Today

- Announcements:
  - Prof. Sherrill is attending a conference today 9-22.
  - HW#3 is due 8am 9-28. HW#4 will be due 8am on 9-28.
- Today: Prof. Walter Benenson, Univ. Distinguished Professor will give a lecture on Einstein and $E=mc^2$.
- If there is time you will watch the end of the Cosmos episode. If there is not time we will watch it on next Tuesday.

How to do the homework problems

- In the lecture you will learn that mass and energy are related.
- The relationship is $E=mc^2$, where c is the speed of light; c = 3.00E+8 m/s
- In all processes that generate or absorb energy, mass is either increased or decreased.
- For example, chemical reactions generate energy by converting a small amount of mass to energy.

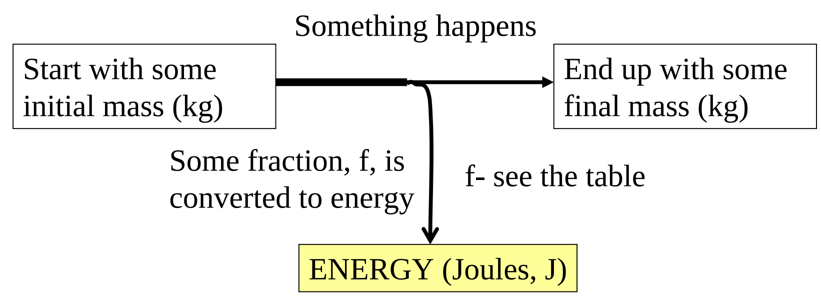
Fraction of Energy Converted

- In a chemical reaction not all the mass can be converted to energy. Actually only a very small fraction (the exact value of the fraction depends on the chemical reaction) about 1×10^{-10} of all the mass is converted to energy.
- Some other fractions:

Reaction	Fraction	Example
Matter-Antimatter Annihilation	1	No common example
Fusion	0.007	Power source of the Sun
Fission	0.001	Nuclear power plant
Chemical	1×10^{-10}	Burning coal
Mechanical	1×10^{-15}	Compressing a spring

Picture

<u>The following is a picture of the process:</u>



The amount of energy is $E = m_{converted}\, c^2$

$m_{converted}$ = (Mass to start) x fraction

Some Samples

- A power plant generates 500 MW of electrical power and 700 MW of waste heat (plants always make more waste heat than electrical power). How many Joules of energy does the plant generate in 1 day?

$$\text{Electrical Energy (1 day)} = 500\text{MW} \times \text{seconds in a day} = 500 \times 10^6 \frac{\text{J}}{\text{s}} \times \frac{60s}{m} \times \frac{60m}{hr} \times \frac{24hr}{d} \times 1d$$

$$\text{Electrical Energy (1 day)} = 4.32\text{E}13 \ \text{J}$$

More on the power plant

- Assume the power plant in the previous problem burns 2.2 kg of oxygen and 1 kg of carbon from coal to make 33 MJ of energy. How many kg of carbon and oxygen will the plant use in a day?

$$\text{mass (kg)} = \frac{\text{total energy produced}}{\left(\text{energy generated}/\text{mass}\right)} = \frac{\text{electrical + waste energy}}{\left(\text{energy generated}/\text{mass}\right)}$$

$$\text{mass (kg)} = \frac{4.32\text{E}13\,\text{J} + 6.048\text{E}13\,\text{J}}{\left(33.\text{E}6\,\text{J}/(2.2\,\text{kg} + 1.0\,\text{kg})\right)} = 1.005E7\ kg$$

How much of that mass was converted to energy?

$$E = m_{\text{converted}} c^2 \Rightarrow m_{converted} = \frac{E}{c^2}$$

$$m_{converted} = \frac{1.04E14\ J}{\left(3E8\, m/s\right)^2} = 1.16 \times 10^{-3}\ kg$$

But we used more than 10^7 kg, where did it all go?

How long will the Sun burn?

- The sun generates 3.82E24 W of power by fusion of hydrogen into helium. Assuming the fraction of mass converted for fusion Is 0.007, how many kg of protons and electrons does the Sun use every second?

$$m_{start} = \frac{m_{converted}}{f} = \frac{E/c^2}{f} = \frac{3.82E24\ J / \left(3E8\, m/s\right)^2}{0.007} = 6.06E9\ kg$$

- The rest of the homework is up to you.