MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

Physics 8.286: The Early Universe — Friday, August 31, 2007
Prof. Alan Guth

COURSE INFORMATION

INSTRUCTOR: Alan H. Guth, Room 6-322, Ext. 3-6265, guth@ctp.mit.edu.
RECITATION INSTRUCTOR: Barton Zwiebach, Room 6-305, Ext. 3-4839, zwiebach@mit.edu.
TEACHING ASSISTANT: Yi Mao, Room 6-413, Ext. 3-9300, ymao@mit.edu.
LECTURE HOURS: Tuesdays and Thursdays, 9:35 – 10:55 a.m., in Room 37-212.
RECITATION HOUR: Fridays, 11:05 – 11:55 a.m., in Room 4-231.

OPTIONAL RECITATION CLASSES:

This semester, for the first time, there will be recitation classes associated with 8.286, taught by Prof. Barton Zwiebach.

Since the recitations were scheduled too late to be an official part of the course, they will be **OPTIONAL.**

The classes will be used to review material from the lectures and reading, to discuss homework problems and perhaps other problems similar to the homework problems, and occasionally to introduce supplementary material. Since the classes are optional, any new material that might be introduced will not be included on any course exams or required problem sets. Students should be advised to keep this time available if at all possible. If they cannot come to the recitations, however, they should be assured that there will be no penalty in terms of grades.

REQUIRED TEXTBOOKS:

Introduction to Cosmology (Addison-Wesley, 2003), by Barbara Ryden.

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

RECOMMENDED BOOKS:

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

The Big Bang (W H Freeman & Co., 2001), by Joseph Silk. Also **The Infinite Cosmos: Questions from the Frontiers of Cosmology** (Oxford University Press, 2006), by Joseph Silk.

Cosmology, Fourth Edition (Clarendon Press, Oxford, 2004), by Michael Rowan-Robinson.

The Inflationary Universe (Perseus Books, 1997), by Alan H. Guth.
(I know him, I think)

Particle Physics in the Cosmos (W.H. Freeman, 1989), edited by R.A. Carrigan, Jr., and W.P. Trower. A collection of readings from *Scientific American*. No longer in print, but Amazon.com still has listings for used copies. It's old, but contains a number of excellent articles, such as Howard Georgi on grand unified theories, Gerard 't Hooft on the structure of gauge theories, Steve Weinberg on grand unified theories and proton decay, and Frank Wilczek on the cosmic asymmetry between matter and antimatter.

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. Weinberg's book has been required reading for this course since the first time it was taught, in 1986. Before 2000 I used Joseph Silk's **The Big Bang** as a second required book in this course, and in 2000 and 2002 we used Rowan-Robinson's **Cosmology** instead. We used Barbara Ryden's book for the first time in 2004.

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.

In previous years the textbooks by Silk or Rowan-Robinson provided a more observationally oriented perspective on cosmology than my own lecture notes. Ryden's book will serve this purpose to some extent, but the emphasis of this book is much closer to that of my lecture notes. The book will therefore be more useful in helping to clarify and reinforce the topics covered in the lecture notes, but a little less useful in opening windows on topics that are not covered in the 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 be assigned every week or two, depending on the length of the problem sets and on the pacing of the material being covered.

SPECIAL RELATIVITY:

In the “old” days I began this course with a unit on special relativity, which consisted of two sets of lecture notes and about four lectures. However, with the advent of 8.033 this seemed a bit redundant, so in 1996 I dropped relativity from the syllabus. Nonetheless, since the notes are written and the subject has some relevance to cosmology, I will still post the lecture notes, for those who want to read them. You will be required to read only the part about the Doppler shift, which is on pp. 1–6, 13–15, and 17–18 of Lecture Notes 1. Except for these sections, there will be no homework and no quiz problems related to special relativity. There are just a few notions from special relativity that are really necessary for the rest of the course (such as $E = mc^2$ — heard of that?), and I will make sure 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 Standard Cosmological Model
9. The Standard Model of Particle Physics
10. Grand Unified Theories and the Magnetic Monopole Problem
11. The Inflationary Universe Model

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 tests. 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. 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, and if discovered it will result in reduced credit for that assignment, possibly down to no credit at all. Solutions to many of the problems have been circulated in previous years, but I urge you for pedagogical reasons not to use these solutions— it is far better for you to figure out the answers, either on your own or with a group of friends. A homework paper which appears to be copied from a solution circulated in a previous term will also be given a reduced grade, possibly a zero. 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 hidden dangers.

MORE ADVANCED READING:

There are some excellent graduate-level textbooks on cosmology that 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 four describe the early universe 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.

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

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