

University of Maryland Department of Physics, College Park, MD
20742
Physics 199M
The Manhattan Project Spring 2012

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Office Hours

Office hours are from 3:00-4:00 Mondays. I am also generally available in my office and happy to see students; just drop by--or, better yet, give me a call and then drop by.

Course Description

"How did the world come to develop nuclear weapons?"

This course seeks to answer this question. As such it is both a course about history and about science. The history deals with one of the critical events in the world's history--- one whose ramifications are of central importance today. However, it is impossible to understand this history without understanding the science behind it.

The course will begin with some essential background: an introduction to some of the critical ideas of nuclear physics and a review of some key historical developments beginning at the end of the first world war (such as the Great Depression and the collapse of Weimar Germany with the rise of the Nazi movement). Nuclear Physics will be developed in a chronological manner starting with the discovery of radioactivity by Becquerel in 1896, and going through to the discovery of fission in Germany in 1938. One advantage of this chronological approach is that students will gain a sense of how scientific knowledge builds. A key question in this part of the course is, "What were the political and social forces which enabled this science to develop?"

The course then turns to the Manhattan Project, the massive US effort to develop the "atomic bomb" (as it was then called). The politics surrounding the project's inception will be studied extensively. A key question here is "What were the political forces which led the United States to devote massive resources during war time for a project which could have seemed to be science fiction?" The history of the Manhattan Project will be studied in some detail including the political, scientific, military, social and economic issues. The scientific community's rapid, and secret, development of an understanding of fission is a critical part of this history. The course will focus on some of the key aspects of this science, including the distinct roles played by slow and fast neutrons, the concept of critical mass, the qualitative differences between uranium 235 versus uranium 238, the discovery of plutonium and the possibility of chain-reactions based on either uranium or plutonium. The engineering challenges associated with the

development of the bomb are also a central focus of the course. These included the need to develop massive facilities to enrich uranium and to breed plutonium. The challenges associated with the design of the bombs themselves will also be discussed with an emphasis on why a simple design was possible for a uranium weapon but a much more complicated implosion design was needed for plutonium weapons. In considering the Manhattan Project, it is useful to compare it to the unsuccessful effort in Germany to develop nuclear weapons and to consider what led to the success of one effort and the failure of the other.

A final theme in this course is the set of ethical issues associated with the Manhattan Project. A central question is whether the scientists involved had a special ethical obligation to consider the ends to which their work would be used.

Mathematical Preparation

This course has no prerequisites. However, the course will use mathematics extensively. While the mathematics required does not go beyond the level of a standard high school algebra 2 course class, students will need to be comfortable applying mathematics at this level. Students are not required to have taken a class at the precalculus level; however, students might find it helpful to have taken a class at that level.

Reading

The primary reading for the course is *The Making of the Atomic Bomb* by Richard Rhodes (Simon and Shuster, 1987); ISBN 0671441337. This book is often considered a masterpiece and won numerous awards including the Pulitzer Prize and the National Book Award. It has been praised by historians and by former Los Alamos weapon scientists. It describes the development of the nuclear physics in the first half of the 20th century as well as the development of the first nuclear weapons during the Manhattan Project. There will also be supplementary readings.

The course also has assigns Michael Frayn's brilliant play *Copenhagen* (Anchor Publisher, 2010) ISBN978-0-4-1377371-5 This Tony Award winning play deals with a meeting between Werner Heisenberg and Niels Bohr in Nazi occupied Denmark in 1941. The play raises many of the issue raised by the course. Students should either read the play, or watch a performance of it. There is a DVD of the play (a PBS Hollywood Presents production) starring Stephen Rea, [Daniel Craig](#) and [Francesca Annis](#); it is available on both Amazon and Netflix.

Pedagogical Approach

The course will have both a lectures and discussion sections. Each of these will address both the scientific and the historical aspects of the course.

Lectures:

The lectures are intended to be as interactive as possible given the size of the class and the instructor will encourage students to ask questions.

One way to ensure that the lectures are interactive is to exploit "clicker" technology. One use of clickers

will be via the “Mazur peer instruction method” developed at Harvard to aid students in understanding conceptual issues in science. Students will be asked a carefully crafted question which focuses on an important and subtle issue. They will then vote on answers using clickers. Next they will be asked to spend a couple of minutes discussing the answers with their neighbors in the lecture room. The students then vote again with the clickers. There is considerable evidence that the discussion with peers greatly improve understanding. Clickers will also be used to take polls of student attitudes on ethical questions of relevance to the course or on broad and controversial issues of history. These poll results will help serve as a basis for discussion on major issues in lectures. Finally, clickers will be used for rapid in-class quizzes.

Sections:

Many activities will take place in the discussion sections.

One standard activity, which will occur most weeks, will be to work through problems similar to those on the problem sets in an informal and highly interactive manner.

Most other activities will be done in small groups of 4 or 5 students. One of these is aimed at working through more complex scientific problems than a typical student could handle easily on their own, but through discussion a group of students should be able to work through. At the end of the activity, one member of the group can describe the solution to the full class. Another small group activity will be the discussion of questions with historical or ethical implications. These questions will be ones, which are open in the sense that reasonable people might come to different conclusions, but for which interesting and insightful analysis is possible. A typical question of this sort might be “Albert Einstein wrote to Franklin Roosevelt about the possibility of ‘extremely powerful bombs of a new type’ based on uranium and urged the US government to secure supplies of uranium and speed experimental work on uranium. This letter helped launch the Manhattan Project. In doing this did he betray his pacifist principles?” Groups will discuss such questions and try to reach a consensus. At the end of the discussion one member of the group will report to the full class the results of the discussion. All students will be expected to report their group’s efforts at least once during the semester.

Assignments and Grading Policies

- Problem sets: 10 problem sets will be assigned during the semester on the scientific aspects of the course. It is impossible to learn the science without working through examples. The problem sets will make up approximately 15% of the course grade. Note, only a representative sample of the problems will be graded. Solutions for the problem sets will be posted on the course web site.
- Papers. There will be two written assignments during the semester. The first of these will be a short paper (3-4 pages) analyzing how the play *Copenhagen* deals critical historical, ethical and scientific issues raised in the course. The second paper will be somewhat longer (5-8 pages). In it students will focus on one of the central figures in the Manhattan Project and analyze his or her role in some key event. Collectively, these papers will account for approximately 25% of the final grade with 10% for the first paper and 15% for the second.
- Quizzes: There will be quizzes on the reading. Collectively these will account for 10% of the grade.

- Class Participation will be worth 10% of the grade. This includes both participation in the activities in the discussion sections and with the “clicker questions” in lecture
- There will be a midterm exam and a final exam in this course. Together these will account for approximately 40% of the total grade.
- Grading policies
 - Grades will NOT in general be given according to the scheme in which numerical scores greater than 90 corresponds to an A, between 80 and 90 a B etc. Rather, the correspondence between letter grades and numerical scores will depend on many factors including the difficulty of the assignment.
 - If a student miss a quiz or a problem set for a legitimate reason, he or she will be awarded the average score obtained for other quizzes or problem sets during the semester.
 - Late problem sets will not be accepted.
 - Late papers will be accepted. However, scores will be reduced by 10% for each day late. Papers more than 10 days late will not be accepted.

Course Outline

A. Background

This unit will develop the scientific and historical background needed to understand the remainder of the course. Background scientific information ranging from the concept of energy to some basic ideas about relativity and quantum mechanics will be introduced. Key developments in nuclear physics from the discovery of radioactivity through the discovery of the nucleus by Rutherford and the discovery of the neutron by Chadwick will be at the core of this unit. The unit ends with the discovery of nuclear through the discovery of fission in 1938.

Historical background will also be developed. Major historical events in the first part of the Twentieth will be reviewed. The circumstances of the late 1930s will be discussed in detail with an emphasis on both the military and political situation and on the particular issues affecting science and scientists including the large number of Jewish scientists who fled the Nazis.

Reading: Chapters 1-9 in Rhodes

Problem sets: There will be 5 problem sets on the material in this section:

1. Basic problems concerning the nature of energy; exponentials
2. Relativistic Mass-Energy relations; radioactive decay chains
3. Quantum Physics and the statistical nature of nuclear decays; the concept of half-lives
4. Atomic and nuclear models
5. Nuclear energetics and fission.

- B. From the discovery of fission to the establishment of Los Alamos** This unit covers the period from 1938 through 1942. During this period World War II erupted with the United States entering

the war following the Japanese attack on Pearl Harbor on December 7, 1941. The unit focuses largely on the how the Manhattan Project emerged and in particular how the US Government became committed to such a massive and secret undertaking. Scientifically the unit focuses on fission. The remarkable scientific advances during the years following 1938 are introduced with an emphasis on the very different behavior of ^{235}U and ^{238}U regarding their responses to fast and slow neutrons and the implications of this for both weapons and reactors. Another critical scientific issue on which the unit focuses is the discovery of the transuranic element plutonium with a fissile isotope, ^{239}Pu .

Reading: Chapters 10-13 in Rhodes; *Copenhagen*

Paper: A short paper (3-4 pages) analyzing how the play *Copenhagen* deals critical historical, ethical and scientific issues raised in the course will be due at the end of this section.

Problem sets: There will be 3 problems sets on the material in this section

6. Elastic and absorption cross-sections
7. Properties of chain reactions; the nature of exponential growth
8. The physics of nuclear reactors

C. The development of the atomic bomb

This unit covers the period from the establishment of Los Alamos in October 1942 through the Trinity test in July 1945. During this period many of the scientific challenges were of an engineering nature. There was need for operations to separate ^{235}U and ^{238}U on an industrial scale for the uranium bomb program. There was also a need to both breed ^{239}Pu in reactors and to chemically separate it from uranium. Finally the design of the weapons was technically quite challenging particularly for the case of the plutonium weapons. The science behind these issues will be covered. On the historical side, the many issues associated with running three secret city-sized facilities will be stressed including the problem of problem of security and espionage.

Reading: Chapters 10-19 + Epilogue in Rhodes

Problem sets: There will be 2 problem sets on the material in this section

9. Enrichment of uranium
10. Mean-free path and critical mass

D. Aftermath

This unit deals what followed the Trinity test. The decision to use the atomic bomb on Japanese cities is central in this as are some of the stark moral issues raised by this decision. The scale of the destruction due to the bombing of Hiroshima and Nagasaki will be central to the unit. Finally the unit deals with attempts of the world in the immediate post war era to come to grips with living with nuclear weapons will be discussed.

Reading: Pages 678-788 in Rhodes; supplementary readings

Paper: A paper of from 5 to 8 pages focusing on one of the central figures in the Manhattan Project and analyze his or her role in some key event will be due at the end of this unit.

