

Midterm Friday

- When you enter, place your bags at the front of the room. Turn off cellphone.
- Leave an empty seat between you and your neighbour(s) if possible.

- Bring with you
 - The “standard” calculator
 - Pencils and pens
 - Ruler and protractor for ray tracing
 - Your student photo-ID
- No leaving the room in the last 5 minutes.
- TAs will collect the tests at the ends of the rows rather than manage a stampede to the front.

Midterm Friday

- Do not enter until we let you know.
- Enter you name and student number on the exam and the bubble sheet. Fill in the “Special Code” of your exam on the bubble sheet. Be sure to fill in the bubbles too.

NAME (Last, First, M.I.)
NEIL ALBERDING

STUDENT NUMBER
2456789

SECTION
1111


SPECIAL CODE
1111

Important!

Electricity and Magnetism

- Time for a major change of topic!!
- We are done with waves and optics. The rest of this course is about electricity and magnetism.
- We will start with chapter 26 and plough straight ahead through about 10 chapters.


Electricity and Magnetism



	Gravity	Weak (Electroweak)	Electromagnetic	Strong
Carried By	Graviton (not yet observed)	$W^+ W^- Z^0$	Photon	Gluon
Acts on	All	Quarks and Leptons	Quarks and Charged Leptons and $W^+ W^-$	Quarks and Gluons

- You are most aware of gravity and EM forces in your everyday life because they are infinite range.
- EM interactions are solely responsible for the structure of matter. Much of physics, all of chemistry and most of biology deals with EM interactions. EM interactions allow life to exist.

Electricity and Magnetism



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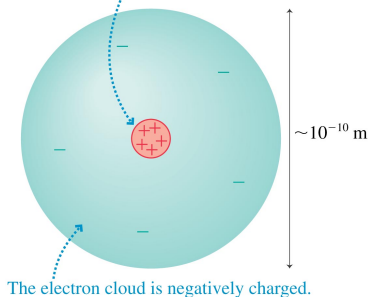
- We live in a technological world driven by EM devices. From the power plant to your toaster...it is inescapable.
- Furthermore, all that “light” stuff we have been doing has been about EM waves....but we never defined EM....

Electricity and Magnetism

- You have certainly heard of both electricity and magnetism before.
- People have known about electric phenomena or magnetic phenomena for thousands of years. Unifying these two is one of the great all-time achievements in physics.
- It was the beauty of EM theory which inspired Einstein to write down special relativity. One postulate plus “EM theory is correct” is all he needed.
- We will start with the electric part and get to magnetism a little later.
- In the end you should get a clear picture of how electricity and magnetism are linked and how to apply EM theory to the world around you.

Electric Charge (26.1 and 26.2)

The nucleus, exaggerated for clarity, contains positive protons.



The electron cloud is negatively charged.

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- You are already quite familiar with charges and with the idea that two types of charges exist: positive and negative.
- You also know that atoms are built of arrangements of positive and negative charges: protons and electrons.
- Charge is a fundamental property of a particle....like mass. It is not possible to have a chargeless electron.
- If we want to understand electric forces we have to start with the concept of a **charge**. (in a way, it defines the force - it is the strength of the interaction).

Electric Charge

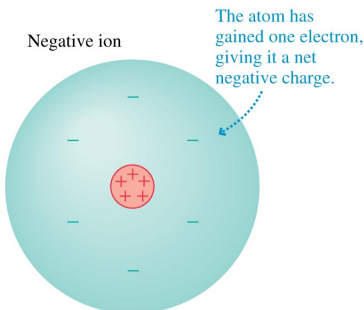
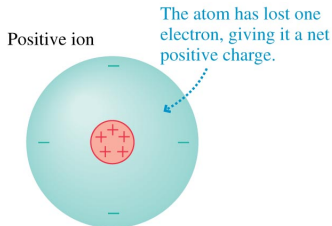
- Charge is quantized. The electron and the proton have exactly equal charges with opposite charges:

$$e \approx 1.60 \times 10^{-19} \text{ C}$$

where C is the SI unit of charge - coulomb.

- $1 \text{ C} \approx 6.25 \times 10^{18}$ elementary charges.
- A bolt of lightning is about 5C.
- Other charges are multiples of e .
- Like charges repel, opposites attract. This we learn from experiment.
- For the most part, objects have the same number of positive and negative charges and so are **neutral**. Please note that neutral does not mean that there are no charges...just that there are **equal numbers of positive and negative charges**.
- Charge may be transferred from one object to another. This transfer is via electrons, not protons (which are too tightly bound).
- **Charge is conserved.**

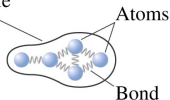
Ionization



- While matter is generally neutral, it can gain a **net charge**. An atom can become an **ion**.

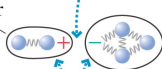
Ionization

Electrically
neutral molecule



These bonds were
broken by friction.

Positive
molecular
ion



Negative
molecular
ion



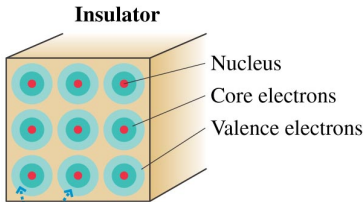
This half of the
molecule lost an
electron as the
bond broke.

This half of the
molecule gained an
extra electron as the
bond broke.

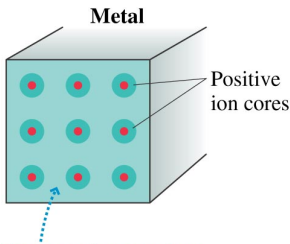
- Charging by friction (e.g., rub a balloon on your head) results in molecular ions.
- One surface ends-up with the negative molecular ion while the other ends up with the positive molecular ion.

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Insulators and Conductors (26.3)

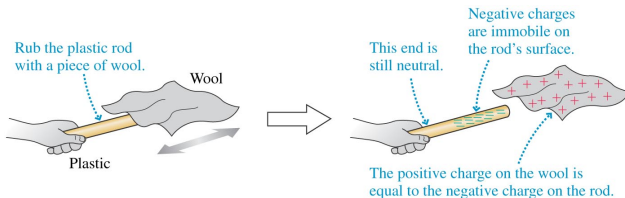


Valence electrons
are tightly bound.



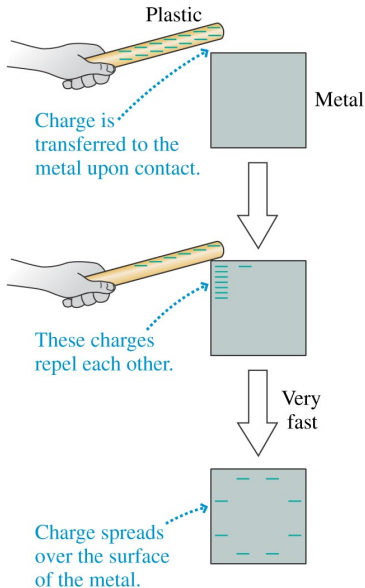
- Electrons in an **insulator** are tightly bound and do not free to migrate.
- In **conductors** the outer atomic (valence) electrons are weakly bound and can flow.
- These properties are really about the flow of charges, not the net charge on the material.
- The charge carriers are the electrons and their motion is called a **current**.

Charging an Insulator



- Insulators can be charged by rubbing, but that charge does not move around.

Charging a Conductor



- Conductors cannot usually be charged by rubbing.
- New electrons entering the conductor push the electron sea in the conductor.
- Once the charges adjust **electrostatic equilibrium** is reached and there is no net force on any charge.
- In an isolated conductor, any excess charge is located on the surface.