B.Sc. Part II Physics Hons

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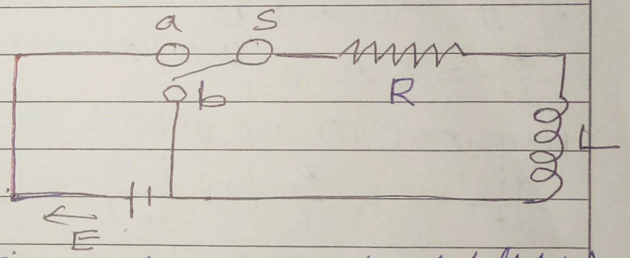
Current Electricity

Growth of Current :-

Let a Circuit Containing a coil of self inductance, L a non inductive resistance R and a cell constant e.m.f. E as shown in figure.

When the circuit is closed by throwing the switch S to a, a self induced e.m.f is set up in the coil which opposes the growth the current in the circuit. Hence the current does not reach its final steady value E/R instantaneously, but grows at a rate depending upon the inductance and resistance of the circuit.



During the variable state when the current is growing. Let i be the current at any instant t. The opposing induced e.m.f. $= L(di/dt)$. Hence the effective e.m.f. driving the current in the circuit at the instant $= E - L\,di/dt$. This by ohm's law must be equal to Ri Hence

$$E - L \cdot di/dt = Ri \quad \text{or} \quad E - Ri = L\,di/dt$$

$$\text{or} \quad dt = L\,di/\,E - Ri$$

on integrating, we get $t = -\frac{L}{R}\log_e(E - Ri) + C.$

where C is the integration constant. At $t = 0$, $i = 0$.

$\therefore\ C = \frac{L}{R}\log_e E.$

Teacher's Signature:

Hence,

$$t = -L/R \log_e (E - Ri) + L/R \log_e E.$$

or; $$-\frac{R}{L} t = \log_e (E - Ri) - \log_e E = \log_e \frac{E - Ri}{E}$$

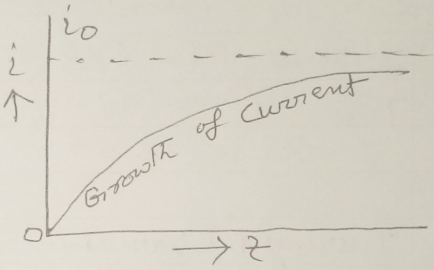
or; $$e^{-(R/L)t} = \frac{E - Ri}{E} = 1 - \frac{Ri}{E}$$

or; $$\frac{Ri}{E} = \left[1 - e^{-(R/L)t}\right]$$

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

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

where $i_0 = E/R$ is the final steady value of the current reached when $t \to \infty$. equ^n (1) shows that the current in the circuit raises according to an exponential law. A Graph between current and time is as shown in figure. The rate of growth of the current is



$$\frac{di}{dt} = i_0 \frac{R}{L} e^{-(R/L)t}$$

From equ^n (1) we get

$$\frac{di}{dt} = i_0 \frac{R}{L}\left(1 - \frac{i}{i_0}\right) = \frac{R}{L}(i_0 - i)$$

Thus it is seen that greater the ratio R/L, or smaller the ratio L/R, the more rapidly does the current approach its maximum value. The ratio L/R is called the inductive time constant of the circuit and is expressed in second.

Decay of Current :

When the switch S is shown over to b as shown in above starting figure the e.m.f. E applied to the circuit becomes zero, yet the resistance of the circuit remains unchanged.

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The Self induction of The Coil now opposes The fall of The Current. During The Variable state when The Current is falling, let i be The Current at any instant t. Since now There is no applied e.m.f. in The Circuit, The Potential difference Ri across The resistance R is equal and opposite to the induced emf $L\,(di/dt)$.

Hence, $-L\, di/dt = Ri$

or $dt = -L/R \; di/i$

one integrating, we get $t = -L/R \log_e i + C$, where C is integration Constant.

At $t = 0$, $i = i_0$

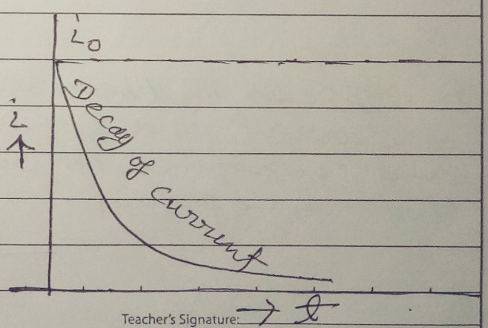
$\therefore \; C = \frac{L}{R} \log_e i_0$, Hence

$t = -L/R \log_e i + L/R \log_e i_0$

or $-\frac{R}{L} t = \log_e i - \log_e = \log_e \frac{i}{i_0}$

or $e^{-(R/L)t} = i/i_0$

or $i = i_0 e^{-(R/L)t}$ —— (2)



Teacher's Signature:

This equ^n ① Shown That The Current in The Circuit decays exponentially, A graph between Current and time is as Shown in figure.
The rate of fall of Current is.

$$\frac{di}{dt} = -i_0 \frac{R}{L} e - (R/L) t$$

from equ^n ②

$$\frac{di}{dt} = -i_0 \frac{R}{L} \frac{i}{i_0} = -\frac{R}{L} i$$

Thus it is Clear That greater The ratio R/L or Smaller the time Constant L/R, The more rapidly The Current die away.