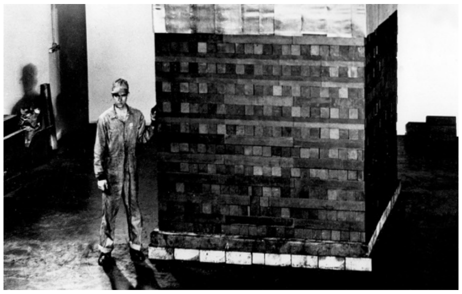
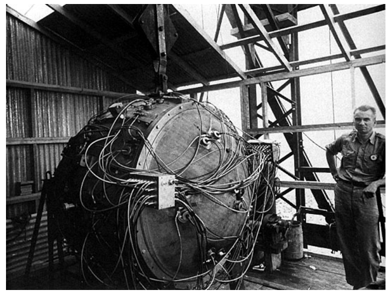
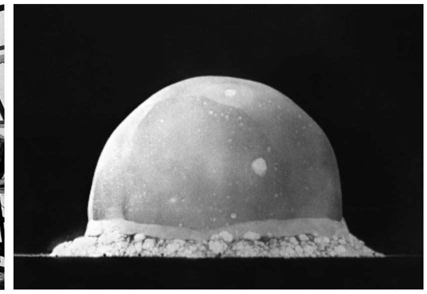
Physics 199M Fall 2017 Course Syllabus – University of Maryland
The Manhattan Project

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Course Information and Assignments

Assigned readings, problem sets and exam dates will be made available on the course **Canvas page.**

Lectures

Mondays and Wednesdays at 4:00pm – 5:15pm, Rm 1410 Physics.

The first lecture is on Monday, August 28, 2017.

Discussion Sections

Mondays (101,102), Tuesdays (103) and Wednesdays (104,105) :: Rm 1402 and Rm 0405 Physics (see Testudo).

Discussion sections will commence weekly meetings during the third week of class: September 11 - 13, 2017.

Office Hours

Office hours are officially from 11:00-12:00 on Mondays, but please contact me or the TAs via email to make an appointment since I am often away from my office.

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 19th century (such as the first World War, 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. We will also compare the Manhattan Project to the unsuccessful effort in Germany to develop nuclear weapons, considering 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, still widely debated today, is whether the scientists involved had a special ethical obligation to consider the ends to which their work would be used.

Mathematical Preparation

<u>This course has no prerequisites, but will make extensive use of mathematics throughout and basic physics principles.</u> 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 pre-calculus level, but may find it helpful.

Reading Requirements

The primary reading for the course is *The Making of the Atomic Bomb* by Richard Rhodes (Simon and Shuster, 2012; **ISBN** 978-1451677614). This book is often considered a masterpiece and has 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 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 and references, such as from these recommended texts:

> *Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians* (Black Dog & Leventhal, 2009; ISBN 978-1579128081)
>
> *Critical Assembly: A Technical History of Los Alamos during the Oppenheimer Years, 1943-1945* (Cambridge University Press, 2004; ISBN 978-0521541176)
>
> *Copenhagen* (Anchor Publisher, 2000; ISBN 978-0385720793).

Command & Control (Peng Rand, 2013; ISBN 978-0143125785).

Made In Hanford: The Bomb that Changed the World (WSU, 2011; ISBN 978- 0874223071).

You will also be assigned to read or listen to "Los Alamos from Below", a lecture by Richard Feynman which is available online. You may either read the lecture or listen to it on YouTube. Other references will be utilized for historical and scientific content throughout the course.

Pedagogical Approach

The course will have two weekly lectures and discussion sections. Each of these will address both the scientific and the historical aspects of the course. The **lectures** will cover the main content of the course and are intended to be as interactive as possible given the size of the class, with students encouraged to ask many questions.

The **discussion sections** will entail many activities. 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.

Grading Distribution and Policies

- **Problem sets (20% of course grade):** 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. Note, only a representative sample of the problems will be graded. Students are allowed to collaborate on problem sets; indeed I strongly encourage students to work in groups on these. However, as always, copying somebody else solution and submitting it as your own is strictly forbidden; this is not "collaboration". Solutions for the problem sets will be posted on the course web site.
- **Term Paper (25% of course grade).** There will be one written assignment during the semester. The required 5-8 page paper will focus on one of the central figures in the Manhattan Project and analyze his or her role in some key event or some particular aspect of the program. This paper will account for approximately 30% of the final grade.
- **Quizzes (5% of course grade):** There will be weekly quizzes based on the reading and information given during the lectures. This will not only test key knowledge about the course, but will also serve to gauge your attention on matters discussed in lectures.
- **Participation (5% of course grade):** This will be counted through lecture and discussion attendance.
- **Exams (45% of course grade):** There will be a midterm exam and a final exam in this course.

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 assignments.

- If a student misses 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, but scores will be reduced by 10% for each day late. Papers submitted more than 10 days late will not be accepted.

Our campus has a standard set of **course policies** regarding (1) the conduct of undergraduate courses and student grievance procedure, and (2) students' excused absences from class. Policies and resources can be found here: http://www.ugst.umd.edu/courserelatedpolicies.html. This page also includes links to resources related to each policy.

Also, there is a governing statement of intent: "An excused absence is an absence for which the student has the right to receive, and the instructor has the responsibility to provide, academic accommodation." More information is provided here: https://faculty.umd.edu/teach/attend_change.html

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 several problem sets on the material in this section covering:
   - Basic problems concerning the nature of energy; Exponentials;
   - Relativistic Mass-Energy relations; radioactive decay chains
   - Quantum Physics and the statistical nature of nuclear decays; the concept of half-lives; Atomic and nuclear models; 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;*
Problem sets: Problems sets on the material in this section will cover:

- Elastic and absorption cross-sections
- Properties of chain reactions; the nature of exponential growth
- 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 14-18 in Rhodes; Richard Feynman's "Los Alamos from below"
Problem sets: Problem sets on the material in this section will cover:

- Enrichment of uranium
- 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.