2017

MADE EASY WORKBOOK

Detailed Explanations of Try Yourself *Questions*

Electronics Engineering

Material Science

MADE EASY Publications

1 Crystalline Structures

T1 : Solution:

(a)

T2 : Solution:

(d)

Intercepts made by plane on 3 axis

$\Rightarrow \quad -A, \frac{B}{3}, \infty$

$\therefore$ Miller indices

$\Rightarrow \quad -1, 3, 0$

2 Dielectric Properties of Materials

T1 : Solution

(b)

T2 : Solution

(d)

$V = gtP = 12 \times 10^{-3} \times 2 \times 10^{-3} \times 0.5 \times 10^{6} = 12\text{ V}$

T3 : Solution

(d)

Permanent dipole moment

= 1.04 debye unit

= $1.04 \times 3.33 \times 10^{-30}$ coulomb-metre

Boltzman constant K = 1.38×10^{-23} J/K

Room temperature T = 300 K

$$\alpha_0 = \frac{P_P^2}{3kT} = \frac{(1.04 \times 3.33 \times 10^{-30})^2}{3 \times 1.38 \times 10^{-23} \times 300} = 0.966 \times 10^{-39} \text{ Farad–meter}^2$$

$$N = 10^{27}\text{ m}^{-3}$$

$$E = 10^{6}\text{ V/m}$$

So orientational polarisation

$$\begin{aligned} P_0 &= N\alpha_0 E \\ &= 10^{27} \times 0.966 \times 10^{-39} \times 10^{6} \\ &= 0.966 \times 10^{-6}\text{ Coulomb meter}^{-2} \end{aligned}$$

T4 : Solution

(a)

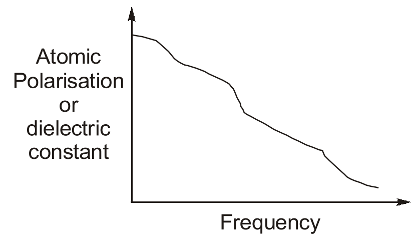
$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} = 5 \times 10^{-4}$$

$\therefore \quad \varepsilon'' = 10.5 \times 10^{-4} = 1.05 \times 10^{-3}$

T5 : Solution

(c)

In an insulating material connected to an a.c. signal, the dielectric constant and atomic polarisation decrease with frequency.



T6 : Solution

(c)

Total polarizability

$$\alpha = \alpha_e + \alpha_i + \alpha_0$$

where $\alpha_e = 4\pi\varepsilon_0 R^3$ = electronic polarizability

α_i = ionic polarizability

$$\alpha_0 = \frac{p_p^2}{3\,kT} = \text{orientational polarizability}$$

We see that orientational polarizability depends on the temperature.

E increases $\longrightarrow$ radius R increases

R increases $\longrightarrow$ α_e increases

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3 Magnetic Properties of Materials

T1 : Solution

(d)

T2 : Solution

(b)

T3 : Solution

(c)

T4 : Solution

Data: $H = 10^6$ A/m, $T = 300$ K

μ_B = Bohr magneton = 9.27×10^{-24}

$$\text{Magnetic moment} = \frac{\mu_0 H \mu_B}{kT} = \frac{1.257 \times 10^{-6} \times 10^6 \times 9.27 \times 10^{-24}}{1.38 \times 10^{-23} \times 300}$$

$$M_{300} = 2.81 \times 10^{-3}\, \mu_B$$

$$M_{4.2} = 0.2\, \mu_B.$$

T5 : Solution

(b)

$$\text{Intensity of magnetization} = \frac{\text{Total magnetic moment}}{\text{Volume}}$$

Magnetic moment = 2.5 A-m^2

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{6.6 \times 10^3}{7.9 \times 10^3} = 0.835\ \text{m}^3$$

$$\text{Intensity} = \frac{2.5}{0.835} \approx 2.99 = 3\ \text{A/m}$$

T6 : Solution

(a)

Permanent magnetic materials are those which retain a considerable amount of their magnetic energy after the magnetizing force has been removed, i.e. the materials which are difficult to demagnetize. Therefore for a permanent magnetic material, the residual induction and coercive field should be large.

T7 : Solution

(d)

Magnetic materials which have low corecive field are known as soft materials. Permanent magnets are made of hard materials which have a broad hysteresis loop (large coercive force), so that they are not subject to self-demagnetisation.

Also, ferrimagnetic material such as ferrites do not have eddy current loss.

T8 : Solution

(b)

Because cast iron has lower permeability than silicon steel.

4 Conductive Materials and Superconductors

T1 : Solution

(c)

T2 : Solution

(c)

$$H_c = 64\times10^3\left[1-\left(\frac{5}{7.26}\right)^2\right] = 33.64 \times 10^3 \text{ Amp/m}$$

T3 : Solution

Relevant equations are

(i) $$v_d = \frac{J}{n\times e} = \frac{I}{Ane};$$

(ii) $$\lambda = T_c\,\bar{v};$$

(iii) $$T_c = \frac{\lambda}{\bar{v}} = \frac{m}{ne^2\rho}$$

The number of conduction electrons per m^3 = n

$$n = \frac{N_d\times\rho\times n_a}{Cu \text{ Atomic } wt.} = \frac{6.023\times10^{23}\times8960\times1}{63.54} = 8.5\times10^{25}/\text{m}^3$$

$$\text{The drift speed} = v_d = \frac{J}{ne} = \frac{I}{Ane} = \frac{10}{(\pi r^2)n\times e}$$

$$= \frac{10}{\pi(0.08)^2\times10^{-4}\times8.5\times10^{25}\times1.602\times10^{-19}}$$

$$= 0.365 \text{ m/sec}$$

$$\text{Mean free collision time} = T_c = \frac{\lambda}{\bar{v}} = \frac{m}{ne^2\rho}$$

$$T_c = \frac{9.1\times10^{-31}}{8.5\times10^{25}\times(1.602\times10^{-19})^2\times2\times10^{-8}}$$

[$\rho = 2\times10^{-8}$ ohm-metre at 20°C]

$$= 2.086\times10^{-11}\text{ sec}$$

$$\lambda = T_c\times\bar{v} = 2.086\times10^{-11}\times1.6\times10^{6}$$

$$= 3.34\times10^{-5}\text{ m}$$

T4 : Solution

(b)

$\chi = \mu_r - 1$, for superconductor $\mu_r = 0$ which is referred as perfect diamagnetism.

5 Semiconductor Materials

T1 : Solution

T1. (a)

Since hall voltage developed is proportional to the product of applied magnetic field and the current flow through the crystal, the device can be used to multiply two signals.

T2 : Solution

(d)

We have

resistivity $\rho_i = 0.47\Omega\text{m} = \frac{1}{\sigma_i}$

$$\mu_e = 0.38 \text{ m}^2 \text{ volt}^{-1} \text{ sec}^{-1}$$

$$\mu_h = 0.18 \text{ m}^2 \text{ volt}^{-1} \text{ sec}^{-1}$$

$$\sigma_i = n_i e(\mu_e + \mu_h)$$

$$n_i = \frac{\sigma_i}{e(\mu_e + \mu_h)} = \frac{1}{e\rho_i(\mu_e + \mu_h)}$$

substituting the values we have

$$n_i = 2.38 \times 10^{19} \text{ m}^{-3}$$

T3 : Solution

(d)

$$D_e = \left(\frac{kT}{e}\right)\mu_e$$

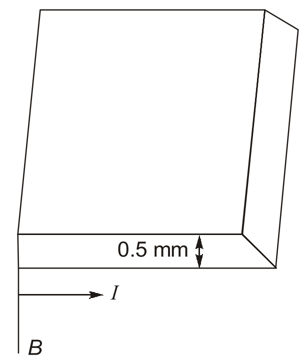
$$D_h = \left(\frac{kT}{e}\right)\mu_h$$

$$D_e = \left(\frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}}\right)0.17 = 44 \times 10^{-4} \text{ m}^2 \text{ sec}^{-1}$$

$$D_h = \left(\frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}}\right)0.025 = 6.47 \times 10^{-4} \text{ m}^2 \text{ sec}^{-1}$$

T4 : Solution

T4.



$$\text{Hall effect voltage} = V_H = Bvd$$

$$V_H = \frac{B \times I}{pw} = \frac{B \times I}{w \times n \times e}$$

$V_H = 150\ \mu\text{V}$, $B = 1.2$ tesla, $I = 50$ A, $w = 0.5$ mm,

$$n = \frac{B \times I}{w \times e \times V_H}$$

$$= \frac{1.2 \times 50}{0.5 \times 10^{-3} \times 1.6 \times 10^{-19} \times 150 \times 10^{-6}}$$

$$= \frac{60}{120 \times 10^{-28}} = 0.5 \times 10^{28}/\text{m}^3$$

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