

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

Your groups can shift around the schedule by mutual agreement.

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1

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2. Some consequences of Copenhagen

Some consequences of Copenhagen

- State of system is determined only by measurement or observation
 - In double slit experiment, which slit did particles go through? Both! $\Psi = \Psi_1 + \Psi_2$ and $P = |\Psi_1 + \Psi_2|^2$. Mixture or Superposition.
 - If light shone on slit 1 to detect particles, will get single slit pattern, $P = |\Psi_1|^2$. *Measurement collapses the wavefunction.*
 - In H atom an e^- will be in mixture of l and m_l states.
 - Particle in box - where is particle likely to be? See squared wave pattern. Without measurement particle is in mixture (superposition) of states.

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2

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3.

Schrödinger's cat

Schrödinger's cat

- Cat in closed box. Radioactive nucleus with 50% chance to decay by observation time. Decay triggers deadly gas release.
- Open box. Cat is either dead or alive.



Source: www.nist.gov

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3

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4.

Schrödinger's cat

Schrödinger's cat

- Cat in closed box. Radioactive nucleus with 50% chance to decay by observation time. Decay triggers deadly gas release.
- Open box. Cat is either dead or alive.
- Until observation cat is in mixed state - dead and alive!
- Is cat a particle? A system? What is Ψ for cat, dead or alive? Ψ for macroscopic system?
- Observation for mutually exclusive possibilities yields one outcome - **collapse of the wavefunction**

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5. Schrödinger's cat questions

Schrödinger's cat questions

- Cat's physical environment, can act as an observer - **decoherence**.
- When is system beyond simple Ψ description?
- Feynman: what does the cat think?
- What is Ψ for universe? Who makes the observation?
- NIST (1996): single Be^+ atom in microscopic "light trap" with "spin up" state (\sim alive). Laser puts 50% in "spin down" state (\sim dead) in position \sim 80 nanometers away. Observation shows interference pattern!

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6. Electron spin

Electron spin

- Back to atoms - Some Problems - why
 - Fine structure in H spectrum
 - Pauli Exclusion Principle for higher Z atoms
- Goudsmit and Uhlenbeck (1925) - electron has intrinsic **spin**
- Quantized angular momentum for **all particles and systems** (l and m_l in H, more complicated for more e^- 's)
- Units of $h/2\pi$ multiplied by integers or half-integers
- so intrinsic spin = $s \times h/2\pi$ *like a spinning top with limits*

$s = 1/2$ half integer spin for **electrons**
and protons, neutrons, quarks (up or down)
 $s = 1$ integer spin for **photons**, weak
vector bosons, gluons

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7. Background to Copenhagen Play

Background to Copenhagen Play

- Read Act 1 for next time **Prepare to discuss**
SOME HISTORY:
 - WWII underway - Germany occupies Denmark 1942
 - 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)
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8. 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

9. Themes of Copenhagen- discuss in groups

Themes of Copenhagen- discuss in groups

- 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?**** (possible essay)
- 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?

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10. 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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10

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