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Department of Mathematics
Fourth Year Honours Thesis Topics

1. Geometry of gerbes and D-branes

In the mathematical theory of electromagnetic fields, we know that the phases of moving a point particle around a closed path can in part be described in terms of a U(1) bundle with connection, a system of locally defined 1-forms glued together via the U(1)-valued transition functions associated to the underlying bundle. In string theory, a particle is described as a tiny /openclosed string the phases of moving a string around can be described in terms of a U(1) gerbe with connection and a curving. This curving is a system of locally defined 2-forms called the "Kalb-Ramond field". The phase is sometimes called the holonomy along a closed surface (a closed trajectory of a string particle).

Strings can have various kinds of boundary conditions. Open strings can have different kinds of boundary conditions called Neumann and Dirichlet boundary conditions such that the endpoint of a string is fixed to move only on some submanifold, called the support of the D-brane. D-branes are actually dynamical objects which have fluctuations and can move around. All these require some deep understanding of geometry of gerbes. D-branes have found many interesting applications in theoretical physics and mathematics. This project would lay down some of mathematical ground for string theory.

2. K-theory and generalized index theory

K-theory and index theory provide fundamental connections algebraic topology, differential geometry and analysis, and have become indispensible tools to mathematical physics. The aim of this project is to help honour students to get some famililarity with these important mathematical results and to investigate various generalizations.

3. Topological invariants via gauge theory and string theory

Gauge theory studies principal bundle connections on a principal Lie group bundle. These connections correspond to gauge fields in physics, such as an electromagnetic field, and the Lie group of the principal bundle corresponds to the symmetries of the physical system. The space of connections satisfying certian non-linear partial differential equations is useful in low-dimensional topology. In fact, in Donaldson theory, the collection of Yang-Mills connections gives topological/differential invariants of 4-dimensional manifolds. In 1994, a new set of partial differential equations is introduced by Seiberg and Witten in their study of string theory, which led to a revolution in the field of low dimensional topology. This project is to explore various new topological invariants using topological field theory and dualities arising from gauge theory and string theory.