

Course Run

Boltzmann Law: Physics to Computing (3T2020)

Instructors

- [Supriyo Datta](#), *Professor of Electrical and Computer Engineering, Purdue University*
- [Shuvro Chowdhury](#), *PhD student, Purdue University*

Audience

This course is intended to be broadly accessible to students in any branch of science or engineering who would like to learn about the conceptual framework for equilibrium statistical mechanics, its application to modern machine learning and the relation to quantum computing.

Estimated Effort

- 8-9 hours/week
- 5 weeks total

Prerequisites

This course is designed for students pursuing an undergraduate degree in engineering or the physical sciences, having a familiarity with differential equations, and linear algebra.

Languages

- Content: English | Videos: English | Transcripts: English

Course Difficulty

- Advanced

Course Learning Outcomes

After completing this course, you will be able to:

- Explain the law of equilibrium and entropy
- Understand the operation of Boltzmann machines
- Understand the operation of quantum circuits

Required Text and Materials

- None

Course Structure

- All lectures are available immediately.
- Multiple-choice self-assessments will follow each lecture to assess your understanding of the material. These questions are not graded.
- There are three (3) Practice Exams included in the course. These questions are not graded.

Course Schedule

Week	Topic	Tasks	Exams
1 Mar.29 – Apr.4	Boltzmann Law	<ul style="list-style-type: none"> Review Syllabus & Schedule tabs Review Onboarding and Exam Requirements Complete the survey View Lectures 1.1 – 1.5 Complete practice exam 1 	<p>Course begins Monday, Mar.29, 8:00 AM ET (12:00 UTC)</p> <p>Proctortrack Onboarding due by: Thursday, Apr.1 8:00 AM ET (12:00 UTC)</p> <p>Exam 1:</p> <ul style="list-style-type: none"> Opens: Thursday, Apr.1, 8:00 AM ET (12:00 UTC) Due: Tuesday, Apr.6, 8:00 AM ET (12:00 UTC) Timed: 50 minutes
2 Apr.5 – Apr.11	Boltzmann Machines	<ul style="list-style-type: none"> View Lectures 2.1-2.5 	
3 Apr.12 - Apr.18	Transition Matrix	<ul style="list-style-type: none"> View Lectures 3.1 – 3.5 Complete practice exam 2 	<p>Exam 2:</p> <ul style="list-style-type: none"> Opens: Thursday, Apr.15, 8:00 AM ET (12:00 UTC) Due: Sunday, Apr.18, 8:00 AM ET (12:00 UTC) Timed: 50 minutes
4 Apr.19– Apr.25	Quantum Boltzmann Law	<ul style="list-style-type: none"> View Lectures 4.1-4.5 	
5 Apr.26– May 2	Quantum Gates	<ul style="list-style-type: none"> View Lectures 5.1-5.5 Complete practice exam 3 Complete the survey 	<p>Exam 3:</p> <ul style="list-style-type: none"> Opens: Thursday, Apr.29, 8:00 AM ET (12:00 UTC) Due: Sunday, May 2, 8:00 AM ET (12:00 UTC) Timed: 50 minutes
May 2	Course closes		
May 4	Certificates available		

Lecture List

Overview

Week 1: Boltzmann Law

- 1.1. State space
- 1.2. Boltzmann Law
- 1.3. Shannon Entropy
- 1.4. Free Energy
- 1.5. Self-consistent Field

Week 2: Boltzmann Machines

- 2.1. Binary Stochastic Neuron
- 2.2. Orchestrating Interactions
- 2.3. Optimization
- 2.4. Inference
- 2.5. Learning

Week 3: Transition Matrix

- 3.1. Markov Chain Monte Carlo
- 3.2. Gibbs Sampling
- 3.3. Sequential versus Simultaneous
- 3.4. Bayesian Networks
- 3.5. Feynman Paths

Week 4: Quantum Boltzmann Law

- 4.1. Quantum spins
- 4.2. One q-bit system
- 4.3. Spin-spin Interactions
- 4.4. Two q-bit system
- 4.5. Quantum Annealing

Week 5: Quantum Transition Matrix

- 5.1. Quantum Gates
- 5.2. Hadamard gates
- 5.3. Grover search
- 5.4. Shor's Algorithm
- 5.5. Feynman Paths

Epilogue

Exams

- To submit exams in this course, every Verified/Master's track learner must have successfully completed an Onboarding session with Proctortrack.
 - See Taking Exams in **Boltzmann Law: Physics to Computing** (link to be inserted) for more details
- Exam Availability:
 - Each exam is available for 60 hours. You must complete the exam within the scheduled dates and times.
 - Each exam is timed. Once you open the exam, the timer will begin. The timer cannot be paused.
 - See *Schedule* tab for dates and times.
- Exams are open notes, but online tools not allowed.
- No calculators allowed.
- Blank scratch paper is allowed.

Grading

This course will be graded based on the following criteria:

Assessment Type	Description	% of Final Grade
Exam 1	Proctored, multiple-choice exam	20%
Exam 2	Proctored, multiple-choice exam	40%
Exam 3	Proctored, multiple-choice exam	40%

- Course grade will be based on three (3) proctored exams.
 - See the *Progress* tab for grade ranges (A, B, C, D, F)
- **Verified learners:** To receive an edX course certificate, you must have a passing grade.
- **Purdue University transfer credit:** Only edX Purdue MicroMasters® courses with a grade “B” or higher may be eligible for transfer to Purdue.
- **Purdue University students:** To use this course toward your MS ECE degree, you must have a grade of “C-” or higher and maintain a plan of study of 3.0.

Getting Help

- **Technical difficulties:** If you experience technical difficulties with the edX platform, contact edX Support using the [Contact Us](#) form in the Connect section at the bottom of your screen.

- **Course content issues:** If you experience any issues with course content, post your concern or question to the discussion forum.
- **For general questions** about using the edX platform, we recommend viewing the [edX Demo course](#).
- **Other edX Resources**
 - [Technical Help](#)
 - [Learner Help Center](#)

Discussion Guidelines

- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Do not hesitate to ask for feedback.
- Be concise and to the point. Give other students the opportunity to join in the discussion.
- Think and edit before you push the “Post” button.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either [emailing](#) or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

[The Purdue Honor Pledge](#)

“As a Boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue”

Accessibility Support

Purdue University and edX strive to make learning experiences as accessible as possible.

If you anticipate or experience physical or academic barriers based on disability:

- You are welcome to let your instructor know so that you can discuss options.
- Instructor: Prof. Supriyo Datta at: datta@purdue.edu
- [edX Accessibility Policy](#)
- [ProctorTrack Web Accessibility Policy](#)

Purdue Student Accessibility Resources

- Purdue students are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.
 - [Purdue Disability Resource Center Website](#)
 - [Purdue Web Accessibility Policy](#)
 - [Purdue Equal Access Frequently Asked Questions \(FAQs\)](#)
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For accessibility concerns beyond this, the **Office of Institutional Equity** is responsible for ensuring Americans with Disability Act compliance, can be contacted with any accessibility concerns at:

- Phone: (765) 494-7253
- Email: equity@purdue.edu
- TTY: (765) 496-1343
- [Website](#)

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. [Link to Purdue's nondiscrimination policy statement.](#)

Academic Guidance due to Quarantine/Isolation

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email: datta@purdue.edu or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Attendance Policy during COVID-19

Students should stay home and contact the Protect Purdue Health Center (496-INFO) if they feel ill, have any symptoms associated with COVID-19, or suspect they have been exposed to the virus. In the current context of COVID-19, in-person attendance will not be a factor in the final grades, but the student still needs to inform the instructor of any conflict that can be anticipated and will affect the submission of an assignment or the ability to take an exam. Only the instructor can excuse a student from a course requirement or responsibility. When conflicts can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or

emergency conflict, when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email, through Brightspace, or by phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases of bereavement, quarantine, or isolation, the student or the student's representative should contact the Office of the Dean of Students via [email](#) or phone at 765-494-1747. Our course Brightspace includes a link on Attendance and Grief Absence policies under the University Policies menu.

Classroom Guidance Regarding Protect Purdue

The [Protect Purdue Plan](#), which includes the [Protect Purdue Pledge](#), is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, wearing a mask [in classrooms and campus building](#), at all times (e.g., no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining proper social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the [Office of the Student Rights and Responsibilities](#). See also [Purdue University Bill of Student Rights](#).