Electrodynamics

SECTION

Early electrodynamics

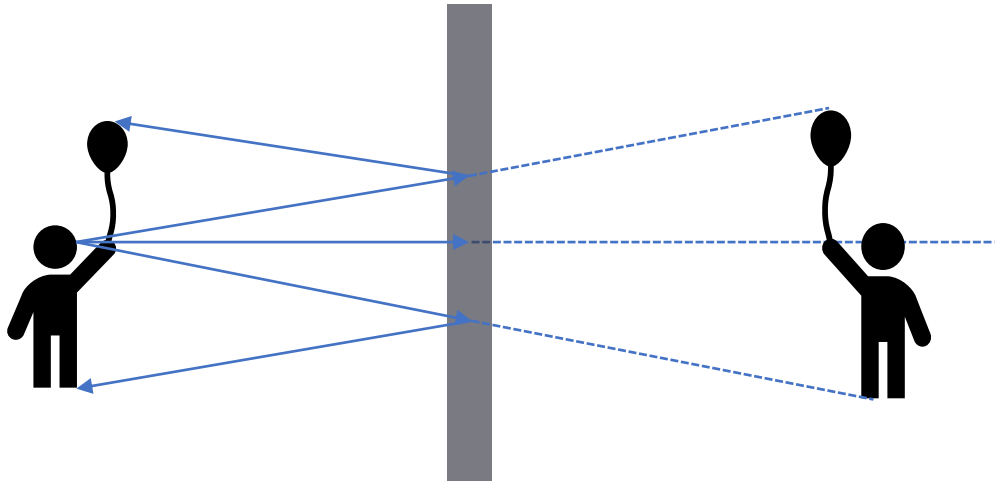
LECTURE

Early theories of light

Particle theory of light

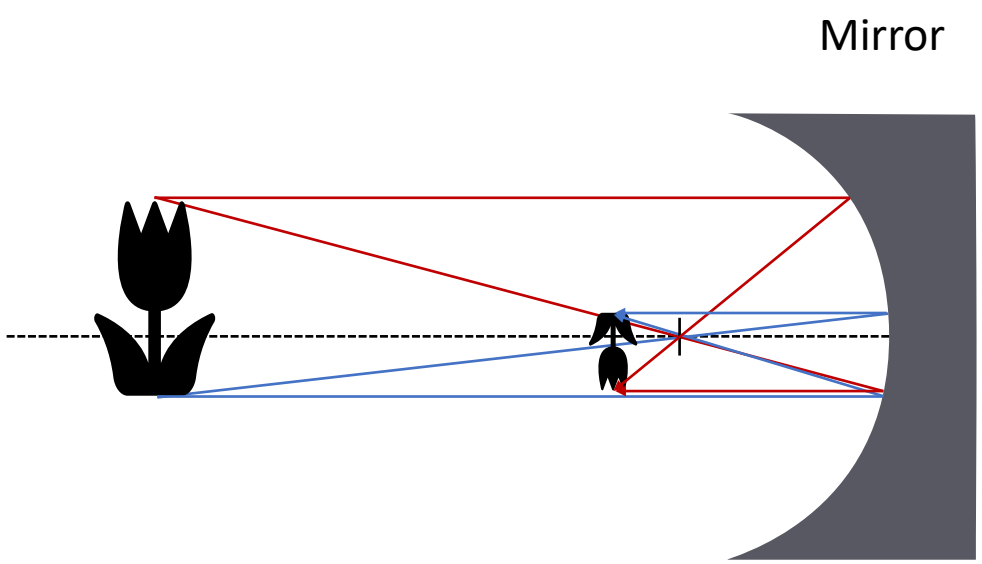
1637 Descartes & **1672** Newton: Particle theory

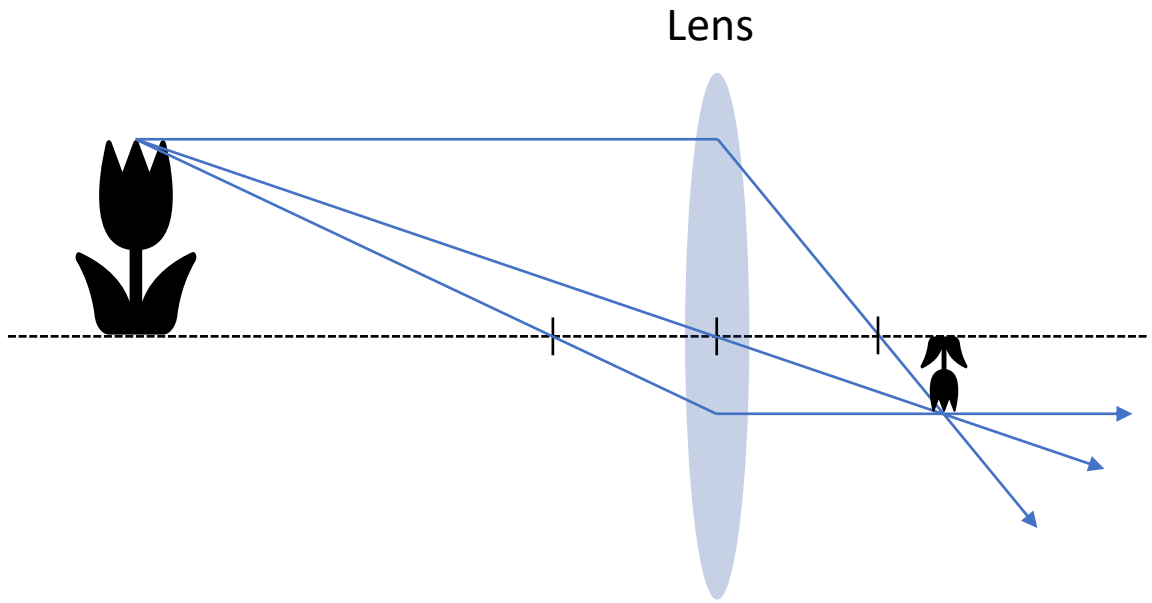
- Every source of light emits a large number of particles
- Perfectly elastic, rigid and weightless
- No refraction, diffraction and interference



Mirror

Geometrical optics

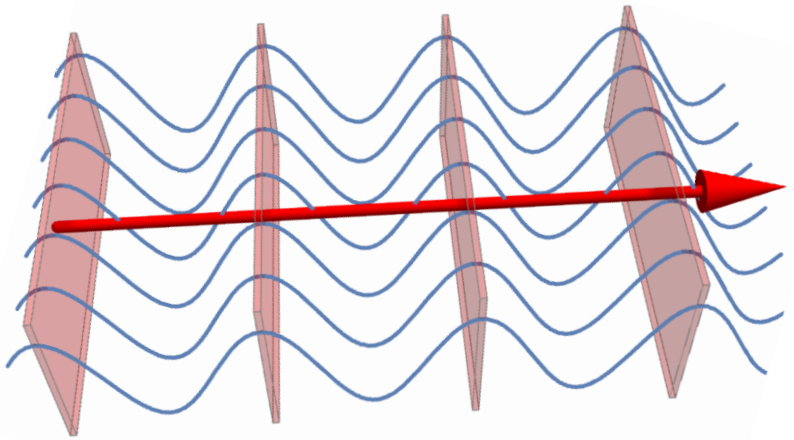




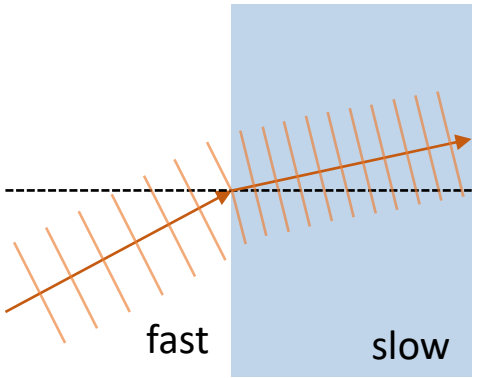
- What happens in the lens?

Wave theory of light

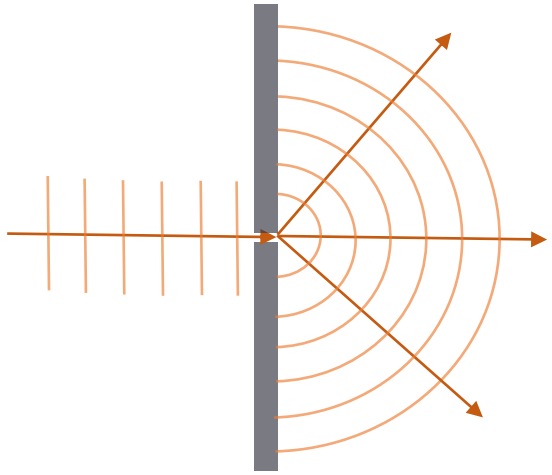
1678 Huygens: Wave theory



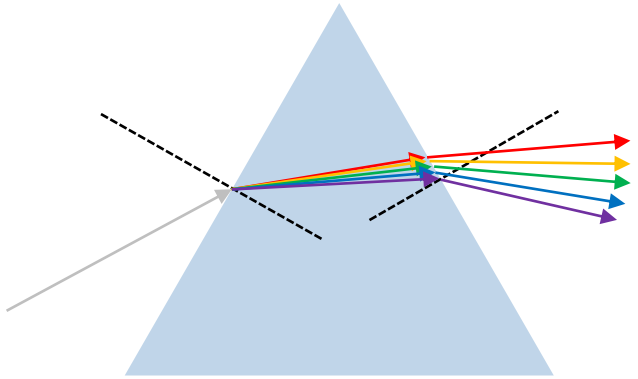
- Refraction



- Diffraction

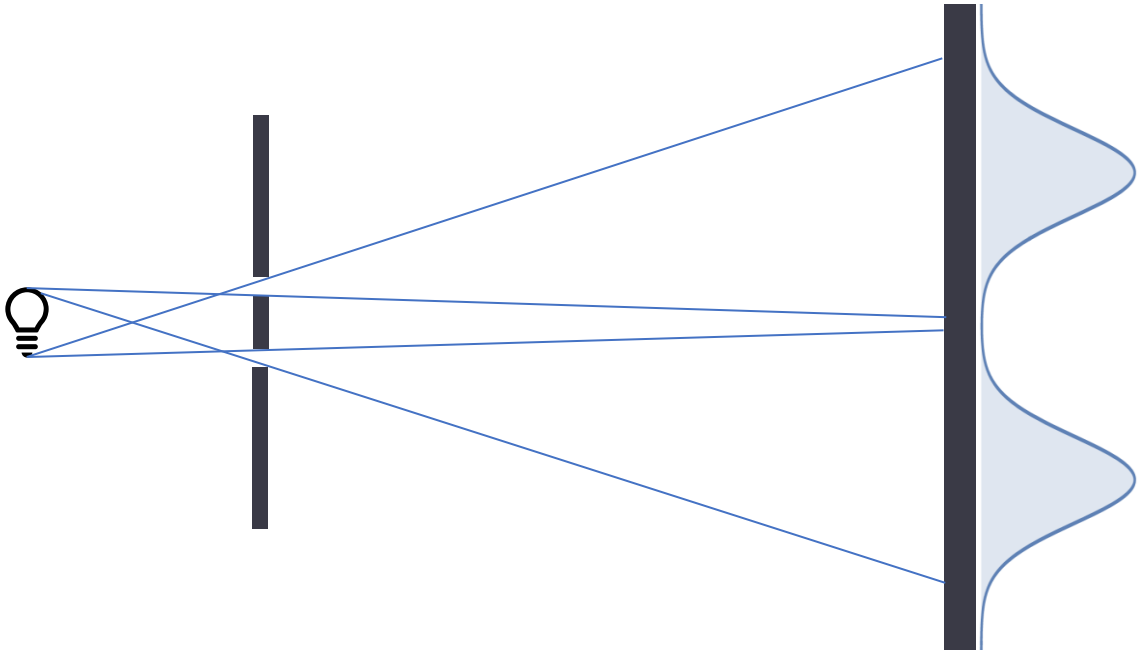


- Colors of light

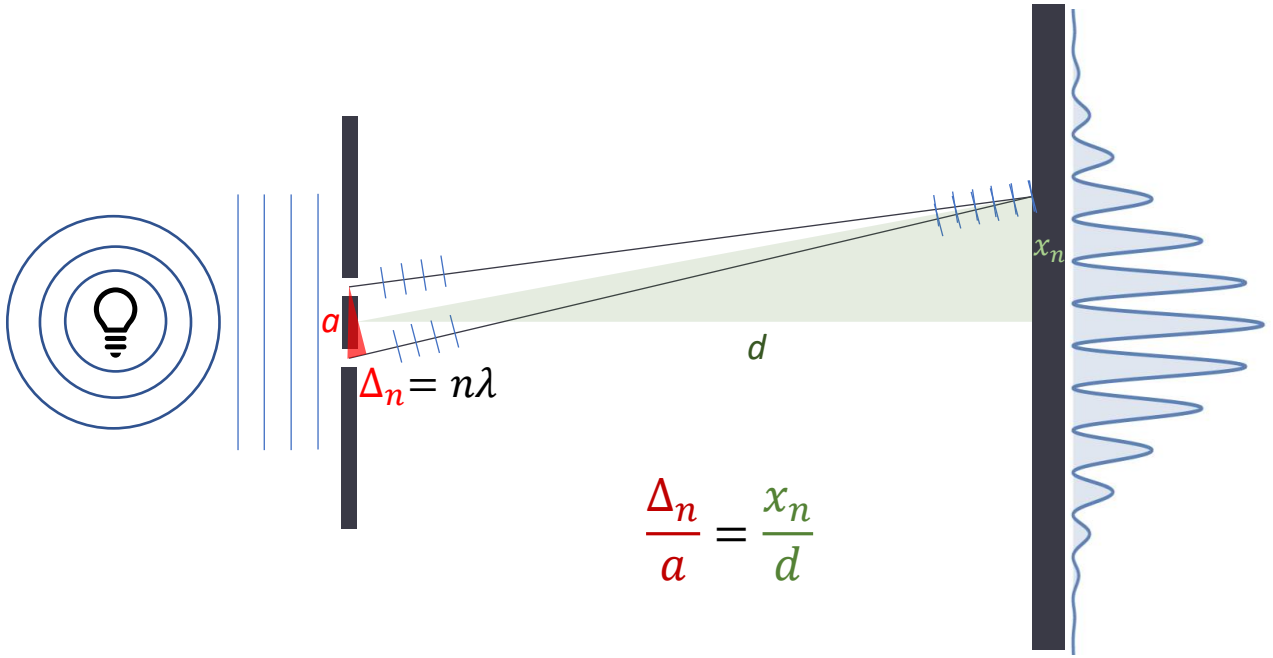


Double-slit experiment

Light as particle



Light as wave



$$\frac{\Delta_n}{a} = \frac{x_n}{d}$$

Intensity maxima distribution in the experiment

$$x_n = \frac{d}{a}\lambda\, n$$

What is light?

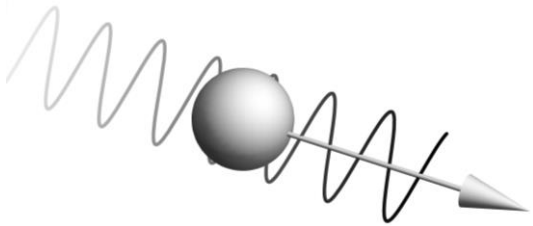
"The whole 50 years of conscious brooding did not bring me closer to the answer to the question 'What are light quanta'. Today every scoundrel thinks he knows, but he is wrong ..."

- Einstein to Besso, 1951

Light

- Wave
  - 1802: Double-slit experiment
  - 1864: Maxwell's electrodynamics

- Particle
  - No mass $m = 0\ \mathrm{kg}$
  - No charge $q = 0\ \mathrm{As}$
  - 1899-1915: Photoelectric effect
  - 1900: Planck law for black-body radiation



1924: Wave-particle dualism

→ Quantum mechanics

"Quantum Physics from Beginner to Expert"

Electrodynamics

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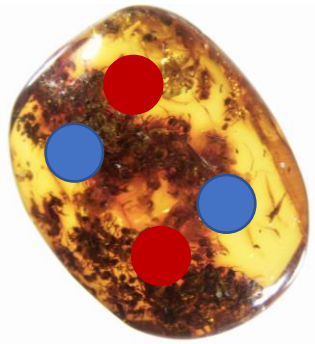
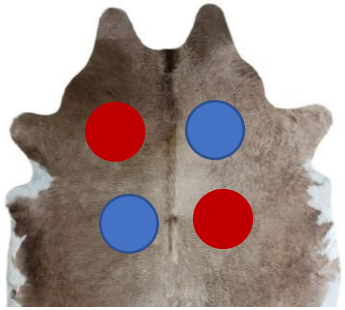
Charge, electric field & Coulomb's law

Charge

550 BC: Thales of Miletus

Rubbing ember (ηλεκτρόν) with fur

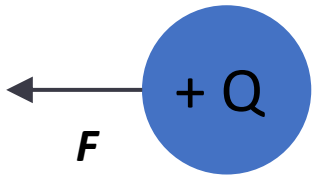


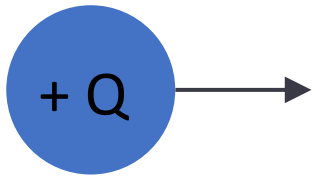


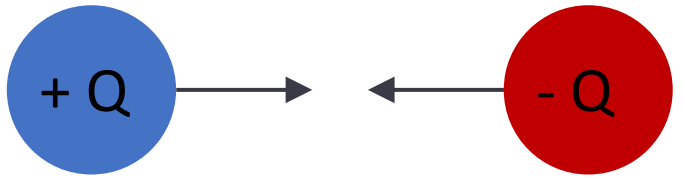
Coulomb's law

1769: Robinson $F \propto r^{-2.06}$

1780s: Coulomb $F = k_e \frac{|q_1 q_2|}{r^2}$ $k_e = \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^9 \,\mathrm{N\,m^2\,C^{-2}}$



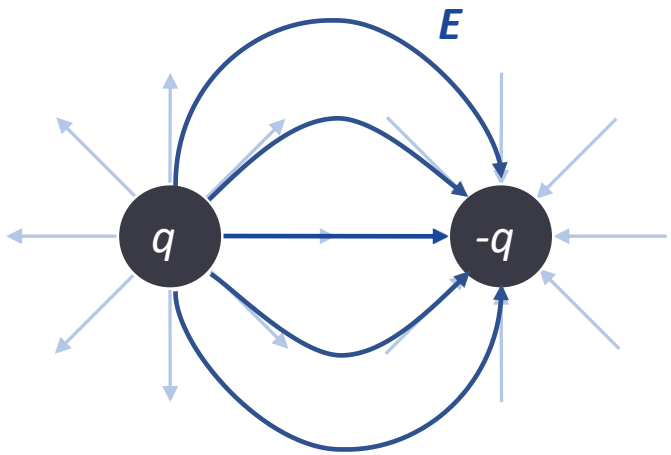


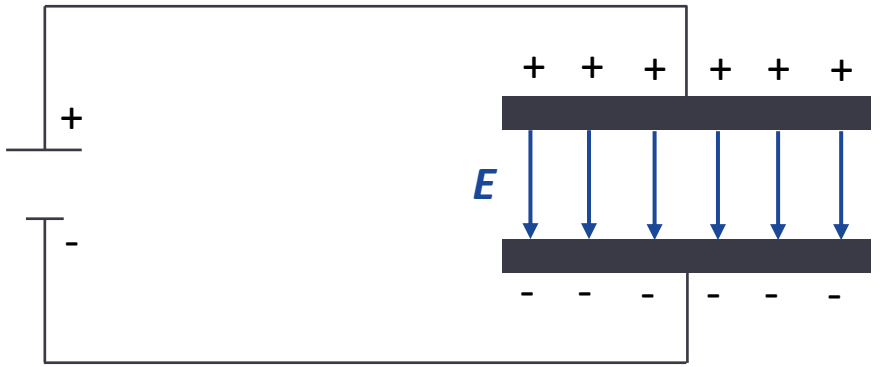


Electric fields

1830s: Faraday ‘Lines of force’ $F = qE$

1740s: First capacitor





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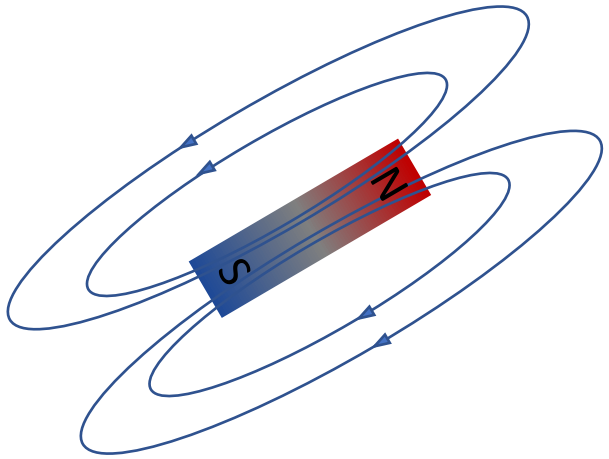
Magnetism & Ampère's law

Magnets

6th century BC: Aristotle



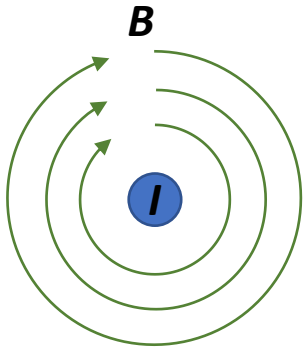
lodestones (naturally magnetized magnetite Fe_3O_4) can attract iron

12th century: Compass

1600: Gilbert: the earth is magnetic

Ampère's law

1825: Ørsted, Ampère

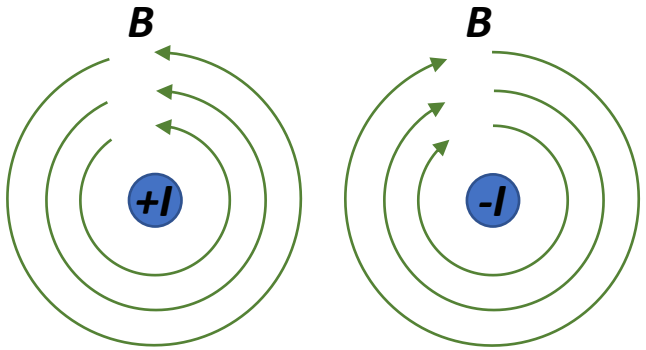


$$\nabla \times \boldsymbol{B} = \mu_0 \boldsymbol{J}$$

Violates continuity equation

$$\nabla \cdot (\nabla \times \boldsymbol{B}) = 0$$

$$\mu_0 \nabla \cdot \boldsymbol{J} = 0$$



$$F \propto \frac{I_1 I_2}{r}$$

Missing term …

$$\nabla \cdot \boldsymbol{J} = -\frac{\partial \rho}{\partial t}$$

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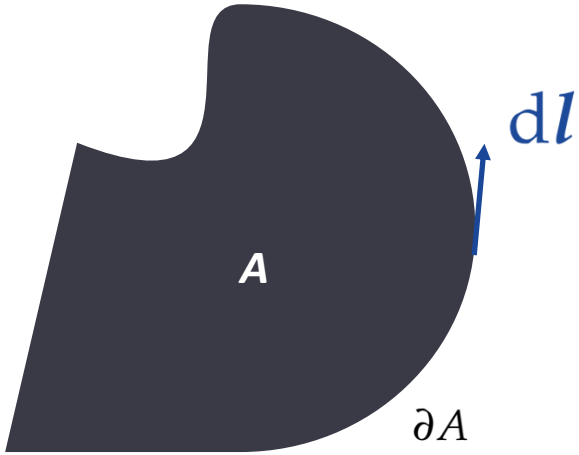
Induction

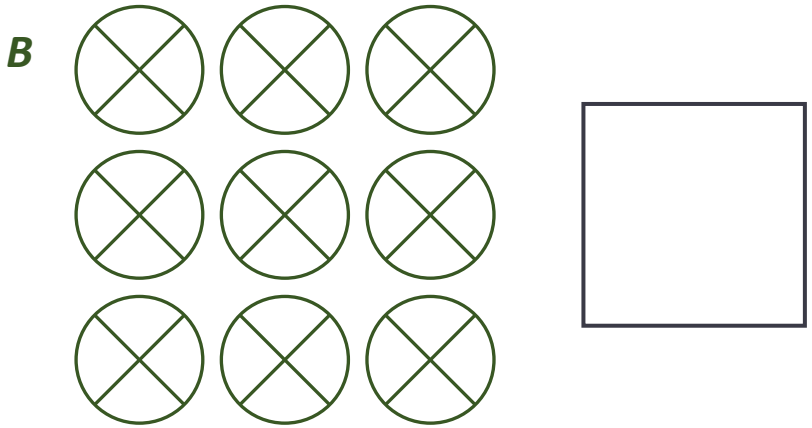
Electromagnetic induction

1830s: Faraday, Lenz and Neumann

$$U_{\text{ind}} = -\frac{\partial}{\partial t}\phi = \oint_{\partial A} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l}$$

Magnetic flux $$\phi = \int_{A} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$





Voltage is induced