

Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	Opt.
Ing.-phys	MA1, MA3	Opt.
Minor in Quantum Science and Engineering	H	Opt.
Photonics minor	H	Opt.
Physicien	MA1, MA3	Opt.
Quantum Science and Engineering	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
<b>Hours</b>	<b>4 weekly</b>
Lecture	2 weekly
Exercises	2 weekly
<b>Number of positions</b>	

## Summary

Lectures on the fundamental aspects of semiconductor physics and the main properties of the p-n junction that is at the heart of devices like LEDs & laser diodes. The last part deals with light-matter interaction phenomena in bulk semiconductors such as absorption, spontaneous & stimulated emission.

## Content

### 1. Electronic properties of semiconductors

- Crystalline structures and energy band diagrams
- Impurities and doping
- Carrier statistics in equilibrium and out-of-equilibrium
- Electron transport in weak and strong fields
- Generation and recombination processes

### 2. Theory of junctions and interfaces

- $p$ - $n$  and metal-semiconductor junctions
- Heterojunction interfaces

### 3. Light-matter interaction in semiconductors

- Fermi's golden rule, absorption, optical susceptibility, Bernard-Duraffourg condition (optical gain condition)
- Spontaneous and stimulated emission of radiation
- Dielectric function, optical constants
- Radiative lifetime, photoluminescence spectra

## Learning Prerequisites

### Recommended courses

Solid State Physics I and II (Bachelor), Quantum Electrodynamics and Quantum Optics (Master)  
Quantum physics I and II (Bachelor)

## Learning Outcomes

By the end of the course, the student must be able to:

- Explain - the main electronic and optical properties of bulk semiconductors (band structure, doping, absorption,

excitonic features) that are behind the first quantum revolution (transistors, LEDs and laser diodes)

- Identify - the main criteria governing the I-V characteristics of the p-n junction and explain its departure from ideality (role of defects and Joule heating)
- Classify - semiconductors depending on their doping level (non-degenerate vs degenerate semiconductors)
- Compute - the Shockley-Read-Hall term, the bimolecular recombination coefficient and the Auger term entering into the ABC model
- Compute - the absorption spectrum of direct bandgap bulk semiconductors
- Compute - the radiative lifetime of a 2-level system and that of a direct bandgap bulk semiconductor
- Explain - the main properties of tunnel diodes and solar cells

### Transversal skills

- Give feedback (critique) in an appropriate fashion.
- Make an oral presentation.
- Demonstrate a capacity for creativity.
- Demonstrate the capacity for critical thinking
- Assess one's own level of skill acquisition, and plan their on-going learning goals.
- Summarize an article or a technical report.

### Teaching methods

Ex cathedra with exercises

### Expected student activities

Weekly graded homeworks to secure 1 point out of 6 (16.6% of the final grade)

Read the bibliographical resources in order to fully integrate and properly use the physical concepts seen in the lectures and the exercises

### Assessment methods

Written exam (with 1 point out of 6 earned via compulsory weekly homeworks (16.6%))

### Supervision

Office hours	Yes
Assistants	Yes
Others	Office hours: appointments to be arranged by emails.

### Resources

#### Bibliography

- S. M. Sze, "Physics of semiconductor devices" 2nd edition (or > 2nd ed.) (John Wiley & Sons, New York, 1981)
- P. Y. Yu and M. Cardona, "Fundamentals of Semiconductors, Physics and Materials Properties" 2nd edition (or > 2nd ed.) (Springer, Berlin, 1999)
- N. W. Ashcroft and N. D. Mermin, "Solid State Physics" (Saunders College Publishing, Fort Worth, 1976)
- E. Rosencher and B. Vinter, "Optoelectronics" (Cambridge University Press, Cambridge, 2002)

#### Ressources en bibliothèque

- [E. Rosencher and B. Vinter, "Optoelectronics"](#)
- [N. W. Ashcroft and N. D. Mermin, "Solid State Physics" \(Saunders College Publishing, Fort Worth, 1976\)](#)
- [S. M. Sze, "Physics of semiconductor devices" 2nd edition \(or > 2nd ed.\) \(John Wiley & Sons, New York, 1981\)](#)

- P. Y. Yu and M. Cardona, "Fundamentals of Semiconductors, Physics and Materials Properties" 2nd edition (or > 2nd ed.) (Springer, Berlin, 1999)

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- <https://go.epfl.ch/PHYS-433>