OPTICS FOR ENGINEERS

INSTRUCTOR:

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VIRTUAL OFFICE HOURS:

Students' questions don't always come at a time convenient for office hours. Please feel free to email me at any time for "virtual office hours." If you think the question will be of general interest, and you are willing, please give me permission to post your question (without your name) and my answer, for the benefit of other students. I will never do this without your explicit permission. If multiple students have similar questions, I may post a generic response, so look on the announcements page.

DISCUSSION GROUPS:

I will start discussion groups on Blackboard, particularly for questions about homework. Because you are encouraged to collaborate on homework, you are also encouraged to use this forum for wider collaboration.

OFFICE HOURS:

Sometimes only real office hours will work. I will be available in the time–honored way.

Thursdays 2:00PM–4:00PM (302 Stearns) or by appointment

TEXT:

I am in the process of writing a text for the course. I will make chapters available for downloading. Please help me improve this text by reporting any errors, any areas that you find difficult or confusing, and any other comments you may have. I will appreciate that effort, as will future students.

LOCATION:

West Village F 178

TIME:

Mon. and Thu. 11:45 AM – 1:25 PM

GRADING:

Mid–Term	25%
Final	25%
Homework	25%
Project Final Report	25%

EXAMS:

Take–home exams will be given at the middle and end of the course. You will have about one week to complete each. It is expected that your exam submission will be the result of your own effort, with the aid of your notes, the text, and other reference books. Please work independently. Do not collaborate or seek help from other experts.

Exams not received by the due date will receive a grade of "F."

PROJECTS:

A list of suggested projects will be distributed. Each project must involve some research in the literature and some independent work. Reviews of the literature alone are not acceptable. If you have your own idea for a project, I would be happy to consider it. I will suggest other projects during class as they arise in the lectures.

HOMEWORK:

Homework Assignments will be available on the course website. Collaboration among students on homework is acceptable. Group submissions will be accepted, and a single grade assigned for all members of the group. Nevertheless, it is the responsibility of each student to have a good understanding of each problem.

SCHEDULE

1 **10, 14 Sep 2009**	**ADMINISTRIVIA. INTRODUCTION;** — History, The spectrum, Perception of Color, specular and diffuse reflection, Maxwell's Equations, the wave equation, Fermat's Principle. **Related Chapters in Text:** 1. **Related Sections in Notes:** 1.
2 **17, 21 Sep 2009**	**BASIC GEOMETRIC OPTICS:** Imaging, ray optics, ray tracing. Refraction at a single surface, total internal reflection, simple optical elements, focal length. **Related Chapters in Text:** 2. **Related Sections in Notes:** 2. **Homework:** Problem Set 1 1–2 Due 24 Sep..
3 **24, 28 Sep 2009**	**MATRIX OPTICS:** Basic transformations, system matrix. Cascading matrices. CARDINAL POINTS: Application to representative systems. Thick lens, air–spaced doublet. **Related Chapters in Text:** 3. **Related Sections in Notes:** 3.
4 **1,5,8 Oct 2009**	**STOPS AND APERTURES:** Entrance and exit pupils. Entrance and exit windows. Object and image space. OPTICAL INSTRUMENTS: Microscope, magnifier, compound microscope, Heads–up display. **Related Chapters in Text:** 4. **Related Sections in Notes:** 4. **ABERRATIONS:** Spherical aberration, other third–order aberrations, matrix methods, exact ray tracing, wavefront methods. **Related Chapters in Text:** 5. **Related Sections in Notes:** 4. **Homework:** Problem Set 1 Remaining Due 13 Oct 2009.

Columbus Day Holiday, 12 Oct

Mid–Term Exam handed out 19 Oct, due 26 Oct

5 **15, 19, 22, 26 Oct 2009**	**POLARIZED LIGHT:** INTERFACE OPTICS: The wave equation, plane waves, Fresnel reflection and refraction at a dielectric interface. JONES CALCULUS: representations and transformations. Partial polarization, including coherency matrices and Mueller Calculus. Optical activity. Poincaré Sphere. **Related Chapters in Text:** 6. **Related Sections in Notes:** 5. **Homework:** Problem Set 2 Due 29 Oct 2009.
6 **29 Oct, 2 Nov 2009**	**INTERFERENCE:** The Michelson interferometer, The Fabry–Perot — laser line selection and tuning. Multi–layer coatings including matrix representation. **Related Chapters in Text:** 7. **Related Sections in Notes:** 6. **Homework:** Problem Set 3 Due 5 Nov 2009.
7 **5, 9, 12 Nov 2009**	**DIFFRACTION:** Interference, Multiple beams, slits and apertures, transmissive and reflective gratings. Littrow gratings. The Fresnel–Kirchoff integral. A/O Modulators. **Related Chapters in Text:** 8. **Related Sections in Notes:** 7.
8 **16,19 Nov 2009**	**GAUSSIAN BEAMS:** Derivation and computational techniques. The complex radius of curvature. Graphical solutions. Higher–order modes. **Related Chapters in Text:** 9. **Related Sections in Notes:** 8. **Homework:** Problem Set 4 Due 23 Nov 2009.
9 **23 Nov 2009**	**COHERENCE:** Coherent and incoherent light, partial coherence, visibility. Coherent and incoherent imaging. Brief comments on quantum theory of coherence, and squeezed states. **Related Chapters in Text:** 10. **Related Sections in Notes:** 9.

Thanksgiving Holiday, 26 Nov

10 **30 Nov 2009**	**FOURIER OPTICS:** point spread function, modulation transfer function. Simple optical data processing. Holiday, 23 Nov. **Related Chapters in Text:** 11. **Related Sections in Notes:** 10.

11 **3, 7, 10 Dec 2009**	**INCOHERENT SOURCES:** The black body spectrum, coherent and incoherent sources. Polar bears. **RADIOMETRY:** Quantities and units, basic measurements, photometry. **Related Chapters in Text:** 12. **Related Sections in Notes:** 11. **Homework:** Problem Set 5 Due 12 Dec 2009.

— Final Exam handed out 10 Dec, due 17 Dec

USEFUL INFORMATION

Table 1

Physical Constants

Speed of Light	c	2.998×10^{8}	meters per second
Planck's Constant	h	6.626×10^{-34}	Joule second
Boltzmann's Constant	k	1.381×10^{-23}	Joules per Kelvin
Electronic Charge	e	1.602×10^{-19}	Coulombs
Thermal Voltage at 273K	kT/e	25.2×10^{-3}	Volts
Permeability Constant	μ_0	1.26×10^{-6}	Henry per meter
Permittivity Constant	ϵ_0	8.85×10^{-12}	Farad per meter
Avogadro's Number	A_n	6.022045×10^{23}	/mol
Gas Constant	R	1.98719	cal/mol/K

Table 2

Constants and Conversion Factors

Quantity	Conversion
Energy/Wavelength	E in ev. $= \dfrac{1.24}{\lambda \text{ in micrometers}}$
Length	2.54 cm/inch 3.28 ft/meter 5280 ft/mile 6080 ft/nautical mile 10^{10} Angstrom/meter
Mass	2.2 lb/kg.
Radius of Earth	≈ 6400 km

Table 3a

Significant Wavelengths

UVA Spectral Range	400-320	nanometers
UVB Spectral Range	280-320	nanometers
Oxygen Band Edge	280	nanometers
Silica Transmission	≈ 350 to 2500	nanometers
Water Transmission	≈ 400 to 1400	nanometers

Table 3b

Some Laser Wavelength Ranges

Fiber–Optical Communication from to	 850 1.8	 nanometers micrometers
Dye Lasers	190–4500	nanometers
Ti: Sapphire	680–1070	nanometers
Carbon Dioxide Laser	9 to 11	micrometers
Hydrogen Fluoride	2.6–3	micrometers
Deuterium Fluoride	3.6 to 4	micrometers
Alexandrite	730 to 780	nanometers

Table 3c

Selected Laser Lines

Argon Dimer (UV)	125	nanometers
Argon Ion (Blue)	488.1	nanometers
Argon Ion (Green)	514.5	nanometers
Copper Vapor	510.6	nanometers
Copper Vapor	578.2	nanometers
Neodymium Yag Laser	1.06	micrometers
Neodymium Yag Laser	1.318	micrometers
Krypton Chloride	222	nanometers
Krypton Flouride	248	nanometers
Xenon Bromide	282	nanometers
Xenon Chloride	308	nanometers
Xenon Fluoride	351	nanometers
Nitrogen	337.1	nanometers
Helium–Neon Laser (Red)	632.8	nanometers
Neodymium YaLo Laser	1.35	micrometers
Ho:YAG	2.10	micrometers
Th:YAG	2.00	micrometers
Carbon Dioxide Laser P(20) Line	10.59	micrometers

Some of the information in Table 3 came from the following sources;

Jelalian, Albert V., *Laser Radar Systems*, Artech House, Norwood, MA, 1991.
Measures, Raymond M., *Laser Remote Sensing: Fundamentals and Applications*, Wiley, New York. 1984.
Laser Focus Buyer's Guide, 1992. Penwell.

Table 4

Indices of Refraction

Pure Water at 589.2 nm	1.33
Complex Index of Water at 420 nm	$1.33 + 4.68 \times 10^{-8}$ i
Suger and Water	up to 1.49
Crown Glass at 589.2 nm	1.52
Germanium at 10.59 μm	4.00
Zinc Selenide at 10.59 μm	2.4
Biological Materials: Visible to Near IR	
Extracellular Fluid	1.35
Cytoplasm	1.37
Nucleus of Cell	1.39
Mitochondria	1.42
Melanin	1.7

Table 5

Multiplier Prefixes

10^{-18}	atto–	a–	10^{-18} boys = 1 attoboy
10^{-15}	femto–	f–	Your Idea Here
10^{-12}	pico–	p–	10^{-12} boos = 1 picoboo
10^{-9}	nano–	n–	10^{-9} goats = 1 nanogoat
10^{-6}	micro–	μ–	10^{-6} scopes = 1 microscope
10^{-3}	milli–	m–	10^{-3} cents = 1 Millicent
10^{3}	Kilo–	k–	2×10^{3} mockingbirds = 2 kilomockingbirds
10^{6}	Mega–	M–	10^{6} phones = 1 megaphone
10^{9}	Giga–	G–	10^{9} los = 1 gigalo
10^{12}	Tera–	T–	10^{12} bulls = 1 terabull
10^{15}	Peta–	P–	10^{15} lumas = 1 Petaluma
10^{18}	Exo–	E–	10^{18} skeletons = 1 Exoskeleton

Decibels

Decibels are a convenient concept to describe gains and losses in electronic systems. The gain of an amplifier is described in terms of the power ratio of output to input, and is expressed in dB. (note lower–case "d," meaning "deci–," and capital "B" for "Bel.") as

$$g = 10 \log \left(p_{OUT} / p_{IN} \right).$$

If the output and input impedances are the same, then the power gain is the square of the voltage (or current) gain, and

$$g = 10 \log \left(\frac{v_{OUT}}{v_{IN}} \right)^2] = 20 \log \left(v_{OUT} / v_{IN} \right).$$

Although it is not needed for this course, signals are often expressed in dBm. This is not a measure of gain, but of signal level. It is the ratio of the power to one milliwatt.

$$y = 10 \log \left(p / 10^{-3} \mathrm{W} \right).$$

Typically, this concept is used with 50–Ohm impedances common in RF work, and

$$y = 10 \log \left(v^2 / 10^{-3} \mathrm{W} / 50 \mathrm{Ohms} \right).$$