PHYS 102-Concepts of Physics II-Spring 2007
Solutions to Homework #4
100 points possible

1. (20 points)
   (a) In a chemical reaction, electrons reconfigure but the nuclei are left unchanged. In a nuclear reaction on the other hand, the nuclei change.
   (b) TNT stands for tri-nitro-toluene
   (c) If you use a metric ton (1000 kg) you get 4×10^6 J/kg. If you use a regular ton (2000 pounds) you get 4.4×10^6 J/kg. Either answer is fine.
   (d) (i) $6.6890704 \times 10^{-27}$ kg
   (ii) $6.6818802 \times 10^{-27}$ kg
   (iii) 7.19×10^{-30} kg (or could write as 0.00719×10^{-27} kg)
   (e) The mass has decreased because energy is released in the nuclear reaction. Calculate the energy release by using $E = mc^2$, putting the mass decrease in for m, and $c = 3 \times 10^8$ m/s. This gives 6.471×10^{-13} joules released (per reaction).
   (f) Multiplying the (joules per reaction) times (1.5×10^{26} reactions per kg) gives 9.7×10^{13} joules released per kg of deuterium.
   (g) Dividing the answer to part (f) by the answer to part (c) gives about 24 million! (or 22 million depending on your answer to part c) Thus, in this example, 24 million times as much energy is released in the nuclear reaction of 1 kg of material as in the chemical reaction of 1kg of another material. This is typical--nuclear reactions yield millions of times the energy of chemical reactions.

2. (10 points) In beta-decay, one of the neutrons changes into a proton plus an electron (plus an exotic particle called an "anti-neutrino"). A Helium-6 nucleus contains 2 protons and 4 neutrons. So we now have an additional proton, for a total of 3, but one less neutron, leaving only 3. So the nucleus is now Lithium-6. The electron is emitted from the nucleus, along with the anti-neutrino.

$$^{6}He \rightarrow {}^{6}Li + electron + anti - neutrino$$

3. (10 points) An alpha particle is a helium-4 nucleus, which consists of 2 protons and 2 neutrons.
   When Polonium-210 (84 protons and 126 neutrons) undergoes alpha decay, it emits an alpha particle, leaving behind 82 protons and 124 neutrons, which is Lead-206.

$$^{210}Po \rightarrow {}^{206}Pb + {}^{4}He$$

4. (10 points) In gamma decay a nucleus in an excited state decays to a lower-energy state by the emission of a high-energy photon. This decay is the nuclear analogue of the emission of light by atoms. The nuclear isotope is unaffected.

$$^{107}Ag^{*} \rightarrow {}^{107}Ag + \gamma$$

5. (5 points) If you count up the number of protons and neutrons on each side of the equation, you’ll find that 55 neutrons and 35 protons must be contained in the missing nucleus. This is Bromine-90.

6. (10 points) If we start with 100 atoms, after one half-life we will have about 50 left, then 25, then 12.5?, then 6.25?? Those are the numbers we get if we divide by two for each half-life, but of course it's impossible to have a fractional number left. The resolution of that paradox is that after each half-life approximately half of the remaining nuclei decay, but it's a probability event, so we can never know for sure. When applying statistics, one hundred is a pretty small number, but if we start with, say, a billion, then we can be pretty confident that we'll have very close to 62.5 million atoms left after 4 half-lives.

7. (15 points) Questions about Trinity site.

   (a) Summary of Einstein’s letter to President Roosevelt.
   (b) The next open house is scheduled for Oct. 6, 2007, but there was one in April 2007 too, before I wrote these solutions, so either answer is fine. Visiting the Trinity site now (more than 60 years after the first Atomic Bomb test there) is not dangerous. According to the Army’s web site:

A one-hour visit to the inner fenced area will result in a whole body exposure of one-half to one millirem. To put this in perspective, a U.S. adult receives an average of 360 millirems every year from natural and medical sources.

   (c) The photo taken 15 seconds after detonation shows a bright fireball in the well-known mushroom-cloud shape. In round numbers sound through air travels about $1/5^{th}$ of a mile per second. So a person stationed 10 miles from the bomb would have to wait 50 seconds before the first sound from the explosion reached him. Until that time, he would see the explosion but not hear it. He would experience it in complete silence.

8. (20 points)

(a) I just used the letter **E** below, but you should have used four or five letters of your choice.
(b) You **<u>must</u>** include your actual drawing for full credit.
(c) The **E** below is composed of lines of thickness 2.5 mm.
(d) A person with normal vision can resolve lines that encompass 1/60th of a degree. Using a little trigonometry, this works out to:

$$(\text{thickness of lines within letters}) = 0.00029\ (\text{distance to letters})$$

and this was the formula stated in class. Using a line thickness of 2.5 mm, this gives a distance of 8621 mm, or about 28 feet (<u>calculated distance</u>).

(e) I had to stand 25 feet away to confidently read the letter **E** below, so this is the <u>measured distance</u>.
(f) Using $x = 20*(\text{calculated distance}/\text{measured distance})$ gives $x = 22.4$. So I have about 20/22 vision, which is a little worse than normal vision. And this was done with my glasses on.
(g) This sounds about right, since when I last got my prescription changed, I had about 20/20 vision with my glasses on, but apparently my sight has worsened a bit.