DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module I Lecture-4

Solving Problems

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1. The saturation magnetic induction of nickel is 0.65 weber/metre^2. If the density of nickel is 8906 kg/m^3 and atomic weight is 58.7, calculate the magnetic moment of nickel atom in Bohr magneton.

Given data

Magnetic induction of nickel

$$B = 0.65 \text{ weber / metre}^2$$

Density of nickel $\rho = 8906 \text{ kg / m}^3$

Atomic weight $(M) = 58.7$

$$\mu_o = 4\pi \times 10^{-7} \text{ H/m}$$

Avagadro's number $N = 6.023 \times 10^{26}$

Solution

We know that $B = N\mu_0\mu_m$

$N = \rho N/M$

N is the number of atoms per unit volume ($atoms/m^3$)

Substituting the given values, we have

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$$N = \frac{8906 \times 6.023 \times 10^{26}}{58.7}$$

$$N = 9.14 \times 10^{28} \text{ atoms / m}^3$$

$$\mu_m = \frac{B}{N\mu_0}$$

$$[\because B = N\mu_o \mu_m]$$

$$\mu_m = \frac{0.65}{9.14 \times 10^{28} \times 4\pi \times 10^{-7}}$$

$$\mu_m = 5.66 \times 10^{-24} \text{ ampere / metre}^2$$

We know that 1 Bohr magneton

$$= 9.27 \times 10^{-24} \text{ Am}^2$$

$$\mu_m = \frac{5.66 \times 10^{-24}}{9.27 \times 10^{-24}}$$

$$\boxed{\mu_m = 0.61 \text{ Bohr magneton.}}$$

2. A paramagnetic material has bcc structure with a cube edge of 2.5×10^{-10} m. If the saturation value of magnetization is 1.8×10^{6} ampere/metre. Calculate the average magnetisation contributed per atom in Bohr magneton.

Given data

Interatomic distance $a = 2.5\,\mathring{A} = 2.5 \times 10^{-10}$ m

Magnetisation $M = 1.8 \times 10^{6}\ \mathrm{Am^{-1}}$

Electronic charge 'e' $= 1.6 \times 10^{-19}$ coulomb

Planck's constant $h = 6.625 \times 10^{-34}$ Js

Solution

Number of atoms per unit volume

$$= \frac{\text{No. of atoms in an unit cell}}{\text{volume of the unit cell } (a^3)}$$

$$= \frac{2}{(2.5 \times 10^{-10})^3} = 1.28 \times 10^{29} \text{ m}^3$$

Total magnetisation $M = 1.8 \times 10^6 \text{ Am}^{-1}$

Average magnetisation produced per atom

$$= \frac{1.8 \times 10^6}{1.28 \times 10^{29}} = 1.406 \times 10^{-23} \text{ Am}^{-2}$$

Bohr magneton $\mu_B = \frac{eh}{4\pi m}$

$$\mu_B = \frac{1.6 \times 10^{-19} \times 6.625 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31}}$$

$$= 9.27 \times 10^{-24}\ \mathrm{Am}^{-2}$$

$$\left.\begin{array}{r}\text{Average magnetisation}\\ \text{produced per atom}\\ \text{in Bohr magneton}\end{array}\right\} = \frac{1.4065 \times 10^{-23}}{9.27 \times 10^{-24}}$$

$$= 1.52 \text{ Bohr magneton}$$

3. Magnetic field intensity of a paramagnetic material is 10^4 ampere/metre. At room temperature its susceptibility is 3.7×10^{-3}. Calculate the magnetization of the material.

Hint: $M = \chi H$

Ans: 37 ampere/metre