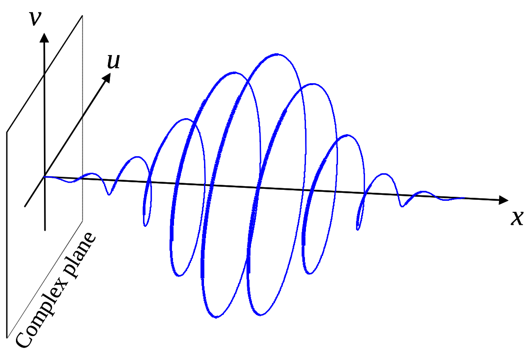
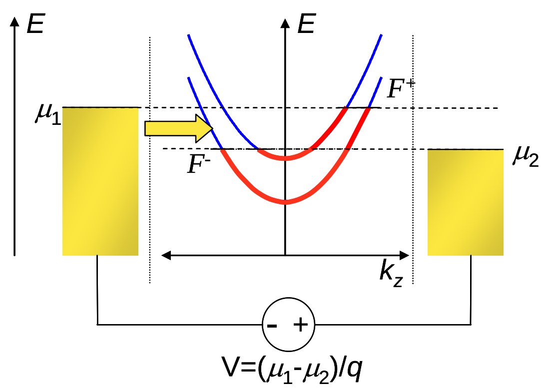
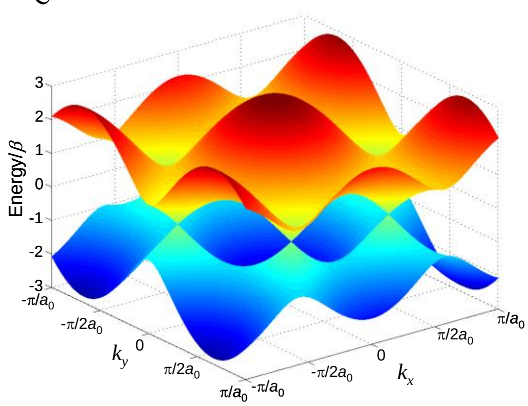
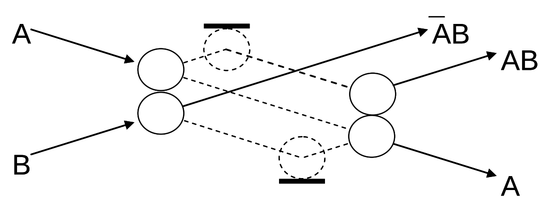
Introduction to Nanoelectronics









Marc Baldo

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Preface to the OpenCourseWare publication

About eight years ago, when I was just starting at MIT, I had the opportunity to attend a workshop on nanoscale devices and molecular electronics. In particular, I remember a presentation by Supriyo Datta from Purdue. He was describing electronic devices from the 'bottom up' – starting with quantum mechanical descriptions of atoms and molecules, and ending up with device-scale current-voltage characteristics.

Although I did not understand the details at the time, it was clear to me that this approach promised a new approach to teaching electronic devices to undergraduates. Building from a few basic concepts in quantum mechanics, and a reliance on electric potentials rather than fields, I believe that the 'bottom up' approach is simpler and more insightful than conventional approaches to teaching electronic transport. After five years of teaching the material, it is still remarkable to me that one can derive the current-voltage characteristics of a ballistic nanowire field effect transistor within a 45 minute lecture.

This collection of class notes is my attempt to adapt the 'bottom up' approach to an undergraduate electrical engineering curriculum. It can serve several roles. For most seniors, the class is intended to provide a thorough analysis of ballistic transistors within a broader summary of the most important device issues in computation. But for those intending to specialize in electronic devices, the class is designed as an introduction to dedicated courses on quantum mechanics, solid state physics, as well as more comprehensive treatments of quantum transport such as those by Supriyo Datta himself. I can recommend both his books[1,2], and the 'nanohub' at Purdue University: http://nanohub.org/topics/ElectronicsFromTheBottomUp.

The notes are designed to be self contained. In particular, this class is taught without requiring prior knowledge of quantum mechanics, although I do prefer that the students have prior knowledge of Fourier transforms.

Finally, I decided to share these notes on MIT's OpenCourseWare with the expectation of collaboration. The 'bottom up' approach is still relatively novel, and these notes remain largely unpolished, with substantial opportunities for improvement! For those needing to teach a similar topic, I hope that it provides a useful resource, and that in return you can share with me suggestions, corrections and improvements.

Marc Baldo
May 2010, Cambridge, MA

1. Electronic Transport in Mesoscopic Systems, Supriyo Datta, Cambridge University Press, 1995
2. Quantum Transport: Atom to Transistor, Supriyo Datta, Cambridge University Press, 2005

Acknowledgements

These notes draws heavily on prior work by Supriyo Datta, 'Electronic Transport in Mesoscopic Systems', Cambridge University Press, 1995 and 'Quantum Transport: Atom to Transistor', Cambridge University Press, 2005. I have also made multiple references to the third edition of 'Molecular Quantum Mechanics' by Atkins and Friedman, Oxford University Press, 1997.

I would also like to thank Terry Orlando, Phil Reusswig, Priya Jadhav, Jiye Lee, and Benjie Limketkai for helping me teach the class over the years.

My work is dedicated to Suzanne, Adelie, Esme, and Jonathan.

Contents