Space, Time, and Matter
PHIL/PHYS 419 and PHIL/PHYS 420

Fall 2016

[IMPORTANT NOTE: PHYS 420 = PHIL 420; and PHIL 419 = PHYS 419. All instances of PHYS 419 in this syllabus can be read as PHIL 419 (the two are interchangeable), and all instances of PHYS 420 in this syllabus can be read as PHIL 420 (the two are interchangeable).]

Time: Every Tuesday and Thursday 2:00pm to 3:20pm CST

Location: Room 144 in Loomis Laboratory

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 Tuesday during the Fall 2016 academic semester 4:00pm to 5:00pm Office #409B in Gregory Hall

Prerequisites: The prerequisites for either PHIL/PHYS 419 or PHIL/PHYS 420 are PHIL 101; PHYS 101 or PHYS 211.

Credits: PHYS/PHIL 419 is worth 3 credits, and PHYS/PHIL 420 is worth 2 credits.

Course Compass 2g Webpage: Go to https://compass2g.illinois.edu and sign in.

Course Website: Go to https://courses.physics.illinois.edu/phys419/index.htm

Teaching Assistant #1: Mr. Travis Tanner (tctanne2@illinois.edu) (See the course website for Mr. Tanner’s office hours)

Teaching Assistant (non-local) #2: Mr. Charles Byrne (bcharles@illinois.edu) (See the course website for instructions on how best to appropriate Mr. Byrne’s help.)

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 physical theories, (b) present the formal content of those physical theories in a way that is accessible to both students of physics and philosophy, (c) teach students how to engage contemporary debates on how best to interpret the formalism of such physical theories, and (d) encourage students to reflect on whether or not solutions to the interpretive debates in physics and philosophy of physics unite or separate the manifest and scientific images of space, time, and matter.

II. Learning Objectives

1. Students will learn about the important distinction between the manifest and scientific image in the philosophy of science.
2. Students will learn about the debate between scientific realists and scientific anti-realists.
3. Students will be introduced to various views about the structure of physical theories.
4. Students will come to appreciate the (perhaps merely apparent) tension between the manifest and scientific images of space, time, and matter.
5. Students will be provided with a preliminary, though still substantive picture, of the scientific images of space, time, and matter in our best physical theories. They will be

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1 The Instructor reserves the right to adjust the course schedule in Section 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.
introduced to debates about the ontology and interpretations of those physical theories as well.

6. Students will wrestle with attempted solutions to the paradoxical tension between the aforementioned images.

7. All students will develop the skill of analyzing and synthesizing information and ideas for the purposes of generating new insights about the history of physics, and analytic philosophy of physics.

8. Students enrolled in PHIL/PHYS 419 will learn how to write an argumentative research paper defending a specific thesis on a topic peculiar to physics, the history of physics, or contemporary analytic philosophy of physics.

III. General Approach

Every Thursday we have class, after taking roll, I will administer five I-clicker questions as part of your weekly quizzes. These questions will be over the assigned reading material, as well as material presented during previous lectures. Subsequent to I-clicker question administration, I will lecture through new material taking questions and interacting with comments as I proceed. I will incorporate various forms of media. We will also have various types of class activities to help encourage learning. All class lectures will be supplemented with PowerPoint slides. On non-quiz days, after taking roll, I will lecture through new material. After lecture time, 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:


   a. ISBN: 978-0-631-22501-0

   a. ISBN: 978-0521578233

*Please make sure you purchase or have an i>clicker remote for the course. Bring the i>clicker with you to every class meeting. See page 10 below for more on i>clickers.

V. Schedule for the Fall Semester

1. Tuesday, August 23: The Syllabus
   a. Homework [due Thursday, September 1st at 2:00pm CST]
      ➢ Reading Assignment #1: The Syllabus (available on Compass)

Part 1: Philosophical Prolegomena
2. Thursday, August 25: Sellars, and the Manifest and Scientific Images
   a. Homework [due Thursday, September 1st at 2:00pm CST]

3. Tuesday, August 30: The Structure of Scientific Theories
   a. Essay Question for Quiz #1 Posted at 10:00am CST
   b. Homework [due Thursday, September 1st at 2:00pm CST]

4. Thursday, September 1: Scientific Realism and Scientific Anti-Realism
   a. Quiz #1 Today: 5 1-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, September 8th at 2:00pm CST]

Part 2: The Newtonian Scientific Image of Space, Time, and Matter
5. Tuesday, September 6: The History of Dynamics from Copernicus to Newton
   a. Essay Question for Quiz #2 Posted at 10:00am CST
   b. Homework [due Thursday, September 8th at 2:00pm CST]
      ✓ Reading Assignment #5: (Cushing pp. 59-86)

6. Thursday, September 8: Newtonian Mechanics
   a. Quiz #2 Today: 5 1-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, September 15th at 2:00pm CST]
      ✓ Reading Assignment #6: (Cushing pp. 87-132); (Maudlin pp. 1-46)

7. Tuesday, September 13: Newtonian Absolute Space and Newtonian Absolute Time
   a. Essay Question for Quiz #3 Posted at 10:00am CST
   b. Homework [due Thursday, September 15th at 2:00pm CST]
      ✓ Reading Assignment #7: (Maudlin pp. 47-66)

8. Thursday, September 15: The History of Electrodynamics from Ampère to Einstein
   a. Quiz #3 Today: 5 1-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday September 22nd at 2:00pm CST]
      ✓ Reading Assignment #8: (Cushing pp. 181-222)
9. Tuesday, September 20: Electrostatics, Magnetostatics, and Electromagnetism
   a. Essay Question for Quiz #4 Posted at 10:00am CST
   b. Homework [due Thursday September 22nd at 2:00pm CST]
      ➢ Reading Assignment #9: (Lange pp. 26-66)

10. Thursday, September 22: The Lorentz Force Law and Maxwell’s Microscopic Equations
    a. Quiz #4 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
    b. Homework [due Thursday September 29th at 2:00pm CST]
       ➢ Reading Assignment #10: (Lange pp. 111-164)

11. Tuesday, September 27: The Ontology of the Electric and Magnetic Fields, and the Einstein-Ritz Controversy
    a. Essay Question for Quiz #5 Posted at 10:00am CST
    b. Homework [due Thursday September 29th at 2:00pm CST]
       ➢ Reading Assignment #11: (Lange pp. 165-174)

Part 4: The Scientific Image of Spacetime and Matter in Special Relativity

12. Thursday, September 29: The History of the Development of Special Relativity
    a. Quiz #5 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
    b. Homework [due Thursday, October 6th at 2:00pm CST]
       ➢ Reading Assignment #12: (Cushing pp. 223-251); (Lange pp. 175-254)

13. Tuesday, October 4: Einstein’s Postulates and their Implications; The Lorentz Transformation(s)
    a. Essay Question for Quiz #6 Posted at 10:00am CST
    b. Homework [due Thursday, October 6th at 2:00pm CST]
       ➢ Reading Assignment #13: (Maudlin 67-105)

Part 5: The Scientific Image of Spacetime and Matter in General Relativity

14. Thursday, October 6: Four Principles of GTR; Einstein’s Field Equation; The Geodesic Principle and the Geodesic Equations of Motion
    a. Quiz #6 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
    b. Homework [due Thursday, October 13th at 2:00pm CST]
       ➢ Reading Assignment #14: (Maudlin pp. 126-152)

15. Tuesday, October 11: GTR and the Relationalism vs. Substantivalism Debate
    a. Essay Question for Quiz #7 Posted at 10:00am CST
    b. Homework [due Thursday, October 13th at 2:00pm CST]
   a. Quiz #7 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, October 20th at 2:00pm CST]
      ➢ Reading Assignment #16: (Cushing pp. 252-270)

17. Tuesday, October 18: No Class
   a. Essay Question for Quiz #8 Posted at 10:00am CST

Part 6: The Scientific Image of Spacetime and Matter in the Standard Cosmological Model

18. Thursday, October 20: A Short History of Modern Cosmology
   a. Quiz #8 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, October 27th at 9:00am CST]

19. Tuesday, October 25: The Friedman-Lemaître-Robertson-Walker Model and the Dynamics of Expansion
   a. Essay Question for Quiz #9 Posted at 10:00am CST
   b. Homework [due Thursday, October 27th at 2:00pm CST]

20. Thursday, October 27: Inflation and the Many Problems of Theoretical Cosmology
   a. Quiz #9 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, November 3rd at 2:00pm CST]

Part 7: The Scientific Image of Time and Matter in Quantum Mechanics

21. Tuesday, November 1 – A Short History of Quantum Mechanics
   a. Homework [due Thursday, November 3rd at 2:00pm CST]
      ➢ Reading Assignment #20: (Cushing pp. 271-289)

22. Thursday, November 3 – Specifying Quantum States
   a. Quiz #10 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, November 10th at 2:00pm CST]

23. Tuesday, November 8: The Measurement Problem and Orthodox Quantum Mechanics
   a. Essay Question for Quiz #10 Posted at 10:00am CST
   b. Homework [due Thursday, November 10\textsuperscript{th} at 2:00pm CST]

   a. Quiz #11 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. Homework [due Thursday, November 17\textsuperscript{th} at 2:00pm CST]
   Section 1 to 10 Only. (Online Resource)

Part 8: The Scientific Image of Time and Matter in Classical Statistical Mechanics
25. Tuesday, November 15: Classical Boltzmannian Statistical Mechanics
   a. Essay Question for Quiz #11 Posted at 10:00am CST
   b. Homework [due Thursday, November 17\textsuperscript{th} at 2:00pm CST]
   ➢ Reading Assignment #24: Christopher G. Weaver, “Statistical Mechanics and the Puzzle of the Arrow of Time”, Handout. Made (available through Compass)

26. Thursday, November 17: The Puzzle of the Arrow of Time
   a. Quiz #12 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass
   b. No Homework

Tuesday, November 22: NO CLASS (Thanksgiving Break)
Thursday, November 24: NO CLASS (Thanksgiving Break)

Part 9: Reconciling the Manifest and Scientific Images: Can We Save Appearances?
27. Tuesday, November 29: Determinism and Freedom
   a. Essay Question for Quiz #12 Posted at 10:00am CST
   b. Homework [Due Thursday, December 1\textsuperscript{st} at 2:00pm CST]

28. Thursday, December 1: Time-Reversal Invariance and Asymmetry
a. Quiz #13 Today: 5 I-clicker Questions at Beginning of Class, Essay Question due at 2:00pm via Compass

b. Homework [Try to read by December 6th in preparation for class.]
   ➢ Reading Assignment #26: Christopher Gregory Weaver, “Solving the Arrow of Time Puzzle” (Available on Compass)

29. Tuesday, December 6: Microphysicalism and Emergence
   a. Homework [No due date. The reading below is merely recommended and not required.]

VI. Things to Do

1. Assignments – (For Students Enrolled in PHIL/PHYS 419, the Assignments Portion of the Course is worth 15% of your Course Grade) (For Students Enrolled in PHIL/PHYS 420, the Assignments Portion of the Course is worth 30% of your Course Grade)
   a. Students will be responsible for responding to five True or False and/or Multiple Choice questions, at the beginning of class every Thursday. Responses will be acquired via the i>clicker technology. The quiz for each week will also include an essay question that will sometimes be exploratory or investigative in that these questions will sometimes require students to (a) read a recent post on a respected science blog (by a respected physicist or philosopher), or (b) read a recent news story, or (c) watch a science-related or science-fiction movie (made available on course reserve in Grainger Engineering Library) or academic video, or academic debate on topics directly relevant to course lessons of the week. Sometimes these essay questions will be about some portion of the assigned reading listed in the course schedule above. All essay portions of quizzes will be open book and open note. Students are not allowed to work with other students on any portion of the quizzes. Each quiz is worth 10 points, and the lowest quiz score will be dropped (essay questions are worth five points, and the remaining five come from the True or False and/or Multiple Choice questions given in class). Essay questions for the quiz of the week will be posted on Tuesdays at 10:00am CST on Compass in the Quizzes section. Responses to quiz essay questions should be provided in Compass as well by the following Thursday at 2:00pm CST. Be sure to follow the instructions provided.

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 Tuesday, October 25th at 10:00am CST and will be due on Tuesday, 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/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, 2016. To acquire my 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 statement should be a completion of the following phrase: “I will argue that....”.
   - The document should be single-spaced, justified, and in Times New Roman font, size 12, with one-inch margins. Please, no title pages and do not include course information.
   - Papers need to be paginated.
   - The paper should be documented in the University of Chicago Manual of Style (click the link here: http://www.chicagomanualofstyle.org/tools_citationguide.html, and then click on the “Author-Date” tab in the middle of the webpage for instructions on how to cite in the aforementioned style). It should include a bibliography. Your bibliography may not be used to fulfill the length requirement. A bibliography section is not a works cited page.
   - If you need help with your paper, I am available to meet with you during office hours, or you can email me to set up an appointment. Also, one should look at the resources found here: http://www.cws.illinois.edu/workshop/writers/ and here: http://www.cws.illinois.edu/.
   - 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).
   - Final paper grades will be posted online at https://compass2g.illinois.edu within two weeks of final draft paper submission.
   - Special instructions and helps will be provided on October 15th, 2016.

   b. Drafts
   - Students enrolled in PHYS 419 are required to submit both a rough and final draft of their final paper assignment.
   - Rough drafts are due November 18th, 2016 at 11:00am (morning) CST.
   - Comments on rough drafts will be returned via compass by November 29th, 2016 at 10:00pm CST.
   - 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, 2016 at 10:00pm CST.
   - The rough and final drafts of your paper should have a word count
between 3,000 and 5,000 words.

4. Final Exam – (For Students Enrolled in PHIL/PHYS 419, the Final Exam Portion of the Course is worth 15% of your Course Grade) (For Students Enrolled in PHIL/PHYS 420, the Final Exam Portion of the Course is worth 30% of your Course Grade)
   a. All students are required to take a final examination on our scheduled final exam date.
      - The final exam will feature two 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 semester ends (pending UIUC administrative approval)</td>
</tr>
<tr>
<td>8 or more excused absences</td>
<td>Dr. Weaver meets with the Dean 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.

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. I-Clicker Technology (Summarized from i>clicker CITL Materials)
All students should bring their i>clicker remotes to class. One must use these to respond to quiz questions, and to provide feedback on discussion questions during lecture time. Attendance will be tracked through i>clicker participation as well (q.v., page 9 above for the attendance policy).

For this class we will prefer the i>clicker 2 model, although older models should work as well. We will not be using REEF polling on mobile devices such as smart phones.

**Registration:** Please register your i>clicker device by August 30th, 2016. Please refrain from registering your i>clicker on iclicker.com. To Register: Visit [https://compass2g.illinois.edu/](https://compass2g.illinois.edu/). Click on the link entitled ‘i>clicker Registration’, and then enter the remote ID. Remote IDs can be found on the very back of the i>clicker itself. If you ever lose your ID number, you can recover it by going to the Illini Union Bookstore [http://www.uofibookstore.illinois.edu/](http://www.uofibookstore.illinois.edu/) and by asking for it there.

**Cheating Policy (with respect to i>clicker use):** Please refrain from using another student’s i>clicker. Please refrain from answering on another student’s behalf. If it is discovered that there are i>clicker votes or inputs in classes you were not present for, or if you have another student’s i>clicker in your possession, your i>clicker points will be taken away, and there may be further consequences. Cheating is against the student code. Please see: [http://studentcode.illinois.edu/](http://studentcode.illinois.edu/)

**Broken and/or Lost i>clicker:** It is your responsibility to make sure that you bring your i>clicker to class. If your clicker is lost or broken, it is your responsibility to purchase a replacement. You will then need to make sure that you follow the directions above for registration. Also, it is your responsibility to ensure that you come to class prepared with a fully functioning i>clicker so that you can answer quiz questions and participate in in-class
activities.

XII. Grades
The regulations and policies of the grading system for undergraduates of the University of Illinois at Urbana-Champaign are explicated here. More information on grades and reports for the College of Liberal Arts and Sciences is available here.

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

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>97.0% to 100%</td>
</tr>
<tr>
<td>A</td>
<td>93% to 96.9%</td>
</tr>
<tr>
<td>A-</td>
<td>90% to 92.9%</td>
</tr>
<tr>
<td>B+</td>
<td>87% to 89.9%</td>
</tr>
<tr>
<td>B</td>
<td>83% to 86.9%</td>
</tr>
<tr>
<td>B-</td>
<td>80% to 82.9%</td>
</tr>
<tr>
<td>C+</td>
<td>77% to 79.9%</td>
</tr>
<tr>
<td>C</td>
<td>73% to 76.9%</td>
</tr>
<tr>
<td>C-</td>
<td>70% to 72.9%</td>
</tr>
<tr>
<td>D+</td>
<td>67% to 69.9%</td>
</tr>
<tr>
<td>D</td>
<td>63% to 66.9%</td>
</tr>
<tr>
<td>D-</td>
<td>60% to 62.9%</td>
</tr>
</tbody>
</table>

Any grade percentage below 60% is an F.