How the course will be taught in Fall 2020

6.637 will be taught virtually via Zoom this semester. While synchronous participation is strongly encouraged, recordings of the lectures will be available for those not able to attend the “live” sessions. The first class will take place at the regularly scheduled default time (TR 2:30 pm). However, a Doodle poll will be sent in late August to all students registered for credit to explore the possibility of alternate times for both the lectures and the optional weekly office hours that will maximize “live” participation. Since 6.161 is not being offered this term, there will be no access to the Modern Optics Lab. PDFs of the class notes will be shared with all the registered students. Homework will be assigned as usual. We will have 4 in-class, open-book mini-quizzes each 30 minutes long (simplified format). The final project report is still a requirement. A cell phone (or scanner) to image and e-mail your hand-written work will be helpful.

Lectures: TR 2:30 - 4:00pm at https://mit.zoom.us/j/97707442869 (unless class reaches a consensus on a different time).

1. Overview

Most 2-D and 3-D optical imaging systems involve the use of one or more of the following: light sources (e.g., lasers, light-emitting diodes, lamps), spatial light emissive or modulation components (e.g., OLED, liquid crystal, electro-optic-crystal and MEMS light modulators), photodetector arrays (e.g., CCDs, photodiodes), information storage devices (e.g., optical disk, photorefractive material), image processing subsystems (e.g., spatial filtering components, color filtering components, lenses gratings, digital signal processing systems) and of course the human eye.

This course starts with a focus on the fundamental principles of optics and optical phenomena, and includes a laboratory focus on imaging devices and systems. The course has significant design activity so mastery of the fundamentals is essential. The topics covered include: the polarization properties of light, reflection and refraction, coherence and interference, Fresnel and Fraunhofer diffraction regimes, Fourier optics; incoherent and coherent 2-D imaging systems; image resolution; optics of the eye; principles of 3-D imaging systems (near eye and projection); static and dynamic holographic imaging systems (including photorefractive systems); electro-optic, liquid-crystal spatial light modulation; 2-D emissive displays such as OLEDs; lasers, principles of image detectors for the visible and infrared; 2-D and 3-D optical image storage technologies; adaptive optical imaging systems.

Lectures are supplemented with weekly problem sets for the first 8 weeks. There are 4 short quizzes scattered throughout the term that will test the student’s mastery of the fundamentals. The course concludes with a final project that explores the details of a special topic in optics, photonics or quantum electronics, etc that is of interest to the student and meets the approval of the Instructor. There is no final exam.

For more theoretical treatments of the topics covered as well as of other areas of optics, the student is encouraged to enroll in other optics subjects that are specifically designed for this purpose (e.g., 6.630, 6.631, 6.634, 6.453, 6.644).

LECTURE: Online - TR 2:30 - 4:00pm at https://mit.zoom.us/j/97707442869 (unless class reaches a consensus on a different time).

PREREQUISITES: The prerequisite is 6.003 or equivalent. Exceptions can be made by the Lecturer. Feel free to contact either the lecturer, Prof. Cardinal Warde for more information (Registered students only).

“The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them” - Sir William Bragg
Course Staff

| Lecturer: Prof. Cardinal Warde |
| Room 13-3102                     |
| Extension 3-6858                 |
| warde@mit.edu                   |
|                                 |

| Teaching Assistant:             |
|                                 |
|                                 |

| Writing Program Coordinator: N/A in 2020 |
| Course Secretary: Josephina Lee |
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2. Course Components

2.1 Homework Problems
The homework often teaches how to apply the material covered in class to real-world problems, and hence it determines a significant percentage of the grade. One homework problem set will be handed out each week for the first 8 weeks of the term. The homework problems are designed to encourage outside reading, and to strengthen your grasp of the fundamentals. How you got to your answer is very important. Show your work! The grader will deduct points for answers which lack justification. Problem sets will not be accepted after the solutions are handed out. Points will be deducted for late problem sets. Late homework should be placed in the bin outside Room 13-3102 or handed directly to the Instructor or the TA.

2.2 Quizzes
There will be 4 mini quizzes each 30 mins long during the term. The quizzes will be given during the regular class period (see class calendar). These quizzes will cover broad ideas, as presented in lecture, lab, and homework. The quizzes will consist of short questions intended to test your knowledge of basic optical principles, imaging and laboratory optics. These quizzes will be open book (Prof. Warde’s class notes). If you have done the reading, attended the lecture, completed the homework, and worked the labs, you should be well prepared for the quizzes. These quizzes will enable the teaching staff to diagnose both their teaching and your comprehension.

2.3 Final Research Project and Oral Presentation
2.3.1 The Project proposal
In preparation for the final project, each student or team of students will submit a one-page design Project Proposal in week 7 that presents an accurate and compelling account of a contemplated project. At this stage, the objective is not to “sell” an incomplete design, but rather to elicit the most useful feedback possible from your audience of experts (Instructor, TA, or other expert). To do so, the student/team should present evidence of the significance of the problem, of the merit of the proposed solution to that problem, and of the novelty of the solution. The project may be experimental or theoretical, and project proposals that include an in-depth investigation or review of an optics, or imaging topic not covered in class are acceptable.

To make all the final projects roughly equal in difficulty and time requirement, we have provided below several possible final projects ideas (which will still allow for, and require, innovation). Additionally, we will allow students to start the final project as soon as they wish, hopefully reducing end-of-the-term stress. We will provide all the necessary lab equipment and all the technical help we can to ensure that your experience is both educational and rewarding. Of course, if you still want to find your own project, or have a hankering to do something different, just tell us and we will try to accommodate you (in such a case, we would encourage you to look around MIT for groups that may have projects that interest you). Often, final projects found outside of class turn into RAships and M.Eng. theses.
2.3.2 Project Report and Oral Presentation

Students may work alone or in a team of two on the research project. At the end of the research project the student/team will: (1) prepare a research report (30-page limit) and (2) make an oral conference-style 10-minute in-class presentation. The goal of the oral presentation is to teach your newly acquired knowledge to the class. The oral presentation must include a discussion of the relevance or the potential impact of the technology on society. The presentations will be graded on: (a) the clarity of the presentation [2 pts], (b) the substance of the material presented [2 pts], and (c) the creativity/innovation in showing or speculating on the impact or application (present or future) of the technology [1 pts]. The accompanying written report is worth 15 pts.

Areas that may be considered for research projects include:

- Challenges in near-eye display technology
- Flat panel display technologies
- Real-time holographic displays
- Electronic imaging systems
- Thermal imaging systems
- 2-D and 3-D optical storage technologies
- Optoelectronic networks and processors
- Optical neural networks
- Adaptive optical systems
- Coherence tomography
- Recent Advances in Microscopy
- Waveguide displays
- Volumetric imaging

2.4 Writing the Final Project Report

The final project report should not exceed 30 pages in length, and should be written in accordance with the outline followed by most professional journals in the field (e.g., Applied Optics or Journal of the Optical Society of America, IEEE journals, etc). Alternatively, you may use the outline provided below.

1. A cover page which states the title of experiment, your name, subject number, the date, and the name of the person who supervised your work.
2. A one-paragraph Abstract that states the problem being addressed or the goals of the research, the procedures used to solve or analyze the problem, and the salient findings, conclusions or implications of the work.
3. An Introduction that contains a brief description of the problem being investigated as well as brief background information to familiarize the reader with the significance or importance of the work to the field. Be sure to define all uncommon terms.
4. A section describing the Approach used. This section should briefly describe the general techniques or methods used to explore the phenomena being investigated. It may, therefore, include a brief theoretical formulation or modeling of the problem. For brevity, you should cover the principles at a level such that one with a similar educational background (MIT junior or senior) can follow your reasoning. Do not re-derive complicated equations. Instead you should state the equation, cite the reference (see 8 below) where one can find the derivation, but interpret each term in the equation so the reader can understand the physical concepts involved.
5. A brief description of the apparatus used, followed by your Experimental Procedure. Use as many diagrams as you need to describe the apparatus and its operating principles, and how the data were taken.
6. A section describing your Experimental Results and Analysis. Present raw data, whenever possible, in tabular form, and derived results or analysis, whenever possible, in graphical form.
7. A section summarizing your Conclusions with comments on the errors in your measurements, and recommendations for improving the measurements or the experiment. Your conclusions should also tie in to the stated objectives of the experiment so that the reader gets your opinion of the overall success of the work. This is also a good place to speculate on the potential applications of your work.
8. A list of References that support claims made in your report.
Should you still be in doubt, use the bold-face words above as section headings in your reports.

3. Grading Rubric
6.637 quizzes have additional quiz and homework problems beyond the core problems for the 6.161 students. The grade distribution is as follows:

- 40% Homework
- 40% Quizzes (10% each)
- 20% Research project

4. General Logistics

4.1 Neatness and Clarity
To ensure that you get the maximum number of points on each Lab and homework assignment, make sure to be neat! The TA/grader will not grade messy work. Additionally, messy work will delay turnaround on both problem sets and homework. Questions on both problems sets and labs must be answered clearly and succinctly. The TA/grader will be looking for demonstrated understanding. It is preferred that you explain in words when possible; this will ensure that you get the maximum number of points for your effort. However, do not neglect mathematical rigor. When math is needed, it must have the proper units and be clearly written. The clearer and succinct your answers, the better. However, do not compromise important details. The TA/grader will not accept numerical answers without their derivation. Likewise, the TA/grader will not accept written answers, without appropriate reasoning.

4.2 Labeling and Formatting
Whenever a problem asks for a graph, the student must create a computer-generated graph. All graphs must be labeled and titled - a copy of the graph must be transferred to your lab notebook or your homework problem solution. Use callouts to point out important regions of your graphs. Any written answers exceeding one page must be typed. It is suggested that you format all your answers using LaTeX or a comparable typesetting package.

Label your answers clearly; the TA/grader will not search extensively for an answer. Circle your answers, and underline key portions of your work which directly aid in the creation of the answer. Points may not be given back if an answer is skipped in the grading process because the answer was difficult to find.

4.3 Use of Computation Software
When computer-based problems are presented, please use Matlab, Mathematica, LabView or Maple to do your work. If you feel much more comfortable with other math packages, that is okay, but please put the code in your public directory along with instructions on its execution. Please include any code and graphs you use in your solutions. Often, unless stated, graphical solutions may be used, especially if they show that you really understand the material. To use Matlab, Mathematica or Maple on Athena, type: add matlab, add math, and add maple at the Athena% prompt.

4.4 Late-Work Policy
Your TA knows that many of you have obligations which inhibit your ability (on rare occasions) to turn in work on time. If such an emergency arises, notify the TA and the professor in charge before the homework is due (if possible). In order to be fair to your classmates, we must still penalize late work (unless the tardiness was due to medical or similarly urgent reasons and you present a Dean’s note). Additionally, an incomplete problem set will not be accepted. We expect you to make an effort on ALL parts of ALL problems. This gives us the chance to see where you are having problems, if any. If you need additional time, ask for it. You will always receive more points for a completed late problem set than an on-time incomplete one (assuming you turn it in before solutions are handed out). If tardiness becomes a chronic problem, it will significantly degrade our final evaluation of your performance.
4.5 Collaboration
Collaboration is encouraged. Talking with peers about problems helps everyone ("To teach is to learn twice." – Joseph Joubert). However, blatant copying and other forms of cheating will not be tolerated. Always acknowledge your collaborators. This will not hurt your grade. In fact, it may help. We care that you learn the material. If you learn best from a friend, that is fine with us.

4.6 Plagiarism
While collaboration is encouraged, plagiarism will not be tolerated. Please become familiar with the various forms of plagiarism so that you avoid making embarrassing and perhaps costly mistakes. Here are two MIT websites where you can learn more about plagiarism:
http://web.mit.edu/writing/Citation/plagiarism.html

4.7 Office Hours
Group office hours will be conducted weekly at Prof. Warde’s Zoom office (https://mit.zoom.us/j/3445367866). Office hours will address questions from the quizzes, and problem sets. Office hours may also include hands-on demonstrations of applied concepts. While office hours are not mandatory (except to deliver oral presentations of your laboratory exercises) concepts and material are often reviewed that may show up on quizzes, homework and labs. Students are expected to ask questions and come to office hours prepared.

5. Textbooks and Reading Materials
Class notes will be provided on each topic we cover. However, several of the basic concepts are covered in the following textbooks:


Purchase of these textbooks is not mandatory. These books are on reserve in the Barker Library - but occasionally disappear during the term (especially when problem sets are due). They are intended for use as reference material. Please note that Hecht was a required book for 8.03, and Saleh was recommended for 6.631.

Portions of the material we will cover can also be found scattered throughout a number of journals and conference proceedings that include:

- *Journal of the Optical Society of America*
- *Applied Physics Letters*
- *Applied Optics*
- *Optics Communications*
- *Optics Letters*
- *Optical Engineering*
- *Journal of Quantum Electronics*
- *Proceedings of the SPIE*
- *Journal of Display Technology*
- *Applied Physics Letters*
- *Optics Communications*

Occasionally, students will be expected to read and apply material covered in articles selected from these journals.