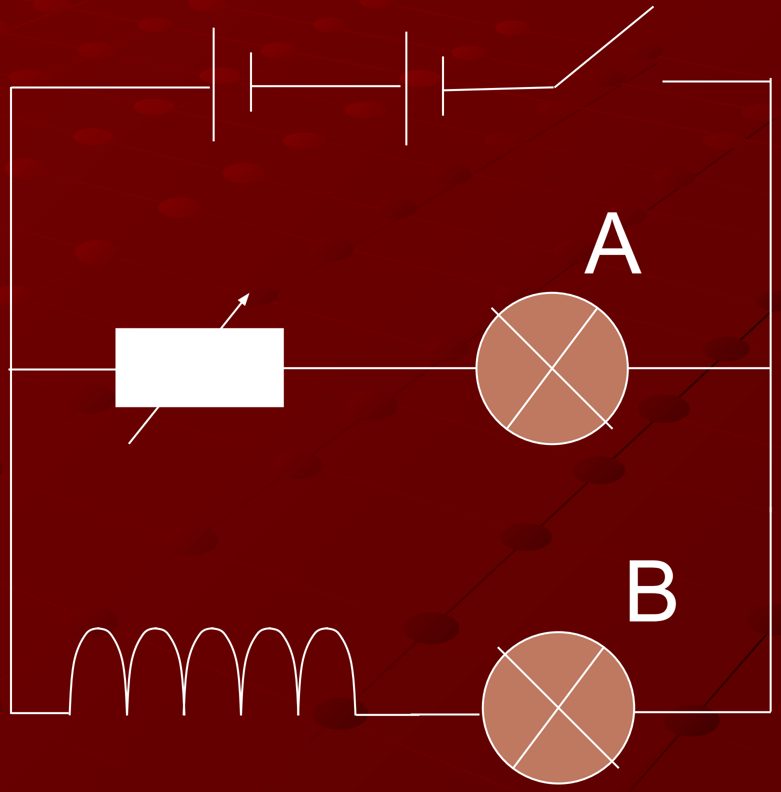
Inductors

- An inductor is essentially a coil of wire with an iron core.
- They store energy in a magnetic field
- The symbol for an inductor is:

What do inductors do?

- Consider this circuit
- What will happen when the switch is closed?
- Lamp A will glow immediately
- Lamp B will take some time to reach full brightness.

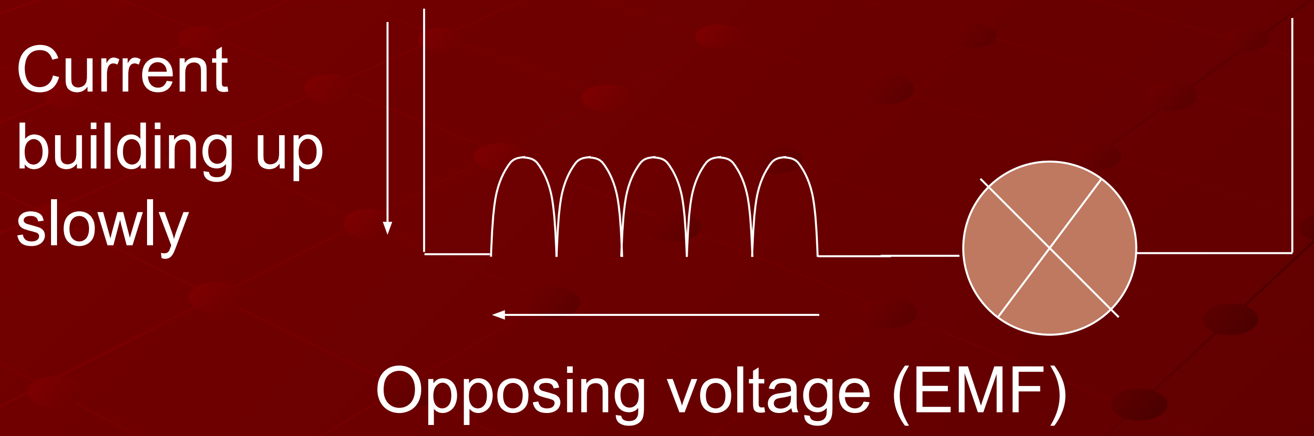


Why?

- As the current starts to flow through the inductor, a magnetic field starts to form around it…..
- As this field forms, the magnetic field lines cut through the coils in the inductor and induce a voltage across the inductor….
- According to Lenz’s Law, this voltage will oppose the voltage that caused it…..

Why?

- This opposing voltage restricts the current build-up in the circuit so it takes a while for the bulb to reach full brightness.



Inductors

- Once the current has reached it's full value, it is no longer changing, so the field lines in the inductor are no longer building up, so there is no induced back EMF. Ie the inductor has no effect on the circuit any longer.

Inductors

- The reverse happens when the current is switched off.
- A collapsing current will cause the field lines around the inductor to collapse.
- The collapsing field lines induce a voltage across the inductor to try and keep the current flowing. (Lenz's Law again)
- This induced voltage can be very large, creating sparks – dangerous!

Inductance

- The effect of an inductor in a circuit is measured as inductance L
- The changing current produces a changing field which produces a changing flux ie $\Phi \propto I$
- The constant of proportionality is the inductance L
- So $\Phi = L \times I$

Inductance

- Faraday's Law states:

$$V = -\frac{\Delta\phi}{\Delta t}$$

$$V = -\frac{\Delta(L \times I)}{\Delta t}$$

$$V = -L\frac{\Delta I}{\Delta t}$$

Inductance

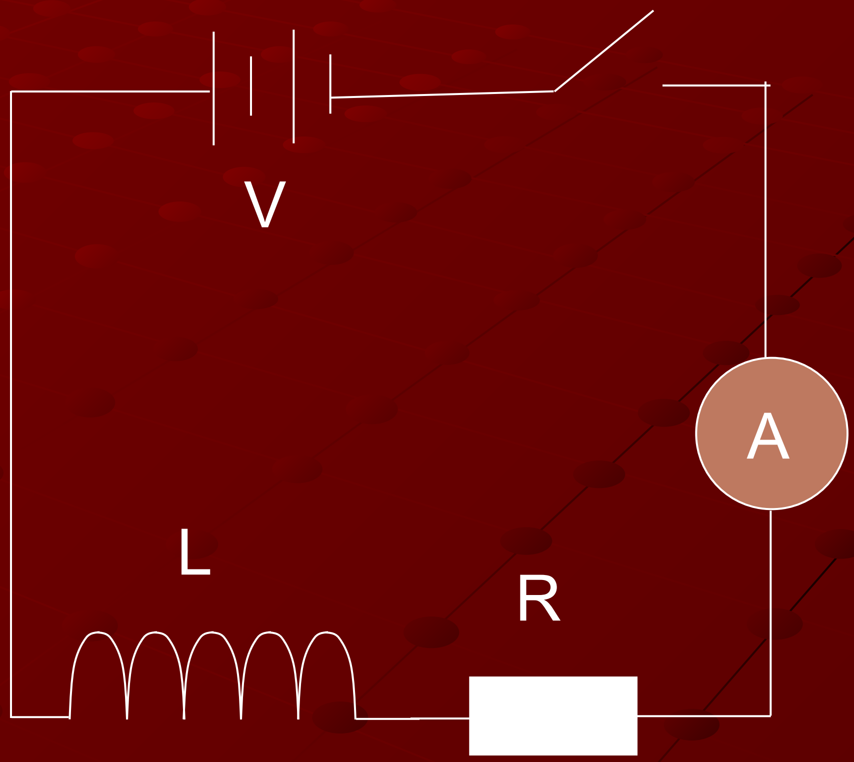
- So the size of the induced back EMF depends on the inductance of the inductor and the rate of change of current.
- The unit for inductance is the Henry H

- An inductor only affects circuits when the current is changing and will always oppose what is happening

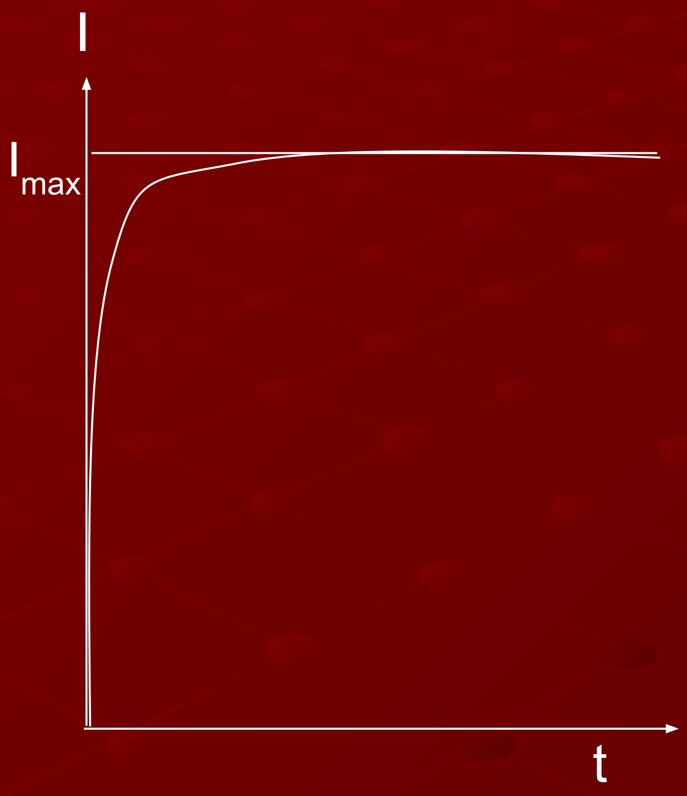
Changing Current

- When the switch is closed, current starts to flow in the circuit
- It will build up to it's maximum value:

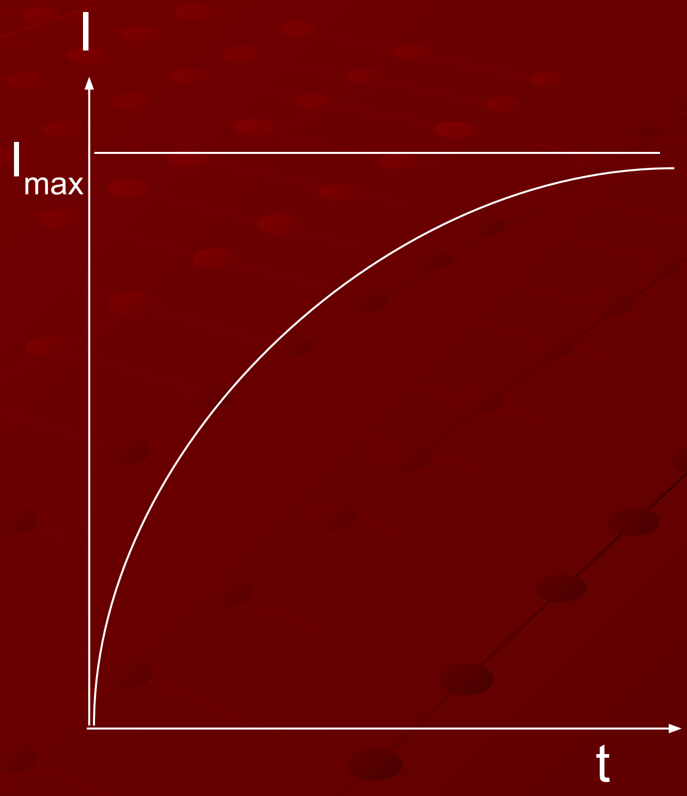
$$I_{\max} = \frac{V}{R}$$



Changing Current

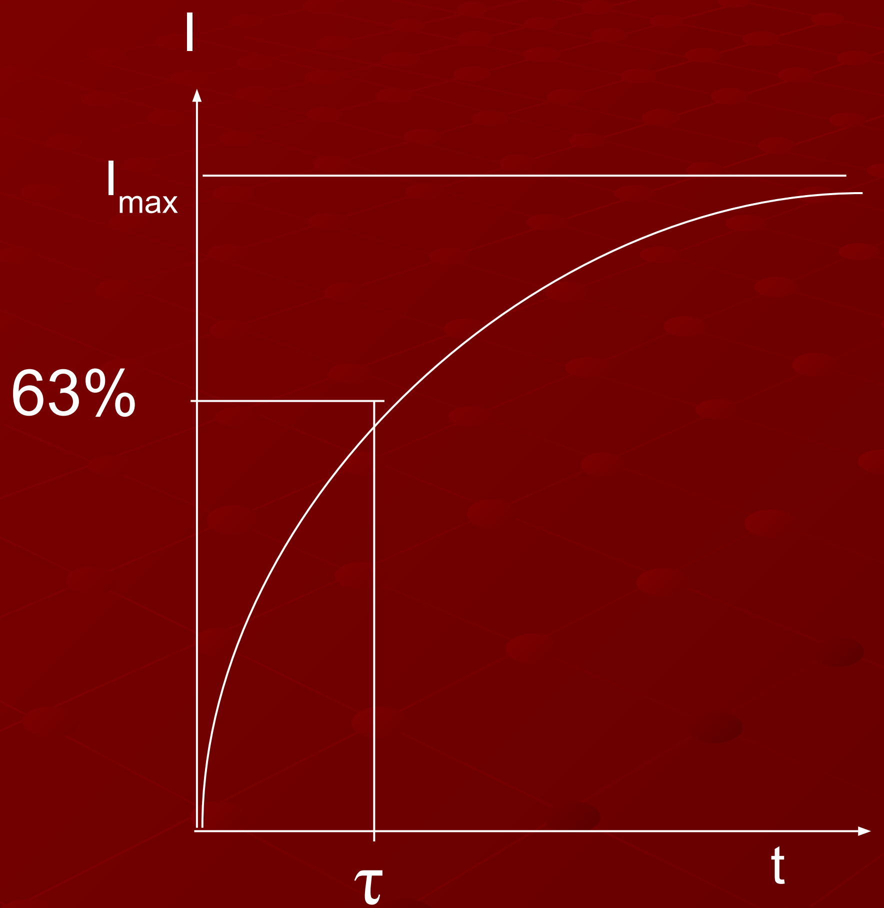


Without Inductor



With Inductor

Time Constant



- The time constant τ is defined as the time taken for the current to reach 63% of it's maximum value.
- A circuit is said to be at maximum current after 3 time constants
- (Same as caps)

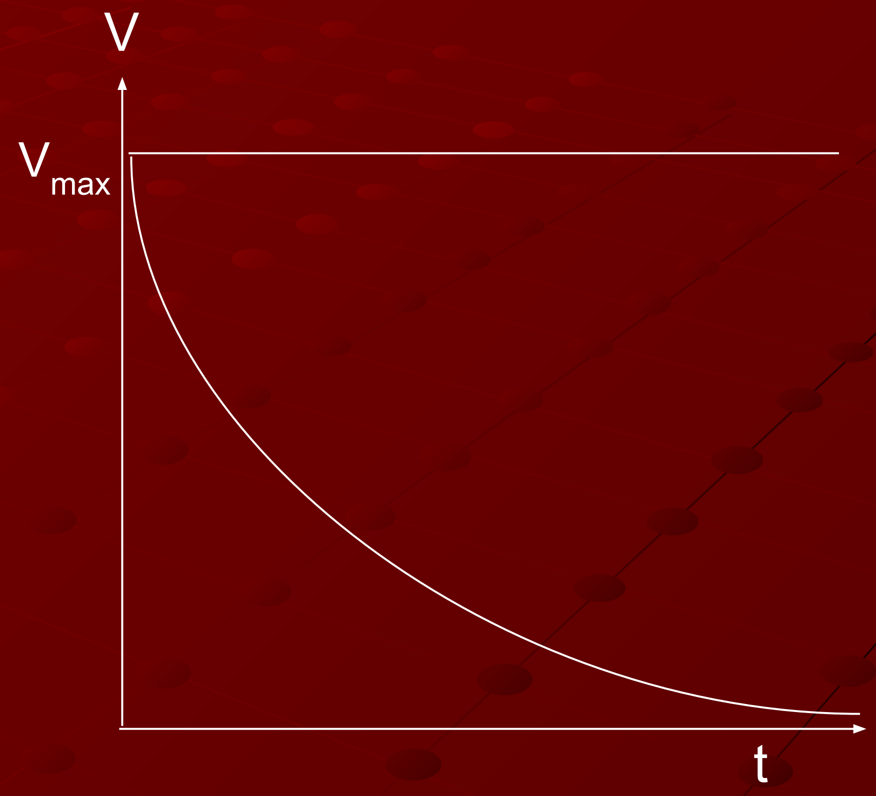
Time Constant

- The time constant depends on:
  - The size of the inductor (bigger L means more back e.m.f so longer for current to reach max)
  - The resistance of the circuit (larger R means smaller circuit current, so less mag field, so less back e.m.f, so shorter time for current to reach max)

$$\tau = \frac{L}{R}$$

Back E.M.F

- The back e.m.f will be large to begin with as the current is changing most rapidly
- It drops to zero as the rate of change of current reduces.
- Again the time constant is the time taken to fall 63% of max value



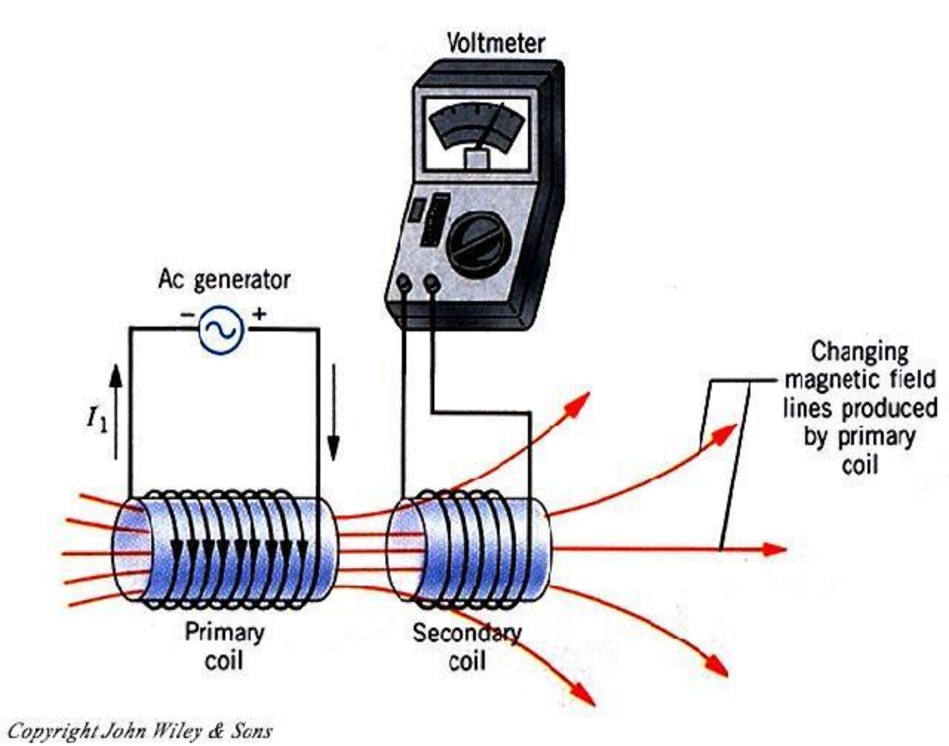
Energy

- Energy is stored in the magnetic field around the inductor.
- If the current is suddenly interupted,a spark may occur as the energy is dissipated. Self inductance can be a major problem in big circuits because of this.

$$E = \frac{1}{2} L I^2$$

Transformers

- These consist of 2 coils wound close to each other.
- Changing the current in one coil makes the field around it change. This changing field induces current in a nearby coil.



Transformers

- The ratio of the windings determines how much voltage/current is induced
- The voltage can be calculated using:

N=number of turns

V=Voltage

P=primary coil

S=secondary coil

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

Transformers

- No transformer is 100% efficient, but assuming it was:
  - Power in = Power out

$$P_{in} = P_{out}$$

$$V_p I_p = V_s I_s$$

Transformers

- 3 Types:
  - Step up : $V_s > V_p$
  - Step down : $V_s < V_p$
  - Isolating (a safety device) : $V_s = V_p$

- They only work with alternating current or switched DC