Physics 252 – **Modern Physics**

Homework Assignment #11

Due **Monday**, April 30, 2007 (the last day of class)

Reading: Feynman chapters 16 and 19; Born chapter VII; Fowler (General Relativity); Weinberg. There is much up-to-date information on the web, in particular in the archive of scientific papers at `http://arxiv.org/` . For example, a summary of CMB studies is at http://arxiv.org/abs/astro-ph/0604101; WMAP data is at http://arxiv.org/abs/astro-ph/0603449; results on the high-z supernova are at `http://arxiv.org/abs/astro-ph/0402512` .

1. One of the ways ${}^{235}_{92}U$ can fission is by absorbing a neutron and converting to the short-lived state ${}^{236}_{92}U$, which promptly decays into

   $$ {}^{99}_{40}Zr \ + \ {}^{134}_{52}Te \ + \ 3 \text{ neutrons} $$

   Look up the masses of these isotopes and find the energy released if one gram of ${}^{235}_{92}U$ is fissioned in this way (don't forget to include the mass of the neutron absorbed).

2. The Z boson is a particle which "carries" the weak interactions (in the same sense that the photon carries electromagnetism). Unlike the photon, it is massive, and it decays. Its most dominant decay product is an electron and a positron. If a Z at rest decays, what is the velocity of the electron and positron?

3. I shine a light horizontally across a room of length $20\,m$. Because of gravity, it lands a distance d lower than it would have in the absence of gravity. What is d?

4. By how much time every day does one need to correct the clocks on the GPS satellites due to the effects of general relativity? You'll need to look up the altitude of the satellites. The satellites are high enough to make g much smaller there, so to get the answer you need to calculate the time difference due to a height difference Δh small enough to treat g as constant, and then integrate this as a function of h.

5. Derive the formula for the Doppler shift, including the effects of special relativity. In other words, your formula should be valid for relative velocities up to the speed of light. Use this formula to derive the velocity of the $z = 1.7$ supernova relative to us.

6. What is the radius (in meters) of the event horizon of the black hole believed to be at the center of our galaxy? Its mass is about 4 million solar masses.

7. Suppose that observations gave a different Hubble relation, so that objects a distance d away were moving away from us with a relative velocity given by $v = \tilde{H} d^2$ instead of the actual $v = Hd$. Show that this would mean that the universe is not homogeneous.

8. Say your height was increasing at the same rate the universe is. By how much would your height have increased after a year?

9. Find the value of frequency which has the greatest photon density in the current cosmic microwave background. What is this frequency when CMB was at a temperature $3000\,K$? What sort of light is this?