

## ***APh 150: Introduction to nanophotonics***

*Course Syllabus – Spring / 2022*

Department of Applied Physics, California Institute of Technology

### **Course Instructor**

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### **Course Description**

*An introductory survey of nanophotonics topics including physics of oscillators and susceptibility, the complex dielectric function, propagating and evanescent fields in complex and subwavelength-structured media, radiation from dipole and multipole sources, dipole-dipole and other near-field interactions, optical response of metals and dielectrics, localized surface plasmons, energy localization and hot spots, frequency dispersion and dispersion relations for surface plasmon polaritons, phonon polaritons and exciton-polaritons, spatial dispersion and nonlocality, local electromagnetic fields near nanostructures, the local density of optical states, light propagation in periodic and resonant structures: cavities, photonic crystals, metamaterials and optical antennas; optical resolution, point-spread function; introductory quantum electrodynamics, Casimir effect, spontaneous emission, spontaneous scattering, Purcell effect, two-level system coupling via Jaynes-Cummings Hamiltonian. Computational methods for nanophotonics: finite element integration, finite difference time domain, boundary element method, rigorous coupled wave analysis.*

### **Course Welcome**

Welcome to APh 150! This is an introduction to the fascinating world of light-matter interactions at the nanoscale - at or below the scale of the optical wavelength itself. The electromagnetic principles we use rest on classical electromagnetic using Maxwell's Equations, but reveal phenomena that are intricate and quite counter-intuitive relative to photonics at larger length scales. We'll build up models for dielectric matter and metals, and will use these

to understand near-field and sub wavelength optical phenomena and we will also explore the metamaterials and quantum optics at the nanoscale.

### Learning Outcomes

By the end of this course, students will be able to:

- Develop models for subwavelength scale antennas, waveguides and cavities
- Understand how self-interference in complex media modifies optical radiation, using the local density of states formalism
- Gain some facility with numerical simulation methods for nanophotonics
- Learn how to design artificial metamaterials with properties quite different from materials found in nature.

### Recommended Text

1. Principles of Nano Optics, Novotny and B. Hecht, Cambridge University Press, 2<sup>nd</sup> Edition, Cambridge, 2013. ISBN 978-1107005464
2. Introduction to Nanophotonics, Sergey V. Gaponenko, Cambridge University Press, Cambridge, 2010; ISBN 978-0-521-76375.
3. Optical Properties of Solids, Mark Fox, Oxford University Press, Oxford, 2010; ISBN-978-0-19-957337.
4. Modern Electrodynamics, A. Zangwill, Cambridge University Press, 1<sup>st</sup> Edition, Cambridge 2013; ISBN-13: 978-0521896979.
5. Plasmonics, S. Maier, Springer, 2007 Edition, Cambridge 2013; ISBN-13: 978-0387331508.
6. The Quantum Theory of Light, R. Loudon, Oxford University Press, Oxford, 2000, ISBN-13: 978-0198501763.

### Course Website or Learning Management System

Online course resources can be accessed through Canvas:

<https://caltech.instructure.com/courses/4473>

### Assessment Rubric

Problem sets (5/term)	36pts.
Mid-Term Exam	30 pts.
<u>Final Electromagnetic Simulation Project</u>	<u>30 pts.</u>
In-Class Presentation/Discussion	4 pts.
Total:	100 pts.

APh 150 Evaluation Policies:

1. Homeworks issued on Thursdays and due on Thursdays, seven days later.
2. Midterm exam will be 1.5 hours in length and will be issued on 4/28/22 and due on 5/3/22.
3. Final simulation project will use electromagnetic simulation software (Lumerical FDTD Solutions) to illustrate a nanophotonic phenomenon.

4. 'Limited' collaboration for homeworks: you can share anything that can be communicated with spoken words, but cannot share written notes or solutions.
5. Late homeworks will be graded according to the following time dependence, in days, where  $t = 0$  is the due date:  $h(t) = h(0)\exp(-t/16)$ .

### Attendance and Participation

*Come to class! We will learn a lot together in the discussion*

### Wellness Policy

- Fostering your health and well-being should be your number one priority, and the best learning occurs if you are well and not under duress.
- The course work should feel challenging in a positive way, but not overwhelming.
- If you find yourself overwhelmed or encountering other personal challenges during the term, please reach out to me so we can develop a plan for you to pursue success in this course in a healthy way. In addition, I encourage you to utilize Caltech's resources.
- Diversity, inclusion, and belonging are all core values of this course. All participants in this course must be treated with respect by others in accordance with the honor code. If you feel unwelcome or unsafe in any way, no matter how minor, I encourage you to talk to me or one of the Deans.
- Student Wellness Services will assess and treat illnesses and medical conditions, and communicate (with student's permission) with the Deans' Office if CASS, part of SWS, can recommend and provide for accommodations needed due to temporary or long-term disabilities. Policies about academic extensions for medical reasons can be found [here](#).
- The Deans' Office may recommend academic exceptions in cases of significant family or personal emergencies, or moderate to severe illness or medical conditions that make it difficult to keep up with coursework. Please reach out to a Dean as soon as possible if you experience these conditions.

### Students with Documented Disabilities

Students who may need an academic accommodation based on the impact of a disability must initiate the request with Caltech Accessibility Services for Students (CASS). Professional staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare an Accommodation Letter for faculty dated in the current quarter in which the request is being made. Students should contact CASS as soon as possible, since timely notice is needed to coordinate accommodations. For more information: <http://cass.caltech.edu/>, [cass@caltech.edu](mailto:cass@caltech.edu).

## Academic Integrity

Academic integrity on campus rests on Caltech's Honor Code: "No member of the Caltech community shall take unfair advantage of any other member of the Caltech community."

Understanding and Avoiding Plagiarism: Plagiarism is the appropriation of another person's ideas, processes, results, or words without giving appropriate credit, and it violates the honor code in a fundamental way. You can find more information at: <http://writing.caltech.edu/resources/plagiarism>.

All instances of plagiarism or other academic misconduct will be referred to the Board of Control for undergraduates. For graduate students, contact the Graduate Office.

## Collaboration Policy

'Limited' collaboration for problem sets: you can share anything that can be communicated with spoken words, but cannot share written notes or solutions.

## My Status as a "Responsible Employee"

As a faculty member, I am required to notify the Institute's Equity and Title IX Office when I become aware of discrimination, sexual harassment, or sex- or gender-based misconduct involving our community members. If one of my students shares such an experience with me, I can help connect them to support resources but will not be able to keep that information confidential as part of fulfilling my responsibility to make sure my students are offered the opportunity to access information and support by the Institute. For more information, you can email [equity@caltech.edu](mailto:equity@caltech.edu), go to [equity.caltech.edu](http://equity.caltech.edu), or review the Institute's Sex- and Gender-Based Misconduct Policy.

If you have experienced such prohibited conduct and would like confidential support, please feel to contact Student Wellness Services [626-395-8331; <https://wellness.caltech.edu/counseling>]; Taso Dimitriadis, Center for Inclusion and Diversity [626-395-8108; [taso@caltech.edu](mailto:taso@caltech.edu)]; or Teresa Mejia, Campus Sexual Violence Advocate [626-395-4770; [teresam@caltech.edu](mailto:teresam@caltech.edu)].

## Course Schedule

Course schedules including lecture topics, associated readings and homework (if appropriate to include in this table for your course) can be clearly laid out in a table format.

Week	Date	Lecture Topic	Associated Readings	Homework Due
1	3/31/2022			
2	4/5/2022			

2	4/7/2022		
3	4/12/2022		
3	4/14/2022		
4	4/19/2022		
4	4/21/2022		
5	4/26/2022		
5	4/28/2022		
6	5/3/2022		
6	5/5/2022		
7	5/10/2022		
7	5/12/2022		
8	5/17/2022		
8	5/19/2022		
9	5/24/2022		
9	5/26/2022		
10	5/31/2022		
10	6/2/2022		

### Academic Resources for Students

- **Online Learning:** Resources, [iPad Loaner Program](#), FAQs, and more for students learning online; <http://learn.caltech.edu/>
- **Tutoring:** The undergraduate dean's office provides a peer tutoring service; If the course isn't listed, students can talk with the dean's office to arrange for a tutor; <http://deans.caltech.edu/>
- **Writing:** The Hixon Writing Center provides professional writing tutors as well as peer tutors, individual and group writing space, and additional resources; <http://writing.caltech.edu>
- **Registrar & FERPA:** The registrar can answer questions about degree progress, privacy of student records, and course enrollment procedures; <http://registrar.caltech.edu>. The website also lists *Option Representatives* for option-specific advising, policies, and information.
- **Library:** Borrow books, retrieve journal articles, receive guidance about research; <https://www.library.caltech.edu/>
- **Dean of Undergraduate Students:** Wide-ranging assistance addressing issues (academic and other) for undergraduates; <http://deans.caltech.edu>
- **Dean of Graduate Studies:** Wide-ranging assistance addressing issues (academic and other) for graduate students; <http://gradoffice.caltech.edu>

**Additional Resources for Students**

- **Student Wellness Center:** Wide variety of health and wellbeing services; <https://wellness.caltech.edu/>
- **Counseling Services:** Free for all students, regardless of insurance plan; <http://counseling.caltech.edu>
- **Occupational Therapy:** Individual sessions and consultations on building healthy habits and routines, time management, planning and organization, and more. Free for all students; <http://ot.caltech.edu>
- **Center for Inclusion and Diversity:** Resources concerning navigating diversity and inclusion, including staff who can speak with students about challenges of harassment and discrimination; <https://diversity.caltech.edu/>
- **Title IX:** Caltech's Title IX Coordinator ([titleix@caltech.edu](mailto:titleix@caltech.edu)) works with students on issues related to sexual harassment, sexual misconduct, and sex discrimination; <http://titleix.caltech.edu/>
- **Caltech Accessibility Services for Students:** The Accessibility Services Specialist works with students with temporary medical conditions, or mental, physical or learning disabilities on accommodation requests and services; <http://cass.caltech.edu>
- **Residential Support:** Resident Associates (RAs) and Residential Life Coordinators (RLCs) are also resources for TAs and students; <http://www.residentialexperience.caltech.edu/>
- **Career Advising and Experiential Learning:** Provides resources to help students make career decisions and implement career plans; <http://www.career.caltech.edu>