How Things Work II  
(Lecture #29)

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Course web site available through COD and Toolkit  
or at http://people.virginia.edu/~gdc4k/phys106/spring08

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Announcements

• Midterms are available and grouped according to your last name. The mean was 19.6 points (out of 26) or 75.3%

• Any questions regarding grading should be written on the front page of the exam. PLEASE DO NOT MAKE ANY MARKS ON ANYTHING OTHER THAN THE COVER SHEET.

• Answers will not be posted until over the weekend. (This is so that I can get the lecture slides posted later today.)

• Problem Set #4 will be posted, and is due Tuesday, April 8th, at 11:59PM.

• Office hours:
  - Today, Friday, from 2-3:30 in room 120 (or my office).
  - Monday from 1:50 until 2:50 in here in the lecture hall.
  - Tuesday from 1-3 in room 120.
Midterm distribution

Bins are 5 percentage points wide and centered at the values shown.

C's or below

B's of some sort

A's of some sort

These grade estimates are based on my “20:60:20" rule, and are approximate only.

Mean = 19.6 points
or 75.3%
Subatomic physics, nuclear power and nuclear weapons

- Nuclear forces, nuclear reactions and why they occur.
- Stars and how they work.
- Nuclear Power and how it works.
- Nuclear weapons and they work.
Questions we will address

• How do we get useful energy from nuclear reactions?
• How safe are nuclear power plants?
• What can be done with the waste?
• Realistically, what are the implications of the use of nuclear weapons?
• What are the key issues relating to the proliferation of nuclear materials, and how does that relate to nuclear power?
• Why do we have a mass of 50 to 100 kg instead of 0.5 to 1 kg?
The structure of atoms

- The atomic nucleus contains protons and neutrons. Collectively they are referred to as “nucleons”.
- The nucleus is surrounded by a cloud of electrons.
- Whereas the nucleus has diameter of a few “femptometers”, or $10^{-15}$ meters, an atom has a diameter of around $10^{-10}$ meters, or an Ångstrom.
- If the atom were the size of a football field, the nucleus would be around one millimeter, or the size of a grain of sand.
The number of protons in the nucleus determines what element the atom is.

This atom has two protons and two neutrons in its nucleus, making it an isotope of helium (He-4).

This atom has three protons and four neutrons in its nucleus, making it an isotope of lithium (Li-7).
Why do nuclear reactions occur?

Nucleons want to rearrange themselves into configurations that have lower energy, i.e. more binding energy.
Types of nuclear reactions

• Neutrons can convert themselves into protons (by emitting an electron or “beta particle”. This is called **Beta Decay**.

• The nucleus can emit an alpha particle, comprising two neutrons and two protons (this is the same as a helium nucleus). This is called **Alpha Decay**.

• A nucleus in an excited state can emit a photon and decay to a less excited state. This is called **Gamma Emission**.

• The nucleus can become unstable, start undergoing big deformations, and split into several pieces. This is called **Fission**. This can happen spontaneously, or can be triggered by the absorption of a neutron.

• Nuclei can simply bang into one another really hard and a different collection of nuclei can emerge. This is what happens inside stars. Fusion is an example of this type of reaction. These types of events are many in number and are generically just called nuclear reactions.
Alpha Decay

\[ ^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + ^{4}_{2}\text{He} \]

Total number of nucleons or the “mass number”

Number of protons or “atomic number”

The nucleus of \(^4\text{He}\), also known as an alpha particle
Question:

When $^{137}\text{Cs}$ undergoes beta decay, what does it become?

A. $^{138}\text{Cs}$
B. $^{138}\text{Ba}$
C. $^{137}\text{Ba}$
D. $^{136}\text{Ba}$
Beta Decay

Total number of nucleons or the “mass number”

\[
{_{55}^{137}}\text{Cs} \rightarrow {_{56}^{137}}\text{Ba} + \beta^-
\]

This is a beta particle, which is really just an electron.

Number of protons or “atomic number”
Fission

An example of fission

\[ ^{235}\text{U} + n \rightarrow ^{236}\text{U} \rightarrow ^{140}\text{Xe} + ^{94}\text{Sr} + 2 \text{n} + 200 \text{MeV} \]