18} \right]^2 \right]$$

$$= 4.276 \times 10^4 \text{ A m}^{-1}$$

i) Critical current

$$I_c = 2\pi r H_c$$

$$= 2 \times 3.14 \times 0.5 \times 10^{-3} \times 4.276 \times 10^4$$

$$= 134.39 \text{ A}$$

ii) Critical density

$$J_c = \frac{I_c}{\pi r^2}$$

$$= \frac{134.39}{3.14 \times (0.5 \times 10^{-3})^2}$$

$$= 1.71 \times 10^8 \text{ A m}^{-2}$$

Critical current $I_c = 134.39 \text{ A}$

Critical density $J_c = 1.71 \times 10^8 \text{ A m}^{-2}$



It is a derived result using Ampere's law.

$\oint H \cdot dl = I_{\text{enclosed}}$
 It is a topic from electro-magnetic theory.

Ques

Prove that susceptibility of superconductor is -1 and relative permeability is zero.

Solution:

Given data:

We know, the induced magnetic field $B = \mu_0(M + H)$... (1)

In superconductor, $B = 0$

Therefore, $0 = \mu_0(M + H)$

Since $\mu_0 \neq 0$, $M = -H$

$$\frac{M}{H} = \chi = -1 \quad \dots (2)$$

Also, $\chi = \mu_r - 1$

$$-1 + 1 = \mu_r = 0$$

Therefore the susceptibility $\chi = -1$

and Relative permeability $\mu_r = 0$

Ques Find the critical current which can pass through a long thin superconducting wire of aluminum of diameter 2 mm, the critical magnetic field for aluminum is $7.9 \times 10^3 \text{ A m}^{-1}$.

Solution:

Given data:

The critical magnetic field $H_c = 7.9 \times 10^3 \text{ A m}^{-1}$

$$\text{Radius } r = \frac{\text{Diameter}}{2}$$

$$= \frac{2}{2} = 1 \times 10^{-3}$$

$$\begin{aligned} \text{Critical current } I_c &= 2\pi r H_c \\ &= 2 \times 3.14 \times 1 \times 10^{-3} \times 7.9 \times 10^3 \text{ A m}^{-1} \end{aligned}$$

$$I_c = 49.65 \text{ A}$$

$$\text{Critical current } I_c = 49.65 \text{ A}$$

Ques The superconducting transition temperature of Lead is 7.26 K. The initial field at 0 K is $64 \times 10^3 \text{ Amp m}^{-1}$. Calculate the critical field at 5 K.

Solution:

Given data:

Critical temperature $T_c = 7.26 \text{ K}$

Critical Field $H_0 = 64 \times 10^3 \text{ Amp m}^{-1}$

Temperature = 5 K

$$\begin{aligned} \text{The Critical Field } H_c &= H_0 \left[1 - \left[\frac{T}{T_c} \right]^2 \right] \\ &= 64 \times 10^3 \left[1 - \left[\frac{5}{7.26} \right]^2 \right] \\ &= 64 \times 10^3 \times 0.5257 \\ H_c &= 33.644 \times 10^3 \text{ Amp m}^{-1} \end{aligned}$$

Ques A magnetic field of 2000 Amp m^{-1} is applied to a material which has a susceptibility of 1000. Calculate the (i) Intensity and (ii) Flux density.

Solution:

Given data:

Magnetic Field $H = 2000 \text{ Amp m}^{-1}$

Susceptibility $\chi = 1000$

i) Magnetisation $M = \chi H$
 $= 2000 \times 1000$
 $= 2 \times 10^6 \text{ Amp m}^{-1}$

ii) Flux density $B = \mu_0(M+H)$
 $= 4 \times 3.14 \times 10^{-7} (2 \times 10^6 + 2000)$
 $B = 2.514 \text{ wbm}^{-2}$

over

The superconducting transition temperature of lead is 7.26 K. The initial field at 0 K is $64 \times 10^3 \text{ Amp m}^{-1}$. Calculate the critical field at 5 K.

Solution:

Given data:

Critical temperature $T_c = 7.26 \text{ K}$

Critical field $H_0 = 64 \times 10^3 \text{ Amp m}^{-1}$

Temperature $T = 5 \text{ K}$

The critical field $H_c = H_0 [1 - (T/T_c)^2]$
 $= 64 \times 10^3 [1 - (5/7.26)^2]$
 $= 64 \times 10^3 \times 0.5257$
 $H_c = 33.644 \times 10^3 \text{ Amp m}^{-1}$

question applied

The magnetic field strength of Silicon is 1500 Amp m^{-1} . If the magnetic susceptibility is (-0.3×10^{-5}) , calculate the magnetization and flux density in Silicon.

Solution:

Given data:

Magnetic susceptibility $\chi = -0.3 \times 10^{-5}$

Magnetic field strength $H = 1500 \text{ Amp m}^{-1}$

Magnetic susceptibility $\chi = \frac{I}{H}$

$$I = \chi H$$
$$= -0.3 \times 10^{-5} \times 1500$$
$$= -4.5 \times 10^{-3} \text{ Amp m}^{-1}$$

We know

$$\mu = H + \chi$$
$$= 1 - 4.5 \times 10^{-3}$$

$$\mu = 0.999$$

Flux density $B = \mu H$
 $= 0.999 \times 1500$

$$B = 1498.5 \text{ web m}^{-2}$$

$$M = \chi H$$
$$= -0.3 \times 10^{-5} \times 1500$$
$$= -4.5 \times 10^{-3} \text{ A/m}$$

$$B = B_0 + \mu_0 M$$
$$= \mu_0 H + \mu_0 M$$
$$= \mu_0 (H + M)$$
$$= 4\pi \times 10^{-7} (1500 - 4.5 \times 10^{-3})$$
$$= 1.885 \times 10^{-3} \text{ T}$$

14. Calculate the critical current which can flow through a long thin super conducting wire of diameter 1 mm. The critical magnetic field is $7.9 \times 10^3 \text{ Amp m}^{-1}$.

Soution:

Given data:

$$\text{Diameter of the wire } d = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$$

$$\text{radius of the wire } r = \frac{d}{2} = \frac{1 \times 10^{-3}}{2} \text{ m}$$

$$\text{The critical magnetic field } H_c = 7.9 \times 10^3 \text{ Amp m}^{-1}$$

Critical current flowing through the wire

$$\begin{aligned} I_c &= 2\pi r H_c \\ &= 2 \times 3.14 \left(\frac{1 \times 10^{-3}}{2} \right) (7.9 \times 10^3) \end{aligned}$$

$I_c = 24.81 \text{ Amp}$

ASSIGNMENT PROBLEMS

1. The saturation value of magnetization of iron is $1.76 \times 10^6 \text{ A m}^{-1}$. Iron had body centered cubic structure with an elementary edge of $2.86 \text{ \AA}$. Calculate the average number of Bohr magnetrons contributed to the magnetization per atom.

(Ans: 2.2 Bohr magnetron per atom)

2. The magnetic field intensity of a ferric oxide piece is 10^6 A m^{-1} . If the susceptibility of the material at room temperature is 10.5×10^{-3} , calculate the flux density and magnetization of the material.

(Ans: $B = 1.259 \text{ T}$ and $M = 1500 \text{ A m}^{-1}$)

3. A magnetic material has a magnetization of 3000 A m^{-1} and flux density of 0.044 Wb m^{-2} . Calculate the magnetic force and the relative permeability of the

material.

(Ans: $M = 203$ and $\mu_r = 17.26$)