Place and Time  Tuesdays and Thursdays 2:30-4PM, 5-134

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Office hours by appointment

This is an advanced graduate course about recent connections between computational complexity and physics, going beyond the fundamental connection established by quantum computing. Topics will include: quantum computing with bosons and fermions (e.g., BosonSampling and FermionSampling); computational aspects of the black-hole firewall problem and the AdS/CFT correspondence; complexity of quantum states and unitary transformations; universality of gates, cellular automata, and billiard-ball models; and quantum computing with closed timelike curves. A major part of the course will be in-class student presentations about recent results. The course is intended for students who have taken a previous quantum computing course, such as 6.845 or 2.111.

Requirements: There are only two class requirements, the paper presentation and the final project. Final grades will be determined as follows: 40% paper presentation, 60% final project. Class participation may also be taken into account in borderline cases.

Paper Presentation: All students taking the class for credit are expected to read a paper and give an in-class presentation about it. The length of the presentation will be 20-25 minutes, depending on how much time we have available. Blackboard presentations are completely fine, but we can also get a projector if there are students who want to use slides. Students should send email to the instructor, by Friday October 2, stating which paper they wish to present. Students will be notified of any conflicts and given the opportunity to pick a different paper. Paper presentations will be scheduled later, most likely for late October or early November. A list of suggested papers is included at the end of this syllabus. Students are also welcome to suggest other papers not on the list, so long as they involve novel (at least at the time the paper was written...) interfaces between computation and physics, and are not already covered in class.

Final Project: Enrolled students are also expected to complete a final project. The final project can be either a survey or synthesis of several related papers, or an original research project; and can be done either individually or in pairs. Students should turn in a final project report, and also give an in-class presentation about their final project (in December). The final project can be related to the paper presentation, but the two in-class presentations should cover different ground (one can build on the other).
Suggested Papers:

Abrams, Lloyd. Nonlinear quantum mechanics implies polynomial-time solution for NP-complete and 

Aharonov, Arad, Eban, Landau. Polynomial quantum algorithms for additive approximations of the 


Aharonov, van Dam, Kempe, Landau, Lloyd, Regev. Adiabatic quantum computation is equivalent to 

Aharonov, Jones, Landau. A polynomial quantum algorithm for approximating the Jones polynomial. 


Bao, Hayden, Salton, Thomas. Universal quantum computation by scattering in the Fermi-Hubbard 

Bennett, Leung, Smith, Smolin. Can closed timelike curves or nonlinear quantum mechanics improve 
quantum state discrimination or help solve hard problems? arXiv:0908.3023


Bremner, Jozsa, Shepherd. Classical simulation of commuting quantum computations implies collapse 

Bremner, Montanaro, Shepherd. Average-case complexity versus approximate simulation of commuting 


ph/0108010.


ph/0001071.

Hayden, May. Summoning information in spacetime, or where and when can a qubit be? arXiv:1210.0913.


Jozsa, Miyake, Strelcuik. Jordan-Wigner formalism for arbitrary 2-input 2-output matchgates and their 


Kalai, Kuperberg. Contagious error sources would need time travel to prevent quantum computation. 


Landau, Vazirani, Vidick. A polynomial-time algorithm for the ground state of 1D gapped local Hamiltonians. 


Morimae, Fujii, Fitzsimons. On the hardness of classically simulating the one clean qubit model. 
Oppenheim, Unruh. Firewalls and flat mirrors: An alternative to the AMPS experiment which evades the Harlow-Hayden obstacle. arXiv:1401.1523.


