Imperial College London

MSc EXAMINATION June 2009

This paper is also taken for the relevant Examination for the Associateship

STRING THEORY SPRING 2009

For Students in Quantum Fields and Fundamental Forces

Friday, 8 May 2009: 14:00 to 17:00

Answer 3 out of the following 5 questions.
Marks shown on this paper are indicative of those the Examiners anticipate assigning.

General Instructions

Complete the front cover of each of the 3 answer books provided.

If an electronic calculator is used, write its serial number at the top of the front cover of each answer book.

USE ONE ANSWER BOOK FOR EACH QUESTION.

Enter the number of each question attempted in the box on the front cover of its corresponding answer book.

Hand in 3 answer books even if they have not all been used.

You are reminded that Examiners attach great importance to legibility, accuracy and clarity of expression.

Turn over for questions

1. Branes ending on Branes

Write down the equations for branes ending on branes for the case of a M2-brane ending on a M5-brane. Please include:

(i) The source equation. [10 marks]

(ii) The term in the action which indicates the interaction between the bulk gauge field and the field strength which is localized on the brane. [5 marks]

(iii) The corresponding Gauss Law, either in differential form or in integral form. [5 marks]

[Total 20 marks]

2. String theory in 8+1 dimensions with 32 supercharges

(i) Write down the little group in 8+1 dimensions and the three corresponding fundamental representations. Use a highest weight notation. [6 marks]

(ii) Compute the field content of the supergravity multiplet in 8+1 dimensions and with 32 supercharges. Specify the different fields and their transformation law under the little group. [8 marks]

(iii) Check that the number of bosonic and fermionic degrees of freedom match. [2 marks]

(iv) What is the dimension of the moduli space of vacua? [2 marks]

(v) Write down the coset space, G/H which is the scalar manifold of the theory, with G the maximally non-compact version of the E_n algebra and H is its maximal compact subgroup. [2 marks]

[Total 20 marks]

3. Branes in Maximally Supersymmetric String theory in 8+1 dimensions

(i) List all the 1/2 BPS branes in this theory. [6 marks]

(ii) Find the origin of these branes from M theory. [7 marks]

(iii) Find the origin of these branes from Type IIB. [7 marks]

[Total 20 marks]

4. Brane Tensions

(i) Write down the dimensionful parameters in M theory on T^2. [2 marks]

(ii) Write down the dimensionful parameters in Type IIB on S^1. [2 marks]

(iii) Write down the different half BPS branes in M theory. [2 marks]

(iv) Write down the different half BPS branes in Type IIB. [4 marks]

(v) Using tension formulas of the branes from M theory and from Type IIB find the duality relations between the M theory parameters and the Type IIB parameters. [10 marks]

[Total 20 marks]

5. Quantum Field Theory on the Brane

(i) Write down the massless bosonic fields that live on the world volume of a single Dp brane. [2 marks]

(ii) Count polarization modes and show the dependence on p. [2 marks]

(iii) Find the R symmetry group and determine the transformation laws of the bosonic fields under this group. [2 marks]

(iv) Write down the little group in $9+1$ dimensions and show how it brakes in the presence of the Dp brane. [2 marks]

(v) For the special case of $p = 9$ find the massless fermion on the world volume of the brane and write its transfomation law under the little group. [2 marks]

(vi) For the special case of $p = 3$ find the massless fermions on the world volume of the brane and write down their transformation laws under the little group and the R symmetry group. [2 marks]

(vii) Find the gauge theory living on the world volume of N Dp branes. Specify the bosonic content of this theory. How many supercharges are there for this theory? [2 marks]

(viii) Find the moduli space of vacua for this system of branes. [2 marks]
space of N Dp branes in Type II theory.

(ix) What is the gauge group on a generic point in the moduli space? Find the special points on the moduli space. What happens on these special points? [2 marks]

(x) Find the most general gauge symmetry on the moduli space. [2 marks]

[Total 20 marks]