All of Electromagnetism!

Gauss' law for electricity: $$\oint_{\text{closed surface}} \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0} \quad (1)$$

Gauss' law for magnetism: $$\oint_{\text{closed surface}} \vec{B} \cdot d\vec{A} = 0 \quad (2)$$

Faraday's law: $$\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt} \quad (3)$$

Ampere-Maxwell law: $$\oint \vec{B} \cdot d\vec{s} = \mu_0\epsilon_0 \frac{d\phi_E}{dt} + \mu_0 i_{enc} \quad (4)$$

Note: $\oint$ is used to specify a line integral meaning the integration must form a closed loop. These equations hold in the absence of magnetic materials.

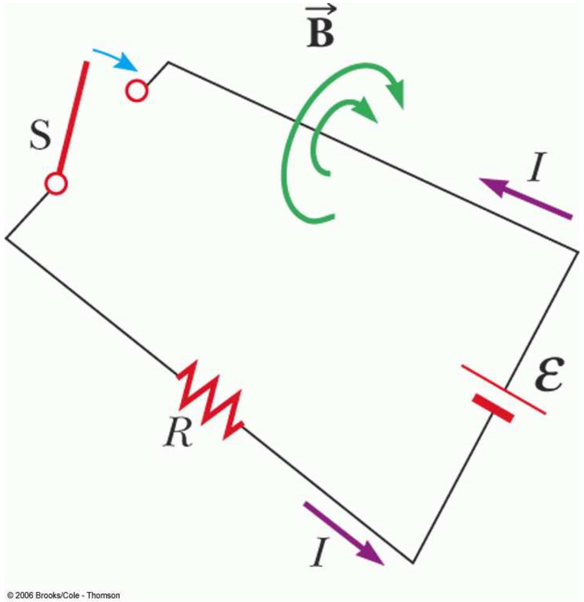
Faraday's Law for a Wire Coil

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$$

$$\Downarrow$$

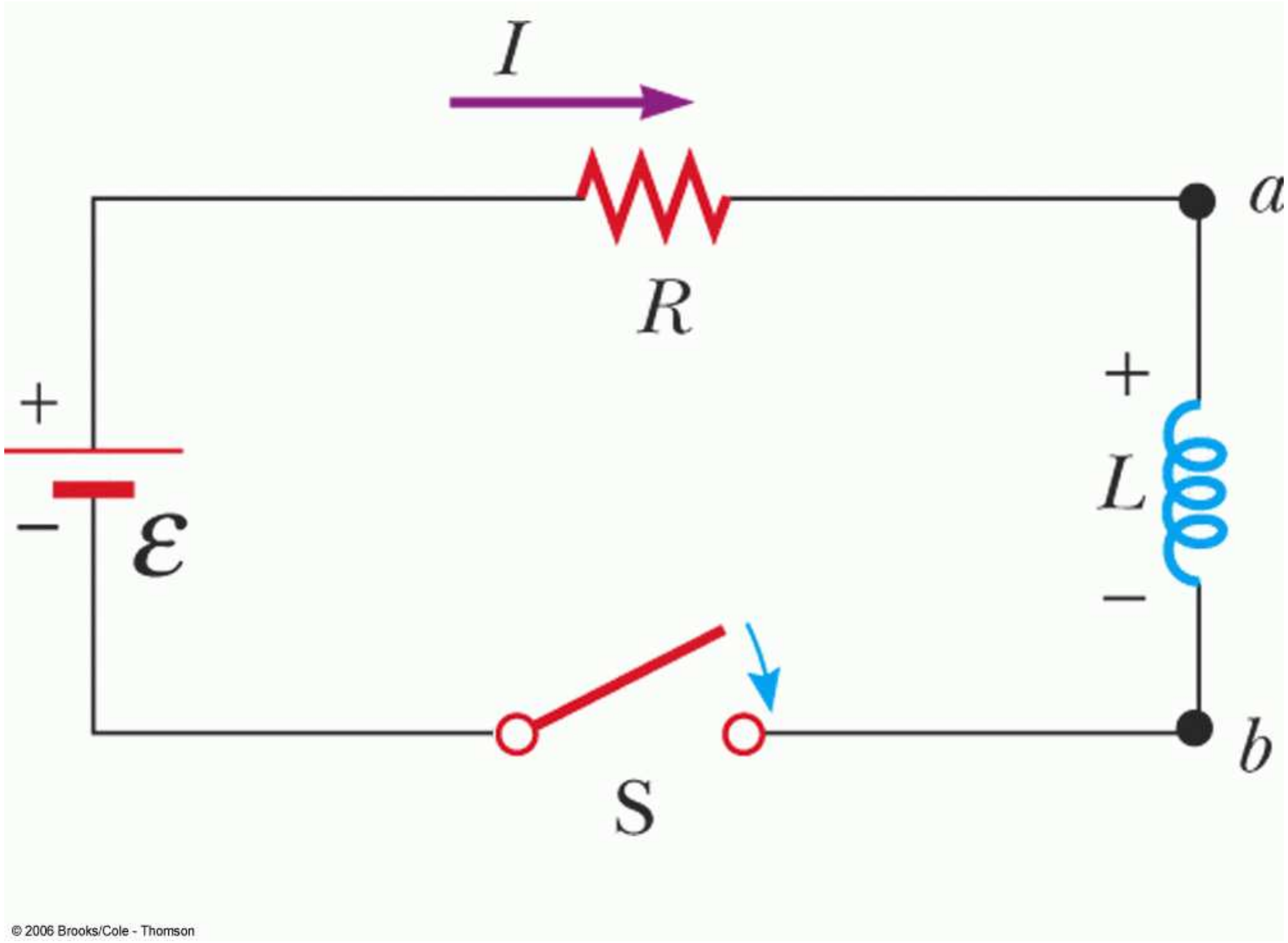
$$V_L = -L\frac{di}{dt}$$

When the switch is closed a current begins to flow creating a magnetic field. This magnetic field is changing as the current rises and induces a *back emf* or *back voltage* that resists the change in the original magnetic field.

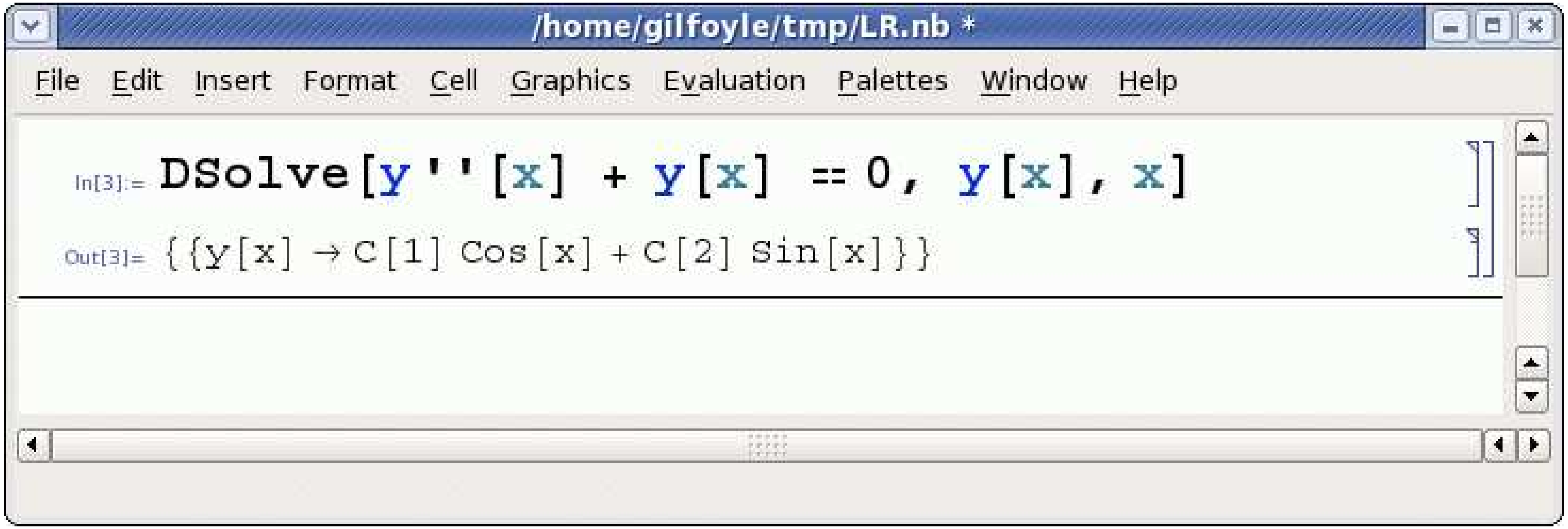


What happens to the current?

Analyze the circuit below for a constant input voltage $\epsilon = V_1$ to obtain the differential equation describing the current.



Using `DSolve` in *Mathematica*



An Example of Applying Faraday's Law

Consider the circuit shown below where $\epsilon = V = 6.0\,V$, $L = 8.0 \times 10^{-3}\,H$, and $R = 4.0\,\Omega$. (a) What is the inductive time constant of the circuit? (b) What is the current at a time $t_1 = 250\mu s$ after the switch is closed? (c) What is the final, steady-state current? (d) When does the current reach 80% of it maximum value?