CHAPTER 23: FROM SPECIAL TO GENERAL RELATIVITY

Reading:

Chapter 23 and also Secs. 24.2, 24.3 and 24.4 of Blandford & Thorne. Note: much of Chapter 23 is review of things learned in Chapter 1, so it should not take as long to read as you might think, looking at the length. Students who were not in this class first term may need to read some sections of Chapter 1, which are cross referenced in Chapter 23. Students who were not in this class second term should read the introduction to Connection Coefficients in Sec. 10.3.

Symbolic Manipulation Software:

Many calculations in general relativity are routine but complicated. Examples that we shall encounter in this course are calculations of the connection coefficients and curvature tensors in various bases and various spacetime geometries. In recent years such calculations have been carried out by most students and researchers using symbolic manipulation software on computers. Some of the exercises in this course will entail such calculations, so you will need to learn to use such software.

There are a number of different software packages that have the capability for such calculations; for a list with web links, see

http://grtensor.phy.queensu.ca/links.html

Among the available packages, the one that is easiest to learn and use is *GRTensor*. The most powerful version is GRTensorII and runs under Maple, but there is a version GRTensorM that is quite adequate for this course which runs under Mathematica. Both are available free at the web site

http://grtensor.phy.queensu.ca/

in the section "Software". GRTensor is also available on the *Wonderland* computers on the third floor of West Bridge. I am passing out to the class the details of a solution to Exercise 23.6(c) that I produced using GRTensorM under Mathematica. I had never used GRTensor before, when I did this exercise; it took me about two hours to download it from the web, implement it on my computer, and figure out how to solve this exercise.

Many professional relativists prefer the software *MathTensor*, which runs under Mathematica but is not free. It is more powerful than GRTensor for many types of calculations. *Macsyma* (an alternative to Mathematica and Maple) has tensor-manipulation capabilities built right in; you don't have to add them via GRTensor or MathTensor. I, personally, have found Macsyma quite useful for some types of calculations. (It also has the virtue of an associated, excellent finite-element package called *PD2Ease*, for solving partial differential equations numerically.)

TA:

This problem set will be graded by Alexander Putilin.

Problems

NOTE: The students in this class have a wide variety of backgrounds in relativity theory, so problems that are appropriate for some students are inappropriate (too sophisticated or too elementary) for others. Choose four problems appropriate for you from the following selection. At least one of your problems should entail computation of connection coefficients on a computer [Ex. 23.5 or Ex. 23.11(b)].

Ex. 23.2: Causality
Ex. 23.4: Index manipulation rules from duality
Ex. 23.5: Connection coefficients for circular coordinates
Ex. 23.7: Stress-energy tensor for a perfect fluid
Ex. 23.10: Stress-energy tensor for a point particle
Ex. 23.11: Proper reference frame
Ex. 23.12: Uniformly accelerated observer
Ex. 24.3: Geodesic equation in an arbitrary coordinate system