# Syllabus for Physics 234A: String Theory I

This course will provide a systematic introduction into the basics of string and superstring theory. In particular, it will concentrate on developing the basic structure of string perturbation theory, and will introduce many of the major ingredients needed for understanding the nonperturbative string-theory phenomena as covered in 234B.

## Week-by-week outline of topics:

**Week 1:** Quantization of the free bosonic string; string action, worldsheet gravity; covariant quantization, light-cone gauge, absence of ghosts, critical dimension.

**Week 2:** BRST quantization of the string action; BRST symmetry and cohomology; definition of physical states; closed and open string.

**Week 3:** String perturbation theory; moduli spaces of Riemann surfaces, scattering amplitudes at tree level and at one loop; the string coupling and the dilaton.

**Week 4:** Two-dimensional conformal field theories; representation theory of the Virasoro algebra; affine Lie algebras and Kac-Moody symmetries; bosonization, WZW models.

**Week 5:** Superstrings in the Neveu-Schwarz formulation with worldsheet supersymmetry; GSO projection, Type IIA, IIB and Type I superstrings, Type 0A,B theories.

**Week 6:** Green-Schwarz formalism and spacetime supersymmetry; Goldstone's theorem and spontaneous breaking of spacetime symmetries by branes; light-cone quantization of the GS superstring.

**Week 7:** Superconformal field theories in two dimensions; representation theory of super Virasoro algebras with various degrees of supersymmetry; chiral rings; spectral flow.

**Week 8:** T-Duality for closed and open strings; dualities in 2d CFT; Type I′ theory; orbifolds and orientifolds.

**Week 9:** D-branes and other solitons in string and superstring theory; perturbative description of D-branes in terms of open strings; tension and Ramond-Ramond charge of D-branes.

**Week 10:** Toroidal compactifications and the heterotic string; $\mathrm{Spin}(32)/\mathbf{Z}_2$ and $E_8 \times E_8$ theories; bosonization on the heterotic worldsheet.

**Week 11:** Strings in background fields, Einstein's equations from string theory; renormalization group flows in two dimensions.

**Week 12:** Spacetime effective supergravity, anomaly cancellation for Type IIB, Type I and heterotic strings; the Green-Schwarz mechanism.

**Week 13:** Elements of Calabi-Yau and flux compactifications, $N = 1$ supersymmetry in four dimensions from string theory.

**Week 14:** Elements of particle phenomenology and cosmology from string compactifications.

**Week 15:** Introduction to the topological string and perturbative mirror symmetry; BRST formulation of topological field and string theories.

## Reading list:


[1] J. Polchinski, *String Theory, Vol. 1: An Introduction to the Bosonic String* (Cambridge University Press, 1998)

[2] J. Polchinski, *String Theory, Vol. 2 Superstring Theory and Beyond* (Cambridge University Press, 1998)

[3] M.B. Green, J.H. Schwarz and E. Witten, *Superstring Theory, Vol. 1: Introduction* (Cambridge University Press, 1987)

[4] M.B. Green, J.H. Schwarz and E. Witten, *Superstring Theory, Vol. 2: Loop Amplitudes, Anomalies & Phenomenology* (Cambridge University Press, 1987)

[5] K. Becker, M. Becker and J.H. Schwarz, *String Theory and M-Theory. A Modern Introduction* (Cambridge University Press, 2006)


## Course requirements:

Weekly homework assignments (40% of the grade), participation in weekly discussions (20% of the grade), final reading assignment and presentation or term paper (40% of the grade).