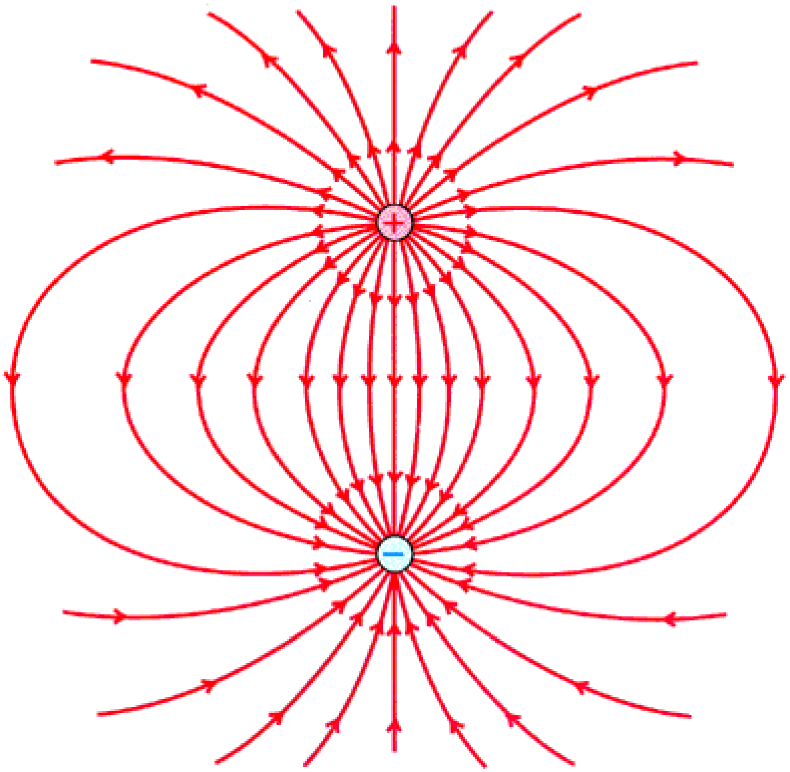
Today

- 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



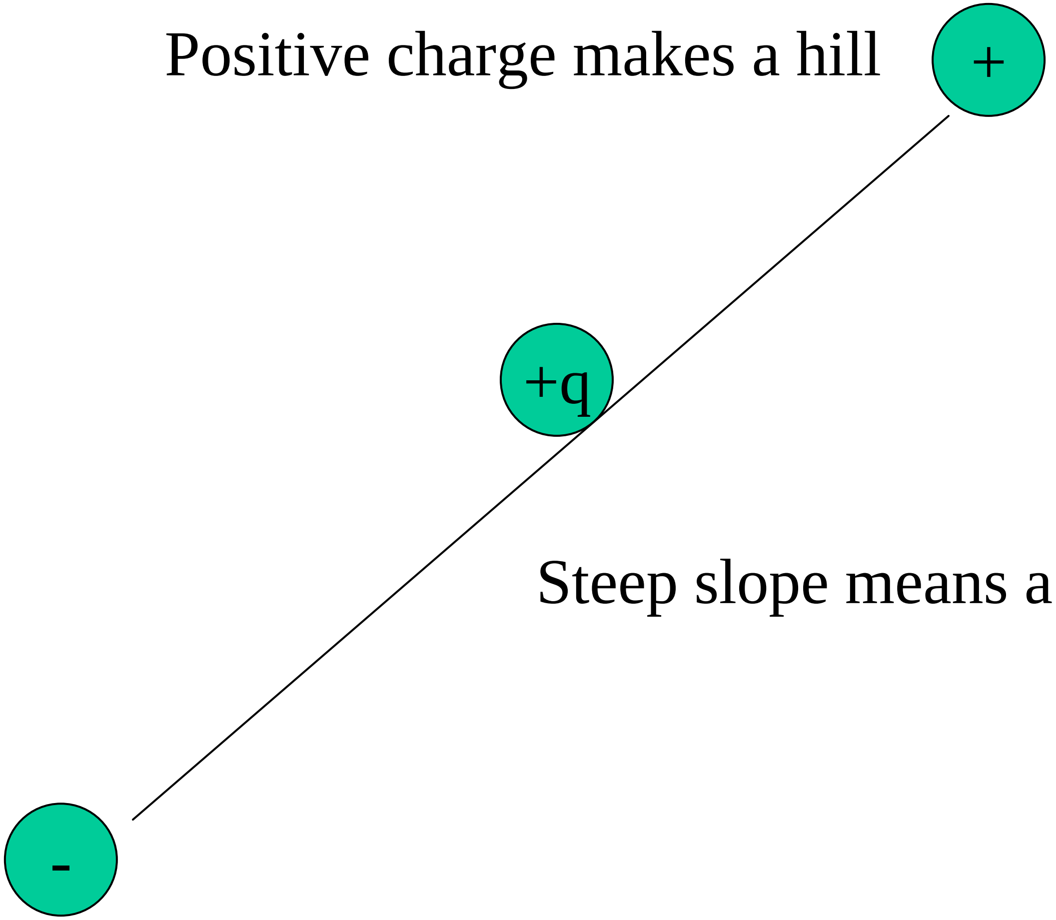
(a)

Charge creates a field.

The field points form
+ to – charge.

A visual picture – Electric Potential

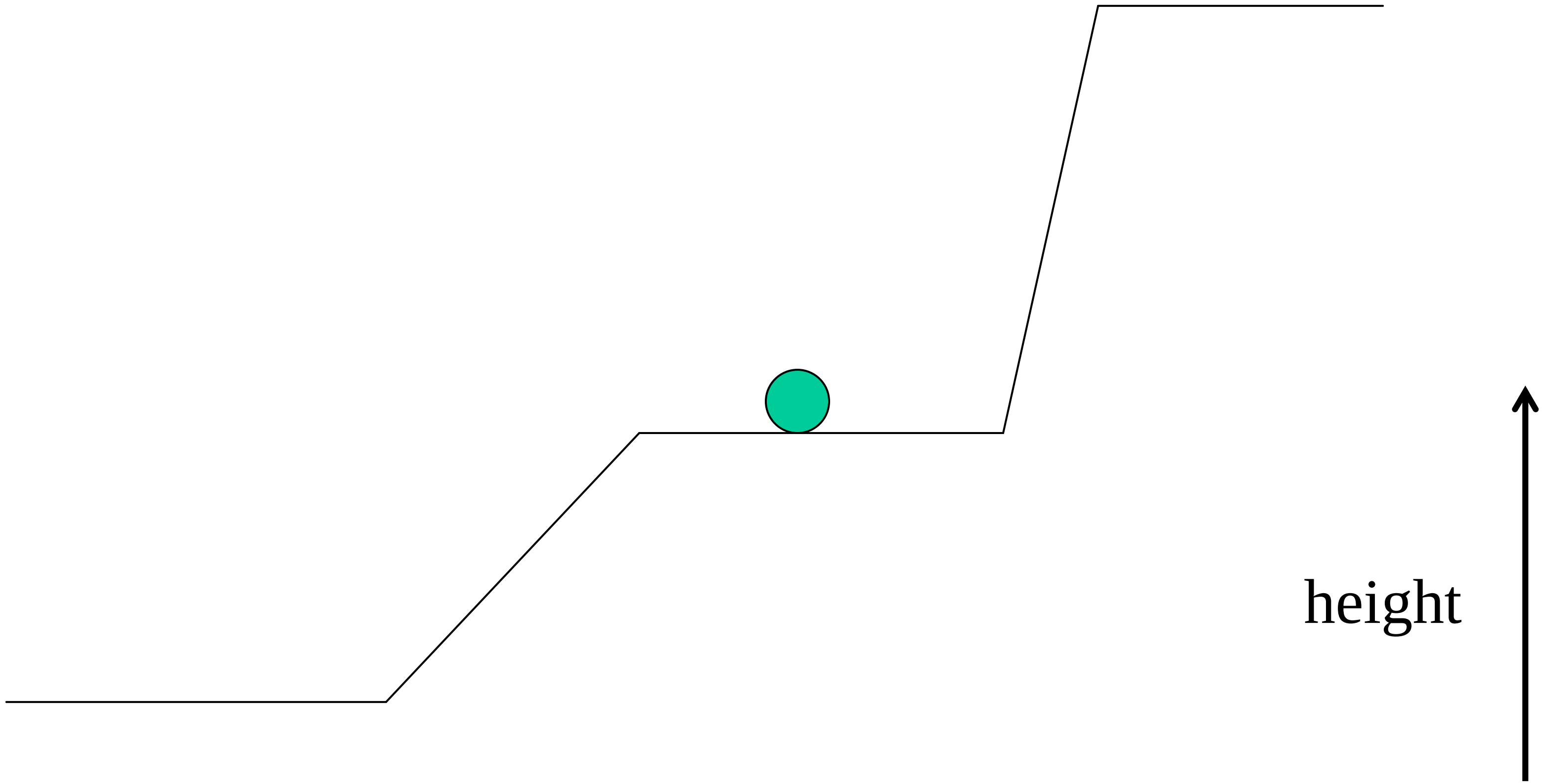
Positive charge makes a hill



Steep slope means a larger force.

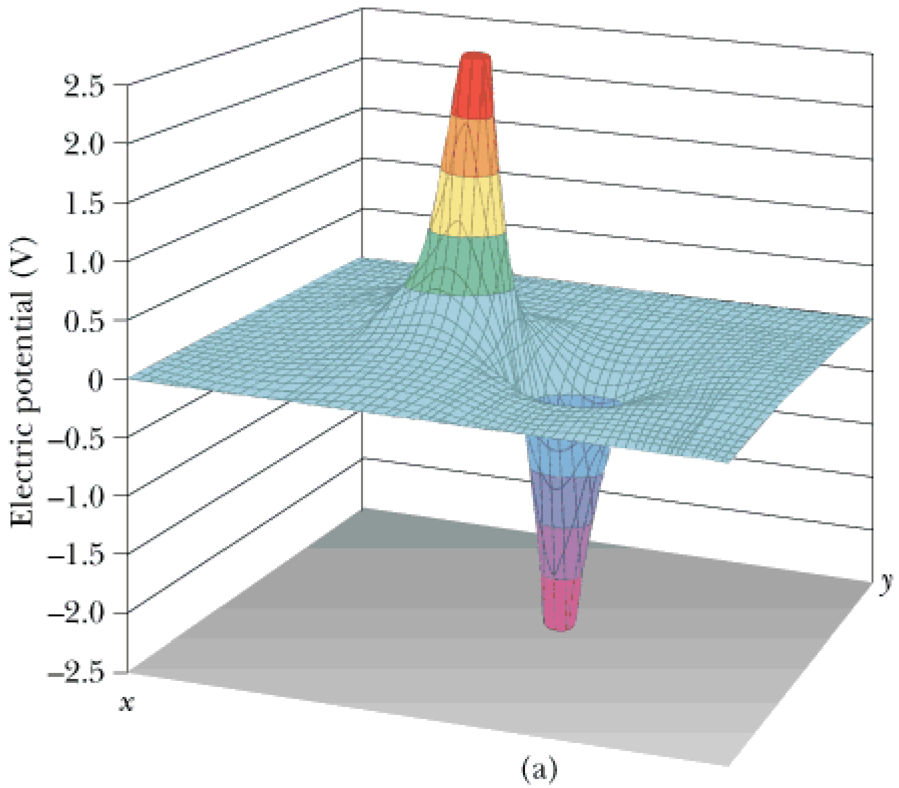
Negative charge makes a valley.

Gravitational (or electric) Potential/Field



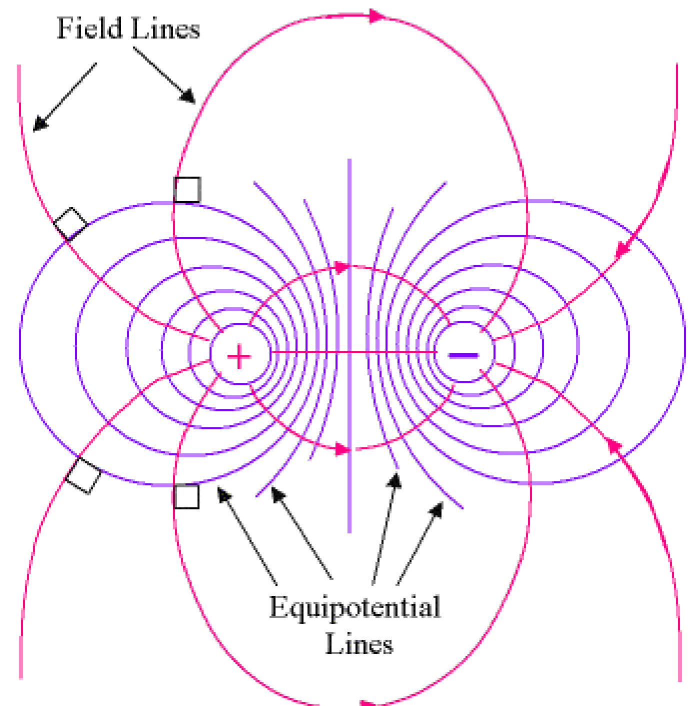
The force is related to the rate of change of potential.

Map for the Electric Field – Electric Potential



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

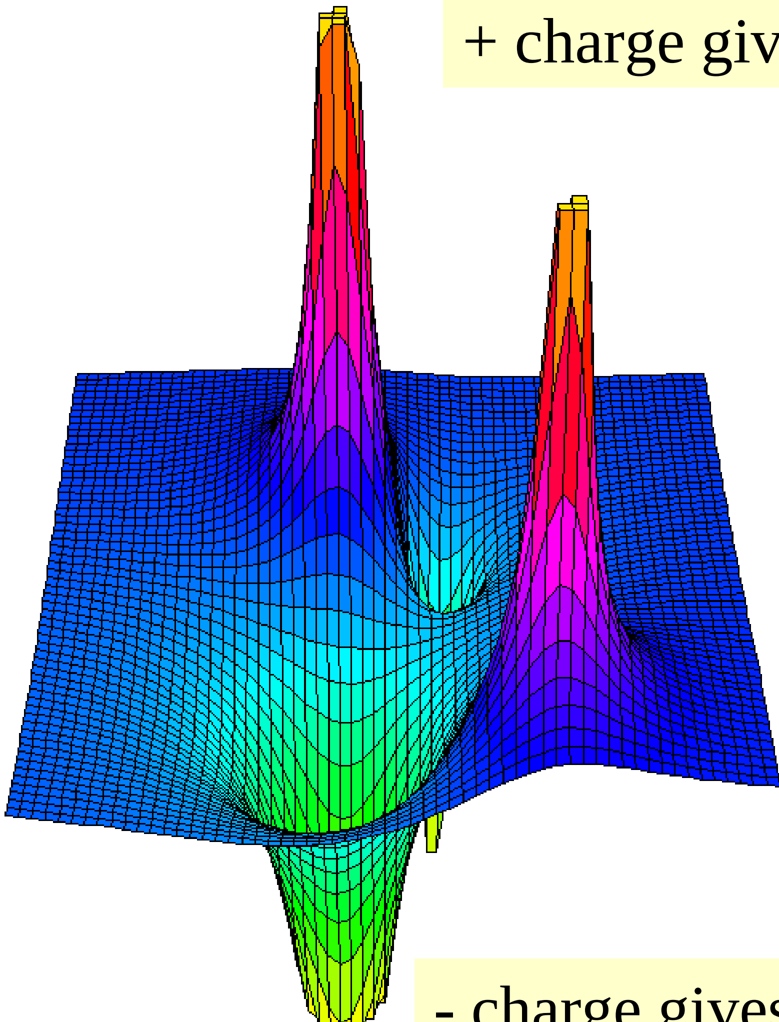
The height is electric potential, V, measured in volts

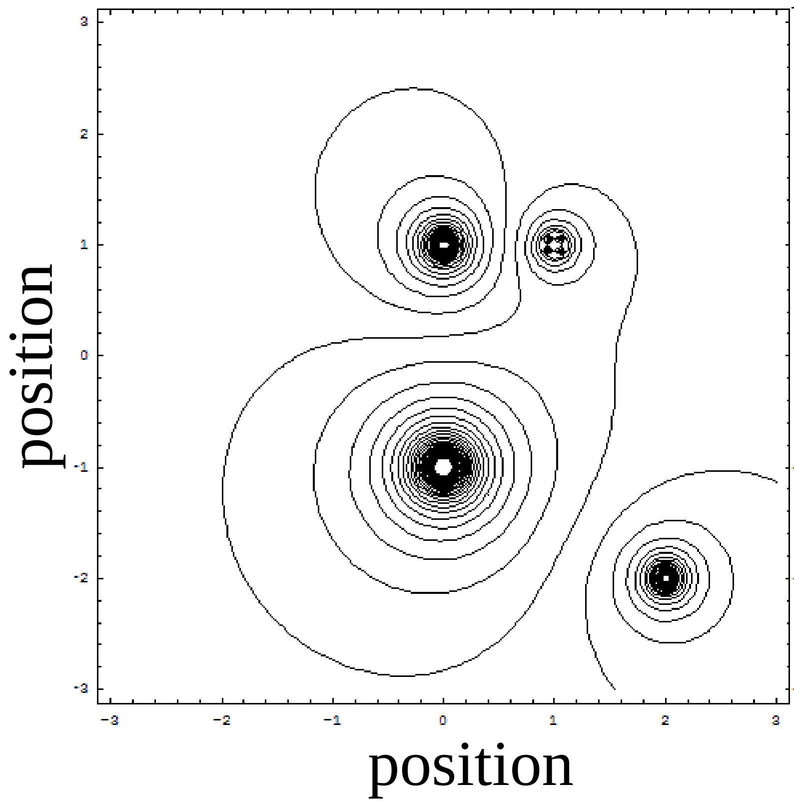


The slope gives a measure of the electric field.

Another example- 4 charges

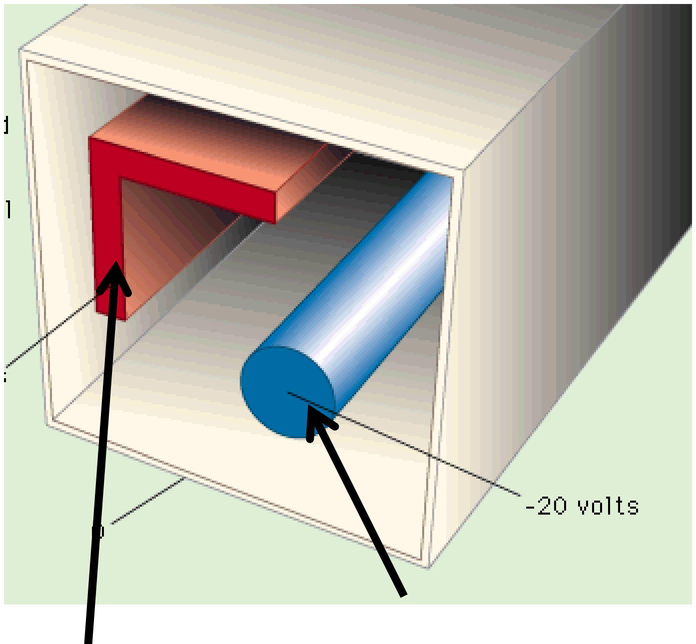
+ charge gives positive potential (V)





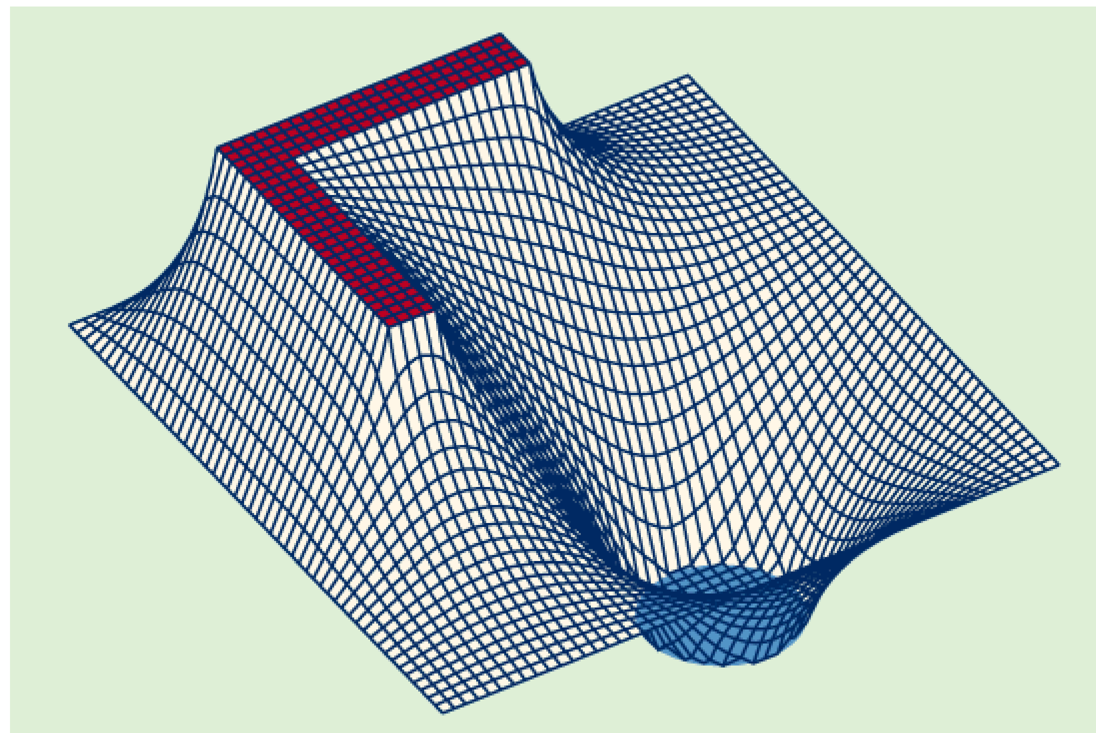
- charge gives negative potential (V)

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.

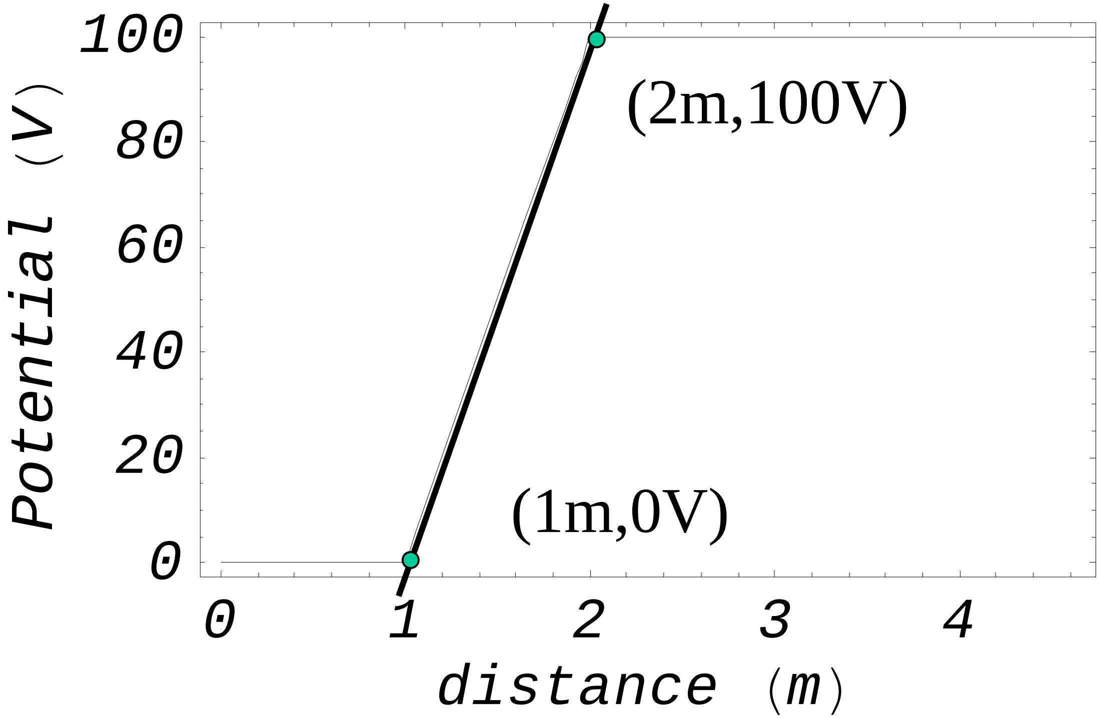
The Strength of the Electric Field

- 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:

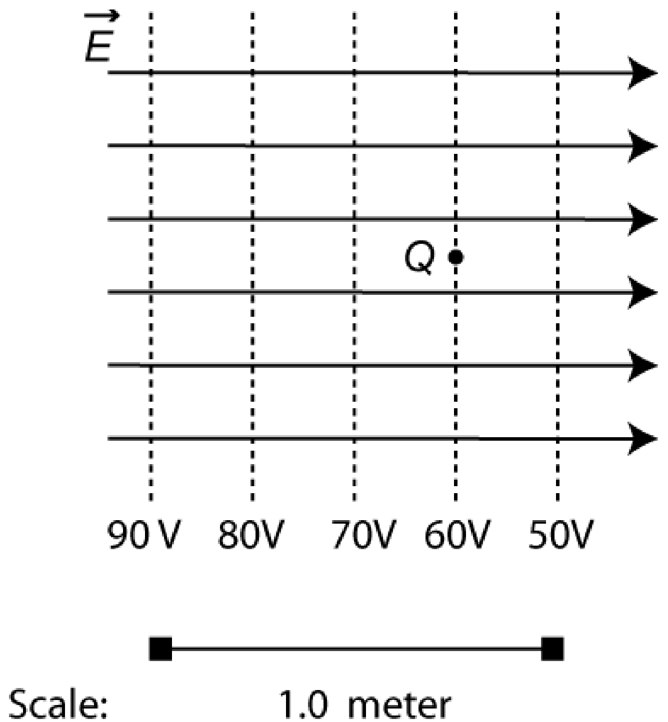
- 0.5 m?
- 1.5 m?
- 3.0 m?

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

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

Electric Field Example

$Q = -0.5\ \mu C = -0.5 \times 10^{-6}$ 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.

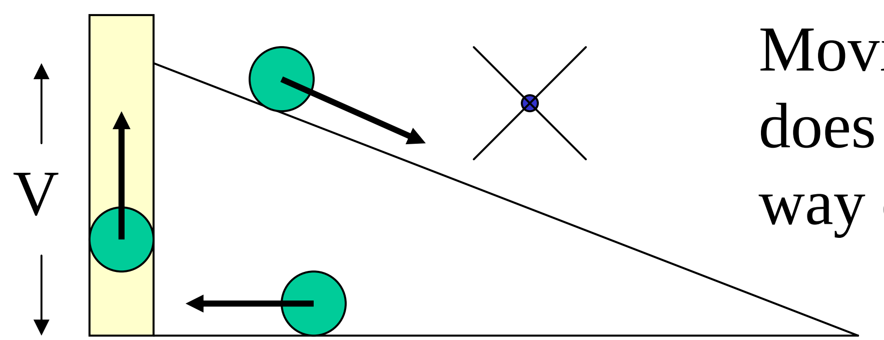
Electric Field

$E = -\Delta V/\Delta x = -(50V-90V)/1m = 40$ 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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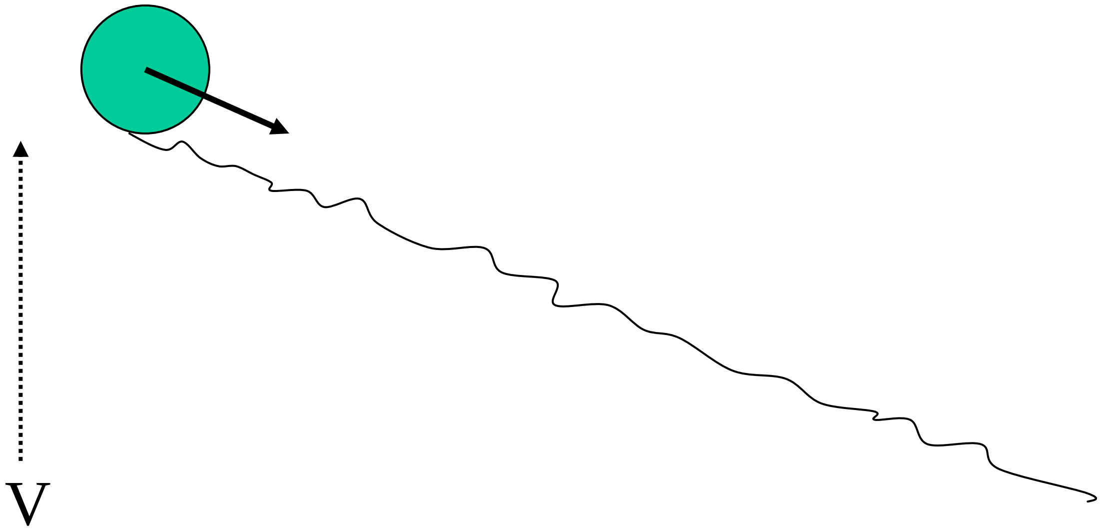
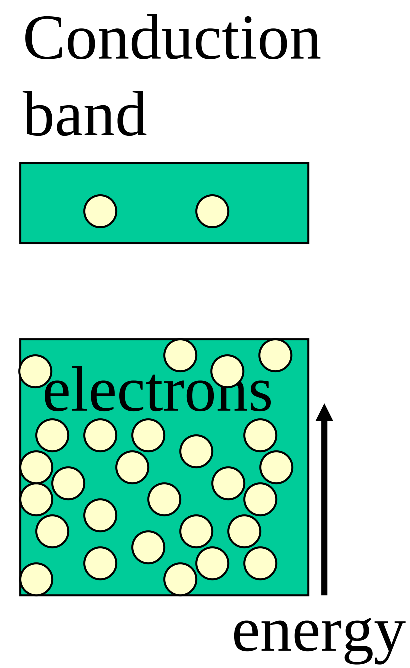
Types of materials

- **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)

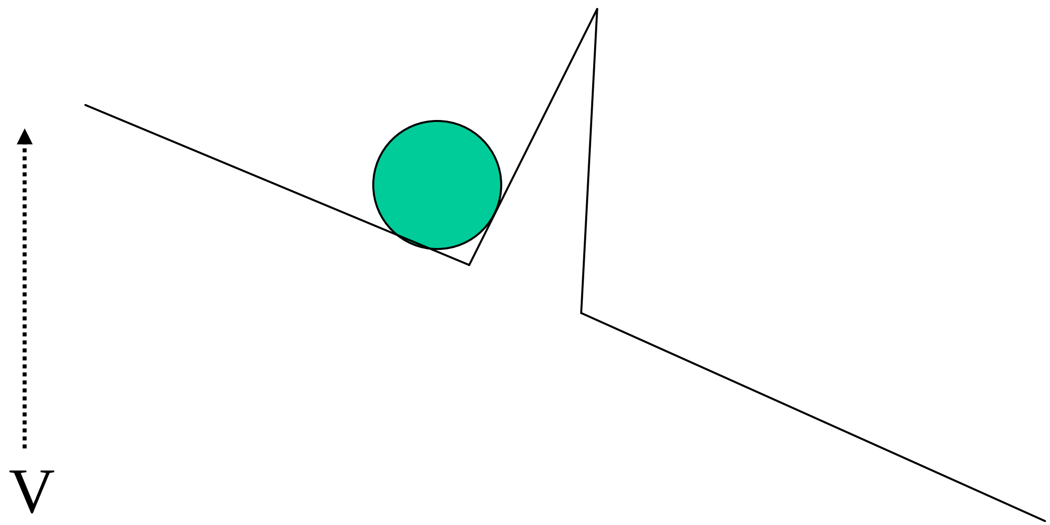
Conductor

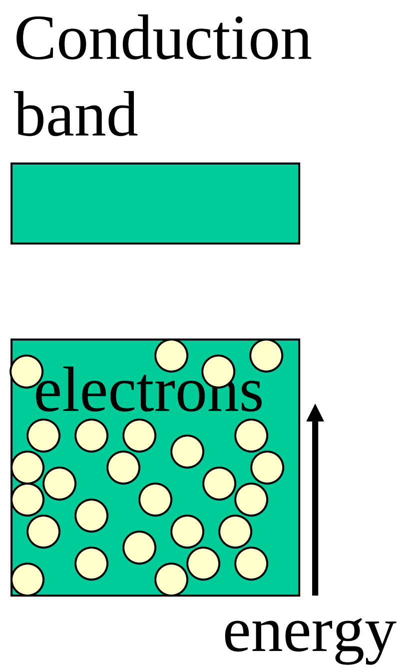




Electrons hit bumps, but are free to roll.

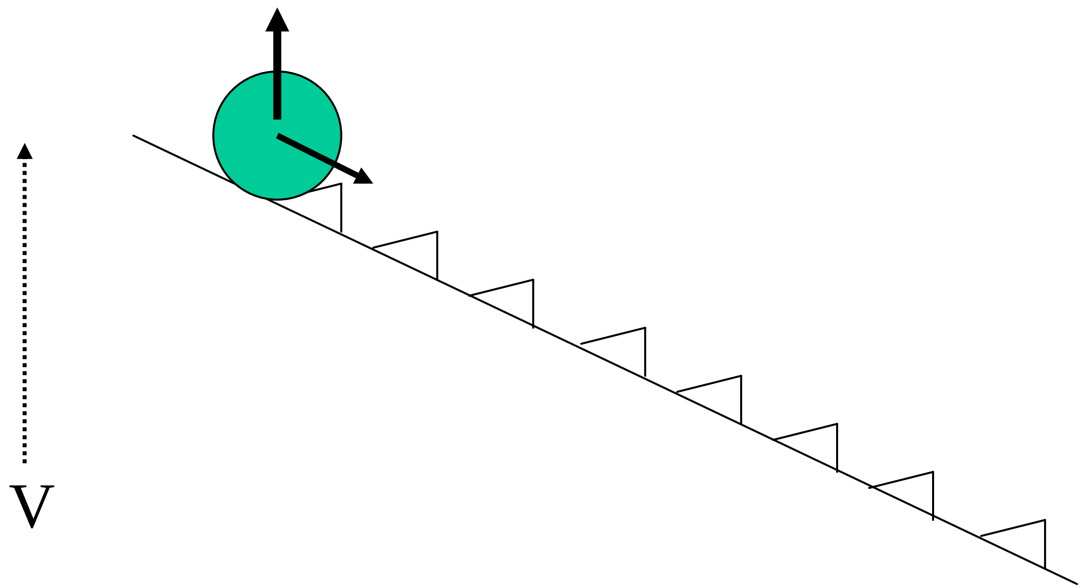
Insulator

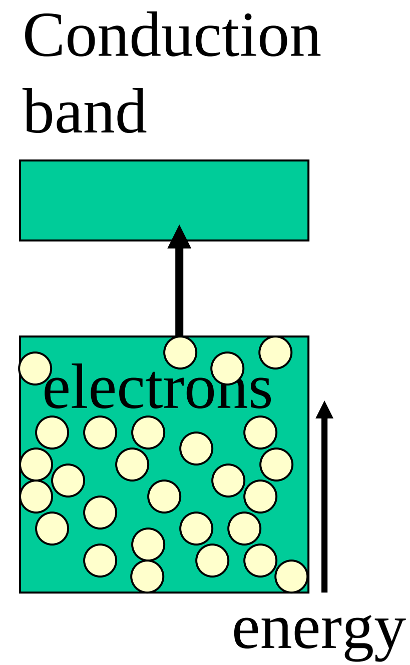


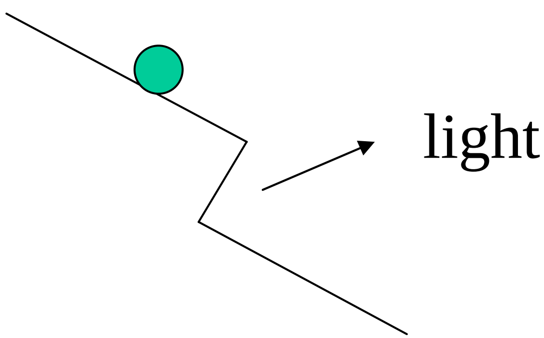


Electrons are not free to roll.

Semiconductor

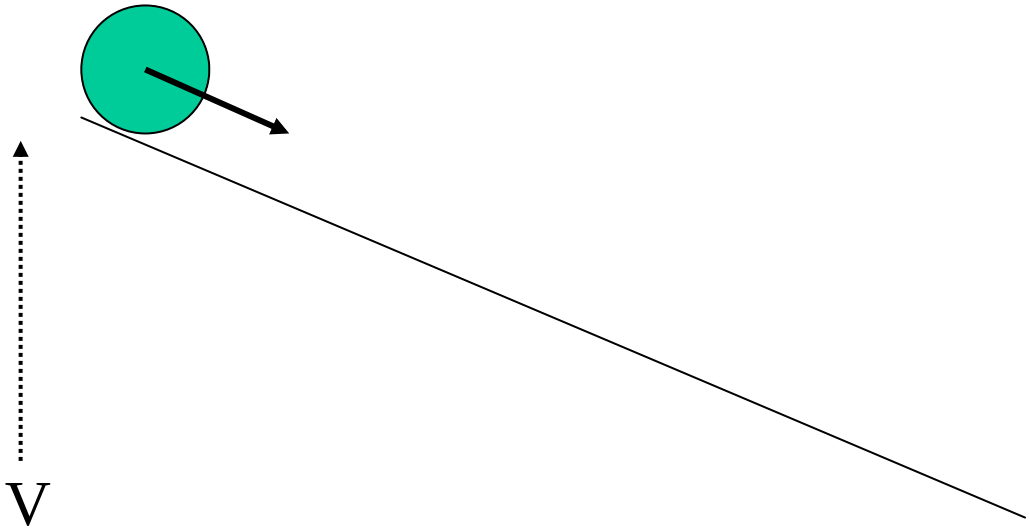


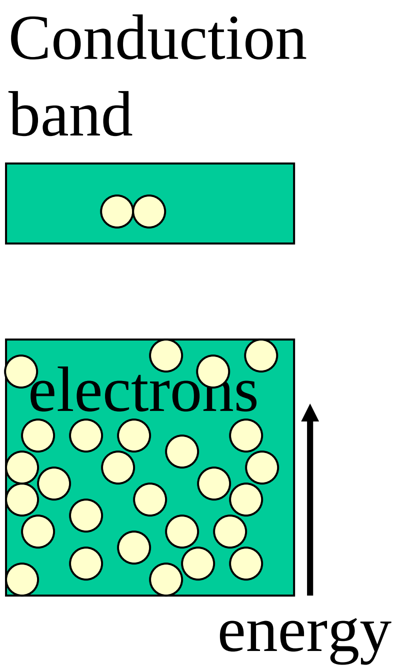




LED – light emitting diode

Superconductor





No resistance to flow (also no use of energy)

Where are we?

We have talked about two forces in nature

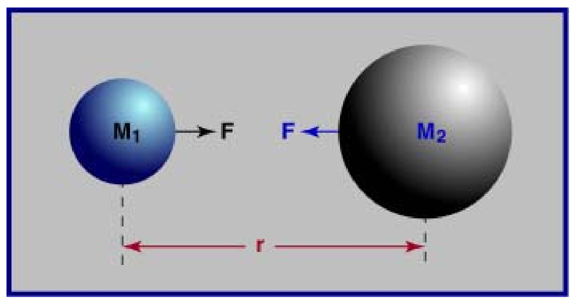
- Gravity – General Relativity (Space and time are tied into a 4 dimensional space-time. Gravity is the result of the curvature of space due to mass.)
- Electromagnetism – Electric and magnetic forces are the result of charge and the motion of charge.

Are the gravity and electricity related?

Gravity and Electric Forces

Newton's Universal Law of Gravity:

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



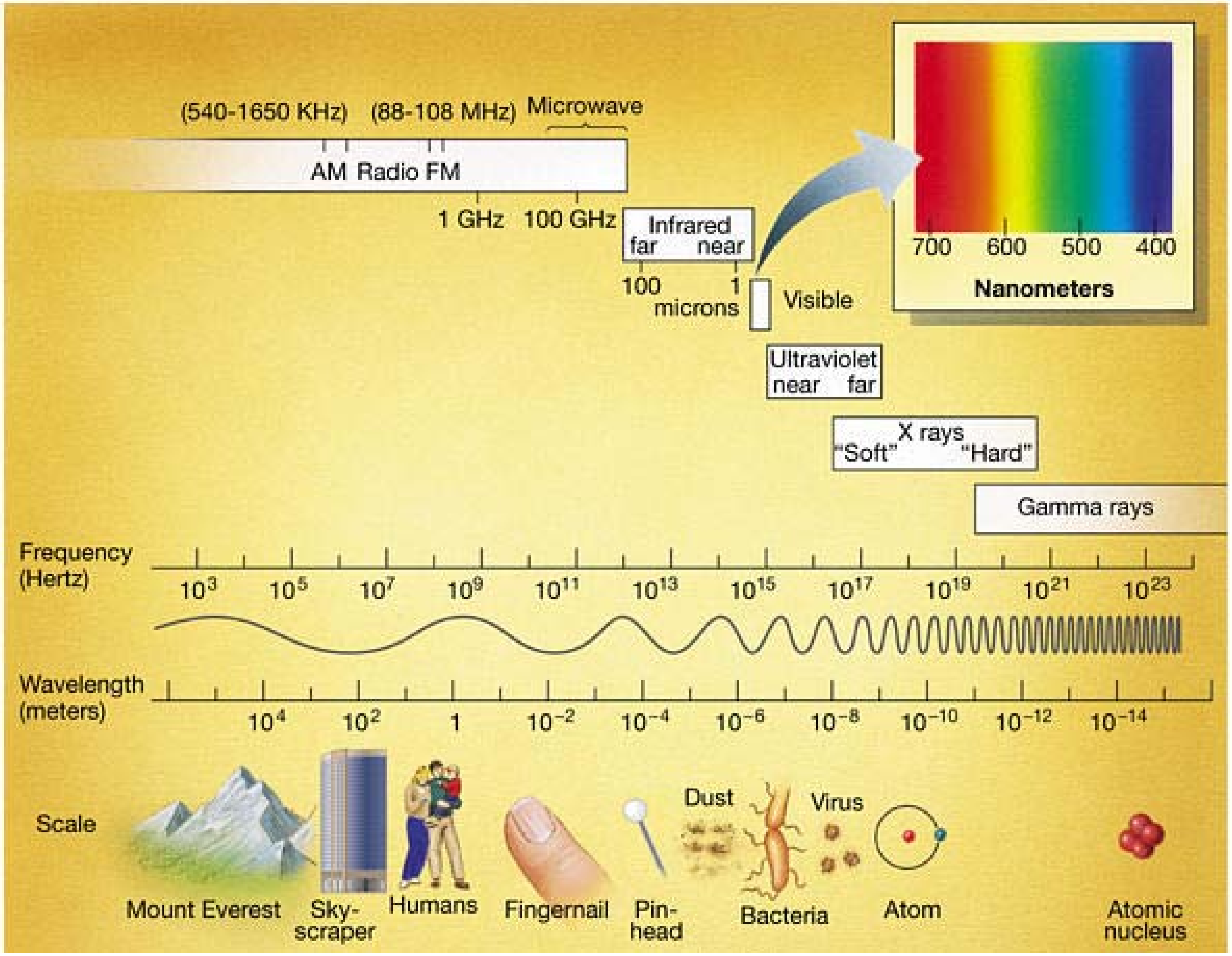
Coulomb's Law (Electric Force)

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

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



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

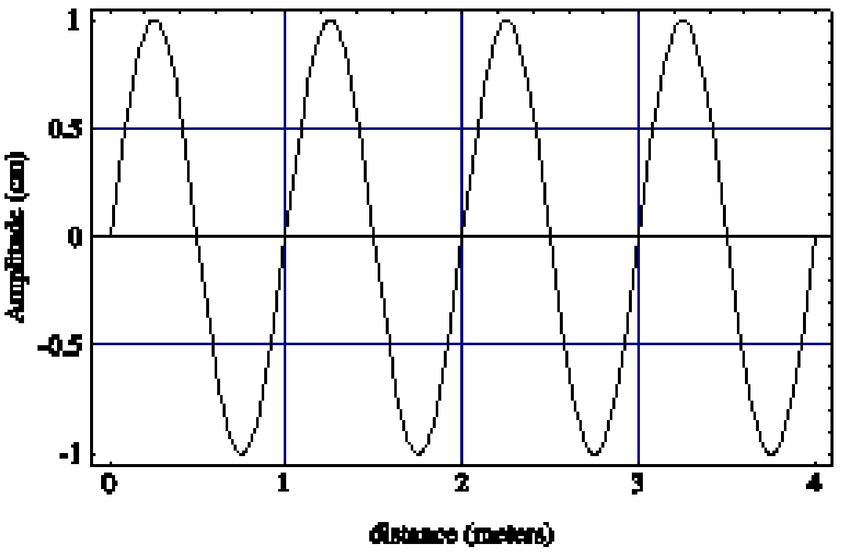
For light
Speed c = 3.0E+8m/s

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

Prentice-Hall 2005

Wavelength and Frequency

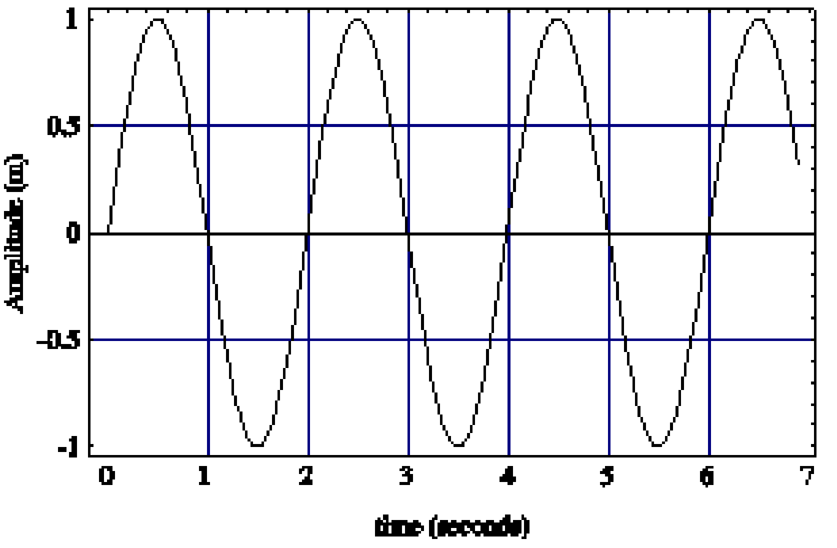
$\lambda = 1.0$ m



Wavelength

Distance over which the wave repeats

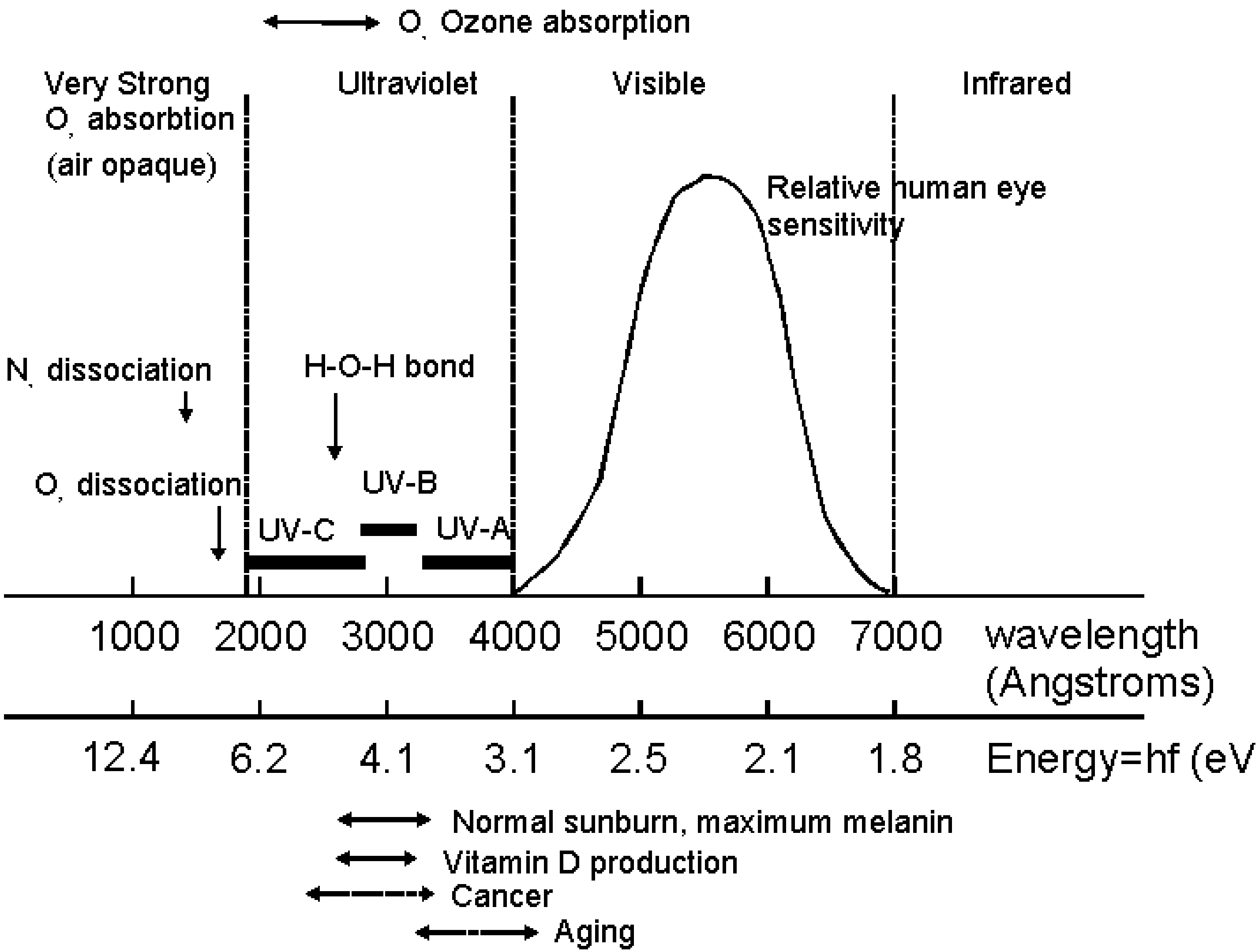
period = 2.0 s



Frequency = 1/period

Number of cycles (repeats) per second.

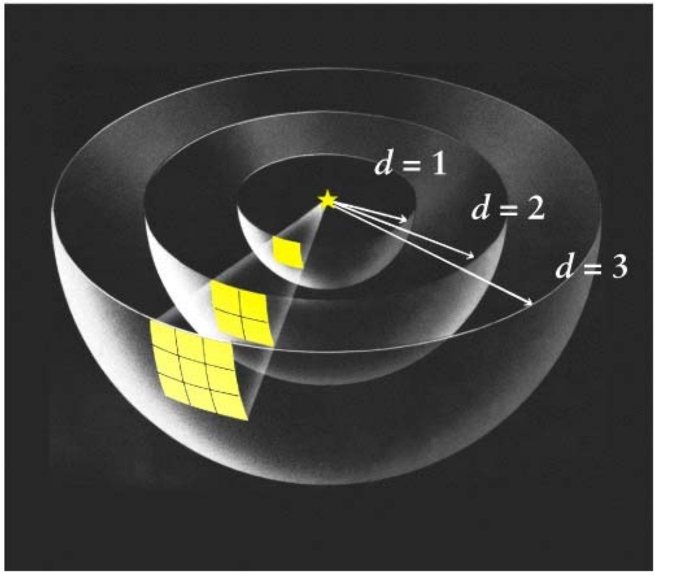
Around Visible Electromagnetic Spectrum



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.