ASTR 220 Quiz Solutions
Spring 2005

Short Answer. Your test may have had these questions in a different order.

1. *(7 pts) Using the concept of spacetime, explain why an object falls when you drop it.*

   Einstein's theory of general relativity says that space and time are one thing: spacetime. The first three dimensions of spacetime are length, width, and depth, like we are used to, and the fourth dimension is time.

   According to general relativity, mass causes spacetime to curve and make a depression or well. The more mass, the more spacetime curves and the deeper the well. The curvature of spacetime is what we see as gravity. For example, the Earth has a lot of mass compared to any of the objects on its surface. The Earth's mass curves spacetime a lot compared to the mass of objects on its surface. When we pick up an object and drop it, the object fall to the Earth's surface because it is rolling "downhill" in spacetime into the "well" of the Earth's gravitational force.

2. *(8 pts) White dwarfs, neutron stars, and black holes are sometimes called stellar remnants. Explain why the stellar remnants with the most mass have the smallest radii.*

   The more mass an object has, the greater its gravitational force on itself. The lowest mass stellar remnants, white dwarfs, have the weakest gravitational force on themselves. Consequently, they cannot compress themselves past the roadblock of electron degeneracy pressure and therefore have the largest radii.

   A neutron star has more mass than a white dwarf. Its gravitational force on itself is stronger and has compressed itself past electron degeneracy pressure so that the protons and electrons combined to form neutrons. The neutron star continues to compress itself until it reaches the roadblock of neutron degeneracy pressure. At that point, its gravitational force is not strong enough to continue the compression.

   A black hole has more mass than a white dwarf or a neutron star. Thus it has the strongest gravitational force. It has compressed itself past the roadblocks of electron degeneracy pressure and neutron degeneracy pressure until it has shrunk into an infinitely small point: a singularity.

3. *(8 pts) We expect the surface of a neutron star to be extremely hot: about $1 \times 10^6 K$.*

   (a) *What is the wavelength of maximum brightness emitted by the neutron star, assuming it emits an continuous spectrum?*

   We can use Wien's law to determine this.

   $$\lambda_{max} = \frac{0.0029 m \cdot K}{T} = \frac{0.0029 m \cdot K}{1 \times 10^6 K} = 2.9 \times 10^{-9} m$$

   (b) *What type of light would you guess this is? Explain why you would guess this.*

   You can use the Sun as a baseline for your guess. You know that the Sun's surface is cooler than the surface of the neutron star (it's 5800 K). The brightest wavelength of the Sun's continuous spectrum is in the visible range. Since the neutron star is hotter, the peak of its continuous spectrum must be in shorter wavelength light, which means it's ultraviolet, x-rays, or gamma rays. Any of these are acceptable answers. A check of Fig. 5.2 in the textbook shows that the wavelength corresponds to x-ray light.

4. *(7 pts) In a high-mass star, explain how the supernova explosion is created.*

   The last stage of fusion in the high-mass star leaves the star with an iron core. Iron cannot produce energy by fusing with any other element, so fusion stops. A lot of the outward pressure is lost, so the gravity of the star's core on itself compresses the core. As it shrinks, it reaches the roadblock of electron degeneracy pressure. In this case, the mass of the star's core is so large that the protons and electrons in the core are forced to combine and create neutrons. This reaction releases a huge number of neutrinos. The neutrinos immediately travel outward to escape from the star. A small fraction of them run into the matter in the star's outer layers. However, this small fraction is enough neutrinos that a lot of the kinetic energy from the neutrinos is transferred to the gas in the outer layers of the star, which causes shockwave in the outer layers. The outer layers are compressed by the shockwave, which heats up the gas until it glows very brightly. The gas is thrown outward in all directions from the supernova. The brightness and outward explosion are the supernova.