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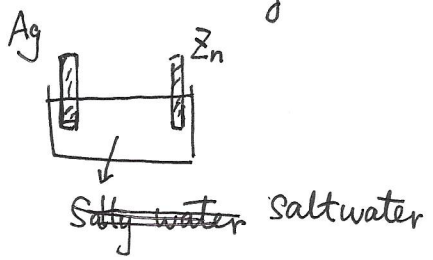
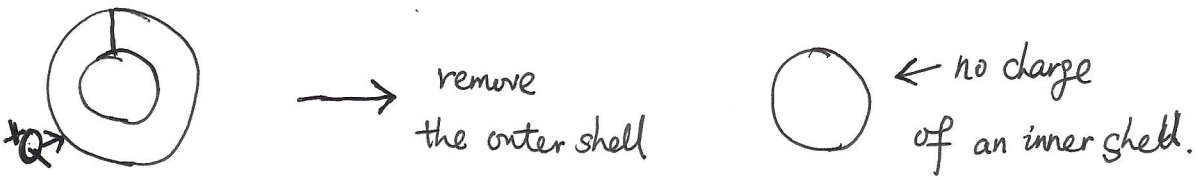
Lect 1 Electromagnetism — an overview

§ History

- Ancient times — lightening
- Ancient China and Greece — ferromagnetism, lodestone
  鬼谷子：慈石召铁， Aristotle: Thales says that a stone has a soul because it causes movement
- triboelectricity (ancient time)
- Leiden jar to store static electric charge (1746 P. Van Musschenbroek)
- Chemical battery — Volta battery (1800)



- Coulomb's law of inverse square force (1785)
  Joseph Priestly (1760's), Henry Cavendish (1772)



This implies the inverse square force.

- 1752, Ben Franklin's experiment demonstrated the lightening in the sky and electricity in the Leiden jar are the same.

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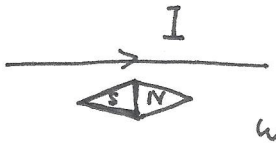
- 1820, Oersteel's experiment — connection between electricity and magnetism



why does this magnetic needle turn around?

- Ampere's law: magnetic field generated by steady current

$$\oint \vec{B}\cdot d\vec{r} = 4\pi I \quad \text{or} \quad \mu_0 I$$

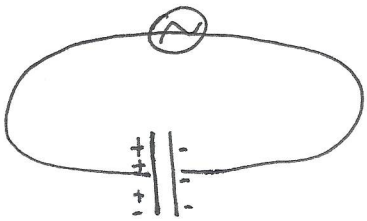
- Faraday's electro-magnetic induction

$$\mathcal{E} = -\frac{1}{c}\, d\Phi/dt \quad \Rightarrow \quad \oint \vec{E}\cdot d\vec{r} = -\frac{1}{c}\frac{d}{dt}\iint \vec{B}\cdot d\vec{S} \quad \text{(SI unit)}$$

$$\text{or} \quad \mathcal{E} = -\, d\Phi/dt \qquad \oint \vec{E}\cdot dr = -\frac{d}{dt}\iint \vec{B}\cdot d\vec{S} \quad \text{(Gauss unit)}$$

- Gauss's law $\oiint \vec{E}\cdot d\vec{S} = 4\pi Q$, or $\oiint \vec{E}\cdot d\vec{S} = Q/\varepsilon_0$

- Displacement current



$$\oint \vec{B}\cdot d\vec{r} = \frac{4\pi I}{c} + \frac{\partial}{c\,\partial t}\iint \vec{E}\cdot d\vec{S}$$

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- prediction of electro-magnetic wave — Maxwell

  light is one kind of E-M wave

- Experiment verification — Hertz

  Marconi 1895 — wireless communication

- Relativity — Einstein (1905) — no-revision of Maxwell

Quantum aspect of electro-magnetism

- Black body radiation — Planck formula

  Quantization of E&M field $1 + e^{-\hbar\omega\beta} + e^{-2\hbar\omega\beta} + \cdots$

  $$= \frac{1}{1 - e^{-\hbar\omega\beta}}$$

- photo-electric effect

  Einstein proposed the concept of photon

- Compton effect — scattering bewteen X-ray (γ-ray) and electron

- Lamb shift, anomoalous Lande factor $g-2$

  fluctuation of vaccum E & M field

- Casimir effect

- Invention of laser (1950s)

- Establishment of quantum electrodynamics

  Renormalization (Feynman, Schwinger, Tomonaga)

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- Quantum optics — manipulation of light quantum, particle nature of optics

- Entanglement of photons — polarization entanglement.

§. Feynman said, if put in the long time scale, such as 10000 years, the importance of the invention of Maxwell equations is far more significant than the U.S. civil war, which took place in the decade.