

Electromagnetism

- **Electromagnetic interaction** is one of four fundamental interactions in Nature.
- **Electromagnetism** is the theory of electromagnetic interactions or of electromagnetic forces.

- **Electric charge Q** can be positive and negative. The total **electric charge is conserved**.

- **Electric current I** is a flow of electric charge.

- Electric **charges** are sources of **electric field E**.

$$Q \implies E$$

- Electric **currents** are sources of **magnetic field B**.

$$I \implies B$$

- Electric field acts on electric charges - **electric force**.

$$E \longrightarrow Q$$

- Magnetic field acts on moving electric charges - **magnetic force**.

$$B \longrightarrow I$$

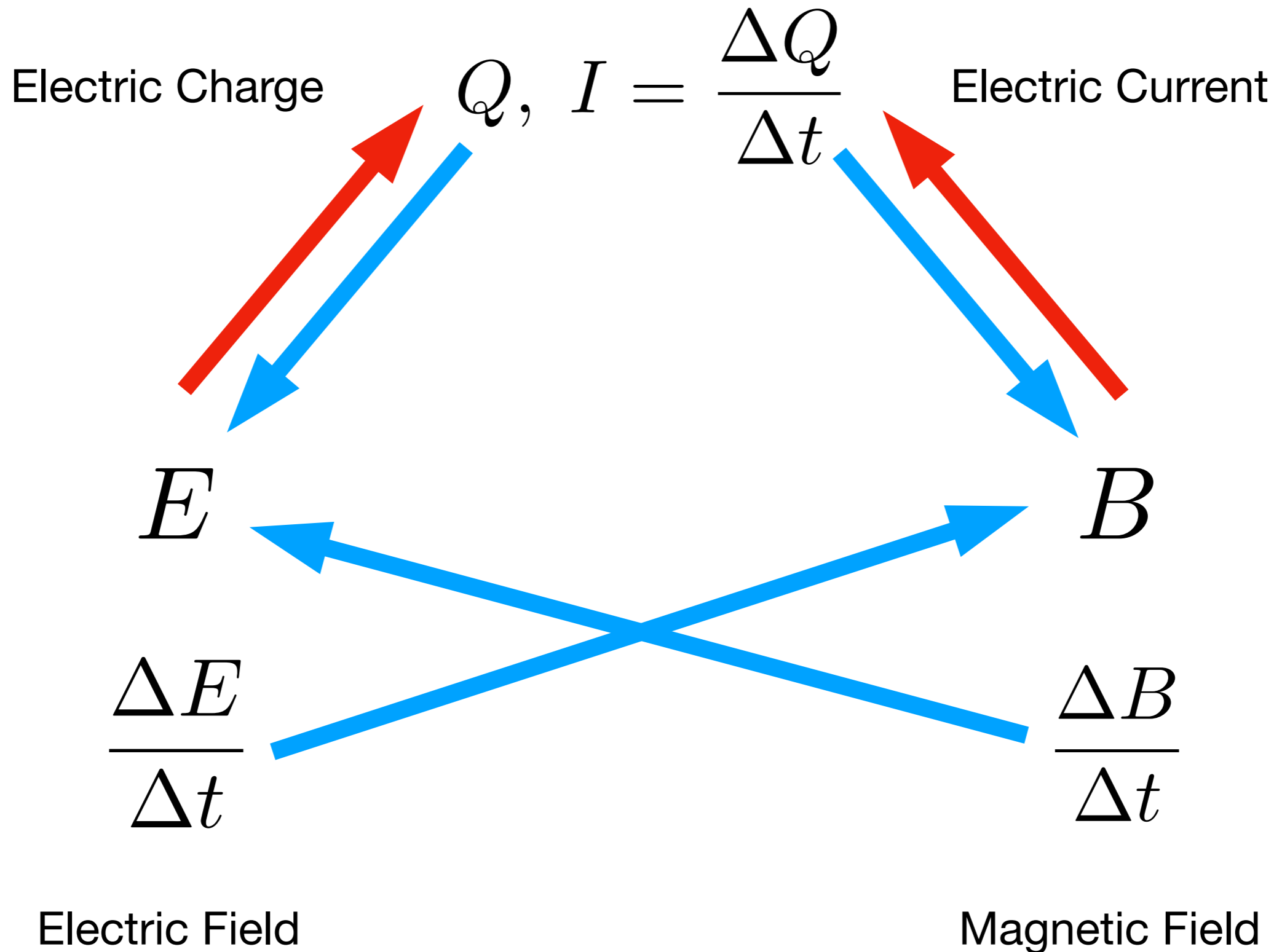
- **Magnetic field** changing in time creates **electric field**.

$$\frac{\Delta B}{\Delta t} \implies E$$

- **Electric field** changing in time creates **magnetic field**.

$$\frac{\Delta E}{\Delta t} \implies B$$

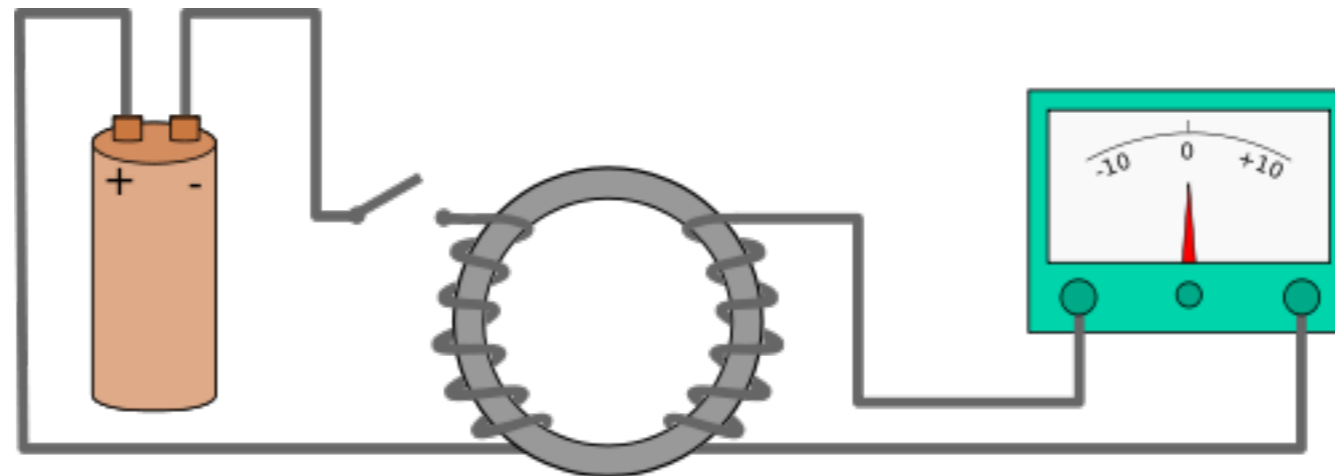
Electromagnetism



Examples

$$\frac{\Delta B}{\Delta t} \implies E$$

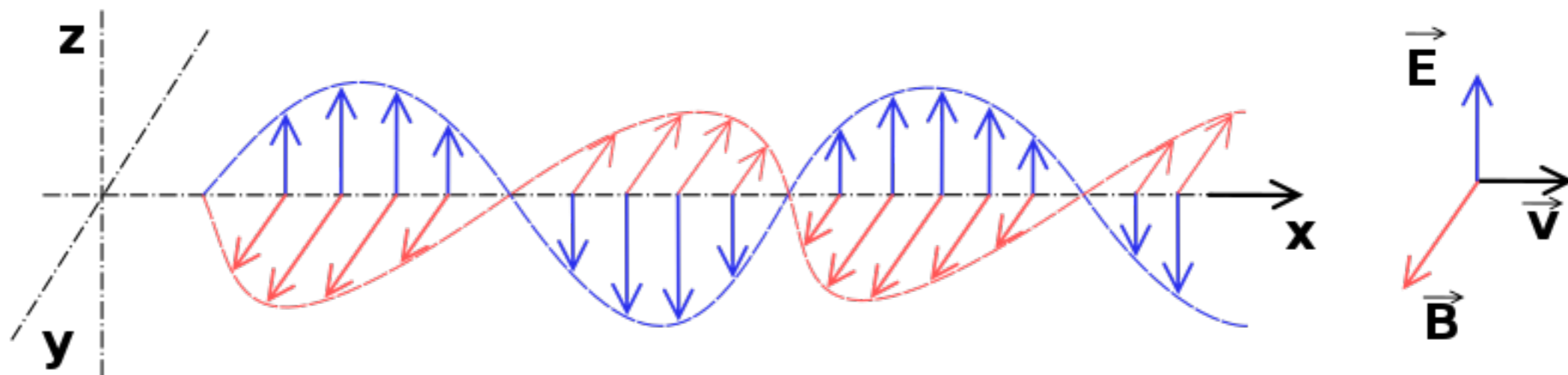
Faraday's Law of Induction



Electric field (from battery) -> Electric force -> Charges move (current) ->
 Changing magnetic field in the ring -> Electric field in the second coil ->
 current in the second coil

Applications: of transformers, inductors, **electrical motors**,
generators and solenoids.

Electromagnetic Wave



$E(t) \rightarrow B(t) \rightarrow E(t) \rightarrow B(t) \rightarrow \dots$ - oscillations of E and B propagating in space. **Electromagnetic Wave.**

Speed of E/M wave in vacuum - **speed of light!**

$$c = 299,792,458 \text{ m/s}$$

$$c \approx 3 \times 10^8 \text{ m/s}$$

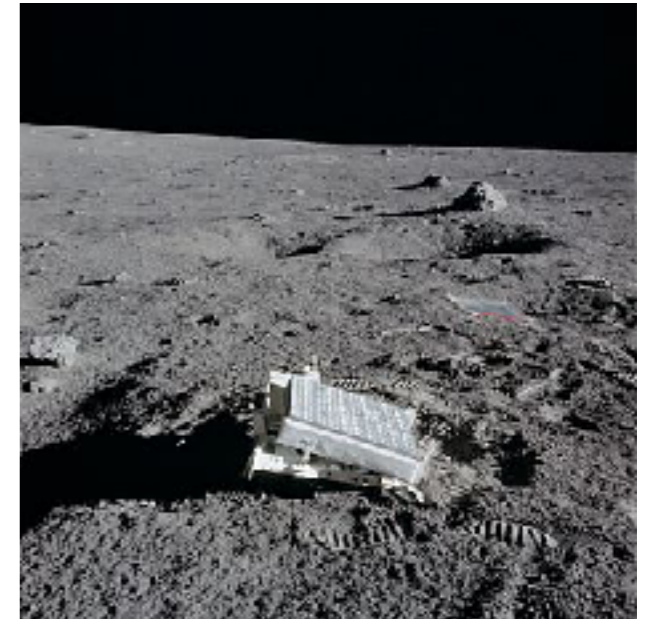
Radio waves, microwaves, infrared, (visible) light, ultraviolet, X-rays, and gamma rays.

Homework

Problem 1

A laser on Earth is aimed at one of the reflectors planted on the Moon during the Apollo program. What time does it take for laser light to travel to the Moon and return to the Earth? The distance to the Moon is approximately 400,000 km.

Remark: Actually, this experiment is designed so that by accurately measuring the time of the return one could tell the distance to the Moon.



Problem 2

The Voyager 2 spacecraft passed close to Neptune in 1989. It communicated to Earth by sending signals by means of microwave electromagnetic radiation. How long did it take the signal to reach the Earth? (you can google the distance between Neptune and Earth)

