Basics of Quantum Mechanics: Lecture 1
01/19/09

Niels Bohr (1885 - 1962):

``Anyone who is not shocked by quantum theory has not understood a single word."

“There is no quantum world. There is only an abstract physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature."

→ <u>So far:</u>

- mechanics: motion of objects; Newton's laws
- electricity, magnetism, Maxwell's equations
- waves, light
- special relativity

⇒ extend of physics at ~ 1900

→ <u>But then:</u>

experiments showed that a very different picture was needed!

- waves act as particles, particles act as waves
- on small scale: "<u>quantized energies</u>"
- same initial conditions → different results
- only <u>probability</u> discription seem possible

- **1864 J.C. Maxwell Light as electromagnetic radiation**
- **1885 J.J. Balmer Formula for Balmer series of hydrogen**
- **1887 H. Hertz Accelerated charges emit radiation**
- **1897 J.J. Thomson Discovery of the electron**
- **1900 M. Planck Theory of thermal radiation (first quantization)**
- **1905 A. Einstein Special relativity theory, photon concept**
- **1909 R.A. Millikan "Oil-drop" experiments (charge *e*)**
- **1911 E. Rutherford Rutherford model of atom**
- **1912 M. von Laue X-ray diffraction by atoms in solids**
- **1913 N. Bohr Quantum theory of hydrogen atom**
- **1914 Frank-Hertz Evidence of quantized energy levels in atoms**
- **1924 L. de Broglie Theory on particle waves**
- **1925 Davisson-Germer Experiments on interference of electrons**
- **1925 E. Schrödinger Wave equation**

⇒ End result: Quantum Mechanics
new theoretical framework

P3316:

- why new theory (QM)?
- introduction to ideas and formalism of QM
- simple examples of consequences of QM
- follow up: 3317 Application of QM

Physics 3316
Basics of Quantum Mechanics
Spring 2009

General Information

Instructor: Matthias Liepe, 110 Newman Lab, MUL2@cornell.edu, 4-8937
Office Hours: W 2-3 pm, F 1 pm -2:30 pm, and by appointment

Recitations: Ben Machta, B-81 Rock, bbm7@cornell.edu, 5-6036
Office Hours: TBA

Class Times:

Lecture:		MWF	9:05-9:55 am	Rock 132
Recitations:		W	1:25-2:15 pm	Rock 127
	or	R	3:35-4:25 pm	Rock 110

Course Website:

www.blackbord.cornell.edu. The course is labeled Basics of Quantum Mechanics. This side will contain announcements, copies of assignments, solutions and lecture notes.

Text:

Required: *An Introduction to Quantum Physics* by French and Talyor
Introduction to Quantum Mechanics, by D.J. Griffiths

Optional: *Modern Physics*, by Serway, Moses, Moyer
Quantum Mechanics, Concepts and Applications, by N. Zettili

Other useful books:

Lectures on Physics, Vol. 3, R. Feynman, R. Leighton, M. Sands
Quantum Physics of Molecules, Solids, Nuclei, and Particles, by R. Eisberg, and R. Resnick
Applied Quantum Mechanics, by A.F.J. Levi
Night Thoughts of a Classical Physicist by R. McCormmach (fiction). We will talk about this book during a Sunday brunch!

Schedule:

First lecture: January 19 (M)
Movie night (participation not mandatory): Sometime second or third week of class
First prelim: Probably March 2 (M)
Spring break: March 14 (Sa) - March 22 (Su)
Second prelim: Probably April 6 (M)
Sunday book brunch (participation not mandatory): After second prelim
Last lecture: May 1 (F)
Final exam: Thursday, May 14, 2:00 - 4:30 pm

Homework:

Homework and reading assignments will be handed out in lecture on Mondays and are due in lecture the following **Monday**. Late homework will result in grade reduction (20% per day). Problem sets will be graded based on effort only: one point for each problem that is **seriously** attempted. I do not expect you to get all the right answers on your first pass through the material, but I do expect you to tackle the questions with *bona fide* effort. I encourage you to study in groups and to help each other on the homework, but only *after* you have made a serious individual effort. **Direct copying is forbidden** and you should give credit if you benefit from someone else's insight by citing them**.**

i-Clicker:

We will use the i-Clicker response system in class. Please get an I-clicker.

Recitations:

Recitations begin the first week of class. Attendance and consistent participation is expected and will improve your understanding of this course greatly. Remember that you can not learn physics by just reading the text or going to lecture! Cooperative learning problems will be regularly assigned in recitation. You will work on these in teams, and show your results to your TA during recitation.

Quizzes:

Short quizzes (15 min) will be given every other week in sections. They will be based on the previous week's material (homework and co-op). Your first quiz will be during the week of January 26. You will be allowed to drop one quiz. Written documentation is required for any additional missed quizzes. No make-up quizzes will be allowed. For CU sports or off-campus university related conflicts contact me.

Computer lab:

We will have three computer labs, in which we will solve Schrödinger's equation numerically. Dates and times will be announced later.

Exams:

We will have two in-class prelims (probably March 2 and April 6) and a final exam (May 14). The final will be cumulative. No make-ups will be allowed. For CU sports or off-campus university related conflicts contact me.

Grading:

Prelims:	20 % each (40% total)
Final:	30 %
Recitations:	30 % (homework, quizzes, section participation)

Syllabus

***F&T**: French, Taylor, Introduction to Quantum Physics*
***GR**: Griffiths, Quantum Mechanics*

I The experimental basis of quantum mechanics (8 lectures):
F&T chapter 1 and 2
Particle aspect of radiation: Double slit experiment, Photoelectric effect, Compton Effect Blackbody Spectrum
Atomic transitions: Line spectra and the Bohr Atom
Wave aspect of particles: Particle waves, wave packets, group and phase velocity, experimental proof of particle waves
The "old quantum theory" and philosophy

II Introduction to wave mechanics (9 lectures):
F&T chapter 3 and 4; GR chapter 1 and 2.1 – 2.3
Approach to the Schrödinger equation
Wave function, probability, expectation values
Stationary states, time-independent SE and the general solution of the SE
Examples: infinite square well, finite square well, boundary conditions, simple harmonic oscillator
Quantitative wave function plots

III Formalism (9 lectures):
GR chapter 3; F&T chapter 6 and 7
Superposition of stationary states
Hilbert space, observables, eigenfunctions, generalized statistical interpretation
Dirac notation
Photon polarization states
Position space and momentum space

IV Free particle, Uncertainty Principle, particle scattering (6 lectures):
F&T chapter 8 and 9; GR 2.4, 2.6, 3.5
Free particle
Uncertainty principle, Energy-time uncertainty relation
Particle scattering and tunneling

V Central potentials, Hydrogen atom (6 lectures):
F&T chapter 5, 10, 11 and 12; GR chapter 4
QM in 3-D: Separable potentials, central potentials
Angular momentum, spherical harmonics, rigid rotator
Spin, Pauli spin matrices
Radial wave function of the Hydrogen atom
Full solution of the Hydrogen atom
Hydrogen like atoms, periodic table …

VI Philosophical difficulties with quantum mechanics (1 lecture)

Academic Integrity in Physics 3316:

Integrity and honesty will be absolutely essential in your future careers as professionals. Consequently, we take issues of academic integrity extremely seriously. Students who are found in violation of Cornell's Code of Academic Integrity can expect to be prosecuted to the full extent allowed by the code.

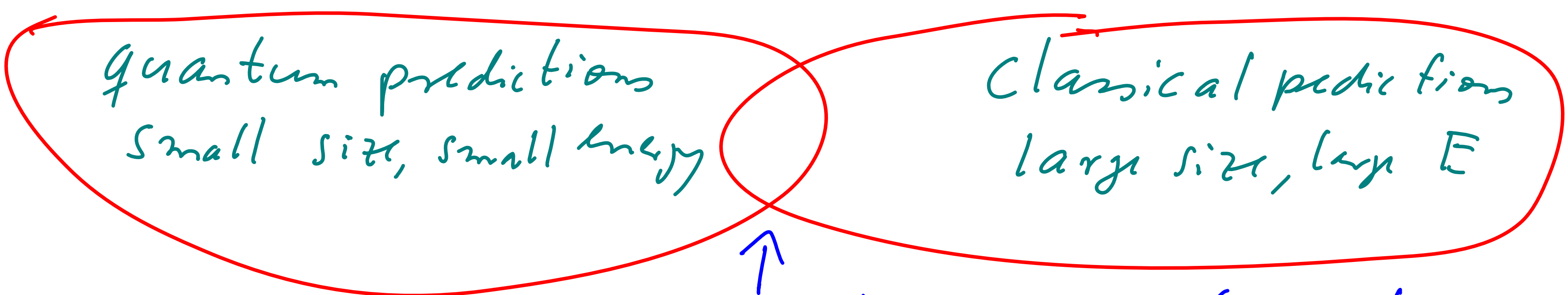
Some examples of violations for which we have prosecuted students in the recent past:

- Turning in homework that has been copied from another student. Discussion of the homework problems with each other is encouraged.
- Copying the work of another student during a quiz or exam.
- Using cheat sheets, notes written on body appendages, clothing and hats, or programmed calculators during a quiz or exam.
- Changing an answer on a quiz or exam after it has been graded and submitting it for a regrade.
- Providing false reasons (e.g., illness, death in the family, interviews, and athletic events) for missing a quiz or exam. Proper documentation must be provided.
- Providing false reasons in requesting a make-up exam. Proper documentation must be provided.

No matter how desperate your situation may seem, you should never violate the code of academic integrity and never make misrepresentations to your TA or your professors. Come talk to your TA or professor for advice on how to resolve your difficulties. As future professionals we will treat you with appropriate deference and respect.

Why is Quantum Mechanics necessary?

- experiments in conflict with classical theories
- classical physics works wonderfully in its regime of validity! (larger size, not too small E)
- **Correspondence Principle (Bohr):**



need to agree in the limit of large "quantum numbers"

I Experimental Basis of QM:

I_1 Evidence for Photons:

$I_{1,1}$ Interference: Double slit:

Classical description: light propagation in empty space

⇒ Maxwell's equations

⇒ wave equation: for E-field (differential equ.)

$$\nabla^2 \vec{E} - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0 \quad \Rightarrow \text{Solution E-field } E(x,t)$$

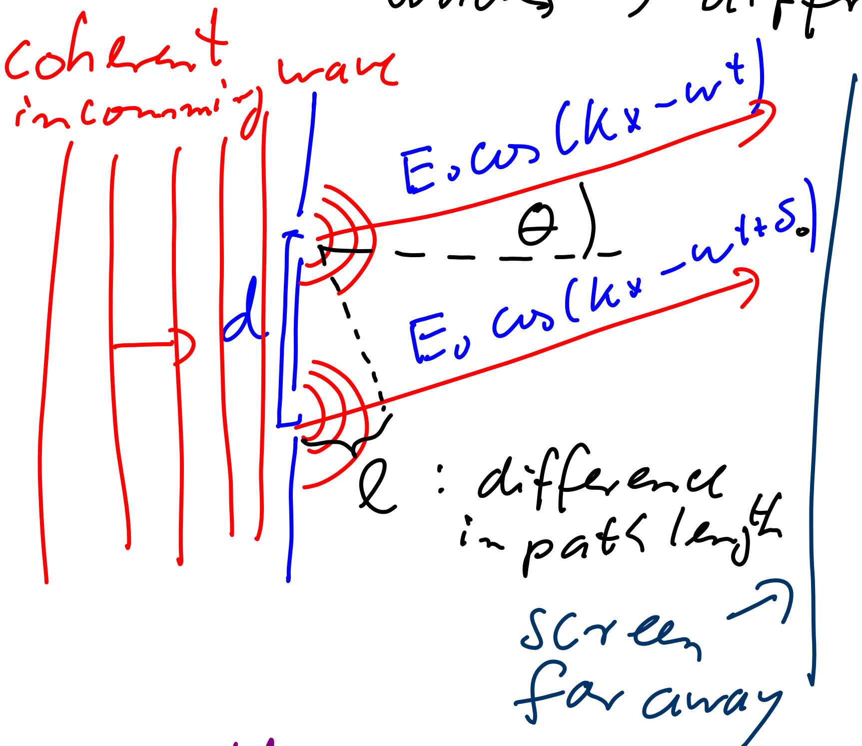
1-D: $\frac{\partial^2 E}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0$

⇒ wave solution: $\vec{E}(x,t) = \vec{E}_0 \cos(kx - \omega t + \delta)$

also: $\vec{E}(x,t) = Re\{\vec{E}_0\, e^{i(kx-\omega t+\delta)}\}$

recall: $e^{i\phi} = \cos\phi + i\sin\phi$

waves → diffraction, interference



δ_0 = phase difference between waves

$$= 2\pi \frac{\ell}{\lambda}$$

$$= 2\pi \frac{d \sin\theta}{\lambda}$$

⇒ add amplitudes to get total wave amplitude at screen

$$E_{total} = E_0 \cos(kx - \omega t) + E_0 \cos(kx - \omega t + \delta_0)$$