

# History of Science 325

## History of Physics: The Classical Period

### Spring 2009

11-12:15 TR 6102 Social Sciences

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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). Required.

Iwan Rhys Morus, *When Physics Became King* (Chicago: Univ. of Chicago Press, 2005). Recommended [the syllabus indicates where you may wish to make use of Morus; you may choose to use this as an alternative to some of the assigned readings].

#### 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. Monday to Thursday, and extended hours in the first weeks.

*All materials are also on reserve at College Library.*

#### 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. 19; due March 3.

Second Take-Home Exam (25%): Distributed April 2; due April 14.

Final Take-Home Exam (30%): Distributed May 7; due 2:25 P.M., Friday, May 15.

#### 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 discussion participation grade (which is worth 25% of the final grade), in the course of the semester I would like you to post 6 short discussion pieces of 1-2 paragraphs in length to the class discussion forum on the course website (on Learn@UW).

You are to post discussion pieces in two different weeks of each five-week segment of the course, between the dates of February 19; April 2; and May 7.

The discussion piece is to be posted by 8 PM on Monday or Wednesday in the relevant week, so that we can incorporate the questions and topics you raise in class discussion the following day.

**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 discussion; 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.

You will also have the opportunity to respond appropriately to discussion pieces from others, but the two pieces required in each five-week segment should open up substantive questions rather than simply comment on someone else's posting.

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://www.mcburney.wisc.edu/>] 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. If you are interested in an additional perspective, I have indicated where Morus's *When Physics Became King* is especially relevant.

### Part I: Newton's Legacy and Enlightenment Science

#### Jan. 20 Introduction and the Sites of Science

#### Jan. 22 Newton's New Theory of Light

Isaac Newton, "A New Theory About Light and Colours," (1672), and Queries 28 and 29 from *Optics* (4<sup>th</sup> 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.

#### Discussion: Introductions

#### Jan. 27 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. 29 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.

#### Discussion: Newton's Work and Legacy

#### Feb. 3 Enlightenment Science: Electricity on Display

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

#### Feb. 5 Coulomb's Quantification and Volta's Current

On Robison and Coulomb see J.L. Heilbron, *Electricity in the 17<sup>th</sup> and 18<sup>th</sup> 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.

#### Discussion: Enlightenment Physics

## Feb. 10 Chemistry in the Enlightenment

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

## Feb. 12 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.

## Discussion: Enlightenment Chemistry

## Feb. 17 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. 19 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.

[On these topics see also Morus, *When Physics Became King*, chap. 2.]

Note: Second Discussion Piece Due; First Take-Home Exam Distributed

## Discussion: Mathematization and the Sciences of Heat

## Part 2: The Romantic Transformation

## Feb. 24 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. 26 Romantic Science and New Concepts of Force

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

[See also Morus, *When Physics Became King*, pp. 54-71.]

## Discussion: Romantic Science

## March 3 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.

Note: First Take-Home Exam Due

*March 5 On Making Facts and Machines*

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

[See also Morus, *When Physics Became King*, chap. 4.]

*Discussion: Cultures of Experiment in Faraday's London*

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

*March 10 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 12 James Joule's Mechanical Value of Heat*

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

Heinz Otto Sibus, "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.

[See also Morus, *When Physics Became King*, pp. 71-86 and 123-143.]

*Discussion: Joule's Manchester*

Spring Break

*March 24 Progress and Dissipation*

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

*March 26 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.

[See also Morus, *When Physics Became King*, pp. 143-155.]

*Discussion: The Science of Thermodynamics*

*March 31 The Treatises and the New Natural Philosophy*

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

*April 2 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: Fourth Discussion Piece Due; Second Take-Home Exam Distributed

*Discussion: Electromagnetism and Empire*

#### April 7 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 9 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.

[See also Morus, *When Physics Became King*, chap. 8.]

*Discussion: The Laboratory Revolution*

#### April 14 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.

Note: Second Take-Home Exam Due

#### April 16 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.

*Discussion: Physics in the U.S.*

### Part 4: The New Physics

#### April 21 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 23 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.

*Discussion: New Directions: Microphysics**April 28 New Directions in Theory: Questioning the Foundations*

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

Christa Jungnickel and Russell McCormach, *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).

*April 30 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.

*Discussion: Physical World Views and the International Community**May 5 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 7 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.

[See also Morus, *When Physics Became King*, chap. 9.]

Note: Sixth Discussion Piece Due; Final Take-Home Exam Distributed

*Discussion: Between Classical and Modern Physics*

*Friday May 15 Final Examination Due (12:25-2:25 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.

Essays will be predominantly based on course materials, but may make sparing reference to other sources in order to back up an argument.

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.