

## **Engineering Tripos Part IIA, 3B5: Semiconductor Engineering, 2018-19**

### **Module Leader**

[Dr H Joyce](#) [1]

### **Lecturers**

Dr H Joyce and Prof S Hofmann

### **Lab Leader**

Prof S Hofmann

### **Timing and Structure**

Michaelmas term. Weeks 1-4 (Dr H Joyce), weeks 5-8 (Prof S Hofmann). 16 lectures.

### **Aims**

The aims of the course are to:

- Provide a framework of basic semiconductor physics to demonstrate how this aids the design process and dictates the operation and performance limitations of devices in circuits and systems.

### **Objectives**

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

- Explain the concept of wave-particle duality especially with regard to electrons.
- Calculate allowed electron energy levels in single atoms from solutions of Schrodinger Equation, and be familiar with the concept of energy bands.
- Explain semiconductor behaviour in energy band and energy band concepts.
- Be familiar with the idea of the Fermi Level, and the formation of n and p type semiconductors by the deliberate addition of dopant atoms.
- Apply the continuity equation to different semiconductor problems.
- Explain the formation of p-n junctions, and be familiar with how current flow across the junction is limited by minority carrier flow.
- Know how p-n junction formation can be used in the design of JFETs and bipolar transistors.
- Compare and contrast the performance of JFET and Bipolar Transistors.
- Know how metal semiconductor junctions can be used in the design of MESFETs and HEMTs, and be able to compare operation with that of the JFET.
- Explain the contrast the operating modes of the MOSFET, and be familiar with how device design affects I-V characteristics.
- Understand how MOSFETs may be utilised as simple memory devices.

### **Content**

#### **Semiconductor Devices**

- Basic physics of semiconductors: wave-particle duality, Schrodinger's equation, E-k diagrams, energy bands, direct and indirect band gaps, density of states, Fermi level, intrinsic and extrinsic semiconductors, drift and diffusion, recombination and generation, continuity equation.
- p-n junctions band diagrams, junction in equilibrium, current flow in p-n junction, metal-semiconductor junctions, heterojunctions.
- The bipolar junction transistor (BJT), the heterojunction bipolar transistor (HBT), the junction field effect transistor (JFET), the metal semiconductor field effect transistor (MESFET), the high electron mobility transistor (HEMT) and the metal oxide semiconductor field effect transistor (MOSFET) - how they operate and I-V characteristics.

### Examples papers

Four examples papers are provided during the course, covering lectures 1-4, lectures 5-8, lectures 9-12 and lectures 13-16.

### Coursework

#### Schottky Barrier Diode

##### Learning objectives:

- Experimentally probe semiconductor engineering concepts related to theory given in lectures.
- Use oscillator circuit to investigate voltage dependence of the capacitance of a Schottky barrier diode and understand how this is a powerful technique for characterisation of semiconductor doping.
- Compare the current-voltage characteristics of Schottky and p-n diodes and explore deviations from ideal diode behaviour.

##### Practical information:

- Sessions will take place in the EIETL, during weeks 1-8 of Michaelmas term.
- This activity involves preliminary work (read and understand the lab handout).

##### Full Technical Report:

Students will have the option to submit a Full Technical Report.

### Booklists

Please see the [Booklist for Part IIA Courses](#) [2] for references for this module.

### Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [3].

### UK-SPEC

The [UK Standard for Professional Engineering Competence \(UK-SPEC\)](#) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the ['Accreditation of Higher Education Programmes' \(AHEP\) document](#) [5] which sets out the standard for degree accreditation.

The [Output Standards Matrices](#) [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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### Links

[1] <mailto:hjj28@eng.cam.ac.uk>

[2] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364091&chapterid=46331>

[3] <http://teaching.eng.cam.ac.uk/content/form-conduct-examinations>

[4] <http://www.engc.org.uk/ukspec.aspx>

[5] <http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/>

[6] <http://teaching.eng.cam.ac.uk/content/output-standards-matrices>