P453 Spring 2001 1/8/01

Book: David Griffiths
Intro. to Quantum Mechanics

Example: In stock at www.amazon.com
But $89.33 plus ~$4.50 shipping

Course Web Site: http://physics.indiana.edu/~charlie/qm

Important for you to check site

Instructor: Charles Horowitz (Chuck)
Office: Swain West 233
E-mail: charlie@iucf.indiana.edu
Office hours: MF 1:30-2:30 or by appointment
(any time you find me is ok)

Grade: Homework (40%) once a week
Midterm (20%)
Final (40%)
Class participation + Numerical project
Extra credit

<u>Note</u> NO LATE HOMEWORK

Grader: Kuiru Li Kuli@indiana.edu

Goal: This course teaches you to "DO" QM by doing QM. We will use QM to calculate properties of physical systems.

Note: 100 Year Birthday of QM. Max ~~B~~ Planck in 1900 first postulated quantized energy levels to explain black body spectrum.

⟹ Read John Wheeler essay on Quantum
Read longer article on course web site
"Max Plank Invents Quantum"

Note Essay on the Movie 2001 I wrote for another class: Physics of Extraterrestrial Life and Death (E105 TOPICS class). Nevertheless I would be interested in any comments you might have.

Time line

Dec 14, 1900 M. Plank presents results on black body radiation to German Physical Soc.

1905 Einstein explains photoelectric effect → invents photons

1913 Niels Bohr proposes quantized model of atom

1924 Louis de Broglie developes idea that matter can behave like waves

1924 Einstein and Satyendra Nath Bose develop Bose-Einst. statistics for identical particles

1925 Wolfgang Pauli develops exclusion principle

1926 Erwin Schrödinger proposes wave equation

1926 Enrico Fermi + Paul Dirac describ properties of Fermi particles that obey exclusion principle

1927 Werner Heisenberg uncertianty principle

1928 Dirac equation and Dirac's pridiction of anti matter

Late 1920s developement of Copenhagen Interpritation of QM and principle of complementarity.

Introduction to QM

I.) QM is all around us
II.) What is QM?
III.) What will we do in this class?

Atomic + Molecular physics

Spectral lines ⟹ Energy levels are quantized: We will understand why thow this quantization comes about.

Revolutionary advance for astrophysics: can use observed spectral lines to identify composition of distant objects.

Quantization is crucial to QM (hence the name) ⟹ Needed for stability of matter otherwise electrons would radiate and spiral into nucleus.

Most important device for spectroscopy is LASER (light amp. by stimulated emission of radiation) which is inherently quantum

Quantum Chemistry

1st principle calculations of chemical properties from solution of Schrodinger eq. for system of electrons + nuclei

Name is redundant: all chemistry follows from quantum behavior of electrons. There is very little "classical chemistry"

Example: Periodic table and shell structure. We will explain this using Pauli Exclusion Principle

Nuclear Physics

Nucleus is so small that almost allways

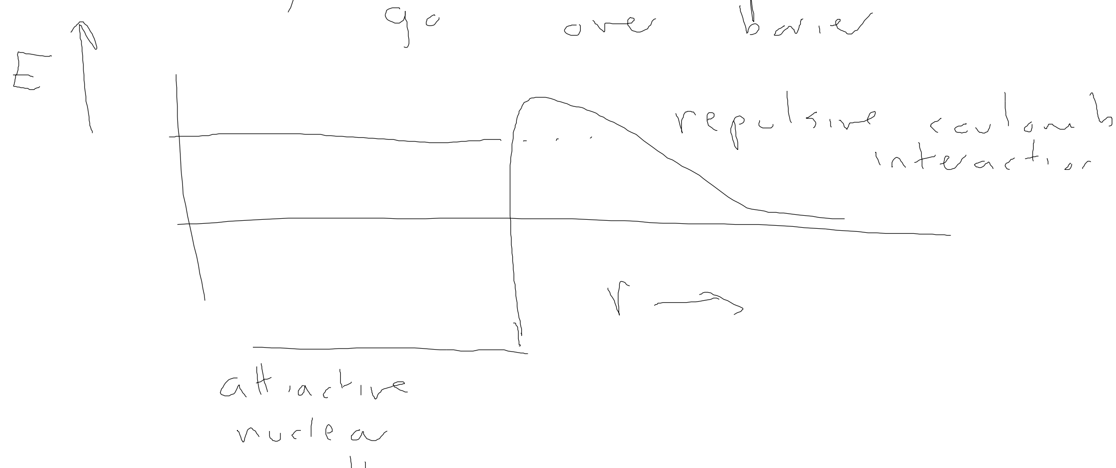
have quantum behavior. Example radioactive decay from quantum tunneling.

Heisenberg Uncert. Principle

$$\Delta p \, \Delta x \geq \hbar/2$$
$$\Delta E \, \Delta t \geq \hbar/2$$

$\hbar = h/2\pi$ h = Plank's constant
dimensions of Energy - time

Classicly particle may not have enough momentum to get through a very thin barrier. However if you include uncert. in momentum Δp you can't prove it did not go over barier



alpha particle can't get out classicaly but can in QM. However th is very small so prob. is very low ⟹ Radioactive half lives can be very long.

In a Household smoke detector a very small amount of man made
^{241}Am $Z = 95$, $N = 146 = 241 - 95$

Produces radiation

$$^{241}Am \rightarrow {}^{237}Np + {}^{4}He \text{ (alpha)}$$

Charged alpha particles will ionize any smoke particles which pass through a small chamber. Charged smoke particles are then attracted to an ellectrical grid producing a current and setting off an alarm.

Tunneling in nuclear reactions crucial to energy production in stars and to the synthesis of the chemical elements

<u>Bottom Line</u>

Quantum mechanics very very important for Universe around us. The vast majority of physicists litteraly do quantum mechanics every day. Only very few exceptions:

General relativity + Gravity

Some accelerator physicists

Thus P453 is first physics course doing what "real" physicists actually do. We don't spend so much of our research time on inclined plane problems

Note QM is very strange and counter intuitive.

It is very important that you complain. Don't take this quantum nonsense sitting down.

Basic Quantum Notation

System described by a **wave function**

$\Psi(x,t)$ = Probability amplitude

Square of wave function is a probability density

$$|\Psi(x,t)|^2 = \rho(x,t) = \text{Prob. density}$$

Probability to find particle between x and $x + dx$ is

$$\rho(x,t)\,\Delta x = \text{Prob.}$$

Prob. density = probability to find particle per unit length

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

$$\Delta v = \frac{\Delta p}{m}$$

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

From

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

Note errors in position Δx and momentum Δp are independent $\Rightarrow$ add errors in quadrature.