MA489 SPECIAL TOPICS COURSE IN GENERAL RELATIVITY PRELIMINARY SYLLABUS

DR. CHRIS MOSELEY

ABSTRACT. This is a preliminary syllabus for an MA489 course on General Relativity, based on the text *Gravity* by James B. Hartle of UC Santa Barbara. This course is intended to give math and physics majors an introduction to Einstein's theory of gravity. It is not intended to be easy: the demands on the students' mathematical abilities and physical intuition will be substantial. The syllabus outlined here is provisional and very much subject to future revision.

1. INTRODUCTION

Einstein's General Theory of Relativity (commonly abbreviated as GR) is renowned for its profound insight into the nature and dynamics of the gravitational field. It also has a reputation for being exceptionally difficult to understand. Many texts on the subject assume basic familiarity with tensors and other tools of differential geometry, placing them out of the reach of all but a few undergraduates.

This special topics course will be based on James Hartle's text *Gravity* [1]. According to the author, the material in this text has been used successfully in teaching junior and senior level students at the University of California, Santa Barbara, for over twenty-five years. It is the first text that I have seen that genuinely seems suited for undergraduate instruction, and this persuaded me to suggest that a course on GR be offered at USMA. Due to unexpectedly enthusiastic student demand, we're going ahead with it!

The course outlined below has the following pedagogical goals: (1) to communicate the fundmental physical ideas in Einstein's theory of gravity; (2) to use this as a vehicle for introducing students to some beautiful and valuable mathematical concepts; and (3) to explore some practical applications of the theory (such as effects on the Global Positioning System). Although the text is intended for undergraduate use, prospective students should be aware that this course will not be easy. To understand even the basics of GR requires much study and mathematical ability.

2. TEXTBOOKS

1) James B. Hartle, *Gravity*, Addison Wesley, San Francisco, 2003
2) Larry Niven, *Protector*, Ballantine Books, New York, 1973

James Hartle's *Gravity* introduces students to the ideas of GR by considering physical ideas first, and introducing mathematical ideas as needed. This is a change from the traditional approach to teaching GR, in which tensor calculus takes first place and physical ideas come later. The traditional approach makes logical sense but Dr. Hartle's approach is better suited for an introduction to the subject.

The second text, Larry Niven's *Protector,* is a science-fiction novel which makes clever (and accurate) use of both special and general relativity, culminating in a space war at

relativistic speeds. I've assigned it partly for sheer entertainment, but also because the story makes the physics of SR and GR come alive.

3. Provisional syllabus

This is a one-semester course with two midterms, a final exam and possibly one or more computer-based projects. There will also be a substantial amount of homework. An outline of the topics to be covered follows.

I. Fundamentals (ch. 1 - 5 in [1])
   A. Geometry in physics
   B. Newtonian gravity
   C. Special relativity

II. Gravity and curved spacetime (ch. 6 - 8 in [1])
   A. The Equivalence Principle
   B. The metric on curved spacetime
   C. Geodesics

III. Predictions (ch. 9, 12, 13, 17-19 in [1])
   A. Spacetime near a spherical star
   B. Schwarzschild black holes
   C. The expanding universe and cosmology

4. Grading

Grading will be allocated according to the following percentages (subject to change):

- Homework / quizzes: 20%
- WPR 1: 20%
- WPR 2: 20%
- Project: 10 %
- TEE: 30%

References

[1] James B. Hartle, *Gravity*, Addison Wesley, San Francisco, 2003
[2] Larry Niven, *Protector*, Ballantine Books, New York, 1973

Department of Mathematical Sciences, U.S. Military Academy, West Point, NY 10996
E-mail address: Chris.Moseley@usma.edu