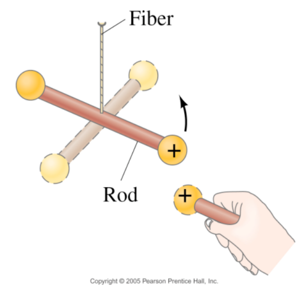
5-10 Types of Forces in Nature

Modern physics now recognizes four fundamental forces:

1. **Gravity**
2. **Electromagnetism**
3. **Weak nuclear force** (responsible for some types of radioactive decay)
4. **Strong nuclear force** (binds protons and neutrons together in the nucleus)

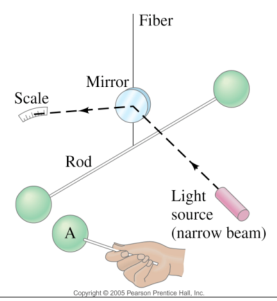
16.5 Coulomb's Law

Experiment shows that the electric force between two charges is proportional to the product of the charges and inversely proportional to the distance between them.



6.1 Newton's Law of Gravitation

Experiment shows that the gravitational force between two masses is proportional to the product of the masses and inversely proportional to the distance between them.



16.5 Coulomb's Law

Coulomb's law:

$$F = k\frac{Q_1 Q_2}{r^2}$$

This equation gives the magnitude of the force.

6.1 Newton's Law of Gravitation

Newton's Law of Gravitation:

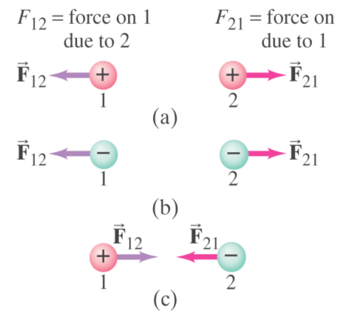
$$F = -G\frac{m_1 m_2}{r^2}$$

This equation gives the magnitude of the force.

How do the four fundamental forces dominate nature?

16.5 Coulomb's Law

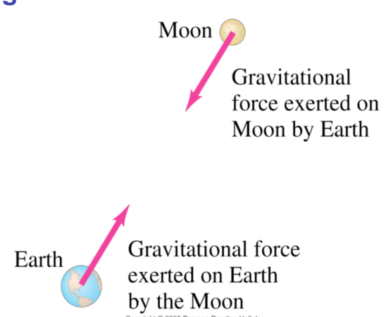
The electric force is along the line connecting the charges, and is attractive if the charges are opposite, and repulsive if they are the same.



How do the four fundamental forces dominate nature?

6.1 Newton's Law of Gravitation

The gravitational force is along the line connecting the masses and is <u>always</u> attractive regardless of the size either mass.



How do the four fundamental forces dominate nature?

16.5 Coulomb's Law

Unit of charge: coulomb, C

The proportionality constant in Coulomb's law is then:

$$k = 8.988 \times 10^9 \, \mathrm{N \cdot m^2/C^2}$$

Charges produced by rubbing are typically around a microcoulomb:

$$1\,\mu\mathrm{C} = 10^{-6}\,\mathrm{C}$$

How do the four fundamental forces dominate nature?

6.1 Newton's Law of Gravitation

Unit of mass: kilogram, kg

The proportionality constant in Newton's law is:

$$G = 6.67 \times 10^{-11}\,\mathrm{N \cdot m^2/kg^2}$$

NOTE: The Gravitational constant is <u>significantly</u> less than the electrostatic constant.

So why doesn't electrostatic charge hold planets together instead gravity?

Because a planet's mass is HUGE!!!!!

How do the four fundamental forces dominate nature?

30.2 Binding Energy and Nuclear Forces

The total mass of a stable nucleus is always less than the sum of the masses of its separate protons and neutrons.

Where has the mass gone?

How do the four fundamental forces dominate nature?

30.2 Binding Energy and Nuclear Forces

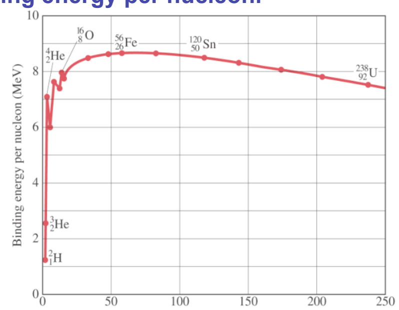
It has become energy, such as radiation or kinetic energy, released during the formation of the nucleus.

This difference between the total mass of the constituents and the mass of the nucleus is called the total binding energy of the nucleus.

How do the four fundamental forces dominate nature?

30.2 Binding Energy and Nuclear Forces

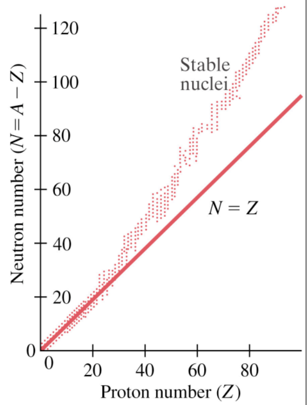
To compare how tightly bound different nuclei are, we divide the binding energy by A (mass number) to get the binding energy per nucleon.



30.2 Binding Energy and Nuclear Forces

The higher the binding energy per nucleon, the more stable the nucleus.

More massive nuclei require extra neutrons to overcome the Coulomb repulsion of the protons in order to be stable.



30.2 Binding Energy and Nuclear Forces

The force that binds the nucleons together is called the strong nuclear force. It is a very strong, but short-range, force. It is essentially zero if the nucleons are more than about 10^{-15} m apart. The Coulomb force is long-range; this is why extra neutrons are needed for stability in high-Z (atomic number) nuclei.

30.4 Alpha Decay

Alpha decay occurs when the strong nuclear force cannot hold a large nucleus together. The mass of the parent nucleus is greater than the sum of the masses of the daughter nucleus and the alpha particle; this difference is called the disintegration energy.

In general, alpha decay can be written:

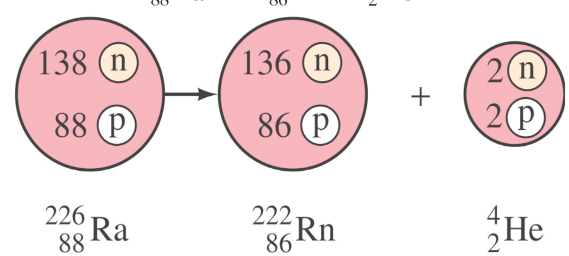
$$^{A}_{Z}\mathrm{N} \rightarrow\, ^{A-4}_{Z-2}\mathrm{N}' + \,^{4}_{2}\mathrm{He}$$

30.4 Alpha Decay

Example of alpha decay:

Radium-226 will alpha-decay to radon-22

$$^{226}_{88}\mathrm{Ra} \rightarrow\, ^{222}_{86}\mathrm{Rn} + \,^{4}_{2}\mathrm{He}$$



30.4 Alpha Decay

Alpha decay is so much more likely than other forms of nuclear disintegration because the alpha particle itself is quite stable.

30.4 Alpha Decay

One type of smoke detector uses alpha radiation – the presence of smoke is enough to absorb the alpha rays and keep them from striking the collector plate.

For more information on Strong Forces:
http://aether.lbl.gov/elements/stellar/strong/strong.html

30.5 Beta Decay

Beta decay occurs when a nucleus emits an electron. An example is the decay of carbon-14:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + e^{-} + \text{a neutrino}$$

The nucleus still has 14 nucleons, but it has one more proton and one fewer neutron.

This decay is an example of an interaction that proceeds via the weak nuclear force.

30.5 Beta Decay

The electron in beta decay is not an orbital electron; it is created in the decay.

The fundamental process is a neutron decaying to a proton, electron, and neutrino:

$$\mathrm{n} \rightarrow \mathrm{p} + e^{-} + \text{a neutrino.}$$

The need for a particle such as the neutrino was discovered through analysis of energy and momentum conservation in beta decay – it could not be a two-particle decay.

30.5 Beta Decay

Neutrinos are notoriously difficult to detect, as they interact only weakly, and direct evidence for their existence was not available until more than 20 years had passed.

The symbol for the neutrino is the Greek letter nu (ν); using this, we write the beta decay of carbon-14 as:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \mathrm{e}^{-} + \bar{\nu}.$$

30.5 Beta Decay

Beta decay can also occur where the nucleus emits a positron rather than an electron:

$$^{19}_{10}\mathrm{Ne} \rightarrow {}^{19}_{9}\mathrm{F} + \mathrm{e}^{+} + \nu$$

And a nucleus can capture one of its inner electrons:

$$^{7}_{4}\mathrm{Be} + \mathrm{e}^{-} \rightarrow {}^{7}_{3}\mathrm{Li} + \nu$$

5-10 Types of Forces in Nature

Thought Question: Which force(s) is/are responsible for **friction**, the **normal** force, **tension**, and so on?

Except for gravity, the forces we experience every day are due to **electromagnetic** forces acting at the **atomic** level.

Review of Fundamental Forces: A Comparison

- **Strong:**
  - Responsible for holding the protons / nucleus together and Alpha Decay
- **Electromagnetic:**
  - Responsible for holding Atoms and Matter together (Tension, Normal, Applied, and Frictional Forces)
- **Gravitational:**
  - Responsible for holding Planets / Stars, etc. together
- **Weak:**
  - Responsible for Beta Decay, Positron Decay, Electron Capture