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Today

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

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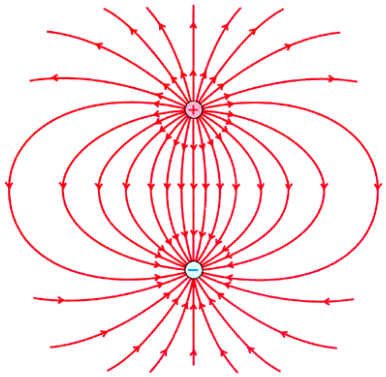
Example of Electric Field Map for two charges



(a)

Charge creates a field.

The field points form + to – charge.

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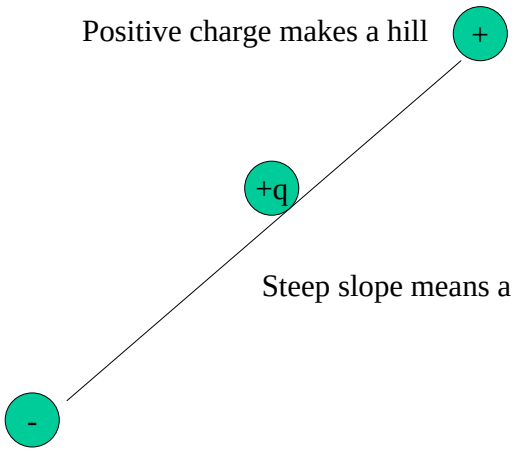
A visual picture – Electric Potential

Positive charge makes a hill



Steep slope means a larger force.

Negative charge makes a valley.

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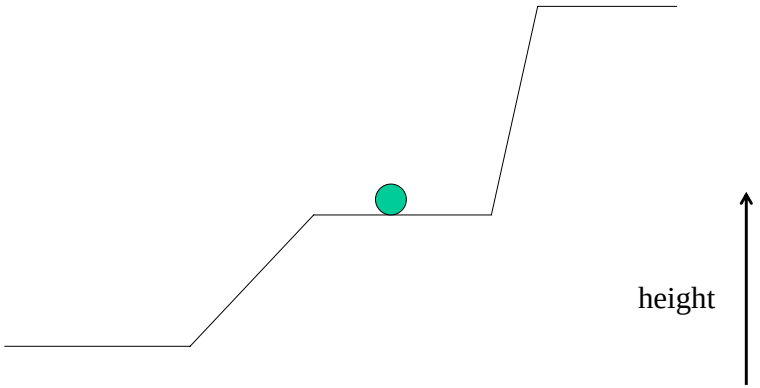
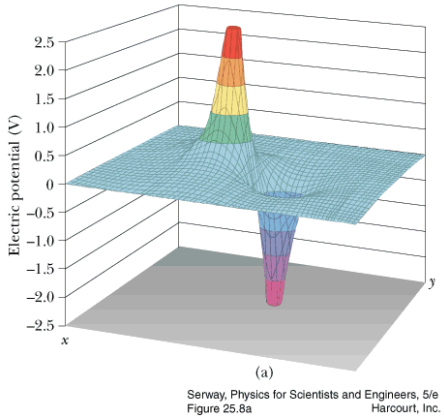
Gravitational (or electric) Potential/Field



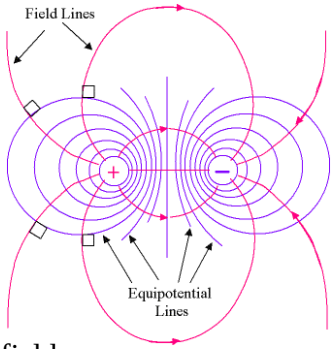
The force is related to the rate of change of potential.

Map for the Electric Field – Electric Potential



Serway, Physics for Scientists and Engineers, 5/e
Figure 25.8a Harcourt, Inc.

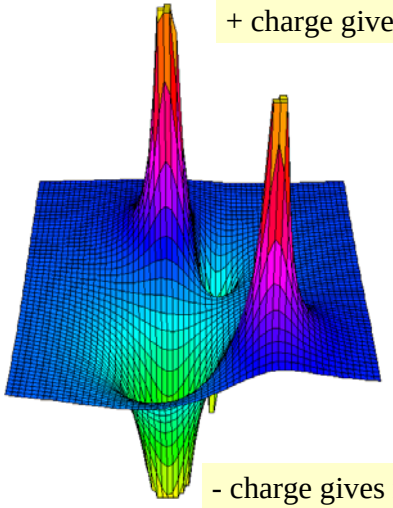
The height is electric potential, V, measured in volts

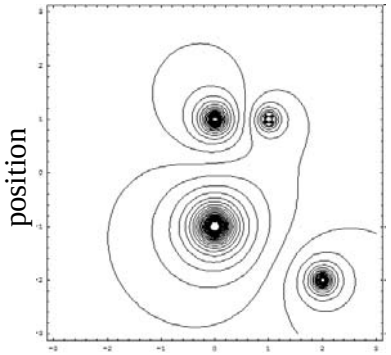


The slope gives a measure of the electric field.

Another example- 4 charges

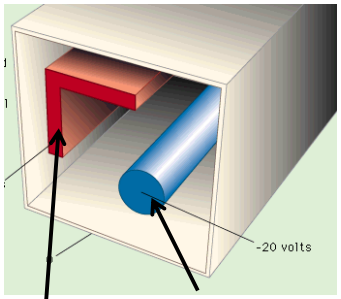
+ charge gives positive potential (V)



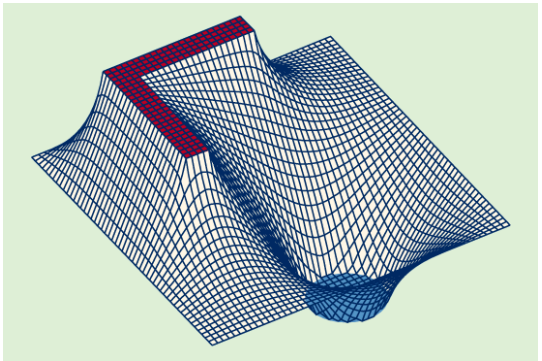


- charge gives negative potential (V)

Example



+20 V -20 V



The electric potential is the same everywhere on a conductor.

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.

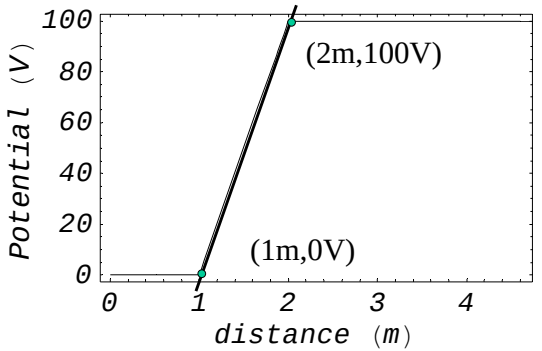
The Strength of the Electric Field

- 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



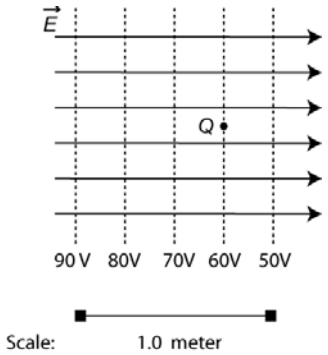
What is the magnitude of the electric field at:
- 0.5 m?
- 1.5 m?
- 3.0 m?

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

$$|E(\text{at } 1.5\text{m})| = \frac{\Delta V}{\Delta x} = \frac{(100V - 0V)}{(2m - 1m)} = 100\frac{V}{m}$$

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 x 40 N/C = 20 N
Not asked for, but the direction is +, to the right.

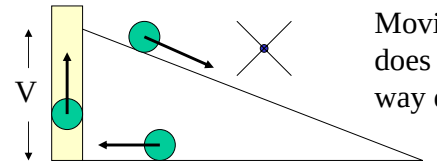
Electric Field

E = -ΔV/Δx =-(50V-90V)/1m= 40 V/m
+ means to the right in this case

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.

A battery is like a pump.



Moving Charge does work on the way down

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Types of materials

- **Conductor** – electrons in the conduction band; electrons relatively free to flow (copper, aluminum, gold, silver)
- **Insulator** – no electrons is the conduction band; electrons can not 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)

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Conductor

Electrons hit bumps, but are free to roll.

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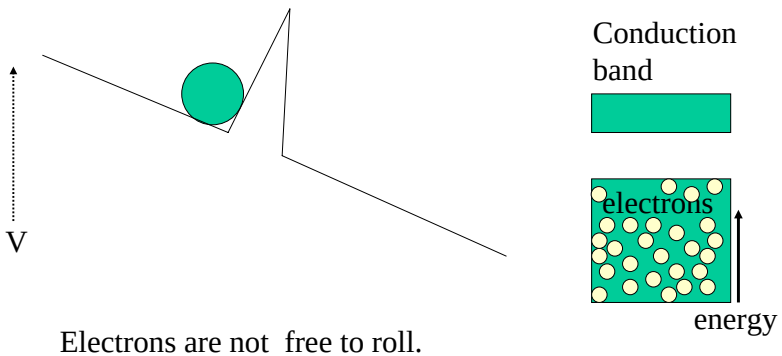
Insulator



Electrons are not free to roll.

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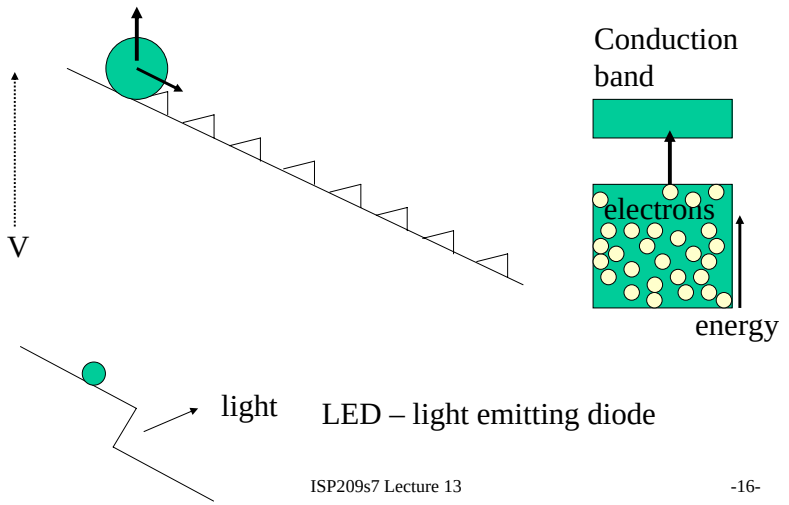
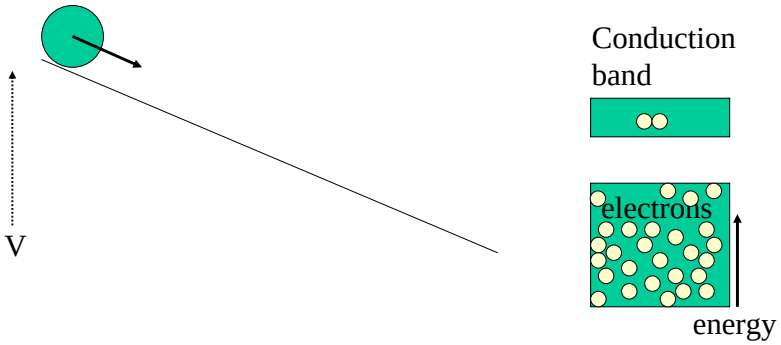
Semiconductor



LED – light emitting diode

Superconductor



No resistance to flow (also no use of energy)

Where are we?

We have talked about two forces in nature

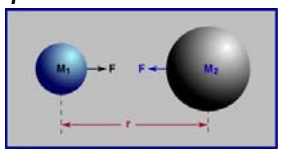
- Gravity – General Relativity (Space and time are tied into a 4 dimensional space-time. Gravity is the result of the curvature of space due to mass.)
- Electromagnetism – Electric and magnetic forces are the result of charge and the motion of charge.

Are the gravity and electricity related?

Gravity and Electric Forces

Newton's Universal Law of Gravity:

$$F = \frac{Gm_1m_2}{r^2}; G = 6.673E-11 \, {Nm^2}/{kg^2}$$



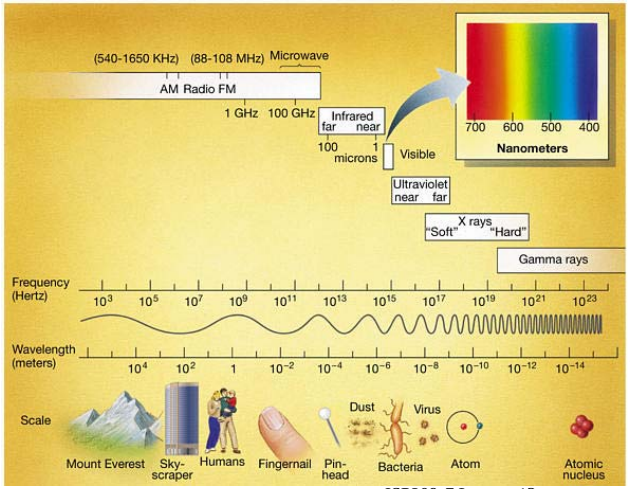
Coulomb's Law (Electric Force)

$$F = \frac{kq_1q_2}{r^2}; k = 8.99E+9 \, {Nm^2}/{C^2}$$

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



Prentice-Hall 2005

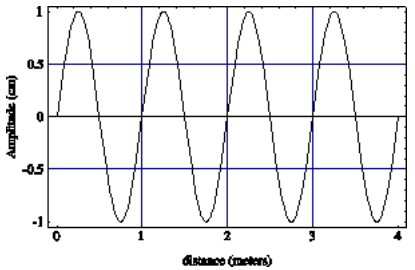
Speed = λ f
λ – wavelength
f – Frequency, Hz
(1/period)(1/s)

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

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

Wavelength and Frequency

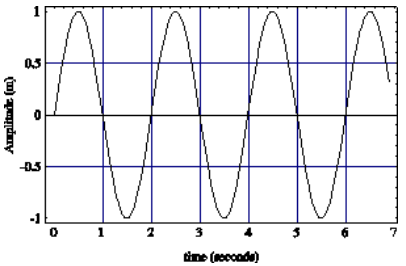
λ = 1.0 m



Wavelength

Distance over which the wave repeats

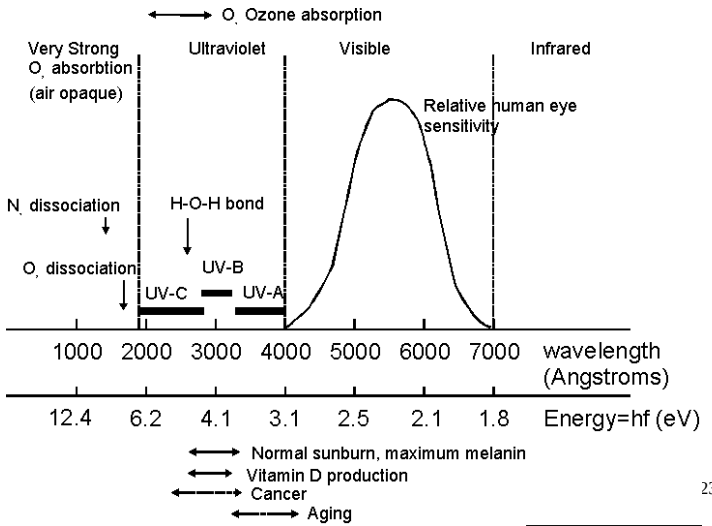
period = 2.0 s



Frequency = 1/period

Number of cycles (repeats) per second.

Around Visible Electromagnetic Spectrum

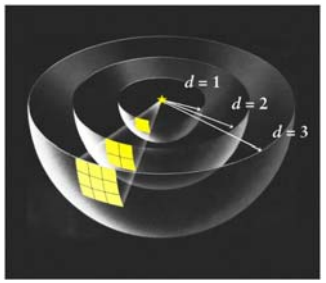


Why is there always r^2? I hate r^2.

Inverse square law

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

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.