8/25/98

P453 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 phys.
Spectral lines ⇒ Energy levels are quantized: We will understand why + how this quantization comes about.
Quantization crucial to QM (hence name)
⇒ Needed for stability of matter why e do not spiral into nucleus.
Most important device for spectroscopy is LASER (light amp by stimulated emission of radiation) inher. quantum

Show spectral lines + CD player

Quantum Chemistry

1st principle calculations of chemical properties from solution of Schrodinger eq. for systems of electrons.

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 nucleosyn.

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

Nuclear Physics
Almost all quantum very v. little classical
Example radioactive decay from

quantum tunneling

Heisenberg Uncert. principle

$$\Delta p \ \Delta x \geq \hbar/2$$

$$\Delta E \ \Delta t \geq \hbar/2$$

allows a particle to go through a classically forbidden region.

In Sun

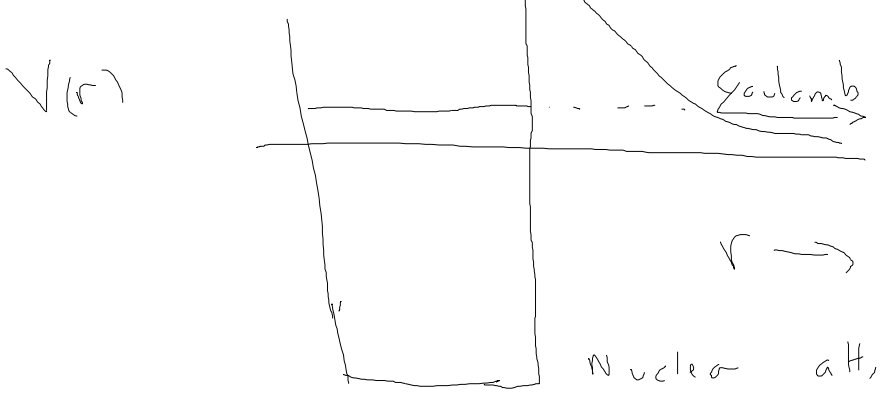
$$p + p \rightarrow D + e^{+} + \nu_e$$

$kT \sim 1.3$ keV (thousand electron volts)

Coulomb barrier between two protons ~ 1 MeV (million electron volts)

$1\text{eV} = 1.6 \times 10^{-19}$ J of energy

Radioactive decay α particle has to tunnel out of a nucleus



In a household smoke detector ^{241}Am which has $Z = 95$ and $N = 241 - 95 = 146$ 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 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 lithely 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 $\psi(x,t)$
= Prob. amplitude

Square of Wave Function

$$P(x \to x+dx) = |\psi(x,t)|^2 dx$$

is prob. to find particle between x and $x+dx$.

Free particle: Wave function spreads with time because of uncert. Δp in momentum

$$\Delta x(t) \sim \left\{ [\Delta x(t=0)]^2 + \left[\frac{\Delta p}{m} t\right]^2 \right\}^{1/2}$$

From $x(t) = x_0 + \frac{p}{m} t$

Show demonstrations: GaussSpread
GaussPacketFast
GaussPacketReflect
pimpg (2 dim)

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 haimonic 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 Δx?

a) Silly 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.