# Today – Exam#2 Review

- Exam #2 is Thursday November 3rd in this room, BPS 1410
- The exam is 40 multiple choice questions. There are a few questions where you will have to use a formula.
- Bring your student ID
- You will have the full 80 minutes for the exam.
- You can bring one 8.5x11 inch sheet of notes (front and back)

# Program for Today

- We will read through the review sheet.
- I will give some sample problems.
- Approximately 10 of the exam problems will be from the homework.
- A couple of the samples we will use as clicker problems

- Grab your review sheet and hold on.

## Where are we?

- There are 4 known forces in nature (Gravity, weak, electromagnetic, strong)
- Gravity does not fit well in our understanding with the others
  - Why is it so weak compared to the others?
  - Quantum mechanics implies that mass can pop into and out of existence. On the small scale this leads to the creation of huge gravity and black holes. This does not seem to happen in nature.
- Our current understanding of nature is by Quantum field theory: EM - quantum electrodynamics, EM+weak - electroweak theory, Strong - quantum chromodynamics).
- The picture involves the exchange of force carrying bosons between particles

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# The particles of the standard model

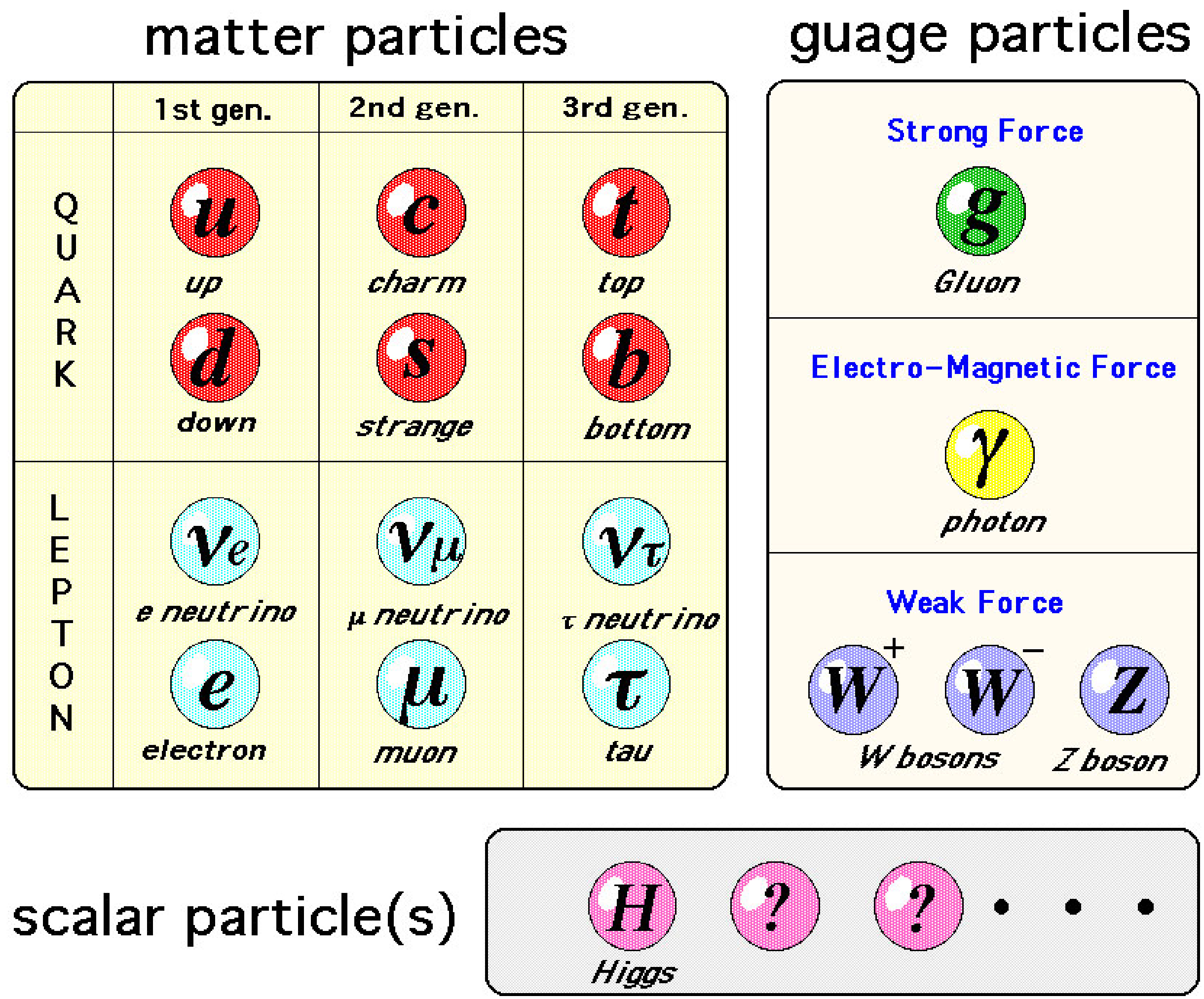
Charge

+2/3 →

-1/3 →

0 →

-1 →




anti-particles have opposite charge

T. Kondo

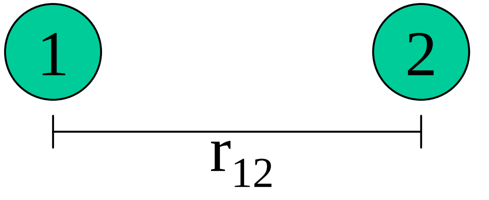
# Coulombs Law

- Charge comes in units of 1.6E-19C.
- How many electrons make up a charge of –2.0 C?

$$number = \frac{\text{charge}}{\text{charge/electron}} = \frac{-2.0C}{-1.6\cdot 10^{-19}} = 1.25\cdot 10^{19}$$

- The force between two charges is:

$$F = \frac{kq_1q_2}{r_{12}^2}; k = 8.99\times 10^9 \frac{Nm^2}{C^2}$$

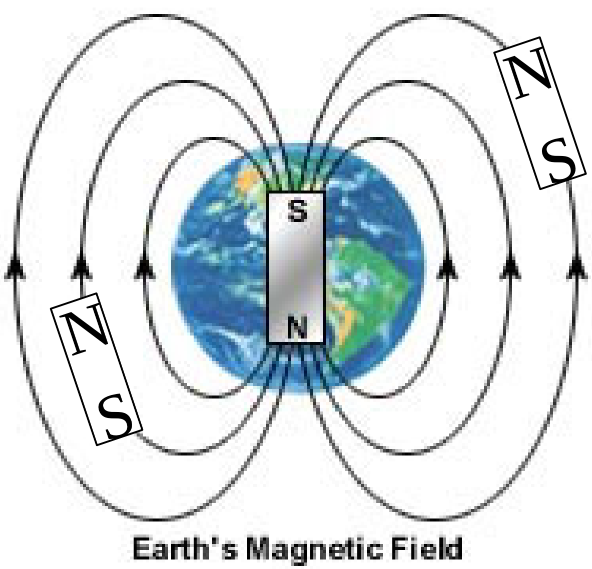



- Example (inverse square law): 4 times the distance

$$F_{4d} = \frac{kq_1q_2}{(4r_{12})^2} = \frac{1}{4^2}\frac{kq_1q_2}{r_{12}^2} = \frac{1}{16}\frac{kq_1q_2}{r_{12}^2} = \frac{1}{16}F_d$$

# The Earth behaves as a large magnet

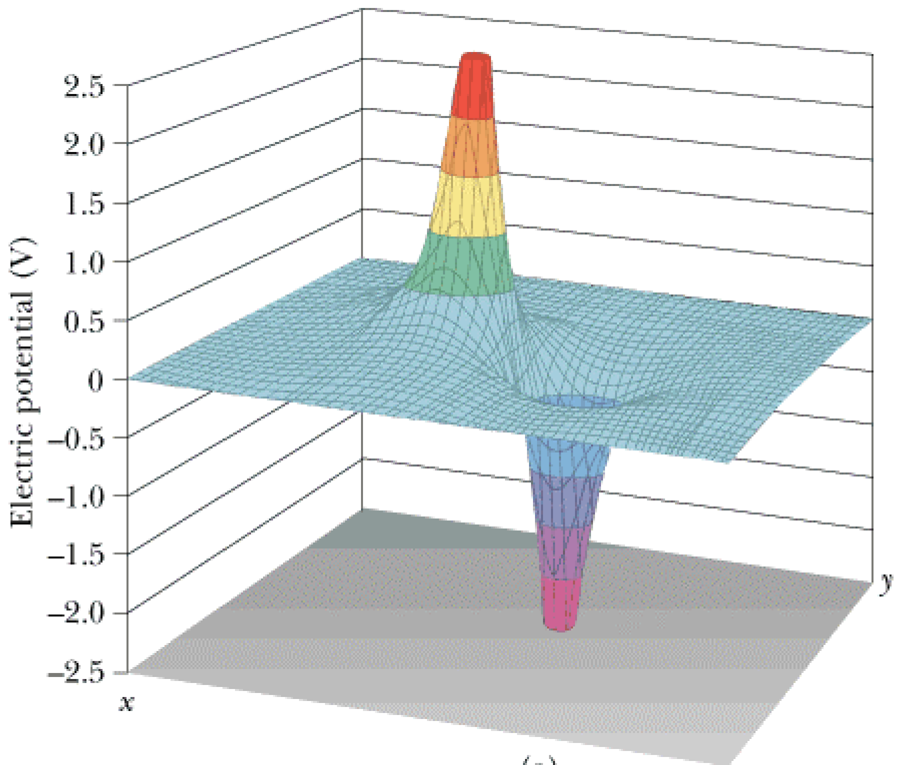
The Earth is like a large magnet with a south magnetic pole at the North geographic pole.




T/F A-true B-false

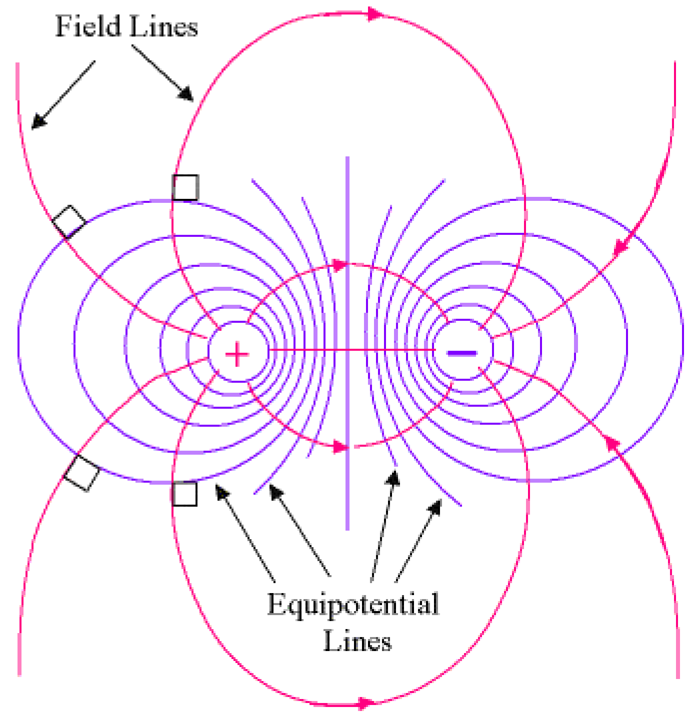
- North pole of a compass points north in northern hemisphere
- North pole of a compass points south in southern hemisphere
- Towards the north in the southern hemisphere
- Towards the north magnetic pole of a bar magnet

# Map for the Electric Field




(a)

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

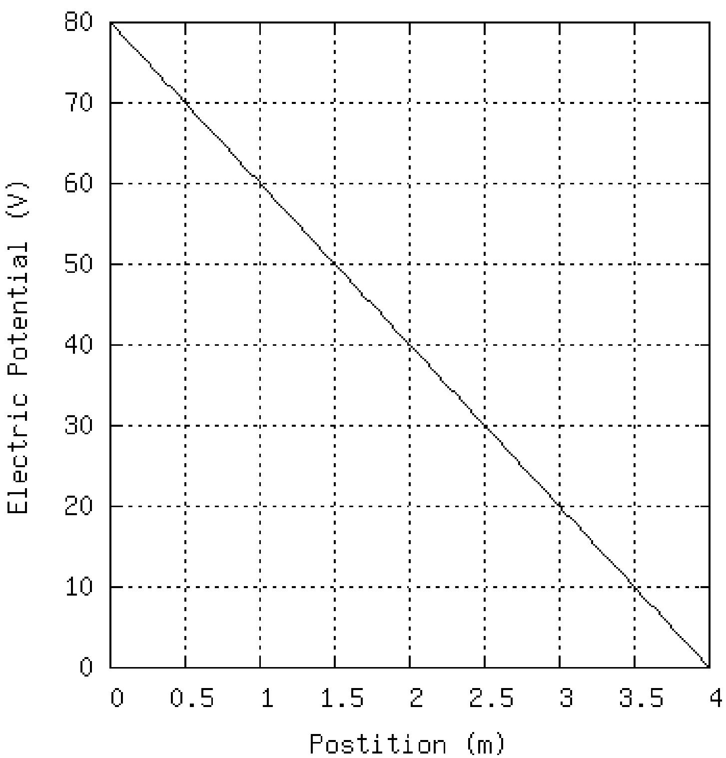



Note: we could make similar maps for all the fields in nature (gravity, weak, EM, strong).

# The relation between electric and magnetic fields

- Charge creates an electric field (and potential, V)
- Moving charge creates a magnetic field
- The photon is responsible for transmitting both the electric and the magnetic forces
- Maxwell's equations describe the relationship
  - Charge makes electric fields
  - Changing magnetic field makes electric fields
  - Changing electric fields make magnetic fields
  - Magnets always come with a north and a south pole
  - EM waves travel at the speed of light (in a vacuum)

# Sample Problem




What is the magnitude of the electric field at 2.0 m?

What is the force on a 2.0 C charge placed at that position?

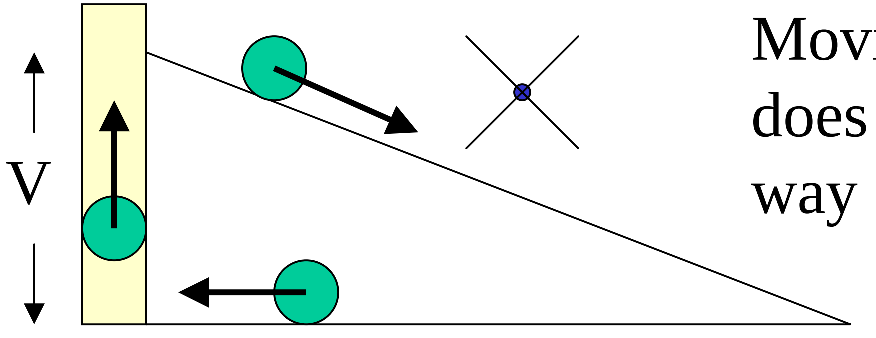
$$E = -\frac{\Delta V}{\Delta x} = -\frac{(0V - 80V)}{(4m - 0m)} = 20.0\frac{V}{m} = 20.0\frac{N}{C}$$

$$F = QE = 20.0\frac{N}{C} \cdot 2.0C = \boxed{40.0N}$$

# Flow of Charge - Current

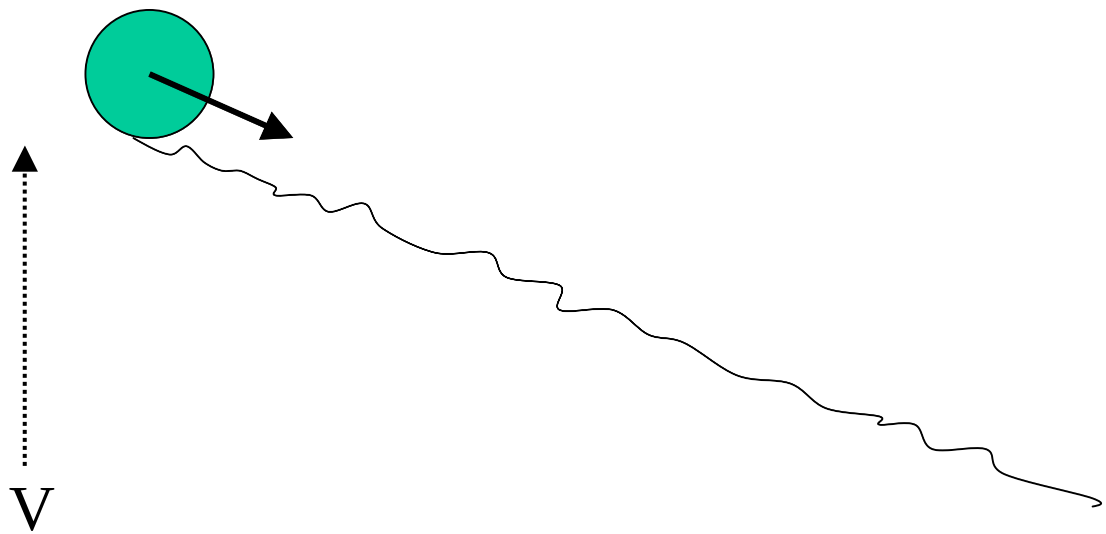
- Batteries are like pumps that lift charge to a higher potential. The charge flows down the hill to the other side of the battery.

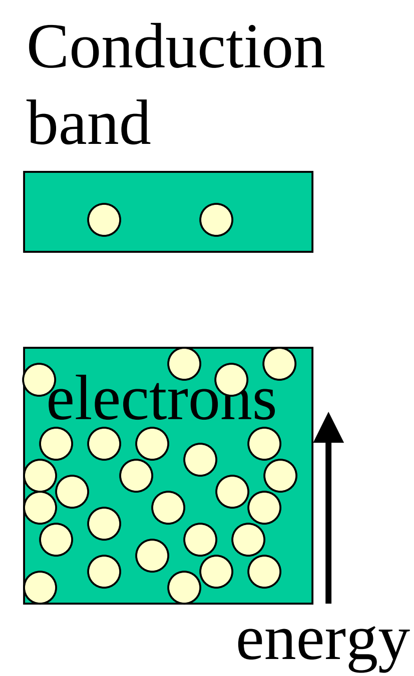
A battery is like a pump.




Moving Charge does work on the way down

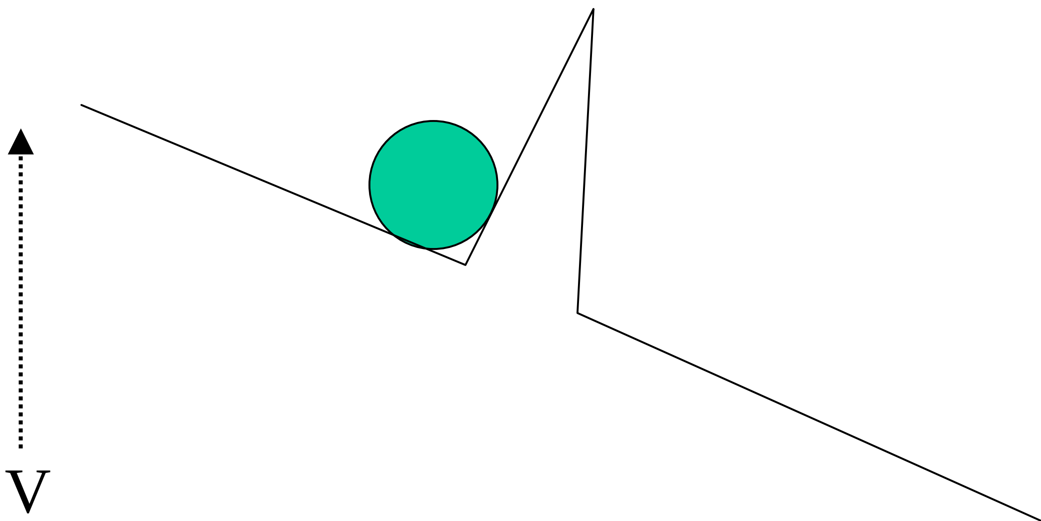
# Conductor

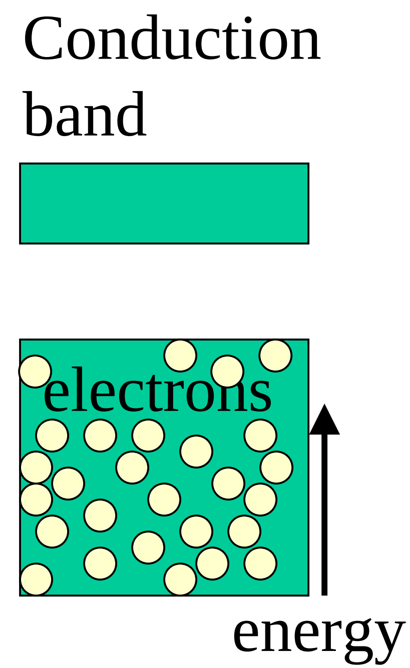



Electrons hit bumps, but are free to roll.

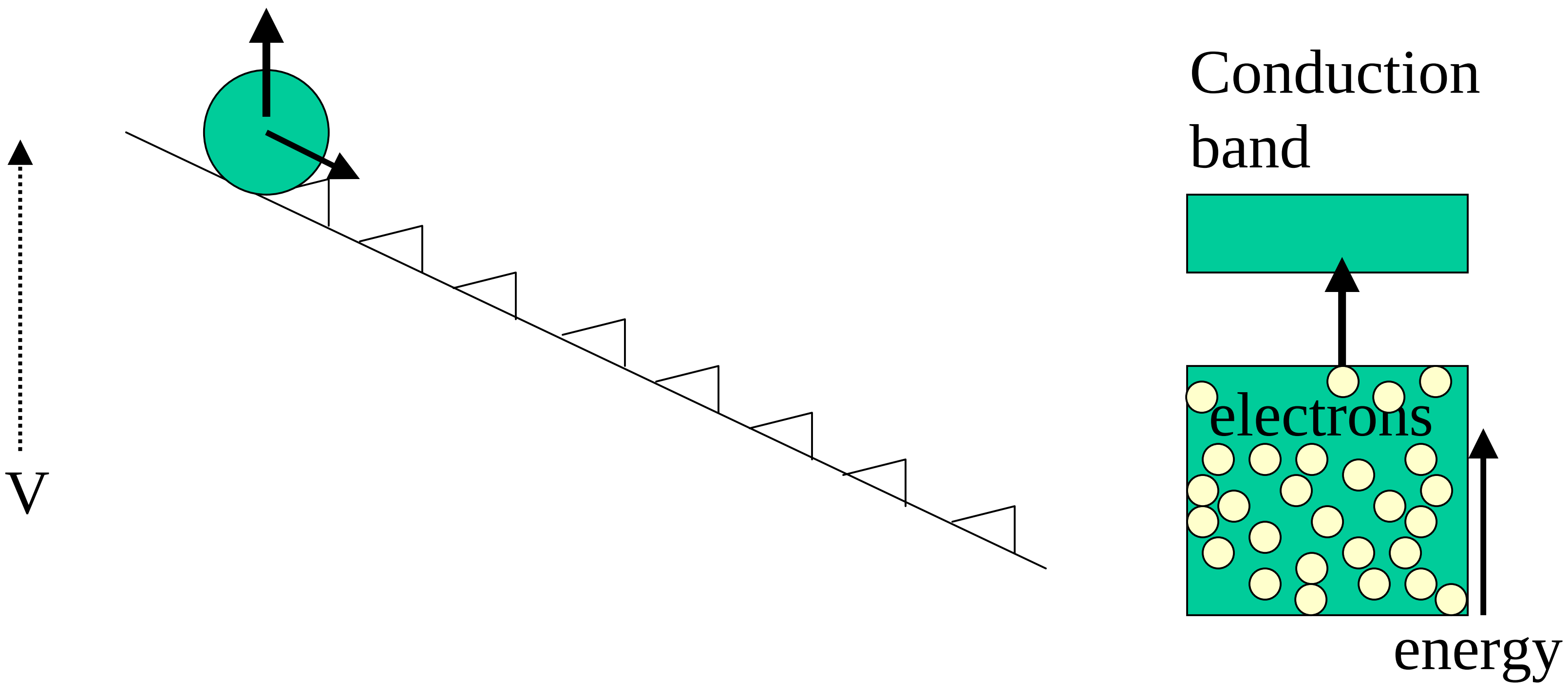
# Insulator



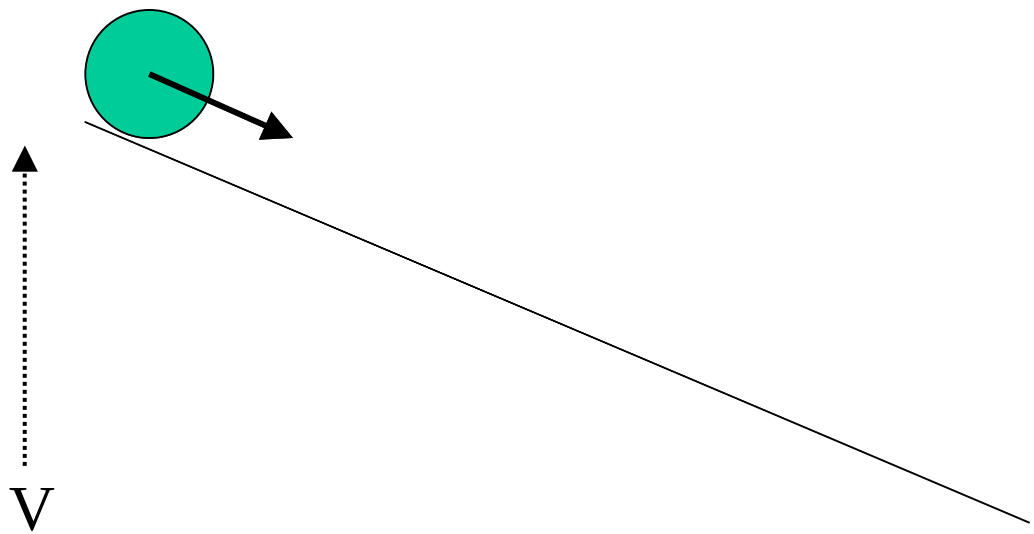



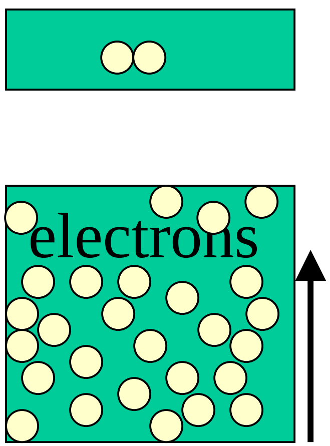

Electrons are not free to roll.

# Semiconductor



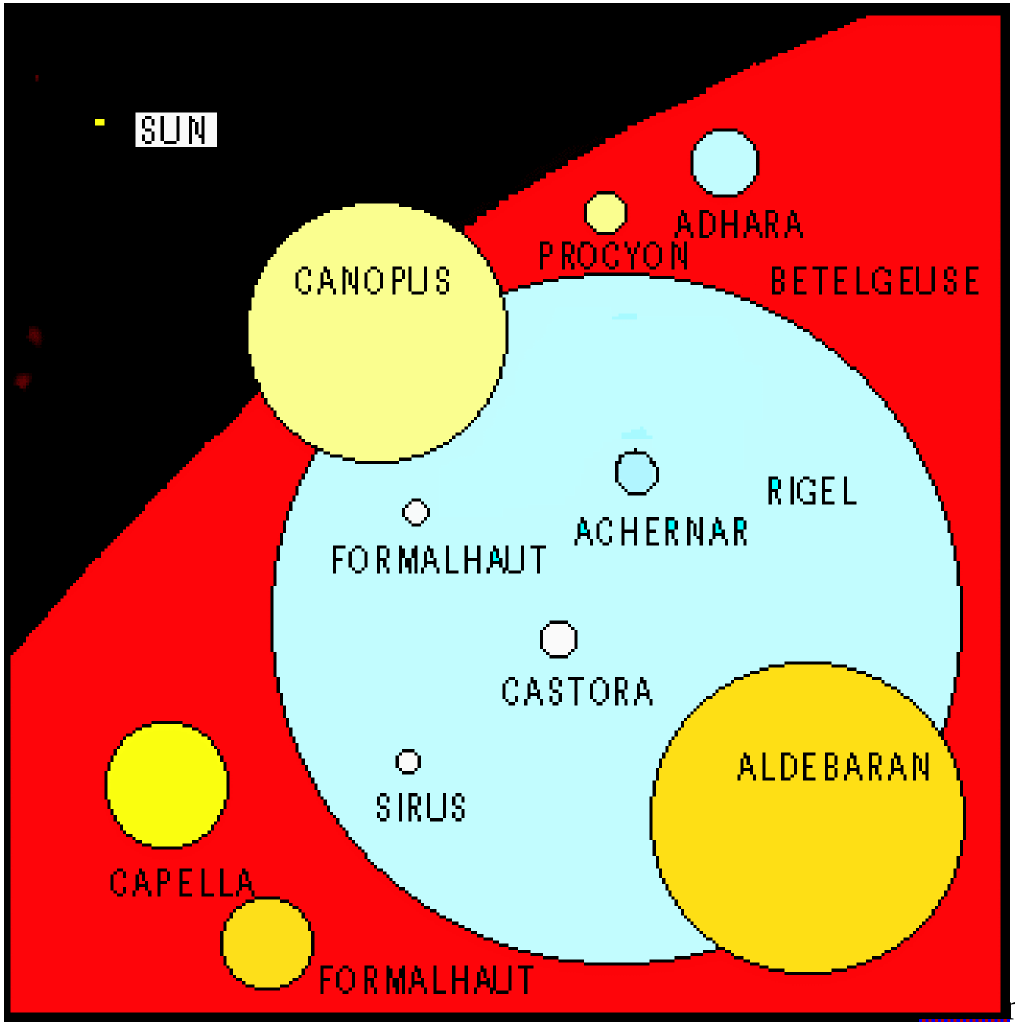
# Superconductor

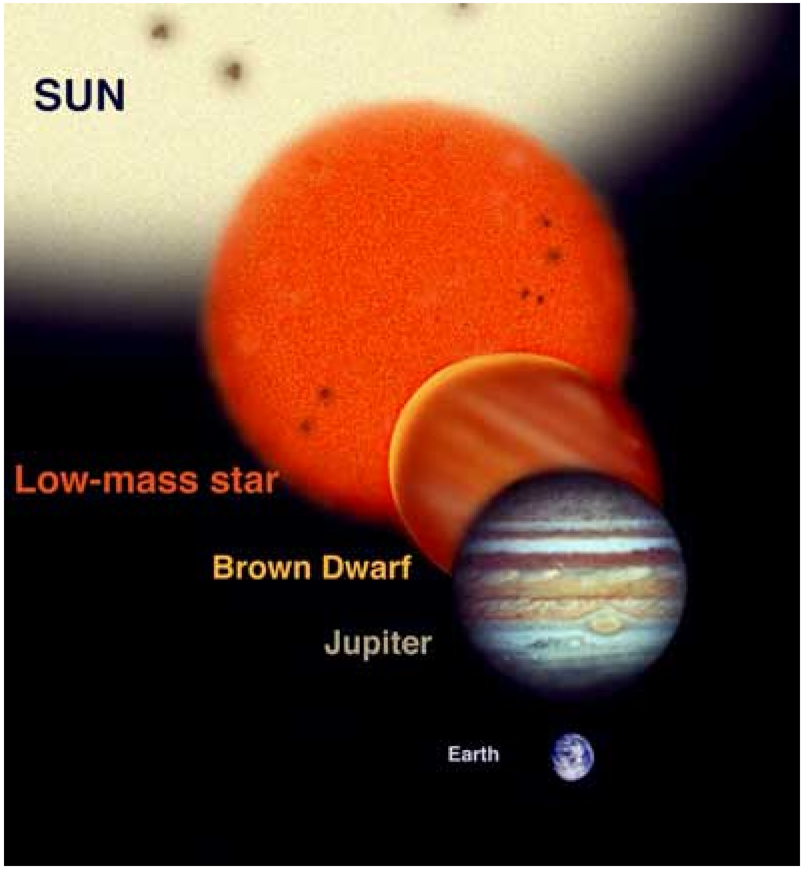



No resistance to flow (also no use of energy)

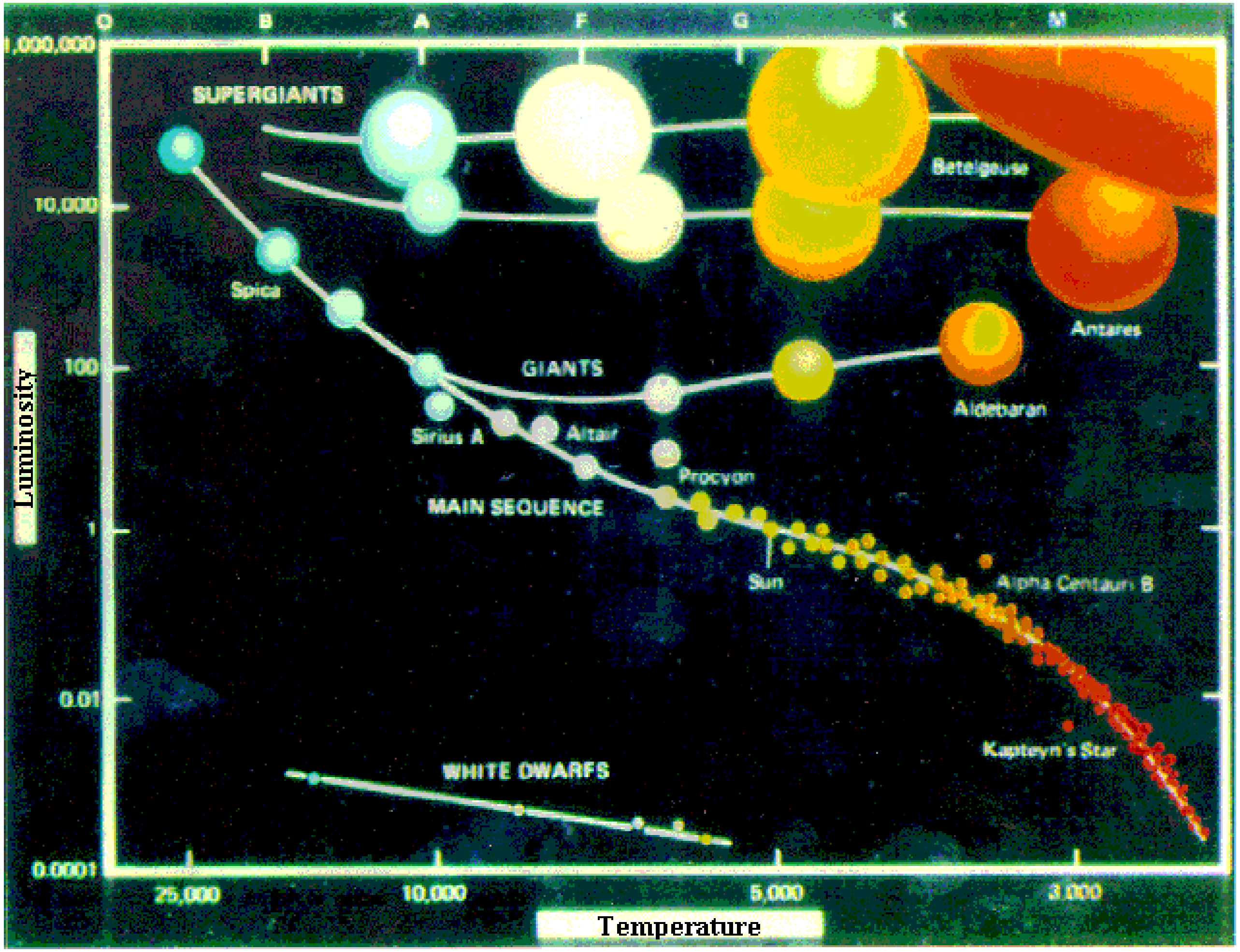
# Relative Sizes of Stars



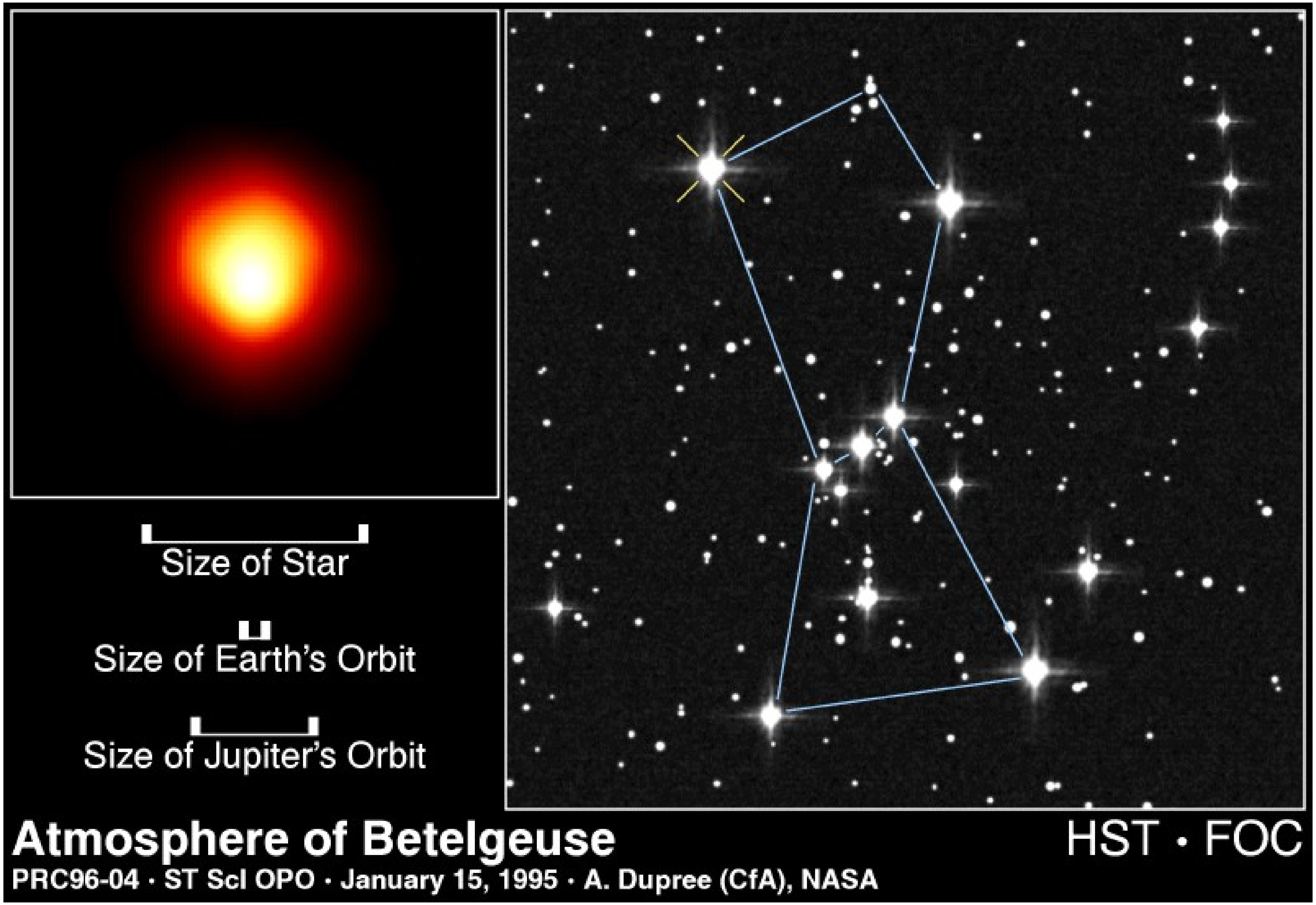




Blue – hot Red - cooler

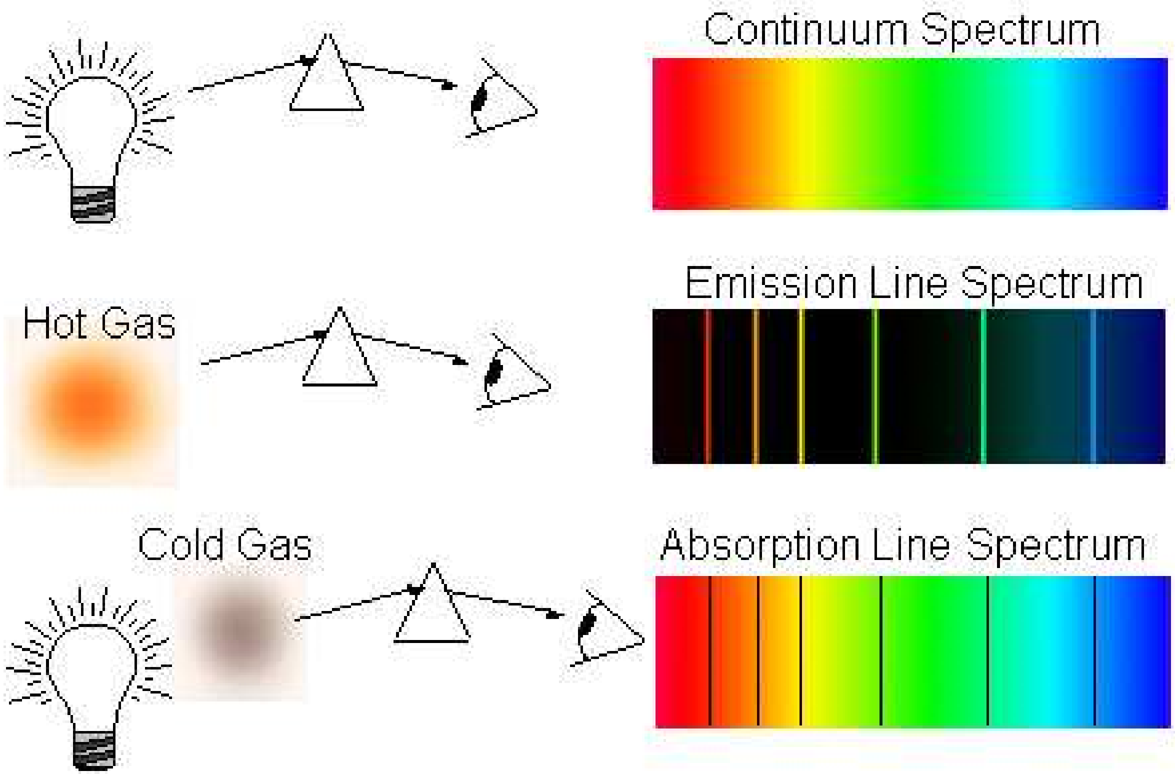
# Hertzsprung-Russell Diagram



# An example of a red supergiant



# Spectra come in 3 kinds




Examples

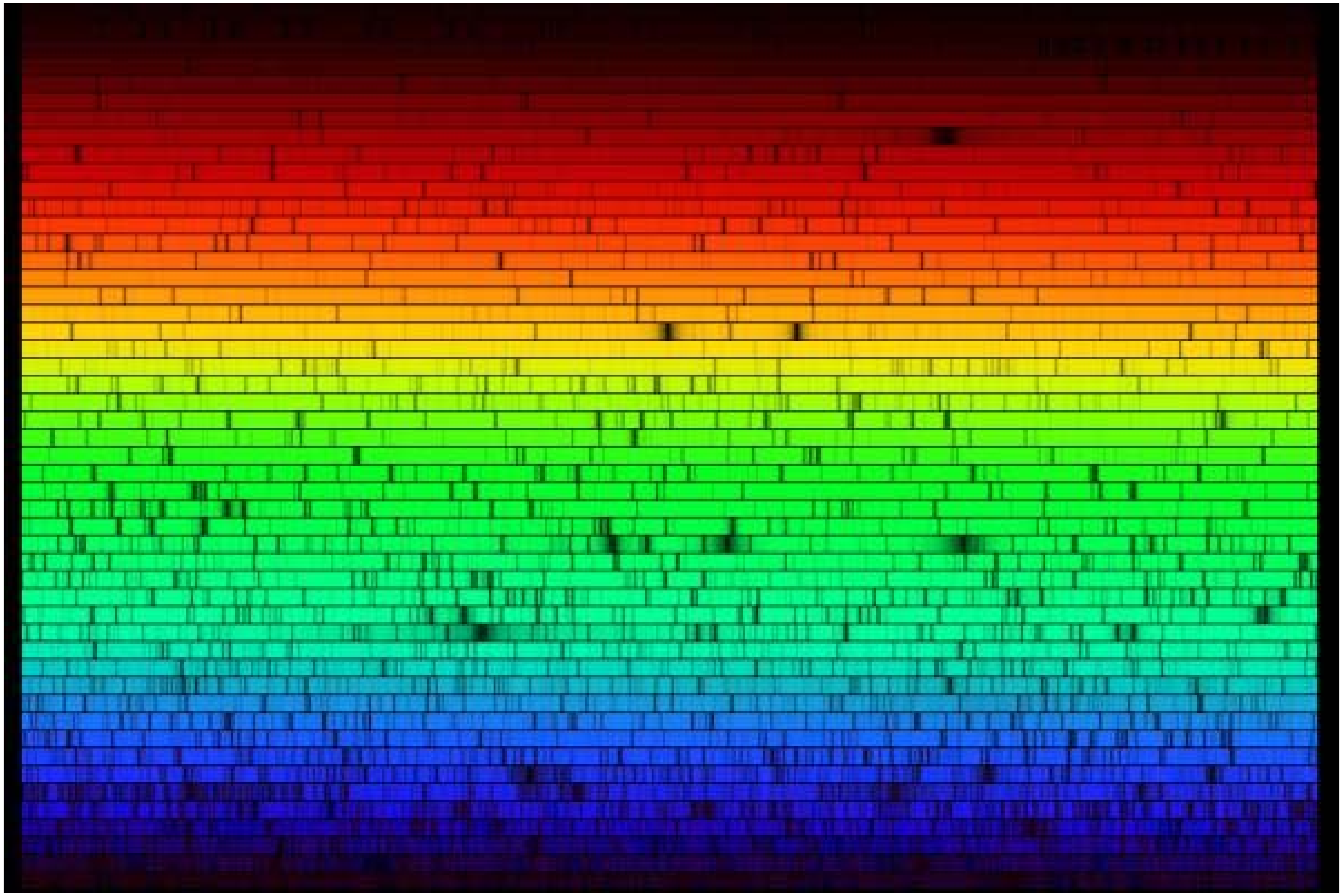
Heated rod or candle

Atoms in a gas excited by high temperature or high energy photons

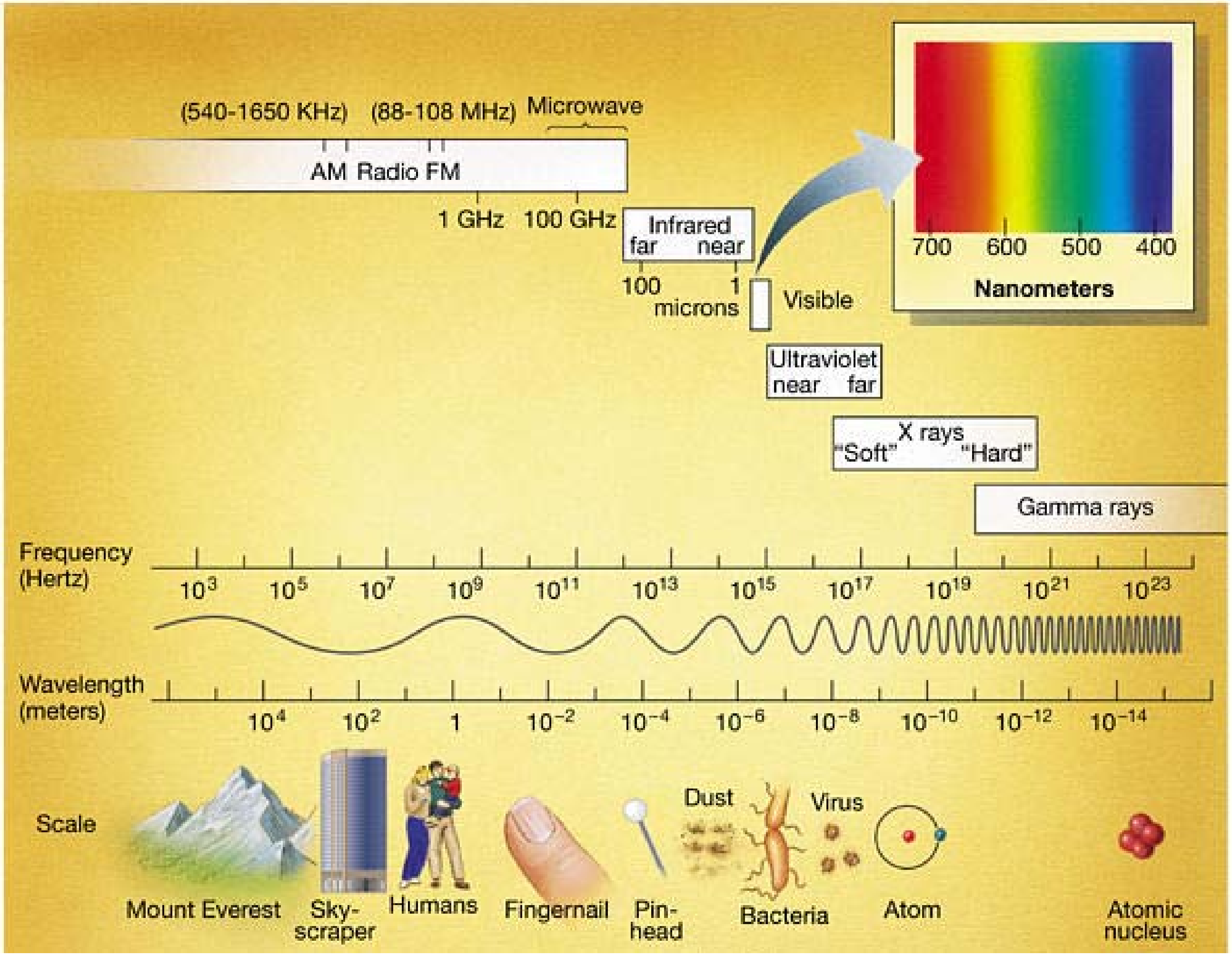
Spectrum from the Sun

The pattern of lines tells what elements are present.

# The spectrum from our Sun



# The Electromagnetic Spectrum




Speed = $\lambda$ f
$\lambda$ – 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

# Quantum Mechanics Review

- Light can be described as an electromagnetic wave or a little bundle of energy (a photon). Light has particle and wave character.
- Waves can overlap – this is called interference
- Particles, for example electrons, have wave and particle properties.
- The thing that is waving in the case of a particle is probability. The square of the height of the wave (wave function) is a measure of the probability density.
- All objects (atoms, molecules, etc.) exist in defined states of energy. The energy is quantized (quantum mechanics)

# An example

One version of the uncertainty principle says that for a short period of time, particles can be created out of nothing. They can pop into and out-of existence. For a time of 1.2E-15 s, what is the maximum energy photon than can exist?

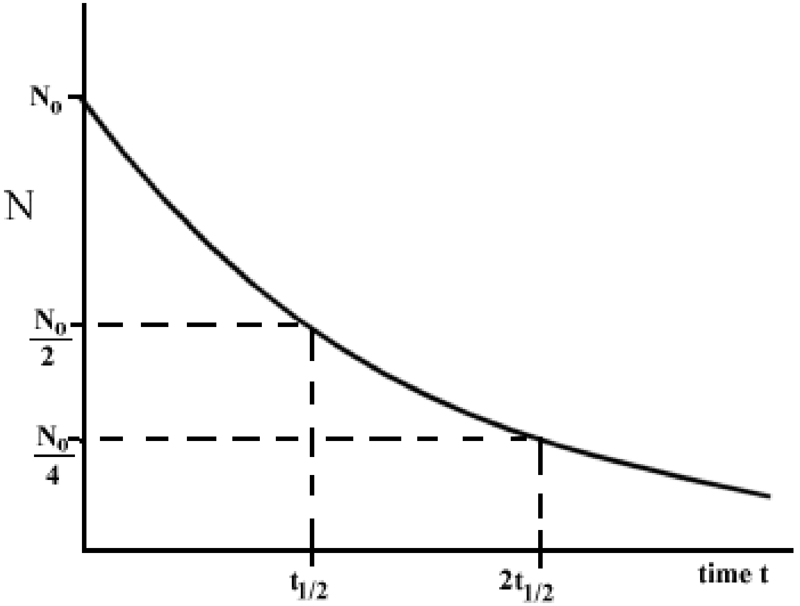
$$\Delta E \Delta t = \frac{h}{4\pi}$$

$$\Delta \mathrm{E} = \frac{h}{4\pi\Delta x} = \frac{4.136\times10^{-15}\,eVs}{4\cdot3.1415\cdot1.2\times10^{-15}\,s}$$

$$\Delta \mathrm{E} = 0.274\,eV$$

# Half life for radioactive decay

Radioactive decay is governed by the rules of quantum mechanics. If we start with N atoms, in the time of one half-life on average half will have decayed. In the next half life, half of those remaining will have decayed, and so on.




$$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$$N(2t_{1/2}) = N_0 \left(\frac{1}{2}\right)^2 = \frac{N_0}{4}$$

$$f = \frac{N}{N_0} = \frac{1}{4} = 0.25$$

# A summary of the forces of nature

| Force | Strength | Carrier | Range (m) |
|---|---|---|---|
| Strong | 1 | Gluon-quarks<br>Mesons-protons/neutrons | $10^{-15}$ size of a proton; exponential decrease |
| Electromagnetic | 1/137 | photon | Infinite; inverse square law |
| Weak | $10^{-6}$ | Vector Bosons | $10^{-16}$ Only 0.1 width of proton; exponetial decrease |
| Gravity | $6x10^{-39}$ | Graviton (?) | Infinite; inverse square law |

# Standard Model Questions – A(true) B(false)

- If the distance between two electrons is doubled, the weak force between them will be 4 times smaller.
- The United States has a storage area with enough anti-matter to meet all US energy needs for one day.
- Neutrinos interact via the weak force with electrons and the strong force with quarks
- One of the advantages of the standard model is that explains why there are 3 families of quarks.

# Feynman Diagrams and rules

Charge, baryon number, and lepton number are conserved

Consider the decay of a +pion into a muon by the Weak force. Which diagram describes this process?

$\pi^+$ $u\bar{d}$