# Department of Mathematics and Statistics

## 2015 PhD Projects

| | |
|---|---|
| **Project title** | Theory of Spin and Charge transport in Nanostructures |
| **Principal supervisor** | Andrey Umerski |
| **Second supervisor** | Uwe Grimm |
| **Discipline** | Applied mathematics |
| **Research area/keywords** | Theoretical Physics, Computational Physics, Quantum theory, Electron spin and charge transport, Spintronics |
| **Suitable for** | Mainly full time students, but exceptional part time students will be considered |

**Background**
Suitable students will have a strong background theoretical physics or applied mathematics, with a knowledge of undergraduate level quantum mechanics. Some computing experience is desirable. Full time candidates are preferred, but strong part-time candidates will be considered.

**Project description**
Spintronics is a hugely important scientific field which attempts to exploit the spin degree of freedom of the electron in addition to its electric charge. The field spans a huge area of scientific endeavour from theoretical physics to technology and industry. The physical quantity which describes the flow of spin through a structure is called the spin-current, and it is the spin-current which is the principal topic of this research proposal. There are a number of potential theoretical problems which could be investigated.

1. Asymptotic behaviour of spin-currents: A typical magnetic nanostructure consists of a Ferromagnet/Non-magnetic/Ferromagnet sandwich. The asymptotic behaviour of the charge current as a function of the non-magnetic component thickness is well understood and displays a rich behaviour. This topic would explore the asymptotic behaviour of spin-currents. It is hoped that this analysis could be extended to the behaviour of spin-currents in materials with strong spin-orbit coupling (e.g. $p$-type semiconductors like GaAs).
2. Spin currents in graphene. Graphene is currently of great scientific interest due to the enormous progress made on the experimental front in its manufacture (2010 Nobel Prize), and because of its unique and highly unusual electronic structure. The behaviour of spin-currents and spin-injection in Graphene is the topic of this project.
3. The behaviour of spin-current in so-called non-local geometries, where the spin current is physically separated from the charge current is of great theoretical and technological interest due to its potential application to magnetic-random-access-memory (MRAM). This topic would be explored in this project.

Other potential topics could also be explored, depending on the interests of the student. All these topics are closely allied to the research interests of the supervisor, and the program of research will explore one or more of these areas in collaboration with the principal supervisor.

**Background reading/references** See Andrey Umerski's home page on: http://mcs.open.ac.uk/au73/, and the recent papers cited there. More general background reading can be gained from Wikipedia, by typing keywords such as: *Spintronics*, *Tunnel magnetoresistance*, *Spin-transfer torque*, and following the links.