8.251 QUIZ

B. Zwiebach Thursday May 6, 2004

Closed notes.

Duration: 30 minutes. **WRITE YOUR NAME HERE:**

Question 1. Let ω be the angular velocity of an open string that rotates rigidly about its midpoint, and let ℓ be the length of the string. Up to constants of proportionality, which of the following relations is true:

(a) $\omega \sim \ell$.

(b) $\omega \sim 1/\ell$.

(c) $\omega \sim \ell^2$.

(d) $\omega \sim 1/\ell^2$.

(e) None of the above.

Question 2. Let J denote the angular momentum of an open string that rotates rigidly about its midpoint, and let E be the energy of the string. Up to constants of proportionality, which of the following relations is true:

(a) $J \sim E$.

(b) $J \sim E^2$

(c) $J \sim 1/E$.

(d) $J \sim 1/E^2$.

(e) None of the above.

Question 3. Consider the light-cone *gauge* quantization of the relativistic point particle. Which of the following commutators vanishes?

(a) $[\,x^+(\tau)\,, x_0^-]$.

(b) $[\,x^+(\tau)\,, p^-\,]$.

(c) $[\,x^3\,, p^3]$.

(d) $[\,x_0^-\,, p^+]$.

(e) None of the above.

Question 4. Consider the light-cone gauge analysis of the *classical* open string. Mark the true statements with a T and the false statements with an F (write your marks to the left of the statements).

(a) The Virasoro modes $L_m^\perp$ are the modes of the coordinate X^-.

(b) A classical motion is completely specified by the values of the modes α_n^I, x_0^- and p^+.

(c) The lowest value of M^2 is negative and is attained by an excitation called the tachyon.

Question 5. The number of independent degrees of freedom of a graviton in ten spacetime dimensions is

(a) 55.

(b) 54.

(c) 36.

(d) 35.

(e) None of the above.

Question 6. Consider canditate closed string theory states. Write a Y/N (for yes/no) to the left of the states that belong/do not belong to the closed string state space:

(a) $|p^+, \vec{p}_T\rangle$.

(b) $\alpha_{-1}^I|p^+, \vec{p}_T\rangle + \bar{\alpha}_{-1}^I|p^+, \vec{p}_T\rangle$.

(c) $\alpha_{-1}^I\bar{\alpha}_{-2}^J|p^+, \vec{p}_T\rangle$.

(d) $\alpha_{-2}^{(2)}\bar{\alpha}_{-2}^{(3)}|p^+, \vec{p}_T\rangle$.

(e) $L_{-2}^\perp\bar{L}_{-2}^\perp|p^+, \vec{p}_T\rangle$.

Question 7. Consider the following statements concerning superstrings. Write a T to the left of the true statements and an F to the left of the false statements.

(a) The fermionic oscillators of the Ramond sector of the superstring are fractionally moded.

(b) The properly truncated Neveu-Schwarz sector of the superstring gives rise to the spacetime fermions of the theory.

(c) There is a unique ground state in the Ramond sector of the theory.

(d) At the massless level the open superstring contains a Maxwell gauge field and a fermion.

(e) The heterotic string is a closed string theory.

Question 8. Answer briefly (one line!) the following questions about type II closed superstring theories (the theories that arise by combining left and right copies of the open superstring):

(a) What are the four sectors of the theory.

(b) What sector of the theory contains the graviton, Kalb-Ramond field, and the dilaton?

(c) What sectors of the theory contain the spacetime fermions ?

(d) What kind of particles (bosons or fermions ?) arise from the R-R sector of the theory?

(e) What does supersymmetry tell you about the bosonic and fermionic excitations at any mass level of the superstring?

Question 9. Back to bosonic strings! Describe precisely the massless fields that live on the world-volume of a Dp-brane (assume $1 \leq p < d$, where d is the number of spatial dimensions).

Question 10. An orientifold Op-plane arises when one keeps the states of closed string theory that are invariant under a certain symmetry operation Ω_p. Describe what this symmetry operation does to the string coordinates $X^i(\tau, \sigma)$ along the Op-plane and to the coordinates $X^a(\tau, \sigma)$ normal to the Op-plane by filling the right hand sides below:

$$\Omega_p \, X^i(\tau, \sigma) \, \Omega_p^{-1} =$$

$$\Omega_p \, X^a(\tau, \sigma) \, \Omega_p^{-1} =$$