NUCLEAR ENERGY!

DAY 1: (RADIATION, FISSION, FUSION)
Nucleus Stability

- Stability of the nucleus depends on the nuclear forces that act between protons and neutrons.
  - Protons repel each other.
  - Protons attract neutrons because of the strong nuclear force.
Nucleus Stability

- Nuclei with too many protons or neutrons are unstable.

- If an atom is unstable, it will try to become stable by splitting into two smaller atoms.

- Nuclei with more than 83 protons are ALWAYS unstable.
Nucleus Stability

- Essentially, nuclear stability is based on the arrangement of the protons and neutrons in the nucleus.
  - The more efficient and tightly packed the nucleus orientation is, the more stable the nucleus is.
So based on this, what is fission?
Fission is the process where a nucleus splits into two or more smaller fragments, releasing neutrons, and energy.

Nucleus must be large for this to happen. Ex: Uranium-235

\[
\frac{235}{92}U + \frac{1}{0}n \rightarrow \frac{140}{56}Ba + \frac{93}{36}Kr + 3\frac{1}{0}n
\]

Uranium-235 only makes up 0.7% of the Uranium in the world. The rest is stable Uranium-238 – The largest naturally occurring element.

Done in nuclear power plants and atomic bombs.
**FISSION**

- Neutrons are used as bullets to break apart the uranium-235 nucleus.

- 3 Products form
  - Fission Products: Barium and Krypton
  - 3 Free Neutrons
  - Energy is released
There are multiple pathways for Uranium to decay. The pathway we concentrate on involves Ba and Kr products. In any case, there will always be 3 products, regardless of pathway.

- Fission Products
- 2-3 Free Neutrons
- Energy is released

\[
^{233}\text{U} + \text{n} \rightarrow \left[ ^{236}\text{U} \right] \rightarrow ^{138}\text{Ba} + ^{88}\text{Kr} + 3\text{n}
\]

\[
^{133}\text{Cs} + ^{97}\text{Rb} + 2\text{n}
\]

\[
^{134}\text{Xe} + ^{98}\text{Sr} + 2\text{n}
\]

\[
^{136}\text{La} + ^{97}\text{Br} + 3\text{n}
\]

\[
^{160}\text{Sm} + ^{64}\text{Zn} + 4\text{n}
\]
Chain Reaction: The 3 neutrons that are released from fission start an additional fission reaction in a different U-235 nucleus. This produces more neutrons and repeats.

The process may be:
- controlled (nuclear power plants/submarines)
- uncontrolled (nuclear weapons).

Video – Chain Reaction with M Traps (3 min)
Chain Reactions

\[ ^{94}_{36}\text{Kr} \quad ^{139}_{56}\text{Ba} \]

Fission Products

Neutrons

Unchanged "fuel"
FISSION ENERGY

- Hahn and Strassman found that the overall **mass decreases** after the reaction happens.

- The missing mass changed into energy
  - \[ E = mc^2 \]
  - Energy = mass * speed of light \(^2\)
  - Speed of light = \(300,000,000\) m/s

- Sooo...
  - \[ E = mc^2 \]
  - \[ E = (1\text{kg}) \times (300,000,000\text{m/s})^2 \]
  - \(E = 90,000,000,000,000,000,000\) Joules
  - \(E = 9 \times 10^{16}\) joules
FISSION ENERGY

- Converting 1 kg of Uranium-235 into energy.
  - \( E = mc^2 \)
  - \( E = (1\text{ kg}) \times (300,000,000\text{ m/s})^2 \)
  - \( E = 90,000,000,000,000,000 \text{ Joules} \)
  - \( E = 9 \times 10^{16} \text{ joules} \)

- Energy produced burning 1 kg of coal (not using \( E = mc^2 \))
  - \( E = 31,000,000 \text{ joules} \)
  - \( E = 3.1 \times 10^7 \text{ joule} \)

- So: 1 kg of Uranium 235, undergoing fission, will produce over 1 trillion times the energy of 1 kg of coal being burned

- Video: Fission Reactions (2 min)
So based on this, what is fusion?
FUSION

- Two lighter nuclei combine to form a heavier nucleus
- Start with:
  - 2 Hydrogen isotopes (deuterium and tritium)
- End with with:
  - 1 Helium atom
  - 1 Neutron
  - Energy
- Occurs in stars/the sun
ENERGY IN FUSION

- A large amount of energy is needed to create very high temperatures so that the isotopes can be hurled at each other and overcome the tendency of positively charged nuclei (the Hydrogen isotopes) to repel each other.

- This is why FUSION occurs in Stars and our Sun

- Video – Sun’s Energy (6 min)
And don’t forget that both release energy!
Nuclear Radiation

- **Radiation:**
  - Emission of energy or particles from an unstable decaying atom

![Sources of Radiation](image)

- Medicine - 14%
- Nuclear Industry - 1%
- Buildings/Soil - 18%
- Cosmic - 14%
- Radon - 42%
- Food/Drink Water - 11%

Natural Radiation 85%
Nuclear Radiation

- **Background radiation:**
  - Radiation that arises naturally from cosmic rays from radioactive isotopes in the soil and air
  - Continuously exposed to radiation from natural sources:
    - sun, soil, rocks, plants
    - More than 80% of radiation exposure due to natural sources

- You can change your exposure based on many things:
  - Air travel, where you live, smoking, x rays, job, etc...
Nuclear Radiation

- Radiation comes in 3 forms:
  - Alpha particles
  - Beta particle
  - Gamma particle

The penetration power of the three types of radiation.

- Thin mica
- Skin or paper stops ALPHA
- Thin aluminium stops BETA
- Thick lead reduces GAMMA
NUCLEAR ENERGY!

DAY 2: (USES, PROS, CONS)
Ways We Use Nuclear Energy

- Nuclear Medicine
- Nuclear Weapons
- Nuclear Power
  - Nuclear power plants
  - Nuclear submarines
Nuclear Medicines

**Nuclear Medicine:** The use of radioactive substances in the diagnosis or treatment of diseases

**POSITIVE:**

- Check body systems to make sure working properly
  - Radiopharmaceuticals are taken orally and then a “gamma camera” captures images of emitted radiation from inside body

- Nuclear Medicine Therapy - Intravenous or oral administered drug
  - Used to treat conditions such as hyperthyroidism, thyroid cancer, and blood disorders
**Nuclear Medicines**

**Nuclear Medicine:** The use of radioactive substances in the diagnosis or treatment of diseases

**NEGATIVE:**
- Produces mild radiation, so it can damage/cause cancer in healthy cells
- Nuclear waste must be stored
- VERY expensive to set up in a facility
Nuclear Weapons

- This is a “Uncontrolled Fission Reaction”
- Tremendous amounts of energy available from small amounts of fuel
  - can be “smuggled easily.”
- Tremendous amount of destruction
- Contamination of the environment for very long amounts of time

- Video: Top 10 explosions ever [http://www.youtube.com/watch?v=yRRGaxx8Zf4](http://www.youtube.com/watch?v=yRRGaxx8Zf4) (4 min)
- Video: Time lapse of every nuclear explosion ever [http://www.youtube.com/watch?v=gJe7fY-yowk](http://www.youtube.com/watch?v=gJe7fY-yowk) (5 min)
Nuclear Weapons

[Graph showing the production of nuclear weapons by the USSR/Russia and the United States from 1945 to 2005.]
Nuclear Reactor: How It Works
Nuclear Reactor: This is a Controlled Nuclear Fission Reaction
Nuclear Reactor: This is a Controlled Nuclear Fission Reaction
Nuclear Reactor: How it works

Video (5 min) [http://www.youtube.com/watch?v=PKNbwclaGng](http://www.youtube.com/watch?v=PKNbwclaGng)
Nuclear Energy in 4 easy steps:

1) A Fission chain reaction begins while the fuel rods are in the water
   - The amount of fission is controlled by lead Control Rods
2) The water heats up and changes to steam
3) The steam turns a turbine
4) The turbine turns a generator, forming electricity
   - The steam is then cooled down in a cooling tower
   - The spent fuel rods need to be stored for hundreds/thousands of years
Nuclear Energy:

- Used Fuel Rods
Nuclear Energy: Where Are They

- 65 Nuclear Power Plants in the United States
  - Produce 19.6% of our energy (2008)
  - SC has 4 plants, producing over ½ of our energy
Nuclear Energy BENEFITS

- Tremendous amounts of energy available from small amounts of fuel
- No air pollution of greenhouse gasses from the burning of fossil fuels
- Can be used anywhere
- Abundance of fuel
- Non-reliance on fossil fuel
NUCLEAR ENERGY NEGATIVES:

- Can cause thermal pollution to water systems (if you put the hot water back into rivers)
- Waste must be stored until it is no longer radioactive – can be a very long time.
- Improper handling of nuclear materials
- Power plant failure – radioactive explosions
- Fukushima Explained - [http://www.youtube.com/watch?v=rBvUtYOPfB8](http://www.youtube.com/watch?v=rBvUtYOPfB8) (5 min)