IF.1106 – Sciences for Digital Systems

Module title: Sciences for Digital Systems
Module code: IF.1106
Person in charge : Mariam CAMARA
ECTS : 4
Workload : 100h, including 42h face-to-face
Teamwork : Yes (project, Labs)
Keywords : Newton, Galilée, relativity, thermodynamics, electromagnetics, microelectronics, quantum electronics, transistors, Bandgap, quantized energy levels, tunneling, charge carrier mobility, integrated circuits, electrical conduction, solid state physics, band structure

Presentation

The digital sciences are a group of disciplines that examine the theoretical, methodological and practical aspects of computer and digital systems. Their main aim is to grasp the theoretical foundations of computer systems, design methods and algorithms, and apply this knowledge to solve concrete problems. In this context, this module focuses on the application of physical concepts to the design and modeling of digital systems. This includes understanding the physical principles underlying electronic components, digital circuits, storage devices and information technologies in general.

Over the course of the semester, we explore these concepts, from the precepts laid down by Galileo and Newton to the quantum revolution and modern applications of microelectronics. This course will provide an in-depth look at how physical principles shape and influence the ever-evolving field of digital science.

Academic Objectives

Prerequisites

- None

Content/program

Concepts

- Sagnac effect
    - Application in global positioning systems (GPS).
    - Gyrolasers.
- Galileo and Newton
    - From gravity to inertia.
    - The basics of classical mechanics: automatic screen adjustment/inclinometer.
- Satellite geolocation
    - How signals emitted in orbit precisely determine position and movement on earth.
- Electromagnetic waves
    - The fundamentals of electromagnetic waves, the backbone of wireless communications and digital technologies.
    - Application of concepts in SHAZAM.
- -Gravitational waves
    - Revolutionary detection of gravitational waves and their impact on cutting-edge digital technologies.
- -Quantum physics
    - Application to electronic components and cameras.

- General and Special Relativity
    - Exploration of Einstein's theories of general and special relativity.
    - Influence on space navigation and clock synchronization.
- Thermodynamics
    - The fundamentals of thermodynamics and their application to heat management in digital systems.
- Microelectronics
    - From Moore's Law to More than Moore (parallel between economy and technological nodes).
    - Manufacturing procedures in industry.
    - Current challenges in microelectronics.

Know-how

- State-of-the-art study.
- Python modeling, simulation, calculation and visualization in a computing environment for scientific applications.
- Implementation of an FDSOI MOSFET and demonstration of front and back gate effects.
    - Design
    - I/V characterization

Tools

- Synopsis : modules Sentaurus
- Scilab : calculation and visualisation
- Scipy : modelisation in Python

Academic methods

Learning Methodes

- Lectures are accompanied by Multiple Choice Questionnaires (MCQs) to facilitate assimilation of the concepts presented.
- Students, grouped in PBL (Problem and Project Based Learning) teams, review the state of the art on a specific topic. Each group, comprising a maximum of 6 students, presents and discusses its findings over the course of the semester.
- Practical work sessions offer students the opportunity to design, characterize and analyze their own devices. They will be encouraged to identify and understand the underlying physical concepts through hands-on experience.

Assesment

- Report on state-of-art (20%)
- Labs reports (30%)
- Presentation et Demonstration (20%)
- MCQs (30%)

Working Languagel

- English

Bibliography, Webography, Other resources

- Pierre Spagnou, Les mystères du temps, CNRS Editions, 2017
- Exemple d'utilisation de Shazam : **https://www.youtube.com/watch?v=UDVtMYqUAyw**
- Evalyn Gates, *Einstein's Telescope*, WW Norton & Co, 2010
- Éric Gourgoulhon, *Relativité restreinte : des particules à l'astrophysique*, EDP Sciences, 2010

- Pierre Spagnou, *De la relativité au GPS*, Ellipses, 2012
- Pierre Spagnou, *Les mystères du temps*, CNRS Editions, 2017
- Pierre Spagnou, *Le trésor des ondes gravitationnelles*, CNRS Editions, 2020
- Kip Thorne, *Trous noirs et distorsions du temps*, Flammarion, 1997
- Kip Thorne, *The Science of Interstellar*, WW Norton & Co, 2014
- Ulrik Uggerhøj et al., *The young centre of the Earth*, European Journal of Physics, Volume 37, 2016
- Clifford Will, *The confrontation between general relativity and experiment*, Living Rev. Relativity, Volume 17, 2014
- Colin Bruce, L'étrange affaire du chat de Madame Hudson, Flammarion, 1998
- Albert Einstein, Boris Podolsky, Nathan Rosen, « Can quantum-mechanical description of physical reality be considered complete? », Phys. Rev. 47 (1935)
- Christophe Grojean, Laurent Vacavant, A la recherche du boson de Higgs, Librio, 2015
- Ronald Hanson et al., Experimental loophole-free violation of a Bell inequality using entangled electron spins separated by 1.3 km, Nature, 726 (2015)
- Hrvoje Nikolic, Quantum mechanics: Myths and facts, Foundations of Physics, 37, 2007
- Hrvoje Nikolic, EPR before EPR: a 1930 Einstein-Bohr thought experiment revisited, Eur. J. Phys. (2012)
- Huw Price, Time's arrow and Archimede Point, Oxford University Press, 1996
- **http://www.bibnum.education.fr/**
- Sentaurus TCAD Training for CMOS Application: Synopsys.com