PHYS 102-Concepts of Physics II-Spring 2003
Solutions to Homework #4
100 points possible

1. (28 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 give millions of times the energy of chemical reactions.

2. (15 points) After one half-life, the carbon-14 activity would reduce from 12.4 decays per minute to 6.2 decays per minute, and in an additional half-life from 6.2 down to 3.1. Thus this sample is 2 half-lives (or whatever the plural of half-life is) old, which is 11,460 years.

3. (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.

4. (16 points) (a) An alpha particle is a helium-4 nucleus, which consists of 2 protons and 2 neutrons.
   (b) radium is atomic number 88, so it has 88 protons. The 226 is the number of neutrons plus the number of protons. Thus radium-226 consists of 88 protons and 138 neutrons
   (c) When radium-226 undergoes alpha decay, it emits an alpha particle, leaving behind 86 protons and 136 neutrons, which is radon-222.

(d) yes, the number of protons is the same before and after the reaction, as is the number of neutrons. this is because, in alpha-decay, no particles change into other particles.

5. (12 points) (a) oxygen is atomic number 8, so oxygen-19 has 8 protons and 11 neutrons
(b) In beta-decay, one of the neutrons changes into a proton and an electron (and an exotic particle called an "anti-neutrino"). So we now have an additional proton, for a total of 9, but one less neutron, leaving only 10. So the nucleus is now fluorine-19. The electron is emitted from the nucleus, along with the anti-neutrino.
(c) Before the reaction, we had 8 protons and 11 neutrons, and after the reaction we have 9 protons and 10 neutrons, so the number of each is NOT the same. The reason for this, of course, is that one of the neutrons changed into a proton plus other stuff.

6. (4 points) Yes, in fact this is exactly what happens during Beta decay. In problem #5, above, ^{19}O decays into ^{19}F. Fluorine is "forward" of Oxygen on the periodic table.

7. (15 points)

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

(thickness of lines within letters) = 0.00029 (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 (calculated distance).

(d) I had to stand 25 feet away to confidently read the letter **E** below, so this is the measured distance.
(e) Using x = 20 (calculated distance/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.
(f) 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.