

# General Physics - E&M (PHY 1308) Lecture

## Notes

### Lecture 003: Electric Field and Simple Distributions of Charge

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no tags

#### Goals of this lecture

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- Discuss in detail Coulomb's Law
  - two point charges
- Discuss principle of superposition
  - more than 2 point charges
- Discuss the concept of the electric field, the FOUNDATIONAL concept of electricity and magnetism
  - allows us to not worry about what charge is being acted upon and thus envision complex geometries
- Discuss the electric dipole
  - dipole force and field, torque, etc.
- Discuss how to handle very large distributions of charge
  - calculus!

#### Electric Force

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As indicated by demonstrations from last lecture, electric charge is able to exert a force. We tend not to notice this force most of the time because the electrons and protons in our bodies, and in the work around us, are largely paired up and thus electrically neutral (zero electric charge) on a human scale.

As the soda can and the candle flame demonstrations show, electric charge and force go hand-in-hand at both the microscopic (ions in the candle flame) and macroscopic (soda can attracted by charged plastic) levels. Many observations and measurements of the relationship between:

- The magnitude of the charges involved
- the distance between the charges (it's direction AND magnitude)
- the sign of the charges
- the force exerted between charges

have been carefully studied. The result is mathematical statement that has been upheld by thousands upon thousands of repeated experiments carried out over hundreds of years - a LAW. This law is known as "Coulomb's Law":

$$\vec{F}_{12} = \frac{k \cdot q_1 \cdot q_2}{r^2} \hat{r}$$

where  $\vec{F}_{12}$  is the force VECTOR (magnitude and direction) that charge 1 exerts on charge 2.  $k$  is a constant, determined from repeated experimentation, whose value is:

$$k = 9.0 \times 10^9 \text{N} \cdot \text{m}^2 / \text{C}^2$$

Let's draw a picture of this and illustrate the pieces of this formula. It combines two key areas of mathematics: standard algebra and vector algebra. The picture will help us to parse the meaning of this formula, considering two cases: a pair of like-signed charged, and a pair of opposite-signed charges.

When solving a problem it's good to develop a strategy for attacking things step-by-step with Coulomb's Law.

## **Strategies for dealing with problems involving the force between two particles**

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Remember: Coulomb's Law reminds us that force is a VECTOR, and thus Coulomb's Law provides us both with the MAGNITUDE and the DIRECTION of the force exerted by charge 1 on charge 2

1. Interpret the problem to determine what you need to figure out: First, make sure that you're dealing with the electric force alone, and that no

other forces also need to be considered. Identify the charge or charges on which you want to calculate the force. Next, identify the charge or charges producing the force - the SOURCE charges. In the above example, we implicitly chose charge 1 and the source and wanted to know the force it exerted on charge 2.

2. Develop a set of information for attacking the problem: Begin with a DRAWING that shows the charges. If you're given coordinates for the charges, place the charges on coordinates; if not, define a suitable coordinate system that makes the problem easier. Determine the unit vectors in Coulomb's Law ( $\hat{r}$ ). If two charges lie along the same coordinate axis, then the unit vector will be one of  $\hat{i}$ ,  $\hat{j}$ ,  $\hat{k}$ . When the charges don't lie simply on a single coordinate axis, find the unit vector by writing the vector  $\vec{r}_{12}$  and determining the unit vector  $\hat{r}$  as follows:

$$\hat{r} \equiv \frac{\vec{r}_{12}}{|\vec{r}_{12}|}.$$

Please note that for simplicity, we will in the future write

$$|\vec{r}_{12}| = r_{12}.$$

3. Evaluate the electric force: Apply Coulomb's Law, using the pieces you assembled during the Interpretation phase of the problem
1. Assess the outcome: Think about your answer to see if it makes sense. Check the little things: does your force point in the direction you expect, based on the charges involved? Compare to an order-of-magnitude estimate of the answer: ignoring the specific values of the numbers involved and multiple just by the appropriate powers of ten, does your answer get within a factor of about 10 of your fully computed answer?

## **Problem Solving: Coulomb's Law**

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To attack a problem involving Coulomb's Law, you need to keep a few definitions in mind:

- $\vec{F}_{12}$  is the *force that charge 1 exerts on charge 2*
- $q_1$  is the charge of the source charge (and is a signed quantity) and  $q_2$