AP Physics C: Electricity and Magnetism

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1 Introduction

1.1 Electric Field

Positive and negative. Benjamin Franklin believed that protons went to electrons; now know it is the opposite

$+ \cdot - = -$	Attract
$+ \cdot + = +$	Repulsion
$- \cdot + = -$	Attraction
$- \cdot - = +$	Repulsion

This works with gravity:

$$F_g = -\frac{Gm_1m_2}{r^2}\hat{r}$$

Negative for attraction!

$$F_E = \frac{kq_1q_2}{r^2}\hat{r}$$

No negative because the charges have negatives attached to them; Columb force. Negative is an attraction. Positive is repulsion.

1.1.1 Maxwell: Field Thinking

What does the $\hat{r}$ mean in electric fields? Vector field for gravity points towards center of mass. Strength of field: $-g\hat{r}$. Ratio: $\frac{\text{N}}{\text{kg}} = \frac{\text{m}}{\text{sec}^2}$
Use positive electron as a "test charge." If we want to mimick vector field of gravity, use electron in middle, as the test charge will be attracted to it.
We can express the strength of a field with $\frac{\text{N}}{\text{C}}$.

1.2 Coulomb

Unit of charge. We calculate by summing charge. Most things are balanced. Example: 18 g of water. H2O. $2 \cdot 1 + 16 = 18$. Positive charges: $10 \cdot 6 \times 10^{24}$ Negative charges: Same amount; balances positive charge. Net charge: 0.

1 Mole $\approx 10^5$ Coulomb of charge 1 Mole $= 6 \times 10^{23}$ $\frac{6\times10^{18}e^-}{1 \text{ Coulomb}}$

1.2.1 What Actually is a Coulomb?

Defined similar to a kilogram. It produces forces.
With mass, we compare against gravitational force (scale).
$From$**??**$\overrightarrow{E} \cdot q = \overrightarrow{F}$. If you know the strength of the electric field and know F, then we can find q. The electric field is similar to g. Same equation as $mg = F$. There is no mathematical difference besides variables.
With mass, we can measure using inertia. **Do we have electrical inertia?**

1.3 Capacitor

A device that uses an electric field to store energy. Collects charge in one place and keeps it; really difficult because charges do not want to stay put; either want to attract or repel.

- Capacitor is like a spring. Electricity into capacitor, it pushes back.
- AM radio 1060 kHz. The unit is simple harmonic motion; the frequency of the circuit.

1.4 Strength of Electric Field

Find $\overrightarrow{E}(r)$. Think:

$$g = -\frac{GM}{r^2}\hat{r}$$
$$\overrightarrow{E}(r) = \frac{kq}{r^2}$$

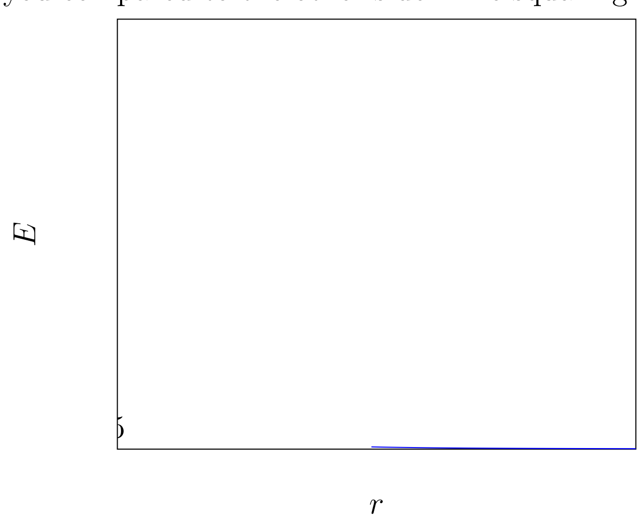
k is analog of G. q is analog of M. Assume even distribution of q. Conductors move charge, insulators keep charge still. To ensure even distribution on sphere, make it out of conductor. If you place charge in one place, spreads out.

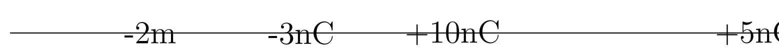
$$k = 9 \times 10^9 \tag{1}$$
$$F_E = \overrightarrow{E} \times q_2 \tag{2}$$

Similar to mg, $m \equiv q$, $G \equiv \overrightarrow{E}$. 10^6, air breaks down, spark.
Flux = total amount of field thorugh area. Total flux = vector E times vector A.

1.4.1 Difficulty of Coulomb's Law

Easy with sphere, as there is nice symmetry, as r is uniform.
Faraday Cage
σ: Density of charge. $\sigma = \frac{q}{A}$. Assume uniform σ for a sphere. Therefore, on the outside, there is no charge, therefore no E. On the inside, if the sphere is hollow, it is similar to gravity. Even off the center, you are closer to one side but that gives you a smaller area influencing you compared to the other side. The squaring affects cancel out—there is no charge as well.





Finding $\overrightarrow{E}$: $\sum \overrightarrow{E}$ = vector sum.

$$E_{-1} = \frac{k(-3 \times 10^{-9})}{1}$$
$$E_0 = \frac{k(10 \times 10^{-9})}{2^2}$$
$$E_{+2} = \frac{k(5 \times 10^{-9})}{4^2}$$

Electric field points toward negative charges
Negative at $-2m$ is different from the negative at $2m$. Points to the right at -2 and to the left at 2. Sketch arrows on the line. Away from the negative charge, toward the positive charge. Positive in this Coulomb's Law means attraction. Positive means out from the center. Negative means in towards the center.
$E = \frac{kQ}{r^2}$. $k = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2}$

- Epsilon naught is the permittivity of free space. Related to c.
- 4π comes from surface area of sphere.
- $\epsilon_0 = 8.85 \times 10^{-12}$
- $\sqrt{\epsilon_0 \mu_0} = c$

https://www.deepspace.ucsb.edu/wp-content/uploads/2010/08/033$_Chapter - 22 - Flux - and - Gauss - Law - PML.pdf$