MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

Physics 8.286: The Early Universe — Wednesday, September 5, 2018
Prof. Alan Guth

COURSE INFORMATION

INSTRUCTOR: Alan H. Guth, Room 6-322, Ext. 3-6265, guth@ctp.mit.edu.

TEACHING ASSISTANT: Honggeun Kim, hgkim@mit.edu.

LECTURE HOURS: Mondays and Wednesdays, 11:05 a.m. – 12:25 a.m., in Room 4-231.

REQUIRED TEXTBOOKS:

Introduction to Cosmology, Second Edition (Cambridge University Press, 2016), by Barbara Ryden.

The First Three Minutes, 2nd paper edition (Basic Books, 1993), by Steven Weinberg.

RECOMMENDED BOOKS:

An Introduction to Modern Cosmology, 2nd Edition (Wiley, 2003), by Andrew Liddle.

The Inflationary Universe (Perseus Books, 1997), by Alan H. Guth. This was written as a popular-level book, and therefore has no equations. It does not, however, shy away from trying to explain the relevant principles of physics and their logical connections. It attempts a kind of story-telling flavor, describing the history of twentieth century cosmology, and also the story of my own involvement in cosmology. The course will in no way follow this book, but you might like it.

LECTURE NOTES AND OTHER READING:

There is no textbook that I know of that is really appropriate for the intended content of this course, although Barbara Ryden's book, **Introduction to Cosmology**, comes much closer than any book I have seen previously. Steven Weinberg's **The First Three Minutes** is a superbly written book which gives an excellent description of cosmology in general, and the synthesis of the light chemical elements in particular. But it does not describe the mathematical details. It has a mathematical appendix, but the description there is very sketchy. We will try to fill in some of the mathematics behind Weinberg's descriptions in class.

The bulk of the course, nonetheless, will be based on lecture notes that will be posted periodically on the course website. The material in these lecture notes will be essential for doing the problem sets and quizzes, and will form the backbone of the course. (Incidentally, David Kaiser and I are currently working on an undergraduate textbook on cosmology, which will be mainly based on these lecture notes.)

For the first part of the course (classical cosmology), the lectures and the associated lecture notes will describe the subject at a level of detail that is much more mathematical than Weinberg's book, and a little beyond the level of Ryden's book. For the second part of the course (modern particle physics and its recent impact on cosmology), we will rely mostly on the lecture notes, although Ryden does have a good chapter on inflation. You will also be asked to read several articles from *Scientific American* or similar publications.

GRADING:

75% of the course grade will be based on quizzes, which will be given in class during the normal lecture period. There will be three of these quizzes, and there will be no final exam. The remaining 25% of the grade will be based on problem sets. Problem sets will normally be assigned every week, but there will be some breaks due to holidays and in-class quizzes. There will be 9 or 10 problem sets altogether.

TENTIVE DATES FOR IN-CLASS QUIZZES:

1) Wednesday, October 3, 2018 (8 preceding classes)
2) Monday, November 5, 2018 (7 classes since first quiz)
3) Wednesday, December 5, 2018 (7 classes since second quiz)

SPECIAL RELATIVITY:

I think that many of you have studied some special relativity, but special relativity is not a prerequisite for this course. For the benefit of those who have not studied special relativity, the basic results are summarized in Lecture Notes 1. I expect that you will be able to understand and occasionally use these statements, but we will not discuss how they are derived. For those who are interested, a few references are mentioned in Lecture Notes 1. I would be happy to talk to students outside of class about how the results of special relativity are derived, or anything else about special relativity. There will be a few more results from special relativity that will be needed as the course progresses ($E = mc^2$, for example), and I will try to point them out and summarize them carefully as we go along.

COURSE OUTLINE:

1. Doppler Effect (and a little Special Relativity)
2. Kinematics of Newtonian Cosmology
3. Dynamics of Newtonian Cosmology
4. Introduction to Non-Euclidean Spaces
5. Black-Body Radiation and the Early History of the Universe
6. The Accelerating Universe and the Cosmological Constant
7. Big-Bang Nucleosynthesis
8. Problems of the Conventional (Non-Inflationary) Hot Big Bang Model
9. Grand Unified Theories and the Magnetic Monopole Problem
10. The Inflationary Universe Model
11. Primordial Density Fluctuations and the Cosmic Microwave Background
12. Eternal Inflation and the Multiverse

HOMEWORK LOGISTICS

Problem sets will ordinarily be due at 5:00 pm on Fridays, to be turned in at the homework boxes at the intersection of buildings 8 and 16 (3rd floor bldg. 8, 4th floor bldg.16). You may also email your problem sets, sending them both to hgkim@mit.edu and guth@ctp.mit.edu. The first problem set will be due on Friday, September 14, 2018.

The problem sets will not all be assigned the same number of points. Your final problem set grade will be the total number of points you receive, divided by the number of points possible. Problem sets with more assigned points, therefore, will count more toward your grade.

All problem sets will count, none will be dropped. My reason for this policy is that I feel that the problem sets are an important component of the course, so I want to encourage you to do every one of them. However, I am fully aware that MIT students are active people who lead complicated lives, and that these complications can make it hard to turn in a problem set every week at 5 pm on Friday. So, to make up for the fact that no problem set grades will be dropped, I will be generous with extensions, while still expecting students to do all the problem sets during the term. If you find that you are having an unusually busy week and cannot fit in the 8.286 problem set, I'm okay with giving you an extension — just send an email describing the situation, and ask me for an extension.

HOMEWORK POLICY:

In this course I regard the problem sets primarily as an educational experience, rather than a mechanism of evaluation. I have allocated 25% of the grade to problem sets in order to encourage you to do them, and to make life easier for students who find it difficult to do well on quizzes. You should feel free to work on these problems in groups, and I would strongly encourage you to do so. With the right mix of students, the homework can be more fun and more illuminating. I will in fact soon be setting up a Class Contact webpage to help you make contact with each other.

However, it is important pedagogically that each student write up the solution independently. The simple copying of a friend's paper is not the kind of effort that the grading is intended to encourage. Using 8.286 solutions that have been circulated in previous years is strictly off limits. Using other sources, such as other textbooks or web documents, is considered perfectly okay, as long as you write up the solution in your own words.

A homework problem which appears to be copied from another student, from a solution circulated in a previous term, or copied more or less verbatim from some other source (without rewriting in your own words) will be given a reduced grade, possibly a zero. Except in blatant cases, however, students will be given a warning the first time this happens, and will be given an opportunity to redo the relevant solutions. Since the homework is intended primarily for learning, and not evaluation, there is nothing that you can do on the homework — in this course — that will lead to an interview with the Committee on Discipline. I say this because I want to strongly encourage you to work in groups on the homework, and I don't want you to feel that there are any hidden dangers. (Remember, however, that you should not assume that this policy holds in other classes; different professors have different points of view on these issues.)

MORE ADVANCED READING:

There are some excellent graduate-level textbooks on cosmology that some of you might want to look at. These books are well beyond the level of this course, but I mention them in case any of you become interested in pursuing some topic at a more advanced level. The first two are written from the astrophysical point of view, while the last five describe the early universe more from the particle physicists' slant:

Cosmological Physics (Cambridge University Press, 1999), by John A. Peacock.

Principles of Physical Cosmology (Princeton University Press, 1993), by P.J.E. Peebles.

Cosmology (Oxford University Press, 2008), by Steven Weinberg.

Modern Cosmology (Academic Press, 2003), by Scott Dodelson.

Physical Foundations of Cosmology (Cambridge University Press, 2005), by Viatcheslav Mukhanov.

The Early Universe (Addison-Wesley, 1990), by Edward W. Kolb and Michael S. Turner.

Particle Physics and Inflationary Cosmology (Harwood Academic publishers, 1990), by Andrei Linde.

THE COURSE WEBSITE:

http://web.mit.edu/8.286/www

We will use the Gradebook of the Stellar system, but all course information will be posted at the URL above.