OPTI 306 – Radiometry, Sources, & Detectors

OPTI 306 - Radiometry, Sources and Detectors - Fall, 2022. Radiometric concepts, symbols, units and nomenclature. Radiative transport in free space and through optical systems. Effect of material properties on radiative transport. Blackbodies and other radiation sources. Fundamentals of radiation detectors, including principles of operation, noise and figures of merit. Illustrative imaging and nonimaging radiometric systems.

Prerequisites:	OPTI201R; knowledge of basic electronics
Class time:	MW, 2.00 pm – 3.15 pm in Meinel 408/410
Discussion:	F, 2.00 pm – 3.15 pm in Meinel 305 (voluntary); examples, labs, Q&A
Instructor:	John Koshel
Email:	jkoshel@optics.arizona.edu
Office:	Meinel Room 403A
Phone:	622-6357
Office Hours:	In person or https://arizona.zoom.us/my/koshel – come anytime or schedule – I get an email when you go into the Zoom room if I am not there
TA:	Luke Somerville
Email:	lukesomerville@arizona.edu
Office:	654
Office Hours:	Monday 10.00 am – 11.00 am, Meinel 654 Thursday 3.00 pm – 4.00 pm, https://arizona.zoom.us/j/87805875137 Friday 12.30 pm – 2.00 pm, Meinel 654
Preceptor:	Kongo Lai (will help in class, especially discussion)
Email:	yongxinlai@arizona.edu

Course Objectives:
This course covers the generation (sources and radiometry), propagation (radiometry), and measurement (detectors and radiometry) of optical radiation. The theory, units, approximations, instrumentation, and applications will be presented in detail.

Learning Outcomes:
1. Understand how to measure optical radiation with physical (radiometric) and psychophysical (photometric) terms,
2. Understand the concept of étendue,
3. Know the types of sources, especially blackbody ones,
4. Know the various type of detectors, and
5. Be able to calculate noise and SNR arising from measurement.

Course Material and Logistics:

Lectures:	PDFs will be uploaded to D2L around each lecture time. Note that not all material will be within the PDFs: supplement the lectures with class notes. All lectures will be live online (Zoom) and a recording will be posted to D2L.
Recitation:	Friday 2.00 pm – 3.15 pm in Meinel 408/410. Homework, solutions, midterm, labs, and so forth will be discussed. Attendance at any recitation is optional.
Homework:	Assignments and solutions will be uploaded to D2L. Assignments may involve lab kits that will be supplied at a later date.
Other:	Other material will be posted on D2L as warranted

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

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Absence: You are expected to follow the UA Policy, but you are adults so I respect your decisions. I follow UA policies for religious beliefs and pre-approved absences. See end of document.

Course Outline (75-minute lectures)

This listing is tentative, and the order and topics may change as the semester progresses.

Lecture Number	Expected Date	Topic(s)
1	8/22/22	Syllabus, My Field, and What is Radiometry
2	8/24/22	Units and Solid Angle
3	8/29/22	Projections and Radiance
4	8/31/22	Intensity and Exitance
5	9/7/22	Irradiance
6	9/12/22	Invariants
7	9/14/22	Étendue
8	9/19/22	Radiative Transfer and Cosine Laws
9	9/21/22	Configuration Factor
10	9/26/22	Integrating Sphere
11	9/28/22	Radiometric Instruments
12	10/3/22	Finish Radiometry
13	10/5/22	Transmittance and Reflectance
14	10/10/22	Scatter and Absorption
15	**10/12/22**	**EXAM I (through Finish Radiometry)**
16	10/17/22	Source Introduction I
17	10/19/22	Source Introduction II
18	10/24/22	Blackbody Radiation
19	10/26/22	Emissivity
20	10/31/22	Examples
21	11/2/22	Laser Safety and Source Selection
22	11/7/22	Introduction to Detectors
23	11/9/22	Introduction to Noise
24	11/14/22	Noise Types and Noise Addition
25	11/16/22	Photon Detector Introduction
26	11/21/22	Photoemissive Detectors
27	11/23/22	Photoconductive Detectors
28	11/28/22	Photoconductive Detectors
29	11/30/22	Photovoltaic Detectors
30	12/5/22	Areal Detectors and Vacuum Detectors
31	12/7/22	Thermal Detectors

See calendar selector for Academic Dates: Undergraduate

Note that the radiometry material is used throughout the lectures that follow the first section. It is imperative that you understand the first "**twelve**" lectures in order to fully understand the lectures that follow:

- Radiometry through lecture 12
  - Exam I: in-class exam, expected 12 October 2022
- Sources through lecture 21
  - Exam II: take-home exam, expected in the week of 14 November 2022
- Detectors through lecture 31

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- Project: last few weeks of course, expected due date 16 December 2022

Texts (recommended) – see D2L > Library Tools for easy access to some:

1. **The Art of Radiometry**, James Palmer & Barbara Grant, SPIE Press, (2010).
   a. GET THIS ONE!
   b. You can get it for free through SPIE since the UA has a site license – look at D2L > Library Tools – should be accessible on and off campus
   c. Off campus & (b) does not work, login with VPN to the UA (requires UA NetID+)
   d. Go to the SPIE website and download
   e. NOTE: I do **NOT** use the notation for projections from this book
2. **Radiometry and the Detection of Optical Radiation**, Robert W. Boyd, Wiley-Interscience (1983).
   a. GET THIS ONE too!
   b. Unfortunately there is not an electronic version
   c. Great book IMO, but the notation is different than #1
   d. NOTE: I use the notation for projections from this book
3. **Optical Radiation Detectors**, Eustace Dereniak and Devon G. Crowe, Wiley Series in Pure and Applied Optics (1984).
   a. Another good book written by individuals with a connection to OpSci
4. **Introduction to Radiometry**, William L. Wolfe, SPIE Press (1998).
   a. Go to SPIE website and download
5. **Handbook of Optics**, Volume II, 3rd Ed., ed. Michael Bass, V. N. Mahajan, and Eric Van Stryland, McGraw Hill (2010).
   a. See chapters on radiometry, illumination, photometry, sources, etc.
6. **Field Guide to Geometric Optics**, John Greivenkamp, SPIE Press (2003).
   a. See #1 then visit the SPIE website and download
7. **Field Guide to Illumination**, Angelo V. Arecchi, Tahar Messadi, John Koshel, SPIE (2007).
   a. See #1 then visit the SPIE website and download
   b. Illumination is based on the field of radiometry
8. **Illumination Engineering: Design with Nonimaging Optics**, R. John Koshel, Wiley-IEEE Press (2013).
   a. You can download this one too

Exams: There will be two exams – Exam I in class and Exam II take home.

Design Project: You will be asked to design a detection system at the end of the course. Included in the project will be the specification of the source, optics, and detector along with an analysis of the expected performance. The details of this project will be provided by early November.

Assignments: After most class lectures a "quiz" will be assigned. These quizzes will include questions from that day's material, surveys, interpretations of material, case studies, and so forth. Each quiz will be due at the end of the day of the next class. Note that for some quizzes there "will be no right answer," so completing them is a necessity to get 100% on those. The lowest three are dropped. Expect around 20 quizzes.

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Homework assignments will be given, and they may involve computer simulations or physical measurements with apparatus to be supplied. Students are encouraged to work together on homework assignments, but the final write-ups must be independent. Homework is to be turned in by the end of the day it is due. Expect 4-6 homework assignments. Homework assignments are worth five quizzes.

Grading:

Assignments	20%	(1 day late -25%, 2 days late -50%, no credit later)
Exam I	20%	(in class, expected 12 October 2022)
Exam II	25%	(take home, week of 14 November 2022)
Project	35%	(due end of finals, 16 December 2022)

Grading: The grade will be determined according to the cumulative percentage earned such that 90-100% = A, 80- 89% = B, 70-79% = C, 60-69% = D, below 60% = E.

For Undergraduates:

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

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

C: Average – has demonstrated a barely acceptable understanding of the material; adequate performance; meets minimum expectations

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

E: Failure – little to no demonstrated understanding of the material; exceptionally weak performance

CLASSROOM BEHAVIOR

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

THREATENING BEHAVIOR

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

ACADEMIC INTEGRITY

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of

independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://new.library.arizona.edu/research/citing/plagiarism.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

NONDISCRIMINATION AND ANTI-HARASSMENT

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy.

ACCESSIBILITY AND ACCOMONDATIONS

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 (520-622-3268, https://drc.arizona.edu/) to establish reasonable accommodations.

SPECIAL NOTES

- **Classroom attendance:**
  - If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
  - Notify your instructor(s) if you will be missing a course meeting or an assignment deadline.
  - Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments.
  - Please communicate and coordinate any request directly with your instructor.
  - If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing.
  - Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus.
  - COVID-19 vaccine is available for all students at Campus Health.
  - Visit the UArizona COVID-19 page for regular updates.

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- **Academic advising:** If you have questions about your academic progress this semester, please reach out to your academic advisor (https://advising.arizona.edu/advisors/major). Contact the Advising Resource Center (https://advising.arizona.edu/) for all general advising questions and referral assistance. Call 520-626-8667 or email to advising@.arizona.edu
- **Life challenges:** If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at (520) 622-2057 or DOS-deanofstudents@email.arizona.edu.
- **Physical and mental-health challenges:** If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 622-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 622-3334.

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