



Electricity and Magnetism

First lecture

Electric Charge and the Structure of Matter

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Outline

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1.1 Introduction

You are surrounded by devices that depend on the physics of electromagnetism, which is the combination (مزيج) of electric and magnetic phenomena. This physics is at the root of computers, television, radio, telecommunications.

The physics of electromagnetism was first studied by the early **Greek philosophers**, who discovered that if a piece of amber is rubbed (دلك) and then brought near bits of straw (قطع القش), the straw will jump to the amber. We now know that the attraction between amber and straw is due to an **electric force**. The Greek philosophers also discovered that if a certain type of stone is brought near bits of iron, the iron will jump to the stone. We now know that the attraction between magnet and iron is due to a **magnetic force**.

From these modest origins with the Greek philosophers, the sciences of electricity and magnetism developed separately for centuries—until 1820, in fact, when **Hans Christian Oersted** found a connection between them: an electric current in a wire can deflect a magnetic compass needle.

In the mid-nineteenth century, **James Clerk Maxwell** put **Faraday's** ideas into mathematical form, introduced many new ideas of his own, and put electromagnetism on a sound theoretical basis. ووضع الكهرومغناطيسية على أساس نظري سليم

1.2 Electric Charge

After rubbing a glass rod (عمود زجاج) with a silk cloth (قطعة حرير), we hang the rod by means of a thread tied around its center (Fig. 1- a). Then we rub (ندلك) a

second glass rod with the silk cloth and bring it near the hanging rod. The hanging rod magically سحري moves away. We can see that a force repels it from the second rod, but how?

In the second demonstration العرض الثاني we replace the second rod with a plastic rod that has been rubbed with fur الفرو . This time, the hanging rod moves toward the nearby rod (Fig. 1- b). Like the repulsion تنافر, this attraction تجاذب occurs without any contact or obvious communication between the rods.

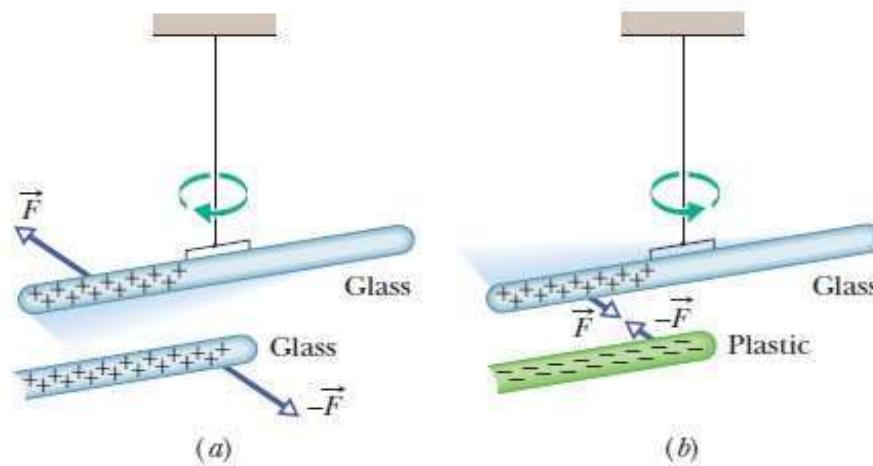


Figure. 1: (a) The two glass rods were each rubbed with a silk cloth and one was suspended by thread. When they are close to each other, they repel each other. (b) The plastic rod was rubbed with fur. When brought close to the glass rod, the rods attract each other.

In the first demonstration, the force on the hanging rod was *repulsive*, and in the second, *attractive*. After a great many investigations, scientists figured out that the forces in these types of demonstrations are due to the **electric charge** that we set up on the rods when they are in contact with silk or fur. **Electric charge is an intrinsic property خاصة جوهريّة of the fundamental particles that make up objects such as the rods, silk, and**

fur. That is, charge is a property that comes automatically with those particles wherever they exist. الشحنة هي خاصية تأتي تلقائيا مع تلك الجسيمات أينما وجدت

1.2.1 Two Types of charge: There are two types of electric charge, named by the American scientist and statesman Benjamin Franklin as positive charge and negative charge. In most everyday objects, such as a mug, there are about equal numbers of negatively charged particles and positively charged particles, and so the net charge is zero, the charge is said to be balanced, and the object is said to be electrically neutral *متعادل كهربائيا*.

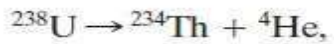
1.2.2 Excess Charge الشحنة الزائدة: Either you gain negative charge from the carpet (at the points of contact between your foot with the carpet) and become negatively charged, or you lose negative charge and become positively charged. Either way, the extra charge is said to be an *excess charge*. Such *charging* and *discharging* تفريغ does not happen in humid conditions (الظروف الرطبة) because the water in the air *neutralizes* your excess charge about as fast as you acquire it.

Note: Particles with the same signs of electrical charge repel each other, and particles with opposite signs attract each other.

1.3 Charge is Conserved

If you rub a glass rod with silk, a positive charge appears on the rod. Measurement shows that a negative charge of equal magnitude appears on the silk. This suggests that rubbing does not create charge but only transfers it from one body to another. This hypothesis of **conservation of charge**, first put forward by **Benjamin Franklin**, has stood up under close examination, both for large-scale charged bodies and for atoms, nuclei,

Important examples of the conservation of charge occur in the *radioactive decay* of nuclei. The total number in ^{238}U is 238. The number of protons in a nucleus is the *atomic number* Z .



From that list we find that in the decay the *parent* nucleus ^{238}U contains 92 protons (a charge of $+92e$), the *daughter* nucleus ^{234}Th contains 90 protons (a charge of $+90e$), and the emitted alpha particle ^4He contains 2 protons (a charge of $+2e$). We see before and after the decay; thus, charge is conserved. (The total number of protons and neutrons is also conserved: 238 before the decay and $234 + 4 = 238$ after the decay.)

1.4 Charge is Quantized

Any positive or negative charge q that can be detected can be written as:

$$q = ne, \quad n = \pm 1, \pm 2, \pm 3, \dots,$$

in which e , the **elementary charge**, has the approximate value:

$$e = 1.602 \times 10^{-19} \text{ C}.$$

The electron and proton both have a charge of magnitude e .

Quarks, the constituent particles of protons and neutrons, have charges of $\pm e/3$ or $\pm 2e/3$.

1.5 Electric Charge and the Structure of Matter

All matter is composed of **atoms**, each of which has a central **nucleus** and one or more electrons that travel in orbits around the nucleus, like satellites around the earth. The nucleus contains one or more **positively** charged particles called **protons**. The positive charge of a proton is 'opposite' to the negative charge of an electron, in the sense that the total, or net, charge of the combination is zero. Thus, an atom that has the same

number of electrons in orbit as it has protons in its nucleus is **electrically neutral**.

Summary of Subatomic Particles		
Proton	Neutron	Electron
In nucleus	In nucleus	Outside nucleus
Tightly Bound	Tightly Bound مرتبط بشدة	Weakly Bound ارتباط ضعيف
Positive Charge	No Charge	Negative Charge
Massive	Massive ضخم	Not very massive

1.6 References

Walker, Jearl, Robert Resnick, and David Halliday. Halliday and resnick fundamentals of physics. Wiley, 2014.

1-What happens when two glass rods, each rubbed with a silk cloth, are brought close to each other?

A) They attract each other. B) They repel each other. C) They remain stationary D) They rotate
E) They stick together

2-when a plastic rod rubbed with fur is brought close to a glass rod, what is the nature of the force between them?

A) Repulsive force B) Attractive force C) No force observed D) Rotational force E) Sticky force

3- Who first proposed the hypothesis of conservation of charge mentioned in the passage?

A) Isaac Newton B) Albert Einstein C) Benjamin Franklin D) Marie Curie E) Nikola Tesla