

History of Science 325

History of Physics: The Classical Period

Spring 2007

9:55 AM MWF 6116 Social Sciences

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Office Hours: 11 M, 2:25 W

This course surveys the history of physics and related sciences from the seventeenth to the end of the nineteenth century, setting the development of the ideas and methods of “classical” science in social and cultural context. Topics include the emergence of an experimental methodology, mechanics and the Newtonian worldview, the history of optics, electricity and magnetism, and thermodynamics. We will trace the interplay of idea and experiment, image and machine across the library, laboratory, exhibition-hall and factory in exploring the changing relations between science and technology, science and religion, and science and the state. Our aim will be to explain the role of the physical sciences in the emergence of the modern industrial world, and to build an understanding of key factors in the vibrant – and troubled – ferment of human knowledge and society circa 1900.

Book List (University Bookstore)

Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998).

Course Reader

Available for \$36 from the History of Science Department Office, 7143 Social Science. Please note that refunds cannot be offered even if the class is dropped. The office is open from 8:00 a.m. - 3:00 p.m. daily.

Assessment

Assessment is through three take-home essay exams written on selected topics (75% of the total grade), and discussion participation (25%). The participation grade will test your comprehension of both lectures and readings, and will be based in part on the completion of 6 short discussion pieces in the course of the semester (see below).

First Take-Home Exam (20%): Distributed Feb. 21; due March 2.

Second Take-Home Exam (25%): Distributed March 28; due April 13.

Final Take-Home Exam (30%): Distributed May 4; due 12:05 P.M., Monday, May 14.

Honors Assessment

Honors students will submit in addition a paper on a topic of their own choice (worth 20% of their overall grade), to be completed by May 7.

Discussion Pieces

As part of your section participation grade (worth 25% of the final grade), in the course of the semester I would like you to write 6 short discussion pieces of 1-2 pages (double spaced).

You are to write two in each five-week segment of the course, between the dates of February 23; March 30; and May 11.

The discussion piece is to be submitted to me before Friday's section, preferably on Wednesday, so that I can incorporate the questions and topics you raise as appropriate. If you can't give it to me at lecture, please leave a copy in my mailbox by noon on Thursday.

Content

The discussion piece should be a forum for discussing the content and the significance of particular readings and ideas raised in class. It could involve analysis of one or more of the assigned readings; discussion of a topic raised in lectures; or a mixture of both. Write about something you find interesting, describing the argument an author has presented and evaluating the evidence they have offered. Do you agree with their point of view? Support your own opinions with concrete examples from the course materials.

The task will help focus our class discussions and will also provide helpful practice in writing.

Participation and Performance

If you have a conflict between an academic requirement and any religious observance, please notify me of the specific dates concerned within the first two weeks of the course and I will find an alternative means for you to fulfill the requirement. Such requests are confidential.

In compliance with the Americans with Disabilities Act, I will make every effort to honor requests for reasonable accommodations made by individuals with disabilities. (If you think you qualify for accommodation, please contact the McBurney Disability Resource Center [263-2741; <http://jumpgate.acadsvcs.wisc.edu/~mcburney/>] to establish your eligibility for services.) Requests for accommodation can be responded to more effectively if I receive them as far in advance as possible, preferably at the beginning of the semester. Such requests are confidential.

If any problems arise, either academic or personal, that might jeopardize your performance in the course, you must try to inform me of the problem at the next available office hour, or by leaving a message with the Department of the History of Science (262-1406).

Syllabus

Apart from references to **Smith's** *The Science of Energy*, all material is in the Course Reader. The readings listed are core material and ideally should be read before the relevant lecture.

Part I: Newton's Legacy and Enlightenment Science

Jan. 22 Introduction and the Sites of Science

Jan. 24 Newton's New Theory of Light

Isaac Newton, "A New Theory About Light and Colours," (1672), and Queries 28 and 29 from *Optics* (4th ed., 1730) as excerpted in William Francis Magie, ed. *A Source Book in Physics* (Cambridge, MA: Harvard University Press, 1963), pp. 298-308.

Simon Schaffer, "Glass Works: Newton's Prisms and the Uses of Experiment," in David Gooding, Trevor Pinch and Simon Schaffer, *The Uses of Experiment: Studies in the Natural Sciences*, (Cambridge: Cambridge Univ. Press, 1989), pp. 67-104.

Jan. 26 Discussion Topic: Introductions

Jan. 29 Force and a New Mechanical Philosophy

John Roche, "Newton's *Principia*," in John Fauvel, Raymond Flood, Michael Shortland and Robin Wilson, eds. *Let Newton be!* (Oxford: Oxford University Press, 1988), pp. 43-61.

Jan. 31 Newton's *Principia*

Isaac Newton, *Principia Mathematica Philosophiae Naturalis* (1687), as excerpted in Magie, *A Source Book*, pp. 30-46.

Albert Einstein, "Isaac Newton," in the *Manchester Guardian*, March 19, 1927, as reprinted in Annual Report of the Smithsonian Institution, 1927, pp. 201-207.

Feb. 2 Discussion Topic: Newton's Work and Legacy

Feb. 5 Enlightenment Science: Electricity on Display

Thomas L. Hankins, *Science and the Enlightenment* (Cambridge: Cambridge University Press, 1985) chap. 3, pp. 46-78.

Feb. 7 Coulomb's Quantification and Volta's Current

On Robison and Coulomb see J.L. Heilbron, *Electricity in the 17th and 18th Centuries: A Study in Early Modern Physics* (Mineola, NY: Dover, 1999), pp. 465-477.

Giuliano Pancaldi, "Appropriating Invention: The Reception of the Voltaic Battery in Europe," in Marie-Noelle Bourget, Christian Licoppe and H. Otto Sibum, eds. *Instruments, Travel and Science: Itineraries of Precision from the Seventeenth to the Twentieth Century* (London: Routledge, 2002), pp. 126-155.

For an overview linking Coulomb and Galvani and Volta, see Heilbron, *Electricity*, "Preface to the Dover Edition," pp. xi-xxv.

Feb. 9 Discussion Topic: Enlightenment Physics

Feb. 12 Chemistry in the Enlightenment

Hankins, *Science and the Enlightenment*, Chap. 4, pp. 81-112.

Feb. 14 Balancing Acts: The Chemical Revolution

Antoine-Laurent Lavoisier, *Elements of Chemistry in a New Systematic Order, Containing All the Modern Discoveries*, trans. Robert Kerr (New York: Dover, 1965), Preface and Part 1, Chap. 1, pp. xiii-xxxvii and 1-25.

Frederic L. Holmes, "The 'Revolution in Chemistry and Physics:' Overthrow of a Reigning Paradigm or Competition between Contemporary Research Programs?," *Isis* 91 (2000), 735-753.

Feb. 16 Discussion Topic: Enlightenment Chemistry

Feb. 19 Laplace and the Rise of Mathematical Physics

Robert Fox, "Laplacian Physics," in Olby, et al., eds. *Companion to the History of Modern Science*, pp. 278-294.

Feb. 21 Challenging Laplace: Joseph Fourier's New Science of Heat

Eugene Frankel, "J.B. Biot and the Mathematization of Experimental Physics in Napoleonic France," *Historical Studies in the Physical Sciences* 8 (1977), 33-72.

Robert Marc Friedman, "The Creation of a New Science: Joseph Fourier's Analytical Theory of Heat," *Historical Studies in the Physical Sciences* 8 (1977), 73-99.

Note: First Take-Home Exam Distributed

Feb. 23 Discussion Topic: Mathematization and the Sciences of Heat

Note: Second Discussion Piece Due

Part 2: The Romantic Transformation

Feb. 26 Alexander von Humboldt and Geophysics: Mapping Space

Michael Dettelbach, "Humboldtian Science," in Nicholas Jardine, James A. Secord and Emma C. Spary, eds. *Cultures of Natural History* (Cambridge: Cambridge Univ. Press, 1996), pp. 287-304.

L. Pearce Williams, *The Origins of Field Theory* (New York: Random House, 1966), Chap. 2, pp. 32-63.

Feb. 28 Romantic Science and New Concepts of Force

Mary Shelley, *Frankenstein, or, The Modern Prometheus* (New York: Doubleday, 1999), pp. 51-76.

March 2 Discussion Topic: Romantic Science

Note: First Take-Home Exam Due

March 5 Basic Facts, Natural Facts, and Honor in Electrodynamics: Ampère and Faraday

Williams, *Origins of Field Theory*, Chap. 3, pp. 64-91.

David Gooding, "'In Nature's School': Faraday as an Experimentalist," in David Gooding and F.A.J.L. James, eds. *Faraday Rediscovered* (Basingstoke: Macmillan, 1985), pp. 105-135.

March 7 On Making Facts and Machines

Iwan Morus, "Different Experimental Lives: Michael Faraday and William Sturgeon," *History of Science* 30 (1992), 1-28.

March 9 Discussion Topic: Cultures of Experiment in Faraday's London

Part 3: The Science of Energy and the Growth of Laboratory Physics

March 12 On Energy and its Histories

Crosbie **Smith**, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), Introduction and Chap. 3, pp. 1-14 and 31-52.

March 14 James Joule's Mechanical Value of Heat

Smith, *The Science of Energy*, Chap. 4, pp. 53-76.

Heinz Otto Sibum, "Reworking the Mechanical Value of Heat: Instruments of Precision and Gestures of Accuracy in Early Victorian England," *Studies in History and Philosophy of Science* 26 (1995), 73-106.

March 16 Discussion Topic: Joule's Manchester

March 19 Progress and Dissipation

Smith, *The Science of Energy*, Chaps. 5-7, pp. 77-149.

March 21 Thermodynamics

T.S. Kuhn, "Energy Conservation as an Example of Simultaneous Discovery," in Marshall Clagett, ed. *Critical Problems in the History of Science* (Madison: University of Wisconsin Press, 1959), pp. 321-356.

Smith, *The Science of Energy*, Chap. 8, pp. 150-169.

March 23 Discussion Topic: The Science of Thermodynamics

March 26 The Treatises and the New Natural Philosophy

Smith, *The Science of Energy*, Chaps. 10-12, pp. 192-267.

March 28 Cables and Field Theory

Smith, *The Science of Energy*, Chap. 13, pp. 268-287.

Bruce J. Hunt, "Doing Science in a Global Empire: Cable Telegraphy and Electrical Physics in Victorian Britain," in Bernard Lightman, ed. *Victorian Science in Context* (Chicago and London: The University of Chicago Press, 1997), pp. 312-333.

Note: Second Take-Home Exam Distributed

March 30 Discussion Topic: Electromagnetism and Empire

Note: Fourth Discussion Piece Due

Spring Break

April 9 The Rise of the Teaching Laboratory

Graeme Gooday, "Precision Measurement and the Genesis of Physics Teaching Laboratories in Victorian Britain," *British Journal for the History of Science* (23) 1990, 25-51.

April 11 Maxwell's Cavendish and Laboratory Metrologies

James Clerk Maxwell, "Introductory Lecture on Experimental Physics," in *The Scientific Papers of James Clerk Maxwell*, ed. W.D. Niven (Cambridge: Cambridge Univ. Press, 1890), 241-255.

Simon Schaffer, "Late Victorian Metrology and Its Instrumentation: A Manufactory of Ohms," in Mario Biagioli, ed. *The Science Studies Reader* (New York and London: Routledge, 1999), pp. 457-478.

April 13 Discussion Topic: The Laboratory Revolution

Note: Second Take-Home Exam Due

April 16 Science in the U.S. and Physics at U.W.

Daniel J. Kevles, *The Physicists: The History of a Modern Scientific Community in America* (Cambridge, MA and London: Harvard University Press, 1995), pp. 25-74.

April 18 Light and Mechanics: Testing Relative Motion

H.A. Rowland, "Plane and Concave Gratings," (1882) as excerpted in Magie, *Source Book*, pp. 365-368.

A.A. Michelson and E.W. Morley, "On the Relative Motion of the Earth and the Luminiferous Ether," (1887) as excerpted in Magie, *Source Book*, pp. 369-377.

H.A. Rowland, "The Highest Aim of the Physicist," (1899) in Spencer R. Weart, ed. *Selected Papers of Great American Physicists* (New York: American Institute of Physics, 1976), pp. 91-103.

April 20 Discussion Topic: Physics in the U.S.

Part 4: The New Physics

April 23 The Discoveries: Roentgen's X-rays

Iwan Rhys Morus, *When Physics Became King* (Chicago/London: Univ. of Chicago Press, 2005), Chap. 6, pp.156-191.

W.C. Roentgen, "On a New Kind of Rays," *Nature* 53 (23.1.1896), 274-276 and A.A.C. Swinton, "Professor Röntgen's Discovery," *Nature* 53 (23.1.1896), 276-277.

April 25 The Discoveries: Radioactivity

Henri Becquerel, excerpt on "The Radiation from Uranium," *Comptes Rendus* 122 (1896), p. 420 as translated in W.F. Magie, *A Source Book in Physics* (Cambridge, MA: Harvard University Press, 1963), pp. 610-613.

P. and M.S. Curie, excerpts on "Polonium," and "Radium," *Comptes Rendus* 127 (1898), pp. 175 and 1215, as translated in Magie, *Source Book*, pp. 613-616.

Helena Pycior, "Reaping the Benefits of Collaboration while Avoiding Its Pitfalls: Marie Curie's rise to Scientific Prominence," *Social Studies of Science* 23 (1993), 301-323.

April 27 Discussion Topic: New Directions: Microphysics

April 30 New Directions in Theory: Questioning the Foundations

Ernst Mach, "The Economical Nature of Physical Inquiry," in *Popular Scientific Lectures*, trans. Thomas J. Mc-Cormmach, (La Salle, IL: Open Court, 1986), 186-213.

Christa Jungnickel and Russell McCormmach, *Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein*. 2 vols, Vol. 2, (Chicago and London: The University of Chicago Press, 1986), pp. 211-245 (and enjoy the illustrations on pp. 193-210).

May 2 Black-Body Radiation and Planck's Theory

David Cahan, "High Temperatures and High Science," in *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871-1918* (Cambridge: CUP, 1989), pp. 143-157.

J.L. Heilbron, *The Dilemmas of an Upright Man: Max Planck as Spokesman for German Physics* (Berkeley: University of California Press, 1986), pp. 1-28.

May 4 Discussion Topic: Physical World Views and the International Community

Note: Final Take-Home Exam Distributed

May 7 Constituting a Community: The Inaugural International Congress of Physicists, Paris, 1900

Henri Poincaré, *Science and Hypothesis* (London: Walter Scott, 1905), "Hypotheses in Physics," and "The Theories of Modern Physics," pp. 140-182.

Henry Adams, *The Education of Henry Adams: An Autobiography*. Edited by Henry Cabot Lodge (Boston and New York: Houghton Mifflin Company, 1918), pp. 376-391.

May 9 On the Co-Creation of Classical and Modern Physics

Ludwig Boltzmann, "On the Development of the Methods of Theoretical Physics in Recent Times (1899)," in *Theoretical Physics and Philosophical Problems: Selected Writings*. Edited by Brian McGuinness (Dordrecht and Boston: D. Reidel, 1974), pp. 77-100.

May 11 Discussion Topic: Between Classical and Modern Physics

Note: Sixth Discussion Piece Due

Monday May 14 Final Examination Due (10:05-12:05 P.M.)

Grading Criteria for Essays

- A: For outstanding essays only. The thesis and argument are clear, thought-provoking, and based on correctly understood facts. Material used to support the argument synthesizes ideas from different parts of the course (readings, lectures, discussions from different weeks). The relationships drawn between facts and ideas are sophisticated, subtle, and/or original. The writing is grammatically correct and succinct, and the argument flows well from point to point. Not a word is wasted!
- AB: For very good essays that for some reason fall short of the criteria described above. The argument may be murky at one point; information may be presented that doesn't directly or clearly contribute to the argument; the writing style may be awkward occasionally, or flawed by one or two consistent (if minor) grammatical errors.
- B: The basic good grade. The essay may pursue a straightforward but not particularly deep or sophisticated argument; it is okay as far as it goes, but doesn't penetrate into the material very far. It may have a flash of brilliance that isn't brought to fruition, because it is counterbalanced by a weakness in argumentation, minor grammatical problems, and/or a significant misunderstanding of events or chronology.
- BC: The essay shows some of the basics of the ideal essay, but is weakened by a lack of serious thinking, or by writing problems. It may make superficial connections without offering sufficient evidence to make the connections plausible or persuasive, or it may have what is in principle a good argument supported by incorrect facts or chronology. Alternatively, it may provide a fairly solid argument with minor flaws, from which the reader is continually distracted by awkward or ungrammatical prose.
- C: A grade signifying some serious problem in essay writing. It may deliver facts without a recognizable thesis or argument; it may wander away from the point; or it may be a thoughtful attempt so weakened by writing problems (grammar, punctuation, word choice) that it is difficult for the reader to understand a crucial point you are trying to make.
- D: A marginal grade. There may be enough here to show that you have attended a few lectures and/or done some of the reading, but the essay indicates no attempt at synthesis or thinking on your own, or shows a serious misunderstanding of the nature of the material and/or the assignment. Also used for essays that are just barely coherent.
- F: For unacceptable essays. An essay may be judged unacceptable if it contains plagiarism; if it consists primarily of content inappropriate to the question or the material for this course; if it shows a complete misunderstanding of the course content; or if the writing fails to meet standard college-level requirements of basic communication in English.

Plagiarism is grounds for automatic failure on an assignment. If you use three or more words in a row from another source, the phrase must be placed in quotation marks and footnoted. Otherwise it is plagiarism. For more on what constitutes plagiarism and how to avoid it, consult *A Pocket Style Manual* by Diana Hacker, or the UW-Madison Writing Center website.