# Engineering Tripos Part IIB, 4B5: Quantum and Nano-technologies, 2020-21

### Module Leader

Prof C Durkan [1]

### Lecturer

Prof C Durkan

### Timing and Structure

Michaelmas term. 14 lectures + examples class. 2 lectures' worth of pre-recorded content to be released online at 8 am on the first day of each week (Thursday), plus live session for Q&A each week. Assessment: 100% exam. See timetable & Teams channel.

### Prerequisites

3B5

## Aims

The aims of the course are to:

- Understand the basic principles behind quantum mechanics and be able to apply it to problems relevant to Electrical Engineering
- Explore the concepts of quantum information processing and quantum computing
- Become familiar with nanotechnology, what it is, where it is used, and how it relates to quantum systems

## Objectives

As specific objectives, by the end of the course students should be able to:

- Apply quantum principles to understand charge transport and current flow at the nanoscale
- Understand quantum confinement, the origin of band structure, and how it relates to quantum size effects
- Be able to predict basic electrical properties of materials
- Understand and explain the principles behind thermal conductivity of materials
- Describe the operation principle of a quantum computer
- Explain the principles behind quantum encryption
- Understand the basic relationships between size and properties of materials, their quantum origin, and their application via nanotechnology

## Content

The aim of this module is to introduce (building on material in 3B5) the concepts underlying quantum mechanics and nanotechnology, and see how to apply them to problems relevant to electrical engineering. We will explore the quantum origin of many of the properties of materials, ranging from resistivity, mechanical properties, colour, and band structure, and how these properties evolve with size. We will approach this from two angles: from the theoretical principles and predictions of quantum mechanics, to the manifestations of these as exploited using nanotechnology.

Lecture content:
All lectures will be delivered by Prof Durkan asynchronously, in small topic-blocks rather than as complete lectures. Details will be disseminated via Moodle and the Teams channel for the module.

The aim is to provide 1 examples class in person, depending on class size, towards the end of Michaelmas term

- The need for quantum description of the world around us.
- The basic assumptions of quantum mechanics.
- Solutions to the Schrodinger equation - confinement, band structures, quantum harmonic oscillator.
- Interpretation of quantum mechanics.
- Everyday examples of quantum mechanics at work.
- A quantum description of electrical properties of materials, and where Ohm's law comes from.
- Mesoscopic transport & the Landauer-Buttiker formalism.
- A look into the principles underlying quantum information processing.
- Entanglement, encryption and quantum computing.
- Nanotechnology - what it is and relationship to quantum mechanics.
- Nanomaterials, evolution of properties of materials with decreasing size, dimensionality.
- Ultimate nanostructures - graphene, molecular systems, novel device architectures.

## Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

## Examination Guidelines

Please refer to Form & conduct of the examinations [2].

## UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

### General Learning Outcomes

Graduates with the exemplifying qualifications, irrespective of registration category or qualification level, must satisfy the following criteria:

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