Welcome To

Physics 8.02T

For now, please sit anywhere, 9 to a table
Class 1: Outline

Hour 1:
  Why Physics?
  Why Studio Physics? (& How?)
  Vector and Scalar Fields

Hour 2:
  Gravitational fields
  Electric fields
Why Physics?
Why Study Physics?

Understand/appreciate nature

• Lightning
• Soap Films
• Butterfly Wings
• Sunsets
Why Study Physics?

Electromagnetic phenomena led directly to Einstein’s discovery of the nature of space and time, see his paper

ON THE ELECTRODYNAMICS OF MOVING BODIES

A. Einstein June 30, 1905

In the last class of the term before the review, we will explain to you how this comes about
Why Study Physics?

• Understand/Appreciate Nature
• Understand Technology
  § Electric Guitar
  § Ground Fault Interrupts
  § Microwave Ovens
  § Radio Towers
Why Study Physics?

- Understand/Appreciate Nature
- Understand Technology
- Learn to Solve Difficult Problems
- It’s Required
Why Studio Physics?
Why The TEAL/Studio Format?

Problems with Large Lectures:
- Lecture/recitations are passive
- No labs → lack of physical intuition
- E&M is abstract, hard to visualize

TEAL/Studio Addresses Problems:
- Lectures → Interactive, Collaborative Learning
- Incorporates desk top experiments
- Incorporates visualization/simulations

Bottom Line: Learn More, Retain More, Do Better
Why The TEAL/Studio Format?

By standard assessment measures, TEAL shows a factor of two increase in learning gains as compared to lecture/recitation format

(see Dori and Belcher, “How Does TEAL Affect Student Learning of E&M Concepts?”, Journal of the Learning Sciences 14(2) 2004.)

Bottom Line: Learn More, Retain More, Do Better
Overview of TEAL/Studio

Collaborative Learning
  Groups of 3, Tables of 9
  You teach, you discuss, you learn

In-Class Problem Solving
Desktop Experiments
Teacher-Student Interaction
Visualizations
PRS Questions
Personal Response System (PRS) Question: Physics Experience

Pick up the nearest PRS (under the table in a holder)
Your Responsibilities

Before Class:
Read Summary

In Class: (You must be present for credit)
Problem Solving, Desktop Experiments, PRS

After Class:
Read Study Guide, Review Visualizations
Homework (Tuesdays 4:15 pm)

Exams
3 Midterms (45%) + Final (25%)
To Encourage Collaboration, Grades Are NOT Curved In 8.02:

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Honesty Issues

Problem Sets:
Please work together BUT
Submit your own, uncopied work

In Class Assignments:
Must sign your own name to submitted work
Signing another’s name is COD offense

PRS:
Use only your assigned PRS
Using another’s PRS is COD offense
Physics 8.02 Staff

Includes:
- Lecturer
- Demo Group
- Graduate TA
- UGrad TAs
Textbooks

Required:
“Introduction to E & M”
Liao, Dourmashkin, and Belcher

Supplemental (not required):
Serway & Jewett 6th Edition; Giancoli;
...

Prefer something else? Let me know!

Important: Find something you can read
Common Questions & Answers

- Dysfunctional Group?
- Must Miss Class?
- Must Miss HW?
- Must Miss Exam?
- Tell Grad TA
- Tell Grad TA
- Tell Grad TA
- Tell me ASAP

Exam dates & times are online
Do NOT schedule early vacation departures, etc. without consulting these times!

Any Questions?
Physics is not Math...
...but we use concepts from 18.02

- **Gradients** \( \vec{E} = -\nabla V \)
- **Path Integrals** \( \Delta V \equiv - \int_{A}^{B} \vec{E} \cdot d\vec{s} \)
- **Surface Integrals** \( \oiint_{S} \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_{0}} \)
- **Volume Integrals** \( Q = \iiint \rho dV \)
PRS Question: Math Background
Don’t Worry!

• For many this is new & I will introduce concepts before use (yell at me if not!)
• Concepts are VERY important – mechanics are almost trivial

Math introduction/review:

A time will be scheduled
Presentation slides will be posted
So what physics do we learn in 8.02 anyway???
What’s the Physics?

8.01: Intro. to basic physics concepts: motion, force, energy, …

How does matter interact?

**Four Fundamental Forces:**

Long range: Gravity (8.01 … Gen. Relativity)

Short Range: Strong and Weak

Mid Range: Electromagnetic (8.02)
8.02: Electricity and Magnetism

Also new way of thinking…

How do objects interact at a distance?

Fields We will learn about E & M Fields: how they are created & what they effect

**Big Picture Summary:**

**Maxwell Equations:**
\[
\oint_S \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{in}}}{\varepsilon_0} \quad \oint_C \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}
\]
\[
\oint_S \mathbf{B} \cdot d\mathbf{A} = 0 \quad \oint_C \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{\text{enc}} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}
\]

**Lorentz Force:**
\[
\mathbf{F} = q \left( \mathbf{E} + \mathbf{v} \times \mathbf{B} \right)
\]
Today: Fields
In General, then
Gravitational & Electric
Scalar Fields

e.g. Temperature: Every location has associated value (number with units)
Scalar Fields - Contours

- Colors represent surface temperature
- Contour lines show constant temperatures
Fields are 3D

- $T = T(x,y,z)$
- Hard to visualize
  → Work in 2D
Vector Fields
Vector (magnitude, direction) at every point in space

Example: Wind Velocity Vector Field
Vector Field Examples

Begin with Fluid Flow
Vector Field Examples

Flows With Sources

(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/02-particleSource/02-ParticleSource_320.html)
Vector Field Examples

Flows With Sinks

(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/01-particleSink/01-ParticleSink_320.html)
Vector Field Examples

Circulating Flows

(http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/vectorfields/03-particleCirculate/03-PartCircMotion_320.html)
Visualizing Vector Fields: Three Methods

Vector Field Diagram
Arrows (different colors or length) in direction of field on uniform grid.

Field Lines
Lines tangent to field at every point along line

Grass Seeds
Textures with streaks parallel to field direction

All methods illustrated in
Vector Fields – Field Lines

• Direction of field line at any point is tangent to field at that point
• Field lines never cross each other
PRS Question: Vector Field

In General: Don’t pick up unit until ready to answer
Then I’ll know when class is ready
Vector Fields – “Grass Seeds”

Source/Sink

Circulating

Although we don’t know absolute direction, we can determine relative direction
PRS Questions: “Grass Seed” Visualizations
Weird Field Contest

Purpose
Gain familiarity with vector fields

Winner
Displayed in MIT Museum Exhibit

Due Date
Turn in with 2\textsuperscript{nd} PSet in Separate Box
Another Vector Field: Gravitational Field
Example Of Vector Field: Gravitation

Gravitational Force:
\[ \vec{F}_g = -G \frac{Mm}{r^2} \hat{r} \]

Gravitational Field:
\[ \vec{g} = \frac{\vec{F}_g}{m} = -G \frac{GMm}{r^2} \hat{r} = -G \frac{M}{r^2} \hat{r} \]

\( M \) : Mass of Earth
Example Of Vector Field: Gravitation

Gravitational Field:

\[ \mathbf{\hat{g}} = -G \frac{M}{r^2} \mathbf{\hat{r}} \]

\[ \mathbf{F}_g = m \mathbf{\hat{g}} \]

Created by M

Felt by m

\[ \mathbf{\hat{r}} : \text{unit vector from } M \text{ to } m \]

\[ \mathbf{\hat{r}} = \frac{\mathbf{r}}{r} \quad \Rightarrow \quad \mathbf{\hat{g}} = -G \frac{M}{r^3} \mathbf{\hat{r}} \]

\( M \) : Mass of Earth
In Class Problem

Find the gravitational field $\vec{g}$ at point P

Bonus: Where would you put another mass $m$ to make the field $\vec{g}$ become 0 at P?

NOTE: Solutions will be posted within one day of class
From Gravitational to Electric Fields
Electric Charge (~Mass)

Two types of electric charge: positive and negative

Unit of charge is the **coulomb** [C]

Charge of electron (negative) or proton (positive) is

\[ \pm e, \quad e = 1.602 \times 10^{-19} \text{ C} \]

Charge is quantized

\[ Q = \pm Ne \]

Charge is conserved

\[ n \rightarrow p + e^- + \bar{\nu} \quad e^+ + e^- \rightarrow \gamma + \gamma \]
Electric Force (~Gravity)

The electric force between charges $q_1$ and $q_2$ is

(a) repulsive if charges have same signs
(b) attractive if charges have opposite signs

Like charges repel and opposites attract !!
Coulomb's Law

Coulomb’s Law: Force by $q_1$ on $q_2$

$$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{r}$$

where

$k_e = \frac{1}{4\pi\varepsilon_0} = 8.9875 \times 10^9 \text{ N m}^2/\text{C}^2$

$\hat{r}$: unit vector from $q_1$ to $q_2$

$$\hat{r} = \frac{\vec{r}}{r} \Rightarrow \vec{F}_{12} = k_e \frac{q_1 q_2}{r^3} \hat{r}$$
Coulomb's Law: Example

\[ \vec{F}_{32} = ? \]
\[ \vec{r}_{32} = \left( \frac{1}{2} \hat{i} - \frac{\sqrt{3}}{2} \hat{j} \right) \text{ m} \]
\[ r = 1 \text{ m} \]

\[ \vec{F}_{32} = k_e q_3 q_2 \frac{\vec{r}}{r^3} = \left( 9 \times 10^9 \text{ N m}^2/\text{C}^2 \right) (3 \text{ C})(3 \text{ C}) \frac{\frac{1}{2} (\hat{i} - \sqrt{3} \hat{j}) \text{ m}}{(1 \text{ m})^3} \]

\[ = \frac{81 \times 10^9}{2} \left( \hat{i} - \sqrt{3} \hat{j} \right) \text{ N} \]
The Superposition Principle

Many Charges Present:
Net force on any charge is vector sum of forces from other individual charges

Example:

\[ \vec{F}_3 = \vec{F}_{13} + \vec{F}_{23} \]

In general:

\[ \vec{F}_j = \sum_{i=1}^{N} \vec{F}_{ij} \]
Electric Field ($\sim g$)

The electric field at a point is the force acting on a test charge $q_0$ at that point, divided by the charge $q_0$:

$$\vec{E} \equiv \frac{\vec{F}}{q_0}$$

For a point charge $q$:

$$\vec{E} = k_e \frac{q}{r^2} \hat{r}$$

Superposition Principle

The electric field due to a collection of $N$ point charges is the vector sum of the individual electric fields due to each charge

$$\vec{E}_{total} = \vec{E}_1 + \vec{E}_2 + \ldots + \sum_{i=1}^{N} \vec{E}_i$$
Summary Thus Far

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<tr>
<th>Mass $M$</th>
<th>Charge $q$ ($\pm$)</th>
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CREATE:

$$\vec{g} = -G \frac{M}{r^2} \hat{r}$$

$$\vec{E} = k_e \frac{q}{r^2} \hat{r}$$

FEEL:

$$\vec{F}_g = m\vec{g}$$

$$\vec{F}_E = q\vec{E}$$

This is easiest way to picture field
PRS Question: Electric Field