Introduction to String Theory

Prof. Sera Cremonini

Instructor's Contact Information:

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Course Information:

PHY 366, Spring 2025
Time: Tuesday, Thursday 9:20-10:35 am
Location: Room 512, Physics Building
Website: https://coursesite.lehigh.edu/

Course Description

This course is an introduction to string theory for upper-level undergraduates and beginning graduate students. Building on concepts from Einstein's theory of general relativity and quantum theory, the course will expose students to the fundamentals of string theory and to some of the latest developments in the field. Advanced topics such as D-branes, non-perturbative dualities and holography will also be covered. The material will be accessible to students who have a working knowledge of quantum mechanics and special relativity, and have had some exposure to general relativity.

Required Textbook

"A first course in string theory" by Barton Zwiebach.

Additional References (not required, of various levels)

- "The Little Book of String Theory" by Steven S. Gubser (introductory level)
- "String Theory For Dummies" by A. Z. Jones and D. Robbins (introductory level)
- "String Theory", Volumes I and II, by Joseph Polchinski (advanced, requires knowledge of QFT)
- "String Theory in a Nutshell" by Elias Kiritsis (advanced, requires knowledge of QFT)
- "Supersymmetry and String Theory: Beyond the Standard Model" by Michael Dine (advanced)
- Useful Websites:
    - http://www.superstringtheory.com/
    - http://www.sukidog.com/jpierre/strings/
    - https://www.quantamagazine.org/20150803-physics-theories-map/
    - http://whystringtheory.com/

Grading:

Students will be graded on the basis of class participation, homework assignments, quality and depth of their presentation and writing assignment. The grades will be determined as follows:

- Homework 50%
- Presentation 10%
- Final paper 30%
- Class participation 10%

Grading Scale

A = 88 – 100 B = 75 – 87 C = 62 – 74 D = 50 – 61

Student Assessment Criteria:

- **Homework** will be assigned on a weekly or by-weekly basis, depending on difficulty level.
- **Final Paper:** Each student should choose a topic they find fascinating and inspiring, related to anything discussed in class, and write a review paper on the subject, appropriately citing background material. A list of possible topics will be provided by the instructor as a guide, but students are free to choose their own topic.
- **Presentation** on the topic chosen for the Final Paper. The purpose of the presentation is to help students think critically about how they would structure their final paper, and to learn to present material in front of a wide audience. This is a skill that they will find useful as they progress in their career. We will reserve a few lectures in the last part of the semester for this purpose.
- **Class Participation** is strongly encouraged and may determine borderline grades.

Initial competences: Working knowledge of special relativity and quantum mechanics.

Final Competences:

The students are expected to:

- Gain an appreciation for the major developments in particle physics, gravity and cosmology over the last few decades
- Develop a basic understanding of the motivation for string theory as a candidate theory of quantum gravity
- Refine their knowledge of special relativity, and develop intuition for the equations of general relativity (Einstein's equations) and properties of black holes
- Learn some of the analytical and technical skills needed to approach simple problems in general relativity and string theory
- Attain a basic understanding of how one can describe the motion of a relativistic string and its vibrational modes
- Gain an appreciation for the fundamental aspects of the holographic gauge/gravity duality and how they can be applied to strongly interacting quantum systems
- Become familiar with some of the main ingredients needed to build string theory models for the early evolution of the universe and particle phenomenology
- Learn to perform literature searches and present work to a wide audience, by preparing written and oral presentations.
- Learn to write scientific, research papers.

Accommodations for Students with Disabilities:

Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this

letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

The Principles of Our Equitable Community:
Lehigh University endorses The Principles of Our Equitable Community
[http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf].
We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

Summary of Topics

- **Historical Introduction**
- **Special relativity and extra dimensions**
- **Electromagnetism in various dimensions and relativistic electrodynamics**
- **The relativistic point particle**
- **The relativistic string**
- **Parametrizing the motion of a string and its physical interpretation**
- **Vibrational modes of a string and quantization**
- **The graviton from string theory**
- **D-branes**
- **Black holes and thermodynamics**
- **Counting microstates of a black hole**
- **Misc topics depending on time, potentially including:**
    - **Holography and the gauge/gravity correspondence**
    - **Cosmological models from string theory and particle phenomenology**
    - **Quantum Gravity constraints on low energy physics**