Logout Randy Bartels (http://www.acns.colostate.edu/single-sign-on-using-shibboleth/#1471272725675-5603b487-ebab)

SBME/ECE 403- Introduction to Optical Methods in Biomedical Engineering

Course Details

Instructor: Randy A. Bartels

Office: B316 Scott Bioengineering

Office Hours: By appointment

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Phone: (970) 491-8971

Lecture: 2:00 pm - 3:15 pm , Tu/Th Engineering B2

Course Description

Engineering design principles of optical characterization techniques for biomedical systems, including optical spectroscopy and microscopy of biomolecules and tissues. This course provides students with a fundamental background in modern and classical optics, as well as principles of optical engineering, and provides students with a broad overview of state-of-the-art topics and cutting-edge research in the area of optics and lasers in medicine and biology. Fundamental concepts of optics and laser-tissue interaction will be discussed in order to provide a basis for the understanding of the current technology.

Textbook

Fundamentals of Biomedical Optics

by Caroline Boudoux

Blurb -- First Edition, 2017

-13: 978-1366446190

https://www.blurb.com/b/7707867-fundamentals-of-biomedical-optics
(https://www.blurb.com/b/7707867-fundamentals-of-biomedical-optics)

Course Schedule

Week	Topic	Preparation for Class	Assignments Due
Week 1	Introduction to optical methods in biomedical engineering	Read Syllabus Read Chapter 1&2 Lecture 1 Slides	
Week 1	Refraction, Lenses, and Polarization	Read Chapters 3&4 Lecture 2 Slides	
Week 2	Optical Interference, Diffraction and Coherence Light-Matter Interactions	Read Chapters 5&6 Lecture 3 Slides Lecture 4 Slides	Quiz01 and HW01
Week 3	Light Emission I Light Emission II	Read Chapters 7&8 Lecture 5 Slides Lecture 6 Slides	Quiz02 and HW02
Week 4	Nonradiative Interactions: Light Treatments and Surgery Optical Scattering	Read Chapters 9&10 Lecture 7 Slides Lecture 8 Slides	Quiz03 and HW03

Week 5	Multiple Scattering and Diffuse Optics Optical Imaging	Read Chapters 11&12 Lecture 9 Slides Lecture 10 Slides	Quiz04 and HW04
Week 6	Microscopes and Applications Homework Review	Read Chapter 13 Lecture 11 Slides	Quiz05 and HW05
Week 7	Exam #1 Review Exam #1	Through Optical Scattering and Homework 5	Exam #1
Week 8	Confocal Microscopy LightSheet Microscopy	Read Chapter 14 Read LightSheet Microscopy Review Paper Lecture 12 Slides Lecture 13 Slides	Quiz06 and HW06
Week 9	Optical Coherence Tomography (OCT) Structured Illumination Microscopy	Read Chapter 16 Read Structured Illumination Review Article Lecture 14 Slides Lecture 15 Slides	Quiz07 and HW07
	Nonlinear Microscopy	Read Chapter 15	

Week 10	Nonlinear Microscopy Super Resolution Microscopy	Read Super Resolution Microscopy Review Article Lecture 16 Slides Lecture 17 Slides	Quiz08 and HW08
Week 11	Vibrational Microscopy Photoacoustic Microscopy	Read Raman Microscopy Review Article Read MidInfrared Microscopy Review Article Read Photoacoustic Microscopy Review Article Lecture 18 Slides Lecture 19 Slides	Quiz09 and HW09
Week 12	Diffuse Optical Imaging Homework Review	Read Diffuse Optical Imaging Review Article Lecture 20 Slides	Quiz10 and HW10
Week 13	**Spring Break**	**Spring Break**	**Spring Break**
Week 14	Exam #2 Review Exam #2		Exam #2
Week 15	Optical Tweezers Optical Detection Applications	Read Optical Tweezers Review Article Lecture 21 Slides Lecture 22 Slides	Quiz11 and HW11

Week 16	Cancer Imaging Neural Imaging	Lecture 23 Slides Lecture 24 Slides	Quiz12

Exam Dates

Midterm 1: March 4, 2021

Midterm 2: April 22, 2021

Final Exam: May 12, 2021

Online Resources

Biology and Biological Optics Resources

Lectures on biology and techniques: https://www.ibiology.org/biology-online/ (https://www.ibiology.org/biology-online/)

Quantitative Biological Imaging (good lectures): https://www.quantitativebioimaging.com/ (https://www.quantitativebioimaging.com/)

Biology numbers: https://bionumbers.hms.harvard.edu/search.aspx (https://bionumbers.hms.harvard.edu/search.aspx)

Biology numbers: http://book.bionumbers.org (http://book.bionumbers.org)

Optics and Physics Resources

Online optics textbook: https://optics.byu.edu/home (https://optics.byu.edu/home)

Online physics textbook: https://opentextbc.ca/universityphysicsv3openstax/ (https://opentextbc.ca/universityphysicsv3openstax/)

Hyperphysics: http://hyperphysics.phy-astr.gsu.edu/hbase/index.html (http://hyperphysics.phy-astr.gsu.edu/hbase/index.html)

Introduction to Scattering:

Introduction to Scattering:

https://www.youtube.com/watch?v=IU-QEm-2hFs (https://www.youtube.com/watch?v=IU-QEm-2hFs)

(https://www.youtube.com/watch?v=IU-QEm-2hFs)

https://www.youtube.com/watch?v=f6sHn3pyAro (https://www.youtube.com/watch?v=f6sHn3pyAro)

(https://www.youtube.com/watch?v=f6sHn3pyAro)

Virtual photonics: https://virtualphotonics.org/ (https://virtualphotonics.org/)

Scattering and absorption spectroscopy: https://omlc.org/~prahl/ (https://omlc.org/~prahl/)

NIST chemistry and spectroscopy database: https://webbook.nist.gov/chemistry/ (https://webbook.nist.gov/chemistry/)

Thorlabs technical guides: https://www.thorlabs.com/navigation.cfm?guide_id=2474 (https://www.thorlabs.com/navigation.cfm?guide_id=2474)

Computational Imaging

Computational Imaging Lecture Series: https://sites.google.com/view/sps-space (https://sites.google.com/view/sps-space)

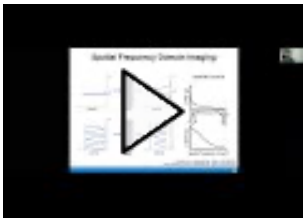
Diffuse Optical Spectroscopic Imaging (DOSI): https://vimeo.com/88174807 (https://vimeo.com/88174807)

Diffuse Imaging:
https://www.youtube.com/watch?v=fKMghVWOoA0 (https://www.youtube.com/watch?

v=fKMghVWOoA0)

(https://www.youtube.com/watch?v=fKMghVWOoA0)

Spatial Frequency Domain Imaging:
https://www.youtube.com/watch?v=l3l9-pfLl4o (https://www.youtube.com/watch?v=l3l9-pfLl4o)



(https://www.youtube.com/watch?v=l3l9-pfLl4o)

Microscope (and optics) Resources

Olympus Microscope Resource Center: https://www.olympus-lifescience.com/en/microscope-resource/ (https://www.olympus-lifescience.com/en/microscope-resource/)

Nikon MicroscopyU: https://www.microscopyu.com/ (https://www.microscopyu.com/)

UofA Microscopy Resources: https://microscopy.arizona.edu/learn/microscopy-imaging-resources-www (https://microscopy.arizona.edu/learn/microscopy-imaging-resources-www)

ImageJ: https://imagej.nih.gov/ij/ (https://imagej.nih.gov/ij/)

Molecular Expressions Primer: https://micro.magnet.fsu.edu/primer/ (https://micro.magnet.fsu.edu/primer/)

Royal Microscopical Society: https://www.rms.org.uk/study-read/news-listing-page/online-microscopy-talks-list.html (https://www.rms.org.uk/study-read/news-listing-page/online-microscopy-talks-list.html)

Fluorescence tutorials: https://www.thermofisher.com/us/en/home/support/tutorials.html (https://www.thermofisher.com/us/en/home/support/tutorials.html)

(https://www.rms.org.uk/study-read/news-listing-page/online-microscopy-talks-list.html)

Weekly Canvas Quizzes

There will be a weekly quiz on Canvas. For this quiz, you will answer several questions that require either a numerical answer or a formula answer. You will have infinite attempts at providing the answer so that, hopefully, everyone is successful with these quizzes. In addition to the answer, you will need to upload a written out answer that explains how you computed your result(s) for the quiz solution as part of the homework assignments. Details of the formatting requirements for homework are provided below.

Software

Mathematica is highly recommended for this course.

Assignments and Canvas

I will post all assignments on Canvas, and all assignments must be submitted through Canvas.

All assignments will be submitted as a pdf file and will be prepared either in Mathematica, LaTex, or a similar program so that all responses are typeset. All code used for calculation must be submitted in the pdf.

It is expected that you will use the following format for submitting all assignments:

LAST.FIRST.ASSIGNMENT.pdf For example: Bartels.Randy.HW01.pdf

Homework Policy

The homework is an essential part of the course. You should attempt all problems yourself, but feel free to argue with your colleagues about them. (Simply copying each other's solutions is, however, counterproductive for all parties and is not acceptable.

A few of the problems will be numerical, not involving heavy computation, but more in the way of modeling pulse propagation through various dispersive elements, so you will need to use your favorite math package (e.g., Mathcad, Maple, Matlab, Mathematica, IDL, etc.).

To clarify, a homework solution MUST include a full explanation of how the problem is set up, the motivation of steps in the analysis, and an interpretation of the results. The entire point of homework is to explore and think about the material presented in the class AND to be able to communicate your findings. The ability to communicate scientific ideas is of critical importance. Moreover, the emphasis of homework is to analyze each physical situation, interpret that analysis, and communicate the meaning. As a result, the emphasis is NOT on algebraic manipulations.

You are encouraged to use Mathematica (and to a MUCH lesser extent other mathematical tools) to write up your solution. All solutions MUST be in a highly simplified form that YOU interpret correctly. Remember: each homework solution should be a short story that includes a reproduction of appropriate diagrams and may require plots of the final solutions you find to explain behaviors.

Homework Formatting Requirements

All homework assignments must be submitted in narrative form. Consider each answer a short essay or paper. In all instances, you should provide a quick background and motivation in the context of Optical Microscopy and then develop your answer to the questions while explaining each step. Below are notes on writing and formatting requirements:

These notes are adapted from Stephen Boyd et al.:
https://web.stanford.edu/class/ee364b/latex_templates/template_notes.pdf
(https://web.stanford.edu/class/ee364b/latex_templates/template_notes.pdf)

You will likely find that when you write out a detailed explanation on a question, you will find that there are gaps in your understanding and thought process. The process of writing out a full explanation will help you clarify your thought and understanding.

John von Neumann once said, “There’s no sense in being precise when you don’t even know what you’re talking about,” and Niels Bohr wrote, “Never express yourself more clearly than you can think.” Keep these in mind.

Write in good english: Always write good English, even when the subject that you are discussion contains mathematics. This includes correct grammar, word choice, punctuation, spelling, phrasing, and common sense. A classic on this topic, only slightly dated, is Strunk and White [1].

Keep the reader in mind: Perhaps the most important principle of good writing is to keep the reader in mind: What do they know so far? What do they expect next and why? Do they have sufficient motivation for stated results? As part of this, make sure you know what level of reader you are writing

for and stay consistent with that level. If the reader is expected to know microscopy, do not keep defining standard concepts like numerical aperture (you will know this well before the end of the course if you don't already know about this)!

Write to allow skipping over formulas: Many readers will first read through the paper ignoring or skipping all but the simplest formulas. Your sentences and overall report should flow smoothly, and make sense, when all but the simplest formulas are replaced by “blah” or a similar placeholder. As a related point, do not simply display a list of formulas or equations in a row; tie the concepts together with a running commentary.

Online Course Details

All lectures will be available online and simultaneous participation will be available with Zoom.

Late Policy

You are expected to manage your schedule and meet all assigned deadlines. Items turned in within 24 hours after a deadline will receive a 25% penalty. Items turned in 24-48 hours late will receive a 50% penalty. Items submitted more than 48 hours late will not be accepted. Any exceptions must be approved in advance. Late submission is not allowed for the final exam.

Honor Pledge

For all work in this course, it is assumed that the following statement is true: I will not give, receive, or use any unauthorized assistance. The exception is that students my discuss approaches and clarifications regarding homework problems. In fact, this is highly encouraged and you may learn a lot from your peers and from helping your peers.

Professionalism and Academic integrity

This course will adhere to the CSU Academic Integrity Policy as found on the Student' Responsibilities page of the **CSU General Catalog (http://catalog.colostate.edu/general-catalog/policies/students-responsibilities/#academic-integrity)** and in the **Student Conduct Code. (https://resolutioncenter.colostate.edu/wp-content/uploads/sites/32/2018/08/Student-Conduct-Code-v2018.pdf)**

For more details on academic integrity, please read **Practicing Academic Integrity.**

(http://learning.colostate.edu/integrity/index.cfm)

At a minimum, violations will result in a grading penalty in this course and a report to the Office of Student Resolution Center.

References

[1] W. Strunk and E. White. The Elements of Style. Macmillan, 1957.

Course Summary:

Date	Details	Due
Thu Jan 26, 2023	Homework 1 (https://colostate.instructure.com/courses/161816/assignments/2024731)	due by 11:59pm
Fri Jan 27, 2023	Quiz 1 (https://colostate.instructure.com/courses/161816/assignments/2024724)	due by 11:59pm
Thu Feb 2, 2023	Homework 2 (https://colostate.instructure.com/courses/161816/assignments/2024734)	due by 11:59pm
Fri Feb 3, 2023	Quiz 2 (https://colostate.instructure.com/courses/161816/assignments/2024725)	due by 11:59pm
Thu Feb 9, 2023	Homework 3 (https://colostate.instructure.com/courses/161816/assignments/2024735)	due by 11:59pm
Fri Feb 10, 2023	Quiz 3 (https://colostate.instructure.com/courses/161816/assignments/2024720)	due by 11:59pm
Thu Feb 16, 2023	Homework 4 (https://colostate.instructure.com/courses/161816/assignments/2024736)	due by 11:59pm
Fri Feb 17, 2023	Quiz 4 (https://colostate.instructure.com/courses/161816/assignments/2024719)	due by 11:59pm
	Homework 5	

Thu Feb 23, 2023	(https://colostate.instructure.com/courses/161816/assignments/2024717)	due by 11:59pm
Fri Feb 24, 2023	Quiz 5 (https://colostate.instructure.com/courses/161816/assignments/2024728)	due by 11:59pm
Sat Mar 4, 2023	Exam #1 (https://colostate.instructure.com/courses/161816/assignments/2024729)	due by 6pm
Fri Mar 10, 2023	Quiz 6 (https://colostate.instructure.com/courses/161816/assignments/2024727)	due by 11:59pm
Mon Mar 13, 2023	Homework 6 (https://colostate.instructure.com/courses/161816/assignments/2024738)	due by 11:59pm
Thu Mar 16, 2023	Homework 7 (https://colostate.instructure.com/courses/161816/assignments/2024739)	due by 11:59pm
Fri Mar 17, 2023	Quiz 7 (https://colostate.instructure.com/courses/161816/assignments/2024721)	due by 11:59pm
Thu Mar 23, 2023	Homework 8 (https://colostate.instructure.com/courses/161816/assignments/2024740)	due by 11:59pm
Fri Mar 24, 2023	Quiz 8 (https://colostate.instructure.com/courses/161816/assignments/2024723)	due by 11:59pm
Thu Mar 30, 2023	Homework 9 (https://colostate.instructure.com/courses/161816/assignments/2024741)	due by 11:59pm
Fri Mar 31, 2023	Quiz 9 (https://colostate.instructure.com/courses/161816/assignments/2024722)	due by 11:59pm
Thu Apr 6, 2023	Homework 10 (https://colostate.instructure.com/courses/161816/assignments/2024732)	due by 11:59pm
Fri Apr 7, 2023	Quiz 10 (https://colostate.instructure.com/courses/161816/assignments/2024718)	due by 11:59pm

Fri Apr 21, 2023	**Exam #2** (https://colostate.instructure.com/courses/161816/assignments/2024730)	due by 5pm
Thu Apr 27, 2023	**Homework 11** (https://colostate.instructure.com/courses/161816/assignments/2024733)	due by 11:59pm
Fri May 12, 2023	**Final Exam** (https://colostate.instructure.com/courses/161816/assignments/2024726)	due by 2pm