# Physics 121: Optics, Electricity & Magnetism

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SFU Physics

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# Outline I

# Acknowledgements


- Lecture Slides: Dugan O'Neil, Spring 2009
- Demonstrations: Jeff Rudd

# Phys 121, Phys 126 and Phys 141

There are at least two options for optics, electricity and magnetism this term. Phys 121 is one choice, Phys 126 is the other.

- Similar list of topics (interchangeable for upper-level prerequisites)
- Phys 126 is faster-paced, a somewhat more challenging. However, grading scale is higher.
- In Spring 2009 196 people in Phys 121 and 22 people in Phys 126
- If you have some sort of “A” in Phys 120 then you can go into Phys 126 instead of Phys 121.
- Phys 141 is a combined lab/lecture/tutorial class, *Studio Physics*, and is open only to those who have taken Physics 140. Class size is max 54. It’s in Surrey.
- Phys 131 is the lab course. Should be taken in conjunction with Phys 121. We will try to correlate the two, but complete correspondence isn’t possible.

# Introduction

Physics 121: Optics, Electricity & Magnetism

| | |
|---|---|
| Time/Rm: | MWF: 9:30 Rm: B9201 |
| Tutorials: | Tues or Thurs – start next week. |
| Instructor: | Neil Alberding |
| Textbook: | "Physics for Scientists and Engineers, Second Edition"<br>Randall D. Knight |
| Office Hrs: | P9444 MW 11:00-12:00 |
| Final Exam: | Wed. April 21, 12:00–15:00 |

# Technical Details

Grading

- Weekly Assign. = 15 %
- Midterm = 2x15% = 30%
- Tutorial Attendance = 5%
- Final = 50 %

Resources

- Notes: http://webct.sfu.ca/
- Mastering Physics: http://www.masteringphysics.com
- Each other, TAs, me
- Other 1st-year texts: Tipler, Halliday-Resnick-Krane, other University Physics textbook.

# Course Web Site: http://webct.sfu.ca

- login using your SFU computing id and password
- Course materials including lecture notes, assignments, etc. all posted there
- Check your grades
- Can use the chat room to discuss with other students and send messages to other students (Warning: Instructors and TAs can see.)

# Mastering Physics: http://www.masteringphysics.com

- We will use “mastering physics” for some assignment questions.
- You need the student access code which comes with your textbook (or you can buy one at the bookstore)
- You must register for the course: SFUPHYSICS121A
- You need your student ID and SFU postal code ”V5A 1S6”

# Assignments, Midterms and Exams

- I really don't mind if you work together on assignments. In fact, I am quite lazy and would rather have you teach each other than do it myself.
- However, if you copy someone else's assignment it will not really be any benefit to you. You will see on the midterms and exam that it was not worthwhile.
- My advice: make sure you understand all of the assignment solutions every week. It is the only way to stay on top of things. Physics is "doing".
- There is no 100% final exam option in this course.

# Assignments, Midterms and Exams

Dick and Jane have each run out of time to do assignment 4. Dick decides to copy solutions from some shady websites. Jane decides that she will do (and understand) as much of the assignment as she can and leave the rest blank. Dick gets 10/10 on the assignment and Jane gets 5/10. Who comes out ahead in the end?

There are about 10 assignments in a term, each worth 1.5%. Therefore, Dick gains 0.75% on his final grade relative to Jane by copying.
That assignment represents about 10% of the course material, so is 10% of the stuff on the final and 20% of the stuff on one of the midterms:

$$0.1 \times 50\% + 0.2 \times 15\% = 8\%$$

Jane fully understands half of that material and so gets 4/8. Dick gets 0/8. Jane comes out ahead (3.25%).

# Standard Calculators

As you know, for midterms and exams you need to use a simple scientific calculator - Aurex SC6145 (or SC6108), available at the bookstore.

# Course Content

The Title of the course says it all: Optics, Electricity and Magnetism. In very broad strokes:

- Waves
- Optics
- Applied Optics (eg. lenses, gratings)
- Electricity (Coulumb's Law, Gauss' Law)
- Applied Electricity (eg. circuits)
- Magnetism
- Applied Magnetism (eg. cyclotrons)

Of course, there will be many other things learned along the way, but that is the gist...

# Particles and Waves

**Physics - according to the dictionary**

Physics is the study of properties and interactions of matter and energy

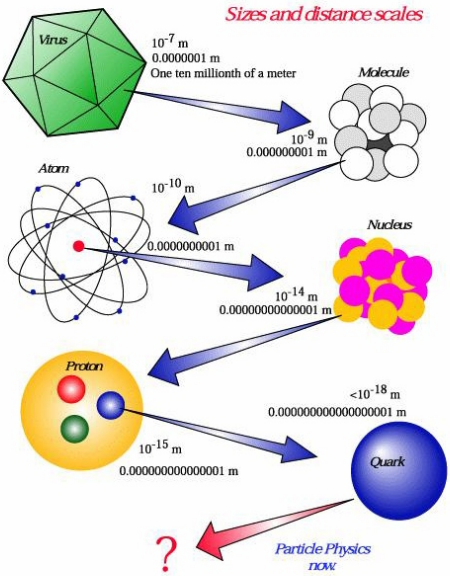
So far (in Physics 120) you have been learning to model nature based on particles. You know how to treat projectiles, billiard balls, etc. You have even taken those particles and allowed them to oscillate (SHM). This is one very useful way to look at things!

## Particle Physics

At the smallest distance scales, what is the world made of? How do those components interact?

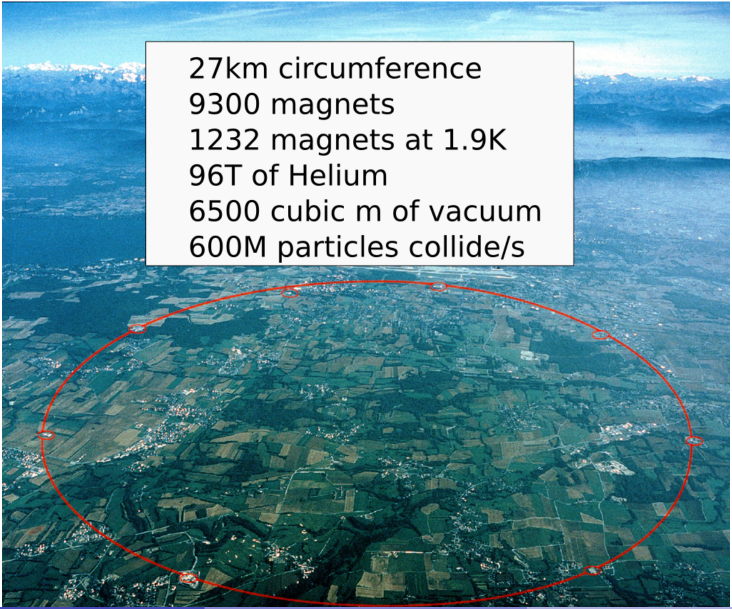

By convention there is color,
By convention sweetness,
By convention bitterness,
But in reality there are atoms and space.
-Democritus (c. 400 BCE)

# Particle Physics




- On the way down in scale we have discovered hundreds of particles
- However, the fundamental ones are few...

# Big Machines to see Small Things (when they work!)



# Why we need big machines to see small things

SLIDE STOLEN FROM P485 - INTRODUCTION TO ELEMENTARY PARTICLES

We use particles as probes, remember what we learned from de Broglie

$$\lambdabar = \frac{\lambda}{2\pi} = \frac{\hbar}{p}$$

| Example | Energy | Wavelength |
|---|---|---|
| visible light | 0.4 eV | $5 \times 10^{-7}$m |
| electron microsope | 90 keV | $4 \times 10^{-12}$m |
| X-rays (crystallography) | 10-50 keV | $10^{-10}$m |
| protons | 100 MeV | $3 \times 10^{-15}$m |
| photon | 200 MeV | $10^{-15}$m |
| Hera (e-p collider) | 314 GeV | $10^{-19}$m |

## Particles have a Wavelength!!!

Even particle physicists need waves. We need them because even particles sometimes look like waves...

If you go on to second-year physics (eg. P285) you will see enough Quantum Mechanics to hear about "wave-particle duality". It is even in Chapter 25 of your textbook...I hope we get to discuss it in a couple of weeks.

# Now, back to the course...let's talk about light

**What is Light?**

This seems like a pretty basic question. Debated for centuries.

- First Greek scientists do not distinguish between light and vision.
- At some point we realize that light is a physical entity in its own right. It actually moves!!

# What is Light?

- 1670s: Newton proposes a “corpuscular” model of light (opposed by Huygens and Hooke).
- 1801: Thomas Young experimentally establishes that light is a wave.
- 1817: Fresnel’s experiments further confirm wave-nature of light. But what is waving?
- 1873: Maxwell establishes that light is an EM wave
- 1902: Lenard’s experiments show the photoelectric effect
- 1905: Einstein proposes a photonic explanation for the photoelectric effect.
- 1927: Bohr proposes complementarity principle in QM. People are now really starting to believe Einstein.
- 2010: Students in Physics 121 are fascinated and confused by light.

# Light is a wave AND a stream of particles

Well, maybe light is a...

- Particle: a stream of photons moves from one point to another carrying information and energy.
- Wave: information and energy move from one point to another, but no material object makes the journey.

An analogy - two ways to communicate:

1. Send a letter ("like a particle")
2. Call on the telephone ("like a wave")

# Light is a wave AND a stream of particles

Think of what happens in a camera:

- You build a lens to focus an image on a screen. We will learn about such lenses in this course, you will use them in P131. Here we see light acting as a wave.
- The light hits film or a sensor (digital camera) which records a hit from a photon - a particle
- Light is acting as one thing at a time...always either a particle or a wave, not both simultaneously. Is it both or neither??
- We will see many examples of the wave-like behaviour of light in this course.
- The object in this course is not to understand what light *is* but to describe what light *does*.

# The Speed of Light - Yes it moves

The speed of light in a vacuum is

$$c = 3.00 \times 10^8 \text{ m/s } (2.99792458 \times 10^8 \text{ m/s } \textit{exactly})$$

- Einstein tells us that nothing can travel faster than $c$.
- $c$ is such a mind-boggling speed that it is difficult to perceive that light moves at all.
- Many brilliant experimentalists tried to measure the speed of light over the centuries.

**Galileo uncovering lamps on distant mountaintops**

"If not instantaneous, it is extraordinarily rapid"

but Fizeau managed it in 1849.

**Douglas Adams**

Nothing travels faster than the speed of light with the possible exception of bad news, which obeys its own special laws.

# The Speed of Light

- The speed of light is not always $c$. Outside a vacuum light travels at a speed less than $c$
$$v = \frac{c}{n}$$
where $n$ is the "index of refraction" and is always at least 1.
- Some examples

| medium | n |
|---|---|
| vacuum | 1 (exact) |
| air (at $0^\circ C$) | 1.00029 |
| water (at $20^\circ C$) | 1.33 |
| glass | $\sim$1.5 |