Physics 222 Complete Lecture Notes

mguiney

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Contents

1 Electric Charge

1.1 Properties of electric charge

- Electric charge is a coherent physical property of certain subatomic particles that is responsible for electrical and magnetic properties
- Subatomic particles can be charged or uncharged

1.1.1 Particle charge examples

Positively Charged Particles:

- proton
- atomic nuclei
- positrons

Negatively Charged Particles:

- electron
- muons

Particles without charge:

- neutrons

1.2 Fundamental Unit of electric charge

The fundamental unit of electrical charge is the Colomb.
charge of an electron: e = 1.6 * 10^{-19}

Conductors, insulators, and charge **Conductors:** Electrons move freely through the medium. More likely to transfer electrons to other objects.

Insulators: Electrons do not move freely through the medium. Less likely to transfer electrons to other objects.

1.2.1 Charging by Direct contact

One way to charge an object is two rub two objects made of materials with different conductivity. The more conductive object will transfer electrons to the more conductive one, thus changing the object's total charge. The drier the climate, the more likely the charge is to transfer.

1.2.2 Charge Polarization

No charges are being transferred, but the charged particles are repelled by/attracted to one another within the object(s) themselves.

1.2.3 Charge simulator

For an example of charging by direct contact in action, check out:
https://phet.colorado.edu/en/simulation/balloons

1.2.4 Charging by induction

When we charge an object by induction, we transfer charged particles between two objects with different charge *without ever touching them together.*

1.2.5 Coulomb's Law

The force on a charge due to another charge is proportional to the product of the charge in each, divided by the square of the distance between them.

Definition

$$F \propto \frac{q_1 q_2}{r^2}$$

Where:

- F = the force on the charge
- q_1 and q_2 = the charges on objects the two objects
- r = the distance between the two objects

NOTE: don't forget that we are not setting these equal, we are stating that they are *proportional* to one another.

Practical Equation In order to apply coulomb's law as an equation, we need to use the constant k, which is columb's constant.

Coulomb's constant: = 8.987551 * 10^9 $N * m^2/C^2$ (or m/F)

$$F = \frac{kq_1 q_2}{r^2}$$

Vector form of Columb's law

$$F_{1,2} = \frac{k|q_1 q_2|}{|r_{1,2}|^3}$$

1.2.6 Superposition

If there are more than two charges present, the total force on any given charge in the group is just the vector sum of the forces created by each of the vector charges.

To find the force that two points exert on a third, the formula would be:

$$F_3 = F_{1,3} + F_{2,3}$$

2 Electric Field

2.1 Conceptual definition

According to Coulomb's Law, the reach of electric force is infinite.

In the early 1800's, **Michael Faraday** proposed the existence of an **Electric Field** which allows charges to exert force on one another, even at great distance, by **"distorting"** space. An intuitive example of how this works is how throwing a rock into a pond causes ripples.

2.2 Mathematical Definition

We quantify Electrical fields by the force they exert on the particles around them.

2.2.1 High-level equation

Our definition of electrical field "E", at location (x,y,z) would be defined as:

$$E(x,y,z) = \frac{F_{onq}}{q}$$

To calculate the force exerted on a point by an electrical field, you would use the variant:

$$F = qE$$

The SI unit used to measure electrical fields is that of the force it exerts, which is to say **Newtons**

Example Problem 1: At location x,y,z a -2 nC chg experiences a force of 5N. What is the strength of the electric field at the location?

$$E = \frac{F}{q}$$

$$E = \frac{5N}{-2nC}$$

$$E = -2.5N$$

2.2.2 Inverse Square Law (practical application equation)

$$F_p = k * \frac{q_1 q_{test}}{r^2}$$

2.3 Electric Field Lines

Rather than representing an electric field as a series of vectors, we can represent it as a series of **Electric Field Lines**.

Density of electric lines (i.e. num of field lines per unit area) is proportional to the magnitude of the Electric field it represents. In other terms:

$$E \propto \frac{Number of Field Lines}{A}$$

IMPORTANT: No two electric field lines will ever cross. Where they interact, the will *bend*, but because charged particles either attract or repel, their fields will not ever cross one another.

We can represent the cumulative electric field of several point charges as the series:

$$E_p = \sum E_{iP}$$

where E_{iP} is the electrical field generated by a given particle.

2.4 Electric Dipole

An **Electric Dipole** occurs anytime there are two opposite charges with a slight seperation between them. Dipoles are either:

- induced by an external electric field
- permanent and naturally existing (as with a water molecule)

2.4.1 Dipole moment

Given: two equal charges, Q+ and Q-, separated by distance L, we can define the **dipole moment**:

$$p = QL$$

where:

- L is a distance measured in meters
- Q is a charge, measured in Coulombs

A dipole in an electric field will have a net force of zero (because the force of the fields are equal and opposite), but it will have a **torque**, which is to say it will rotate.

The **torque** can be defined as:

$$\tau_{net} = pEsin(\theta)$$

If the electric field causes the dipole to rotate. It has done **work** on it. The work done by the electric field can be represented as:

$$dW = -\tau E\theta$$