

- 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

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Chapter 13: The Electric Field

• Concept of "fields" (dividing out the object contribution)

$$\vec{\mathsf{E}} = rac{ec{\mathsf{F}}}{q}$$

• Electric fields due to point charges

$$ec{\mathsf{E}} = rac{1}{4\pi\epsilon_0}rac{q}{\left|ec{m{r}}
ight|^2}\mathbf{\hat{r}}$$

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

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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

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Chapter 15: Charge Distributions

- For any distribution:
 - Divide into small pieces
 - Determine direction and expression for $\Delta \vec{E}$
 - 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

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Chapter 16: Electric Potential

Relation to potential energy

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

Potential Difference in electric field

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

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

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Chapter 17: Magnetic Fields

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

$$I = |q| n A \bar{v}$$

• Magnetic fields due to currents

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

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

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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

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

- 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

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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

Power =
$$I\Delta V$$

- Real batteries
- Included HW15, VHW5,6

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Chapter 20: Magnetic Forces

• Magnetic Force:

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

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

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Chapter 21: Gauss and Ampere

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

$$\oint \vec{\mathbf{B}} \cdot d\hat{\ell} = \mu_0 I_{enc}$$

Included HW19, VHW7

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Chapter 22: Faraday's Law

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

$$\oint \vec{\mathbf{E}} \cdot d\hat{\boldsymbol{\ell}} = -\frac{d}{dt} \int \vec{\mathbf{B}} \cdot \hat{\mathbf{n}} \, dA$$

• 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

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Chapter 23: Radiation

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

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

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

$$\vec{\mathsf{S}} = rac{1}{\mu_0} \vec{\mathsf{E}} imes \vec{\mathsf{B}}$$

Included HW21-23

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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

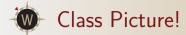
$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Interference

$$\Delta({\sf phase}) = k\Delta x + \Delta\phi_0 = egin{cases} \pm 2\pi m & {\sf constructive} \\ \pm 2\pi (m+rac{1}{2}) & {\sf destructive} \end{cases}$$

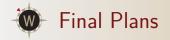
- Special Lens Rays
- Included HW24, VHW8

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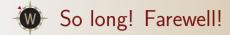
- I always take an end-of-semester class picture in each class I teach
- Unfortunately we can not gather together this year, so if you would be so kind to take a snapshot of yourself with your webcam or phone at the moment and email it to me, I'm going to compile them all together so I have something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

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- 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.

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

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