Optical Design and Instrumentation I

Fall 2019

John E. Greivenkamp
James C. Wyant College of Optical Sciences
University of Arizona

Syllabus

College of Optical Sciences
The University of Arizona

OPTI 502 **Optical Design and Instrumentation I**

Fall, 2019; Mon/Wed/Fri 8:00-9:15

John E. Greivenkamp

Objective: This course will provide the student with a fundamental understanding of optical system design and instrumentation. The course begins with the foundations of geometrical optics, which includes the first-order properties of systems, and paraxial raytracing, continues with a discussion of elementary optical systems, and concludes with an introduction to optical materials and dispersion. A special emphasis is placed upon the practical aspects of the design of optical systems.

Instructor Notes: will be required and will be distributed on line.

Course Web Page: http://wp.optics.arizona.edu/jgreivenkamp/classes/opti-502/

Required Text:

Field Guide to Geometrical Optics J. E. Greivenkamp
081945294-7

Note that this book is available as an e-book through the UA library as well as an app for Android (search "SPIE").

<u>References:</u>

Optics of the Human Eye	Atchison & Smith
Optical Instrumentation	Begunov at al
Field Guide to Lens Design	Bentley and Olson
Radiometry and the Detection of Optical Radiation	Boyd
Geometrical and Trigonometric Optics	Dereniak
Modern Geometrical Optics	Ditteon
Seeing the Light	Falk, Brill & Stork
Optical System Design	Fischer, Tadic-Galeb & Yoder
Camera Technology - The Dark Side of the Lens	Goldberg
Field Guide to Radiometry	Grant
Optics	Hecht
Schaum’s Outline of Theory and Problems in Optics	Hecht
Building Electro-Optical Systems	Hobbs
Fundamentals of Optics	Jenkins & White
Optics and Optical Instruments	B. K. Johnson
Optical Systems Engineering	Kasunic
Introduction to Geometrical Optics	Katz
Fundamental Optical Design	Kidger
History of the Telescope	King
Optical System Design	Kingslake
History of the Photographic Lens	Kingslake
Lens Design Fundamentals	Kingslake
Optics in Photography	Kingslake
Lens Design	Laikin
Optical Imaging and Aberrations	Mahajan
Geometrical and Instrumental Optics	Malacara
Handbook of Lens Design	Malacara & Malacara
Geometrical Optics and Optical Design	Mouroulis & Macdonald
Visual Instrumentation	Mouroulis
Elements of Modern Optical Design	O’Shea
Art of Radiometry	Palmer and Grant
Introduction to Optics	Pedrotti & Pedrotti
Mirror, Mirror	Pendergrast
Applied Photographic Optics	Ray
Scientific Photography and Applied Imaging	Ray

Fundamentals of Photonics	Saleh & Teich
Aberrations in Optical Imaging Systems	Sasián
The Science of Imaging	Saxby
Field Guide to Visual and Ophthalmic Optics	Schwiegerling
The Art and Science of Optical Design	Shannon
Modern Lens Design	W. Smith
Practical Optical System Layout	W. Smith
Modern Optical Engineering - the Design of Optical Systems; Fourth Edition	Warren J. Smith
The Eye and Visual Optical Instruments	G. Smith & Atchison
Concepts of Classical Optics	Strong
Optical Engineering Fundamentals	Walker
Useful Optics	Welford
Aberrations of Optical Systems	Welford
Infrared Handbook	Wolfe
Optical Engineer’s Desk Reference	Wolfe
Handbook of Optics	Optical Society of Am.
Military Handbook 141 - Optical Design	Department of Defense
Basic Optics and Optical Instruments	Bureau of Naval Pers.
Optics Source Book	McGraw Hill
Schott Glass Catalog	

Other Volumes in the SPIE Field Guide Series

Field Guide to Atmospheric Optics	Andrews
Field Guide to Adaptive Optics	Tyson and Frazier
Field Guide to Visual and Ophthalmic Optics	Schwiegerling
Field Guide to Polarization	Collett
Field Guide to Optical Lithography	Mack
Field Guide to Optical Thin Films	Willey
Field Guide to Spectroscopy	Ball
Field Guide to Infrared Systems	Daniels
Field Guide to Interferometric Optical Testing	Goodwin and Wyant
Field Guide to Illumination	Arecchi, Messadi and Koshel
Field Guide to Lasers	Paschotta
Field Guide to Microscopy	Tkaczyk
Field Guide to Laser Pulse Generation	Paschotta
Field Guide to Optical Fiber Technology	Paschotta
Field Guide to Infrared Systems, Detectors, and FPAs (2nd Ed)	Daniels
Field Guide to Special Functions for Engineers	Andrews
Field Guide to Physical Optics	Smith
Field Guide to Binoculars and Scope	Yoder and Vukobratovich
Field Guide to Optical Fabrication	Williamson
Field Guide to Diffractive Optics	Soskind
Field Guide to Probability, Random Processes and Data Analysis	Andrews and Phillips
Field Guide to Radiometry	Grant
Field Guide to Adaptive Optics (2nd Ed)	Tyson and Frazier
Field Guide to Image Processing	Iftekharuddin and Awwal
Field Guide to Optomechanical Design and Analysis	Schwartz and Burge
Field Guide to Lens Design	Bentley and Olson
Field Guide to Terahertz Sources, Detectors and Optics	O’Sullivan and Murphy
Field Guide to Nonlinear Optics	Powers
Field Guide to Distance Measuring Interferometry	Ellis
Field Guide to Holography	Blanche
Field Guide to Astronomical Instruments	Keller, Navarro and Brandl
Field Guide to Digital Micro Optics	Kress
Field Guide to Fiber Optic Sensors	Udd and Spillman
Field Guide to Linear Systems in Optics	Tyo and Alenin
Field Guide to Lidar	McManamon
Field Guide to Molded Optics	Symmons and Schaub
Field Guide to Crystal Growth	Batra and Aggarwal

Field Guide to Infrared Optics, Materials and Radiometry	Daniels
Field Guide to Infrared Systems, Detectors, and FPAs, 3rd Ed.	Daniels
Field Guide to Atmospheric Optics, 2nd Ed.	Andrews
Field Guide to Colorimetry and Fundamental Color Modeling	Kruschwitz
Field Guide to Solid State Physics	Wartak and Fong

Class Schedule:

As SPIE President-Elect, I have an extensive amount of travel that will be required during the semester. In order that I can teach the class and provide the proper number of lectures, a mandatory recitation session has been schedule for Fridays. When I am in town, we will be holding class on Friday (8:00-9:15) to make up for missed Mondays and Wednesdays. As a result, these Fridays are mandatory attendance. The total number of lectures should not change. The schedule will be announced well in advance and posted to the course website.

Course Web Page: http://wp.optics.arizona.edu/jgreivenkamp/classes/opti-502/

Grading and Exams:

Homework	20%	
Midterm Exam – In Class	35%	Wednesday 10/30
Final Exam – In Class	45%	Wednesday 12/18 8:00-10:00

Only a basic scientific calculator may be used for the in-class exams. This calculator must not have programming or graphing capabilities. An acceptable example is the TI-30 calculator. Each student is responsible for obtaining their own calculator. Please note that this type of calculator is also required for the Ph.D. Comprehensive/Preliminary Exam in Optical Sciences.

Please note the final exam date that has been assigned by the University – plan your holiday travel accordingly as the final exam will not be available prior to this date. If the midterm date has not yet been determined, it will be announced well in advance.

Grading:

A: Excellent – has demonstrated a more than acceptable understanding of the material; exceptional performance; exceeds expectations

B: Good – has demonstrated an acceptable understanding of the material; adequate performance; meets expectations

C: Average – has not demonstrated an acceptable understanding of the material; inadequate performance; does not meet expectations

D: Poor – little to no demonstrated understanding of the material; exceptionally weak performance

Pop Quizzes: If class attendance fall below a reasonable level, the instructor reserves the right to give pop quizzes at the start of a lecture. These quick quizzes will be given during the first 2-3 minutes of random classes and will be counted as part of the Homework score for the course. The purpose of the quizzes is to monitor basic material understanding as well as to promote on-time class attendance.

Missed quizzes cannot be made up.

Distance students – the instructor is counting on your integrity to do the quiz during the allotted time period. Please return the quiz as you would any homework set.

Homework: Homework will be assigned regularly throughout the semester, and it will usually be due in one week. The solutions to the homework will be posted at the same time as the homework is assigned. The purpose of the homework is for you to practice the techniques discussed in class or to reinforce this material. Completion of the homework is important to fully master this material. Collaboration and discussion of the homework is encouraged.

Because of the irregular class schedule, homework will be turned in to the Academics Office (Room 403) by 10:00 AM on the due date. Anything turned in after that time is considered late. Approval for early or late homework must be obtained in advance from the instructor.

A student may only turn in their own homework. No electronic submissions are permitted. Any homework turned in to the TA will receive zero credit.

Because the homework solutions are available as a resource during the completion of the assigned homework, the grading of the homework will be based upon verification that the homework problems have been completed and turned in.

Late Homework Policy for On-Campus Students:

- Homework that is turned in after 10:00 AM on the due date is considered late.
- Late HW that is turned in on the due date will receive a 20% penalty.
- Late HW that is turned in on the day after the due date will receive a 50% penalty.
- Late HW that is turned in two or more days after the due date will receive no credit.

- All late homework must be turned in at the Academics Office. Any HW turned in to the TA will receive zero credit.

- Homework must be turned in during normal business hours. Do not slip late HW under a door or leave it in the box outside a door. It will get zero credit.

- When issues arise, please contact the instructor as soon as possible so that appropriate accommodations can be made.

Absence: It is expected that students will regularly attend class and be on time for class. Late arrivals to class are distracting to both the instructor and the other students. Attendance for this class is not part of the course grade (but please note the pop quiz policies).

In Keeping with University policies:

- All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion.
- Absences pre-approved by the UA Dean of Students (or Dean's designee) will be honored.

Since there is no grade for attendance for this course, these policies would apply primarily to scheduled exams and quizzes. The instructor must be notified at least one week prior to any such absence so that appropriate arrangements can be made.

Academic Integrity

Students will abide by the University's Student Code of Academic Integrity:

Principle:

Integrity and ethical behavior are expected of every student in all academic work. This Academic Integrity principle stands for honesty in all class work, and ethical conduct in all labs and clinical assignments. This principle is furthered by the student Code of Conduct and disciplinary procedures established by ABOR Policies 5-308 through 5-404 *(see chapter 5)*, all provisions of which apply to all University of Arizona students. This Code of Academic Integrity (hereinafter "this Code") is intended to fulfill the requirement imposed by ABOR Policy 5-403.A.4 and otherwise to supplement the Student Code of Conduct as permitted by ABOR Policy 5-308.C.1. This Code of Academic Integrity shall not apply to the Colleges of Law or Medicine, which have their own honor codes and procedures.

Prohibited Conduct:

Students enrolled in academic credit bearing courses are subject to this Code. Conduct prohibited by this Code consists of all forms of academic dishonesty, including, but not limited to:

1. Cheating, fabrication, facilitating academic dishonesty, and plagiarism as set out and defined in the Student Code of Conduct, ABOR Policy 5-308-E.10, and F.1
2. Submitting an item of academic work that has previously been submitted or simultaneously submitted without fair citation of the original work or authorization by the faculty member supervising the work.
3. Violating required disciplinary and professional ethics rules contained or referenced in the student handbooks (hardcopy or online) of undergraduate or graduate programs, or professional colleges.
4. Violating discipline specific health, safety or ethical requirements to gain any unfair advantage in lab(s) or clinical assignments.
5. Failing to observe rules of academic integrity established by a faculty member for a particular course.
6. Attempting to commit an act prohibited by this Code. Any attempt to commit an act prohibited by these rules shall be subject to sanctions to the same extent as completed acts.
7. Assisting or attempting to assist another to violate this Code.

Student Responsibility:

Students engaging in academic dishonesty diminish their education and bring discredit to the academic community. Students shall not violate the Code of Academic Integrity and shall avoid situations likely to compromise academic integrity. Students shall observe the generally applicable provisions of this Code whether or not faculty members establish special rules of academic integrity for particular classes. Students are not excused from complying with this Code because of faculty members' failure to prevent cheating.

Faculty Responsibility:

Faculty members shall foster an expectation of academic integrity and shall notify students of their policy for the submission of academic work that has previously been submitted for academic advancement, as well as any special rules of academic integrity or discipline specific ethics established for a particular class or program (e.g., whether a faculty member permits collaboration on coursework; ethical requirements for lab and clinical assignments; etc.), and make every reasonable effort to avoid situations conducive to infractions of this Code.

Student Rights:

Students have the right to a fair consideration of the charges, to see the evidence, and to confidentiality as allowed by law and fairness to other affected persons. Procedures under this Code shall be conducted in a confidential manner, although a student has the right to an advisor in all procedures under this Code. The Dean of Students serves as advisors to students on any questions of process related to this Code.

It is expected that students observing violations of this code by other students will report these violations to either the Instructor or to the Associate Dean for Academic Programs at the College of Optical Sciences.

Other Policies:

As a courtesy to the instructor and other students in the class, the use of cell phones, pagers, text messaging, personal music devices, etc. is prohibited during class. Computers are to be used only for class-related activities, such as note taking.

Students must abide by all aspects of the University's Student Policies, Procedures and Codes: https://deanofstudents.arizona.edu/policies-and-codes/code-academic-integrity Of particular note are the previously mentioned Code of Academic Integrity and the Policy Against Threatening Behavior By Students.

Information contained in this course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.

Disability Resource Center:

Accessibility and Accommodations: At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu/) to establish reasonable accommodations.

Students who are registered with the Disability Resource Center must contact the instructor by Friday October 4 so that the necessary accommodations can be arranged. For this course, exams will be administered here at the College of Optical Sciences rather than at the DRC.

Instructor: John E. Greivenkamp
College of Optical Sciences, Rm. 741
University of Arizona
Tucson, AZ 85721
(520) 621-2942
greiven@arizona.edu

Office Hours: Monday 2:00-3:00

I also maintain an open door policy related to this course. Feel free to knock even if the door is physically closed. If the time is bad, we will set something up.

Course Web Page: http://wp.optics.arizona.edu/jgreivenkamp/classes/opti-502/

In addition, the site is used for distribution of other course materials, additional course notes and corrections, and exam schedules.

Teaching Assistant and Grader:

Sunglin Wang

slwang@email.arizona.edu

Office Hours: TBD

Office hours will be held in the 7th floor discussion area (Optical Sciences West Wing). Help is also available by email and appointment. Please email to set up an individual appointment.

Special Instructions for Distance Learning Students

Send all correspondence to the address below. Do not send duplicate copies of homework or exams to me. This allows the material to be properly logged in and will decrease overall confusion. Be sure to include my name and the course number on all correspondence.

Send all correspondence to:

Cindy Robertson
College of Optical Sciences
Meinel Building Rm #419
University of Arizona
1630 E University Blvd
Tucson, AZ 85721
(520) 626-4719
(520) 626-4514 FAX
cindyr@optics.arizona.edu

Feel free to contact the TA or me with questions. This can be done via e-mail or phone. Please include your phone number in any emails. We will do our best to get you a quick answer. There are many people in this class, so try to start with the TA and then me if you need additional help.

Since there is often a delay between the date a lecture is given and the date you view it, there is some flexibility in the due dates for homework and exams. Homework and the midterm exam must be received in Tucson within one week of the on-campus due date or exam date. Any course material received after this limit will receive zero credit. Please contact the instructor in advance if schedule issues arise. Once we receive your assignments, we will grade and return them as soon as possible.

All course materials (including the final exam) must be received in Tucson by **5 PM on Thursday December 19, 2019**. The exam may be scanned and emailed, and it is the Student's responsibility to see that this requirement is met by their proctor.

I would also appreciate it if you would send me a brief paragraph about your job and educational background. I find it interesting to see the diversity of employment of our distance students.

OPTI-502 Syllabus

Optical Design and Instrumentation I -- 3 Credit Hours (29 Lectures)

Rays and Waves, Snell's Law, Mirror and Prism Systems, Gaussian Imagery and Cardinal Points, Paraxial Raytracing, Stops and Pupils, Radiometric Transfer, Vignetting, Elementary Optical Systems (Objectives, Telescopes, Illumination Systems, Projectors, Photographic Systems), Optical Materials, Dispersion, Achromatic Doublet.

Foundations of Geometric Optics

1. Assumptions of geometrical optics; refractive index; optical path length; rays and wavefronts; Fermat's principle; Snell's law; refraction and reflection; critical angle; sign conventions.

2. Plane mirrors; systems of plane mirrors; parity and orientation.

3. Non-dispersing prisms and prism types; plane-parallel plate; tunnel diagrams; reduced thickness.

4. Imaging with a thin lens; focal length; conjugates; magnification; imaging equations.

5. Real and virtual images; negative lenses; thin-lens afocal systems.

6. Imaging and optics; optical spaces; principal planes; paraxial refraction equation; power and focal lengths of general systems.

7. Gaussian imagery; magnification; cardinal points and planes; Newtonian and Gaussian equations; conjugate planes; afocal systems.

8. Object-image relationships and zones; longitudinal magnification; colinear transformation.

9. Transfer between surfaces; two component systems; Gaussian reduction.

10. Single reflecting surface; thick lens; thin lens; systems of two thin lenses.

11. Paraxial ray tracing; cardinal points by raytracing; back focal distance; virtual objects.

12. Stops and pupils; marginal and chief rays; field of view; Lagrange invariant.

13. Determination of pupil location by Gaussian optics and raytracing; numerical aperture; f-number.

14. Vignetting; real ray traces.

15. Radiometric Transfer; AΩ product; camera equation.

Elementary Optical Systems

16. Objectives; collimators; depth of focus and hyperfocal distance; Scheimpflug condition.

17. Zoom lenses; simple magnifier; magnifying power.

18. Keplerian telescope; eye relief; field lenses; eyepieces; Galilean telescope; mirror systems.

19. Image erection and relay systems; microscopes.

20. Telecentric systems; imaging properties of afocal systems.

21. The stop and its effects on image quality and system performance.

Optical Materials and Dispersion

22. Glass properties; dispersion and Abbe number; other optical materials.

23. Dispersing prisms; minimum deviation; index measurement; prism spectrometer.

24. Thin prisms; combinations of thin prisms; achromatic prism; direct vision prism.

25. Longitudinal chromatic aberration; thin lens achromatic doublet; rainbows.

Other Optical Systems

26. Illumination systems; diffuse illumination; projection condenser system; Kohler illumination; critical illumination; slide projector.

27. Light Sources; integrating sphere and bars; practical considerations; dark field and Schlieren systems; overhead projector; Fresnel lenses.

28. The Eye

29. Photographic systems; viewfinders and focusing aids; autofocus systems; autocollimator; scanners.