

History of Science 325

History of Physics: The Classical Period

Fall 2011

9:30-10:45 TR 101 Agricultural Engineering

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From the seventeenth through to the end of the nineteenth century, physics set its stamp on the intellectual world, and increasingly, the world of business and industry: for many, it was the premier scientific discipline. Here we set the development of the ideas and methods of “classical” physics and related sciences in social and cultural context. Topics include the emergence of an experimental methodology, mechanics and the Newtonian world view, the history of optics, electricity and magnetism, and thermodynamics. Tracing the interplay of idea and experiment, image and machine across the library, laboratory, exhibition-hall and factory provide ways of 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 (A Room of One's Own, 307 W. Johnson St.)

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.

*Bruce J. Hunt, *Pursuing Power and Light: Technology and Physics from James Watt to Albert Einstein* (Baltimore: Johns Hopkins Univ. Press, 2010). Recommended.

Course Reader Available for \$36 by cash or check from the History of Science Department Office (210 Bradley Memorial); note that returns are not possible.

*Note that the syllabus indicates where you may wish to make use of Morus and/or Hunt; you may choose to use them as an alternative to some of the assigned readings but should not rely solely upon them.

All reading materials are also available on reserve at the 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 Oct. 6; due Oct. 18.

Second Take-Home Exam (25%): Distributed Nov. 10; due Nov. 22.

Final Take-Home Exam (30%): Distributed Dec. 15; due 9:25 P.M. Thurs. Dec. 22.

Honors Assessment

Honors students will submit in addition a paper – and may give a presentation to the class as a whole – on a topic of their own choice. This to be completed by Dec. 15 and is worth 20% of the overall grade.

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 October 6; November 10; and December 15.

The discussion piece is to be posted by 4 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).

To limit the spread of disease due to H1N1 influenza (or similar), everyone on campus must consider it prudent to stay home from work and class at the first sign of influenza symptoms (fever of 100 degrees F/37.8 degrees C or higher with cough or sore throat) until at least 24 hours after they have been completely fever-free (without fever-reducing medication). For most people, this takes three to five days. If I am in that situation I will communicate via email and the course website on Learn@UW. Please communicate by email or telephone if you have to miss classes or a deadline due to illness.

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; you should be ready to discuss readings indicated with an asterisk* in class. For those interested in an extra perspective, I have indicated where the books of Morus and Hunt are especially relevant.

Part I: Newton's Legacy and Enlightenment Science

1. Introduction and the Sites of Science (Sept. 6)

2. Newton's New Theory of Light (Sept. 8)

"The Introduction," and "An Accompt of the Improvement of Optick Glasses," *Philosophical Transactions* 1 (1665-1666): 1-3.

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.

Discussion: Introductions and Newton on Light

3. Force and a New Mechanical Philosophy (Sept. 13)

*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.

4. Newton's *Principia* (Sept. 15)

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

5. Enlightenment Science: Electricity on Display (Sept. 20)

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

Anthony Elliott and Charles Lemert, *The New Individualism: The Emotional Costs of Globalization*, rev. ed. (London and New York: Routledge, 2009), pp. 43-53.

6. Coulomb's Quantification and Volta's Current (Sept. 22)

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.

Discussion: Enlightenment Physics

7. Chemistry in the Enlightenment (Sept. 27)

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

8. Balancing Acts: The Chemical Revolution (Sept. 29)

*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.

Note Rosh Hashanah, Sept. 29-30

Discussion: Enlightenment Chemistry

9. Laplace and the Rise of Mathematical Physics (Oct. 4)

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

10. Challenging Laplace: Joseph Fourier's New Science of Heat (Oct. 6)

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: Romantic Transformations

11. Alexander von Humboldt and Geophysics, between Society and Nature: Mapping Space, Defining Freedom (Oct. 11)

*John Tresch, "Even the Tools Will Be Free: Humboldt's Romantic Technologies," in David Aubin, Charlotte Bigg and H. Otto Sibum, eds. *The Heavens on Earth: Observatories and Astronomy in Nineteenth Century Science and Culture* (Durham/London: Duke Univ. Press, 2010), pp. 253-84.

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

12. Romantic Science and New Concepts of Force (Oct. 13)

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

13. Basic Facts, Natural Facts, and Honor in Electrodynamics: Ampère and Faraday (*Oct. 18*)

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

14. On Making Facts and Machines (*Oct. 20*)

*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; Hunt, *Pursuing Power and Light*, pp. 68-79.]

Discussion: Cultures of Experiment in Faraday's London

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

15. On Energy and its Histories (*Oct. 25*)

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.

16. James Joule's Mechanical Value of Heat (*Oct. 27*)

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.

[See also Morus, *When Physics Became King*, pp. 71-86 and 123-143; Hunt, *Pursuing Power and Light*, pp. 4-35.]

Discussion: Joule's Manchester and the Isolation of Innovation

17. Progress and Dissipation (*Nov. 1*)

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

18. Thermodynamics (*Nov. 3*)

*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; Hunt, *Pursuing Power and Light*, pp. 35-45.]

Discussion: The Science of Thermodynamics

19. The *Treatises* and the New Natural Philosophy (Nov. 8)

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

20. Cables and Field Theory (Nov. 10)

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.

[See also Hunt, *Pursuing Power and Light*, pp. 79-93.]

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

Discussion: Electromagnetism and Empire

21. The Rise of the Teaching Laboratory (Nov. 15)

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.

22. Maxwell's Cavendish and Laboratory Metrologies (Nov. 17)

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; Hunt, *Pursuing Power and Light*, pp. 93-118.]

Discussion: The Laboratory Revolution

23. Science in the U.S. and Physics at U.W. (Nov. 22)

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

Thanksgiving

24. Light and Mechanics: Testing Relative Motion (Nov. 29)

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

*Edmund Russell, James Allison, Thomas Finger, John K. Brown, Brian Balogh, and W. Bernard Carlson, "The Nature of Power: Synthesizing the History of Technology and Environmental History," *Technology and Culture* 52 (2011), 246-59.

[See also Hunt, *Pursuing Power and Light*, pp. 142-148.]

Part 4: The New Physics

25. The Discoveries: Roentgen's X-rays (Dec. 1)

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

[See also Hunt, *Pursuing Power and Light*, pp. 148-159.]

Discussion: Physics in the U.S. and New Directions: Microphysics

26. The Discoveries: Radioactivity (Dec. 6)

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.

27. New Directions in Theory: Questioning the Foundations (Dec. 8)

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

Christa Jungnickel and Russell McCormack, *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).

Discussion: Physical World Views and the International Community

28. Black-Body Radiation and Planck's Theory (Dec. 13)

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.

[See also Hunt, *Pursuing Power and Light*, pp. 46-67, 159-162.]

29. On the Co-Creation of Classical and Modern Physics (Dec. 15)

*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.

T.C. Chamberlin, "A Group of Hypotheses Bearing on Climatic Changes," *The Journal of Geology* 5 (1897), 653-683 on pp. 653-657 and 680-683.

[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

Thursday December 22 Final Examination Due (9:25 P.M.)

Grading Criteria for Essays

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

- 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.

Note that **plagiarism** is grounds for automatic failure on the 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.