Space, Time, and Matter
PHIL 419, 420 and PHYS 419, 420
Fall 2018

Time: Every Tuesday and Thursday 2:00pm to 3:20pm CST (August 27th to December 12th, 2018)
Location: Loomis Laboratory 136
Professor: Dr. Christopher Gregory Weaver, Assistant Professor of Philosophy at the University of Illinois at Urbana-Champaign
E-mail: wgceave9@illinois.edu (I prefer to be contacted through email. Please see my email correspondence policy below.)
Office Hours and Location: Every Friday 10:00am to 11:00am in Office #409B in Gregory Hall
Prerequisites: The prerequisites for either PHIL/PHYS 419 or PHIL/PHYS 420 are (PHIL 101 (or) (either PHYS 101 or PHYS 211)).
Credits: PHIL/PHYS 419 is worth 3 credits, and PHIL/PHYS 420 is worth 2 credits.
Course Compass 2g Webpage: Go to https://compass2g.illinois.edu and sign in.
Course Website: https://courses.physics.illinois.edu/phys419/fa2018/index.htm

Teaching Assistant #1: Instructor Nick Louzon
Email: nlouzon2@illinois.edu
Office Hours: Thursdays from 11:00am to 12:00pm (noon) in Gregory Hall Room 400B

Teaching Assistant #2: Instructor Suraj Shankaranarayana Hegde
Email: shegde2@illinois.edu
Office Hours: Mondays from 10:00am to 11:00am in the Engineering Science Building 4105

Teaching Assistant #3: Instructor Charles A. Byrne
Email: bcharles@illinois.edu

Teaching Assistant #4: Instructor Andrew Ferrante
Email: aferran2@illinois.edu
Office Hours: Wednesdays 11:00am to 12:00pm (noon) in Grainger Library Room 401

I. Course Description
Space, Time, and Matter is an advanced and intensive history and philosophy of physics course that aims to (a) introduce students to the history of both theoretical and experimental physics (more specifically we will travel from Aristotle’s physics all the way to the development of the standard model of particle physics), (b) briefly introduce students to the basic formulae and accompanying (sometimes competing interpretations) of classical Newtonian mechanics, classical electrodynamics (both 3-vector and relativistic versions), thermodynamics, (classical) Boltzmannian statistical

---

1 The Instructor reserves the right to adjust the course schedule in sect. V of the course syllabus when he deems that a change is necessary. Revisions to the course schedule will be announced, and revised versions of the schedule will appear on the course compass2g webpage if revisions are made.

2 Graduate students taking this course should speak with Instructor Weaver outside of class regarding their responsibilities and assignments.

3 Instructor Byrne is a non-local teaching assistant. He will therefore not have office hours although one can reach him via email.
mechanics, special relativity, general relativity, the standard $\Lambda$-CDM cosmological model, and both non-relativistic and relativistic quantum mechanics, (c) introduce students to debates in the foundations of physics, and (d) give special attention to philosophical debates concerning scientific realism and anti-realism, the relationship between the manifest and scientific images, and the nature of space and time.

II. Learning Objectives
1. Students will learn about the philosophical debate between scientific realists and anti-realists.
2. Students will learn about the philosophical debate concerning the structure of physical theories.
3. Students will learn to appreciate the (perhaps merely apparent) tension between the manifest and scientific images of space, time, and matter.
4. Students will be provided with a preliminary—though still substantive—picture of the scientific images of space, time, and matter supplied by our best physical theories. They will be introduced to debates about the ontology and interpretations of those physical theories as well.
5. All students will develop the skill of analyzing and synthesizing scientific and philosophical information for the purpose of generating new insights about the history of physics, and analytic philosophy of physics.
6. Students enrolled in PHIL/PHYS 419 will learn how to write an argumentative research paper defending a specific thesis on a topic peculiar to the history of physics, or contemporary analytic philosophy of physics.

III. General Approach
Every Thursday we have class I will administer a five-question quiz. These questions will be over the assigned reading material, as well as material presented during previous lectures. Subsequent to quiz administration, I will lecture through new material taking questions and interacting with comments as I proceed. On non-quiz days I will lecture through new material. If we have time, subsequent to lecture period, students will be asked to participate in certain learning activities. Some extra credit will be made available via these activities.

IV. Textbooks
The required textbooks for this course are:


V. Schedule for the Fall Semester

1. August 28th: Review Course Syllabus
   a) Homework: Please read over the course syllabus.

Part 1: Early Physics and Astronomy

2. August 30th: The Manifest and Scientific Images
   a) Homework: None
3. September 4th: Wrapping up Manifest and Scientific Images
   a) Homework: Please read – (Cushing, 15-22)
4. September 6th: Scientific Realism and Anti-Realism
   a) Homework: Please read – (Cushing, 43-58, and 59-66)
5. September 11th: The Physics of Aristotle
   a) Homework: Please read – (Cushing, 15-22 (review))
6. September 13th: Brahe, Kepler, and some Galileo (Guest Speaker: Dr. Michael Weissman)
   a) Homework: Please read – (Excerpts from Julian B. Barbour, The Discovery of Dynamics, 264-273); (Cushing, 66-73); (Gingerich, “Kepler and the Laws of Nature”)
7. September 18th: The Modified Geocentric View of Ptolemy & The Heliocentric Theory of Copernicus
   a) Homework: Please read – (Cushing, 43-58, 59-66 (review))
8. September 20th: Galileo’s Observational Evidence for Copernicus’s Heliocentric Theory (Guest Speaker: Dr. Lauren Pearce)
   a) Homework: Please read – (Holton and Brush, “The Telescopic Evidences for the Copernican System” & “Toward a Physical Basis for the Heliocentric System” both from Physics, the Human Adventure: From Copernicus to Einstein and Beyond, 52-58)
9. September 25th: Galileo’s Kinematics and Dynamics
   a) Homework: Please read – (Cushing, 74-86)

Part 2: The Development of Classical Mechanics

10. September 27th: Kepler and Laws of Nature Generally
11. October 2nd: The Physics of Descartes: Part 1
   a) Homework: Please read – (Excerpts from Gerd Buchdahl’s Metaphysics and the Philosophy of Science: The Classical Origins: Descartes to Kant, 79-180)

---

Homework readings that are underlined will be made available on Compass.
   a) Homework: Please read – Review (Excerpts from Gerd Buchdahl’s *Metaphysics and the Philosophy of Science: The Classical Origins: Descartes to Kant*, 79-180)

13. October 9th: Newton’s Optics: Part 1
   a) Homework: Please read – (Cushing, 83-131)

14. October 11th: Newton’s Optics: Part 2
   a) Homework: Please read – Review (Cushing, 83-131)

15. October 16th: Newtonian Mechanics and (a little about) the Development of Hamiltonian and Lagrangian Mechanics
   a) Homework: Please read – (Cushing, 148-163)

**Part 3: The Development of Electrodynamics**

16. October 18th: Øersted, Ampère, and Faraday
   a) Homework: Please read – (Excerpts from E.T. Whittaker, *A History of the Theories of Aether and Electricity I. The Classical Theories*, 81-89; 170-197); (Cushing, 195-207)

17. October 23rd: Maxwell’s Field Theory and Modern Electrodynamics and The Problem of the Arrow of Electromagnetic Radiation
   a) Homework: Please read – (Excerpts from Huw Price, *Time’s Arrow and Archimedes’ Point*, 49-77)

**Part 4: The Development of Thermodynamics and Statistical Mechanics**

18. October 25th: Boltzmannian Statistical mechanics
   a) Homework: Please read – (Excerpts from David Z. Albert, *Time and Chance*, 22-70)
   b) Mid-Terms Available on Compass Today!

19. October 30th: Entropy and the Problem of the Arrow of Time

**Part 5: The Development of Special Relativity, General Relativity, and Modern Cosmology**

20. November 1st: The History of Special Relativity
   a) Homework: Please read – (Cushing, 225-251)

21. November 6th: Minkowskian STR and Lorentzian STR
   a) Homework: Please read – (Maudlin, 27-147)

   a) Homework: Please read – (Cushing, 252-262)

   a) Homework: Please read – (Cushing, 262-270)
24. November 15th: The Road to Λ-CDM
   a) Homework: Please read/view – (Joel Primack’s “Historical Introduction to ΛCDM Cosmology” & Joel Primack’s YouTube Video “Introduction to Cosmology”)

   Fall Break November 17th to November 25th

Part 6: The Development of Quantum Mechanics and the Standard Model of Particle Physics

25. November 27th: The Old Quantum Theory
   a) Homework: Please read – (Cushing, 273-282)

26. November 29th: The Transition to Modern Quantum Mechanics
   a) Homework: Please read – (Cushing, 282-304)

27. December 4th: The Measurement Problem in Non-Relativistic Quantum Mechanics
   a) Homework: Please read – (Cushing, 305-315; Maudlin, “Three Measurement Problems”)

28. December 6th: Bell’s Inequalities and Non-Locality
   a) Homework: Please read – (Maudlin, 6-26; 148-204)

29. December 11th: Quantum Field Theory and the Standard Model of Particle Physics
   a) Homework: Please read – (Excerpts from Chris Quigg, Gauge Theories of the Strong, Weak, and Electromagnetic Interactions, 1-18)

VI. Things to Do

1. Assignments – (For students enrolled in PHIL 419 or PHYS 419, the assignments portion of the course is worth 15% of your course grade; For students enrolled in PHIL 420 or PHYS 420, the assignments portion of the course is worth 30% of your course grade)
   a) Students will need to complete five-point quizzes administered in class every Thursday. These weekly in-class quizzes will be supplemented with a weekly essay question (worth five points). So, every week one has to complete a 10point quiz, five points of which can be earned in class by responding correctly to the questions/problems/challenges provided, and another five points of which can be earned by responding accurately/correctly to an essay question provided via Compass. All essay portions of the weekly quizzes will be open book and open note since the essay questions will be made available through Compass on Tuesdays at 10:00am CST. Responses to the essay questions should be provided in Compass by the immediately following Thursday at 2:00pm CST. Be sure to follow the instructions provided. Students are not allowed to work with each other.

2. Mid-Term – 30% (For All Students)
   a) Students will be required to take a mid-term exam that will consist of three essay questions. The mid-term will be made available on Compass
and will be open book and open note. Students are not allowed to work with each other. The mid-term will be made available on October 25th at 10:00am CST and will be due on November 1st at 10:00pm CST.

b) Special instructions for the mid-term will be provided on the mid-term exam itself (e.g., word limits, etc.).

3. Final Paper – 30% (For Students Enrolled in PHIL 419 or PHYS 419 Only)
   a) Directions
      ➢ Your final paper should be on a topic covered in class or in one of the textbooks. Please have your final paper topic approved by Professor Weaver by October 15th. To acquire approval of your topic, please email me with the subject heading “Final Paper Topic for Approval”, then in the body of your email state the thesis you intend to argue for. Your thesis should be a completion of the following phrase: “I will argue that…”.
      ➢ The document should be single spaced, the text should be justified, and in Times New Roman font, size 12, with one-inch margins. Please do not include a title page. Please do not include course information.
      ➢ Please paginate your papers.
      ➢ Please document your paper in the University of Chicago Manual of Style. It should include a bibliography.
      ➢ All drafts of final papers are due in PDF format via Compass.
      ➢ A late (required final draft) paper will receive a one-point reduction every hour it is late (e.g., if your paper is 70 minutes late, your final paper will receive a one-point reduction).
   b) Drafts
      ➢ Students enrolled in PHIL 419 or PHYS 419 are required to submit both a rough and final draft of their final paper assignment.
      ➢ Rough drafts are due November 16th at 11:00am (morning) CST.
      ➢ Comments on rough drafts will be returned via Compass by November 29th.
      ➢ All students who submit a rough draft will receive comments on their rough drafts and will be expected to make revisions in light of those comments. The revised version of your paper constitutes the final draft.
      ➢ Final drafts are due on December 13th at 10:00pm CST.
      ➢ The rough and final drafts of your paper should have a word count between 3,000 and 5,000 words.
      ➢ Failing to turn in a rough draft can negatively affect the final draft grade.

4. Final Exam – (For students enrolled in PHIL 419 or PHYS 419, the final exam portion of the course is worth 15% of your course grade; For students enrolled in PHIL 420
or PHYS 420, the final exam portion of the course is worth 30% of your course grade.)

a) All students are required to take the final examination on your scheduled final exam date (December 14th from 8:00am to 11:00am CST\(^5\))

- The final exam will feature four essay questions.
- A study guide will be provided for all students.

5. Class Participation – 10% (For all students)

a) Class participation points include a possible 100 points in all. However, class participation grades are only worth 10% of your final grade. Class participation grades will be negatively affected if disrespect is shown to others. Also, class participation grades can be negatively affected by accumulating absences (see the table below):

<table>
<thead>
<tr>
<th>Absence Amount</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 unexcused absences</td>
<td>The student’s class participation grade is reduced by half (50/100 points)</td>
</tr>
<tr>
<td>4 unexcused absences</td>
<td>The student’s class participation grade is reduced by 75% (25/100 points)</td>
</tr>
<tr>
<td>5 unexcused absences</td>
<td>The student’s class participation grade is reduced to a zero (0/100 points)</td>
</tr>
<tr>
<td>6 or more unexcused absences</td>
<td>Excessive unexcused absences numbering six or more in amount can result in further consequences as allowed by the Student Code and the appropriate UIUC administrative bodies</td>
</tr>
<tr>
<td>Between 6 and 8 excused absences</td>
<td>An incomplete grade and makeup work after the semester ends (pending UIUC administrative approval)</td>
</tr>
<tr>
<td>8 or more excused absences</td>
<td>Dr. Weaver seeks advice from the appropriate Dean’s office to discuss how to proceed</td>
</tr>
</tbody>
</table>

VII. Current Academic Integrity Policy

To view the current academic integrity policy, visit the following link here (http://www.las.illinois.edu/students/integrity/). That policy is binding for this course.

Please be sure to avoid plagiarism. Plagiarism is discussed and defined in the current academic integrity policy linked above. There are significant and serious consequences for committing plagiarism in this course.

\(^5\) I will announce location details for the final exam via Compass.
VIII. Food, Cell Phone, and Computer use Policies
I do not allow students to consume food in class. If you would like to use an electronic device to take good notes, and you would like to make use of electronic copies of your reading and/or lecture notes, you may use your computer, tablet, or smart phone, but please put your electronic devices in airplane mode shortly before class starts. Class participation grades will be reduced if Professor Weaver discovers that you are interacting with non-course related material during class. Prior to the start of class please silence all electronic devices.

IX. Email Correspondence Policy
All email correspondence with your instructor must be done using your academic (usually the one provided for you by the University of Illinois at Urbana-Champaign) email address (that’s an email address ending with .edu). Email correspondence received from non-academic email addresses will be ignored. Email correspondence sent to any other email address besides wgceave9@illinois.edu in an attempt to communicate with me will be ignored. All email correspondence with Professor Weaver should include one’s first and last name.

Students can expect to receive a reply to their emails within 24 hours on weekdays. If your email is sent after 5 pm on Friday, or during the weekend you can expect a reply by 11:00 am the following Monday.

X. Academic Accommodations
The Division of Disability Resources and Educational Services has a webpage here (http://www.disability.illinois.edu/academic-support/accommodations). If one has need of academic accommodations, please speak with me outside of class.

XI. Grades
Information on grades and reports for the College of Liberal Arts and Sciences is available here.

XII. Grading Scale
The grade scale for PHIL 419, PHYS 419, PHIL 420, and PHYS 420 is provided below:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Minimum Percentage</th>
<th>Grade</th>
<th>Minimum Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>97.0% to 100%</td>
<td>C+</td>
<td>77% to 79.9%</td>
</tr>
<tr>
<td>A</td>
<td>93% to 96.9%</td>
<td>C</td>
<td>73% to 76.9%</td>
</tr>
<tr>
<td>A-</td>
<td>90% to 92.9%</td>
<td>C-</td>
<td>70% to 72.9%</td>
</tr>
<tr>
<td>B+</td>
<td>87% to 89.9%</td>
<td>D+</td>
<td>67% to 69.9%</td>
</tr>
<tr>
<td>B</td>
<td>83% to 86.9%</td>
<td>D</td>
<td>63% to 66.9%</td>
</tr>
<tr>
<td>B-</td>
<td>80% to 82.9%</td>
<td>D-</td>
<td>60% to 62.9%</td>
</tr>
</tbody>
</table>
Any grade percentage below 60% is an F.\textsuperscript{6}

\textsuperscript{6} Again, if you are a graduate student, please speak with Professor Weaver outside of class regarding your assignments and duties. Thank you.