Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.008 Introduction to Inference
Fall 2018

Information Sheet

Lecturers

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Lectures:	Monday and Wednesday, 10-11am, Room 32-155
Recitations:	Tuesday and Thursday, 12noon-1pm (35-308) or 1-2pm (34-302) or 2-3pm (34-302)
Lab Hours:	Wednesday 4-8pm, Thursday 5-9pm, Friday 11am-2pm (38-530)
Office Hours:	Days, times and locations posted on web site.

Welcome to 6.008 !

We live in a world in which we constantly need to extract information from data. This is the central problem of inference. And computationally efficient methods for such inference are enabling technologies for an enormous range of applications.

Example domains abound, and include search and retrieval, data mining, computer vision and computational imaging, voice recognition and natural language processing, communication and compression, robotics and navigation, computational biology and bioinformatics, medical diagnosis, distributed sensing and monitoring, and finance.

Many of the most successful inference algorithms arise out of probabilistic modeling and analysis. If you want to learn the fundamentals of this discipline and see some of what you can do with it, this subject is the place to start. Indeed, it will provide a solid foundation for more advanced subjects that build on this framework of reasoning. As such, the subject is targeted at (and likely to strongly appeal to) students both across and beyond Course 6 (EECS).

Lectures, Recitations, Lab Sessions, and Office Hours

As with other core subjects, 6.008 has lectures and recitations, which are designed to complement each other. Recitations begin the first week of classes. There are three possible recitation times from which you can choose. Select to attend whichever suits your schedule best; if strong imbalances result, we will make adjustments.

6.008 also has scheduled lab hours that while optional are highly recommended and will help you with the laboratory component of the class. Lab hours start the first week of classes.

In addition, there will be several scheduled staff office hours throughout the week, the details of which are provided on the class website. You are welcome and encouraged to come to any and all of them you think might be helpful to you in digesting the material.

Prerequisites

The official prerequisite is calculus. Effectively, we are assuming you are comfortable with (and fluent in) basic mathematical analysis to the level of, e.g., 18.02. In addition, we assume you are familiar with the basics of the python programming language, but will provide a tutorial in the first week of classes (specifically, Thursday, Sep. 6, 7-8pm in 38-530) to help you come up to speed on the aspects of python that will be needed in the laboratory component of the subject. Finally, we emphasize that no prior exposure to probability is required, as we develop the necessary foundations in probability as part of this class.

Degree Requirements

For EECS students, the requirements satisfied by 6.008 will change in the future as the department implements the new undergraduate curriculum. The following requirements are true for the Fall 2018 offering of 6.008:

- EECS students can use this as one of their EECS or EECS12 subjects.
- EECS students in 6-2 program may use 6.008 as one of their EE or CS foundation subjects.
- All EECS students may petition to use 6.008 as an introductory subject instead of 6.01/6.02/6.03/etc. Note that the petition must be submitted and approved (by the lecturers) before the Fall 2018 add date.
- EECS students may use this as their PROB subject.
- EECS students in 6-3, 6-7, and 6-14 may petition to take 6.008 instead of the required subject 6.042, and use it as a prerequisite for more advanced subjects

that require 6.042. Note that the petition must be submitted and approved (by the lecturers) before the Fall 2018 add date. In approving this petition, we need to verify that you either have sufficient background in constructing formal proofs (an essential component of 6.042 that more advanced subjects rely on) or that you are committed to acquiring such background on your own.

- All EECS students may use 6.008 as one of their free elective subjects.
- M.Eng. students may petition to use 6.008 as one of their Math Restricted Elective subjects. As always, no double counting is allowed.

Non-EECS students should consult their departments about what degree requirements 6.008 can satisfy for them.

If you have additional questions about degree requirements, please contact the lecturers. We will be happy to meet with you and discuss.

Reading

There is no existing text that matches the content of this relatively new subject and the style in which we teach it. However, we have been actively developing detailed course notes for the class, which we will distribute in parts throughout the term. In this development stage, the notes will be necessarily rough in places and contain bugs, which we will count on you to help us catch.

In addition, you may find the following text a useful auxiliary resource for the subject:

> D. P. Bertsekas and J. N. Tsitsiklis, *Introduction to Probability*, 2nd ed., Athena Scientific, 2008.

If having your own copy would be handy, it may be purchased through, e.g., Amazon. We will also place this book on reserve at the MIT libraries (Barker). Other possibly useful readings will be posted on the course web site as appropriate.

We emphasize that the course notes do *not* replace the lectures and recitations. The notes will be necessarily incomplete, and many of the perspectives, interpretations, and insights will be developed in class. Conversely, lectures and recitations are not a substitute for the notes. Indeed, we will defer many details of our development to the reading materials. Thus, you should view class and the written materials as strongly complementary.

Worked Exercises and Videos

To supplement the course notes, we are starting to develop a collection of worked exercises that demonstrate how to apply the concepts in simple settings. When we have them, we will make such exercises available in conjunction with the problem

sets. You may find these useful to go through after reading the relevant sections of the course notes as a way to help you get started with the homework. We emphasize, however, these posted exercises are entirely optional reading—use them if/however you think they will be helpful to you.

In addition to written materials, we have also been developing a repository of Khan Academy style videos to help you digest the reading and further explain concepts in the subject. These videos are optional viewing; they are another supplementary resource for the class.

Problem Sets and Computational Labs

There will be 11 problem sets (1-11) and 5 computational labs (I-V). The problem sets emphasize analysis aspects of the material, while the computational labs involve a programming component, based on python (version 3), to help you explore computational aspects of the material.

Problem sets and computational labs will be concurrent (and jointly designed), so that at any time you will be working on one problem set and one computational lab. It will be important to manage your time carefully, and allow enough time for them.

Problem sets will be due by 10am on Wednesday, in lecture. Computational labs will be due by 5pm on their submission dates and are to be submitted electronically. Solutions will be available on the course web site immediately after the due dates and times, and thus we cannot accept late submissions for grading. To help with your planning, due dates are listed on the schedule at the end of this handout.

While you should do all the assigned problems and computational lab components, only a subset will actually be graded. Also, you will find a set of "practice" problems in every problem set. These are not required, but you may find it helpful to work through them if you are looking for more practice working with the concepts introduced in class.

Don't be misled by the relatively few points assigned to homework in the final grade calculation. While the grade you get on your homework is only a minor component of your final grade, working through (and, yes, often struggling with!) the homework is a crucial part of the learning process and will invariably have a major impact on your understanding of the material.

In undertaking the problem sets and computational labs, moderate collaboration in the form of joint problem solving with one or two classmates is permitted provided your writeup (and all code) is your own and that you identify your collaborators in your writeup.

Exams

There will be two evening quizzes and a final exam in the subject. Dates for the quizzes are Wednesday, October 3, 7:30-9:30pm (conflict date: October 4, 9-11am),

and Wednesday, November 7, 7:30-9:30pm (conflict date: November 8, 9-11am). Both quizzes will be held in Room 32-141. Please let us know at least three weeks in advance if you have a conflict with the quiz time and need to make use of the conflict date. Note also that because of the evening quizzes, the corresponding Wednesday, October 3 and Wednesday, November 7 lectures are canceled.

The final exam will be during Finals Week, the exact date of which we will announce when scheduled by the Registrar.

The quizzes and final exam will all be *closed book*. You will be allowed to bring *one* 8.5 × 11-inch sheet of notes (both sides) to Quiz 1, *two* 8.5 × 11-inch sheets of notes (both sides) to Quiz 2, and *three* 8.5 × 11-inch sheets of notes (both sides) to the Final Exam.

Course Grade

The final grade in the course is based upon our best assessment of your understanding of the material during the semester. Roughly, the weights used in grade assignment will be:

Quiz 1	20%
Quiz 2	20%
Final Exam	30%
Problem Sets	10%
Computational Labs	15%
Classroom participation	5%

with the additional property that if you do better on the Final Exam than either quiz, and you have done all the problem sets, then the corresponding quiz will not count, i.e., the quizzes can only help you if you are doing all the homework. Also, please note that completing all the computational labs is a subject requirement.

Finally, as always, other factors such as contributions to the discussion in class and other interactions can make a difference in your final grade.

Course Web Site, Email, and Piazza

We will make announcements via email, and we will post information and handouts on the course web site.

You should first make sure that you have an active Athena account (by visiting `http://ist.mit.edu/support/accounts/` if necessary) as well as a personal certificate (by visiting `https://ca.mit.edu/ca/` if necessary). If you have problems or if you are not a regular MIT student, please contact one of the TAs for assistance.

The course web site is:

`http://web.mit.edu/6.008`

You will need to have a valid certificate *and* be on the official course list to access the web site. If you have pre-registered for 6.008, this should have already been set up. Otherwise, contact one of the TAs. If you can access content on the web site, you should also be receiving all of the course announcements.

We use piazza as an on-line discussion forum. Through piazza you can post questions or comments about any aspects of the material, which your peers and the staff can respond to. It is great way to clarify potential points of confusion in course notes, problem sets, recitation handouts, computational labs, etc. You can access the piazza forum through the link provided on the class web site. Once you enroll yourself, you can fully participate in the discussions.

Administrative Questions and Help

If you have administrative questions during the term, you can send email to

`6.008-admin@mit.edu`

We will be glad to help you, but please do not ask questions that are already answered in this handout!

Tentative Syllabus and Schedule

	Date	Topic	HW out	HW due
W	9/5	L1: Introduction and overview	1 (L1), I	
F	9/7	Optional Python review, Room TBA		
M	9/10	L2: Probabilistic modeling		
W	9/12	L3: Discrete random variables, information measures	2 (L2,3)	1
F	9/14			I
M	9/17	L4: Joint distributions, marginalization, joint information		
W	9/19	L5: Conditioning, Bayes Rule, conditional information	3 (L4,5)	2
F	9/21	*Student Holiday – no lab hours*		
M	9/24	L6: Independence structure, mutual information	II	
W	9/26	L7: Decision-making, most probable configurations, MAP rule	4 (L6,7)	3
M	10/1	L8: Graphical models, message-passing, hidden Markov models Optional Quiz Review, 7:30-9:30pm, Room TBA		
W	10/3	**Quiz 1** (through L7), 7:30-9:30pm, Room 32-141, *no class*		
F	10/5	*Add Date*		
M	10/8-9	*Columbus Day – no class*		
W	10/10	L9: HMM marginalization: forward-backward algorithm	5 (L8,9)	4
F	10/12			II
M	10/15	L10: HMM most probable configuration: Viterbi algorithm	III	
W	10/17	L11: Parameter estimation, Maximum Likelihood method	6 (L10,11)	5
M	10/22	L12: Model learning; Naïve Bayes Models and HMMs		
W	10/24	L13: Learning structure in graphical models	7 (L12,13)	6
M	10/29	L14: Markov/Chebyshev bounds, law of large numbers		
W	10/31	L15: Typical sets, compression and hashing	8 (L14,15)	7
F	11/2		IV	III
M	11/5	L16: Joint typicality, classification and communication Optional Quiz Review, 7:30-9:30pm, Room TBA		
W	11/7	**Quiz 2** (through L15), 7:30-9:30pm, Room 32-141, *no class*		
M	11/12	*Veterans Day — no class*		
T	11/13	*No recitation*		
W	11/14	L17: Atypical sequences, large deviations and max-entropy	9 (L16,17)	8
F	11/16			IV
M	11/19	L18: Markov chains and random walks		
W	11/21	L19: Sampling and approximate inference *Drop Date*	10 (L18-20)	9
Thu/F	11/22-23	*Thanksgiving – no recitation, no lab hours*		
M	11/26	L20: Markov chain Monte Carlo and Gibbs sampling	V	
W	11/28	L21: Continuous random variables, information measures		
M	12/3	L22: Joint PDFs; continuous inference		
W	12/5	L23: Jointly Gaussian random variables, innovations	11 (L21-25)	10
F	12/7			V
M	12/10	L24: Gaussian inference and modeling; linear inference		
W	12/12	L25: Central limit theorem, Laplace approximations		
		Final Exam, *Finals Week, 12/17–12/21*		