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Assignment - 6

1) A toroid has no. of turns 1250, internal radius 52 mm, external radius 95 mm & thickness of the ring 13mm. Calculate the inductance

=> Soln

no. of turn (N) = 1250

internal radius (a) = 52 mm $\times 10^{-3}$ = 0.052

external radius (b) = 95 mm $\times 10^{-3}$ = 0.092

thickness (h) = 13 mm $\times 10^{-3}$ = 0.093

intuctance (L) = ?

we know, that

$$L = \frac{\mu_0 N^2 h}{2\pi} \times \ln\left(\frac{b}{a}\right)$$

$$= \frac{4\cancel{\pi} \times 10^{-7} \times 1250^2 \times 0.013}{2\cancel{\pi}} \times \ln\left(\frac{0.092}{0.052}\right)$$

$$= 2.32 \times 10^{-3}\ H$$

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2) A solenoid having a inductance of 6.3 μH is connected in series with a 1.2 k Ω resistance

(a) If a 14V battery is connected across the pair how long it will take for the current through the resistor to reach 80% of its inital value?

(b) What is the current through the resistor at time $t = T_T \cdot 0$

=> Solⁿ

a) If the battery is switched into the circuit at $t=0$, then, the current at a later time t is given by

$$i = \frac{\varepsilon}{R}\left[1 - e^{-t/\tau_L}\right]$$

where, $T_L = \frac{L}{R}$. Our goal is to find the time at which $i = 0.8\, \varepsilon/R$. This means

$$0.8 = 1 - e^{-t/\tau_L} \rightarrow e^{-t/\tau_L}$$

$$= 0.2$$

taking the natural logarithm of both side we obtain $-t/\tau_L = \ln(0.2) = -1.609$

$$t = 1.609\, T_T = \frac{1.609 L}{R} = \frac{1.609(6.3 \times 10^{-6})}{1.2 \times 10^{3}}$$

$$= 8.45 \times 10^{-9}\, s.$$

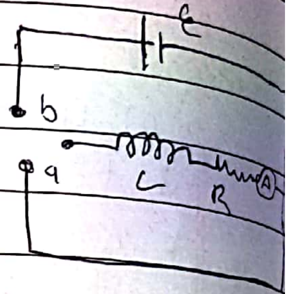
b) At $t = 1, T_L$ the current in the circuit is

$$i = \frac{\varepsilon}{R}(1 - e^{-1}) = \frac{14}{1.2 \times 10^3}(1 - e^{-1})$$

$$= 7.37 \times 10^{-3}\ A$$

3) An inductance L is connected to a battery of emf through a resistance. Show that the potential difference across the inductance after time t is $V_L = \varepsilon e^{-\frac{Rt}{L}}$. At what time is the potential difference across the inductance equal to that across the resistance such that $i = \frac{i_0}{\alpha}$.

=> Sol^n,



The growth of current through RL circuit

$$i = i_0\left[1 - e^{-t/\tau}\right] = i_0\left[1 - e^{-(R/L)t}\right]$$

The potential differen across the inductor

$$V_L = L\frac{di}{dt} = -Li_0 \times \left(-\frac{R}{L}\right)e^{-(R/L)t}$$

$$= i_0 R e^{-(R/L)t} = \varepsilon e^{-(R/L)t}$$

When the potential diff. across the inductor is equal to the resistance then we have

$$V_L = V_R$$

$$\varepsilon e^{-(R/L)t} = iR$$

$$e^{(R/L)t} = \frac{\varepsilon}{iR}$$

According to question. $\frac{i_0}{i} = 2$

$$e^{(R/L)t} = 2$$

$$\therefore t = 0.693\frac{L}{R}\ \text{sec.}$$

i) A solenoid is 1.3 m long & 2.6cm in diameter carries a current of 18 A. The magnetic field inside the solenoid is 23 mT. Find the length of the wire forming the solenoid. Also calculate the inductance of solenoid. (108 m, 8.967×10^{-4} H)

=> Soln,

length $(l) = 1.3m$

radius $(r) = \frac{d}{2} = \frac{2.6}{2} = 0.013$ cm

current $(I) = 18$ A

Magnetic field $(B) = 23$ mT
$= 23 \times 10^{-3}$ T

we know,

$$B = \mu_0 n I$$

$$B = \mu_0 \left(\frac{N}{l}\right) I$$

$$N = \frac{B \times l}{\mu_0 I}$$

$$N = \frac{23 \times 10^{-3} \times 1.3}{4\pi \times 10^{-2} \times 18} = 1321.87 \simeq 1322$$

Then,

$$\text{length } (L) = N \times 2\pi r$$
$$= 322 \times 2\pi \times 0.013$$
$$= 107.98 \text{ m.}$$

again,

Inductance of solenoid $(L) = \mu_0 n^2 A l = \mu_0 \left(\frac{N}{l}\right)^2 A l$

$$= 4\pi \times 10^{-7} \times \frac{1322}{l7} \times \pi \times (0.013)^2 \times l$$

$$= 4\pi \times 10^{-7} \times \frac{(1322)^2}{1.3} \times (0.013)^2$$

$$L = 8.96 \times 10^{-4} \text{ H.}$$

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5) What must be the magnitude of a uniform electric field have the same energy density that passed by a 0.5 T magnetic field? (1.5×10^8 V/m)

$\Rightarrow$ Soln,

$B = 0.5T$

we know,

$$u_B = \frac{B^2}{2\mu_0}$$

Also,

$$u_e = \frac{1}{2}\epsilon_0 E^2$$

By question.

$$u_B = u_e$$

$$\frac{B^2}{2\mu_0} = \frac{1}{2}\epsilon_0 E^2$$

$$E = B\sqrt{\frac{1}{\mu_0\epsilon_0}}$$

$$= 0.5\sqrt{\frac{1}{4\pi\times10^{-7}\times8.85\times10^{-12}}}$$

$$E = 1.5\times10^8 \text{ V/m}$$

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