Phys 6580 Electromagnetic Theory II

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Textbook: Classical Electromagnetism, 3-rd edition
J.D. Jackson
ISBN: 0-471-30932-X

Meeting times: scheduled time: MWF 11:00am … 11:50am

Office hours: MW, 10:00 am –10:50 am; other times by appointment

Class format: As any math-intensive subject, electromagnetism is best understood by solving problems. Therefore, students are required to read and work through the relevant material before the class. The instructor will summarize the material during one or two classes per week. Students will solve and discuss selected homework problems the remaining classes.

Prerequisites: Math Methods II

Homework grading policy: Student's performance while solving the problem on the blackboard will count towards 50% of homework score. The other 50% of homework score will be based on graded homeworks. Teamwork is permitted and encouraged during homework solutions. However, it must be acknowledged.

Quizzes: will be based on material covered in class. Quizzes are closed/books/notes, and will be assigned throughout the problem-solving classes;

Midterm exam: is closed books, closed notes, based on problems assigned for in-class and homeworks.

Final exam is closed books, closed notes, based on homework problems and on problems solved in class. One single-sided formula sheet (prepared by the students) will be available during final exam.

Regrade policy: It is student's responsibility to prove that grading mistake has been made. When the issue of the regrade concerns the general method of solving the problem, partial credits, etc., the student will be asked to solve the problem on the blackboard in with closed books/closed notes. The instructor will then question the student on the related course material, and assign a new grade for the problem. The new grade can be higher or lower than the original grade.

Grading policy: The grade is determined according to the total score based on:

In-class performance/homeworks:	20%
Quizzes	30%
Midterm:	25%
Final exam:	25%

E-mail communication with instructor: The instructor will use SIS to e-mail important course updates, class notes, etc. to the class. It is assumed that the students regularly check their e-mail.

Missed classes/exams/homeworks: as a rule, there are no makeup exams/homeworks/quizzes. In extraordinary circumstances (severe but short illness, jury duty, etc.) the homework may be postponed, the makeup exam can be arranged, or the score of other assignments can be prorated to cover the missed work. In these cases, the student must inform the instructor as early as possible, and obtain a written approval.

Academic integrity: any suspected cheating or other academic fraud cases will be reported and prosecuted according to UML policy:
(http://www.uml.edu/catalog/undergraduate/policies/academic_dishonesty.htm)

Students with disabilities: will be accommodated according to general policy of the University. Please contact Disability Services at Wellness Center (x4-6800)

Tentative Course Schedule:

Week #		Chapter	Analytical HW	Numerical HW
1	Jan 18, 20 23, 25,	7.1-7.2 Plane waves in homogeneous (isotropic/anisotropic/chiral) media; energy flow, polarization, Stokes parameters		
2 3	Jan, 27, 30 Feb 1, 3 Feb 6,8,10	7.3-7.5 Reflection/refraction, evanescent waves, multilayer systems (transfer matrix formalism), 1D photonic crystals	7.1,V1,V2 *Due Feb 10*	
4 5	Feb 13,15,17	7.8-7.11 Wavepackets, group velocity, dispersion, Casuality, Kramers-Kronig, Permittivity models		TMM code (V3) *Due Feb. 22*
6	Feb. 21,22,24 Feb 27.	8.1 Metals, skin effect, impedance boundary condition	7.4,7.9, PBG (V4) *Due Feb. 24*	
7	Mar 1,3	8.2-8.6 Waveguides, energy flow in waveguides, dielectric waveguides, surface waves	7.10, 7.19, V6 *Due Mar 20*	V5
8	Mar 6, 8, 10	Waveguides (continued), midterm		
9	Mar 20,22,24	9.1-9.3 Radiation	8.2, 8.5, V7,V8 *Due Mar 24*	V9
10	Mar 27,29,31	Radiation (continued) *Planar guides (discussion)*	9.5, 9.6, 9.9 *Due Apr 14*	
11	Apr. 3,5,7	10.1 Scattering at Long wavelength 10.2 Blue sky		
12	Apr 10,12,14	10.5, 10.7 Diffraction		
13	Apr. 19,21	11.1-11.2 Einstein postulates 11.3 Lorentz transformations	10.1,10.3 *Due Apr 28*	V10

14	Apr. 24,26,28	11.4-11.5 Relativistic energy 11.6, 11.9, 11.10 Covariant E&M	11.3, 11.15, 11.19 *Due May 1*	

Updated versions of the schedule will be posted online/e-mailed to the class.

Additional problems (Vxx):

1. Show that the value Stokes parameters S1…S3 does not depend on the basis used
2. Derive dispersion relation and analyze polarization of the waves propagating in gyrotropic medium for
   a. $\hat{\epsilon} = \begin{pmatrix} \varepsilon & i\delta & 0 \\ -i\delta & \varepsilon & 0 \\ 0 & 0 & \varepsilon \end{pmatrix}$
   b. $\hat{\epsilon} = \begin{pmatrix} \varepsilon & 0 & i\delta \\ 0 & \varepsilon & 0 \\ -i\delta & 0 & \varepsilon \end{pmatrix}$

   (assume $k_y = 0$)

3. Write your own TMM for TE and TM-polarized waves; assume that the waves propagate inside isotropic materials, parameterized by relative permittivity ϵ_i, with layer boundaries being at z_i, assume further that direction of propagation is parameterized by k_x value; Debug your TMM to reproduce analytical reflection and transmission spectra from a dielectric/air interface. NOTE: you will use your TMM in the next 2 homeworks; think before writing your code. Submit: print of $R(\theta), T(\theta)$ spectra for both TM, and TE-polarized light, incident from the first layer in the following structure:
   glass ($\epsilon = 2.25$)-25 nm metal ($\epsilon = -10 + 1i$)-air ($\epsilon = 1$); vacuum wavelength $\lambda_0 = 1\mu m$
4. Consider propagation of a TM-polarized wave through periodically stratified medium (periodic stack of material, thickness d_1 and d_2, with relative permittivity ϵ_1 and ϵ_2, respectively (relative permeability $\mu = 1$).
   a. Use TMM to *analytically* derive dispersion relation for such wave,
   $$\cos q\,\Lambda = \cos k_1 d_1 \cos k_2 d_2 - \frac{1}{2}\left(\frac{\epsilon_1 k_2}{\epsilon_2 k_1} + \frac{\epsilon_2 k_1}{\epsilon_1 k_2}\right) \sin k_1 d_1 \sin k_2 d_2$$
   with $k_i^2 = \epsilon_i \frac{\omega^2}{c^2} - k_x^2$ being the z – component of wavevector in the medium $i = 1,2$.
   Hint: Reduce the problem to the eigenvalue-type form. Mathematica or Maple may be used to simplify the resulting determinant
   b. Expand dispersion relation for the photonic crystal in the limit $k_1 d_1, k_2 d_2, q\Lambda \ll 1$ and show that it is equivalent to the dispersion of the plane wave propagating in uniaxial anisotropic medium with components of permittivity tensor $\frac{d_1\epsilon_1 + d_2\epsilon_2}{d_1 + d_2}, \frac{(d_1+d_2)\epsilon_1\epsilon_2}{d_2\epsilon_1 + d_1\epsilon_2}$

5. Analyze the divergence of the optical beam, based on your analytical solution for $A(k)$, for problem 7.19(b,d) as a function of index of refraction and confinement scale a, α. Represent a wavepacket as a linear combination of plane waves with $A(k)$ describing the k_x spectrum of the wavepacket (or, equivantly, the shape of the wavepacket at $z = 0$). Plot the distribution of the intensity in the wavepacket as a function of x, z coordinates for $n = 1$ and for $n = 4$, for two representative confinement scales (use the same set of confinement scales for both indices). Submit: eight surface plots; clearly mark each plot with refractive index and confinement scale parameter used, mark coordinates on your plots; make sure that aspect ratio is correct.
6. Verify that impedance boundary condition $E_\tau = \zeta[H \times n]$ is valid for TE-polarized mode as well. Derive, analytically, reflectivity of TE polarized wave using impedance boundary condition; Compare the predictions of reflectivity of TE-polarized wave for impedance boundary conditions to your TMM calculations for the plane wave incident from glass (relative permittivity 2.25) to materials with ($\epsilon_r = -1000, -100 + 10i$, 100, 10). Submit: analytical derivations of reflectivity, plots of comparisons.
7. Derive dispersion relations for axially-symmetric TE-polarized modes in a cylindrical waveguide (radius R) with PEC walls.
   Hint: use cylindrical polar coordinates; assume plane-wave-like dependence on z, and take advantage of the fact that your fields do not depend on ϕ.
8. Show that an interface between metal ($\epsilon_m < 0$) and dielectric ($\epsilon_d > 0$) supports a propagation of a guided TM-polarized mode; derive dispersion of this mode
9. Use your TMM to calculate dispersion of the modes in a dielectric waveguide formed by a planar slab of glass ($\epsilon_g = 2.25$, thickness $d = 200\ nm$) suspended in air. Plot propagation constant for both TM and TE modes as a function of free-space wavelength. Analyze the behavior of the lowest-order TM and TE waves in the regime $\lambda \gg d$. Explain what you see. Prove your explanation by plotting the relevant field distributions
10. Re-derive the angular distribution of intensity produced by a diffraction grating with N identical slits, width a, distance d between the slits (center-to-center); plot your distribution for $a = 10\lambda_0$; $d = 50\lambda_0$; $N = 1,2,5,10,50$