Reading Instructions and Questions
History 181B, Spring 2008
Modern Physics
Prof. Cathryn Carson

UNIT 1: CLASSICAL WORLD PICTURES

1/25 **Class 2:** Isaac Newton, selections from *Mathematical Principles of Natural Philosophy* (commonly called the *Principia*, 1686), trans. Andrew Motte and Florian Cajori (Berkeley: University of California Press, 1934), vii-viii (table of contents), 1-7, 12-14, 401-410, 543-547 (General Scholium, added 1713);

Newton, selections from *Opticks, or A Treatise on the Reflections, Refractions, Inflections & Colours of Light* (1704) (New York: Dover, 1952), 26-33, 186-191, 317-320, 338-341.

To a modern reader, what looks strange about the first part of the *Principia*? If it doesn't look like a work of physics, what does it look like instead? (Perhaps several things.)
What argument was Newton advancing in the *Principia*'s collection of phenomena? In the following propositions? How were the two arguments related?
What is going on in the General Scholium?
What did Newton find so interesting about the colors of light?
How did Newton's approach differ in the *Principia* and the *Opticks*?

Extra: If you've studied mechanics, you've seen a different version of Newton's three laws. Of course, people in the past often did things differently from us, and not because they're ignorant. What might have motivated Newton to write his laws as he did?
Extra: What is the connection between Newton's comments on absolute and relative space, on the one hand, and his arguments about planetary orbits, on the other?

1/28 **Class 3:** James Prescott Joule, "On the Mechanical Equivalent of Heat" (1849), in *The Scientific Papers of James Prescott Joule* (London: Dawsons of Pall Mall, 1887), 298-328.

Read pp. 298-306, skim the middle, read pp. 327-328 (beginning "The following table").

What is the point of the first 5 pages? (Why is Joule telling us this history?)
Describe the essence of the experiment he was performing.
What did Joule mean by "the mechanical equivalent of heat"? Why did he go to such efforts to ascertain it?
What would your high-school science teacher think of Joule's lab write-up?

Extra: What do you think is the point of the starred footnote on p. 328?

1/30 **Class 4:** Rudolf Clausius, selection on "The Second Law of Thermodynamics" (1850), in *A Source Book in Physics*, ed. William Francis Magie (Cambridge, MA: Harvard University Press, 1963), 228-233.

This will be easier to understand if you first read it before class, then reread it afterwards. For an animation of the process Clausius is describing, I will try to post a **diagram on the course website**, linked from the outline for this class.

Describe the physical setup that Clausius was discussing. (A schematic picture of a steam engine may help; see the animated Newcomen engine also linked on the course website.)
What process is described by Fig. 43? Note that the x-axis in Clapeyron's graphical representation is volume; the y-axis, pressure. "Mariotte's law" is what French and Germans called the law that English scientists called "Boyle's law."
Did Clausius himself do any experiments with this setup?
What conclusion did he draw from his discussion? What did he conclude about Carnot?

2/1 **Class 5:** Charles-Augustin Coulomb, "Law of Electric Force" (1785), in *A Source Book in Physics*, ed. William Francis Magie (Cambridge, MA: Harvard University Press, 1963), 408-417.

What was Coulomb's goal in these experiments? What had he determined by the end?
Describe the most important features of his apparatus and its operation.

Extra: What might make these experiments hard to carry out as Coulomb described them?

2/3 **Class 6:** James Clerk Maxwell, selection from "On Faraday's Lines of Force" (1855), in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890; New York: Dover, 1952), v. 1, 155-159;

Maxwell, letter to Thomson, 10 December 1861, in *Origins of Clerk Maxwell's Electric Ideas as Described in Familiar Letters to William Thomson*, ed. Sir Joseph Larmor (Cambridge: Cambridge University Press, 1937), 34-35;

Maxwell, selection from "On Physical Lines of Force" (1861), *Scientific Papers*, v. 1, 488-489.

What did Maxwell mean by a physical analogy? What were its advantages relative to purely mathematical formulas on the one hand, to physical theories on the other?
Why did he believe a physical analogy was appropriate at this stage of his science?
The essential physical analogy in the first paper likens Faraday's lines of force to the flow of an incompressible fluid. How did Maxwell flesh out the analogy?
What startling result does Maxwell obtain on p. 35 of his letter to Thomson?

Extra: This final intuition is explored further in the article that follows (of which you are reading only the end). Try mapping Maxwell's specifications on p. 34 of his letter onto Fig. 2 of his article.

AND start reading McCormmach, *Night Thoughts of a Classical Physicist*

2/6 **Class 7:** Pierre Duhem, selection from *The Aim and Structure of Physical Theory* (1906), trans. Philip P. Wiener (Princeton: Princeton University Press, 1982), 80-86.

What was Duhem objecting to?
What would he tell physicists to do instead?

Extra, if you know something about thermodynamics, philosophy, or history of science: What is Duhem known for in any of these fields?

2/8 **Class 8:** Ernst Mach, "The Economy of Science" (1883), in *The Science of Mechanics: A Critical and Historical Account of its Development*, trans. Thomas J. McCormmack, 3rd ed. (Chicago: Open Court, 1907), 481-494.

What did Mach say the world was made up of?
What did he mean by the economical nature of science?
In Mach's view of things, when would a scientist be satisfied that he had gone as far as possible in understanding nature?

2/11 **Class 9:** *Night Thoughts of a Classical Physicist*: See separate instructions on the course website.

2/13 **Class 10:** Martin J. Klein, "Mechanical Explanation at the End of the Nineteenth Century," *Centaurus* **17** (1972): 58-82.

This is a difficult piece. Don't get bogged down by the math or the monocycles; skip section 3 if you like. Read the essay for two things: a birds-eye review of much that we have covered so far, and a first introduction to statistical mechanics.

Who carried the torch of the mechanical world picture at the end of the nineteenth century?
What challenges did they face? Lay these out in a list or simple scheme.
Would you agree with Whitehead that this was "an age of successful scientific orthodoxy"?

2/15 **Class 11:** Paul Forman, John L. Heilbron, and Spencer Weart, selections from "Physics circa 1900: Personnel, Funding, and Productivity of the Academic Establishments," *Historical Studies in the Physical Sciences* 5 (1975): 1-185, Tables I and A.5.

Imagine a young American physicist ca. 1900 making plans for a grand tour: What countries are the world powers in academic physics? Who is the leader, and who is close behind?

Extra: Of the data provided in these tables, which are most significant?

UNIT 2: CHALLENGES

2/20 **Class 12:** W.C. Röntgen, "On a New Kind of Rays," *Nature* 53 (1896): 274-276.

Röntgen's new phenomenon is identified already in the first paragraph of this report. What is the point of the following paragraphs on the first page?
And in the rest of the paper? (What question was Röntgen trying to answer?)
What conclusion did Röntgen end up drawing about the nature of the rays?

AND

Marie Curie, "Radium and Radioactivity" (1904), http://www.aip.org/history/curie/article.htm.
"Marie Curie and the Science of Radioactivity," http://www.aip.org/history/curie/.

After the 1904 article, read through the chapters of the main exhibit (just use the "Next" links) through "The Radium Institute" (i.e., you can stop before "The next generation of Curies"). The side links are optional.

By what route did Curie end up working on radioactivity? Why did she pick up the topic? What did she expect to find?
What lab equipment and procedures were needed? What other sorts of infrastructure?
For what did she receive each of her Nobel Prizes?
Besides knowing more about Curie herself, what do you learn from the personal details?
And what from the information about her efforts to raise money and build institutes?

2/22 **Class 13:** J.J. Thomson, "Cathode Rays," *Philosophical Magazine* 44 (1897): 293-316.

Read pp. 293-297, skip pp. 298-307 if you like, pick up on p. 307 with the paragraph beginning "Before proceeding . . ." and read through p. 314, then skip the rest of you like.

What was the point of Thomson's first experiment (shown in Fig. 1)? Why was it necessary?
Work through Thomson's account of how the apparatus depicted in Fig. 2 functions. Then see what he used it to measure following the argument on pp. 307-308.
What were Thomson's central conclusions about the nature of the carriers on p. 310?
Thomson's discussion on pp. 311-314 connects the carriers to atoms and to matter. What strikes you as unexpected about his account?

Extra: If you skim the sections you don't have to read, what's going on in them? Where does it fit in the standard account of Thomson, discoverer of the electron?

2/25 **Class 14:** Cathryn Carson, "The Origins of the Quantum Theory," *Beam Line* (Stanford Linear Accelerator Center) 30:2 (2000): 6-19.

First assignment: Read through p. 13.

How did Planck come to be interested in blackbody radiation?
What did Planck originally think was the significance of the constant *h*?
What did Einstein suggest about radiation that went beyond Planck?

2/27 **Class 15:** ***Physical Review*** essay: See separate instructions on the course website.

2/29 **Class 16:** Albert Einstein, "On the Electrodynamics of Moving Bodies" (1905) in *Einstein's Miraculous Year: Five Papers That Changed the Face of Physics*, ed. John Stachel (Princeton: Princeton University Press, 1998), 123-160.

This is Einstein's relativity paper. Read what you can, minimally pp. 123-130. For the rest, if the equations don't mean much to you, read the parts where there aren't any. For an animation of the paper's opening gambit, see the **diagram on the course website**. It is linked from the outline for this class.

What is the point of Einstein's first two pages? That is, not just what is the familiar conclusion ("The introduction of a 'light ether' will prove to be superfluous"), but how did Einstein argue for it?
Why did he then move to a discussion of clocks and measuring rods?
How did he come back to electromagnetism?

3/3 **Class 17:** Werner Heisenberg, "The Theory of Relativity," in *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper & Row, 1958), 110-127.

First assignment: Read through p. 120. For an animation of the Michelson-Morley interferometer, see the **diagram on the course website**. It is linked from the outline for this class.

What did Heisenberg mean by a "principle of relativity" (p. 113)?
What did it have to do with the Michelson-Morley experiment? That is, what was the result of that experiment, and what did it have to do with a "principle of relativity"?
How does Heisenberg describe what was radical about what Einstein did?
How did the result change the meaning of the term "simultaneity"?

3/5 **Class 18:** Albert Einstein, selections from "Autobiographical Notes," in *Albert Einstein: Philosopher-Scientist*, vol. 1, ed. Paul Arthur Schilpp, (New York: Harper Torchbooks, 1949), 2-53.

What did Einstein mean by his “epistemological credo” (pp. 11-13)?
What did Einstein take from late nineteenth-century debates about the foundation of physics on mechanics? What did he take from Mach? What from Maxwellian electromagnetism?

Extra: Who would have disagreed with Einstein's epistemological credo? (Or with whom was Einstein disagreeing?)

3/7 **Class 19:** Werner Heisenberg, “The Theory of Relativity,” in *Physics and Philosophy: The Revolution in Modern Science* (New York: Harper & Row, 1958), 110-127.

Second assignment: Read pp. 121-127.

Where did general relativity go beyond Einstein’s first theory (special relativity)?
What did Heisenberg see as the philosophical consequences of relativity?

3/10 **MIDTERM EXAM**

UNIT 3: THE QUANTUM MECHANICAL ERA

3/12 **Class 20:** No reading assignment.

3/14 **Class 21:** Cathryn Carson, "The Origins of the Quantum Theory," *Beam Line* (Stanford Linear Accelerator Center) 30:2 (2000): 6-19.

Second assignment: Read pp. 13-19.

Why was it a radical step for Bohr to apply the quantum to atomic structure?
What was the procedure of "quantization"? What was the correspondence principle?
What two routes in quantum theory led into the final formulation of a quantum mechanics?

Extra: How is the story of Bohr's atom told here different from the conventional one from high-school chemistry or physics textbooks?

3/17 **Class 22:** Werner Heisenberg, "Quantum Theory and its Interpretation," in *Niels Bohr: His Life and Work as Seen by His Friends*, ed. S. Rozental (Amsterdam: North-Holland, 1967), 94-108.

How did Heisenberg compare Sommerfeld's, Bohr's, and his own styles of doing physics?
How did he describe the essence of quantum mechanics?
What was at stake in the Copenhagen discussions of Schrödinger's theory?

FIRST NOBEL OPTION (Extra Credit) DUE. See the course website.

3/19 **Class 23:** Werner Heisenberg, "The Physical Content of Quantum Kinematics and Mechanics" (1927), in *Quantum Theory and Measurement*, ed. John Archibald Wheeler and Wojciech Hubert Zurek (Princeton: Princeton University Press, 1983), 62-84.

This is Heisenberg's "uncertainty paper." Read what you can, minimally pp. 62-68 and pp. 82-84. For an animation of the thought experiment with the gamma-ray microscope, see the **diagram on the course website**. It is linked from the outline for this class.

Why did Heisenberg argue that the concepts of position and velocity needed redefinition?
Outline the gamma-ray microscope argument (pp. 64-65). What was it meant to show?
What large conclusions did Heisenberg draw in the paper's final paragraphs?

Extra: What was going on in the "Addition in proof"?

3/21 **Class 24:** Albert Einstein, selections from "Autobiographical Notes," in *Albert Einstein: Philosopher-Scientist*, vol. 1, ed. Paul Arthur Schilpp, (New York: Harper Torchbooks, 1949), 80-87.

What is the essential difference between conceptions A and B? Which one was Einstein's, and which was the Copenhagen Interpretation?
How does the argument with the two separated systems work?
Which conception (A or B) did Einstein think was undermined by that argument?
Einstein did not object to quantum mechanical statistics per se, but to its claim to represent a complete description. What work did the notion of "reality" do in his argument?

3/31 **Class 25:** George Gamow, "The Exclusion Principle," *Scientific American* 201:1 (July 1959): 74-86.

This is a semi-historical account of Pauli's exclusion principle, written by a colleague after the fact. Read it as a source of information *and* as a piece of historical writing.

According to Gamow, what was the physical puzzle that Pauli was trying to solve?
Why was Pauli's proposal an "answer" to this puzzle? (If the exclusion principle is a postulate, why is a postulate an answer?)
Depending on how you count, Gamow gives three or four different versions of the Pauli principle. Outline them. Then what makes them all the same principle?

AND

Wolfgang Pauli, "Exclusion Principle and Quantum Mechanics" (1946), in *Nobel Lectures: Physics, 1942-1962* (Amsterdam: Elsevier, 1964), 27-42.

Focus on pp. 27-32. You can read more if you're interested, but it's not required.

When Pauli came up with his "two-valuedness not describable classically," what problems were concerning him?
At the start, could Pauli give a deep meaning to this "two-valuedness" or a logical reason for the exclusion principle? What did it take before they were better understood?
How does Pauli's account of his efforts differ from Gamow's? If they disagree, which should you trust more? Why?

4/2 **Class 26:** Spencer R. Weart, "The Birth of the Solid-State Physics Community," *Physics Today* 41:7 (July 1988): 38-45.

What does Weart mean by the "unification" of the field of solid-state physics?
In enabling unification, how does he describe the relative importance of intellectual and social dynamics? Could unification have taken place without the one or the other?
If the field had not congealed as it did, what might have happened instead? What alternative outcomes can you imagine?

4/4 **Class 27:** Paul A.M. Dirac, "Theory of Electrons and Positrons" (1933), in *Nobel Lectures: Physics, 1922-1941* (Amsterdam: Elsevier, 1965), 320-325.

After quantum mechanics, what did Dirac think was the next step for quantum theory?
How did he connect the theory of elementary particles to relativity?
How did he interpret the negative-energy solutions that came out of his equations? What were the positrons to which he connected them? What did he mean by a hole?
How seriously would you have been inclined to take this theory if positrons had not yet been found experimentally?

Extra: Look at the steps by which Dirac set up his wave equation (3).

4/7 **Class 28:** Freeman J. Dyson, "Field Theory," *Scientific American* 188:4 (April 1953): 57-65.

This article starts off in 1953. But it quickly moves backwards in time, to the era when quantum field theory was developed. Focus on the latter.

How are quantum fields different from classical fields?
What "miracle" do quantum fields bring about in our understanding of physical reality?
What work does history do in this piece? That is, why did Dyson trace things back to Maxwell or Einstein? What did he gain from doing so?
What do you make of his physical analogies or mechanical models? Do they assist with understanding, or do they mislead? Why was Dyson ambivalent about using them? (What would Maxwell say about his approach?)

AND start reading Frayn, *Copenhagen*.

4/9 **Class 29:** "Breaking Through: A Century of Physics at Berkeley," http://bancroft.berkeley.edu/Exhibits/physics/.

Read the first two parts, "The Origins of Physics and Berkeley, 1868-1900 " and "Learning the 'Language of the Atom,' 1900-1930."

What were the job expectations for early physics faculty at Berkeley? What conflicting pressures were they under?

Does Berkeley seem characteristic of the state of American physics that you saw in the early years of the *Physical Review*?
If Berkeley was beginning to make a name for itself by the 1920s, what was it known for?

4/11 **Class 30:** "Lawrence and his Laboratory: A Historian's View of the Lawrence Years," http://www.lbl.gov/Science-Articles/Research-Review/Magazine/1981/index.html.

First assignment: Read ch. 1-2 and episode 1.

What was the purpose of the nuclear physics machines built in the 1920s? That is, what research did people want to do with them?
What in Lawrence's background and training prepared him for this work? How much nuclear physics did he need to know?
What tasks occupied Lawrence's growing lab during the 1930s?
What physical discoveries did the lab make? What did it miss?
Where did the support come from? Why should this matter?
What made Lawrence such a leader in his field?

AND

"Oppenheimer: A Life," print version of http://ohst.berkeley.edu/Oppenheimer/exhibit.

First assignment: Read pp. 1-14 (ch. 1-2 online).

In what ways was Oppenheimer's career typical for an American physicist of his day? In what ways atypical? Who was more representative of the discipline: Oppenheimer or Lawrence?
What are the ingredients necessary to create a "school" of physics?
What was Oppenheimer's route into nuclear physics?

SECOND NOBEL OPTION (Extra Credit) DUE. See the course website.

4/14 **Class 31:** Otto Robert Frisch, "The Interest Is Focussing on the Atomic Nucleus," in *Niels Bohr: His Life and Work as Seen by His Friends*, ed. S. Rozental (Amsterdam: North-Holland, 1967), 137-148;

O. Hahn and F. Strassmann, "Concerning the Existence of Alkaline Earth Metals Resulting from Neutron Irradiation of Uranium" (1939), in *The Discovery of Nuclear Fission*, ed. Hans G. Graetzer and David L. Anderson (New York: Arno Press, 1981), 44-47;

Lise Meitner and O.R. Frisch, "Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction," *Nature* 143 (1939): 239-240.

What was the compound nucleus (or liquid drop) model?
Why was it hard to make sense of Hahn and Strassmann's results?
What was it like to be an experimental nuclear physicist in the 1930s?

4/16 **Class 32:** Selections from *Physics and National Socialism: An Anthology of Primary Sources*, ed. Klaus Hentschel and Ann M. Hentschel (Basel: Birkhäuser, 1996), 1-5, 18-21, 119-127, 152-157.

What kinds of arguments did the opponents of relativity theory advance?
What did the advocates of "German physics" (or "Aryan" or "Nordic physics") want?
How did Heisenberg respond? Were his actions and strategies justified?

4/18 **Class 33:** *Copenhagen*: See separate instructions on the course website.

UNIT 4: WORLD WAR II AND BEYOND

4/21 **Class 34:** "Lawrence and his Laboratory: A Historian's View of the Lawrence Years," http://www.lbl.gov/Science-Articles/Research-Review/Magazine/1981/index.html.

Second assignment: Read ch. 3 and episode 2.

List the different scientific contributions Lawrence's lab made to the war effort.
Then, along with scientific knowledge, what else did the lab provide?
In what ways did the war change the lab's atmosphere and operation?
Extra: What would have happened to the Manhattan Project without Lawrence's lab? What would have happened to Lawrence's lab without the Manhattan Project?

AND

"Oppenheimer: A Life," print version of http://ohst.berkeley.edu/Oppenheimer/exhibit.

Second assignment: Read pp. 15-24 (ch. 3 online).

How did Oppenheimer's skills as a laboratory leader relate to his skills as the head of a school of theoretical physics?
What were his views on how the bomb should be used? Do you find them surprising?
How did the University of California end up managing Los Alamos?

4/23 **Class 35:** Victor Weisskopf, "Working on the Bomb," in *The Joy of Insight: Passions of a Physicist* (New York: Basic Books, 1991), 122-155;

Andrei Sakharov, "The Tamm Group," in *Memoirs*, trans. Richard Lourie (New York: Alfred A. Knopf, 1990), 90-105.

How did Weisskopf and Sakharov describe the atmosphere? Their own motivations?
How did the Anglo-American and Soviet projects differ?

4/25 **Class 36:** "Lawrence and his Laboratory: A Historian's View of the Lawrence Years," http://www.lbl.gov/Science-Articles/Research-Review/Magazine/1981/index.html;

Arthur Roberts, "Take Away Your Billion Dollars," *Physics Today* 1:7 (1948): 17-21.

Third assignment: Read ch. 4 and episode 3.

How did the Atomic Energy Commission end up responsible for Lawrence's lab?
What were the scientific payoffs of the new research program?
What new kinds of knowledge and skill were required?
What might the tradeoffs have been?

AND

"Oppenheimer: A Life," print version of http://ohst.berkeley.edu/Oppenheimer/exhibit.

Third assignment: Read pp. 25-37 (ch. 4-5 online).

What factors fed into Oppenheimer's downfall? Was the outcome inevitable?
How could Lawrence and Oppenheimer have such different political trajectories? Was this the best of times or the worst of times?

4/28 **Class 37:** Banesh Hoffmann, Postscript, *The Strange Story of the Quantum*, 2nd ed. (New York: Dover, 1959), 243-263.

First assignment: Read pp. 243-254.

In this situation of crisis in quantum field theory, what were the relative roles of experiment and theory in showing the way out? How did the Lamb shift actually help?
"It is cheating, of course. But inspired cheating." If renormalization works (i.e., it gets the right numbers to match experimental data), why should a physicist want anything more?
Where else have we seen the strategy of avoiding the difficulties instead of dealing with them? Did past physicists consider it legitimate or not?

4/30 **Class 38:** Banesh Hoffmann, Postscript, *The Strange Story of the Quantum*, 2nd ed. (New York: Dover, 1959), 243-263.

Second assignment: Read pp. 254-263.

Put Feynman's accomplishment in your own words.
Hoffmann suggests that Feynman's visual representations were key to making new sense of quantum field theory. What was it about his graphs (or diagrams) that made them more helpful than equations alone?
How do Feynman's diagrams compare with previous visual representations we have seen?

AND

Freeman J. Dyson, "Tomonaga, Schwinger, and Feynman Awarded Nobel Prize for Physics," *Science* 150 (1965): 588-589.

What made Dyson consider QED so successful?
How were theory and experiment related in this episode?
Who were the radicals over whom Dyson's conservatives triumphed?

Extra: If the problems discussed here are so complicated and messy, and three different physicists tackled it in very different ways, how could people see that they were ultimately doing the same thing?

5/2 **Class 39: *Bulletin of the Atomic Scientists*** essay: See separate instructions on the course website.

5/5 **Class 40:** Steven Weinberg, "A Unified Physics by 2050?", *Scientific American*, special edition on *The Edge of Physics* (Spring 2003): 4-11.

When Weinberg writes about unification, what does he mean?
What sorts of unification have been accomplished in the Standard Model, and what not yet?
Does Weinberg have confidence that full unification will someday be realized? Why or why not? (How does he argue?)
How is the era of physics that Weinberg sees ahead different from, say, Maxwell's era?
Where does he think the exciting physics of the future lies, in experiment or in theory?
What work does history do in this piece?

5/7 **Class 41:** George Gamow, "Galaxies in Flight," in *Scientific American Reader* (New York: Simon and Schuster, 1953), 5-12.

What branches of physics were needed to make contact with astronomy?
What knowledge or skills beyond physics were needed to address these problems?
Why should the findings described here have been surprising?

5/9 **Class 42:** Richard D. Mattuck, selections from *A Guide to Feynman Diagrams in the Many-Body Problem*, 2nd ed. (New York: Dover, 1976), 1-24.

The diagrams may look complicated, but the ideas are plainer than it may seem.

What do the fictitious bodies (section 0.1) do? What is a quasi particle (section 0.2)?
Then what is a collective excitation (section 0.2)?
What is the basic strategy involved in using Feynman diagrams? Looking especially at section 1.2, put it in words. What are the propagators?
These techniques remind us of renormalized QED and come out of elementary particle physics. But at the bottom of p. 1 Mattuck writes that the many-body problem is not limited to any one branch of physics. What is his point?

Extra: Does the strategy described here remind you of any problem-solving approaches from ordinary life?

AND

P.W. Anderson, "More is Different," *Science* 177 (1972): 393-396.

What did Anderson mean by the reductionist hypothesis? The constructionist hypothesis? By analysis and synthesis?
What did he mean by a "shift from quantitative to qualitative differentiation"? By "more is different"? What did this have to do with complexity and many-body problems?
What did he intend his argument about broken symmetries to show? (If you can't follow the details, focus on the parts of the argument that don't rely so heavily on them.)

Extra: Beyond pure scientific ideas, what else in the atmosphere of physics in the early 1970s do you think Anderson was responding to?

THIRD (AND LAST!) NOBEL (Extra Credit) OPTION DUE. See the course website.

5/12 **Class 43:** J.S. Bell, "Six Possible Worlds of Quantum Mechanics," in *Speakable and Unspeakable in Quantum Mechanics: Collected Papers on Quantum Philosophy* (Cambridge: Cambridge University Press, 1987), 181-195.

Bell's first few pages should be familiar; don't spend much time on them. What is unfamiliar about what follows?

What alternatives did Bell offer to the Copenhagen Interpretation?
Which one do you think he found most appealing?

Extra: On what basis could one chose among these possible worlds? Is this still physics?

AND

J.L. Heilbron, "An Historian's Interest in Particle Physics," in *Pions to Quarks: Particle Physics in the 1950s*, ed. Laurie M. Brown, Max Dresden, and Lillian Hoddeson (Cambridge: Cambridge University Press, 1989), 47-54.

Who is Heilbron addressing, and what views of history does he anticipate they hold?
What kind of history is he arguing for? How does he justify this?
Does his account of the reasons for building the Bevatron (Ernest Lawrence's big postwar particle accelerator) tell us something essential about particle physics in the 1950s, or just something contingent, time-bound, and ephemeral?
Should history of physics aim to become more like general history? Or is there something fundamentally different about it?
What do you make of his analogy between history and physics?