PHY114 S09 Lecture 1

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1 Introduction

This course is mainly about electricity, magnetism and light. We will see that these phenomena are intimately related to each other. Of course, everyone is familiar with light. Electricity is familiar to everyone in a modern world: practically every device we use involved electricity. Magnetism is also very useful: for example, they are used to make electricity.

1.1 Why Should You Learn It?

A physicist like me studies these phenomena because they are an important part of the natural world. But other scientists also need to know about them because they are so useful: no doctor's office can function without electricity. Chemistry can be deduced from electrical properties of atoms and molecules. And chemistry is an important part of how living things function: DNA, proteins etc. Thus if we are to dig deep into how anything works-living or not- we will come up with electricity and magnetism.

1.2 Why does Physics look hard?

That said, learning physics is very different from learning other subjects. For one thing, we discourage memorizing lots of facts in physics. It is easier to understand it by learning how to deduce everything from a few simple facts. These are the fundamental laws of nature. At first they look complicated and mysterious. They were mysterious to the people who discovered them. They still are when you learn them the first time. But in time, and with practice, you start to see simple patterns of thought that can take you very far. Learning physics is really about thinking of the world in a new way.

1.3 Web Page

Everyone should look frequently at the course website.
http://www.pas.rochester.edu/~stte/phy114S09/

It has a more detailed discussion of information, rules and requirements pertaining to the course, and it will be a primary means of communicating information to you.

There is a calendar that shows what you can expect to see in each lecture. There will be some variations, as the pace of the course will depend on how I see the students are doing: I may speed up (not by much) or slow down (by a lot, if needed!) as we go on.

The homework problems will be posted there, as well as exams and solutions. Also, the formula used to calculate your numerical grade is posted there.

1.4 Workshops and Problem Solving

How will you know you have learned it? By predicting things that happen in nature. Or, in this course, by solving lots of problems. That is why all our tests will involve problem solving; and the homeworks are meant to prepare you for the tests. If you are ingenious you can find solutions for homeworks online or get someone else to do them for you. That would be cheating. *But worse, you would be cheating yourself.* It would be like joining a gym and getting someone else to do the exercises for you. In the exams you will be all alone. And the way we have designed the course, it is the exams that matter: the homeworks are only graded to see if you put in a good effort.

1.5 Examinations

The grades will be mostly determined by the exams. There will be three midterms and a final. The midterms will be on Feb 17, Mar 24 and Apr 21. All are on Tuesdays and all are during the normal lecture hours, in Hoyt Hall. You can do badly or miss one of these exams without doing damage to your grades. But if you miss more than one or if you miss the final you have to take this course over again. The date for the final exam will be May 6.

1.6 Labs

A separate component of the course are the labs. No one will get a grade in this course without completing the lab work. 90% of life is showing up, they say: labs are that way. Just do them.

1.7 Lectures

The purpose of the Lecture is to highlight one or two main points from each chapter of the book. For example, in this first lecture, the main point is Coulomb's Law. The Lecture cannot cover everything in the book: you have to read the book and be familiar with even things I won't have time to cover in the Lecture. Life is not fair, in case you haven't figured it out yet.

Most of your effort must go into reading each chapter before you come to class; and doing as many of the problems assigned as possible yourself after the class. The workshops are there to help you through this process.

2 Coulomb's Law

2.1 Remember Gravity

Much of physics is about forces. The most familiar one is the force of gravity. You have already seen how to find the strength of gravitational attraction between two bodies. Newton's law of Gravitation says it is

$G\frac{M_1M_2}{r^2}$

Here, $M_1$and M_2 are the masses of the two bodies: how much matter is contained in them. r is the distance between them. G is a constant, the same for all bodies. It is called Newton's constant and its value is $6.7 \times 10^{-11}Nm^2kg^{-2}$.

2.2 Units

Remember, by the way, that mass is measured in kilograms (kg); distance in meters (m) and force in Newtons N.

2.3 Charge

It turns out that electricity is also a force of nature. We don't notice it everyday because the force only acts when a body has an electric charge: most things we see everyday have zero charge. Actually there are two kinds of charge, positive and negative: it is the difference between the two that determines the force. Most things have equal amounts of positive and negative charges, so the net is zero.

2.4 Electrons and Protons

The negative charge is carried by tiny particles called electrons. The positive charges are carried by protons. Electrons weigh much less than the protons, so they are easy to move around. So the way to create net charge is to move the electrons from one object to another. This happens when you rub a piece of plastic or cloth. This is called static electricity, as the charges don't move once they are separated.

2.5 The unit of charge: Coulomb (C)

The electric charge of a body is determined by the number of protons minus the number of electrons in each bodies. The actual number of these particles is huge (like many trillions) is hard to work with, so we use another unit called a Coulomb, shortened to C.

A proton carries 1.6×10^{-19}C of charge. An electron carries the same amount, but is counted as negative $-1.6 \times 10^{-19}C$. Thus if we move a trillion (10^{12}) electrons from a body A to B, then the electric charge of A will be $1.6 \times 10^{-7}C$ and the that of B will be -1.6×10^{-7}C. Each time we rub two things together, trillions of electrons are exchanged: electrons are so small that we don't notice it usually.

Even when such large numbers of electrons are exchanged, most charges we encounter are still tiny fractions of a Coulomb: rarely more than a millionth of a Coulomb (μC). That is because an electron is so tiny: the smallest thing ('elementary particle') we know of yet.

2.6 The Coulomb Law of Force

The simplest situation is to have two charges separated by a fixed distance r. The force between them has magnitude

$k\frac{Q_1 Q_2}{r^2}$

Here Q_1 and Q_2 are the electric charges of the two bodies. r is the distance between them. k is a constant, whose value is $9 \times 10^9 Nm^2C^{-2}$.

So far it looks just like Newton's law of gravity. Instead of masses, we count charges. Instead of Newton's constant G we have k.

But there is a very important difference. The mass of a body is always positive. But charge can be either positive or negative. The force between a positive charge and a negative charge is attractive: they want to come together. Two negative charges repel each other, they want to get away from each other. So do two positive charges. Herein lies the biggest difference: *gravity is always attractive while electric force can be attractive or repulsive.*

Force being a vector, has a direction as well as a magnitude. The direction of the force is along the line that connects the two bodies: if attractive it points towards the other body; if repulsive it points away from the other body.

2.7 Warning: There are too many things called k

If you look in the front of the textbook, you will see something called Boltzmann's constant, also called k. This has nothing whatever to do with electricity. It is unfortunate that English only has twentysix letters so we have to use the same lettter for very different things. You can tell from context which constant you mean. For example, the units of our k are Nm^2C^{-2} while Boltzmann's k involves temperature.

2.8 Many particles

If you have more than two particles, we can find the net force on each particle by adding the forces due to each other particle: but they are to be added as vectors and not as numbers. The direction must be taken into account as well.

This is typical of the way physics works. We understand what happens at the tiniest level and can then build up what happens at larger levels.