String Theory I (PHY 622)

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Mon & Wed 9:30 – 10:50 in the YITP common room

We start from scratch, and introduce in the fall semester the following four subjects:

- Bosonic string,
- Spinning string,
- T-duality,
- D-branes.

The requirements for this course are some basic quantum field theory (QFT) and some elementary General Relativity (GR). More in detail:

QFT: the actions for a real massless scalar field and for Maxwell theory ($\mathcal{L} = -\frac{1}{2}\partial_\alpha\phi\partial^\alpha\phi$ and $\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu}$); the canonical quantization of a scalar field in 4 dimensions, also its path integral quantization ($p = \frac{\partial}{\partial\dot{\phi}}L$ and $Z(J) = e^{\frac{i}{\hbar}S+\int J\phi d\sigma dt}$);

GR: general coordinate transformations of tensors in curved space; the Hilbert-Einstein action and its field equations.

Typed notes are handed out in class. There are weekly homework assignments, and (for those who are interested) the solutions to the homeworks are discussed every week in a special session.

At the end of the fall semester there is both a written and an oral "exam". (This "exam" is often an opportunity to discuss issues that were not clear to you even after study.)

We teach "interactively": questions are most welcome and you can come to our offices whenever you get stuck. Here is a detailed list of topics (they will all be explained, and none is assumed to be known).

Bosonic string.

1. Action ($\mathcal{L} = -\frac{1}{2}T\sqrt{-h}h^{\alpha\beta}\partial_\alpha X^\mu\partial_\beta X^\nu\eta_{\mu\nu}$)
2. Local worldsheet symmetries (E and W)
3. Rigid spacetime symmetries (Poincaré)
4. Field equations and boundary conditions in E-W gauge ($h_{\alpha\beta} = \eta_{\alpha\beta}$)

5. Mode expansions $\left(X^\mu(t,\sigma) = \frac{1}{2}\left(X_L(t+\sigma) + X_R(t-\sigma)\right)\right)$
6. Canonical quantization $([\alpha_m^\mu, \alpha_n^\nu] = m\eta^{\mu\nu}\delta_{m+n,0})$
7. Constraints $T_{\alpha\beta} = 0$ (the field equations of $h_{\alpha\beta}$)
8. Conformal symmetry and light-cone gauge $(X_{osc}^+ = 0)$
9. Mass formula and spectra (open and closed)
10. Introduction to covariant BRST quantization (b, c, d)
11. Covariant BRST quantization of strings (open and closed)
12. Cohomology of open strings (gives same spectra as before)
13. Cohomology of closed string (gives same spectra as before)

Spinning string. The same topics as for the bosonic string, but also a gentle introduction to rigid supersymmetry and supergravity (= local supersymmetry).

T-duality and D-branes

1. Closed bosonic string on a compact space and winding modes
2. A symmetry of the spectrum and T-duality of the closed bosonic string
3. T-duality and the open bosonic string lead to D-branes
4. T-duality of the closed spinning string–Type IIA vs Type IIB
5. T-duality of the open spinning string and D-brane charges
6. T-duality of Ramond-Ramond fields

D-brane solutions in supergravity–I do not know how much of this will fit into the first semester

1. Strings in curved backgrounds
2. Low energy effective actions and supergravity
3. M-theory and 11D supergravity
4. M-theory BPS solutions

5. Dimensional reduction to D=10
6. D-brane solutions in type IIA
7. T-duality and D-brane solutions in type IIB