Electromagnetism

1. **Course number and name:** 020EMECI3 Electromagnetism

2. **Credits and contact hours:** 4 ECTS credits, 2x1:15 contact hours

3. **Name(s) of instructor(s) or course coordinator(s):** Remi Z. DAOU

4. **Instructional materials:**
   Textbook : Physique MP/MP* - MPI/MPI*. Tout-en-un, J'intègre – DUNOD ($5^{ème}$ édition)

5. **Specific course information**
   a. **Catalog description:**
   This course starts with a separate study in the stationary case of the electric and the magnetic fields. Geometrical symmetries are used to benefit from the properties of the flux and the circulation of a vector field. Stationary local equations are introduced as a special case of Maxwell equations. After a presentation of the Maxwell equations and the electromagnetic (EM) energy, attention is focused on the propagation of EM waves in vacuum, in conductors, in plasma and far away form an EM oscillating dipole.

   b. **Prerequisites**: 020SPHCI1 Physical Signals and 020ANGCI1 General Analysis

   c. **Required/Selected Elective/Open Elective:** Required

6. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**
   - Express the electrostatic field created by a discrete distribution of charges.
   - Exploit the symmetries and invariances of a distribution of charges to characterize the electrostatic field created.
   - Relate the electrostatic field to the potential. Express the potential created by a discrete distribution of charges.
   - Determine a potential difference by circulation of the electrostatic field in simple cases.
   - Establish the expressions for the electrostatic fields created at any point in space by a sphere uniformly charged in volume, by an infinite cylinder uniformly charged in volume and by an infinite plane uniformly charged on the surface.
   - Establish and quote the expression for the capacitance of a plane capacitor in a vacuum.
   - Explain the dipole approximation. Show the field lines and equipotential surfaces of an electrostatic dipole.
   - Relate the current intensity to the flux of the volume current density vector.

- Exploit the properties of invariance and symmetry of the sources and properties of the field created.
- Establish the expressions for the magnetostatics fields created at any point in space by an infinite rectilinear wire of non-zero cross-section, traversed by currents uniformly distributed in volume, by an infinite solenoid, assuming that the field is zero on the outside.
- Express the magnetic moment of a plane current loop.
- Establish the local equation for the conservation of charge in Cartesian coordinates in the one-dimensional case.
- Associate the Maxwell-Faraday equation with Faraday's law.
- Cite, use and interpret Maxwell's equations in integral form.
- Make a qualitative association between the space-time coupling between electric and magnetic fields and the propagation phenomenon. Check the consistency of Maxwell's equations with the local conservation of charge equation.
- Derive the propagation equations from Maxwell's equations.
- Establish the Poisson and Laplace equations of electrostatics.
- Use the flux of the Poynting vector through an oriented surface to evaluate radiated power.
- Carry out an energy balance in local and integral form.
- Name the solutions to the one-dimensional d'Alembert equation.
- Describe the structure of a plane wave and a travelling plane wave in a space devoid of charge and current.
- Determine the dispersion relation. Name the domains of the electromagnetic wave spectrum and associate applications with them.
- Recognize a linearly or circularly polarized wave.
- Use polarizers and study Malus's law quantitatively.
- Express the complex conductivity of the medium and establish the dispersion relation.
- Describe the phenomenon of dispersion.
- Calculate the group velocity from the dispersion relation.
- Associate the group velocity with the propagation of the envelope of the wave packet.
- Establish and interpret the expression for the characteristic attenuation length of the electromagnetic wave in an ohmic medium.
- Establish the expression for the reflected wave using the transition relationships provided. Interpret qualitatively the presence of localized surface currents.
- Recognize and characterize a standing wave.

b. **PIs addressed by the course:**

PI	1.2	1.3
Covered	x	x
Assessed	x	x

7. **Brief list of topics to be covered**

- Electric charge - Field created by a point charge - Field created by a distribution of charges - Symmetry properties (1 lecture)
- Field flow and electrostatic potential - Field flow and Gauss's theorem (1 lecture)
- Topography of the field - Analogy with the gravitational field (1 lecture)
- Tutorials (2 lectures)
- Methods of studying fields and potentials - Charged sphere (1 lecture)
- Charged cylinder - Charged plane (1 lecture)
- Surface modelling - Planar capacitor (1 lecture)
- Electrostatic dipole (1 lecture)
- Tutorials (3 lectures)
- Electric current - Properties of the magnetostatics field - Ampère's theorem (1 lecture)
- Symmetry properties (1 lecture)
- Infinite cylinder - Long solenoid (1 lecture)
- Magnetic dipole (1 lecture)
- Tutorials (3 lectures)
- Law of conservation of charge - Electromagnetic field (1 lecture)
- Maxwell's equation (1 lecture)
- Tutorials (3 lectures)
- Electromagnetic field energy - Poynting's vector (1 lecture)
- Poynting equation - Examples in stationary and variable regimes (1 lecture)
- Tutorials (2 lectures)
- Equation of propagation in a vacuum - Monochromatic Travelling Plane Wave (1 lecture)
- Polarization - Complex notation - Energetic study of MPPOs (1 lecture)
- Tutorials (2 lectures)
- Propagation in plasma - Dispersion relation (1 lecture)
- Phase velocity - Wave packet - Group velocity (1 lecture)
- Electromagnetic waves in a conductor - Perfect conductor - Standing wave (1 lecture)
- Skin effect – Waveguide (1 lecture)
- Tutorials (2 lectures)
- Dipolar radiation - Rayleigh scattering (1 lecture)
- Tutorials (1 lecture)