Exercise Solutions

Question 1: The magnetic intensity H at the centre of a long solenoid carrying a current of 2.0 A, is found to be 1500 A m^{-1}. Find the number of turns per centimeter of the solenoid.

Solution:
Current in the solenoid = I = 2A (given)
Magnetic intensity H at the centre = 1500 Am^{-1} (Given)

We know, Magnetic field produced by solenoid = B = $\mu_o ni$ ..(1)

Where,
i = current in the solenoid
n = number of turns per unit length
μ_0 = absolute permeability of vacuum

And, magnetizing field intensity (H) in the absence of any material :

H = B/μ_0 ...(2)
Where B is net magnetic field

From (1) and (2),

H = ni

1500 = n x 2

=> n = 750 turns/m or 7.50 turns/cm

Number of turns per cm of the solenoid is 7.5 turn/cm.

Question 2: A rod is inserted as the core in the current-carrying solenoid of the previous problem.
(a) What is the magnetic intensity H at the centre?
(b) If the magnetization I of the core is found to be 0.12 A m^{-1}, find the susceptibility of the material of the rod.
(c) Is the material paramagnetic, diamagnetic or ferromagnetic?

Solution:
(a) Since the magnet and rod are long and we are interested in the magnetic intensity at the center, the end effects can be neglected. There is no effect of the rod on the magnetic intensity in the middle. So, magnetization intensity remains the same.

Therefore, magnetic intensity H at the centre = H = 1500 Am^{-1} (using from previous problem as given)

(b) Magnetization of the core = I = 0.12 Am^{-1}

We know, I = χH

χ = susceptibility of material of the rod.

χ = 0.12/1500

=> χ = 8 x 10^{-5}

(c) The material is paramagnetic.

Question 3: The magnetic field inside a long solenoid having 50 turns cm^{-1} is increased from 2.5 × 10^{-3} T to 2.5 T when an iron core of cross-sectional area 4 cm^2 is inserted into it. Find
(a) the current in the solenoid,
(b) the magnetization I of the core and
(c) the pole strength developed in the core.

Solution:
Number of turns per cm = 50
Magnetic field inside solenoid with iron core = 2.5 T
Magnetic field inside without iron core = 2.5× 10^{-3} T
Cross-sectional area = 4cm^2

Magnetic field inside the solenoid without iron core:

$B = \mu_0 ni$

Or $i = B/ \mu_0 n$

i = 2.5 x 10^{-3}/[4πx10^{-7}x5000] = 0.4 A

(b)

$I = B/\mu_0 - H$

B = 2.5 T (Known)

Where, I = Magnetization of the core and H=magnetization intensity

The difference between two magnetic fields strengths, say B_1 and B_2 is

$$I = \frac{2.5 \times 10^{-3}}{4\pi \times 10^{-7}} \; (B_2 - B_1)$$

$$= \frac{2.5\left(1 - \frac{1}{1000}\right)}{4\pi \times 10^{-7}}$$

$$= 2 \times 10^{6} A/m \text{ (approx)}$$

(c) Intensity of magnetization:

I = M/V = m(2l)/A(2l) = m/A

=> m = IA

=> m = 2 x 10^2 x 4 x 10^{-4} = 800 A-m

Question 4: A bar magnet of length 1 cm and cross-sectional area 1.0 cm^2 produces a magnetic field of 1.5 × 10^{-4} T at a point in end-on position at a distance 15 cm away from the centre.
(a) Find the magnetic moment M of the magnet.
(b) Find the magnetization I of the magnet.
(c) Find the magnetic field B at the centre of the magnet.

Solution:
(a) Magnetic field at a point in the axis of magnet:

$B = \mu_0/4\pi \times 2Md/(d^2 - l^2)^2$

Substituting given values,

1.5 x 10^{-4} = [3x10^{-8}xM]/[5.01x10^{-4}]

Or M = 2.5 A

(b) Intensity of magnetization:

I = M/V = 2.5/[10^{-4}x10^{-2}] = 2.5 x 10^6 A/m

(c) We know, $H = M/4\pi l d^2$

Total magnetic field intensity(H) is the sum of magnetic field intensities due to north pole and south pole, which are equal in magnitude.

$\Rightarrow H = M/4\pi l d^2 + M/4\pi l d^2 = M/2\pi l d^2$

$H = 2.5/[2 \times 3.14 \times 0.01 \times (0.15)^2]$

$\Rightarrow H = 2 \times 884.6\ Am^{-1}$

Now net magnetic at the centre B:

$B = \mu_0 (H + I)$

I = Intensity of magnetization

$\Rightarrow B = 4\pi \times 10^{-7} \times [(2 \times 884.6) + (2.5 \times 10^6)] = 3.14\ T$

Question 5: The susceptibility of annealed iron at saturation is 5500. Find the permeability of annealed iron at saturation.

Solution:
Susceptibility of iron at saturation = χ = 5500

We know,

$\mu = \mu_0(1 + \chi)$

$\mu = 4\pi \times 10^{-7} (1 + 5500) = 6.9 \times 10^{-3}$

$\mu = 6.9 \times 10^{-3}$ Henry/m

Question 6: The magnetic field B and the magnetic intensity H in a material are found to be 1.6 T and 1000 A m^{-1} respectively. Calculate the relative permeability μ_r and the susceptibility χ of the material.

Solution:
Magnetic field in the material = 1.6 T
Magnetic intensity = H = 1000 Am^{-1}

We know, $\mu = B/H$ and $\mu_r = \mu/\mu_o$

$\Rightarrow \mu_r = B/H\mu_o = 1.6/[1000 \times 4\pi \times 10^{-7}] = 1.3 \times 10^3$

Relation between χ and μ_r is

μ_r =1 + χ

or χ = 1.3 x 10^3 – 1 = 1299

or χ = 1.3 x 10^3 (approx.)

Question 7: The susceptibility of magnesium at 300 K is 1.2 × 10^{-5}. At what temperature will the susceptibility increase to 1.8 × 10^{-5}?

Solution:
Susceptibility at temperature T_1, χ_1 = 1.2 x 10^{-5}
Susceptibility at temperature T_2, χ_2 = 1.8 x 10^{-5}

According to Curie's law, χ = C/T

We have, χ_1/ χ_2 = T_1/ T_2

=> [1.2 x 10^{-5}]/ [1.8 x 10^{-5}] = T_1/ 300

=>T_2 = 200 K

Question 8: Assume that each iron atom has a permanent magnetic moment equal to 2 Bohr magnetons (1 Bohr magneton equals 9.27 × 10^{-24} A m^2). The density of atoms in iron is 8.52 × 10^{28} atoms m^{-3}. (a) Find the maximum magnetization I in a long cylinder of iron.
(b) Find the maximum magnetic field B on the axis inside the cylinder.

Solution:

We know, Intensity of magnetization = I = M/V ...(1)

For 1m^3 volume, the number of atoms will be 8.52 x 10^{28}

So, total magnetic moment = M = 8.52× 10^{28}× 2×9.27× 10^{-24}Am^{-2}

=>M = 1.58 x 10^6 Am^2

(1)=> I = 1.58 x 10^6 Am^{-1} : maximum magnetization

Now,
The net magnetic field: B = μ_o(I + H)

Magnetizing field intensity (H) = 0, as we have to find the maximum magnetic field on the axis of cylinder.

So, $B = \mu_o I$

$B = 4\pi \times 10^{-7} \times 1.58 \times 10^{-6} = 2$ T (approx.)

Question 9: The coercive force for a certain permanent magnet is 4.0×10^4 A m^{-1}. This magnet is placed inside a long solenoid of 40 turns/cm and a current is passed in the solenoid to demagnetize it completely. Find the current.

Solution:
Coercive force for magnet = Magnetic intensity = H = 4.0×10^4 Am^{-1}
Number of turns per cm inside solenoid = 40
Number of turns per m inside the solenoid = 4000 turns/m

Magnetic field produced by solenoid at the centre :

$B = \mu_o nI$

And magnetizing field intensity in the absence of any material:

$H = B/\mu_o$

=> H = nI (From above equations)

Or $I = H/n = 4 \times 10^4/4000 = 10$ A, which is the required current.