

NSERC USRA Summer 2019, Fall 2019, Winter 2020

Professor: Hadi Salmasian

First Project

Title: The Heisenberg group and uncertainty principle in mathematical physics.

Brief overview: One of the most remarkable features of quantum mechanics is *Heisenberg's Uncertainty Principle*, which roughly states that there is a limit to the precision of simultaneous measurements that can be made in particle physics. The classical mathematical model to explain this principle is based on an algebraic structure which is called the *Heisenberg group*. It is a miracle that the Heisenberg group appears in connection with many areas of mathematics, including number theory, analysis, and the theory of special functions.

The goal of this project is to study various connections of the Heisenberg group (and Heisenberg algebras) to mathematical physics, but also to other areas of mathematics, such as representation theory and harmonic analysis. This project is most suitable for students with a strong background in algebraic structures (groups, rings and fields) and undergraduate-level analysis.

Second Project

Title: Category theory and supergeometry.

Brief overview: Supergeometry is a mathematical theory that was introduced in the 1970's in connection with advancements in particle physics (e.g. supersymmetry, string theory, the standard model, the Higgs boson, etc. which are currently being studied by physicists using the Large Hadron Collider). The main idea of supergeometry is to replace geometric spaces with their "graded" analogues. Sometimes the objects are as simple as vector spaces and linear maps, but usually one works with more sophisticated and therefore more interesting objects.

It turns out that one can use categories and functors to construct objects of supergeometry. The goal of this project is to implement such a construction to obtain "reproducing-kernel vector spaces" in the super setting.

Students with a strong background in Algebraic Structures (MAT2143) are encouraged to apply. Familiarity with category theory is not needed, but will be an advantage.