CLASSIC AND MODERN PHYSICS, ELECTRONICS, MATERIALS 2 FIELD_12 ECTS

Introducing

Description

Évaluation

L'évaluation des acquis d'apprentissage est réalisée en continu tout le long du semestre. En fonction des enseignements, elle peut prendre différentes formes : examen écrit, oral, compte-rendu, rapport écrit, évaluation par les pairs...

Practical info

Location(s)

Toulouse

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Thermodynamics

Introducing

Description

Programme (detailed content) :
Introduction: The fundamental mathematical tools of thermodynamics: partial derivatives, Jacobian, exact and inexact total differential, Legendre transformation, notion of extensive and intensive quantities, integrating factor.

I - Part: The formalism of thermodynamics:
- Postulates for simple systems,
- Variables of state, equation of state of simple systems,
- Calorimetric coefficients of simple systems,
- Legendre transforms,
- Thermodynamic potentials, free energies of transformation, and their applications
- Stability conditions of simple systems,
- Order parameter, 1st and 2nd order phase transition.

II - Part: Applications
- thermal machines - balance and efficiency
- Perfect gases, Mixtures of perfect gases,
- Real gases, Van der Waals model
- Solid-liquid-vapour transformation of a simple system
- Changes of state,
- Phase diagram,

III - Part: Heat and matter transport phenomena
- Diffusion phenomena.
- applications: thermoelectric effects (Peltier, Seebeck, ...)

IV - Part : Thermodynamic model of the greenhouse effect.
- Modelling and influence of the atmosphere compositio

Objectives

At the end of this module, the student should have understood and be able to explain (main concepts):
- The laws of thermodynamics, the notions of work, heat, energy associated with a transformation,
- The application to thermal machines, thermodynamic cycles, and the calculation of efficiency.
- This course is intended to provide students with an understanding of the laws of thermodynamics and the concepts of work, heat and energy associated with a transformation,
- simple phase diagrams and binary materials.
- This course is intended to provide students with the opportunity to learn more about the following topics: - The concepts of diffusion and heat/matter transport.

The student will have to integrate notions, contextualise them and then be able to decontextualise them to be able to project them into an adidactic situation.

Necessary prerequisites

Basics of mathematical analysis: functions of several variables, derivatives, integrations, differential equations.
General notions of thermodynamics of physical-chemical systems

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Practical info

Location(s)

Toulouse

Point defects and diffusion

Introducing

Description

Program (detailed contents):
Introduction: The role of diffusion mechanisms and defects in materials.
I- Nature of defects: volumetric, surface, linear, point defects, in crystalline materials, ionic crystals, amorphous solids.
II - Thermodynamic aspects of point defects: enthalpy of formation, enthalpy of migration, defect concentration at thermodynamic equilibrium.
III - Basics of diffusion: flow equation, Fick's laws, macroscopic aspects, microscopic aspects, calculating the diffusion coefficient, influence of temperature.
IV - Defect generation and annihilation: generation of defects by radiation exposure and diffusion (lacunae, amorphization, doping), annihilation of defects by heat treatment.
V - Electronic and optical properties: colored centers in ionic crystals, the effect of doping in semiconductor materials.
VI - Techniques for measuring defect concentration: electrical, geometric and specific heat measurements.
VII - Applications.

Objectives

At the end of this module, the student should have understood and be able to explain (main concepts):
- The laws of matter diffusion in solid materials.
- The nomenclature of defects present in solid materials, the mechanisms by which defects are created and annihilated, the electronic and optical properties induced, and their applications.

Students will need to integrate notions, contextualize them and then be able to decontextualize them to project them into an adidactic situation.

Necessary prerequisites

Basic mathematical analysis: functions of several variables, derivatives, integrations, differential equations.
General concepts of the thermodynamics of physical-chemical systems.

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Quantum physics

Introducing

Description

Program (detailed content) :

Brief review of the wave function and introduction to Dirac's formalism.
Fundamental measurement postulates in quantum mechanics.
Dynamics of quantum systems.
Harmonic oscillator theory.
Kinetic momentum theory.

Main difficulties usually encountered by students :
Difficulties are essentially mathematical (new formalism and notations, solving the eigenvalue equation of a matrix, etc.).

Objectives

At the end of this module, the student should have understood and be able to explain (main concepts):
Fundamental postulates of measurements in quantum mechanics.
The time evolution of a quantum system.
The notion of plane wave and localized wave packet.
Harmonic oscillator theory and its applications.
Angular momentum theory and its applications.

The student should be able to :
Solve Schrödinger's equation (energy and eigenstates) in matrix formalism.
Apply the fundamental postulates relating to the measurement of a physical quantity.
Calculate the time evolution of a quantum state.
Manipulate the ladder operators of the harmonic oscillator and angular momentum.

Necessary prerequisites

-Nanophysics: Optics, Photonics, Nanotechnologies
-Electrostatics
-Classical mechanics

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Statistical physics

Introducing

Description

Fundamental assumptions of statistical physics. Macroscopic states, microscopic states and density of states.
Closed systems in equilibrium, microcanonical distribution. Temperature and Boltzmann distribution. Z, U and S functions. Thermodynamic link.
Closed systems in contact with a thermostat, canonical distribution.
Systems in contact with a particle reservoir, grand canonical distribution. Chemical potential.
Fermions and Bosons. Fermi Dirac and Bose Einstein distributions. Application examples.

Objectives

At the end of this module, the student should have understood and be able to explain (main concepts):
Basic principles of statistical physics (origin of entropy).
Microcanonical distribution, temperature, partition function and U, S functions.
Canonical and grand canonical distributions
Fermi-Dirac and Bose Einstein distributions.

The student should be able to:
Calculate the equilibrium properties of a simple closed and open system.
use the Fermi Dirac or Bose Einstein distributions in solid-state physics.

Necessary prerequisites

- Classical mecanic
- Hamiltonian Mecanic
- Thermodynamique
- Electrostatic
- Electromagnetism

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Cohesion

Introducing

Description

Cohesion of Solids :

- Models of cohesive energy of the solid state - Lennard-Jones potential - Condon-Morse potential

- Properties and physical quantities related to cohesion: compressibility, thermal expansion, melting temperature, allotropic transformations

- Applications to ionic crystals and crystals based on van der Waals interaction

Objectives

By the end of this teaching unit, students should have understood and be able to explain (main concepts) the physical models of cohesion of solid materials on the atomic and molecular scales, as well as the links between these models and macroscopic physical quantities.

Necessary prerequisites

L2 degree in physics or materials science

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Dislocations and deformations

Introducing

Description

Plastic deformation and fracture of crystalline materials :
- Brittleness, ductility, plasticity of crystalline materials
- Dislocations : definition, theory of dislocations, interaction, mobility and plasticity.
- Brittle fracture, cleavage.

Objectives

At the end of this module, the student will have understood and be able to explain (main concepts) the relations between defects and dislocations in the atomic structure and some macroscopic mechanical properties of crystals.

The student will be able to describe from a geometric and energetic point of view the dislocations and their interactions, and put them in relations with mechanical properties of the crystalline material : fragility and ductility

Necessary prerequisites

Know how to use tensor notation (seen during anisotropy lectures)

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Anisotropy

Introducing

Description

Chapter 1: tensors
- Definition of tensor (use, order, transformation rules)
- Writing tensor relations: classical mathematical notation, Einstein convention, matrix notation.
- Tensors and symmetries (symmetric tensors, invariances and symmetries of the system)

Chapter 2: tensors and mechanical properties
- Definition of stress, strain, elasticity and rigidity tensors.
- The different types of stress/deformation (traction, shear).
- Voigt/engineer notation (6-component notation).
- Isotropic elasticity tensor
- Physical constants of isotropic elasticity (Young, Poisson, Coulomb moduli and Lamé coefficients).

Chapter 3: static couplings
- Direct and inverse piezoelectricity
- The piezoelectric tensor.
- The acousto-optic effect
- Couplings between static properties: general concepts and definition of effects (pyroelectricity, thermal expansion, etc.).
- Statistical theory of couplings and matrix representation (Voigt notation).
- Primary and secondary effects (e.g. primary and secondary pyroelectricity)

Chapter 4: anisotropic optics
- The representation of a tensor of order 2: the ellipsoid of indices and its geometric interpretation.
- Permittivity tensors and optical indices.
- Optical propagation along one of the main axes of an anisotropic system and the retarders (quarter-wave and half-wave blades).
- Optical propagation in any direction in an anisotropic system: birefringence and beam-splitters.

Objectives

Learn the fundamental ideas behind tensor theory and operation, as well as how they can be applied to characterize the anisotropic properties of crystals. A number of applications will be discussed in relation to anisotropic optics (wave plates, birefringence, etc.) and couplings (piezoelectricity, acousto-optic effect, etc.).

Necessary prerequisites

Linear algebra, mathematical analysis of functions with several variables, solid mechanics, wave optics.

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