OPTI 306 – Radiometry, Sources, & Detectors

OPTI 306 - Radiometry, Sources and Detectors - Fall, 2024. 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 422
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:	Chase Toncheff
Email:	cat6@arizona.edu
Office:	Meinel Room 654
Office Hours:	W 10-11 AM, Th 1-2 PM, and/or https://arizona.zoom.us/j/88212256539

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 theoretically and experimentally 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.
Recitation:	Friday 2.00 pm – 3.15 pm in Meinel 305. Homework, solutions, exam prep, labs, and so forth will be discussed/done. Attendance at the 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
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 for a little more detail.

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Course Outline (75-minute lectures)

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

Lecture	Date	Day	Topic(s)	Quiz Due	HW Due	Other
1	8/26/24	M	Syllabus, My Field, and What is Radiometry			
2	8/28/24	W	Units and Solid Angle	Q1		Survey
	8/30/24	F	Recitation: HW/Lab #1 help	Q2		
	9/2/24	M	NO CLASS - LABOR DAY			
3	9/4/24	W	Projections, Radiance & Luminance		HW1	
	9/6/24	F	Recitation: radiometry examples	Q3		
4	9/9/24	M	Intensity and Exitance			
5	9/11/24	W	Irradiance and Power	Q4		
	9/13/24	F	Recitation: HW/Lab #2 help	Q5		
6	9/16/24	M	Invariants: Throughput & Étendue		HW2	
7	9/18/24	W	Radiant Transfer	Q6		
	9/20/24	F	Recitation: radiometry examples	Q7		
8	9/23/24	M	Configuration Factor			
9	9/25/24	W	Far-Field, Approximation with Far-Field	Q8		
	9/27/24	F	Recitation: HW/Lab #3 help	Q9		
10	9/30/24	M	Cosine Laws, Radiometers: Apertures		HW3	
11	10/2/24	W	Radiometers: Lenses, Integrating Sphere	Q10		
	10/4/24	F	Recitation: radiometry examples			
12	10/7/24	M	Transmittance and Reflectance	Q11		
13	10/9/24	W	Scatter	Q12		
	10/11/24	F	Recitation: radiometry review			
14	10/14/24	M	Absorption, Source Introduction: Luminescent			
15	10/16/24	W	**EXAM I: RADIOMETRY**			
	10/18/24	F	Recitation: materials examples	Q13		Homecoming
16	10/21/24	M	Source Introduction: Thermal	Q14		
17	10/23/24	W	Blackbody Radiation	Q15		
	10/25/24	F	Recitation: BB examples	Q16		Honors Convocation
18	10/28/24	M	Emissivity			
19	10/30/24	W	Examples	Q17		
	11/1/24	F	Recitation: HW/Lab #4 help	Q18		
20	11/4/24	M	Examples		HW4	
21	11/6/24	W	Laser Safety & Source Selection	Q19		
	11/8/24	F	Recitation: BB examples	Q20		
	11/11/24	M	NO CLASS - VETERANS DAY			
22	11/13/24	W	Introduction to Detectors and Noise			
	11/15/24	F	Recitation: materials & sources review			Exam II out, GCRB 136
23	11/18/24	M	Noise Types and Noise Addition			Exam II Due 11/17/24
24	11/20/24	W	Photon Detector Introduction	Q21		
	11/22/24	F	Recitation: HW/Lab #5 help	Q22		
25	11/25/24	M	Photoemissive Detectors		HW5	

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Lecture	Date	Day	Topic(s)	Quiz Due	HW Due	Other
26	11/27/24	W	Photoconductive Detectors	Q23		
	11/29/24	F	NO RECITATION - THANKSGIVING			
27	12/2/24	M	Photovoltaic Detectors			
28	12/4/24	W	Array Detectors	Q24		
	12/6/24	F	Recitation: detector examples	Q25		
29	12/9/24	M	Thermal Detectors & Color		HW6	
30	12/11/24	W	Class Choice!	Q26		Survey

Note: typically ± 1 lecture for the material covered
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 "**eleven**" lectures in order to fully understand the lectures that follow:

- Radiometry through lecture 11
  - Exam I: in-class exam, expected 16 October 2024
- Sources and Materials through lecture 21
  - Exam II: take-home exam, expected 15 November 2024
- Detectors through lecture 30
  - Project: last few weeks of course, expected due date 20 December 2024

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

1. I have placed all the notes under D2L > Content > Text
   a. There are three files – one for each section of the course
   b. They are the overheads collated from the 2023 notes
   c. Expect some changes and additions to the overheads for the 2024 version of the course
2. **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
3. **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
4. **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

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5. **Introduction to Radiometry**, William L. Wolfe, SPIE Press (1998).
    a. Go to SPIE website and download
6. **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.
7. **Field Guide to Geometric Optics**, John Greivenkamp, SPIE Press (2003).
    a. See #1 then visit the SPIE website and download
8. **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
9. **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 in 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/recitation. 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 26 quizzes.

Homework assignments will be given, and most likely 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 6 homework assignments.

Grading:

Quizzes	8%	(1 day late -25%, 2 days late -50%, no credit later)
Homework	12%	(1 day late -25%, 2 days late -50%, no credit later)
Exam I	20%	(in class, expected 11 October 2024)
Exam II	25%	(take home, around 8 November 2024)
Project	35%	(due end of finals, 20 December 2024)

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

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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.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

SAFETY ON CAMPUS AND IN THE CLASSROOM

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview.

Also watch the video available at https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy000000000003560.

ADDITIONAL RESOURCES FOR STUDENTS

- **UA Academic policies and procedures** are available at
  - http://catalog.arizona.edu/policies
- **Campus Health**
  - http://www.health.arizona.edu/
  - Campus Health provides quality medical and mental health care services through virtual and in-person care
  - Phone: 520-621-9202
- **Counseling and Psych Services (CAPS)**
  - https://health.arizona.edu/counseling-psych-services
  - CAPS provides mental health care, including short-term counseling services
  - Phone: 520-621-3334
- **The Dean of Students Office's Student Assistance Program**

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  - https://deanofstudents.arizona.edu/support/student-assistance
  - Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services
  - Email: DOS-deanofstudents@arizona.edu
  - Phone: 520-621-7057
- **Survivor Advocacy Program**
  - https://survivoradvocacy.arizona.edu/
  - The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support
  - Email: survivoradvocacy@arizona.edu
  - Phone: 520-621-5767
- **Confidentiality of Student Records**
  - http://www.registrar.arizona.edu/ferpa
- **University-wide Policies link**
  - Links to the following UA policies are provided here,
  - http://catalog.arizona.edu/syllabus-policies
    - Absence and Class Participation Policies
    - Threatening Behavior Policy
    - Accessibility and Accommodations Policy
    - Code of Academic Integrity
    - Nondiscrimination and Anti-Harassment Policy
    - Subject to Change Statement

SPECIAL NOTES FOR OPTI 306

- **Classroom attendance and assignment deadlines:**
  - I do not take attendance – I would love to see all of your smiling, happy faces at each lecture, but I understand things happen, etc.
  - I will say, 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 me BEFOREHAND if you will be missing an assignment deadline or in-class exam.
  - 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.
  - Remember – the lowest three quizzes are dropped.