LES10A020 Engineering Physics

Assignment 10

Task 1

N = 10

Side of the cube = 0.1 m

Area of the cube = 0.1 * 0.1 = 0.01 m^2

Vacuum permeability, $\mu_0 = 1.2566 \cdot 10^{-6}\ H/m$

Relative permeability, $\mu_r = 200000$

Current, I = 1 Ampere

Calculate the inductance of the inductor = ?

Solution 1:

The inductance of the inductor L is given as,

$$L = \frac{\mu_0 \mu_r N^2 A}{l} = \frac{1.2566E-06 \frac{H}{m} * 200000 * 100 * 0.01\ m^2}{0.1\ m} = 2.51\ H$$

Energy stored in an inductor for 1 Ampere current is given as,

$E_{ind} = \frac{1}{2} LI^2 =$ L/2 = 1.255 J.

Task 2a

For nail:

Total length of the nail = 10 cm = 100 mm.

Length of the nail which is not to be included = 8.8 mm.

Therefore, total length of the nail around which wire layers is = 100 – 8.8 = 91.2 mm = 0.0912 m

For copper wire:

Diameter = 0.5 mm.

Size of the insulation around the wire = 0.15 mm.

Total diameter of the wire = Diameter + 2 sides insulation = 0.5 + 0.3 = 0.8 mm

Number of loops around the nail, N: (Only one layer of wiring)

The number of loops around the nail made by the copper wire is 0.0912/0.0008 = 114 = N.

(Note: One loop can be removed, so N = 113 is also accepted answer in the moodle.)

Now to calculate the inductance of the inductor =

$$L = \frac{\mu_0 \mu_r N^2 A}{l} = \frac{1.2566E-06 \frac{H}{m} * 200000 * 114 * 114 * 0.0034^2\ m^2}{0.0912\ m} = 0.414\ H$$

Task 2b

Perimeter of the nail = nail thickness * 4 = 3.4 mm * 4 = 13.6 mm = 0.0136 m.

Length of the wire which is surrounded around the nail is N * Perimeter of the nail =

114 * 0.0136 m = 1.5504 m.

Total length of the wire including connected to the battery = 1.5504 m + 0.2 m = 1.7504 m.

Resistance, R = $\rho l / A = \frac{1.7E-08 * 1.7504}{\pi * (0.00025)^2} = 0.1516\ ohms$

(Note: For finding the Resistance, some students have used for the calculation of the area based on diameter of the copper wire including the insulation. Points have been also given to those students.)

Current I, V/R = 8.5/0.1516 = 56.07 Amperes.

Now, finally, to calculate the magnetic field of the solenoid, $B = \frac{\mu_0 \mu_r N I}{l} =$

$B = \frac{\mu_0 \mu_r N I}{l} = \frac{1.2566E-06 \frac{H}{m} * 200000 * 114 * 56.07}{0.0912\ m}$=17614.4 Tesla

Task 3

EMF voltage is 8 V

Resistance, R = 7.5 Ω

Inductance, L = 2.5 H.

Calculate the current, $I(t = 2\ s)$?

Solution:

Current flowing in the RL-circuit is given by,

$$I(t = 2s) = \frac{U_{emf}}{R}\left(1 - e^{-Rt/L}\right) = \frac{8}{7.5}\left(1 - e^{-7.5*2/2.5}\right) = 1.064\ A$$

Task 4

Resistance, R = 25 Ω

Inductance, L = 5 mH

Capacitance, C = 4 μF

Frequency, f = 50 Hz

Solution:

Capacitive resistance: $X_c = \frac{1}{2\pi fC} = \frac{1}{2*3.14*50*0.000004} = 795.77\ \Omega$

Inductive resistance, $X_L = 2\pi fL = 2 * 3.14 * 50 * 0.005 = 1.5708\ \Omega$

Impedance of the circuit is given as, $Z = \sqrt{R^2 + (X_L - X_C)^2}$ = $\sqrt{25^2 + (1.5708 - 795.77)^2} = 794.59\ \Omega$