

21.01

What is Physics?

- **Physics** = the study of physical phenomenon and the mechanisms that cause them
 - This class is focused on **electromagnetism**
- Physics first discovered by the Greek philosophers
 - Rub piece of amber and it “pulls” straw near it
- **Hans Christian Oersted** = physicist who discovered the *unity* of electricity and magnetism (~1820)
 - Prior to this, the two phenomenon were assumed to be independent of one another
- **Michael Faraday** = physicist that pioneered much of the properties of electromagnetism
 - Didn’t break these laws down into concrete formulas
 - * Physicists *love* them some formulas
- **James Clerk Maxwell** = physicist who made Faraday’s discoveries more concrete
 - Created **Maxwell’s Equations**
 - * **Gauss’s Law**
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$
 - * **Gauss’s Law for Magnetism**
$$\nabla \cdot \mathbf{B} = 0$$
 - * **Faraday’s Law of Induction**
$$\nabla \times \mathbf{E} = -\frac{\delta \mathbf{B}}{\delta t}$$
 - * **Ampere’s Circuital Law**
$$\nabla \times \mathbf{B} = \mu_0 \left(\mathbf{J} + \epsilon_0 \frac{\delta \mathbf{E}}{\delta t} \right)$$
- **Benjamin Franklin** = American scientist
 - Credited with describing the two electric charges as “positive” and “negative”
 - Also introduced the idea of **excess charge**
 - * **Excess charge** = an imbalance in positive and negative charge

Conductors and Insulators

- **Conductor** = a material that permits electrons to move relatively freely
 - **Superconductors** = a material that acts as a *perfect* conductor
 - * Offers no resistance to electric flow
 - Generally, conductors have electrons on the outer shells whose ionization energy is small
- **Insulators** = a material that blocks electrons from moving freely
 - Also called **nonconductors**
- **Semiconductor** = a material whose capacity to permit electrons to move freely is in between **insulators** and **conductors**
- **Induced charge** = a phenomenon in which an object's internal electric field will orient itself to align with an external electric field and create a **dipole**
 - **Dipole** = an object that is positively charged on one side and negatively charged on the other

Coulomb's Law

- **Electrostatic force** = the force that charged particles exert on one another
 - Vector quantity—the direction always points towards or away from the particle in question
- **Coulomb's Law** = an equation that describes the magnitude of the **electrostatic force**
 - Named after Charles-Augustin de Coulomb
 - Discovered in 1785

$$\vec{F} = k \frac{q_1 q_2}{r^2} \hat{r}$$

$$\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

$$k = \frac{1}{4\pi\epsilon_0} = 9.99 \times 10^9 \frac{Nm^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

- ϵ_0 is called the **permittivity constant**
 - * Mostly used for historical reasons, as it made simplifying other equations easier
- Very similar to equation for Newtonian gravity

$$\vec{F}_g = G \frac{m_1 m_2}{r^2} \hat{r}$$

Electric Charge and Current

- SI unit for charge is **Coulomb(C)**
 - For practical reasons, the **Coulomb** is defined using the **Ampere**
- **Ampere** = SI unit for current
 - Current is defined as the following, where i is current and q is charge

$$i = \frac{dq}{dt}$$