College of Optics & Photonics

Spring 2016

OSE-3053 Electromagnetic Waves for Photonics

Time: **Tuesday and Thursday** 1:30 PM – 2:45 PM
January 11, 2016 – May 2, 2016

Location: CREOL-A-214

Credit Hours: 3 hours

Prerequisite: OSE3052 or C.I.

Description: Electromagnetic theory of light, Fresnel reflection and refraction, polarization and crystal optics, metallic and dielectric waveguides.

Learning Outcomes:
Upon completing this course, the students will be able to:

- Explain the concept of electromagnetic fields and Maxwell's equations.
- Apply Maxwell's equations to determine the electric and the magnetic fields and the power and their dependence on the medium electromagnetic properties.
- Analyze the propagation characteristics of plane waves including the propagation constants, electric and magnetic fields, and power flow.
- Determine the polarization state for a given field.
- Analyze the reflection and transmission of light at planar interfaces and the dependence on the incident wave polarization and angle of incidence.
- Analyze the reflection/transmission from a single film on a substrate and design a thin film AR coating.
- Explain the principles of crystal optics and analyze simple components that control the polarization and the intensity of light.
- Explain the principles of waveguides and determine the guided modes.

Instructor: Dr. Jim Moharam, Professor
Office CREOL – 274
Email: moharam@creol.ucf.edu

Office Hours: Monday and Wednesday 3:00 PM - 4:00 PM or by appointment.

Course Materials: Class materials, notes, and problem sets are posted on:
https://webcourses.ucf.edu

General Information:

- Students are required to attend the class in person.
- Your e-mail of record at UCF will be used for communication.
- My preferred method of communication (other than in person) is e-mail. It is checked regularly including on weekends.
- If you have questions, out of office hours. E-mail me and I will get back to you within a reasonable time.

Course Requirements and Grading Policy:

- **Problem sets: 20%**
  - Problem sets are to be submitted before the beginning of the class on the due date in person or by e-mail.
  - Late homework is not accepted.
  - You may work with others but the submission must be all yours.
- **Midterm Exam I: 20%**
  - Monday February 22, 2016 1:30 PM -2:45 PM
- **Midterm Exam II: 20%**
  - Monday, April 4, 2015 1:30 PM -2:45 PM
- **Final Exam: 40%**
  - Monday, May 2, 2015 1:00 PM -3:50 PM

Exams are comprehensive and are closed book and notes.

Make up Work/Exam Policy:

If an emergency arises and a student cannot submit assigned work by the due date or cannot take an exam on the scheduled date, the student must notify the instructor no less than 24 hours before and no more than 48 hours after the scheduled date.

Grading Scale (%) Interpretation:

Plus and minus grades will be used.

85 -100	A,A-	Excellent, has a strong understanding of all concepts and is able to apply the concepts in all and novel situations. Has full mastery of the content of the course.
75 - 85	B,B+	Good, has a strong understanding of most or all of the concepts and is able to apply them to stated and defined situations.
60 -75	C-,C,C+,B-	Average, has a basic understanding of the major concepts of the course and is able to apply to basic situations.
50 - 60	D+,D,D-	Below average, has a basic understanding of only the simple concepts and is able to apply to only a limited number of the most basic situations.
0 - 50	F	Demonstrates no understanding of the course content.

Calendar:

January (6)		**February (8)**		**March (9)**		**April (7)**	
		1	3		2	**4 (MT)**	6
		8	**10 (R)**	**7 (SB)**	**9 (SB)**	11	13
11	13	15	17	14	16	18	20
18 (H)	20	**22 (MT)**	24	21	23	25	
25	27	29		28	30	**2 (F)**	

- **National Holiday-University Closed** January 18, 2016
- **Withdrawal deadline** March 23, 2016
- **Spring Break** March 7-12, 2016 – no classes

Financial Aid and Attendance:

- Students' academic activity at the beginning of each course must be documented. In order to document that you began this course, student must complete the ***academic participation verification question*** *posted on* ***Webcourses*** no later than week after the first class. Failure to do so will result in a delay in the disbursement of financial aid.

Class Attendance:

- Regular class attendance is necessary for students to fully grasp the course concepts. If you miss a class session, it will be your responsibility to find out the materials that were covered.

Professionalism:

- Per university policy and plain classroom etiquette, mobile phones, etc. must be silenced during all classroom lectures, unless you are specifically asked to make use of such devices for certain activities. You should be present in class before the lecture begins.

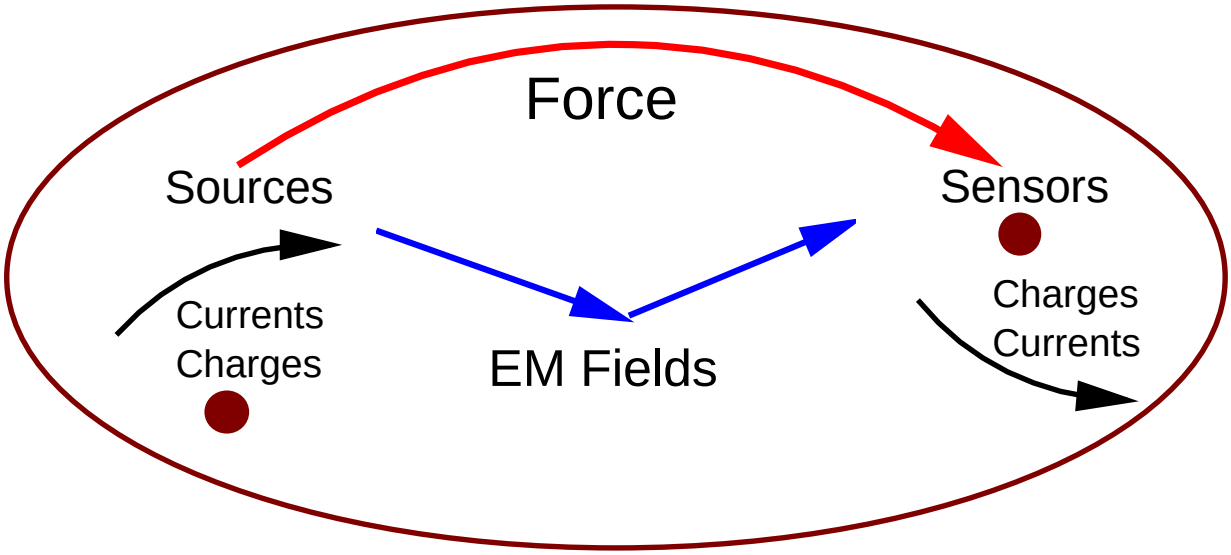
Ethics:

- As in all university courses, "The Golden Rule of Conduct" will be applied. If you are uncertain as to what constitutes academic dishonesty, please consult "The Golden Rule" in the UCF Student Handbook (www.goldenrule.sdes.ucf.edu) for further details. Violation of these rules will result in a record of the infraction being placed in your file and additional sanctions may be applied.

Students with Special Testing/Learning Needs:

- Students with documented special needs and requiring special accommodations must be registered with UCF Student Disability Services (www.sds.sdes.ucf.edu) or at (407) 823-2371 prior to receiving those accommodations. Students must inform the instructor of their special needs as early as possible in the first week of classes.

Electromagnetic Theory



- The concept of fields is introduced to formulate the governing equations.
- “A field is the influence of some agent in a region.”
- The source charges and currents produce “electromagnetic fields”.
- These fields exert forces on the sensor charges and currents.

Topics:

Vector Analysis: (3 lectures)

- Vector algebra, coordinate systems, vector representation, and vector coordinate transformation
- Vector integration: The divergence theorem and Stoke's theorem
- Vector differentiation: Gradient of scalar function, divergence of vector field, curl of vector function, Laplacian of a scalar function, and vector Laplacian of vector function

Electromagnetic Theory and Maxwell's Equations: (2 lectures)

- Coulomb's Law, electric field intensity, electric flux density - permittivity of free-space
- Biot-Savart Law, magnetic field intensity, magnetic flux density, and permeability of free-space
- Lorentz force equation
- Gauss's, Ampere's, and Faraday's Laws; displacement current

Electromagnetic Fields in Materials: (1 lecture)

- Electromagnetic properties of materials:
  - Conductor and conduction current - Conductivity
  - Dielectric materials and their polarization - Permittivity
  - Magnetic materials and their magnetization – Permeability
  - The constitutive relations between the field intensity and the flux density in materials

Maxwell's Equations and Boundary Conditions: (3 lectures)

- Maxwell's equations in integral form
- Maxwell's equations in differential form
  - Continuity equation and the displacement current
- The Poynting's theory and electromagnetic power
- Time harmonic fields and their representations
- Time harmonic Maxwell's equations
- Maxwell's equations in material regions
  - The concept of complex permittivity
- Electromagnetic field boundary conditions at the interface between two layers

Review and First Midterm: (2 lectures)

Plane Wave Propagation in Materials: (3 lectures)

- The wave equation in source free region
- The time harmonic wave (Helmholtz) equation in source free region
- Plane wave solution of the Helmholtz equation
  - The concept of refractive index
  - Propagation vector, phase velocity, wavelength
  - Relationship between the propagation vector and electric and magnetic fields
- The Poynting's theory and electromagnetic power for a plane wave
- Polarization of plane waves: Linear, circular, elliptical

Plane Wave Reflection and Transmission at Planar Boundaries: (4 lectures)

- Plane wave reflection and transmission at plane boundary between two media
- Parallel (TM) and perpendicular (TE) polarizations
- Brewster angle and total transmission, the critical angle and total reflection
- Surface and evanescent waves
- Plane wave reflection at a perfectly conducting plane

Reflection and Transmission at multiple interfaces: (1 lecture)

- Quarter and half-wave transformers
- Applications include anti-reflection coating

Review and Second Midterm: (2 lectures)

Crystal Optics: (2 lectures)

- Anisotropic media such as crystals
- Propagation of light through anisotropic media
  - Retardation and retardation plates
- Polarization devices – wave plates, polarization rotators, amplitude modulators
  - Application: Liquid crystal displays

Metallic and dielectric planar waveguides: (3 lectures)

- Guide modes in metallic waveguides
  - TEM modes in two plate planar waveguides – cut-off condition
  - TM and TE modes in rectangular waveguides – cut-off condition
- Guide modes in dielectric waveguides
  - Symmetric waveguides
  - TM and TE modes in planar waveguides – cut-off condition
  - Single mode waveguides

Review and Final Exam:

Relationship of Course to ABET Criteria:

ABET Criteria	Level of Emphasis (Low, Medium, High)
a) An ability to apply knowledge of mathematics, science, and engineering.	H
b) An ability to design and conduct experiments, as well as to analyze and interpret data.	L
c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	M
d) An ability to function on multidisciplinary teams.	L
e) An ability to identify, formulate, and solve engineering problems.	H
f) An understanding of professional and ethical responsibility.	L
g) An ability to communicate effectively.	M
h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.	L
i) A recognition of the need for, and an ability to engage in life-long learning.	L
j) A knowledge of contemporary issues.	M
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H