Announcements

- Last video homework due tonight!
- I am, unfortunately, still not done with the Test 3 grading
- Hopefully I got a grade report posted with what I DO have graded though...
- We'll talk the final at the end of the day

Upcoming:

A Semester in Review

Chapter 13: The Electric Field

- Concept of “fields” (dividing out the object contribution)

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q}$$

- Electric fields due to point charges

$$\vec{\mathbf{E}} = \frac{1}{4\pi\epsilon_0}\frac{q}{|\vec{\mathbf{r}}|^2}\hat{\mathbf{r}}$$

- Superposition of electric fields (they just add!)
- Dipoles
- Included HW1-3, VHW1

Chapter 14: E-Field Interactions

- Charge is conserved
- Differences between conductors and insulators
- How to charge objects
- Polarization of Insulators
    - Induced dipoles
- Polarization of Conductors
    - Electron Sea
    - Drift Speeds
    - Electric field inside conductors
- Included HW4,5, VHW2,3

- For any distribution:
  - Divide into small pieces
  - Determine direction and expression for $\Delta\vec{\mathbf{E}}$
  - Add up all contributions
  - Check yourself!
- Looked at electric fields due to:
  - Charged lines
  - Charged rings
  - Charged surfaces
  - Charged shells and spheres
- Introduction to capacitors
- Included HW6,7, VHW4

- Relation to potential energy

$$\Delta U = q\Delta V$$

- Potential Difference in electric field

$$\Delta V = -\sum \vec{\mathbf{E}} \cdot \mathrm{d}\hat{\ell} = -\int \vec{\mathbf{E}} \cdot \mathrm{d}\hat{\ell}$$

- Relation to electric fields:

$$E_x = -\frac{\partial V}{\partial x}, \qquad E_y = -\frac{\partial V}{\partial y}, \qquad E_z = -\frac{\partial V}{\partial z}$$

- Potential differences add
- Path independent
- Potential at single location defined with respect to infinity
- Dielectrics
- Included HW8-10

- Need moving charges

$$\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{q\vec{\mathbf{v}}\times\hat{\mathbf{r}}}{|\vec{\mathbf{r}}|^2}$$

- Definition of current

$$\mathrm{I} = |q|nA\bar{v}$$

- Magnetic fields due to currents

$$\Delta\vec{\mathbf{B}} = \frac{\mu_0}{4\pi}\frac{\mathrm{I}\Delta\hat{\ell}\times\hat{\mathbf{r}}}{|\vec{\mathbf{r}}|^2}$$

- Magnetic field due to current distributions: line current, loop of current (magnetic dipole)
- No magnetic monopoles!
- Included HW11,12

Chapter 18: Electric Fields and Circuits

- Equilibrium vs Steady State
- Current Node Rule: What goes in must come out
- Electric field and drift speed related

$$\bar{v} = u\vec{\mathbf{E}}$$

- Charge buildup on wire surfaces
  - Same current throughout the circuit
  - E Field always points in direction of current
- Loop Rule: $\Delta V = 0$ along any closed path in a steady state circuit
- Role of batteries
- Included HW13,14

Chapter 19: Capacitors and Resistors

- Defining capacitance

$$Q = C|\Delta V|$$

- How capacitors add in circuits
- Charge the same in capacitors in series, voltage the same in capacitors in parallel
- Resistance

$$R = \frac{L}{\sigma A}$$

- Dependence on microscopic properties
- How resistors add in circuits
- Power in circuits

$$\text{Power} = \mathrm{I}\Delta V$$

- Real batteries
- Included HW15, VHW5,6

- Magnetic Force:

$$\vec{\mathbf{F}} = q\vec{\mathbf{v}} \times \vec{\mathbf{B}} = \mathrm{I}\Delta\hat{\ell} \times \vec{\mathbf{B}}$$

- Determining circular motion and properties
- The Hall Effect
- Motional Emfs
  - Motion of conductor in magnetic field creates force
  - Force separates charges, creates ΔV, so current flows
  - Current flowing creates opposing force
  - Converts between mechanical and electrical energy
- Included HW16-18

- Electric Flux

$$\Phi_E = \int \vec{\mathbf{E}} \cdot \hat{\mathbf{n}} \, \mathrm{d}A$$

- Gauss's Law
  - Electric flux through a closed surface proportional to the charge enclosed

$$\oint \vec{\mathbf{E}} \cdot \hat{\mathbf{n}} \, \mathrm{d}A = \frac{Q_{enc}}{\epsilon_0}$$

- Ampere's Law
  - The sum of magnetic fields around a loop is proportional to the current enclosed

$$\oint \vec{\mathbf{B}} \cdot \mathrm{d}\hat{\ell} = \mu_0 \mathrm{I}_{enc}$$

- Included HW19, VHW7

- Magnetic Flux

$$\Phi_B = \int \vec{\mathbf{B}} \cdot \hat{\mathbf{n}}\,\mathrm{d}A$$

- Faraday's Law:
  - Changes in magnetic flux create curling electric fields

$$\oint \vec{\mathbf{E}} \cdot \mathrm{d}\hat{\ell} = -\frac{\mathrm{d}}{\mathrm{d}t}\int \vec{\mathbf{B}} \cdot \hat{\mathbf{n}}\,\mathrm{d}A$$

  - If a conductor surrounds the loop, can get an emf:

$$\mathcal{E} = -\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$$

- Also relates to motional emfs
- Included HW20

- Maxwell-Ampere's Law
  - Adds correction term for changing electric flux

$$\oint \vec{\mathbf{B}} \cdot \mathrm{d}\hat{\ell} = \mu_0 \left(\mathrm{I}_{enc} + \epsilon_0 \frac{\mathrm{d}\Phi_E}{\mathrm{d}t} \right)$$

- Light Waves are self-propagating electromagnetic fields
  - $\vec{\mathbf{E}}$ crossed with $\vec{\mathbf{B}}$ points in direction of wave travel
  - $\left|\vec{\mathbf{E}}\right| = c\left|\vec{\mathbf{B}}\right|$
  - Waves travel at the speed of light
- Created by accelerating charges
  - Create ripple in electric/magnetic fields
- Poynting Vector contains information about wave energy

$$\vec{\mathbf{S}} = \frac{1}{\mu_0}\vec{\mathbf{E}} \times \vec{\mathbf{B}}$$

- Included HW21-23

Supplementary: Optics

- Sinusoidal waves

$$f = A\cos(\omega t - kx - \phi_0)$$

- Waves travel slower or faster in different materials

$$n = \frac{c}{v}$$

- Snell's Law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- Interference

$$\Delta(\text{phase}) = k\Delta x + \Delta\phi_0 = \begin{cases} \pm 2\pi m & \text{constructive} \\ \pm 2\pi(m + \frac{1}{2}) & \text{destructive} \end{cases}$$

- Special Lens Rays
- Included HW24, VHW8

Class Picture!

- I always take an end-of-semester class picture in each class I teach
- Unfortunately we can not gather together this year, so if you would be so kind to take a snapshot of yourself with your webcam or phone at the moment and email it to me, I'm going to compile them all together so I have something from this class for this semester!
- Do it now so you don't forget!

Final Plans

- Due on Saturday by noon
- I'm going to be posting more formal instructions by this evening but the main gist is:
  - One video solution for a problem I will give you from this latest section on optics and waves
  - 4 test questions written by you for me from objectives from the entire rest of the semester
    - Choose the 4 objectives you feel to be the most important / capture the essence of what you were supposed to learn in this class. In your solution key, take a sentence or two to justify why you chose this objective and felt it to be of this importance.
    - There are lots of fine answers here, but there are some objectives I would definitely raise my eyebrows at unless you explained yourself *REALLY* well.
    - If it is the same objective as one you already did, then ok, but the question needs to be new
    - Should still be valid *test* questions, so capable of being done in 10 minutes.
    - Still need to submit your solution key separately.

So long! Farewell!

Thank you all so much for the lovely and *memorable* semester!
Stay healthy!