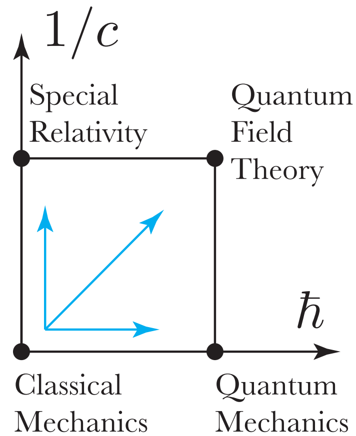
Class Meeting: **M**, **W** & **F** 2-3:20pm
Class Location: TBD
Lab Meeting: **Th** 2-3:20pm
Lab Meeting Location: TBD

Email: haggard@bard.edu
Office: Rose 112
Office Hours: **TBD**
Office Phone: (845) 758-7302

Course Description — There was an explosion in our understanding of physics at the turn of the 20th century. Einstein imagined riding along with a light wave and realized as a consequence that parts of the foundation of our understanding of physics, e.g. our notion of time, need to be revised when we take into account objects moving near the speed of light. Thus began special relativity. Simultaneously, a collection of physicists realized together that some physical observables, like the energies of an electron orbiting the nucleus, are not well described by a continuum of values, but rather by discrete quantum jumps. Incorporating this discreteness into physical models also required an upheaval of the bedrock of physics, classical mechanics, and led to the invention of quantum mechanics.



In retrospect, one way to capture these two revolutions is to say that they each introduced a new fundamental physical scale, captured by a constant of nature. These are the speed of light, c, and Planck's constant, $\hbar$. As you turn on these constants you move from classical mechanics to special relativity and quantum mechanics respectively, see the Figure. If you do an experiment where they are both relevant at once you move towards the upper right corner of the Figure and the end of the modern physics era, the discovery of quantum field theory.

A third revolution, which built more slowly but with inexorable strength, was the study of many particles through thermodynamics and statistical mechanics. Unlike relativity and quantum mechanics, which changed what we think the world is made of, statistical mechanics changed how we approach the description and quantification of the world. We left behind detailed understanding of a few objects, and turned towards a much broader understanding of bodies with $\sim 10^{23}$ constituents.

The goal of this course is to combine these three revolutions to understand the interaction of light and matter. This necessitates a deep understanding of classical and quantum waves. The rich questions of how light transfers energy to matter and how matter radiates light will motivate every aspect of the course and lead us to applications in particle physics, nuclear physics, optical and molecular physics, condensed matter physics, and astronomy.

Texts: Our primary text will be my typed *Class Notes*. We will also use a few chapters excerpted from the recommended texts below. All excerpts will be provided to you. For the lab, I ask that you purchase *A Practical Guide to Data Analysis for Physical Science Students*, by L. Lyons.

Grading Structure	
Weekly Homework	25%
Physical & Computing Labs	20%
Lab Paper	5%
Take home 1	15%
In-class exam	15%
Take home 2	15%

Course website: `http://faculty.bard.edu/hhaggard/teaching/phys241Fa20/`

Week	Topics	Lab	Recommended Reading
8/31	Special Relativity: Space & Time	Measurements & Statistics	Hartle Ch. 4
9/7	Special Relativity: Energy & Momentum	Speed of Light	Hartle Ch. 5
9/14	Spacetime diagrams, Vectors, & Complex Numbers	Michelson Interferometer	Hecht Ch. 2 (Ch. 1 opt.)
9/21	Classical & Electromagnetic Waves, Matter	Electron Charge-Mass Ratio	*Notes*
9/28	Pressure, Temperature, & Heat	No Lab **Take home 1**	Schroeder Ch. 1
10/5	Classical Thermodynamics	Brownian Motion	& Ch. 2
10/12	Kinetic Theory	Blackbody radiation	Einstein paper
10/19	Statistical Mechanics	Spectrum of Mercury	*Notes*
10/26	Light-Matter Interaction	Rydberg Constant	Tipler &
11/2	Blackbody radiation	No Lab **In-class exam**	Llewellyn Ch. 4
11/9	Quantum Theory	Photoelectric Effect	Einstein paper
11/16	Quantum Mechanics (QM) in 1D	Millikan Oil Drop	Griffiths
11/23	QM in 3D *(Thanksgiving 11/26-27)*	No Lab	Chs. 1 & 2
11/30	Degeneracy, Neutron Stars, & Black Holes	Radioactivity	Krane 1, 3, 6
12/7	(**Wed. 12/9 Adv. day**) The Solid State	No Lab	*Notes*
12/14	**Completion days begin 12/14**	**Take home 2**	*Notes*

Note: I reserve the right to adjust this syllabus during the semester

Take homes — Twice during the semester I will give you take home exams. These will be 4 hour, open note, self-timed exams. You can study as much as you like using any resource up to opening the exam. However, once you have opened the exam I ask that you only refer to your class notes and to me directly. I ask that you honor your peers and the effort that we all put into the class by not going over time or referencing any outside materials. If you have any questions about whether something is appropriate, don't hesitate to ask me.

Labs — I ask that you keep a meticulous lab notebook. Every time you add notes you should enter the date and indicate what they pertain to with a heading. You should collect all data in tables. Make careful sketches and tape in cutout photographs. You should also always include written summaries of what you are doing, even if these are brief. You want to be able to reconstruct what you were doing years from now.

Before you begin a lab, you will want to ask what is the central plot I hope to make when I am done with this lab? What data will I need to make this plot? What will this plot demonstrate and how will I argue for my main conclusion from the plot? You should submit a captioned plot accompanied by a few sentences explaining it clearly for each lab you complete. In addition to the lab notebooks, and these plots, I will ask you to do a full lab write up once in the semester. Writing physics is invaluable for the same reason as any written account—it allows you to think through writing.

Homework — There will be homework due every ??? at ???. The goal of the homework is for us to engage each other in a discussion of physics regularly, please visit or arrange online meetings with me as often as you like to chat. Along these lines, I recommend that you work together; this is invaluable in learning physics. Please write things up yourself to show me *and you* that you understand it (this helps battle the illusion of explanatory depth, or knowledge illusion). Please do not use the internet as a resource for anything but definitions of terms; if ever you are in doubt about the appropriateness of a resource, just ask me.

Homework Feedback — In the spirit of promoting discussion, I would like to go through and score homework together in small group or individual meetings. Let's discuss this option together on the first day of class and finalize how we will proceed with it.

Recommended Texts:
Gravity: An Introduction to Einstein's General Relativity, by J. B. Hartle
Optics, by E. Hecht
An Introduction to Thermal Physics, by D. V. Schroeder
Modern Physics, by P. A. Tipler & R. Llewellyn
Introductory Nuclear Physics, by K. S. Krane
Introduction to Elementary Particles, by D. J. Griffiths

Original Papers:
A. Einstein, "On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat," *Annalen der Physik (ser. 4)* **17** (1905) 549. [Translation]
A. Einstein, "Concerning an Heuristic Point of View Toward the Emission and Transformation of Light," *Annalen der Physik* **17** (1905) 132. [Translation]

I have read over this syllabus. I agree not to look at solutions manuals or use the internet for anything other than looking up reference information. I agree not to use my peers or other people to gain unfair advantage in the course. Finally, I commit to stick to the parameters of the take home exams and stay within the allotted time.

Signed: Date: