Graphene: Revisiting old questions in a new material

By

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Date: 13 January 2012, Friday
Time: 2.00pm to 3.00pm
Venue: Hilbert Space (PAP-02-02)
Host: Asst. Prof. Yu Ting

Abstract
From the hard-drives that harness giant magneto-resistance to the transistors that drive modern processors, solid state physics is at the very heart of the technological revolution. Implied in this effort is a thorough understanding of electronic systems in nanoscale geometries. In this context, the complex interplay between disorder, electron-electron interactions and quantum interference is an interesting backdrop to many of the unsolved mysteries in condensed matter physics. About five years ago, a new electronic material appeared – notable not only for its ease of preparation and theoretical simplicity, but also by its promise for future electronic devices [1]. Single monatomic sheets of carbon, known as graphene, have an electronic dispersion that is reminiscent of light, in that they can be described as a massless Dirac particle. In many ways, graphene is a textbook system to test physical models – for instance, similar to field-effect transistors, the electron density in graphene sheets can be modulated by a backgate. However, unlike conventional semiconductors, the carrier density can be continuously tuned from electron-like carriers for large positive gate bias to hole-like carriers for negative bias, with the Dirac point defined as the singularity that marks the transition from electrons to holes. When graphene is close to charge neutrality, its energy landscape becomes highly inhomogeneous, forming a sea of electron-like and hole-like puddles, which determine the properties of graphene at low carrier density. In this talk, I will discuss how the electronic properties of the Dirac point provide an intriguing example of how the competing effects of disorder, electron-electron interactions, and quantum interference conspire together to give a surprisingly robust state whose properties can be described using semi-classical methods. Armed with this success, I will discuss how future graphene experiments could shed light on some long-standing open questions in condensed matter physics.

References

Biography
Shaffique Adam is a theoretical physicist and a National Research Council Fellow with the Electron Physics Group at the Center for Nanoscale Science and Technology, a division of the National Institute of Standards and Technology in Gaithersburg, MD (USA).

Shaffique was born in Nairobi, Kenya. After completing his A-level studies in Kenya, he went on to Stanford University where he completed his bachelor of science, majoring in physics with a minor in mathematics. He graduated with both departmental honors and a University distinction. After spending 4 months as an exchange student at Magdalen college in Oxford University, Shaffique went on to pursue his doctorate in theoretical physics at Cornell University where he worked with Piet W. Brouwer on the magnetic properties of nanoscale conductors. He then moved to the condensed matter theory center at the University of Maryland where he worked with Sankar Das Sarma on the electronic transport properties of graphene.

Shaffique's background is in an area of mesoscopic physics that is concerned with understanding the properties of electrons in nanoscale conductors. In particular, he is interested in the interplay between quantum mechanics, disorder and many-body electronic interactions in these confined geometries. Nanoscale physics presents both fundamental challenges to our understanding of electronic phenomena, as well as the potential to harness these materials for improved technology. Shaffique has published over 30 manuscripts in prominent journals including Nature, Nature Physics, the Proceedings of the National Academies of Sciences and Physical Review Letters trying to understand the physical mechanisms at play in a variety of technologically important advanced materials including semiconductor quantum dots, magnetic nanoparticles, and graphene.

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