MATHEMATICS 4130
INTRODUCTION TO GENERAL RELATIVITY

This course will provide an introduction to Einstein's theory of general relativity. It will begin with Minkowski spacetime and the corresponding geometrical foundation of special relativity. Particular attention will be paid the relationship between geometry and causality and the relativistic mechanics of particles. We will then introduce curved spacetimes and study their geometry with the help of the metric tensor and geodesics. Using these tools we'll see how the geometry may be reinterpreted as a gravitational field and geodesics as freely falling reference frames.

The second part of the course will study the most important exact solutions of Einstein's equations: Schwartzschild and Kerr black holes and the Friedmann-Robertson-Walker cosmological solutions. These will be studied both as four-dimensional geometric objects and as models of real, physical phenomena. Along the way we'll examine black hole singularities, the nature of an event horizon, what "time" actually means in the presence of such extremes, the twisting of spacetime by rotating black holes and simple descriptions of the big bang. If time permits, we will also consider approximate solutions such as gravitational waves.

Finally, having understood these solutions we'll actually discuss Einstein's equations themselves. We'll motivate them from basic principles and then introduce the machinery of tensor calculus and in particular such things as the covariant derivative, the Riemann curvature tensor, and the stress-energy tensor to translate those principles into mathematics.

Texts. Two possibilities are *Gravity: An introduction to Einstein's General Relativity* (Addison-Wesley) by James Hartle, and *An Introduction to General Relativity: Spacetime and Geometry* (Addison-Wesley) by Sean Carroll.

Marks. While the exact formula may vary from semester to semester, it is typical to assign 50% to term work (20% for the midterm test and 30% for assignments) and the remaining 50% for a final exam.

Calendar description. **4130 Introduction to General Relativity** (same as Physics 4220) studies both the mathematical structure and physical content of Einstein's theory of gravity. Topics include the geometric formulation of special relativity, curved spacetimes, metrics, geodesics, causal structure, gravity as spacetime curvature, the weak-field limit, geometry outside a spherical star, Schwarzschild and Kerr black holes, Robertson-Walker cosmologies, gravitational waves, an instruction to tensor calculus, Einstein's equations, and the stress-energy tensor.
Prerequisites: Mathematics 3202 and one of Physics 3220, Mathematics 4230 or permission of the Head of Department. Mathematics 4230 may be taken concurrently.

Offered. Alternate Winters