Physics 471-01: Introduction to General Relativity and Cosmology

Fall 2019 | Department of Physics, Loyola Marymount University

Lecturer: J. R. Mureika
Class meetings: MW 12:40-14:10, Seaver 109
Office (hours): Seaver 102A (M 14:15-15:15, W 11:00-12:00, R 13:15-14:15, or by appointment)
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Outline:

Einstein's Theory of General Relativity (GR) is perhaps one of the greatest achievements of theoretical physics in the 20th century. Almost a century later, it has masterfully withstood every experimental test and continues to provide a satisfactory explanation for new observations. This course will explore the physical and mathematical foundations of GR, including tensor mathematics, manifolds, curvature, and differential geometry. Einstein's equations are derived and their solutions – spacetime metrics – are discussed, specifically the Schwarzschild, Reissner-Nordström, and Kerr-Newman metrics. Associated black hole solutions will be examined. Lastly, applications of GR to observation, *i.e.* cosmology and gravitational waves, are examined and the relevant equations and metrics are derived. Alternate theories of gravity will be described for comparison, as well as current perspectives on quantum gravity.

Learning Outcomes: By the end of this course, you will:

- Understand the link between spacetime curvature and matter.
- Appreciate the impact of Lorentz invariance in physics.
- Understand the importance of geodesics and the equivalence principle.
- Differentiate coordinate and physical singularity behavior in black hole solutions.
- Appreciate the limitations of GR and cosmology in light of experimental evidence.

Math background: This course requires an advanced knowledge of calculus (MAT 234), differential equations (MATH 245), and linear algebra (MATH 250). Familiarity with group theory (MATH 331), topology (MATH 471), and differential geometry (MATH 473) is useful, but not required. You should know how to use Maple and/or Mathematica for heavy-duty equation solving, as we will make extensive use of this to calculate and solve otherwise-daunting coefficients and equations.

Textbooks and Reading:

- Required: *Gravity: An Introduction to Einstein's General Relativity,* James B. Hartle (ISBN 0-07-239714-4)

  Other relevant material will be distributed in handout form and/or as a downloadable document on the website. Readings will generally be assigned for each upcoming class. *Please be sure to complete them prior to coming, and bring questions*!

Marking scheme:

Problem sets	10 @ 4%	40%
Midterm exam	1 @ 30%	30%
Final exam	1 @ 30%	30%
Total:		100%

A	95-100%	C+	76-79%
A-	90-94%	C	73-75%
B+	86-89%	C-	70-72%
B	83-85%	D	60-69%
B-	80-82%	F	0-59%

Problem Sets: There will be 10 problem sets distributed at regular intervals during the term. In addition to usual problem solving, some may also be focusing on numerical and symbolic solution techniques using Maple/Mathematica or other computer applications. Problem sets must be submitted *in class* on the due date indicated, and will not be accepted for credit beyond that time.

Midterm exam: The midterm exam will be a **48 hour take-home format**. It will be available for pick-up **Monday 07 October** at the beginning of class.

Final Exam: The final exam will be cumulative, and will also be a **take-home exam** written during finals week**.** Details will be specified as the course proceeds.

Attendance: Class attendance is strongly encouraged in order for you to master the material. Three unexcused absences will result in a full letter grade reduction, as will each subsequent unexcused absence. A maximum of six unexcused absences will result in ***failure of the course***. Any medical-related absence *must* be documented by appropriate documentation from the attending physician, or this will count as an unexcused absence.

Class conduct advisory: The use of cellular phones, PDAs, and other electronic equipment is not allowed during class time. Cell phones must be set to vibrate before entering the classroom and must be kept inside a backpack, purse or pocket. Bluetooth earpieces must be removed and music players must be put away before entering the classroom. Emergency communications are exempted.

Statement of Academic Honesty: Academic dishonesty will be treated as an extremely serious matter, with serious consequences that can range from receiving no credit for assignments/tests to expulsion. It is never permissible to turn in any work that has been copied from another student or copied from a source without properly acknowledging the source. It is your responsibility to make sure that your work meets the standard of academic honesty set forth in the "LMU Honor Code and Process" in the Undergraduate Bulletin 2008-2010 pages 61 – 64.

THIS SYLLABUS AND ITS CONTENTS ARE SUBJECT TO REVISION; STUDENTS ARE RESPONSIBLE FOR ANY CHANGES OR MODIFICATIONS ANNOUNCED IN CLASS, ON THE CLASS WEBSITE, OR VIA EMAIL.