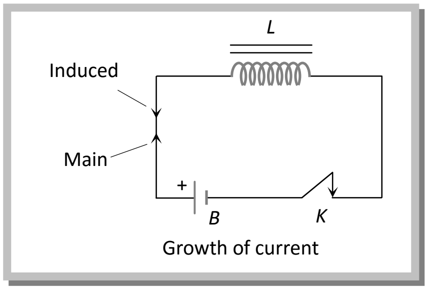
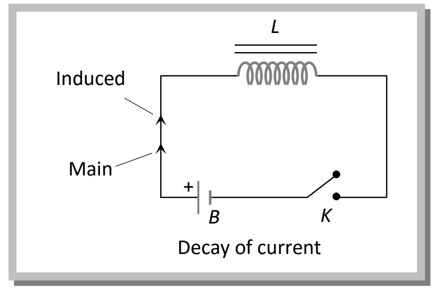
Growth and Decay of Current in LR-Circuit.

If a circuit containing a pure inductor L and a resistor R in series with a battery and a key then on closing the circuit current through the circuit rises exponentially and reaches up to a certain maximum value (steady state). If circuit is opened from its steady state condition then current through the circuit decreases exponentially.



Growth of current



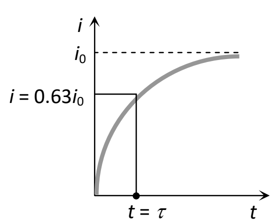
Decay of current

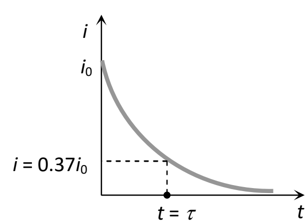
The value of current at any instant of time t after closing the circuit (i.e. during the rising of current) is given by $\boldsymbol{i = i_0\left[1 - e^{-\frac{R}{L}t}\right]}$; where $i_0 = i_{max} = \frac{E}{R}$ = steady state current.

The value of current at any instant of time t after opening from the steady state condition (i.e. during the decaying of current) is given by $\boldsymbol{i = i_0 e^{-\frac{R}{L}t}}$

(1) Time constant (τ)

In this circuit $\tau = \frac{L}{R}$; It's unit is second. In other words the time interval, during which the current in an inductive circuit rises to 63% of its maximum value at make, is defined as time constant or it is the time interval, during which the current after opening an inductive circuit falls to 37% of its maximum value.





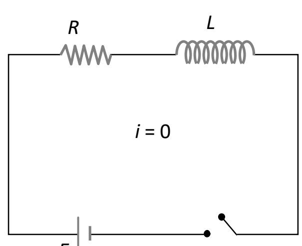
Note: The dimensions of $\frac{L}{R}$ are same as those of time i.e. M0L0T1

Half life (T) : In this time current reduces to 50% of its initial max value i.e. if $t = T$ then $i = \frac{i_0}{2}$ and again half-life obtained as T = 0.693 $\frac{L}{R}$ or T = 70% of time constant.

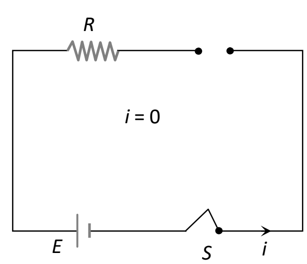
Now from $U = \frac{1}{2}Li^2$ so in half life time current changes from $i_0 \rightarrow \frac{i_0}{2}$ hence energy changes from $U_0 \rightarrow \frac{U_0}{4}$

(2) Behavior of inductor

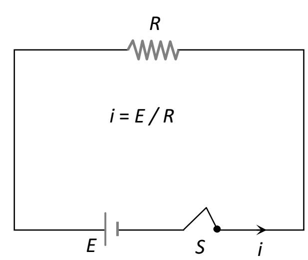
The current in the circuit grows exponentially with time from 0 to the maximum value $i\left(=\frac{E}{R}\right)$. Just after closing the switch as i = 0, inductor act as open circuit i.e. broken wires and long after the switch has been closed as i = i0, the inductor act as a short circuit i.e. a simple connecting wire.



Initially



Just after closing S



Long after closing