

## 1. Announcements

### Announcements

- Exam 2 - Thursday, Apr. 6 -
    - Practice Exam, practice problems, list of concepts in *Course Documents*
    - Solutions will appear Tuesday
  - Group presentations after Exam  
10 minutes maximum - choose your medium (Excel graphs, Powerpoint, transparencies, posters, chalk board) - put on memory key or CD for efficiency
- | <u>Date</u> | <u>Groups</u> |
|-------------|---------------|
| Apr.11      | 1 & 2         |
| Apr.13      | 3 & 4         |
| Apr.18      | 5 & 6         |
| Apr.20      | 7 & 8         |
| Apr.25      | 9 & 10        |
- **Next Tuesday** begin to read handout "On the Building of Bombs"
  - After exam download Frisch & Peierls memorandum from *Course Documents* and look at *Important Concepts* to focus on.
  - Remainder of course is on nuclear weapons and reactors

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## 2. Background to Copenhagen Play

### Background to Copenhagen Play

- Read Act 1 for next time **Prepare to discuss**
- SOME HISTORY:
- WWII underway - Germany occupies Denmark from Apr. 1940
- Bohr holding on & helping immigrant physicists
- Fission was discovered in Dec.1938 by Hahn, Strassmann, Meitner(!)
- Early 1939 Bohr & Rosenfeld bring the news to US while puzzling over its implications. Bohr & Wheeler work out theory that also shows **no fast fission**
- July 1939 Einstein-Szilard letter
- 1940 Frisch & Peierls found a way for **fast fission**
- 1940-42 intense activity in US and UK. Heisenberg heads German nuclear project.
- Sept. 1942 Gen. Groves appointed head of Manhattan Project. Chooses Oppenheimer as science head (see Sherwin&Bird book)
- Dec.2, 1942 Fermi's pile.
- 1943 Los Alamos. (See Rhodes *Making of the Atomic Bomb* & GG Meitner paper [http://www.physics.ucla.edu/~cwp/articles/gold\\_meitn.html](http://www.physics.ucla.edu/~cwp/articles/gold_meitn.html))

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### 3. Approaches to Reading Copenhagen

#### Approaches to Reading Copenhagen

- Who are the characters? Their importance in history of science & modern history? Their relation to each other.
- How many time periods are presented & what are they?
- How are they presented?
  - Through characters remembering
  - Through scenes set in past
  - What is the present?
- What was happening in their worlds in those periods?
- What is the most **important event** for the play that they recall?
- What physics developments & theories do they discuss? Does audience need to know physics?
- How do **physics theories relate to human activities** that are recalled, that are presented in "the present", that form the structure of the play?
- What is this play about? List ideas ---
  - History of 20th century
  - History of 20th century science
  - Subjectivity of history & science

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### 4. Themes of Copenhagen

#### Themes of Copenhagen

- What happened in the meeting among the 3 characters in 1941?
- Why does account of meeting get repeated three or four times?
- What are agreed upon facts of meeting? How do motives compare to 2-slit (or more) experiments?\*\*\*\*
- How is Uncertainty Principle involved?\*\*\*\*
- What is Margrethe's role?
- Bohr & Heisenberg's relationship is seen differently by each. How? What's role of drowned son? Who's rebellious son? Mentor & student.
- Does WH acknowledge the horror of Nazism? Was he a detached seeker of scientific truth? Ambitious? What?
- What did 2 men know about fission bomb feasibility?

Demo: Atoms in a Box - probability clouds for Hydrogen

<http://daugerresearch.com/orbitals/>

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## 5. More questions

### More questions

- What is skiing metaphor? How do H & B do this differently?\*\*\*
- How is Schrödinger's cat used here? Gamow or Casimir?\*\*\*
- Do theories belong to people or are they objective? H & Uncertainty vs. B & Complementarity.
- Why did Schrödinger's visit to Copenhagen cause H's distress?
- Collapse of wavefunction upon observation.
- H blames US for working on bomb that killed so many. Why did they work on it? MB reiterates hypocrisy of H's position when Jewish physicists being driven out.
- What were H's happiest times?
- What did H's group actually do?

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## 6. And more

### And more

- Act 2 starts with recollections of 1924-27. What happens? Who were in Bohr's orbits?
- Probability states of atoms c.f. Bohr walking in Copenhagen\*\*\*\*
- Spin and trains? Waves &/or particles -cloud chamber \*\*\*\*
- Did H&B work closely together? How did their styles compare?
- How does QM put humans back at center of universe?\*\*\*\*
- What were H's motives for leading the project?
- Why did H return in 1947?
- Should H have left Germany? The Project? Or subvert effort?
- What kind of "bomb" were they building? What did H get wrong in his calculations? A slip or deliberate?

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7.

Ethical-political questions

## Ethical-political questions

- Quantum ethics? What is right? How precarious is life?
- Was it right to work on a super-bomb?
- Was it right to drop two?
- Should B have killed H to stop his project?
- Should H have plotted to kill Hitler?
- Is a scientist's responsibility to truth? Or country? Or family, friends, future generations?
- Is science always wrapped up in political exigencies? Why work on fission?
- Are there correspondences to these issues today?
  - (NPR story Apr 4, 2006 on Pakistan's reaction to US nuclear deal with India e.g Parviz Hoodbhoy  
see npr.org and Morning Edition)

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