P 453 Intro. to QM

Goal: This course teaches you to "do" QM by doing QM. Doing - use quantum mechanics to calculate properties of physical systems.

Text: Griffiths Intro to QM

(a) Course: Information + Mechanics
(b) Introduction to QM
 QM is all around us
 What is QM
 What will we do in this class

Atomic + Molecular physics.
 Spectral lines \( \Rightarrow \) Energy levels are quantized: We will understand why and how this quantization comes about.

Quantization crucial to QM (hence name)
 \( \Rightarrow \) Needed for stability of matter why we do not spiral into nucleus.

Most important device for spectroscopy is LASER (light amp by stimulated emission of radiation) inher. quantum
Show spectral lines + CN player

Quantum Chemistry
1st principle calculations of chemical properties from solution of Schrödinger eq. for systems of elections.

Name is redundant: all chemistry follows from quantum behavior of electrons.
Example: Periodic table and shell structure
We will explain this. Also need Pauli exclusion principle.
Example: Nuclear shell structure and r-process nucleosynthesis.

Condensed matter physics
Development of QM in 1920s led to understanding of electrons in crystals
⇒ solid state physics, transistor, integrated circuits...

Nuclear Physics
Almost all quantum very unlike classical
Example: radioactive decay from
quantum tunneling
Heisenberg Uncertainty principle
\[ \Delta p \Delta x \geq \frac{\hbar}{2} \]
\[ \Delta E \Delta t \geq \frac{\hbar}{2} \]
allows a particle to go through a classically forbidden region.

In Sun
\[ p + p \rightarrow D + e^+ + \nu_e \]
\[ kT \approx 1.3 \text{ keV (thousand electron volts)} \]
Coulomb barrier between two protons \[ \approx 1 \text{ MeV (million electron volts)} \]
\[ 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J of energy} \]

Radioactive decay an alpha particle has to tunnel out of a nucleus

\[ V(r) \]
\[ \text{Coulomb repulsion} \]
\[ \text{alpha particle} \]
\[ \text{Nucleus attraction} \]
In a household smoke detector, Am\textsuperscript{241} produces radiation which ionizes smoke particles in a chamber. The charged smoke particles are then accelerated with an electric field and produce a detectable current.

Tunneling in nuclear reactions is crucial to energy production in stars and to the production of the elements — nucleosynthesis.

**Bottom line**
Quantum mechanics very very important for universe around us.

The majority of physicists likely do quantum mechanics every day.

Only very few exceptions: General rel. + gravity, some E+M + accel. physics is classical.

Thus P453 is first course doing what "real" phys. actually do.
QM is very strange and counter intuitive. Yes it is to you.

Physicists deal with it every day and it is so important to everything they do that it becomes second nature.

Basic Quantum Notion

System described by a wave function \( \psi(x,t) \)

\[ = \text{Prob. amplitude} \]

Square of Wave Function

\[ P(x \rightarrow x+dx) = |\psi(x,t)|^2 \, dx \]

is prob. to find particle between \( x \) and \( x+dx \).

Free particle: Wave function spreads with time because of uncertainty \( \Delta p \) in momentum

\[ \Delta X(t) \sim \left\{ \left[ \Delta X(t=0) \right]^2 + \left[ \frac{\Delta p \cdot t}{M} \right]^2 \right\}^{\frac{1}{2}} \]

From

\[ X(t) = X_0 + \frac{p}{M} \cdot t \]
How to teach QM?

a) Historical: failures of classical mech. (black body radiation for example)

b) Postulates of QM: Hilbert spaces, herm. operators, unitary transformations... to dry

c) Do QM: Start with Schrodinger equation and solve a few problems such as harmonic osc. Then come back and discuss formalism of QM once we know a little about how things work. This is organization of Griffiths and what we will do.

What does QM mean?? I don't think we yet fully understand.
Phil. of QM is nontrivial and unsolved. Each of you must come to grips with the deep questions yourself.

Where is the electron even if my knowledge of its position has a large \( \Delta x \)?

a) S.1st question: Only ask questions about things you can measure. We will talk in detail about making measurements and how they disturb the system.

b) It is really not defined. QM is complete description.

c) It is some well defined place and QM is an incomplete description of the system. Uncertainty principle is simply a statement about our knowledge.