PHIL 8670: Seminar in Philosophy of Science (Spring 2019, 3 units)

January 9, 2019

Instructor: Prof. Samuel C. Fletcher (scfletch@umn.edu)
Class Meetings: Th 4:00–6:30 in Heller 731
Office Hours: M 2:15–3:15, Th 11:00–12:00 in Heller 754, and by appointment

Course Website: `https://canvas.umn.edu/courses/95441/`. Please check Canvas often for course updates.

Required Text: Michael E. Cuffaro and Samuel C. Fletcher (eds.) *Physical Perspectives on Computation, Computational Perspectives on Physics*, Cambridge University Press, 2018. (Hereafter *PPCCPP*.) Available at the campus bookstore, and online through the library. If you order the book from the publisher (`http://www.cambridge.org/9781107171190`), use the code CUFFARO2018 at checkout for a 20% discount.

Other Required Materials: Please bring to every class meeting either a pencil or a pen in blue or black ink.

Description and Objectives

This seminar will focus on the historical, mathematical, philosophical, and scientific interconnections between theories of computation and theories of physical phenomena. It will be guided topically by the chapters in the recently published volume, *Physical Perspectives on Computation, Computational Perspectives on Physics* (Cambridge University Press, 2018). These are divided into four parts:

1. The Computability of Physical Systems and Physical Systems as Computers. Topics include pancomputationalism and variations on the Church-Turing thesis, including historical aspects thereof.

2. The Implementation of Computation in Physical Systems. Topics include explanations of the power of quantum computing, the physics of information, and accounts of physical computational implementation, including in biological systems.

3. Physical Perspectives on Computer Science. Topics include intermediate Turing degrees, how physics has motivated the problems of scientific computing, and the implications of general relativity for theories of computation.

4. Computational Perspectives on Physical Theory. Topics include the thermodynamics of computation, Landauer's principle, Maxwell's demon, and information-theoretical reconstructions of quantum theory.

Because of the evident diversity of topics, seminar participants should expect to be unfamiliar with some of them, but different participants will be unfamiliar with different ones. One objective of the seminar is to maintain a weekly community of discussion through which we can all learn from each other; accordingly, I am not planning on lecturing, in general. Instead, everyone in the course will lead discussion for one or more of the seminar meetings. (Those taking the course for a grade will lead two; those auditing, one.) That can include creating a slide presentation, or a handout, or can even be done using the whiteboard. The goal is to guide everyone through the important ideas of the readings, raising questions, facilitating discussion, etc. I will only play a consulting role before and during each seminar meeting.

The reading assignment for the first class meeting provides two classes of considerations:

1. Some background concepts and formalism for the rest of the semester. *Do not worry* if some (or most) of this is unfamiliar to you. I will lead the first seminar discussion guiding us through these topics.

2. An introduction to the topics for each of the course meetings. Those attending the course should use this information to select their seminar presentation preferences, for which a Doodle poll will be sent ahead of time.

Although many of the topics we will encounter during the seminar will have technical aspects, we will try to focus on the conceptual underpinnings of those aspects in discussion.

Grading

Basis for Evaluation

Discussion Participation (14%) Students should attend all seminar meetings when possible and make some contribution to the discussion during those meetings.

Seminar Presentations (40%) Each student taking the course for a letter grade will lead seminar discussions for two class meetings on the readings assigned for that day. (Auditors will lead one.) This can include creating a slide presentation, or a handout, or can even be done using the whiteboard. Grading will be based on clarity, accuracy, judicious comprehensiveness, explaining any needed or helpful background ideas, and raising and facilitating interesting topics for discussion. Each presentation will be worth 20% of one's final grade.

Term Paper (46%) Students taking the course for a letter grade must submit by May 15th a 4,000–8,000-word term paper developing a novel argument on a topic derived from the course material.

Understanding Your Letter Grade

How to Compute Your Letter Grade

	$90 >$ B+ ≥ 87	$80 >$ C+ ≥ 77	$70 >$ D+ ≥ 67	
A ≥ 93	$87 >$ B ≥ 83	$77 >$ C ≥ 73	$67 >$ D ≥ 63	F < 60
$93 >$ A- ≥ 90	$83 >$ B- ≥ 80	$73 >$ C- ≥ 70	$63 >$ D- ≥ 60	

Grades in the following ranges represent the following corresponding levels of achievement relative to the level necessary to meet course requirements:

A: Outstanding.
B: Significantly above.
C: Adequate in every respect.
D: Worthy of credit despite not fully meeting course requirements.
F: Not meeting enough course requirements to be deserving of credit.

Students taking this course "pass/fail" will receive an "S," representing satisfactory achievement, for any standard final letter grade of "C-" or higher that he or she would have been assigned. Such students will receive an "N," representing unsatisfactory achievement, for any standard final letter grade of "D+" or lower that he or she would have been assigned.

For additional information about University policies about grading and transcripts, please refer to: `http://policy.umn.edu/education/gradingtranscripts`.

Policies

Student Conduct Code

The University seeks an environment that promotes academic achievement and integrity, that is protective of free inquiry, and that serves the educational mission of the University. Similarly, the University seeks a community that is free from violence, threats, and intimidation; that is respectful of the rights, opportunities, and welfare of students, faculty, staff, and guests of the University; and that does not threaten the physical or mental health or safety of members of the University community.

As a student at the University you are expected adhere to the Board of Regents Policy: Student Conduct Code. To review the Student Conduct Code, please see: `http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf`.

Note that the conduct code specifically addresses disruptive classroom conduct, which means "engaging in behavior that substantially or repeatedly interrupts either the instructor's ability to teach or student learning. The classroom extends to any setting where a student is engaged in work toward academic credit or satisfaction of program-based requirements or related activities."

Use of Personal Electronic Devices in the Classroom

Using personal electronic devices in the classroom setting can hinder instruction and learning, not only for the student using the device but also for other students in the class. To this end,

the University establishes the right of each faculty member to determine if and how personal electronic devices are allowed to be used in the classroom. (For complete information, please reference: http://policy.umn.edu/education/studentresp.)

In this class, the use of laptops, tablets, and other electronic devices is permitted as long as it would not reasonably be a distraction to others. Reasonable distractions include movies and social media. Students violating this policy will be asked to put their offending device away for the rest of the class session.

Writing Resources

Student Writing Support (SWS) offers free writing instruction for all University of Minnesota students at all stages of the writing process. In face-to-face and online collaborative consultations, SWS consultants help students develop productive writing habits and revision strategies. SWS consultants are teachers of writing: graduate and undergraduate teaching assistants and professional staff. Some consultants specialize in working with multilingual writers, and others have experience with writing in specific disciplines. Consulting is available by appointment online and in Nicholson Hall, and on a walk-in basis in Appleby Hall. For more information, go to writing.umn.edu/sws or call 612-625-1893. In addition, SWS offers a number of web-based resources on topics such as avoiding plagiarism, documenting sources, and planning and completing a writing project.

Scholastic Dishonesty

You are expected to do your own academic work and cite sources as necessary. Failing to do so is scholastic dishonesty. Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. (Student Conduct Code: http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf.) If it is determined that a student has cheated, he or she may be given an "F" or an "N" for the course, and may face additional sanctions from the University. For additional information, please see: http://policy.umn.edu/education/instructorresp.

The Office for Student Conduct and Academic Integrity has compiled a useful list of Frequently Asked Questions pertaining to scholastic dishonesty: http://www1.umn.edu/oscai/integrity/student/index.html. If you have additional specific questions regarding what would constitute scholastic dishonesty in the context of this class, please ask.

Make-up Work for Legitimate Absences

Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include illness (inclusive of dependents), whether mental or physical, medical conditions related to pregnancy, participation in intercollegiate

athletic events, subpoenas, jury duty, military service, bereavement, and religious observances. Such circumstances do not include voting in local, state, or national elections. For complete information, please see: http://policy.umn.edu/education/makeupwork.

Under such legitimate circumstances leading a student to be absent for any graded activity, that student must contact me about it at least two weeks in advance, or as soon as possible if the circumstances are known later.

Appropriate Student Use of Class Notes and Course Materials

Taking notes is a means of recording information but more importantly of personally absorbing and integrating the educational experience. However, broadly disseminating class notes beyond the classroom community or accepting compensation for taking and distributing classroom notes undermines instructor interests in their intellectual work product while not substantially furthering instructor and student interests in effective learning. Such actions violate shared norms and standards of the academic community. For additional information, please see: http://policy.umn.edu/education/studentresp.

Sexual Harassment

"Sexual harassment" means unwelcome sexual advances, requests for sexual favors, and/or other verbal or physical conduct of a sexual nature. Such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance or creating an intimidating, hostile, or offensive working or academic environment in any University activity or program. Such behavior is not acceptable in the University setting. For additional information, please consult the Board of Regents' policy on the matter: http://regents.umn.edu/sites/regents.umn.edu/files/policies/SexHarassment.pdf.

In my role as a University employee, I am required to share information that I learn about possible sexual misconduct with the campus Title IX office that addresses these concerns. This allows a Title IX staff member to reach out to those who have experienced sexual misconduct to provide information about the personal support resources and options for investigation that they can choose to access. You are welcome to talk with me about concerns related to sexual misconduct. Within the requirements of my job, I will be as responsive to your requests for confidentiality and support as possible. You can also or alternately choose to talk with a confidential resource that will not share information that they learn about sexual misconduct. Confidential resources include The Aurora Center (http://aurora.umn.edu/), Boynton Mental Health (https://boynton.umn.edu/clinics/mental-health) and Student Counseling Services (https://counseling.umn.edu/).

Equity, Diversity, Equal Opportunity, and Affirmative Action

The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. To this effect, please notify me if you have a preferred name or pronoun not indicated in your official enrollment data. For more information, please consult the

Board of Regents' policy on the matter: http://regents.umn.edu/sites/regents.umn.edu/files/policies/Equity_Diversity_EO_AA.pdf.

Disability Accommodations

The University of Minnesota is committed to providing equitable access to learning opportunities for all students. The Disability Resource Center (DRC) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations. If you have, or think you may have, a disability (e.g., mental health, attentional, learning, chronic health, sensory, or physical), please contact the DRC at 612-626-1333 to arrange a confidential discussion regarding equitable access and reasonable accommodations. If you are registered with the DRC and have a current letter requesting reasonable accommodations, please contact me as early in the semester as possible to discuss how the accommodations will be applied in the course. For more information, please see the DRC website, https://diversity.umn.edu/disability/.

Mental Health and Stress Management

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University of Minnesota services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: http://www.mentalhealth.umn.edu.

Academic Freedom and Responsibility

Academic freedom is a cornerstone of the University. Within the scope and content of the course as I have defined it, this includes the freedom to discuss relevant matters in the classroom. Along with this freedom comes responsibility. Students are encouraged to develop the capacity for critical judgment and to engage in a sustained and independent search for truth. Students are free to take reasoned exception to the views offered in any course of study, but they are responsible for learning the content of any course of study for which they are enrolled. Reports of concerns about academic freedom are taken seriously, and there are individuals and offices available for help, including me, the Philosophy Department Chair Prof. Valerie Tiberius (tiberius@umn.edu), your adviser, or College of Liberal Arts Associate Dean for Arts and Humanities Jane Blocker (block023@umn.edu).

Tentative Course Schedule

Texts other than PPCCPP, which is listed by chapter, will be linked in the Canvas site. Reading averages 40 pages per class period. You are advised to have the reading assigned for a particular day done before that day's seminar; in any case, prioritize readings in the

order listed.

24 January: Introduction, with visit from Mike Cuffaro (Cuffaro & Fletcher)

- Course Syllabus (9 pages)
- PPCCPP Introduction (19 pages)

The Computability of Physical Systems and Physical Systems as Computers

31 January: Zuse's Thesis, Gandy's Thesis, and Penrose's Thesis (Copeland, Shagrir, & Sprevak)

- PPCCPP Ch. 2 (21 pages)
- Copeland, B. Jack, Sprevak, Mark and Shagrir, Oron. (2017). Is the whole universe a computer? In B. J. Copeland, J. Bowen, M. Sprevak, and R. Wilson (eds.) *The Turing Guide*. Oxford: Oxford University Press, pp. 445–462.

7 February: Ontic Pancomputationalism (Piccinini & Anderson)

- PPCCPP Ch. 1 (16 pages)
- Fredkin, Edward. (1992). A new cosmogony. In *Workshop on Physics and Computation, Dallas, TX, USA, 1992*, Washington: IEEE, pp. 116–121. https://doi.org/10.1109/PHYCMP.1992.615507
- Lloyd, Seth. (2013). The universe as a quantum computer. In Zenil, Hector (ed.) *A Computable Universe*. Singapore: World Scientific, pp. 567–582.

14 February: Visit from Gualtiero Piccinini (Missou, St. Louis)

- Anderson, Neal G. and Piccinini, Gualtiero. (2017). Pancomputationalism and the Computational Description of Physical Systems. Unpublished manuscript, 34 pages. http://philsci-archive.pitt.edu/12812
- Chalmers, David J. (1996). Does a rock implement every finite-state automaton? *Synthese* 108(3): 309–333. https://doi.org/10.1007/BF00413692

21 February: Church's Thesis, Turing's Limits, and Deutsch's Principle (Lupacchini)

- PPCCPP Ch. 3 (21 pages)
- Post, Emil L. (1936). Finite Combinatory Processes—Formulation 1. *The Journal of Symbolic Logic* 1(3): 103–105. https://www.jstor.org/stable/2269031
- Deutsch, David. (1985). Quantum theory, the Church-Turing principle and the universal quantum computer. *Proceedings of the Royal Society of London A: Mathematical and Physical Sciences* 400(1818): 97–117. https://doi.org/10.1098/rspa.1985.0070

The Implementation of Computation in Physical Systems

28 February: How to Make Orthogonal Positions Parallel: Revisiting the Quantum Parallelism Thesis (Duwell)

- PPCCPP Ch. 4 (20 pages)
- Steane, Andrew M. (2003). A quantum computer only needs one universe. *Studies in History and Philosophy of Modern Physics* 34(3): 469–478. https://doi.org/10.1016/S1355-2198(03)00038-8
- Duwell, Armond. (2007). The Many-Worlds Interpretation and Quantum Computation. *Philosophy of Science* 74(5): 1007–1018. https://doi.org/10.1086/525640

7 March: How Is There a Physics of Information? On Characterizing Physical Evolution as Information Processing (Maroney & Timpson)

- PPCCPP Ch. 5 (24 pages)
- Landauer, Rolf. (1991). Information is Physical. *Physics Today* 44(5): 23–29. http://dx.doi.org/10.1063/1.881299
- Landauer, Rolf. (1996). The physical nature of information. *Physics Letters A* 217: 188–193. https://doi.org/10.1016/0375-9601(96)00453-7
- Ladyman, James. (2009). What does it mean to say that a physical system implements a computation? *Theoretical Computer Science* 410(4–5): 376–383. https://doi.org/10.1016/j.tcs.2008.09.047

14 March: Abstraction/Representation Theory and the Natural Science of Computation (Horsman, Kendon, & Stepney)

- PPCCPP Ch. 6 (23 pages)
- Fletcher, Samuel C. (2018). Computers in Abstraction/Representation Theory. *Minds & Machines* 28(3): 445–463. https://doi.org/10.1007/s11023-018-9470-9

Physical Perspectives on Computer Science

28 March: Physics-like Models of Computation (Sutner)

- Margolus, Norman. (1992). A Bridge Of Bits. *Workshop on Physics and Computation, Dallas, TX, USA, 1992*, Washington: IEEE, pp. 253–257. https://doi.org/10.1109/PHYCMP.1992.615551
- PPCCPP Ch. 7 (19 pages)
- Margolus, Norman. (1984). Physics-like models of computation. *Physica D* 10(1–2): 81–95. https://doi.org/10.1016/0167-2789(84)90252-5

4 April: Feasible Computation: Methodological Contributions from Computational Science (Moir)

- PPCCPP Ch. 8 (23 pages)
- Tedre, Matti. (2011). Computing as a Science: A Survey of Competing Viewpoints. *Minds & Machines* 21(3): 361–387. https://doi.org/10.1007/s11023-011-9240-4

11 April: Relativistic Computation (Andréka, Madarász, Németi, Németi, & Székely)

- Section 2 of: Manchak, John and Roberts, Bryan W. (2016). Supertasks. *The Stanford Encyclopedia of Philosophy* (Winter 2016 Edition), Edward N. Zalta, ed. https://plato.stanford.edu/archives/win2016/entries/spacetime-supertasks/
- PPCCPP Ch. 9 (21 pages)

Computational Perspectives on Physical Theory

18 April: Maxwell's Demon Does not Compute (Norton)

- Norton, John D. (2011). Waiting for Landauer. *Studies in History and Philosophy of Modern Physics* 42(3): 184–198. https://doi.org/10.1016/j.shpsb.2011.05.002
- PPCCPP Ch. 11 (17 pages)

25 April: Intension in the Physics of Computation: Lessons from the Debate about Landauer's Principle (Ladyman)

- Ladyman, James and Robertson, Katie. (2013). Landauer defended: Reply to Norton. *Studies in History and Philosophy of Modern Physics* 44(3): 263–271. https://doi.org/10.1016/j.shpsb.2013.02.005
- Norton, John D. (2013). Author's Reply to Landauer Defended. *Studies in History and Philosophy of Modern Physics* 44(3): 272. https://doi.org/10.1016/j.shpsb.2013.04.005
- PPCCPP Ch. 10 (21 pages)

2 May: Quantum Theory as a Principle Theory: Insights from an Information-Theoretic Reconstruction (Koberinski & Müller)

- PPCCPP Ch. 12 (23 pages)
- Felline, Laura. (2018) Quantum theory is not only about information. *Studies in History and Philosophy of Modern Physics* (forthcoming, 10 pages). https://doi.org/10.1016/j.shpsb.2018.03.003
- Henderson, Leah. (2018). Quantum reaxiomatisations and information-theoretic interpretations of quantum theory. *Studies in History and Philosophy of Modern Physics* (forthcoming, 9 pages). https://doi.org/10.1016/j.shpsb.2018.06.003