Study Questions for Lectures of April 3 to April 7

1) Give at least three examples of elements that are abundant on Earth, and explain, using our knowledge of the process of element formation in stars, why these elements are abundant.

2) After a star has burned all of its nuclear fuel (producing iron), two possible final outcomes for it are possible, depending on whether the mass remaining in the core of the star is greater than or less than about 3 times the mass of the sun. Describe these two possible outcomes and explain why the mass of the stellar core is crucial in determining which outcome occurs.

3) What is a pulsar, and why does it "pulse?"

4) Why is it necessary to talk about paths of objects in space-time, rather than just in space, to describe in a unified way what gravity does to objects?

5) What is the "Principle of Equivalence?" Give some examples. If you drop a rock and a sheet of paper, why might the result seem --- at first glance --- to violate the Principle of Equivalence? What is the explanation, and how could you see that the rock and paper don't actually violate the Principle?

6) What do airline routes tell us about curved spaces? Explain.

7) What is a geodesic? Give both its original meaning (referring to the Earth) and its general meaning (referring to arbitrary spaces or space-times).

8) Describe at least two ways that you could know if your space was curved without ever leaving the space. Make your answers concrete by using, as an example of a space, the two-dimensional surface of the Earth.

9) In discussing Einstein's theories, I described three key ingredients that motivated his understanding of gravity. Two of these ingredients dealt with features of gravity or its effects, and one dealt with the effects of being in a curved space. Describe these ingredients, and explain how Einstein's General Relativity incorporates or explains them.

10) How would Newtonian physics explain why a planet moves in a curved path around the sun? How would Einstein's General Relativity explain the same path?

11) During an eclipse in 1919, astronomers made careful measurements of the apparent position of a star that was in approximately the same direction from us as the sun. What prediction of General Relativity did those measurements confirm? Briefly explain why Einstein's theory makes that prediction.

12) What is "gravitational lensing?"

13) Using words or pictures, explain what a black hole is and why it is impossible to leave a black hole once you are inside. Why is Newton's theory of gravity inadequate to explain black holes?

14) In explaining why even some new, as-yet-undiscovered force would be unable to stop the collapse of a star to a black hole, I used the term "gravitational judo." What is "gravitational judo?"

15) When General Relativity is applied to the universe as a whole, we find there are three possible shapes for the universe. What are those three shapes? Be sure to say which shape(s) is (are) infinite in extent and which shape(s) is (are) finite in extent.

16) An assumption that goes into proving the previous result (that there are 3 possible shapes for the universe) is that the universe is "homogeneous." What does that mean? Reconcile the statement that the universe is homogeneous with the obvious fact that our classroom, the Earth, the solar system, the Milky Way, and even our local cluster of galaxies are definitely ***not*** homogeneous.

17) The world we live in has three spatial dimensions --- objects can move in any of three independent directions: right-left, forward-back, or up-down. How can you reconcile that obvious fact with the statement that our universe might be "flat?" Wouldn't "flat" mean objects could only move in two directions?

18) How is the density of energy (or mass) in the universe related to the shape of the universe?

19) Before the time of decoupling, photons smoothed out any "small" lumps in the distribution of matter. Explain why. Further, explain why the photons didn't (couldn't) smooth out "big" lumps. What is the size that distinguishes "small" from "big" in this context?

20) What is the shape of our *observable* universe? Explain in some detail how we know this from measurements of the cosmic microwave background.