Intro Physics II
Physics 11b

Electricity and Magnetism
Light and Optics
Modern Physics
Teaching Staff

- **Masahiro Morii** gives the lectures
  - Here (Sci. Ctr. B) Tuesday and Thursday @ 10:00-11:30

- **Shaun Serej** leads the sections
  - With TFs Vincenzo Vitelli, Loren Hoffman, and Lars Grant
  - 1 hour/week

- **Pamela Gay** supervises the lab
  - With TFs Yina Mo and Timofey Rostunov
  - 3 hours every 2 weeks

- **Carol Davis** keeps it all running smoothly
Prerequisite Courses

- **Physics 11a**
  - Introductory Physics: Mechanics, Waves
  - If you have not finished 11a, you need to get a written permission from David Morin

- **Mathematics 21a**
  - Linear Algebra and Differential Equations
  - This can be taken concurrently
  - I assume you are familiar and comfortable with 1-dimensional calculus
Textbooks

- **Physics for Scientists & Engineers** (Serway and Jewett vol. II)
  - Required
  - Simple and practical textbook
  - Good illustrations

- **Introductory Electromagnetism** (Purcell)
  - Suggested reading
    - Main textbook for Physics 15b
  - Deeper understanding of physics behind E&M
  - Slightly more advanced math
Homework

- Problem sets are distributed on Thursdays
  - You get the first one today
- You are encouraged to work together in groups
  - Each of you must write up & turn in your own report
  - Copying your neighbor’s won’t do much for your exam
- Problem sets due next week Friday at 4 PM
  - Mailboxes outside Sci. Ctr. 109
  - Answers are posted immediately on course website
  - No late homeworks accepted
  - Graded reports will be returned at the sections
Sections

- Twelve 1-hour discussion sections are offered
  - Monday  2 PM, 2 PM
  - Tuesday  2 PM, 3 PM, 7 PM
  - Wednesday 9 AM, 1 PM, 1 PM, 7 PM
  - Thursday  9 AM, 2 PM, 3 PM
- Locations (in Sci. Ctr.) are on the syllabus and will be posted on the web
- Please use online sectioning tool to sign up by the end of the Study Card Day
- Next week’s sections will be “Meet the TF Hour”
  - Go to any section you like and ask questions
Labs

- 12 lab sections are offered
  - Monday 7 PM
  - Tuesday 3:30 PM, 7 PM
  - Wednesday 12 PM, 3:30 PM, 7 PM
  - Thursday 3:30 PM

- Five experiments in 10 weeks
  - Each takes 3 hours + writing your report

- Reports are due at 8 AM, 1 week after each lab
  - Mailboxes outside SC 109

- Please use online sectioning tool to sign up for a lab section by the end of the Study Card Day
Exams

- Two midterms and a final exam
  - Midterms (tentatively) on March 3 and April 7
    - First one just before the 5th Monday
  - Final during the exam period: May 19-27

- Final will be graded for “resurrection”

  \[
  \text{Full score of your final} = 200 + \frac{\text{What you missed in HW and midterms}}{2}
  \]

- Can make up half of HW & midterm points missed
- We will tell each of you individually how much before the final
Grades

- Add up
  - Homework 300 pts.
  - Mid-terms 150 + 200 pts.
  - Laboratory 150 pts.
  - Final Exam 200-525 pts.

- Will curve if necessary
  - Only small adjustments
  - “Resurrection” mechanism takes care of calibration

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<th>Grade</th>
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<tr>
<td>950-1000</td>
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<tr>
<td>900-949</td>
<td>A-</td>
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<td>770-799</td>
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<td>670-699</td>
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<td>630-669</td>
<td>D</td>
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<td>600-629</td>
<td>D-</td>
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<tr>
<td>&lt;600</td>
<td>God forbid</td>
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I don’t check your attendance
  - TFs are paying attention in the labs and sections

If you aren’t
  - Coming to the lectures
  - Going to the labs
  - Going to the sections
  - Then you aren’t getting what you are paying for

Homework and exams are not everything!
Getting Best Out of Us

- Come and talk to us!
  - Ask questions in the lecture, lab and sections
  - Come to office hours (to be announced soon)
  - I am in Lyman 239 most of the time
    - Other staff’s contact info on the web

- Want something changed or improved?
  - Use “Early Evaluation” on website for anonymous feedback
Plan for the Semester

- **Electricity and Magnetism**
  - Electrical and Magnetic phenomena
  - Circuits
  - Maxwell’s equations
  - Electromagnetic waves (a.k.a. “light”)

- **Electromagnetic Crisis ➔ Quantum Mechanics**
  - Quantum states
  - Basics of atomic structure
Physics 11a
Lecture #1

Electric Charge
Coulomb’s Law
Goals for Today

- Introduction
  - Electromagnetism in the Big Picture
- Electric charge
  - Conservation law
- Coulomb’s Law
  - Forces between two charged objects ➔ Inverse-square law
  - More than two objects ➔ Superposition principle
Four Forces

There are 4 fundamental forces in Nature

- **Gravity**
  - Long distance. Keeps planets and satellites in orbits
  - Classical model (Newtonian) simple and accurate
  - Modern model (General Relativity) complex and more accurate

- **Electromagnetic force**
  - Long distance. Responsible for most daily things
  - Classical model (Maxwell) simple, accurate, and identical to the modern model

- **Strong nuclear force**
  - Short distance. Keeps protons and neutrons in atomic nuclei

- **Weak nuclear force**
  - Short distance. Responsible for nuclear β-decays
Electrical Charge

- Objects don’t always respond to electricity
  - Something must be added ➔ or they must be “charged”
- Experiments have told us:
  - Charges can be positive or negative (Franklin)
  - They come in small same-sized units (Millikan)
    - Each unit is so small, and the number of units in human-size object so large (~$10^{23}$), it looks like continuous
- Turns out to be an intrinsic property of the elementary particles that make up any object in the universe
  - Proton is positively charged
  - Electron is negatively charged by the same amount
Conservation of Charge

- Charge cannot be created or destroyed
  - You can only move them from one object to another
- True even in extreme conditions where particles are destroyed and created
  - Example from high-energy collision of an electron and a positron (anti-electron)

\[ e^+ e^- \rightarrow \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \]

Two particles destroyed
Six particles created
Total charge remains zero

An event from the CLEO Experiment
Courtesy of A. Foland
Forces Between Charges

- Unlike most forces in 11a, the electric force ($F_e$) between two charges ($q_1$ and $q_2$) work over distance ($r$)
  - Smaller $r \Rightarrow$ stronger $F$
  - Larger $r \Rightarrow$ weaker $F$

- Measurements show
  - $F \propto \frac{q_1 \times q_2}{r^2}$
  - Proportional to both charges
  - Inversely proportional to the square of the distance

- Same inverse-square law as gravity
  - $F_{\text{grav}} \propto \frac{m_1 \times m_2}{r^2}$
Coulomb’s Law

- Force has direction as well as strength ➔ Vector
  - Parallel to the line connecting the charges
  - Which way?

\[ \mathbf{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{\mathbf{r}} \]

- Coulomb constant
- Force caused by 1 acting on 2

- Sign of \( F_{12} \) depends on whether \( q_1 \) and \( q_2 \) have the same or opposite signs
There are two systems of units in E&M: SI and CGS. We stick with SI, as Serway and Jewett do.

Charge is measured in Coulomb (symbol C)

\[ 1 \text{ Coulomb} = 6.24 \times 10^{18} \text{ protons} \]

Force is measured in Newton, distance in meter.

Now we can write down the constant

\[ k_e = 8.9875 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]

8987500000 Newtons
Coulomb’s Law – SI Version

- In SI, we usually write Coulomb’s law as
  \[ F_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1q_2}{r^2} \hat{r} \]

  - Constant \( \varepsilon_0 \) is known as permittivity of vacuum
    \[ \varepsilon_0 = 8.8542 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \]

- This absurdity will start to make sense when we do capacitance
Inverse-Square Laws

- Electric force and gravity share the \( r \)-dependence

\[
\mathbf{F}_e = \frac{1}{4\pi \varepsilon_0} \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}
\]

\[
\mathbf{F}_g = -G \frac{m_1 m_2}{r^2} \hat{\mathbf{r}}
\]

- Both are inverse-square laws
  - Much of what you learned about gravity will apply to electricity
  - One major difference: the signs

<table>
<thead>
<tr>
<th>Charge or Mass</th>
<th>Force</th>
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<tbody>
<tr>
<td>Electric force</td>
<td>positive or negative</td>
</tr>
<tr>
<td>Gravity</td>
<td>only positive</td>
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Superposition Principle

- Suppose we have many charges distributed in space.
  - What is total force on charge $Q$ from all the other charges?
- Principle of Superposition
  - Just add them up
  - Force from each one not affected by the others

\[
F_Q = \sum_i \frac{1}{4\pi\varepsilon_0} \frac{Qq_i}{r_{iQ}^2} \hat{r}_{iQ}
\]

\[
= \frac{Q}{4\pi\varepsilon_0} \sum_i \frac{q_i}{r_{iQ}^2} \hat{r}_{iQ}
\]

Force from the $i$-th charge.
Electric charge = How object responds to electric force
- Comes in positive and negative flavors
- Conserved

Electric force
- Coulomb’s Law
  \[ F_e = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r} \]
  - Same inverse-square law as gravity
  - Sign makes the dynamics different

Superposition Principle
\[ F_Q = \frac{Q}{4\pi\varepsilon_0} \sum_i \frac{q_i}{r_{iQ}^2} \hat{r}_{iQ} \]
- Next lecture will use this to explore more interesting problems