

B.Sc. Part II
Paper IV

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Current Electricity

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Current ElectricityGrowth 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

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

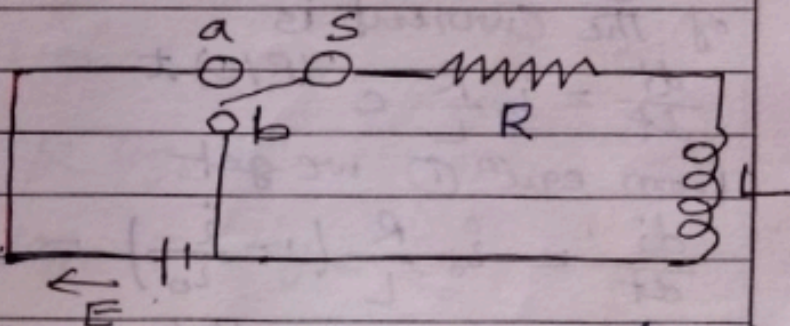
$$\text{or} \quad dt = L \frac{di}{E - Ri}$$

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,

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

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

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

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

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

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

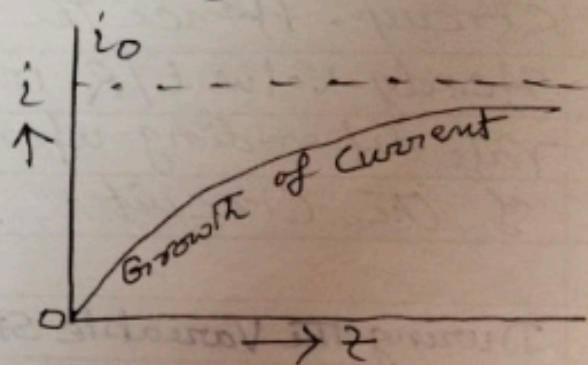
where $i_0 = E/R$ is the final steady value of the current reached when $t \rightarrow \infty$. equⁿ (1) shows that the current in the circuit rises according to an exponential law. A Graph between

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 equⁿ (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.

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 $dt = -L/R di/i$

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

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

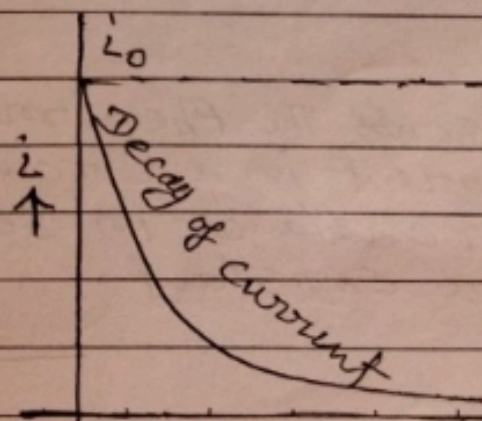
$\therefore C = \frac{L}{R} \log_e i_0$, Hence

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

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

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

or $i = i_0 e^{-(R/L)t}$ — (2)



This equⁿ ① shows 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 equⁿ 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.

