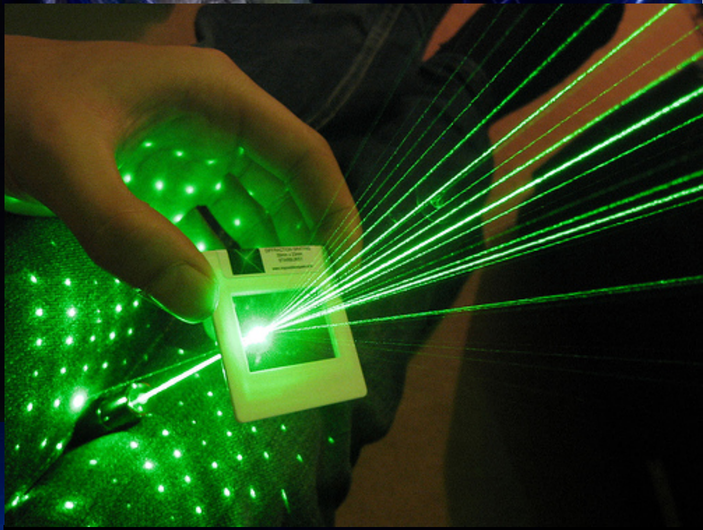
Physics 430/530, *Optics Lab Course*

Prof. Young-Min Shin
La Tourette Hall 206
Physics Department
Northern Illinois University

Spring Semester 2014
11:00 am – 12:15 pm
Tuesday and Thursday
Faraday Hall 237 (Lecture)
Faraday West 219 (Lab)



Course Information

- **Designator/Number: PHYS 430 (Undergraduate)**
  PHYS 530 (Graduate) – Spring in 2014
- **Course Title: Optics (Lab)**
- **Credit Hours: 4**
- **Classroom Location: FH-237 (Lecture), FW-219 (Lab)**
- **Office Hours: 10 – 11 am, Tuesday and Thursday**
- **Course Website: http://alcolpeter.wix.com/niuopticslab**

Course Description

- **The Optics Lab Course is for undergraduate and graduate students in spring semester. The course content covers a wide scope of topics *from historical overview of classical optics to contemporary subjects in modern optics*. The lecture begins with review of basic E&M theory and electrodynamics such as Maxwell equations and plane wave equations. It will go over fundamental concepts of wave dynamics to complex optical phenomena in nature, including Lorentz oscillator model, reflection/refraction at a dielectric interface, Fabry-Perot, multilayer films, polarization, Jones calculus, Fraunhofer diffraction, single/double/multi slit diffraction, and so on.**

Interaction with Instructor

Contact Information

- **Instructor: Prof. Young-Min Shin**
- **Office Location: Faraday West 206**
- **Office Telephone: 815-753-6456 (NIU), 630-840-8478 (Fermilab)**
- **Email Address: yshin@niu.edu, youngmin@fnal.gov, and alcolpeter@gmail.com**
- **Office Hours: 10 – 11 am, Tuesday and Thursday**
- **Preferred Method of Contact: email**
- **Prof. Shin's Professional Website (TBU):**

  http://www.linkedin.com/pub/young-min-shin/58/2a3/56

  http://alcolpeter.wix.com/niuopticslab

  http://www.physics.niu.edu/physics/directory/faculty/Shin.shtml

I try to respond to email daily, Monday through Friday. Generally, expect to receive a response to most weekday email within 24 hours. On weekends, I cannot guarantee a response to email.

So, that I can recognize email message from you, I ask that you type "PHYS 430 (or 530)/your name" in the subject box of every email you send to me. It's possible that I may not read your email message without this information. Please use a proper greeting and sign your name to all email message you send to me.

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Course Objectives

This course will change the way you look at the world. Literally.

We'll talk about things you see every day but generally don't question.

- **Why do windows act like mirrors at night?**
- **Does light really always travel in a straight line?**
- **What's the difference between a laser and a light bulb?**
- **What's going on in a rainbow?**
- **Why is the sky blue?**
- **Why is an oily film on a puddle so colorful?**
- **What's all this business about light slowing down and speeding up?**

After completing this course, you will be able to:

1. ***Understand natural phenomena and science/technology with relevant E&M & Optics Theories***
2. ***Get deep knowledge on classical and modern optics***
3. ***Acquire skills to handle optical apparatus and components***
4. ***Experience historically well known optics experiments with modern test equipment***
5. ***Improve your creativity by conceiving new ideas in lab experiments***

Additional Requirements

Required Media and Technology Access

- Novell Login ID and student Z-ID number
- Labs: recording device (digital video camera, smart phone, etc)
- Public web account (youtube, etc) to upload movie files
- Math Software (MathCAD, Mathlab, Python, etc) and computer interface programs

Instructional Approach

- The preferred method of teaching consists of a variety of instructional techniques including lecture and lab exercises. The course will begin each class with lectures on each topic and follow-up quizzes. Students will have chances to utilize their learning to lab exercises to reinforce the concepts and principles presented.
- ***This course is primarily hands-on in its approach to technology and learning. Therefore, it will include numerous lab activities and projects to offer you the opportunity to demonstrate your abilities and new skills.***

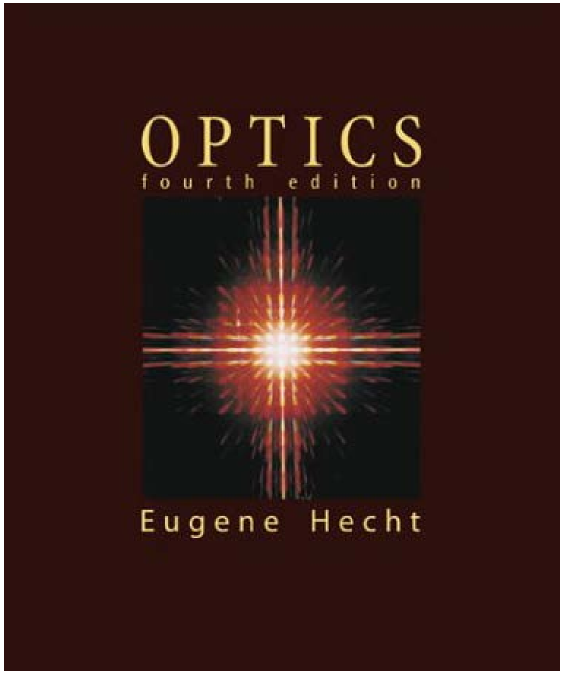
Optics Lab Homepage (http://alcolpeter.wix.com/niuopticslab)

- We will be mainly interacting through the existing optics lab homepage that already have many resources for the course. The website is often updated, so the students will need to keep monitoring it over the semester.

Blackboard

- Blackboard (Bb) is the online course management system (CMS) that we will be using extensively throughout the semester. Several course documents are available on our course site and others will be available at different times throughout the semester.

Books for Bed Time Reading



Required Textbook:

Eugene Hecht, Optics, 4th ed.

Other interesting books:

J.F. James, A Student's Guide to Fourier Transforms

R.N. Bracewell, The Fourier Transform and Its Applications

G.R. Fowles, Introduction to Modern Optics

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More References of Advanced Optics

- Photonic Crystals -

(1) John D. Joannopoulos, et. al, Photonic crystals: Molding the Flow of Light (2nd Edition)
(2) Maksim Skorobogatiy, Jianke Yang, Enlarge Image Fundamentals of Photonic Crystal Guiding, Cambridge University Press, 2008, ISBN: 9780511575228

- Plasmonics

(1) Stephan Alexander Mier, Plasmonics: Fundamentals and Applications
(2) Mark L. Brongersma, Pieter G. Kik, Surface Plasmon Nanophotonics (Springer Series in Optical Sciences)
(3) Eric C. Le Ru, Pablo G. Etchegoin, Principles of Surface-Enhanced Raman Spectroscopy: And Related Plasmonic Effects

- Metamaterials

(1) Metamaterials with Negative Parameters: Theory, Design and Microwave Applications, Ricardo Marqués, et. al.

(2) Optical metamaterials: Fundamentals and Applications, Wenshan Cai, Vladimir Shalaev

(3) Metamaterial handbook: Two volume slipcase set, Filippo Capolino

(4) Metamaterials: Theory, Design, And Applications, Tie Jun Cui, David R. Smith, Ruopeng Liu

(5) Electromagnetic Metamaterials: Transmission Line Theory And Microwave Applications : The Engineering Approach, Christophe Caloz, Tatsuo Itoh

(6) Negative-Refraction Metamaterials: Fundamental Principles and Applications, George V. Eleftheriades

(7) Metamaterials: Physics And Engineering Explorations, Nader Engheta, Richard W. Ziolkowski

- Ultrafast Optics

(1) Andrew Weiner, Ultrafast Optics, ISBN: 978-0-471-41539-8

(2) Robert W. Boyd, Nonlinear Optics (3rd)

(3) Frits Zernike, AJohn E. Midwinter, Applied Nonlinear Optics

(4) Jean-Claude Diels, Wolfgang Rudolph, Ultrashort Laser Pulse Phenomena

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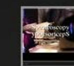
Optics Lab

Faraday West 219

1. Index of Refraction of a Glass Prism and Dispersion
September 5, 2012

To measure the index of refraction of a trianglar glass prism by the minimum deflection method. By doing this at several wavelength of light, the dispersion of the index of refraction can be measured

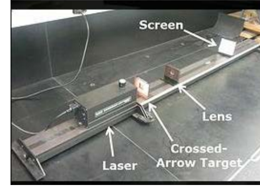
Lab_01.pdf



2. Optical Fiber Interrogator
December, 08 2013

To observe grating dynamics in optical fiber. A wide scope of creativity can be embedded in the experiment, depending upon how the devices are set up with test samples.

Lab_02.pdf



3. Thin Spherical Lenses
December, 08 2013

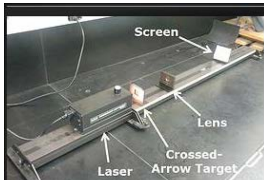
To study thin spherical lenses.

Chapter 5: Geometrical Optics

5.2: Lenses

5.2.3: Thin Lenses (Thin Lens Equation)

Lab_03.pdf



4. Thin Spherical Lenses-II
December, 08 2013

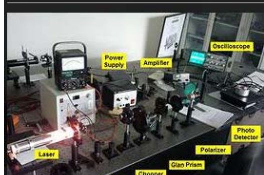
To study a special thin lens combination and learn more about thin lens object and image making.

Chapter 5: Geometrical Optics

5.2 Lenses

5.2.3 Thins Lens Equation

Lab_04.pdf



5. Polarization 1 (Malus' Law)
December, 08 2013

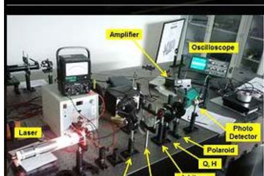
To test Malus' Law with Real Polarizers

Chapter 8: Polarization

8.2 Polarizers

8.2.1 Malus' Law

Lab_05.pdf



6. Polarization 2 (Retardation Plates)
December, 08 2013

To study the function and principles of half-wave plates and quarter-wave plates. Also to estabilish and analyze elliptically polarized light

Chapter 8: Polarization

8. 7: Retarders

Lab_06.pdf

7. Michelson Interferometer
December, 08 2013

In the optics laboratory are sets of Pasco Precision Interferometers, on which we may set up several different kinds of inteferometers, including the Michelson, Fabry-Perot, and Twyman-Green interferometers.

Chapter 9: Interference

9.4: Amplitude-Splitting Inteferometers

9.4.2: Mirrored Interferometers

Lab_07.pdf

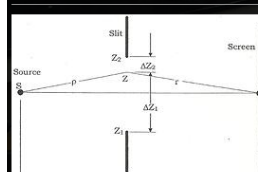
8 - 10. Fraunhfer Diffraction
December, 08 2013

To study the Fraunhofer patterns of light from single, double, and multi slits. Accurate measurements could yield the wavelength of monochromatic light, provided that the slit width was given accurately.

Chapter 10: Diffraction

10. 2: Fraunhofer Diffraction

Lab_08.pdf Lab_09.pdf Lab_10.pdf



11. Fresnel Diffraction
December, 08 2013

To study the complex phenomenon of Fresnel Diffraction from a single slit and to qualitatively compare observed spectra with spectra computed from Fresnel integrals.

Chapter 10: Diffraction

10. 3: Fresnel Diffraction

Lab_11.pdf

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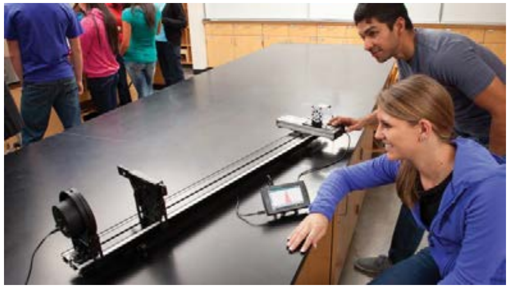
Lab Report

Each experiment will require a lab report. The handout for each experiment will deal mostly with the equipment and procedure, with some theory for guidance. You will be responsible for the theory part, in some cases, along with the presentation of data and some kind of discussion.

<u>I regard the discussion as the most important part</u>, as this is where you give thought to the results and explain how well they verify the theory behind the experiment. Alternatively, if there is a discrepancy, you should attempt to explain the reason. The paper should be typed with the following sections included in the same order:

- Title
- Objective
- Theory – often just some master equation and a mention of where it came from.
- Procedure – sketch of procedure from handout, or else, <u>what you actually did</u> if different than handout.
- Data and graphs.
- Discussion – did experiment verify equation? or if not, why not?
- ***<u>Visualization of Lab Activity – performing a lab experiment is recorded with any type of recording device (video camera, smart phone, etc) and a video file should be submitted with a lab report. The procedure is detailed below.</u>***

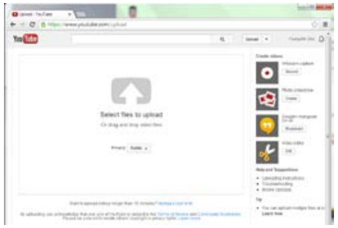
Lab Experiment



Recording

Upload
5 – 10 min

Youtube



Link
URL

Optics Lab Homepage

http://alcolpeter.wix.com/niuopticslab

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Course Project

For Graduates (530)

- Project Topic

→ Advanced Optics

: Metamaterials, Photonics, Plasmonics, Transformation Optics, Optical Fibers, etc

- Project Tasks

(1) Literature survey (scientific journals and books)

(2) Understand physics of optoelectronic structures and phenomena

(3) Theoretical investigation and simulation benchmarking

(4) Design modeling and simulation analysis

(5) Experimental Demonstration*

- Research resource (papers, books, simulation tools, experimental apparatuses, etc) will be provided

Project Evaluation

- Research Report

- Title
- Biography
- Abstract
- Introduction
- Theoretical background
- Method/Procedure
- Data and graphs.
- Analysis
- Discussion

- Technical Presentation

- Oral Presentation
- 15 ~ 20 min (talk) + 5 ~ 10 min (Q&A).
- Any date by end of semester (final exam)
- Narrate goal, background, logistics, methodology, progress, results, analysis, discussion, etc
- Powerpoint slides strongly recommended
- Please feel free to contact me, should you have any questions

Grading

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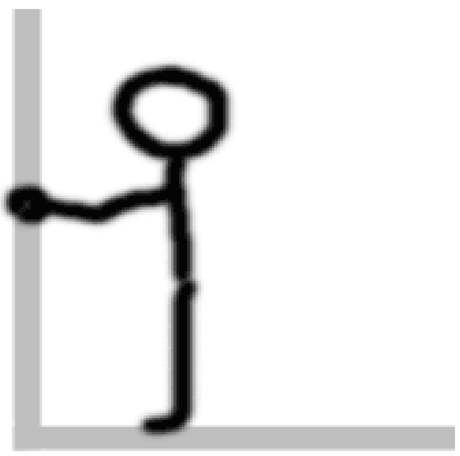
(1) Midterm exam will be held sometime before spring recess. **(Midterm exam = 25%)**
(2) Final Exam is to be held on **Tuesday, May 10, 10-11:50 AM**. **(Final exam = 30%)**
(3) Lab: 9 labs are required. If you do less than 9 of the experiments (or fail to report on them) you will jeopardize your grade in the course, no matter what your relative standing with respect to the exams and homework. I will normalize the lab contributions to 9 experiments, so if you do more than 9, you can get extra credit. **You need to score at least 60% in the lab to pass the course.**
(Lab Report (15 %) + Video (15%) = Total Lab (30%))
(4) Homework: (Homework: 15%)

- Grading Scale:

A = 95 - 100%, B- = 90 – 94.9 %, B = 85 – 89.9 %, B- = 80 – 84.9 %, C+ = 75 – 79.9 %, C = 70 – 74.9 %, D = 60 – 69.9 %, F = 0 %



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Course Policies

In-Class Exercises and Attendance. **You should come to class because there's a lot that I'll say that won't be in the Power Point files, which will be on the tests.** In the past, people who have skipped a lot of classes have received very bad grades. Conversely, people who've come to most or all of the classes nearly always receive A's and B's. **Please note: in-class exercises cannot be made up. It would be in your best interest, therefore, to regularly attend class! There will be no one-on-one instruction for a missed class.**

Participation and Classroom Demeanor. I expect each of you will have something to contribute to the class – please ask questions and be prepared to speak when called upon. Even though classroom participation does not count toward the final grade I expect that your participation and demeanor be active, helpful, and respectful of peers, the instructor, and guest speakers, if any.

Late Work. Homework/lab report will be firmly due on its due date. Late Homework/lab report will be accepted but with a 25% penalty per week. You can work with others on homework but write it up yourself with your own words. Explain your work. I'll drop your lowest homework score, so if you have a bad week, don't sweat it.

Tardiness. If you personal an/or professional schedules prevent you from regularly arriving to class on time, please discuss this with the instructor immediately. Being tardy twice (15 minutes or more late) will reduce total earned by 5 points for each late arrival thereafter.

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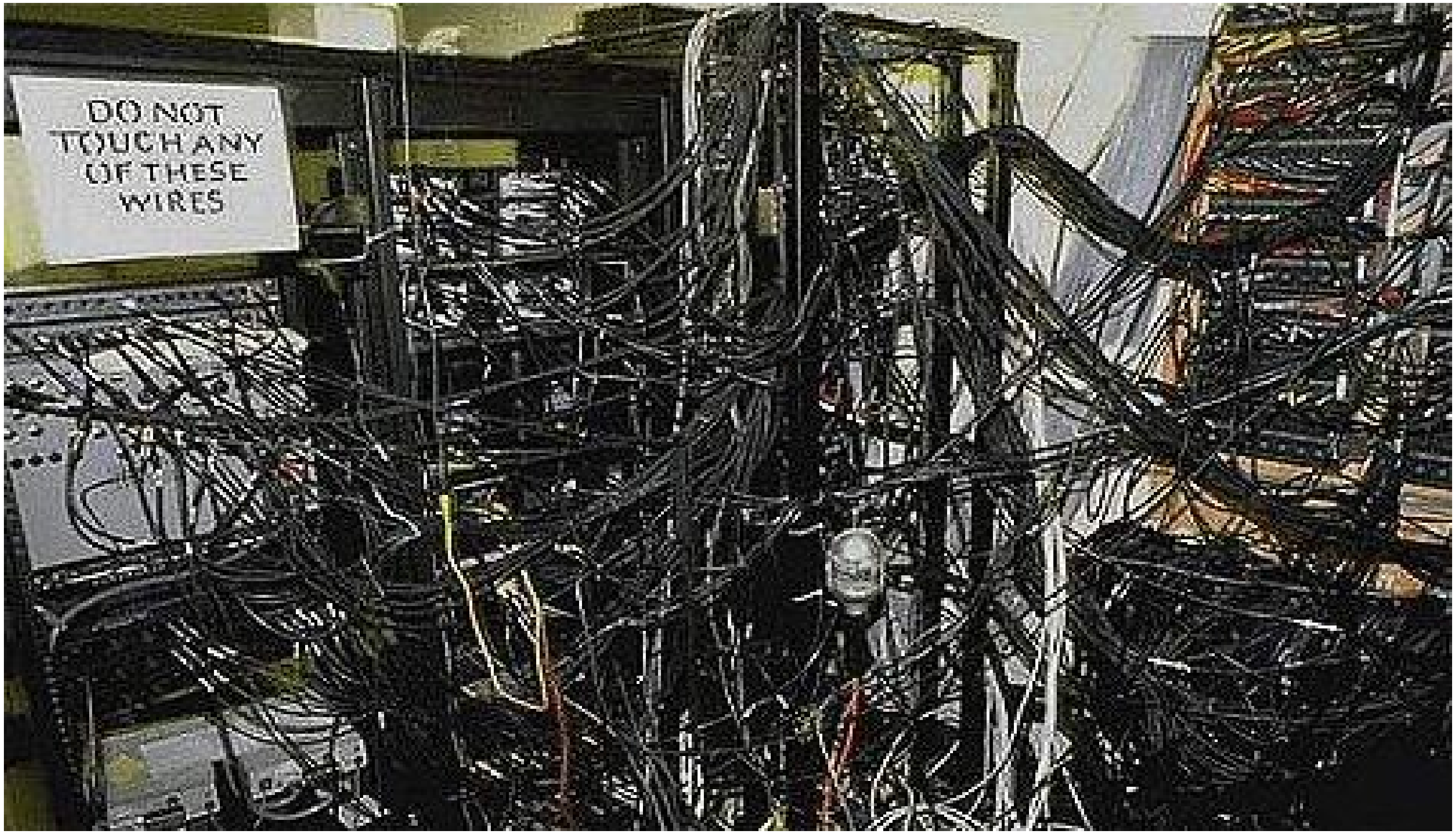
Course Policies

<u>Academic Integrity.</u> If you are "caught" in any act of academic dishonesty in this course, no matter your total points earned for the course at the end of the semester, your final grade will be reduced by ***at least one letter grade***.

Good academic work must be based on honesty. The attempt of any student to present as his her own work that which he or she has not produced is regarded by the faculty and administration as a series offense. Students are considered to have cheated if they copy the work of another during an examination or turn in a paper or assignment written, in whole or in part, by someone else. Students are responsible for plagiarism, intentional or not, if they copy material from books, magazines, or other sources without identifying and acknowledging those sources or if they paraphrase ideas from such sources without acknowledging them. Students responsible for, or assisting others in, either cheating or plagiarism on an assignment, quiz, or examination may receive a grade of F for the course involved and may be suspended or dismissed from the University (2010/2011 NIU Undergraduate Graduate Catalog, (http://catalog.niu.edu/cotent.php?catoid=14&navoid=413)

Why study optics?

Lasers and fiber optics will soon replace most wires.



Optics often has some counterintuitive ideas

But when you think about them for a while, they make sense.

What will be covered (1)

Ch. 2: Some **Mathematical basis** of wave motion.

Ch. 3: A quick review of elementary **Electromagnetic Theory**; Maxwell's equations, light.

Ch. 4: **Propagation of Light**. We will begin with some phenomenological descriptions and progress to the Fresnel equations. Fresnel equations are the basis for most of the interactions of light with matter and are very important. We will spend little time on sections 4.4, 4.5, & 4.6.

Ch. 5-6: Geometrical Optics. We don't want to spend a lot of time on lenses, mirrors,prisms, etc., but we will examine a few things. We will begin with elementary descriptions of refraction at curved surfaces, and then jump ahead to section 6.2 and develop the rest of the theory of thin and thick lenses by using a matrix approach. We will go back and look at some examples to put the theory on a sound basis. We will then make brief mention of properties of selected mirrors and prisms, aperture stops, aberrations and finish with a couple of lectures on Fiber optics and thin film wave guides.

What will be covered (2)

Ch. 7: We will dwell on sections 7.1 through 7.4. The rest is interesting but we will reach back later if we need any of those developments in our theories.

Ch. 8: **Polarization**. We will develop a sophisticated mathematical description of polarization including Jones vectors and matrices. Then we will briefly discuss practical devices for creating the unusual polarization states.

Ch. 9: **Interference**. We probably will go back and pick up the Stokes treatment of reflection and refraction (Section 4.5) and then proceed to multiple reflection situations and interferometers.

Ch. 10: **Diffraction**. We will investigate the theories of diffraction for both the simpler Fraunhofer diffraction and the complicated Fresnel diffraction. There are many diffraction experiments in our repertoire.

If time permits, we will try to look into the principle of Fourier transform or advanced optics (metamaterials, photonic crystals, etc)

Tentative Timeline (430/530 2014)

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This curriculum schedule can change depending on the progress of the class

Date			Chapter	PPT	Topic	Lab		HW	
Month	Tue	Thur				Handout	Due	assn	Due
	14		1	1	**Syllabus (Orientation)/Introduction (historical Review)**				
		16	2	2	**Mathematical basis**			1	
	21		3	3	**EM Theory (Maxwell)**				
		23	3	4	**EM Theory (Waves)**				1
	28								
1		30	3	5	**EM Theory (Light/Matters)**	1		2	
	4								
		6	4	6	**Propagation (Scattering)**				2
	11								
		13	4	7	**Propagation (Reflection)**	2	1		
	18								
		20						3	
	25		5,6	8	**Geometrical Optics**	3	2		
2		27							3
	4							4	
		6			**Midterm**	**4**	**3**		
	11								
		13			**Spring Recess**				4
	18		7	9	**Superposition**				
		20						5	
	25		8	10	**Polarization**	5	4		
3		27							5
	1					6	5		
		3						6	
	8		9	11	**Interference**	7	6		
		10							6
	15					8	7	7	
		17	10	12	**Diffraction**				
	22					9	8		7
		24							
4	29					10	9	8	
		1			**Four Transform/Advanced optics**				
	6								8
5		**8**			**Final**		**10**		

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Understanding the ideas of each lecture requires the knowledge of the previous lectures.

If you keep up, you won't end up looking like this the night before the test!