National University of Engineering (UNI)
School of Computer Science
Syllabus 2027-I

1. COURSE

CS201. Optics and electromagnetism (Mandatory)

2. GENERAL INFORMATION

2.1 Course	:	CS201. Optics and electromagnetism
2.2 Cycle	:	3rd Cycle.
2.3 Credits	:	5
2.4 Hours	:	4 HT; 2 HP;
2.5 Duration of the period	:	16 weeks
2.6 Type of course	:	Mandatory
2.7 Learning modality	:	Face to face
2.8 Prerrequisites	:	BFI101. Physics I. (1st Sem)

3. PROFESSORS

Meetings after coordination with the professor

4. INTRODUCTION TO THE COURSE

Optics and Electromagnetism is the direct sequel to Physics I and completes the foundation of classical physics required for computer science students. Building on the mechanics covered previously, the course develops electromagnetic theory from electrostatics through Maxwell's equations, culminating in the propagation of electromagnetic waves and their behavior as light. The study of geometrical and wave optics connects this classical framework to the physical principles underlying optical communications, sensors, displays, and photonic devices that are increasingly central to computing technology.

5. GOALS

- Apply Coulomb's law and Gauss's law to determine electric fields and flux for discrete and continuous charge distributions with symmetry.
- Determine electric potential and solve boundary-value problems using Poisson's and Laplace's equations.
- Analyze energy storage in capacitors and the macroscopic behavior of dielectric materials.
- Apply Kirchhoff's laws to analyze direct-current circuits, including the transient response of RC circuits.
- Apply the Biot-Savart and Ampère laws to compute magnetic fields produced by steady currents.
- Characterize the magnetic behavior of materials, including paramagnetism, diamagnetism, and ferromagnetism.
- Apply Faraday's law of induction to compute induced EMFs, self-inductance, and mutual inductance.
- Formulate Maxwell's equations and use them to describe the propagation of electromagnetic energy via the Poynting vector.
- Analyze the propagation, reflection, and refraction of electromagnetic waves in dielectric and conducting media.
- Apply the principles of geometrical optics to the design and analysis of optical instruments.
- Analyze interference and diffraction phenomena in wave optics, including the resolution limits of optical systems.

6. COMPETENCES

AG-C07) Computing Knowledge: Applies knowledge of mathematics, science, and computing. (Usage)

7. TOPICS

Unit 1: Electrostatics: Electric Field and Gauss's Law (6 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Coulomb's law for point charges and the principle of linear superposition • The electric field vector $\vec{E}$ for discrete and continuous charge distributions • Gauss's Law in integral form and its relation to enclosed charge • Differential form of Gauss's Law: $\nabla \cdot \vec{E} = \rho/\epsilon_0$ • Applications of Gauss's Law to spherical and cylindrical symmetry	• Calculate the electrostatic force and field for charge distributions using superposition and Gauss's Law [Usage] • Evaluate the electric flux through surfaces and relate it to enclosed charge [Assessment] • Determine volume charge density from a given expression of the electric field using Gauss's law in differential form [Usage]
Readings : [Gri17], [YF15]	

Unit 2: Electric Potential and Poisson/Laplace Equations (6 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Definition of the scalar potential V and the relation $\vec{E} = -\nabla V$ • The conservative nature of the electrostatic field: $\nabla \times \vec{E} = 0$ • Calculating potential from continuous line, surface, and volume charge distributions • Properties of equipotential surfaces and their relation to field lines • Derivation of Poisson's equation $\nabla^2 V = -\rho/\epsilon_0$ • Laplace's equation $\nabla^2 V = 0$ in charge-free regions • The first and second uniqueness theorems for electrostatic solutions • The method of images for planar and spherical grounded conductors • Solution of Laplace's equation via separation of variables in Cartesian and Spherical coordinates • Expansion of potential in terms of Monopole, Dipole, and Quadrupole moments	• Compute the potential energy of a configuration of point charges [Usage] • Derive the electric field vector from a given scalar potential function [Usage] • Solve Laplace's equation for a rectangular pipe with given boundary conditions [Assessment] • Apply the method of images to find the force between a point charge and an infinite conducting plane [Usage] • Analyze the dominant term of the multipole expansion for a charge distribution at large distances [Assessment]
Readings : [Gri17]	

Unit 3: Electrostatic Energy and Dielectrics (6 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Work required to assemble a distribution of charges • Energy density in the electric field: $u = \frac{1}{2}\epsilon_0 E^2$ • Definition of capacitance $C = Q/V$ and calculation for standard geometries • Atomic polarization and the polarization vector $\vec{P}$ • Bound surface and volume charges in polarized media • The electric displacement vector $\vec{D}$ and Gauss's Law in matter • Linear dielectrics, electric susceptibility χ_e, and relative permittivity ϵ_r • Interface boundary conditions for $\vec{E}$ and $\vec{D}$ vectors • Energy in dielectric systems: $W = \frac{1}{2}\int \vec{D} \cdot \vec{E} d\tau$ • Microscopic description of dielectrics and the Clausius-Mossotti relation	• Calculate the capacitance of a parallel-plate capacitor filled with a linear dielectric [Usage] • Evaluate the bound charge distribution for a dielectric sphere with uniform polarization [Assessment] • Solve for the electric field on both sides of a dielectric interface using boundary conditions [Usage] • Analyze the force exerted on a dielectric slab being pulled into a capacitor [Assessment]
Readings : [Gri17], [SJ18]	

Unit 4: Electric Current, Circuits, and Kirchhoff's Laws (4 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Definition of current, current density, and the continuity equation • Ohm's law, resistivity, and temperature dependence of resistance • Kirchhoff's Current Law (KCL) for circuit node analysis • Kirchhoff's Voltage Law (KVL) for circuit loop analysis • Series and parallel circuit simplification and equivalent resistance • RC and RL circuit transients and engineering time constants	• Apply KCL and KVL to solve multi-loop DC circuits relevant to digital hardware design [Usage] • Calculate power dissipated and determine time constants for RC and RL circuits [Assessment] • Analyze the transient response of RC and RL circuits and relate it to signal timing in digital systems [Usage]
Readings : [SJ18], [YF15]	

Unit 5: Magnetostatics: Biot-Savart and Ampere's Laws (7 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Lorentz force law for point charges: $\vec{F} = q(\vec{E}+\vec{v}\times\vec{B})$ • Magnetic force on current-carrying wires and loops • Biot-Savart Law for the magnetic field of a current element • Ampère's Law in integral form for high-symmetry currents • Differential form of Ampère's Law: $\nabla \times \vec{B} = \mu_0 \vec{J}$ • The solenoidal nature of $\vec{B}$: $\nabla \cdot \vec{B} = 0$ • The magnetic vector potential $\vec{A}$ and its relation $\vec{B} = \nabla \times \vec{A}$ • The Coulomb gauge $\nabla \cdot \vec{A} = 0$ in magnetostatics • Magnetic dipole moment $\vec{m}$ of a current loop • Multipole expansion of the vector potential and the dipole term	• Calculate the magnetic field of an infinite straight wire using Ampère's Law [Usage] • Compute the magnetic field on the axis of a circular current loop using the Biot-Savart Law [Usage] • Verify that a given magnetic field satisfies the solenoidal condition $\nabla \cdot \vec{B} = 0$ [Assessment] • Determine the magnetic vector potential for a uniform magnetic field [Usage] • Analyze the torque and force on a magnetic dipole in a non-uniform magnetic field [Assessment]
Readings : [Gri17], [YF15]	

Unit 6: Magnetic Properties of Matter (7 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• The magnetization vector $\vec{M}$ as magnetic dipole moment per unit volume • Bound surface currents $\vec{K}_b$ and volume currents $\vec{J}_b$ • The magnetic field intensity $\vec{H}$ and Ampère's Law in matter • Physical principles of diamagnetism and paramagnetism • Ferromagnetism, magnetic domains, and the hysteresis loop • Interface boundary conditions for $\vec{B}$ and $\vec{H}$ vectors • Linear magnetic media and magnetic permeability μ • The magnetic scalar potential in current-free regions • Introduction to perfect diamagnetism and the Meissner effect	• Find the bound current distribution for a long cylinder with uniform longitudinal magnetization [Usage] • Classify materials as diamagnetic, paramagnetic, or ferromagnetic based on their susceptibility [Assessment] • Solve for the $\vec{B}$ and $\vec{H}$ fields in a linear magnetic sphere placed in a uniform field [Usage] • Analyze the energy loss per cycle in a ferromagnetic material from its hysteresis curve [Assessment]
Readings : [Gri17]	

Unit 7: Electrodynamics: Faraday's Law and Induction (6 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Faraday's Law of induction and Lenz's Law for direction • The flux rule for electromotive force (EMF) in moving circuits • The non-conservative nature of the induced electric field: $\nabla \times \vec{E} = -\partial \vec{B}/\partial t$ • Mutual inductance M between two circuits • Self-inductance L and the back-EMF in inductors • Energy stored in the magnetic field: $W = \frac{1}{2\mu_0} \int B^2 d\tau$ • Formation of eddy currents and magnetic braking • Formalism of the inductance matrix for multi-circuit systems • The Neumann formula for calculating mutual inductance	• Calculate the induced EMF in a rotating loop within a constant magnetic field [Usage] • Apply Lenz's Law to determine the direction of the induced current in a given physical scenario [Assessment] • Compute the total magnetic energy stored in a long solenoid [Usage] • Evaluate the mutual inductance between a long wire and a neighboring rectangular loop [Assessment]
Readings : [Gri17], [SJ18]	

Unit 8: Maxwell's Equations and Gauge Transformations (8 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Maxwell's displacement current and its role in completing Ampere's Law • The complete set of four Maxwell's equations in integral and differential forms • Poynting's theorem and energy conservation in electromagnetic fields • The Poynting vector $\vec{S} = \vec{E} \times \vec{H}$ as energy flux density • Gauge invariance and the formulation of potentials in electrodynamics	• State all four Maxwell equations and identify their physical content [Familiarity] • Calculate the displacement current and the Poynting vector for an electromagnetic configuration [Usage] • Analyze energy flow and power transport in electromagnetic systems including transmission lines [Assessment]
Readings : [Gri17], [SJ18]	

Unit 9: Electromagnetic Waves and Propagation in Media (8 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Derivation of the electromagnetic wave equation in vacuum • Monochromatic plane wave solutions and their properties • Polarization states: linear, circular, and elliptical • Energy density, intensity, and momentum of plane waves • Reflection and refraction at normal incidence on an interface • Fresnel equations and Brewster's angle for oblique incidence • Wave propagation in conducting media and the skin depth δ • Frequency dependence of permittivity and the physics of dispersion • Phase velocity versus group velocity in dispersive media • TE and TM modes in rectangular waveguides	• Derive the dispersion relation and the speed of light from Maxwell's equations [Usage] • Determine the polarization state of a wave from its vector components [Assessment] • Apply Fresnel's equations to find the reflection coefficient for TE and TM polarizations [Usage] • Analyze how the skin depth varies with frequency for a given metallic conductor [Assessment] • Calculate the Brewster angle for an interface between air and glass [Usage]
Readings : [Gri17], [Hec17]	

Unit 10: Geometrical Optics and Optical Instruments (9 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Fermat's Principle and the derivation of reflection/refraction laws • The Lens-Maker's formula and spherical mirror equations • Thick lenses, cardinal points, and system matrices • Abbe theory of image formation and resolution limits • Compound microscopes, Keplerian/Galilean telescopes, and cameras • Paraxial ray tracing using the ABCD matrix formalism • The five Seidel aberrations: Spherical, Coma, Astigmatism, Curvature, Distortion	• Design a telescope system with a specific angular magnification using two thin lenses [Usage] • Evaluate the position and nature of an image formed by a combination of a mirror and a lens [Assessment] • Calculate the equivalent ABCD matrix for a complex optical train of three components [Usage]
Readings : [Hec17]	

Unit 11: Wave Optics: Interference and Diffraction (9 hours)	
Competences Expected: AG-C07	
Topics	**Learning Outcomes**
• Principle of superposition and phasor representation of waves • Young's double-slit experiment and interference fringe intensity • The Michelson Interferometer: Measurement of small displacements • Fraunhofer diffraction by single, double, and N slits • Diffraction by circular apertures and the Airy disk • The Rayleigh criterion for the limit of resolution • Fresnel diffraction and Fresnel zone plates • Multi-beam interference and the Fabry-Perot interferometer	• Calculate the fringe spacing on a screen for a double-slit setup with 532 nm light [Usage] • Determine the minimum resolvable separation of two stars using a 10-inch telescope [Assessment] • Compute the finesse and free spectral range of a Fabry-Perot cavity [Usage]
Readings : [Hec17], [SJ18]	

8. WORKPLAN

8.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

8.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

8.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

9. EVALUATION SYSTEM

Theory Sessions:
The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

Lab Sessions:
In order to verify their competences, several activities including active learning and roleplay will be developed during lab sessions.

Oral Presentations:
Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

Reading:
Throughout the course different readings are provided, which are evaluated. The average of the notes in the readings is considered as the mark of a qualified practice. The use of our virtual campus allows each student to access the course information, and interact outside the classroom with the teacher and with the other students.

The final grade NF depends on the following grades:

- PE: Partial Exam.
- FE: Final Exam.
- P: Permanent Evaluation (Average of practical work and graded assignments).

The final grade NF is calculated as follows:

$$NF = \frac{PE + FE + P}{3}$$

10. BASIC BIBLIOGRAPHY

[YF15] Hugh D. Young and Roger A. Freedman. *Sears and Zemansky's University Physics with Modern Physics*. 14th. Pearson Education, 2015.

[Gri17] David J. Griffiths. *Introduction to Electrodynamics*. 4th. Cambridge University Press, 2017.

[Hec17] Eugene Hecht. *Optics*. 5th. Pearson Education, 2017.

[SJ18] Raymond A. Serway and John W. Jewett. *Physics for Scientists and Engineers with Modern Physics*. 10th. Cengage Learning, 2018.