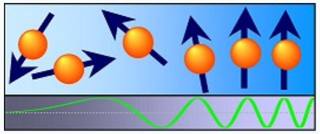
Experimental Physics EP2a

Electricity and Wave Optics

– Magnetic induction –



https://bloch.physgeo.uni-leipzig.de/amr/

History

Francesco Zantedeschi

August 20, 1797
March 29, 1873
Verona, Italy

Joseph Henry

December 17, 1797
Albany, New York, USA

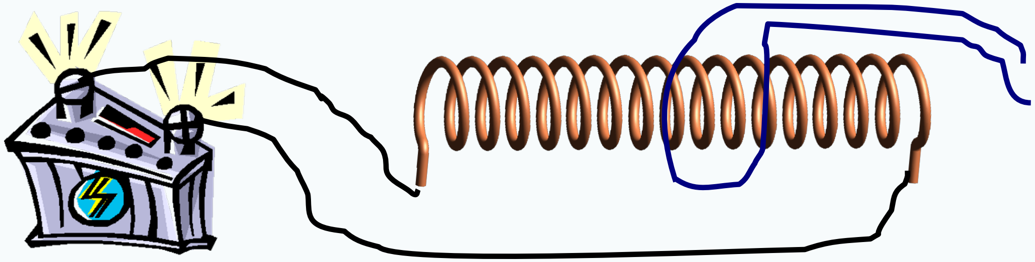
May 13, 1878 (aged 80)
Washington, D. C., USA

Michael Faraday

22 September 1791
Worcester, England

25 August 1867
Middlesex, England

Electromagnetic induction - 1831



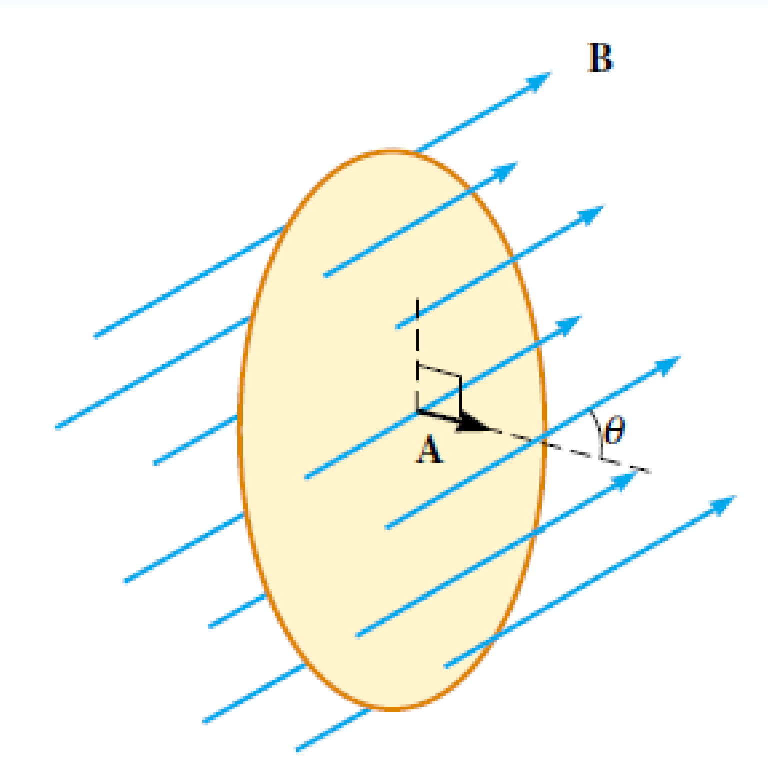
Faraday's law of induction

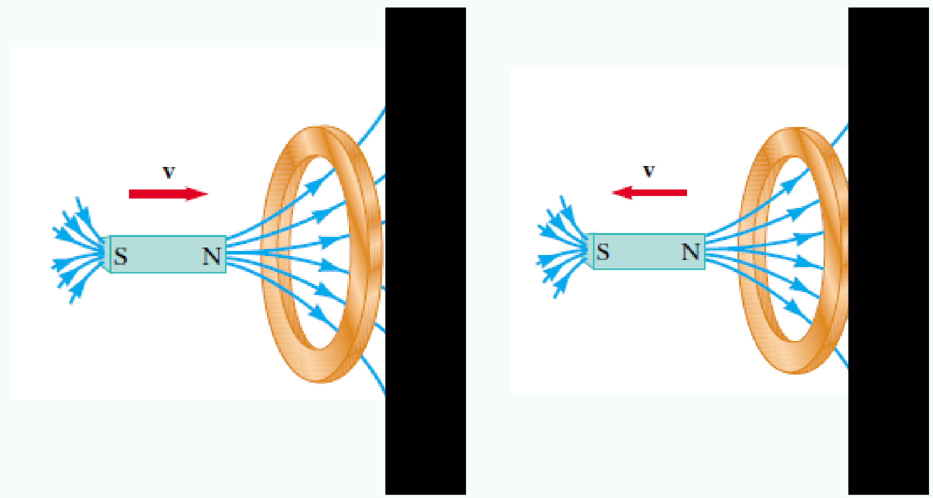
$$\varepsilon = -\frac{\partial \Phi}{\partial t}$$

$$\Phi = \int \vec{B} \cdot d\vec{A}$$

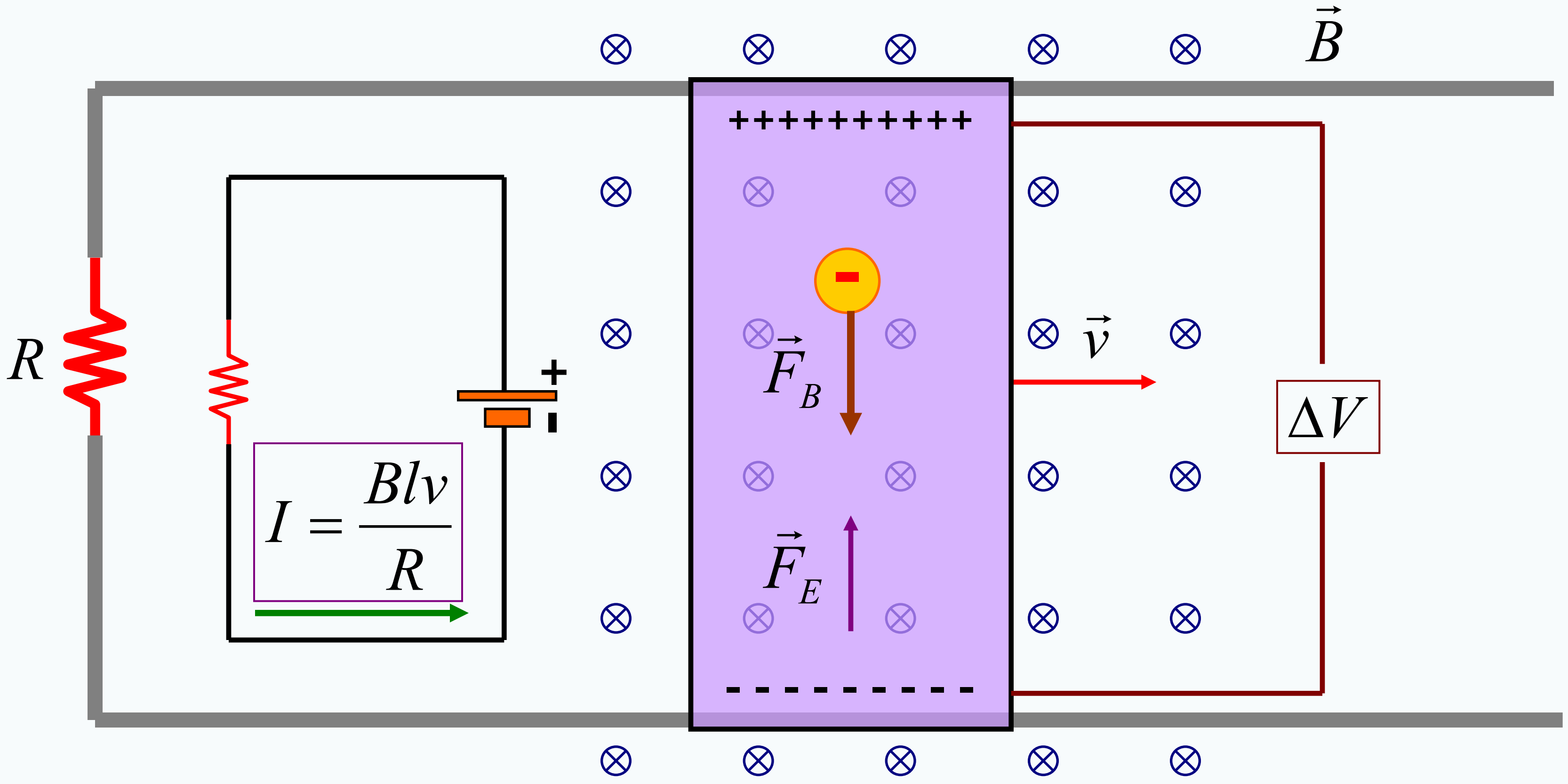
$$\varepsilon = -\frac{\partial}{\partial t}\left(BA\cos\theta\right)$$

Lenz's law: The polarity of induced emf is such that the current produced by the emf in a closed loop will induce magnetic magnetic field, which opposes the change of the magnetic field enclosed by the loop.





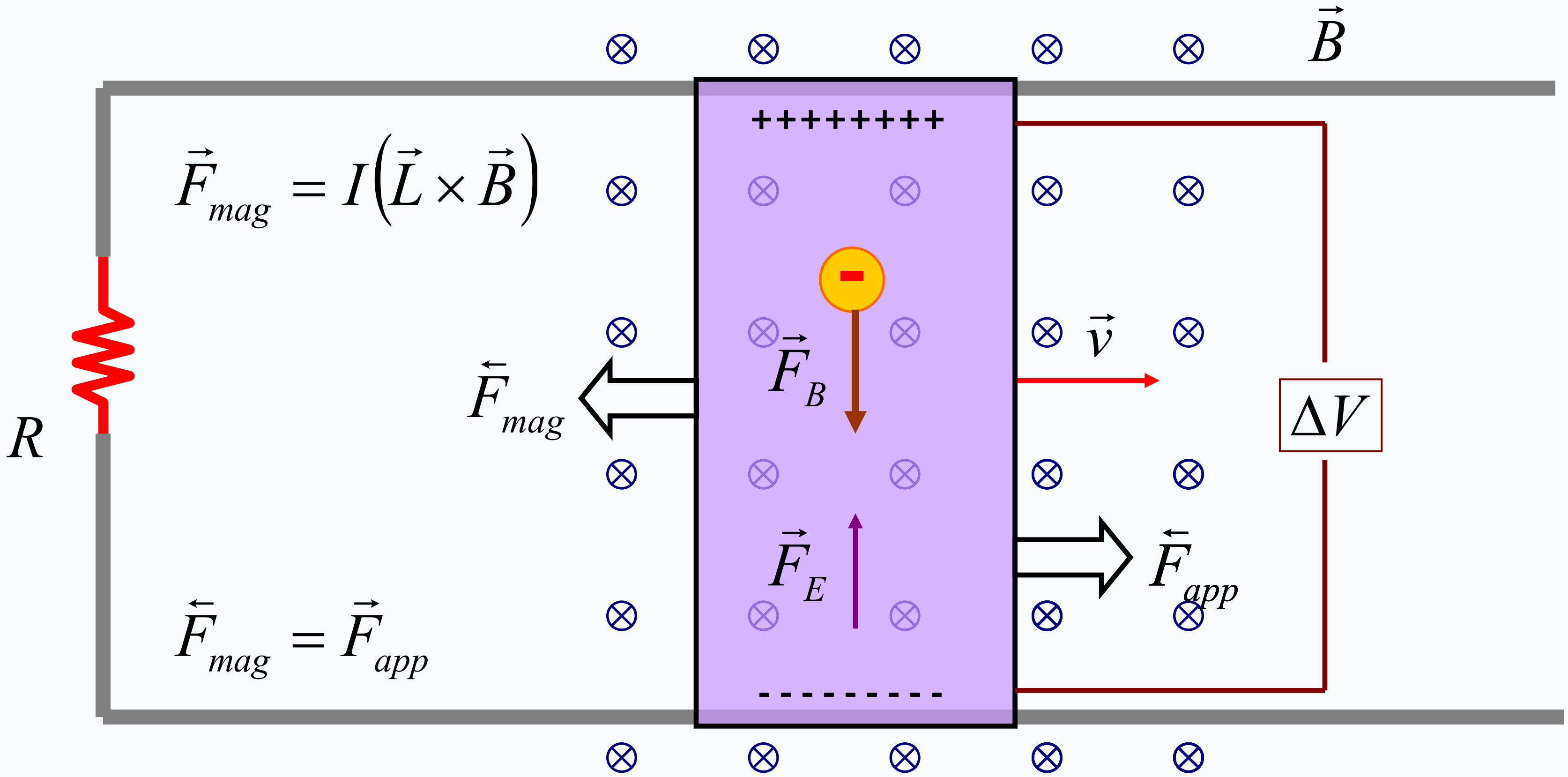
Conductor moving in a magnetic field



$$\vec{F}_B = q\vec{v} \times \vec{B} \qquad \vec{F}_E = q\vec{E} \qquad \Delta V = El = vBl$$

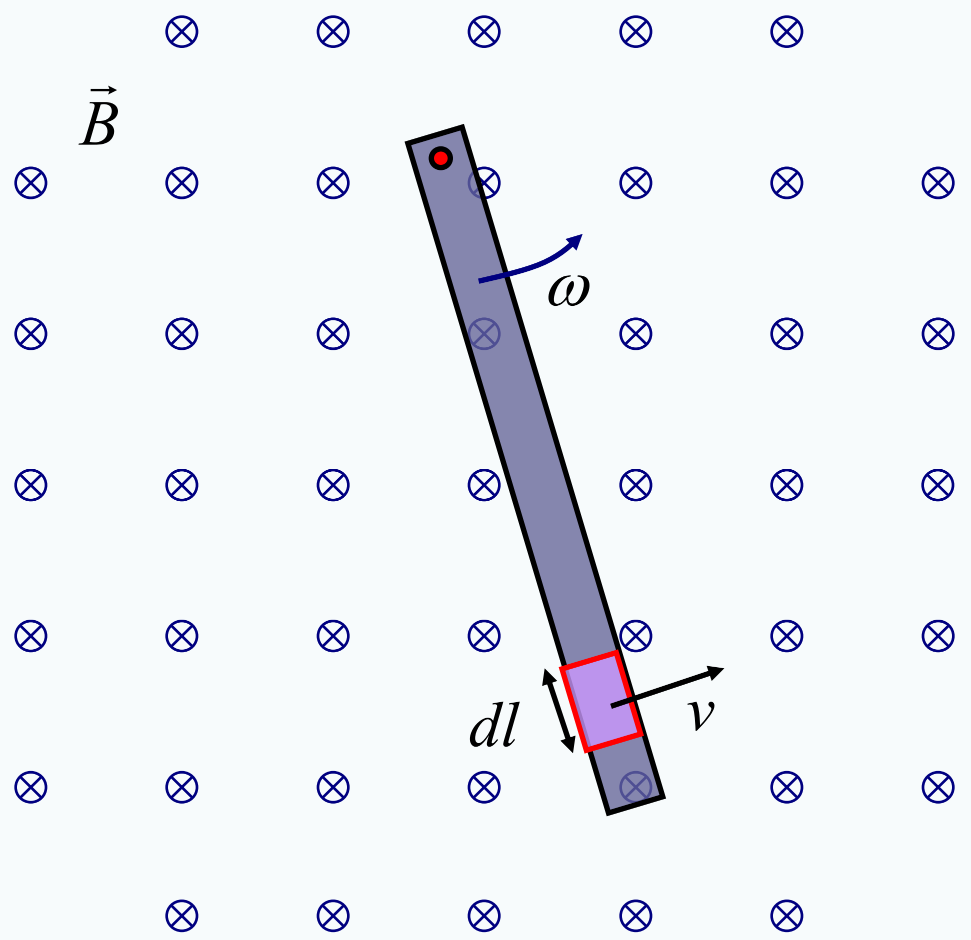
$$\varepsilon = -\frac{\partial}{\partial t}\left(BA\cos\theta\right) = -\frac{\partial}{\partial t}\left(Blx\right) = -Blv \qquad \frac{\partial x}{\partial t} = v$$

Energy conservation



$$ILBdx = \varepsilon dq \qquad Id\Phi = \varepsilon Idt \qquad \varepsilon = \frac{d\Phi}{dt}$$

Rotating bar

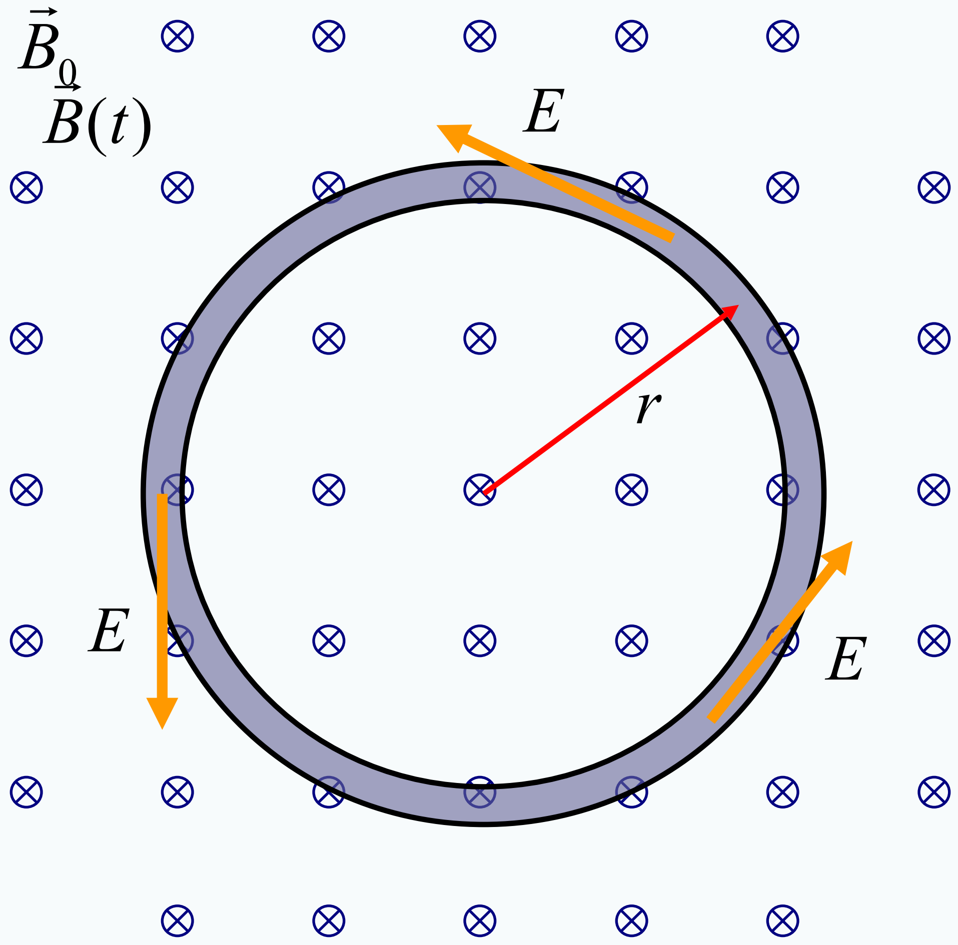


$$d\varepsilon = Bvdl$$

$$\varepsilon = B\omega\int_0^L l\,dl$$

$$\varepsilon = \frac{1}{2}B\omega L^2$$

Moving conductor in magnetic field



$$\varepsilon = -\frac{\partial \Phi}{\partial t}$$

$$W = q\varepsilon$$

$$W = qE \cdot 2\pi r$$

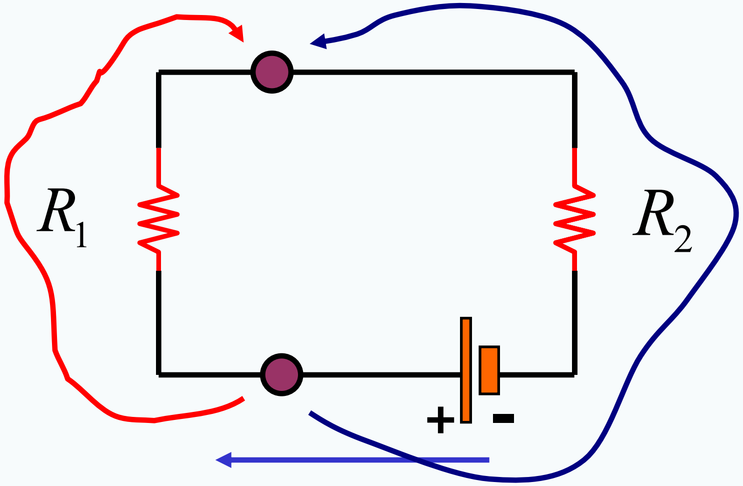
$$E = \frac{\varepsilon}{2\pi r}$$

$$\Phi = B \cdot \pi r^2$$

$$E = -\frac{r}{2}\frac{\partial B}{\partial t}$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{\partial \Phi}{\partial t}$$

Conservative and non-conservative fields



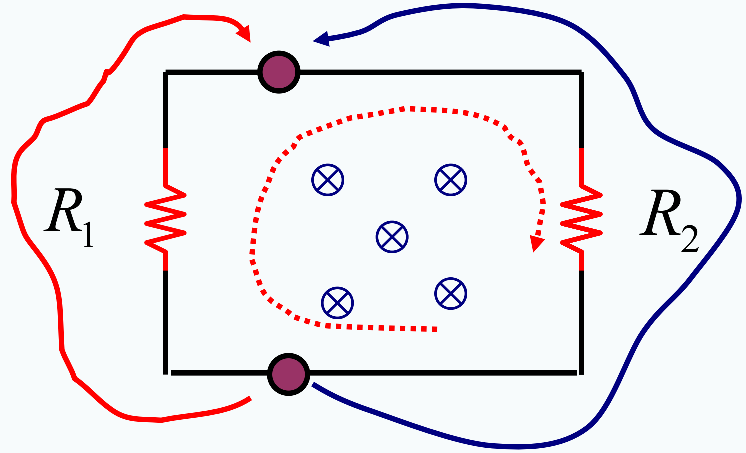
$+V \qquad +\mathcal{E} - Ir$

$$+\mathcal{E} - Ir - IR_1 - IR_2 = 0$$

$$\Delta V_{red} = -IR_1$$

$$\Delta V_{blue} = -\varepsilon + Ir + IR_2$$

$$\oint_{loop} \vec{E} \cdot d\vec{s} = 0$$



$$\Delta V_{red} = -I_{induced} R_1$$

$$\Delta V_{blue} = I_{induced} R_2$$

$$\oint_{loop} \vec{E} \cdot d\vec{s} = \varepsilon(t) = -\frac{\partial \Phi}{\partial t}$$

To remember!

- **Induced emf is equal to the rate of change of the magnetic flux through a surface bounded by the circuit. This is Faraday's law of induction.**
- **The emf induced has a direction to oppose the change that produces it. This is Lenz's law.**
- **Motional emf is induced by the motion of a conductor in a magnetic field.**
- **The electric field induced in this way is non-conservative!**