Overview of the Undergraduate Physics Curriculum

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1 Objectives

2 Review of Preparatory Subject Matter

A summary of the content in the core required courses:

- **PHY 9A - Classical Physics (5)** *Lecture—3 hours; laboratory—2.5 hours; discussion—1 hour. Prerequisite: Mathematics 21B. Introduction to general principles and analytical methods used in physics for physical science and engineering majors. Classical mechanics. Only 2 units of credit to students who have completed course 1A or 7B. Not open for credit to students who have completed course 9HA. GE credit: SciEng — SE. - III. (III.)*

- **PHY 9B - Classical Physics (5)** *Lecture - 3 hours; laboratory - 2.5 hours; discussion - 1 hour. Prerequisite: course 9A [or 9HA], Mathematics 21C, 21D (may be taken concurrently). Continuation of course 9A. Fluid mechanics, thermodynamics, wave phenomena, optics. Only 2 units of credit to students who have completed course 7A. Not open for credit to students who have completed course 9HB, 9HC, or Engineering 105. - I. (I.)*

- **PHY 9C - Classical Physics (5)** *Lecture - 3 hours; laboratory - 2.5 hours; discussion - 1 hour. Prerequisite; course 9B [or 9HC], Mathematics 21D, 22A (may be taken concurrently). Electricity and magnetism including circuits and Maxwell's equations. Only 3 units of credit to students who have completed course 7C. Not open for credit to students who have completed course 9HD. GE credit: SciEng — SE. - II. (II.)*

- **PHY 9D - Modern Physics (4)** *Lecture - 3 hours; discussion - 1.5 hours. Prerequisite: course 9C [or 9HD] and Mathematics 22A; Mathematics 22B recommended (may be taken concurrently). Introduction to physics concepts developed since 1900. Special relativity, quantum mechanics, atoms, molecules, condensed matter, nuclear and particle physics. Not open for credit to students who have completed course 9HB, 9HC, or 9HE. GE credit: SciEng — SE.- III. (III.)*

- **PHY 9HA - Honors Physics (5)** *Lecture - 3 hours; discussion/laboratory - 4 hours. Prerequisite: Mathematics 21B (may be taken concurrently) or consent of instructor. Classical mechanics. Same material as course 9A in greater depth. For students in physical sciences, mathematics, and engineering. Only 2 units of credit to students who have completed course 7B. Not open for credit to students who have completed course 9A. GE credit: SciEng — SE. - I. (I.)*

- **9HB - Honors Physics (5)** *Lecture - 3 hours; discussion/laboratory - 4 hours. Prerequisite: Physics 9HA or 9A, Mathematics 21C (may be taken concurrently). Special relativity, thermal physics. Continuation of course 9HA. Only 2 units of credit to students who have completed course 7A. Not open for credit to students who have completed course 9B or 9D. GE credit: SciEng — SE. - II. (II.)*

- **9HC - Honors Physics (5)** *Lecture - 3 hours; discussion/laboratory - 4 hours. Prerequisite: course 9HB and Mathematics 21D (may be taken concurrently). Waves, sound, optics, quantum physics. Continuation of Physics 9HB. Only 2 units of credit to students who have completed course 7C. Not open for credit to students who have completed course 9B or 9D. GE credit: SciEng — SE.- III. (III.) Recent Syllabi and More Complete Descriptions*

- **9HD - Honors Physics (5)** *Lecture - 3 hours; discussion/laboratory - 4 hours. Prerequisite: course 9HC and Mathematics 21D. Electricity and magnetism. Continuation of Physics 9HC. Not open for credit to students who have completed course 9C. GE credit: SciEng — SE. - I. (I.)*

- **9HE - Honors Physics (5)** *Lecture - 3 hours; discussion/laboratory - 4 hours. Prerequisite: course 9HD and Mathematics 22B (may be taken concurrently). Application of quantum mechanics. Not open for credit to students who have completed course 9D. GE credit: SciEng — SE. - II. (II.)*

- **PHY 40 — Introduction to Physics Computation (4)** *Lecture—2 hour(s); Laboratory—4 hour(s). Introduction to programming using C++ with examples from computational physics. Introduction to modern tools used for scientific analysis, including Scientific computing with Python. GE credit: SE. Effective: 2018 Summer Session 2.*

- **PHY 80 — Experimental Techniques (4)** *Lecture—2 hour(s); Laboratory—5 hour(s). Prerequisite(s): PHY 009D or PHY 009HD. Open to Physics and Applied Physics majors only. Experimental techniques. Design of circuits. Data analysis, sources of noise, statistical and systematic uncertainties. Light sources, detection, and measurement in basic optical systems. Effective: 2017 Fall Quarter.*

3 Review of Core Subject Matter

The present core required courses are:

PHY 104A	4	Introductory Methods of Mathematical Physics	
PHY 105A	4	Analytical Mechanics	
(PHY 105B)	4	Analytical Mechanics	
PHY 110A	4	Electricity and Magnetism	
PHY 110B	4	Electricity and Magnetism	
(PHY 110C)	4	Electricity and Magnetism	
PHY 112	4	Thermodynamics and Statistical Mechanics	115A
PHY 115A	4	Quantum Mechanics	104A,105A
PHY 115B	4	Quantum Mechanics	

Typical schedule for preparatory and core subject matter of 4 yr BS majors, omitting 80 (considered a lab).

For Junior transfers the typical schedule is:

A summary of the content in the core required courses:

year	fall	winter	spring
Freshman	9A/9HA	9B/9HB	9C/9HC
Sophomore	9D/9HD	(9HE)	40
Junior	104A 105A	105B 110A	110B 115A
Senior	115B 110C 112		

year	fall	winter	spring
Junior	9D/9HD 104A 105A 102	 105B 110A	40 110B 115A
Senior	115B 112		

- **PHY 104A - Introductory Methods of Mathematical Physics** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B with grade C- or better or consent of instructor. Introduction to the mathematics used in upper-division physics courses, including applications of vector spaces, Fourier analysis, partial differential equations. - I. (I.)*

  Recently taught by Scalettar and Luty. Luty teaches this as a boot camp for upper division courses: vectors, expansion in small parameters, and PDEs. All topics which are in principle should have been seen before, but students clearly need practice with problems.

- **PHY 105A - Analytical Mechanics** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B passed with grade C– or better; or consent of department; course 104A and 105A passed with a grade C– or better or consent of department required for 105B. Principles and applications of Newtonian mechanics; introduction to Lagrange's and Hamilton's equations. - I-II. (I-II.)*

  Recently taught by Calderon, Cebra, Svoboda, and Conway. Covers Morin 1-5. This course is heavy on problem solving. Morin focuses more on challenging problems, and less on mathematical formalism (e.g. leaves out Hamiltonian) Not all instructors reach 5 in first quarter.

- **PHY 105B - Analytical Mechanics** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B passed with grade C– or better; or consent of department; course 104A and 105A passed with a grade C– or better or consent of department required for 105B. Principles and applications of Newtonian mechanics; introduction to Lagrange's and Hamilton's equations. - I-II. (I-II.)*

  Recently taught by Pickett, Conway. Covers Morin 6-11. Picket supplement chapter 5 with supplemental material for Hamiltonian.

- **PHY 110A - Electricity and Magnetism** *Lecture - 3 hours; extensive problem solving.*

Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B passed with grade C– or better, or consent of department; prerequisite for 110B is courses 110A and 104A passed with a grade of C– or better or consent of department; prerequisite for course 110C is courses 110B and 104B passed with a grade of C– or better, or consent of department. Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves. - II-III-I. (II-III-I.)

Recently taught by Da Silva Neto and Yu. Covers Griffiths 1-4. Yu extends to include complex analysis of La Place's equation. Includes a recap of vector calculus, but Da Silva Neto reports a benefit from 104A (Math Methods.)

- **PHY 110B - Electricity and Magnetism** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B passed with grade C– or better, or consent of department; prerequisite for 110B is courses 110A and 104A passed with a grade of C– or better or consent of department; prerequisite for course 110C is courses 110B and 104B passed with a grade of C– or better, or consent of department. Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves. - II-III-I. (II-III-I.)*

  Recently taught by Yu. Griffiths 5-9. Rapid pace for subject matter, so problem solving is left mainly for homework. No breathing room for computational physics.

- **PHY 110C - Electricity and Magnetism** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D [or 9HB, 9HC, 9HD] and Mathematics 21D, 22A, and 22B passed with grade C– or better, or consent of department; prerequisite for 110B is courses 110A and 104A passed with a grade of C– or better or consent of department; prerequisite for course 110C is courses 110B and 104B passed with a grade of C– or better, or consent of department. Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves. - II-III-I. (II-III-I.)*

  Recently taught by Yu and Luty. Rest of Griffiths. Potentials (including vector potential), radiation in matter, special relativity.

- **PHY 112 - Thermodynamics and Statistical Mechanics** *Lecture - 3 hours; extensive problem solving. Prerequisite: course 115A or the equivalent. Introduction to classical and quantum statistical mechanics and their connections with thermodynamics. The theory is developed for the ideal gas model and simple magnetic models and then extended to studies of solids, quantum fluids, and chemical equilibria. - I. (I.)*

  Recently taught by Singh, Da Silva Neto. Based on Shroeder. Fast review of 1 (Thermodynamics), full coverage of 2 and 3 (Entropy/Temperature starting from quantum systems up to ideal gas) skip 4 (Heat engines), Free energy part of 5, full coverage of 6+7 (Boltzman and Quantum statistics).

- **PHY 115A - Foundation of Quantum Mechanics** *Lecture - 3 hours; extensive problem solving. Prerequisite: courses 104A and 105A with grade C- of better, or consent of instructor. Introduction to the methods of quantum mechanics with applications to atomic, molecular, solid state, nuclear and elementary particle physics. - III. (III.)*

  Recently taught by Fong,Curro. Townsend for undergraduate version of Sakurai's spin-first approach. Chapters 1-5, sometimes 6.

- **PHY 115B - Applications of Quantum Mechanics** *Lecture - 3 hours; extensive problem solving. Prerequisite: course 115A passed with a grade of C– of better, or consent of department. Angular momentum and spin; hydrogen atom and atomic spectra; perturbation theory; scattering theory. - I. (I.)*

  Recently taught by Curro. Townsend 6,7, skip 8 (path integrals), then 9-10. Leaves off perturbation theory, identical particles, scattering.

4 Objectives

5 Open Questions

- What is the role of advanced classes not part of any major or specialization: 104C,123,... Is 105C ever offered? It seems required for physical oceanography.
- What actually is the maximum number of required credits allowed in a major? Looks empirically like 90 for some reason...

6 Answered Questions

- Can we require a class if e.g. less than A in certain prerequisites? No. C- is threshold for pre-req.
- Do specializations have to stay within any credit limits? Could we have "Physics BS with specialization in Computational Physics" that exceeds credit limits? No.
- Astrophysics specializations comes at high extra course load: 180,150-156, and lab course 157. Is this "fair" to the non-astro faculty? Can this foot print be reduced? For elective courses, students vote with their feet, and Astronomy electives are popular. Labs have been discontinued and many of these courses are offered only every other year.

7 Proposed Changes

- Classes we should no longer offer: 110C, 102, 9HE. This does not reduce required credits, since 9H sequence is already optional, and removing one credit 102 leaves only the four credit 104B, cancelling the loss of three credits in 110C.
- Regain the lost sophomore year for 9H (and 9A fall) students. These students will now take 40 in the winter of their second year, followed by a new honors mechanics course (105H) for five credits. These also take 104B concurrently with 105H for computational physics with scientific python, focused on classical mechanics (or 9-level EM and QM).
- Provide a more consistent tempo for Junior-year transfers. Current system throws them into a brick wall (9D, 104A, 105A). Instead they take take the sequence 104A (F), 105A (W), and 105B (S). They put off 115A until their senior year.
- Quantum mechanics is extended to three quarters. However, 112 is now taken concurrently with 115A.

- Make 105B (or 105H) a pre-req for 115A. This has maximum unit consequences to applied physics majors that will need to be addressed.
- Make 80 a pre-req for 116 sequence, make 116C elective. 116A becomes discrete electronics, and 116B becomes integrated electronics. Move 80 to fall and winter offering.
- Tighten up the content in core courses. Particular features:
  - Damped harmonic oscillator needs to be taught somewhere.
  - Hamiltonian formalism needs to be included.

8 B.S. Requirements (Minimal)

Preparatory Subject Matter: 49-50 (*: recommended)

PHY	9A	5	F,S		Classical Physics *(Class. Mech.)*
	9B	5	F,W		Classical Physics *(Waves, Thermo., Optics.)*
	9C	5	W,S		Classical Physics *(Elec. and Magn.)*
	9D	4	F,S		Modern Physics *(Rel. and Quant. Mech.)*
	or				
PHY	9HA	5	F		Honors Physics *(Class. Mech.)*
	9HB	5	W		Honors Physics *(Rel. and Stat. Mech.)*
	9HC	5	S		Honors Physics *(Waves and Quant. Mech.)*
	9HD	5	F		Honors Physics *(Elec. and Magn.)*
MAT	21A	4	F		
	21B	4	W		
	21C	4	S		
	21D	4	F		
	22A	3	F		
	22B	3	F		
PHY	40	4	S	?	Introduction to Physics Computation
	80	4	W,S	9D or 9HD	Experimental Techniques
	185*	1	S		
	190*	1	F		

Core Subject Matter: 40-45 (*: recommended)

PHY	105A	4	104A	Classical Mechanics I
	105B	4	105A	Classical Mechanics II
	115C*	4	115B,112	Applications of Quantum Mechanics
	or			
PHY	105H	5	104A, 9HA-D	Honors Classical Mechanics
	115C	4	115B,112	Applications of Quantum Mechanics
PHY	104A	4	C:9D or C:9HD	Mathematical Physics
	104B	4	40, C:105B or C:105H	Computational Physics
	110A	4	104A	Electricity and Magnetism I
	110B	4	110A	Electricity and Magnetism II
	115A	4	105B or 105H, 104B	Quantum Mechanics I
	115B	4	115A	Quantum Mechanics II
	112	4	C:115A	Thermodynamics and Statistical Mechanics
PHY	116A	4	F	
	116B	4	W	
	or			
PHY	122A or B	4	W	

Advanced Electives: 12
Two Additional Electives: 7-8
Total Units: 108-115

year	fall	winter	spring
Freshman	9HA(5)	9HB(5)	9HC(5)
Sophomore	9HD(5) 104A	40(4) *80*	105H(5) 104B(4)
Junior	115A(4) 112(4)	115B(4) *110A(4)*	115C(4) *110B(4)*
Senior		*116A(4)*	*116B(4)*

year	fall	winter	spring
Junior	9D(4) 104A(4)	105A(4) *110A(4)* 40(4)	105B(4) *110B(4)* 104B(4)
Senior	115A(4) 112(4) 80(4)	115B(4) 116A(4)	115C(4) 116B(4)

9 Example Schedule

Note that 116A-B in this sequence can be replaced with 122A or B in the winter.

10 Problems and Ideas

- Relevant stuff for QM (Angular Momentum, Central Forces) is in 105B, but only 105A is a preq. In general, 105B is major absence from applied physics requirements. Not all 105A+B instructors even cover Hamiltonian formalism.
- 104A is taught by Luty as a sort of boot camp for problem solving in upper division courses... but only a pre-req for 115A.
- Damped driven oscillator is missing from mechanics.
- We don't always cover Hamiltonian formalism before reaching QM.
- Drop 110C. Need to cover vector potential in B. Need to cover special relativity elsewhere.
- Curro thinks we need to add QIT somewhere, at least as elective, or risk being left behind.

11 Big Ideas

- We have three tracks, essentially: 9H, 9, and transfers. Current policy amounts to asking 9H students to wait for everyone else. Maybe we can make 9H students overlap other tracks in Sophomore (vs Junior) year.
- More computing!!!

INTRODUCTORY CLASSICAL MECHANICS

* WITH PROBLEMS AND SOLUTIONS *

David Morin

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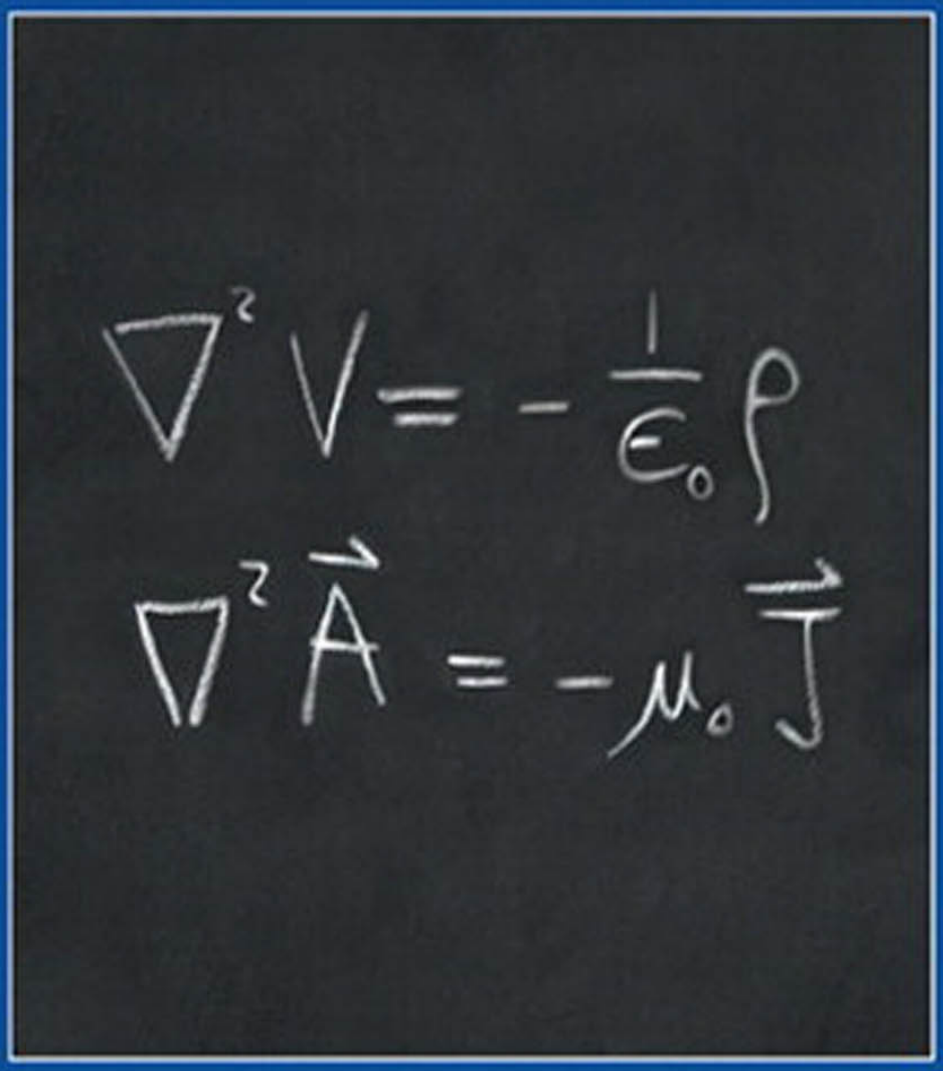

DAVID J. GRIFFITHS

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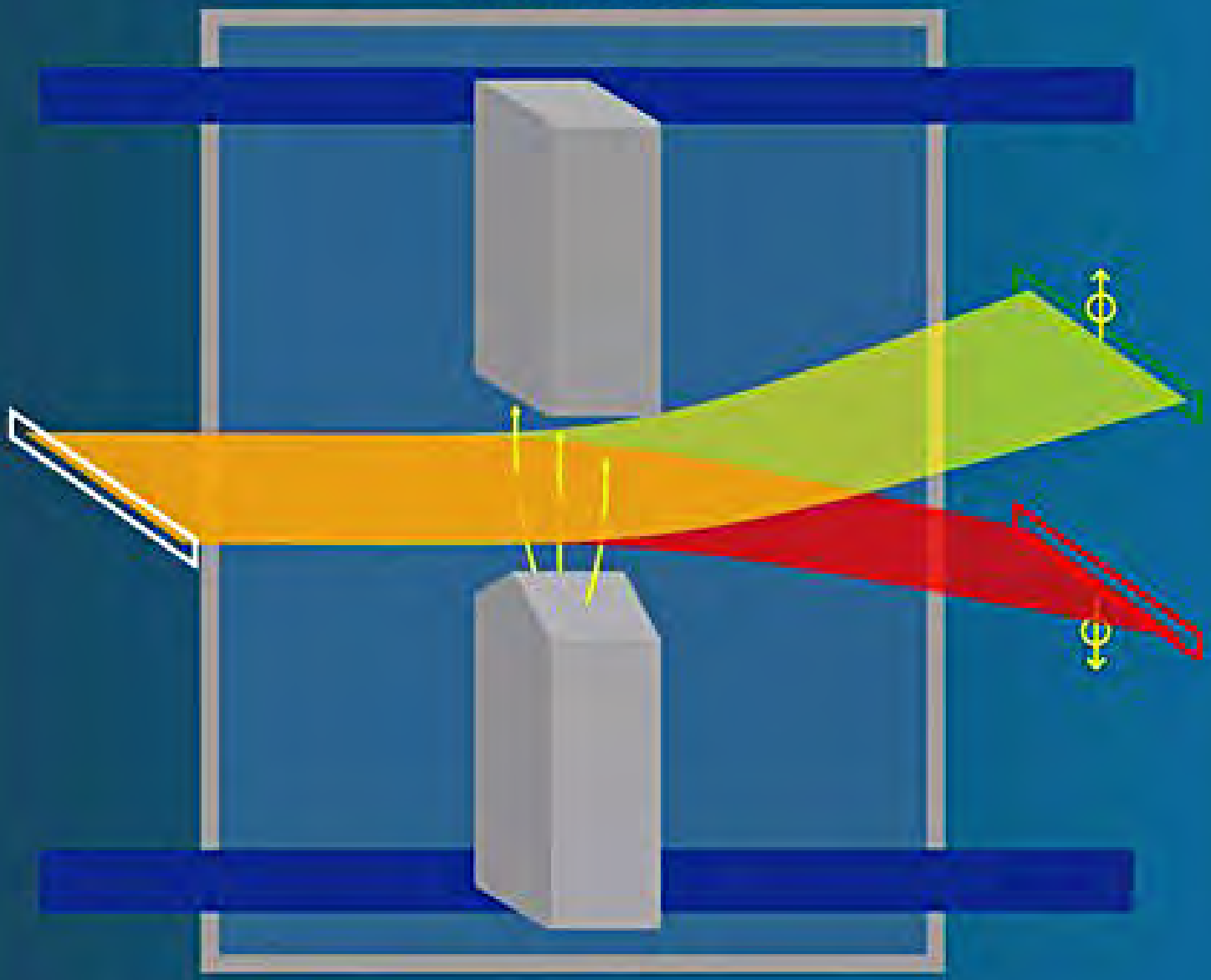

John S. Townsend

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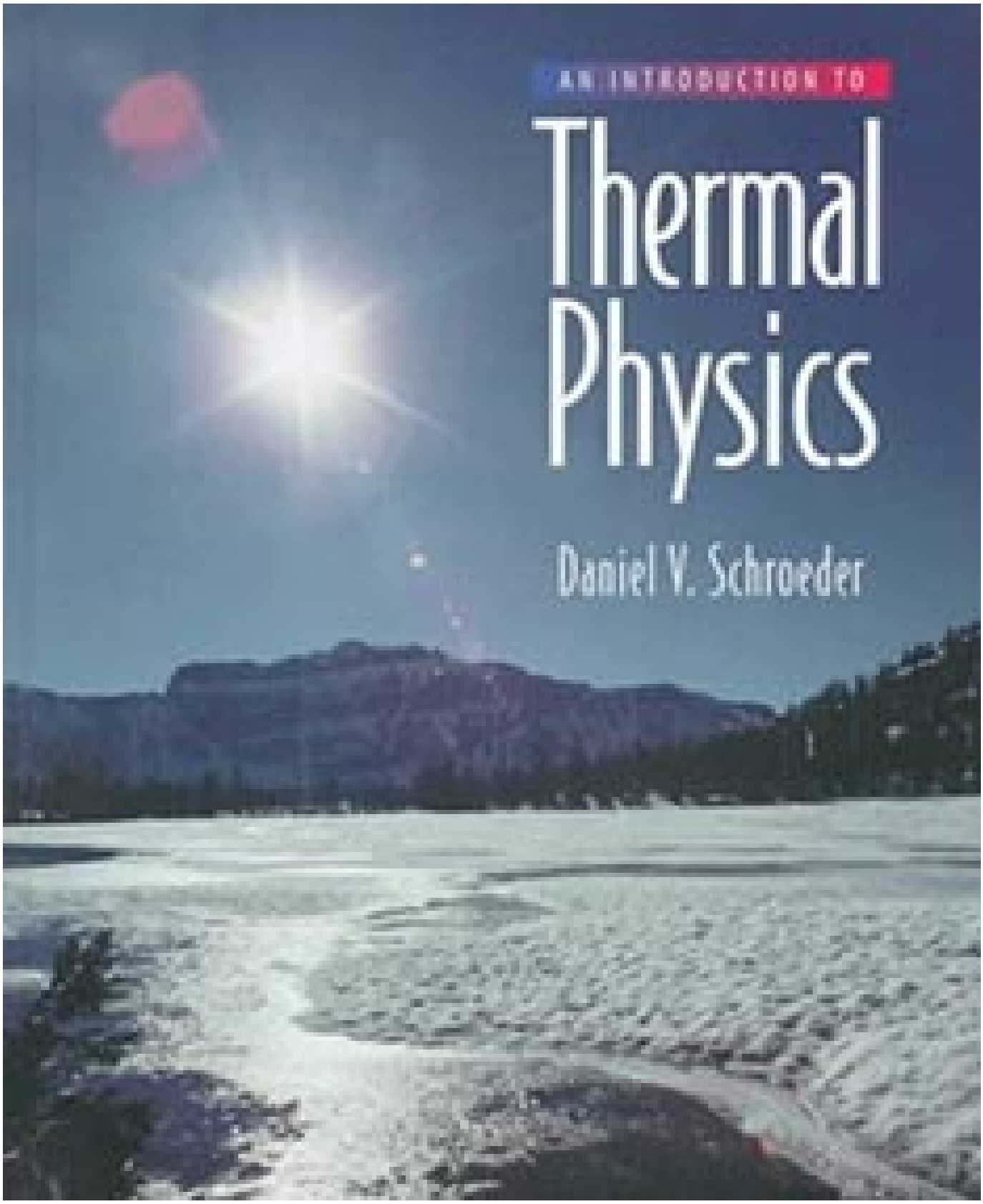
AN INTRODUCTION TO
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