HISTORY 107
History of the Physical Sciences

Revised COVID19 Online Version – 1.20.2021

***PLEASE NOTE**: This is a **traditional lecture and discussion course** that is being implemented this semester as an online course, per Chancellor White's COVID-19 mitigation order. As a lecture and discussion course, **attendance is mandatory**. This is a **synchronous** online course, meaning **you must be 'virtually present' at the scheduled meeting times, just like a traditional class**. Careful attention to the readings and class participation will be crucial for a lively course.*

Michael Epperson	**Spring 2021**
Email: epperson@csus.edu	**T, TH 9:00 - 10:15 am** **via Canvas / Zoom**
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Phone: 916-400-9870	**Office Hours: T, TH 12:00 - 1:00 pm** **via Zoom (886-379-8303)**

Description

Study of the development of the major physical laws currently used in describing our physical world. Some considerations of the influences of these developments on other areas of knowledge and on society in general. This course satisfies **GE Area B5**. Cross Listed: PHSC 107 (only one may be counted for credit).

In more detail:

In recent decades, the physical sciences and the technologies borne of them have become so highly formalized and proprietary that it is often the case that even professional scientists have little understanding of fundamental scientific theories beyond the scope of their own specialties. Thus, as our worldview becomes more and more centered upon science and technology, the average person is ironically expected to understand less and less about that worldview. One might therefore anticipate that as science continues to evolve, our engagement of it will likely steadily drift more and more toward passive, uncritical inheritance rather than active participation. But the history of the evolution of our current scientific worldview reveals a very different story—one where it is not only the science that drives the worldview, but also one in which the worldview drives the science.

In this course, we will explore this thesis by studying the historical evolution of the intuitive (i.e., in the Greek sense of careful *koinos nous* or 'common sense') conceptual foundations of modern physics, including the special and general theories of relativity and the latest interpretations of quantum mechanics. We will trace this evolution from its origins in ancient natural philosophy, through the medieval and early modern periods and the Enlightenment, up to the present day.

Within the discipline of history, this course falls within the framework of the **history of ideas**--a field of research in history that deals with the expression, preservation, and evolution of ideas. The history of ideas is a central component of the discipline of **intellectual history**. Intellectual history refers to the history of ideas and thinkers, and, as practiced by historians, includes the history of philosophy and the history of science.

Course Outcomes: Students will achieve • an understanding of the history of science and technology and the evolution of the conceptual foundations of modern science from its early roots in ancient Greek philosophy; • an understanding of the most important sources for the study of the history of the physical sciences; • an understanding of foundational scientific questions that remain unsettled today, the historical roots of these questions, and the historical evolution of scientific thought aimed at their answer; • the ability to understand the ways in which history has informed, and continues to inform, the evolution of scientific progress from the ancient period to the present day; • the ability to apply historical knowledge of the origins and evolution of modern science, gained via the above 4 areas of understanding, to a critical evaluation of contemporary scientific claims; • the ability to critically evaluate and employ literary and material evidence in studying the history of science and its evolution from Greek philosophy of nature and mathematics.

GE Area B (B5) Outcomes: This course will • Develop an understanding of the principles underlying and interrelating natural phenomena including the foundations of our knowledge of living systems. • Introduce students to one or more of the disciplines whose primary purpose is to acquire knowledge of the physical universe rather than merely to apply existing knowledge. • Develop an appreciation of the methodologies of science, the requisite features of scientific endeavors, and the limitations of scientific inquiry. Students will be able to: • Demonstrate a knowledge and understanding of natural phenomena.• Apply the methodologies of science when approaching a scientific problem. • Explain the limitations of scientific inquiry.

Course Requirements

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For this special, synchronous online version of the course, you will need the following:

- Internet connection (DSL, LAN, or cable connection desirable)
- Access to Canvas

Canvas:

This course will be delivered entirely online through the course management system *Canvas*. To access this course on Canvas you will need access to the Internet and a supported Web browser (Chrome, Firefox, Safari). To ensure that you are using a supported browser and have required plug-ins, please visit the "Which browsers does Canvas support (Links to an external site.)" website.

You will use your Saclink account to login to the course from your My Sac State (Links to an external site.) account and click on the Canvas button or login directly through the Canvas Login Page.

If you need technical assistance at any time during the course **or to report a problem with Canvas** you can:

- Submit a Ticket (Links to an external site.)to Report a Problem to the Information Resources and Technology Support Team
- Call the Canvas Support line at Sac State: M-F 8a.m. – 5p.m.
  (916) 278-2450.
- Schedule a Consultation (Links to an external site.)to get assistance with Canvas and other Academic technologies
- Visit the Canvas Instructor Video Guides (Links to an external site.)
- Visit the Canvas Student Video Guides (Links to an external site.)
- Visit the Canvas Student Web Tutorials (Links to an external site.)

Examinations and Papers:

There will be two examinations--one take-home mid-term and one final. There will be one 6-8 page paper. All due dates are given in the reading and lecture schedule below. Late submissions are not accepted. If you are ill with symptomatic COVID19, or are experiencing some similar emergency, please contact me.

Attendance*:*

It is impossible to succeed in this course if you miss the lectures. To encourage attendance, students are permitted only 2 unexcused absences for the semester. Class participation is weighted at 10% of your final grade. 3 or more absences results in a 0%. The only exception to this rule is if you are severely ill (e.g., diagnosed with symptomatic COVID19) or are experiencing some similar long term emergency.

Note: With the exceptions above, anyone who misses 2 lectures in the first 2 weeks of class will be administratively dropped to make room for students who are attempting to add.

If you are sick, stay home. If you are experiencing any COVID- like symptoms (fever, cough, sore throat, muscle aches, loss of smell or taste, nausea, diarrhea, or headache) or have had exposure to someone who has tested positive for COVID contact Student Health & Counseling Services (SHCS) at 916-278-6461 to receive guidance and/or medical care. You are asked to report any possible COVID related illnesses/exposures to SHCS via this link COVID-19 Illness/Exposure Report Form. Expect a call from SHCS within 24 hours. The CDC provides a good source of information regarding COVID-19 and a way to self-check symptoms: https://www.cdc.gov/coronavirus/2019-ncov/index.html. (Links to an external site.)

Powerpoint Presentations and Pre-outlined Lectures:

I do not use these in my courses (other than for the occasional diagram, table, graph, or some other image of this kind.) The ability to listen attentively to a lecture or discussion, follow its structure, identify its key points, and take proper notes, is crucial. If this is done for you via Powerpoint slides, or lecture outlines (whether pre-distributed or written on the chalkboard), you are denied the opportunity to exercise and strengthen this ability, or develop it in the first place if

you haven't already. It is not difficult, but requires effort. Whatever your intended profession, this is an ability that you will need, and one that many employers lament is deficient or even non-existent in recent college graduates.

For other arguments against Powerpoint-based lectures, including scientific studies demonstrating their hazards, see this article by Edward Tufte, Professor Emeritus of Political Science, Computer Science and Statistics, and Graphic Design at Yale: https://www.wired.com/2003/09/ppt2/ (Links to an external site.). See also this article on the work of Dr. John Sweller, University of New South Wales:

www.smh.com.au/news/technology/powerpoint-presentations-a-disaster/2007/04/03/1175366240499.html (Links to an external site.).

Finally, see the following paper by R. Mayer, J. Heiser, and S. Lonn, "Cognitive Constraints on Multimedia Learning: When Presenting More Material Results in Less Understanding." *Journal of Educational Psychology*. Vol. 93:1 (2001): 187-198 (Links to an external site.).

Texts and Materials:

- Edward Grant. *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century*. Cambridge: Cambridge University Press, 2007 (Text designated as '**HNP**' in reading schedule.)

  Average cost new: $22, used $15 – Free ebook version available at CSUS Library

- Thomas S. Kuhn, *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press, 1970, 2nd ed., 1970, 3rd ed., 1996, or 4th ed., 2012 (Text designated as '**SSR**' in the reading schedule.)

  Average cost new: $9, used $5

- Albert Einstein and Leopold Infeld. *The Evolution of Physics: From Early Concepts to Relativity and Quanta*. New York: Simon and Schuster, 1966 or Touchstone, 1967 (Text designated as '**EP**' in the reading schedule.)

  Average cost new: $9, used $1.50

- Readings downloaded from course website / Canvas (Designated as '**D**' in reading schedule.)

Grading

Class Participation:	10%	4 or more absences results in 0%
Weekly Reading Quizzes:	10%	Due prior to Class Meeting 1 each week
Midterm Exam:	25%	Due 10/19 by 5 pm
Essay:	25%	Due 11/18 by 5 pm
Final Exam:	30%	Due 12/17 by 5 pm

A-level work: All students begin this course with an A. In order to maintain it, all written work (paper, mid-term, and final exams) must exhibit complete, well-argued responses to the questions asked. This requires reference to the

readings and lectures. For this reason, on-time attendance of all lectures and completion of all scheduled readings are requirements for success in this course.

A	93-100%	Excellent work
A-	90-92%	Nearly excellent work
B+	87-89%	Very good work
B	83-86%	Good work
B-	80-82%	Mostly good work
C+	77-79%	Above average work
C	73-76%	Average work
C-	70-72%	Mostly average work
D+	67-69%	Below average work
D	60-66%	Poor work
F	0-59%	Failing Work

Academic Standards: All sources in papers must be cited and given appropriate credit. The author of any information from the Internet must be given credit; using such information without indicating the source constitutes plagiarism, as it would with print publications. Students are allowed to discuss lectures and even assignments with each other, but they must do their own work. Students are required to read the University policy on academic honesty, which can be found here:

https://www.csus.edu/umanual/student/stu-100.htm (Links to an external site.)

Students with Disabilities: If you have a documented disability and require accommodation or assistance with assignments, tests, attendance, note taking, etc., please see the instructor during the first week of the semester so that appropriate arrangements can be made to ensure your full participation in class. Also, you are encouraged to contact the Services for Students with Disabilities (Lassen Hall) for additional information regarding services that might be available to you.

Important Note: This syllabus, along with course assignments and due dates, are subject to change. It is the student's responsibility to check Canvas for corrections or updates to the syllabus. Any changes will be clearly noted in course announcement or through Canvas email.

Reading and Lecture Schedule

Week 1: 1/26, 28

Introduction

- The role of history in the evolution of science, and the study of the ways in which scientific theories are at once *conditioned by* and *conditioning of* the conventional worldviews from which the theories derive. Likewise, scientific theories are at once conditioned by and conditioning of the fundamental presuppositions and first principles from which these conventional worldviews derive.
- The ways in which scientific 'paradigms' mediate this reciprocal conditioning.

Readings:

- For Meeting 1: Kuhn [**SSR**] Chapters 1-2 (pp. 1-22)
- For Meeting 2: Kuhn [**SSR**] Chapters 3-5 (pp. 23-51)

Week 2: 2/2, 4

Why studying history and philosophy of science is especially important today

- The increasing centrality of science and technology in society, and the ways in which popular disseminations of science often mask underlying tensions (and sometimes fundamental incompatibilities) between competing paradigms. Examples include the Standard Model of particle physics compared to the Standard Model of cosmology, the related incompatibility of quantum mechanics and the general theory of relativity, etc.
- A closer look at the latter as a case study of clashing paradigms: The physics of the very large vs. the physics of the very small, the incompatible conceptual presuppositions of each, and the popular portrayal of each as exhibiting the fundamental character of the natural world, despite their incompatibility.
- The ways in which increasingly specialized and increasingly abstract conceptual formalisms give popular disseminations of modern science the character of truths revealed via authority, rather than truths that can be reasoned by the common person. In what ways is this an historical regression from the Enlightenment theme of autonomy via reason back to the medieval theme of heteronomy via authoritative revelation?

Readings:

- David Albert. "On the Origin of Everything" - Review of *A Universe from Nothing* by Lawrence Krauss." *New York Times Sunday Book Review* (23 March 2012) [D] (Links to an external site.)
- Ross Anderson. "Has Physics Made Philosophy and Religion Obsolete?" Interview of Lawrence Krauss. The Atlantic Monthly (23 April 2012) [D] (Links to an external site.)

Week 3: 2/9, 11

The Beginnings of Western Science

- The historical, philosophical, and practical evolution of modern science from its roots in ancient natural philosophy.
- Preliterate origins.
- Ancient Egypt and Mesopotamia.
- Pre-Socratic Hellenic natural philosophy and medicine.

Readings: [**HNP**] 1-21

Week 4: 2/16, 18

Plato

- His attempt to relate seemingly incommensurable cosmological paradigms—those grounded in nature's necessary features (viz. logical and mathematical conceptual relations) with those grounded in nature's contingent features (viz. causal physical relations). As we will see throughout the remainder of this course, in many ways, the history of science is fundamentally a history of attempts to discover the true nature of the relationship between logic and causality (cf. the Krauss readings from Week 2 re: the relationship between mathematical and physical structure in modern cosmology.)
- His critique of the reductive-deductive analysis of wholes into parts —i.e., the presumption that a fundamental understanding of the whole derives from the fundamental understanding of the most fundamental part.

Readings:

- [**HNP**] 21-26
- Plato, excerpts from *Theaetetus* [**D**] (Links to an external site.)
- Plato, excerpt from *The Republic*, Book VI [**D**] (Links to an external site.)

Week 5: 2/23, 25

Aristotle

- His proposed bridging of the chasm that Plato believed separated the order of causal relation (what appears to be) from the order of logical implication (what is reasoned to be).
- An overview of Aristotle's life and works, and the historical preservation of his writings.
- An overview of Aristotelian natural philosophy and cosmology

Readings:

- [**HNP**] 27-51
- Aristotle, excerpt from "On the Heavens" [D] (Links to an external site.)

Week 6: 3/2 , 4 ***Natural Philosophy in the Middle Ages***

- The medieval university
- The impact of Aristotelian natural philosophy in the early 13th century; William of Auvergne (ca. 1180-1249)
- University lectures on natural philosophy
- The classification of the sciences and the subject of natural philosophy
- The occult sciences and natural philosophy

Readings: [**HNP**] 143-178

Midterm exam: Take-home exam prompt distributed in class on **3/2**. It is due by 5 pm on **3/15**. It will cover all material through Week 5.

Week 7: 3/9, 11 ***The Transformation of Medieval Natural Philosophy from the Early Modern Period to the End of the Nineteenth Century***

- The fate of medieval natural philosophy during the sixteenth and seventeenth centuries.
- The new natural philosophy of the seventeenth century: The Transformation of Natural Philosophy; introduction to the ideas of Copernicus, Tycho, Kepler, Galileo; Newton; experiments; the dissemination of scientific knowledge; the forms of literature in the new natural philosophy; scientific societies and journals; natural magic; natural philosophy and religion.

Readings:

- [**HNP**] 274-302
- Bacon, excerpts from the *New Organon* [**D**] (Links to an external site.)

Week 8: 3/16, 18 ***The Transformation of Medieval Natural Philosophy from the Early Modern Period to the End of the Nineteenth Century*** **(continued)**

- The relations between natural philosophy and science in the seventeenth and nineteenth centuries; the medieval background; Francis Bacon: Natural philosophy is "The Great Mother of the Sciences"
- The revolution in natural philosophy from the middle ages to the nineteenth century
- Isaac Newton
- Natural philosophy as a synonym for physics and science in the 19th century
- The continuity of history and the problem of names and terminology
- Thesis: "Although the exact sciences and natural philosophy were largely distinct from one another in the late Middle Ages, the horizons of each began to expand as they gradually came together. The fusion manifested itself bilaterally: natural philosophy influenced the exact sciences to seek the physical causes of relevant phenomena, and thereby broaden the scope of their activities; as this occurred, natural philosophy was inevitably mathematized and its scope expanded. By this process, natural philosophy was the basic instrument in the development of our many modern sciences." (Grant, 319)

Readings:

- [**HNP**] 303-322
- Galileo, "Corpuscularianism" from *The Assayer* (1623) [**D**] (Links to an external site.)
- Boyle, "Of the Excellency and Grounds of the Corpuscular or Mechanical Philosophy" (1674) [**D**] (Links to an external site.)

Midterm exam: Due by 5 pm on **3/15**.

3/22 - 3/28 ***SPRING BREAK***

Week 9: 3/30, 4/1 ***From Scientific Revolution to Scientific World View***

- Thesis: Empirical discoveries are inspired by phenomena deemed 'anomalous' by the current conventional conceptual framework. When conventional scientific theories are incapable of accommodating these new empirical discoveries, new scientific theories emerge. When these new theories cannot be coherently bridged to existing theories (and the conventional worldview informed by these theories), a scientific revolution can ensue—often bringing with it an eventual change in the conventional worldview.
- Throughout the remainder of this course, we will investigate this thesis by examining the evolution of today's physical sciences (and today's 'scientific' worldview) from this point in history forward.

Readings: Kuhn [**SSR**], Chapters 6-10 (pp. 52-135)

Week 10: 4/6, 8 ***The Rise of the Mechanical View***

- Galileo and Newton
- The notion of philosophical generalizations founded on empirical results; e.g., "in mechanics the future path of a moving body can be predicted and its past disclosed if its present condition and the forces acting upon it are known. Thus, for example, the future paths of all planets can be foreseen. The active forces are Newton's gravitational forces depending on the distance alone." (Einstein & Infeld, p. 67)
- "The great results of classical mechanics suggest that the mechanical view can be consistently applied to all branches of physics, that all phenomena can be explained by the action of forces representing either attraction or repulsion, depending only upon distance and acting between unchangeable particles." (Einstein & Infeld, p. 67)
- The kinetic theory of matter exemplifies the above in its explication of the phenomenon of heat, ultimately leading to a new understandings of the structure of matter.

Readings: [**EP**] 3-65

Essay: The topic of the 5 page essay will be assigned in class on **4/6**. It is by 5 pm on **4/26.**

Week 11: 4/13, 15 ***The Decline of the Mechanical View***

- How electricity and magnetism undermine the mechanistic-materialistic paradigm.
- Attempts to characterize light as a corpuscular substance; Newton and the riddle of color; Huygens and the wave model of light.
- Ether and the mechanical view; "Waves spreading in a medium consisting of particles, with mechanical forces acting between them, are certainly a mechanical concept. But what is the medium through which light spreads and what are its mechanical properties? There is no hope of reducing the optical phenomena to the mechanical ones before this question is answered. But the difficulties in solving this problem are so great that we have to give it up and thus give up the mechanical views as well." (Einstein & Infeld, p. 126)

Readings: [**EP**] 69-122

Week 12: 4/20, 22 ***The Field – A Paradigm Shift in Physics***

- A new concept appears in physics, the most important invention since Newton's time: the field.
- "It needed great scientific imagination to realize that it is not the charges nor the particles but the field in the space between the charges and the particles which is essential for the description of physical phenomena." (Einstein & Infeld)

Readings: [**EP**] 125-184

Week 13: 4/27, 29 ***Relativity – The Paradigm Shifts Further***

- The theory of relativity arises from the field problems explored last week. The contradictions and inconsistencies of the old theories force us to ascribe new properties to the time-space continuum, to the scene of all events in our physical world.
- The special theory of relativity: Based on two assumptions: 1. physical laws are the same in all co-ordinate systems moving uniformly, relative to each other; 2. the velocity of light always has the same value. From these assumptions, the theory allows for two key deductions: 1. changes in the lengths and rhythms of moving rods and clocks—changes that defy classical convention and that have been empirically confirmed; 2. the combination of the conservation laws of mass and energy, such that mass is now understood as energy, and energy is understood as having mass. Thus, the theory of relativity entails a revolutionary revision of the classical laws of mechanics.
- The general theory of relativity: Extends the special theory beyond the restriction of inertial (non-accelerating) coordinate systems. The general theory of relativity addresses previous deficiencies in the understanding of gravity, formulating new structure laws for the gravitational field. It also rehabilitates the classical intuition that geometry (and mathematical structure in general) is not merely an epistemic construct of the human mind, but rather an ontological (physically significant) feature of the world itself.

Readings: [**EP**] 185-245

Essay: The essay assigned on 4/6 is due by 5 pm on **4/26.**

Week 14: 5/4, 6 ***Quantum Theory and the Crisis for Deterministic, Mechanistic Materialism: The Emergence of a New World View***

- Continuity and discontinuity; elementary quanta of matter and electricity; the quanta of light.
- Quantum indeterminacy; attempts to bridge quantum theory to conventional deterministic physics (and more broadly, the conventional deterministic, mechanistic-materialist worldview); the incompatibility of quantum theory and relativity theory; the failure to reduce quantum theory to conventional deterministic physics.
- The crisis in physics, and the rise of exotic interpretations that undermine classical logic (and the implications for the scientific method, which depends upon classical logic.)

Readings:

- [**EP**] 249-279
- Aristotle, Heisenberg, and Quantum Mechanics – *Science News* article [**D**] (Links to an external site.)

Week 15: 5/11, 13 ***Quantum Theory and the Crisis for Deterministic, Mechanistic Materialism: The Emergence of a New World View*** **(continued)**

- A new understanding of substance and logic in quantum mechanics.
- A potential new paradigm shift in physics: Understanding physical systems as histories of quantum events.

Readings:

- [**EP**] 280-297
- Aristotle, Heisenberg, and Quantum Mechanics – *Science News* article [**D**] (Links to an external site.)

Final Exam: Prompt distributed in class on **5/11.**

Final Exam: **Due 5/20 by 5:00 pm.**