UNIVERSITÀ DI PISA

ELECTROMAGNETIC MATERIALS AND ELECTRON DEVICES

SIMONE GENOVESI

Anno accademico	2023/24
CdS	MATERIALS AND NANOTECHNOLOGY
Codice	730II
CFU	12

Moduli	Settore/i	Tipo	Ore	Docente/i
ELECTROMAGNETIC MATERIALS	ING-INF/02	LEZIONI	48	SIMONE GENOVESI EMANUELE TAVANTI
ELECTRON DEVICES	ING-INF/01	LEZIONI	48	PAOLO MARCONCINI

Obiettivi di apprendimento

Conoscenze
ELECTROMAGNETIC MATERIALS
Electromagnetic properties of materials, propagation of electromagnetic waves in multilayered materials, transmission line theory.

ELECTRON DEVICES
Main concepts of semiconductor and electronic device physics.

Modalità di verifica delle conoscenze
ELECTROMAGNETIC MATERIALS
Team project in Matlab and oral exam.
ELECTRON DEVICES
Oral exam.

Capacità
ELECTRON DEVICES
Ability to understand the main properties of materials for electronic applications and the operating principles of the main electronic devices.

Modalità di verifica delle capacità
ELECTROMAGNETIC MATERIALS
Team project in Matlab and oral exam.
ELECTRON DEVICES
Oral exam.

Comportamenti
ELECTRON DEVICES
Attendendance of lessons and/or study of the suggested textbooks.

Modalità di verifica dei comportamenti
ELECTROMAGNETIC MATERIALS
Team project in Matlab and oral exam.
ELECTRON DEVICES
Oral exam.

Prerequisiti (conoscenze iniziali)
ELECTRON DEVICES
Knowledge of basis physics (above all of basic electromagnetism).

Programma (contenuti dell'insegnamento)

ELECTROMAGNETIC MATERIALS
The following program could be slighlty changed by introducing a couple of new topics.
Course introduction and motivation.
Recall of some necessary pre-requisetes (complex numbers, phasors, scalar product and vector product. Scalar and vector fields. Gradient of a scalar field. Curl of a vector field. Curl theorem, Divergence).
Maxwell’s equations in time domain: differential and integral form. Maxwell’s equations in frequency domain: differential and integral form. Boundary conditions.
Constitutive parameters. Plane waves in time domain. Polarization of a plane wave: linear, circular and elliptical. Plane waves in frequency domain. Dispersive and lossy media.
Reflection and transmission coefficient for a plane wave normally impinging on a single planar interface.
Special case for reflection/transmission: dielectric-conductor, dielectric-PEC. Stationary wave. Poynting's theorem - time domain, interpretation. Poynting's theorem - frequency domain, real and imaginary part. Poynting's theorem: active power, reactive power. Poynting's vector of a plane wave: incident and reflected waves. Transmitted power density. Reflection and transmission of plane waves through multiple interfaces. Boundary condition for calculating the overall reflection and transmission coefficient for a multilayered strucutre. Absorbed average power.
Introduction to transmission lines. Transmission line: circuit approach. D'Alembert equation.
Characteristic impedance of a transmission line. Phase velocity. Coaxial cable dimensioning. Polarization in dielectric materials. Dielectric losses. Brief discussion on reflection/transmission coefficient and emissivity/absorption ("Taming the blackbody with metamaterials" paper by Padilla et. alii.)
Voltage and impedance along a transmission line. Transmission line closed on a matched load, a short circuit and an open circuit.
Time-average power flow. Quarter-wave transformer. Voltage standing wave on a transmission line. Voltage Wave Standing Ratio. Generalized reflection coefficient. Reflection coefficient on the complex plane. Smith chart: impedance chart. Practice on Smith Chart for solving problems involving transmission lines, interfaces, etc.
Practice on Matlab: arrays, matrixes, cell, structures. Script to evaluate the impedance and the reflection coefficient of a load connected to a transmission line. Script to evaluate the impedance and the reflection coefficient of a load connected to a transmission line. Definition, implementation and use of function. Automatic reporting. Debugging. Use of 'if','switch', 'while'and 'for' instructions. Code optimization by using functions inside a 'for' loop. Use of a 'cell' element for defining the legend.

ELECTRON DEVICES
The course describes the physics of the fundamental properties of the electron devices that represent the building blocks of modern electronic circuits and systems.
The main program topics are:
a) basic introduction to: quantum mechanics, statistical physics (Fermi-Dirac statistics) and solid state physics (Drude model, band structure);
b) main concepts of electrical transport in semiconductors (electron and hole concentration, doped semiconductors, drift and diffusion current, equilibrium conditions, generation and recombination, continuity equation);
c) detailed description of the physics, operation and fabrication of pn junctions (diodes): potential and electric field behavior, equilibrium conditions, biased conditions, demonstration of the current expressions, small-signal equivalent circuit, control charge model, reverse bias conditions;
d) detailed description of the physics, operation and fabrication of bipolar effect transistors (BJT): charge control model, demonstration of the Ebers-Moll equations and circuit, input and output characteristics, small-signal equivalent circuit;
e) detailed description of the metal-oxide-semiconductor (MOS) capacitor: band structure, distribution of the voltage difference, threshold voltage, charge behavior, capacitance-voltage curves;
f) detailed description of the physics, operation and fabrication of metal-oxide-semiconductor (MOS) field-effect transistor transistor: dependence of the threshold voltage on the voltage between source and bulk, demonstration of the output characteristics, body effect, small-signal equivalent circuit, short-channel effects.
For more details, see: https://unimap.unipi.it/registri

Bibliografia e materiale didattico

ELECTRON DEVICES
G. Pennelli, "Fisica dei dispositivi elettronici", Pisa University Press (in Italian);
S. M. Sze [and other Authors, depending on the edition], "Semiconductor Devices. Physics and Technology", Wiley & Sons (in English);
S. M. Sze, "Dispositivi a semiconduttore. Comportamento fisico e tecnologia", Hoepli (in Italian);
B. G. Streetman, "Solid state electronic devices", Prentice Hall (in English);
G. Ghione, "Dispositivi per la microelettronica", McGraw-Hill (in Italian);
R. S. Muller, T. I. Kamins, M. Chan, "Device Electronics for Integrated Circuits", Wiley & Sons (in English);
Y. Taur, T. H. Ning, "Fundamentals of Modern VLSI Devices", Cambridge University Press (in English).

Indicazioni per non frequentanti

ELECTRON DEVICES
For non-attending students it is suggested to read the log of the lectures on
https://unimap.unipi.it/registri
to check the webpage
http://brahms.iet.unipi.it/marconcini/marconcini.html
and to study the corresponding topics on the suggested textbooks (for example, G. Pennelli and S. M. Sze for Italian and non-Italian students, respectively).

Modalità d'esame

ELECTROMAGNETIC MATERIALS
Team project in Matlab and oral exam.
ELECTRON DEVICES
Oral exam.

Altri riferimenti web

ELECTRON DEVICES
http://brahms.iet.unipi.it/marconcini/marconcini.html

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