

**BOSTON COLLEGE**  
**Department of Physics**

**PHYS 1400**

**ART OF PHYSICS**

**SUMMER 2018**

**Instructor** Prof. Andrzej Herczyński  
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**Lectures** M, Tu, Th, F: 9:30 – 10:45 & 11:00 – 12:15; W: tours & museum visits

**Location** Dipartimento di Scienze Matematiche, Fisiche e Informatiche,  
Università degli Studi di Parma

**Main Textbooks**

- (1) Richard Feynman, *The Character of Physical Law* (a series of lectures recorded by the BBC at Cornell University, BBC 1965; MIT Press, 2001).
- (2) Steven Weinberg, *To Explain the World: The Discovery of Modern Science*, (First ed., Harper Collins Publishers, 2015). Additional suggested textbooks are listed below.

**Course Description**

This summer course is a modern introduction to classical physics themes, primarily for students in the humanities. It will address the following questions: What do we mean by classical physics? Is classical physics subsumed by newer theories – e.g. Quantum Mechanics and General Theory of Relativity? What should a scholar in the humanities know about physics? This course is in part *about physics* (that is descriptive), and in part *in physics*, as it will endeavor to develop useful quantitative skills (i.e. dimensional analysis, estimates, problem solving techniques, and practical applications). It is hoped that students will gain awareness of the methods and tools of physics, enabling them to engage in informed discussions with scientists, better understand advances in technology, and have a basis for assessing science news and physics discoveries (or claims of such).

The sequence of lectures is not a regular introductory course squeezed into four weeks, but a somewhat subjective selection of topics meant to serve as an invitation to consider the power and beauty of physics and its place among the liberal arts. What is the scope of Newtonian Mechanics, and why was it a radical shift from the Aristotelian view of the world? What is knowable in this framework, what we understand and in what sense, and what are the unresolved (or irresolvable) questions? How do classical theories, such as Maxwell's Theory of Electromagnetism, though logically self-contained, point toward modern physics (Special Theory of Relativity)? How is the direction of time set? How does order lead to, or emerge from chaos?

The course will have an interactive character – students will vote in class (using cards) to answer questions and express views and preferences, thus helping to steer the discussion. Two experimental investigations and some demonstration experiments will be included. Numerous class visits to science (and art) museums, places of historical significance for the early science development, and physics facilities are planned (day-long trips to Bologna, Florence, and Padua).

### **Course Prerequisites**

There are no formal prerequisites but some familiarity with physics concepts will be helpful. Facility with simple (symbolic) algebraic operations and basic trigonometry will be required, but a “refresher” will be offered, if needed. Conduct in accordance with BC academic integrity standards and the honor code, as well as sensitivity to local customs and culture, will be expected.

### **Participation & Projects**

The principal requirement of the course is attending all classes and participating. Class work will include discussion of problems and multiple-choice Concept Questions. It is expected that students will help set the pace by raising questions and by providing feedback, particularly when more detailed explanations are needed. By engaging and participating, students will thus help “customize” this course. Homework will be assigned during or after most lectures, and collected and discussed at the next class meeting. Two experimental investigations will be included also.

There will be no exams, but short in-class exercises may be introduced. One written midterm project will be assigned (requiring research, open-ended, and likely 5-10 pages long) plus a more substantial final project due before the end of summer.

### **Course Outline** (tentative, a selection of topics listed in Part III will be offered)

#### Part I: Historical Notes

1. The quest of physics.
2. Early scientific developments.
3. From natural philosophy to physics.

#### Part II: Quantitative Skills

4. Units and why they matter.
5. Dimensional analysis and applications.
6. Dimensionless parameters and their meaning.
7. Orders of magnitude. Estimates.
8. Math Interlude – functions, graphs, derivatives.
9. Notes on kinematics in 1D and 2D.
10. Critique of Newton’s Laws.
11. Solving basic problems.
12. Translations & rotations.

#### Part III: Qualitative Glance

13. Forces of Nature. Force expressions.
14. Newton’s Gravitational Law – a case study.
15. Conservation principles. Symmetry.
16. The solar system, Kepler’s Laws. Expanding Universe.
17. Systems of many – statistical concepts and thermodynamics
18. Electric and magnetic phenomena. Unification.
19. Mathematics & physics – unreasonably good fit?
20. Limits of classical physics. Is it still relevant?
21. Chaos and order. Fractal geometry.

## A Few Recommended Books

1. Alfred North Whitehead, *An introduction to Mathematics*, (Oxford University Press, first printing 1948).

A beautiful, self-contained, yet quite “minimalist” introduction to the basic concepts of mathematics (symbolism, complex numbers, elements of Cartesian geometry, conic sections, functions, and – on just 12 pages (chapter 15) – to the concept of derivative. The shortest “calculus course” imaginable!

2. Albert Einstein and Leopold Infeld, *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta* (Simon & Schuster, 1965).

The book presents a historical account of the development of physics, with thorough but accessible discussion, progressing from Newtonian mechanics, to the theory of electromagnetic field, special and general relativity theory, and quantum mechanics. Addressed to a curious reader, the text does not require any mathematical preparation.

3. Richard Feynman, *The Character of Physical Law* (a series of lectures recorded by the BBC at Cornell University, BBC 1965).

A set of seven lectures on the search for, and character of, physical laws, starting with Newton’s Gravitational Law which serves as the primary example. A highly idiosyncratic, informal discussion, with occasional brilliant insights. The book takes up such topics as the relation between mathematics and physics, and the distinction between past and future, and includes a beautifully succinct discussion of quantum mechanics and its inescapable strangeness (lecture 6).

4. Richard Feynman, *QED*, (Princeton University Press, 1985).

A presentation of Quantum Electrodynamics (QED) for a general reader, dedicated to Feynman’s friend, Alix Mautner, who was a professor of English at California State University at Los Angeles, and who had an unquenchable curiosity about physics. It treats, as the subtitle suggests, “the strange theory of light and matter,” starting with particles of light (photons), then electrons and the interactions between the two.

5. Euan Squires, *To Acknowledge the Wonder—the story of fundamental physics*, (Adam Hilger Ltd, 1985).

In the words of the author, this book is a “story” about fundamental physics. It describes the recent (as of 1985) developments in understanding the world of atoms and their nuclei, the protons and the neutrons, and the “mysterious quarks.” The exposition uses some mathematics at the level of an introductory physics course, but is also conceptually quite challenging. Its main focus is the so-called “standard model” of particle interactions, and it includes many advanced topics necessary for the discussion.

6. Steven Weinberg, *Dreams of a Final Theory* (Pantheon Books, New York, 1992).

A readable, entertaining, and illuminating account of the search for the unified theory of physical interactions for a general reader. It is divided in three parts (and a coda about the SSC, Superconducting Super Collider). The first three chapters (Part I) present the idea of the final theory; chapters 4-8 (Part II) are about the progress that have been made in approaching the final theory; while chapters 9-11 (Part III) speculate on the “shape” of the final unified theory.

7. Steven Weinberg, *The First Three Minutes*, (Basic Books, Inc., Publishers, New York, 1977).

A beautifully written account of the first three minutes after the Big Bang, in effect a physicist’s story of the creation of the universe. This little book for a curious reader does not require any mathematical preparation and is the first authoritative presentation of what is currently (as of 1976) known about the creation of elements—during the initial explosive genesis (light elements like Hydrogen and Helium) and in nuclear reactions inside stars (heavier elements). Especially notable is chapter VI, a “historical diversion,” which illuminates the nature of scientific research. Weinberg concludes: “I do not think it is possible really to understand the successes of sciences without understanding how hard its is—how easy it is to be led astray, how difficult it is to know at any time what is the next thing to be done.”

#### **Four Historical Accounts**

1. Anthony Alioto, *A History of Western Science* (Second edition, Prentice Hall, 1993).

An engaging, attractively written, comprehensive history of Western science from the early antiquity and Greek philosophy through the Middle Ages to the Renaissance and the scientific revolution, nineteenth century developments, and the beginning of modern physics (relativity and quantum mechanics). The emphasis is on evolving scientific ideas and concepts, and their relations to the external culture. The book aims also to explore the “human side of science,” that is the rational and irrational factors that influenced thinkers over the centuries.

2. E. J. Dijksterhuis, *The Mechanization of the World Picture: Pythagoras to Newton*, (first Princeton University Press paperback, 1986, Oxford University Press, 1961)

A classic, encyclopedic work on the development of mathematics and mechanics, and also chemistry and astronomy, from the Pythagoreans up through the seventeenth century. Comprehensive and detailed.

3. Steven Weinberg, *To Explain the World: The Discovery of Modern Science*, (First edition, Harper Collins Publishers, 2015)

This is a much needed book, a physicist's history of science from the Greeks through the scientific revolution. A delightful, irreverent, and insightful account of the forging of modern science and the slow, fitful, uneasy emergence of what we call now the scientific method. The book offers an unflinching appraisal of early scientific work, in modern physics terms, and the debates that shaped science, and included a wonderfully written Technical Notes (occupying approximately last 100 pages of the book) for readers who would like to understand exactly the ancient and early modern arguments in contemporary mathematical language.

4. A. Alexander, *Infinitesimal: How a Dangerous Mathematical Theory Shaped the Modern World*, (Scientific American / Farrar, Straus, and Giroux, 2014)

A witty and engaging account of the early development of the calculus and related advances in physics and astronomy in the early modern period, and the mathematical-philosophical-theological controversy the idea of the "infinitesimal" ignited, particularly in Italy. The principal characters are Galileo, Clavius, Cavalieri, Wallis, Torricelli, Newton, Bacon, and Hobbs.

### **Some Conceptual Textbooks**

1. *The Mechanical Universe, Introduction to Mechanics and Heat*, R. P. Olenick, T. M. Apostol, and David Goodstein (Cambridge University Press, 1985).
2. *From Alchemy to Quarks*, Sheldon Glashow, (Brooks Cole Publishing Company, 1994).
3. *Conceptual Physics*, Paul G. Hewitt (Pearson/Addison Wesley, 10<sup>th</sup> edition 2009).
4. *Physics: Concepts & Connections*, Art Hobson (Pearson/Addison Wesley, 4<sup>th</sup> edition 2007).
5. *Physics Matters: An Introduction to Conceptual Physics*, James Trefil and Robert Hazen (John Wiley & Sons, 2004).