Phys 231 Sp 2026

Lecture 1

Introduction

* Syllabus
* Course Website
  ↳ course materials page
* D2L page info
* Grade composition:
  - HW roughly once / week
  - three class exams – note dates.
  - final exam – note date

see pg 2-3.

Fri: Read 3.1 → 3.5

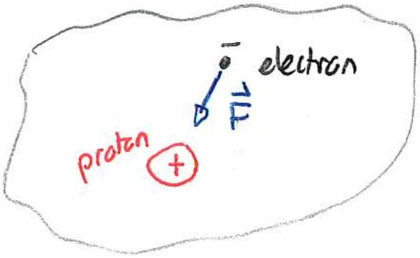
Mon: HW 1

Introduction to quantum theory

This course provides an introduction to quantum theory, a broad general theory of physics used to describe many phenomena. The way in which it does this is very different to classical physics and the results and predictions can be strikingly different. Consider a hydrogen atom.

Question for class – what is structure of hydrogen atom?
– what motion occurs? How would this be described?

We would use classical physics as follows:



→ Newton's 2^{nd} Law $\vec{F}_{net} = m\vec{a}$ → Predicts
* centripetal acceleration
* circular motion

Unfortunately, classical electromagnetic theory predicts that a circularly orbiting charge radiates energy. Thus the circular orbit must collapse and calculations show this happens very quickly.

DEMO: PhET Models of H Atom – Spectra Tab

Quantum theory also addresses this situation

Consider possible energies
Do not consider trajectories

→ Basic rules of quantum theory predict how the atom behaves

→ Predicts
* how state changes
* how atom absorbs or emits light

DEMO: PhET H models

Quantum theory can do this very successfully for the hydrogen atom. But it has many more applications

Question for class - do you know how/where quantum theory applies?

Examples of applications include:

* atoms / molecules
* light
* solid state physics
* electronics
* lasers
* NMR / MRI
* quantum information.

For some highlights see

* Physics magazine page 1YQ
* " " Quantum Physics.

This course will

1) describe some important quantum theory phenomena
2) describe the development of quantum theory
3) introduce the ideas and concepts of quantum theory
4) develop some techniques associated with quantum theory

The material includes

1) calculus - integration + differentiation
   - some differential equations (developed in class)
2) complex numbers (reviewed in class)
3) waves (reviewed / developed in class)

Light and interference of light

Since its beginnings quantum theory has had a close association with phenomena involving light and the interaction of light and matter.

Consider the following situation that only involves light passing through a Mach-Zehnder interferometer.

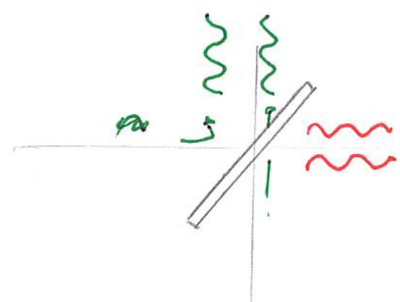
DEMO: Mach-Zehnder Slides

Quiz 1 25%

DEMO: Results of M-Z interferometer

In classical physics this is described using interference and that uses a wave description of light. Each beamsplitter divides the light wave and the two waves recombine after the second beamsplitter.

Interference describes how to combine the waves



DEMO: Waves Slides

Interference I → 4V

Constructive + destructive

Thus after the second beam splitter there is constructive interference between one pair, resulting at light arriving in the upper detector. Destructive interference along the horizontal results in no light at that detector. Classical physics succeeds here.

Electromagnetic theory → Electromagnetic waves → Interference of waves → Succeeds in predicting correctly for ordinary intensity light sources

Waves → Electromagnetic waves

Now suppose we reduce the intensity. We will still find that all light arrives at one detector.

DEMO: QuVis Interferometer experiment - continuous

We will find that there are individual detection events

DEMO: QuVis Interferometer experiment - single photons

What if we considered the paths that the photons could take? We could do this by inserting detectors after the first beam splitter, or equivalently removing the second beamsplitter

Quiz 2 75% - 100%

DEMO: QuVis - single photons

Note that

* each photon only arrives at one detector - photons do not split.
* in this configuration, arrival probabilities are the same.

This behavior is the same as for classical particles. Now suppose we tried to combine these ideas. Either beamsplitter reflects or transmits photons with equal probability.

Quiz3 80% -

If the photons behaved like classical particles, then any travelling along the lower arm have a 50% chance of reaching the "horizontal" detector. The same is true for any that arrive on the upper arm.

We cannot say that any given photon

EITHER travels along the lower arm OR along the upper arm

We also cannot say that any given photon splits between the two arms

This kind of paradox is common in quantum theory and we cannot reconcile it with a picture of classical particles.