Today

• Announcements:
  – HW#6 is due by 8:00 am Wednesday February 27th.
• Electric Fields
• Electric Circuits
• Light and the Electromagnetic Spectrum

Example of Electric Field Map for two charges

Charge creates a field.
The field points form + to – charge.

A visual picture – Electric Potential

Positive charge makes a hill
Steep slope means a larger force.

Negative charge makes a valley.

Gravitational (or electric) Potential/Field

The force is related to the rate of change of potential.
Map for the Electric Field – Electric Potential

The slope gives a measure of the electric field.

The height is electric potential, $V$, measured in volts.

Another example- 4 charges

+ charge gives positive potential ($V$)

- charge gives negative potential ($V$)

Example

Electric fields and potential

- In equilibrium the electric field in a metal conductor (electrons to move) is zero.
- This means that inside a metal the electric potential is flat, like the flat top of a table.
- Sitting inside a metal cage is like sitting on top of a large, flat table. As long as you are in the center, there is no danger of falling off.
- This is why being in a car during a thunder storm is relatively safe.
The Strength of the Electric Field

- Electric potential – SI unit is the Volt (V)
- Electric field is rate of change of potential

\[ E = -\frac{\Delta V}{\Delta x} \]

- The minus sign means that electric fields point from + to – charge.

Sample Problem

What is the magnitude of the electric field at:
- 0.5 m?
- 1.5 m?
- 3.0 m?

The field is 0 V/m at 0.5 m and 3.0 m since the slope is zero.

\[ |E(1.5m)| = \frac{\Delta V}{\Delta x} = \frac{(100V - 0V)}{(2m - 1m)} = \frac{100V}{m} \]

Electric Field Example

Q = -0.5 μC = -0.5x10⁻⁶ C

What is the magnitude of the electric force on Q?

\[ F = qE \]
\[ F = 0.5E-6C \times 40 \text{ N/C} = 20 \text{ N} \]

Not asked for, but the direction is +, to the right.

Flow of Charge - Current

- Current is the rate of flow of charge. SI units is Ampere = 1 Coulomb/second
- Batteries are like pumps that lift charge to a higher potential. The charge flows down the hill to the other side of the battery.
Types of materials

- **Conductor** – electrons in the conduction band; electrons relatively free to flow (copper, aluminum, gold, silver)
- **Insulator** – no electrons in the conduction band; electrons cannot flow (wood, most rubber, most glass, most plastic)
- **Semiconductor** – at finite temperature, some electrons are in the conduction band (used in most electronics; silicon, germanium)
- **Superconductor** – at very low temperature electrons pair and can move freely without resistance (Niobium, Titanium, Lead)
Superconductor

No resistance to flow (also no use of energy)

Where are we?

We have talked about two forces in nature
• Gravity – General Relativity (Space and time are tied into a 4 dimensional space-time. Gravity is the result of the curvature of space due to mass.)
• Electromagnetism – Electric and magnetic forces are the result of charge and the motion of charge.

Are the gravity and electricity related?

Gravity and Electric Forces

Newton’s Universal Law of Gravity:

\[ F = \frac{Gm_1m_2}{r^2}; \quad G = 6.673 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \]

Coulomb’s Law (Electric Force)

\[ F = \frac{kq_1q_2}{r^2}; \quad k = 8.99 \times 10^9 \text{Nm}^2/C^2 \]

The Electromagnetic Spectrum

• The modern picture of electromagnetism is that the electric force is carried by the photon.
• A photon is a small bundle of energy. We see photons in the range of 1.8 eV (red) to 3.1 eV (violet) [1 eV = 1.6E-19 J]
• The full range of different photon energies is called the electromagnetic spectrum.
The Electromagnetic Spectrum

Speed = \lambda \cdot f
\lambda = \text{wavelength}
f = \text{Frequency, Hz}
(1/\text{period})(1/s)

For light
Speed c = 3.0E+8 m/s

Energy = h \cdot f
h = 6.625E-34 Js
= 4.136E-15 eVs

Wavelength and Frequency

\lambda = 1.0 \text{ m}
period = 2.0 \text{ s}

\text{Distance over which the wave repeats}
\frac{1}{\text{Number of cycles (repeats) per second}}

Around Visible Electromagnetic Spectrum

Why is there always r^2? I hate r^2.

Inverse square law

intensity = \frac{L[\text{Watts}]}{4\pi d^2}

L is the luminosity (measured in watts), d is the distance to the source.

This explains why the electric force has the form it does. The strength of the force is related to the probability of being hit by a photon. That decreases as the square of the distance.