Phys 231 2021

Lecture 1

Intro: 1) Syllabus + Introduction

2) Course website → course materials page

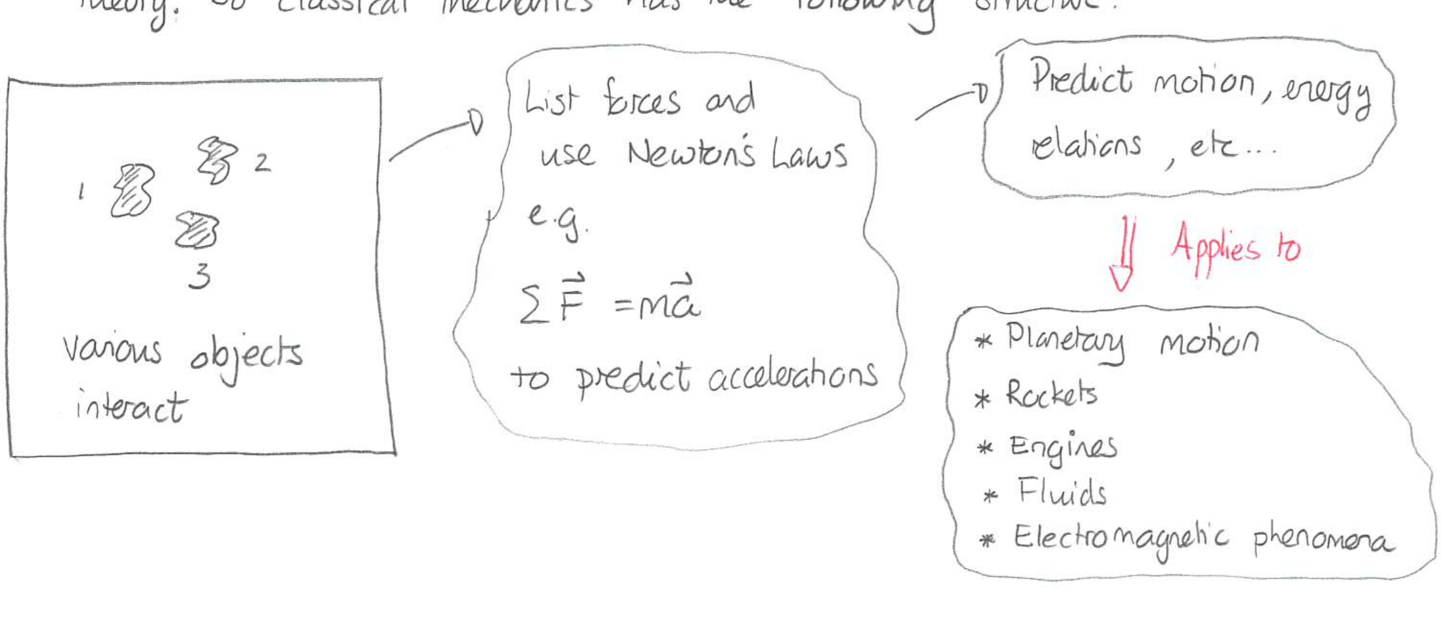
3) D2L page

4) Grade Composition:

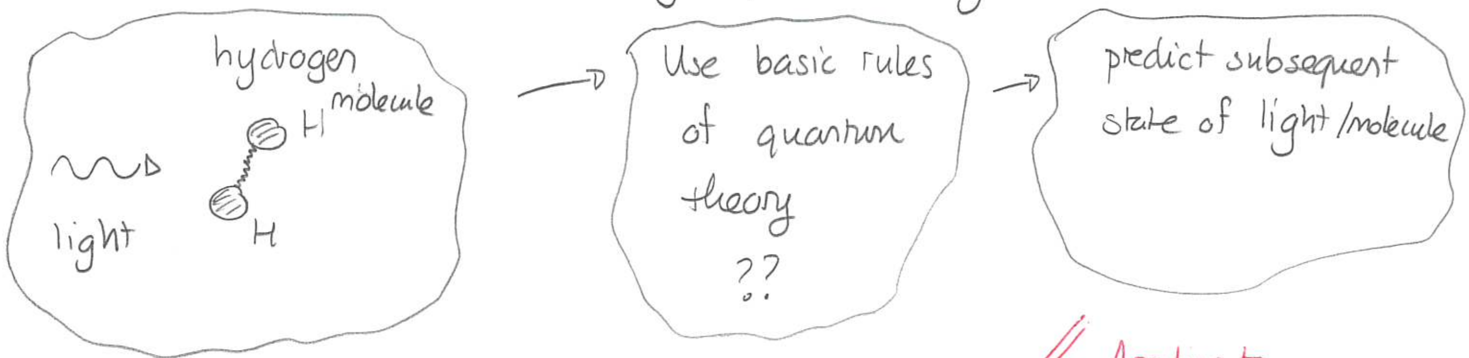
* HW about once per week.
* Three class exams. - dates pg 2
* One final " - date pg 2
* Grade breakdown pg 2

Course Content

This course is an introduction to quantum physics and the theory that has been developed to describe this. Quantum theory is a general physics theory that addresses or describes a wide range of physical phenomena. It is a general theory in the same sense that classical mechanics is a general theory. So classical mechanics has the following structure:



Quantum theory is also a fundamental theory in the sense that it gives a similar framework of basic rules that ultimately describe a vast range of phenomena. It is often most successful at small scales - atoms, molecules, single particles of light



Applies to:

* Atoms/molecules
* Light
* Solid state physics
* Electronics
* Lasers
* Nuclear Magnetic Resonance
* Quantum Information.

Aside from practical implications such as those listed, quantum theory has implications for understanding the universe:

1) Why is the periodic table the way it is?
2) Why are atoms stable?
3) How do light and matter interact?
4) Can an action in one location affect near simultaneous actions at another location (EPR paradox)?

* Show Physics magazine page.

This course will:

1) describe some of the important phenomena in early quantum theory
2) describe the development of quantum theory
3) give an overview of the concepts of quantum theory
4) give some techniques associated with quantum theory.

The material requires:

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

~~Demo~~ ~~Mach Zehnder Slides~~

~~Quiz 1~~

Classical Physics

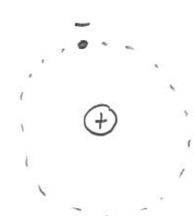
Classical physics describes the physical universe using Newton's Laws that ultimately predict positions, velocities and accelerations of particles. In various situations one has to append additional laws to the core Newton's Laws. Examples are:

1) gravity

2) electromagnetism

By the end of the 19^{th} century this framework had successfully described many observed phenomena. However, there were various physical situations where this framework failed:

1) <u>stability of atoms</u> The simplest atom, the hydrogen atom, could be modelled as a "solar system." Classical electromagnetism predicts that this will radiate energy via electromagnetic waves. The electron must then spiral inwards. The predicted lifetime for this is very short.



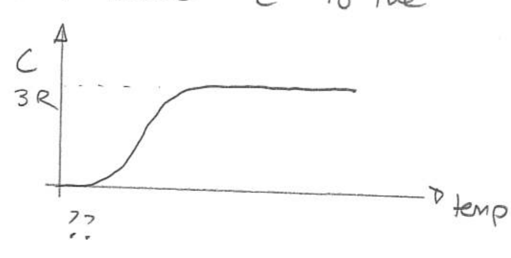
Demo: PhET Model of H-atom

2) <u>atomic spectra</u> Atoms emit light in discrete wavelengths. Why is the spectrum not continuous? How could one predict the spectrum?

3) <u>heat capacities of solids</u> the heat absorbed by a material Q is related to the temperature change ΔT by $Q = c\Delta T$ where c is the heat capacity. Classical physics predicts (per mole)

$$C = 3R$$

where R is the gas constant



This does not agree with experimental observations. How can one predict the low temp behavior?

Interference of light

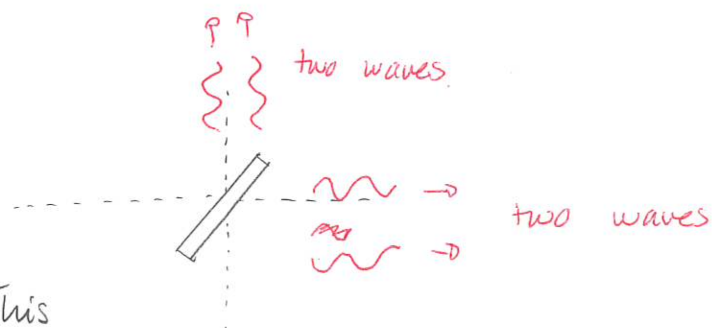
Some of the earliest developments in quantum theory considered the interaction of light and matter. We consider simple experiments that involve light.

Demo: Mach-Zehnder Slides

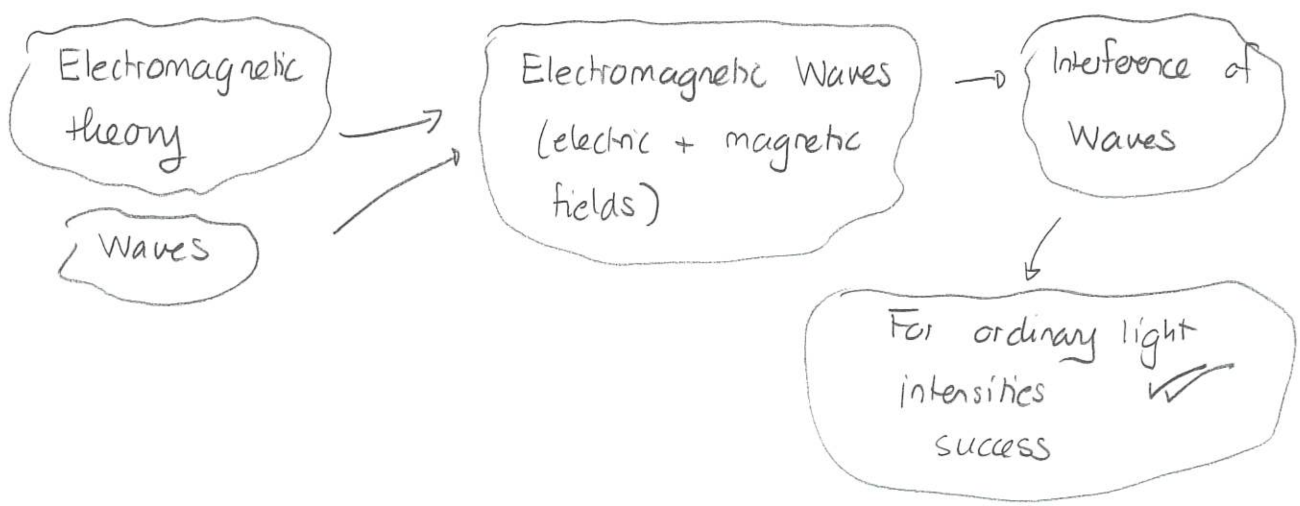
Quiz 1

Demo: Results

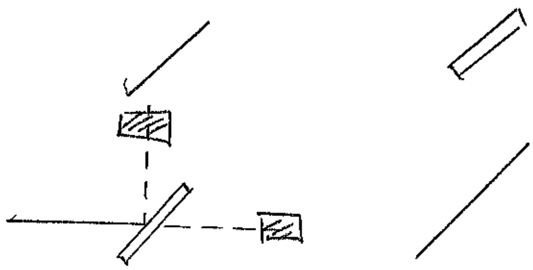
These slides illustrate a property of light called interference. The beams that emerge on either side of the second beamsplitter interfere with each other. So we have :



We can then use the idea of interference to describe why no light arrives at one detector and all light arrives at the other. This is a success of classical physics



What if the intensity of the light is reduced? The same predictions will still match the observations. However, there will be a problem if we insert detectors earlier.



dectectors

With the right type of light and a sufficiently low intensity we will observe that only one of these detectors registers. Then repeated runs of this show that we cannot predict which one. In this way it appears that light:

1) is not behaving like a wave that can be split.
2) behaves like an indivisible particle.

But if it is indivisible then how can we predict that it emerges at the same detector after the second beamsplitter: