PHGN200 - TOC

PHGN 200 - 2024-08-20

#notes #phgn200 #physics

housekeeping stuff

- Section D (I'm going to forget)

general course outline

- electrostatics, circuits, magnetcs, electromagnetism

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actual physics (that took twelve minutes)

some general basic facts

- we've identified two types of charges (positive and negative)
- two negative charges next to each other are going to repel
- opposites attract, etc, etc
- that will get you *shockingly* far
  - ba dum tiss
- Electrons have a charge of $q = -e = -1.602 \times 10^{-19} C$
- Protons, on the other hand, have $q = e = 1.602 \times 10^{19} C$
  - That's on the equation sheet, don't need to memorize, but is fun regardless
- Moving charges is generally moving electrons, because they're comically light
- Charges are conserved in a closed system
  - Also quantized: you could count it, it'll exclusively be whole units of e

matter! (it does)

- insulators and conductors
  - charges in insulators can't move and are "fixed"

        - well, that's not really true, they can move a *little bit,* but not really
            - ie, if a charged object with positive charge would be nearby, the protons would *slightly* sneak away
    - conductors, meanwhile, are having a grand old time
        - protons and electrons are floating in a soup, and super movable
        - if that same positively charged object were to be brought near a conductor, protons would scramble as far away as they could, and electrons would huddle in like the sheep they are

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physics, never change (five part example problem)

- starting with a big, positively charged sphere and two little spheres that are far away

2. Gambling that charges are going to move over and polarize
3. Ok little sphere A is going to be negative, little sphere B is going to be positive (because now they're going to swippy swappy charges around, because now they're essentially one big object)
4. After they were touching if they bring them apart, they'll keep having their charges, even if moved away from the big sphere

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ok back to housekeeping ig

- If you answer 75% of the clicker questions, that counts for the whole day
- 2% extra credit exists, so that's nice
- Exclusively whole letter grades from .00 to 9.99
- Six total quizzes (three free response, three traditional {with questions taken from the homework and studio})
    - Only five are counted towards your grade (neat)
- Quizzes have some curve shenanigans going on
    - If version A had an average of 80%, B of 75%, and C of 75%, B and C will get normalized up to 80% so you're not punished for having a harder quiz
- Nothing on a quiz that you've never seen before (exclusively from homework, discussion, or studio) (same for the final)

toDo

- read everything on canvas
- note logistic questions
- make sure you can access webwork
- have clicker be ready

PHGN 200 - 2024-08-22

#notes #phgn200 #physics

physics!

coulomb's law

- This is for finding the force between two charges, which is equal to

$$\vec{F}_{1,2} = \frac{kq_1q_2}{r^2_{1,2}}\hat{r}_{1,2}$$

> - $\hat{r}$ is our unit vector in this situation, which is telling us where we're going
>   > - normal r down there is just the distance between them

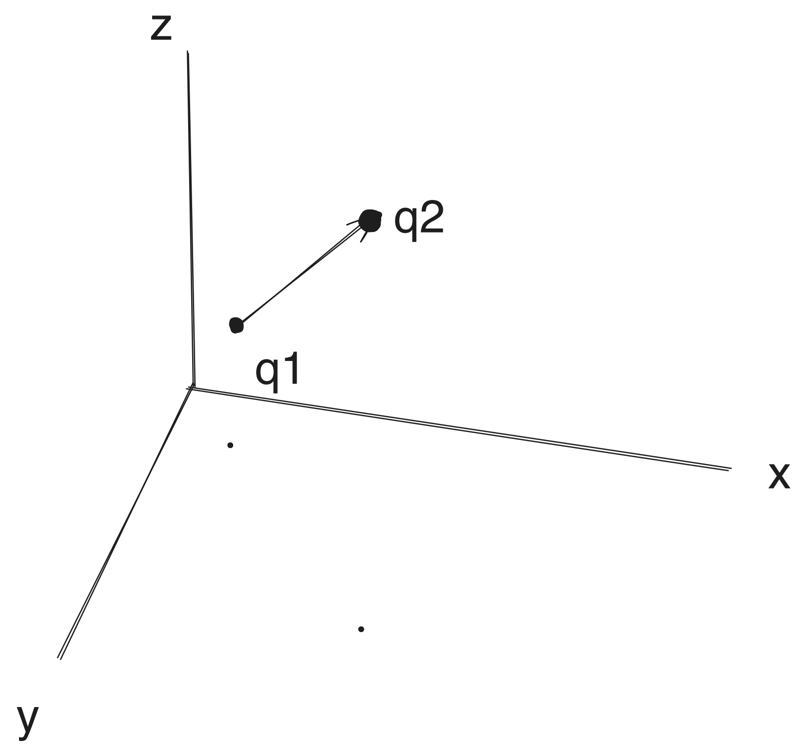
- $$\hat{r} = \frac{\hat{r}}{r} = \frac{r_x\hat{\imath} + r_y\hat{\jmath} + r_2\hat{k}}{r}$$
- Any time you're working in more than one dimension, it's generally easier to work using the equation

$$= \frac{kq_1q_2}{r^3_{1,2}}\vec{r}_{1,2}$$

- Which, again, is all the same
- $\vec{r}$ is always going to point from cause to effect, so similar to gravity, we would say something like q_1 is causing q_2 to experience a force

> - Same notation as in the past, where the force from q_1 on q_2 would be $\vec{F}_{1,2}$

Got a charge $q_1 = 5\mu C$ located at $(1, 2, 3)$ and charge $q_2 = -8\mu C$ located at $(4, 7, 8)$, what is the force exerted by q_1 on q_2



$$F_{1,2} = \frac{Kq_1q_2}{r^3}\vec{r}$$

So just doing the location vectors, the (non unit) vector for direction is going to be $< 3, 5, 5 >$, which is fun, so that'll be $\vec{r}_{1,2}$ (if we're being physics with it, they'll probably say $3\hat{\imath} + 5\hat{\jmath} + 5\hat{k}$)

$\hat{r}_{1,2}$ though is going to be that divided by $|\vec{r}_{1,2}|$, which is going to be like $\sqrt{59}$, which is... kind of ugly, but whatever, so $\hat{r}_{1,2} = \frac{1}{\sqrt{59}} * (3\hat{\imath} + 5\hat{\jmath} + 5\hat{k})$
(or like, you could distribute, but.... I'm really lazy.) (or like, rationalize, but being honest, $\frac{\sqrt{59}}{59}$ isn't exactly more comprehensible)

- You can then plug in and solve, so micro is 10^{-6}, so it'll be

superposition

- The net force (from electrostatics) is the sum of all the individual forces, ie

$$\vec{F}_{net} = \sum_i \vec{F}_i$$

- Three charges are arranged in a whole fashion
- $$\vec{F}_{1,2} = \frac{Kq_1q_2}{d_2^3}\vec{r}_{1,2} = \frac{Kq_1q_2}{d_2^3}(-d_2\hat{\jmath})$$

$$\vec{F}_{3,2} = \frac{Kq_3q_2}{d_3^3}\vec{r}_{3,2} = \frac{Kq_3q_2}{d_3^3}(-d_3\hat{\imath})$$

$$\vec{r}_{1,2} = 0\hat{\imath} + -d_2\hat{\jmath} + 0\hat{k}$$

$$\vec{r}_{3,2} = d_3\hat{\imath} + 0\hat{\jmath} + 0\hat{k}$$

$$\sum \vec{F}_2 = \vec{F}_{1,2} + \vec{F}_{3,2} = \frac{Kq_1q_2}{d_2^3}(-d_2\hat{\jmath}) + \frac{Kq_3q_2}{d_3^3}(-d_3\hat{\imath})$$

Electric Field

- Electric fields tell you what would be happening *if* you were to put any charge of your choice at a location in the field
- Has units of Newtons per Coulomb, or $\frac{N}{C}$
- Equations for this are as follows

$$\vec{E} = \frac{kq_{source}}{r^3}\vec{r}$$

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

- So the "cause" term is still floating in the $\vec{E}$, we just moved the effect outside

Electric Field Lines Rules

- Always begin on positive charges and end on negative charges
- Lines around isolated charges are symmetrical
- Number of lines around a charge are proportional to the magnitude of the charge.
- Density of the lines at any point are proportional to the strength of the field at that point
- Far away from a system, the lines should look roughly like they came from a single net charge
- Field lines do not cross.

PHGN 200 - 2024-08-27

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Continuous Charge Distribution

So, we know that the field due to *one* charge is our $\vec{E} = \frac{kQ}{r^3}\vec{r}$
Because $\vec{E}$ is a vector, the electric due to a whole bunch is $\sum_i \frac{kQ_i}{r_i^3}\vec{r}_i$, which is, again, known

If we have a ton of tiny charges though, we move to an integral

$$\vec{E} = \int \frac{kdQ}{r^3}\vec{r}_i$$

$$\vec{F}_e = q\int \frac{kdQ}{r^3}\vec{r}$$

- Our dQ is a very very very small chunk of something - it does *not* mean that it's changing, just that it's very small
    - Derivatives are ratios of infinitesimals, for fun reference
- Hey, so, we kinda need to know what's going on with dQ
    - For one dimension (lines of stuff),
    - $$dQ = \lambda dl$$ $$\lambda = \frac{Q_{total}}{L_{total}}$$
    - Two dimensions though

    $$dq = \sigma dA$$

    $$\sigma = \frac{Q_{total}}{A_{total}}$$

    - Finally, wrapping out in three dimensions

$$dQ = \rho dV$$

$$\rho = \frac{Q_{total}}{V_{total}}$$

- Ok, sure, the arc is one dimensional. Sure.

$$dQ = \lambda * Rd\theta$$

$$\lambda = \frac{Q_{total}}{L_{total}}$$

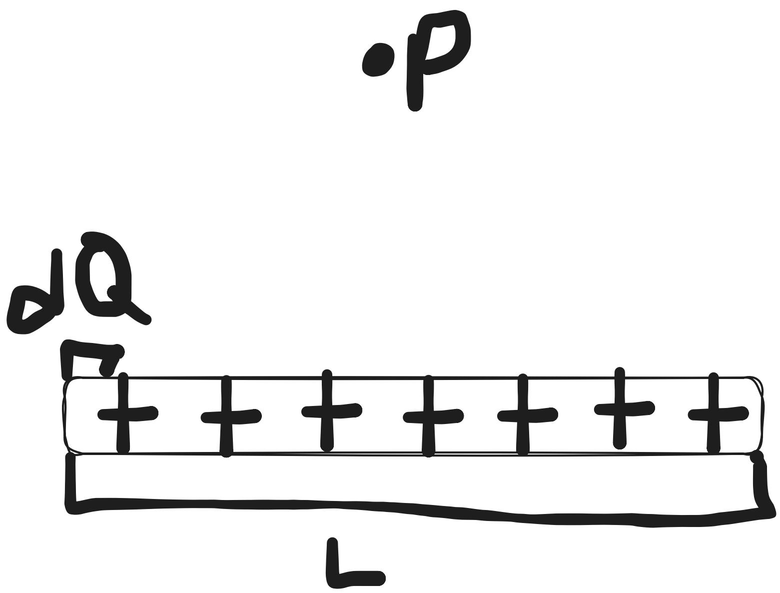
$$dQ = (\frac{Q_{total}}{\pi R}) * Rd\theta$$

$$dQ = \frac{Qd\theta}{\pi}$$

A circle with charge density λ and radius r would spit out a dQ of $dQ = \lambda r d\theta$\

- Draw sketch, label dq, do algebra, etc, etc

Big line charge sketch



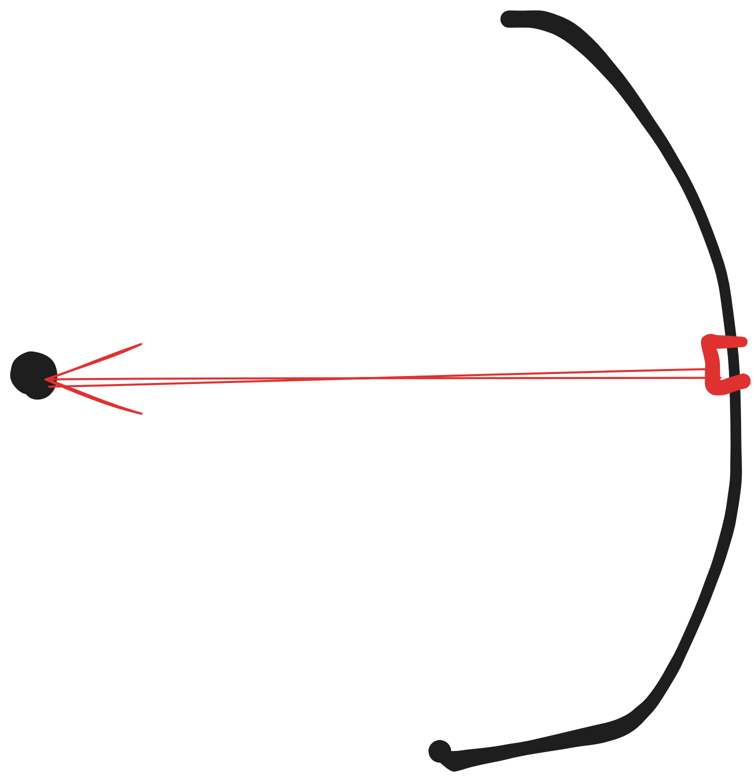
$$\vec{E} = \int \frac{kdQ}{r^3}\vec{r}$$

$$dQ = \lambda * d\ell$$

$$\lambda = \frac{Q}{L}$$

$$d\ell = dx$$

$$dQ = \frac{Q}{L} * dx$$



- The overwhelming majority of the time it's really convenient to make cartesian coordinates, ie

$$\vec{r} = r_x(\hat{\imath}) + r_y(\hat{\jmath}) + r_z(\hat{k})$$

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PHGN 200 - 2024-08-29

#notes #phgn200 #physics

fluxxy

- Flux is how much of an electric field poinst through a surface
- Electric flux through a closed surface is directly proportional to the amount of charge enclosed by that surface

$$\Phi_E = \frac{q_{enc}}{\epsilon_0}$$

- What does the ϵ_0 mean?
  - Great question! It's a constant. L, bozo.
  - 8.854187817 $*10^{12}$

- As long as the charge is enclosed within something, where the charge is and the shape itself do *not* matter
- We're going to do some bullshit to conjure a closed surface to deal with flux on open stuff
- Gaussian surface, we, essentially, just make shit up in order to figure out flux.
  - We can change size, shape, position, whatever! We just out here making shit up.

brief symmetry overview

- spherical symmetry: you can rotate in any direction and it'll be the exact same
- Cylindrical symmetry: You can translate or rotate along an axis without changing (for long cylinders, not short uns)
- "What defines long vs short?" "It's a little bit of a vibe"
  - So many "short cylinder" problems that "long cylinders" don't have to deal with
- Planar Symmetry: An object can be translated in either direction without being changed (too much)

$$\text{Flux through cube: } \Phi = \frac{Q}{\epsilon_0}$$

$$\text{Flux through one face: } \Phi_{face} = \frac{Q}{6\epsilon_0}$$

new flux

$$\Phi_E = \int \vec{E} \cdot d\vec{A} = \frac{q_{encl}}{\epsilon_0}$$

- $d\vec{A}$ is a small differential piece of area, and our electric field may vary depending on where we are

sign of flux

- On an open surface, you, uh, you get to pick! Have fun with that.
- If the shape is closed, strict convention that our vectors point outwards
- Flux is essentially the "concentration" of fields, a big area with less field lines with have less flux than a big area with more field lines, and similarly the same amount of field, but a bunch of it "missing" a small area will also lead to less flux
- Same vector spits out a 1, perpendicular spit out a 0 (just for reminders)
- Orientation matters!

> - It's the area *vector,* which is essentially the perpendicular thing you define a plane by

some example bullshit

$$\vec{E} = Axy\hat{\imath} + Bx^2\hat{\jmath} + Cy\hat{k}$$

Is our electric field, with some cube of side length ℓ

$d\vec{A}$ is in the direction of $\hat{k}$, and then $d\vec{A}$ is just going to by $dxdy$

$$\int < Axy, Bx^2, Cy > \cdot < 0, 0, dxdy >$$

$$\int < (0) + (0) + (Cy * dxdy)$$

$$\int Cy * dxdy$$

$$\frac{Cxy^2}{2}$$

- Quick jumpscare from multivariable calculus, let's find out if I did this right!
-

PHGN 200 - 2024-09-03

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Gauss's Law

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{encl}}{\epsilon_0}$$

You can always find the flux if you know the charge enclosed by the surface

- Sometimes, you can solve for $\vec{E}$, but that requires symmetry shenanigans

As a vague algorithm for how you can do this, you can:

1. Write out the law and draw a picture!
2. Invent a Gaussian surface for funsies that's actually useful
3. Solve the left hand side, taking note of symmetries and all that

1. See if the field is parallel or perpendicular to the area vector
4. Find q_{encl}
5. Set both sides equal and solve for E

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example

- We have our long solid cylinder with radius R and. charge density ρ uniformly distributed throughout
- Cylinder?
  - I mean like, our hypothetical gaussian surface is just... a ~~bigger~~ smaller! cylinder? Right?
- If the electric field always points exactly parallel or perpendicular to the Gaussian surface, you can.. toss out the dot product, and toss out the vectors
- And if we can guarantee that it doesn't change, then we can just yoink the E outside the integral.

So if we're always exactly parallel or perpendicular

$$\oint \vec{E} \cdot d\vec{A} = \int E dA$$

And if it doesn't change,

$$E(2\pi r \ell)$$

- Just as a note, r is a coordinate most of the time, where we're looking at, whereas R is fairly often a constant of something's radius.
  - Radius of the Gaussian surface is actually almost always small r

Q for non-uniform charge distributions

$$Q_{encl} = \text{GO CHECK SLIDES FILL THIS IN}$$

PHGN 200 - 2024-09-12

#notes #phgn200 #physics

- Avid Dattenborough talking about bees
  - Actually fascinating insight into the charge of bees and flowers and how they do some charge shenanigans.

quick recap of voltage stuff

$$\Delta U = q\Delta v$$

- Yeah, that's that. Wowee. Shocking stuff.

$$V = \frac{kq}{r}$$

Is the amount of potential energy per unit charge when you bring a charge in from infinity

$$\vec{E} = \vec{\nabla} V$$

$$\nabla f = \frac{\partial f}{\partial x}\hat{\imath} + \frac{\partial f}{\partial y}\hat{\jmath} + \frac{\partial f}{\partial z}\hat{k}$$

$$2xyz + x^2 z + x^2 y$$

- Electric field is the ***NEGATIVE*** gradient. The gradient is just the partials, the e-field is the ***NEGATIVE*** gradiant.

NEGATIVE GRADIENT

$$E = -\frac{dv}{dr} = \frac{-\Delta V}{\Delta r} = \frac{9}{d}$$

$$F = qE, F = -e\frac{-9}{d} = \frac{9e}{d}, a = \frac{9e}{md}$$

$$v_f^2 = v_0^2 + 2ad$$

$$v_f^2 = (\frac{9e}{md})d, v_f^2 = \frac{9e}{m}, v_f = \sqrt{\frac{18e}{m}}$$

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

$$\Delta V = V_f - V_i = \int_i^f \vec{E} \cdot d\vec{\ell}$$

$$\vec{F} = \hat{\imath} + \hat{\jmath} + \hat{k}, \int_{x=0,y=0,z=0}^{x=1,y=1,z=1} \vec{F} \cdot d\vec{\ell}$$

$$\int_{x=0,y=0,z=0}^{x=1,y=1,z=1} \vec{F} \cdot d\vec{\ell} = \int_{0,0,0}^{1,0,0} \vec{F} \cdot d\vec{x} + \int_{1,0,0}^{1,1,0} \vec{F} \cdot d\vec{y} \int_{1,1,0}^{1,1,1} \vec{F} \cdot d\vec{z}$$

$$= 1 + 1 + 1 = 3$$

2?

PHGN 200 - 2024-09-17

#notes #phgn200 #physics

it'S CIRCUIT TIME YIPPEEEEEEEEE

Conductors allow electrons tot ravel freely

- This happens for a avariety of reasons, including a raging hatred for other electrons.
- When electrons move in a material, that's electric current, and is given by

$$I = \frac{\Delta Q}{\Delta t}$$

- Example is eight electrons moving out of a section of wire in two seconds, giving a current of $4eA$

That son of a bitch Benjamin Franklin

- We pretend that protons are moving, not electrons, when dealing with current. This leads to a bunch of random negative signs. Blame Benny F.

Current

If we have a wire, with cross sectional area A, and drift velocity v_d, over some time Δt

$$\ell = v_d \Delta t$$

- Number of charge carriers per unit volume is n
- Charge on each carrier is q
- Drift speed of each charge is v_d
- Distance a charge travels in some time is $\ell = v_d \Delta t$
- Sticking all of this together, we get the total charge that flows through some length, in some time.

$$\Delta Q = nqA\ell = nqA(v_d \Delta t)$$

$$\left(\frac{\cancel{\text{Num Carriers}}}{\cancel{\text{Volume}}}\right)\left(\frac{\text{Charge}}{\cancel{\text{Num carriers}}}\right)\cancel{(\text{Volume (area *length))}} = \text{Charge}$$

- Current uses units of coulombs per second, or Amperes.

$$I = n|q|Av_d$$

You are never safe from the risk of getting integrated.

$$dI = n|q|v_d * dA$$

$$10 = (8.47 * 10^{28})(\pi * (\frac{1}{1000})^2) * v_d * 1e$$

$$v_d = \frac{10}{(8.47 * 10^{28})(\frac{\pi}{1000000}) * 1.602 * 10^{-19}} \approx 2 * 10^{-4} \frac{m}{s}$$

- Current has a direction, but is definitively not a vector (I was questioning why, but it's because current can be looped, and vector math would say that a loop is 0)

$$\hat{J} = nq\vec{v}_d$$

$$I = \int \vec{J} \cdot d\vec{a}$$

Resistance is, the effort to push electrons through non-perfect conductors.

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

- Longer resistors have higher resistance, quirkily though, inversely proportional to area, this is because electrons aren't fighting so hard to fucking murder each other when you spread them out over like, Kansas.

$$\Delta V = IR$$

- There's my boy. My lad. The classic. We're dealing exclusively with Ohmic resistors, which are the same depending on voltage drop or current.
  - Air is a non-ohmic resistor, fun fact. It works as a conductor over a certain point, which gives ya lightning.

Series and Parallel

- Series are... in a row. You gotta go through all of them... in series (roll credits)
- Parallel are arranged so they see the same voltage drop across all of them... they're parallel to each other.

Series

- Current is the same across all of them
- Voltage is going to add together (which you can also get to by adding resistance together)
-

In Parallel

- Voltages are the same across all
- Currents are the same

$$I_{tot} = V(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3})$$

$$V\sum_i \frac{1}{R_i} = \frac{V}{R_{eq,parallel}}$$

- Example, if you have two 1 ohm resistors, in parallel, you'll end up with

$$\frac{1}{R_t} = \frac{1}{1} + \frac{1}{1} = \frac{1}{R_t} = \frac{2}{1} = \frac{1}{2}\Omega$$

- 1.5 ohm

$$\frac{1}{1} + \frac{1}{2} = \frac{3}{2} = \frac{2}{3}\Omega$$

PHGN 200 - 2024-09-19

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note: quiz next Thursday on everything covered up to today. be ready.

Powah

- Power is energy over time, or $P = \frac{\Delta U}{\Delta t}$
- Power is also $P = \Delta VI$

- Units are watts, also known as Joules / second. You do some dimensional analysis to get there, it works out, I swear.
- We can also do some Ohm's Law shenanigans to go more
  - $P = \Delta VI = I^2R = \frac{\Delta V^2}{R}$

---

example (it's a circuit with one R in series and the other two in parallel)

- Total resistance is $\frac{3}{2}R$
- $V = IR$
  - $I = \frac{V}{\frac{3R}{2}}, I = \frac{2V}{3R}$
  - $P = \frac{2V^2}{3R}$

Suffering with Resistors

- For most things, you can just use $R = \frac{\rho L}{A}$
  - Where ρ is the resistivity, L is the length, A is the cross sectional area
  - A varying ρ or A would use $dR = \frac{\rho dL}{A}$

Resistance over a non-uniform object

- Square wire of length L that starts at x=0, the width of the wire is given by $S = 4 + 3x$. Total resistance is

$$\int_0^L \frac{\rho dx}{(4+3x)^2}$$

Kirchhoff's Rules

Junction Rule

- Comes from conservation of charge
- Sum of the currents into a junction must equal the sum of currents *out* of the junction.

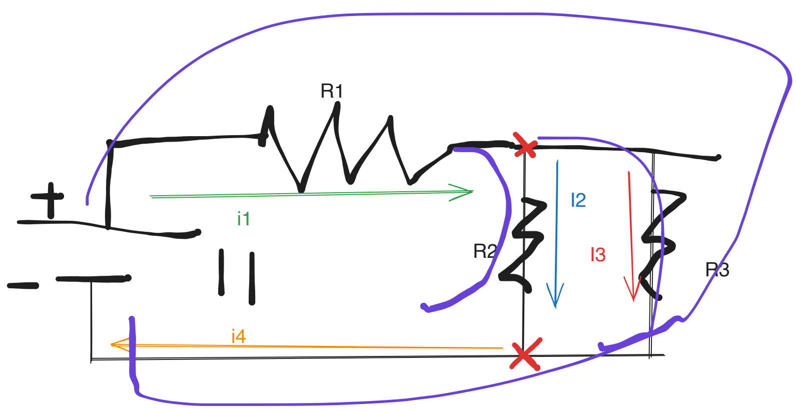
- The formal math for this is something like $\sum I_{in} = \sum I_{out}$, which feels obvious but like, thanks Kirchhoff, I guess.

Loop Rule

- Conservation of Energy shenanigans
- If you go around *any* closed loop in a circuit, the sum of the changes in potential must equal zero.

Sign Conventions

- Going opposite the direction of current flow, resistor would be positive, and battery would be negative.
  - This is going from the negative terminal to the positive terminal.
- Going with the current flow, the battery is going to be positive, and resistor will be negative.
- huge shoutout to a guy muttering "thanks a lot ben franklin"



- Top junction we have that $I_1 = I_2 + I_3$
- One on the bottom we have $I_2 + I_3 = I_1$
- Outer Loop
  - $V - IR_1 - I_3R_3 = 0$
- Inner Loop
  - $V - I_1R_1 - I_2R_2 = 0$
- Inner Loop 2
  - $I_3R_3 + I_2R_2 = 0$
-

PHGN 200 - 2024-09-24

#notes #phgn200 #physics

Capacitors!

The hell is a capacitor, anyway?

- Two isolated conductors (often metal plates) used to store electric potential energy. It's essentially a battery that just discharges really quickly
    - Ie, old camera flashes used capacitors - it's a lot of energy, delivered over a very short time, and a proportional amount of capacitance in a battery would've been a bit... chonky.
- A capacitor has capacitance, which is measured in farads using $C = \frac{Q}{\Delta V}$
    - Imagine a capacitor as miles per gallon for a car - it doesn't care how much voltage you end up applying - the capacitance is going to be the same.
    - Convention says capacitance is positive and depends on geometry and what the hell it's made of.
    - A fully charged capacitor has two plates each fully charged with a respective charge - all the positive charge is shoved into one side, which by virtue of coulomb's law shoves all the other ones out the other side, leaving just negative charges behind.
    - A fully charged capacitor becomes a resistor of infinite ohms
        - Quick aside
            - Field of a single (infinite) plane is $\vec{E} = \frac{\sigma}{2\epsilon_0}$
            - Two next to each other add together, so we just end up with $\frac{\sigma}{\epsilon_0}$
        - Finding our ΔV using $\Delta V = -\int \vec{E} \cdot d\vec{l}$
        - Using that σ = Q/A
        - So we get $\frac{\sigma}{\epsilon_0} \int_0^d d\ell$
        - $\frac{\sigma d}{\epsilon_0} = \frac{-Qd}{A\epsilon_0}$
        - And then $C = \frac{Q}{\Delta V}$
        - So $C = Q(\frac{A\epsilon_0}{Qd}) = \frac{A\epsilon_0}{d}$
        - And that, quite conveniently, is the capacitance of a parallel plate capacitor, which comes up quite a bit.

Buncha Clickers

- If you turn the battery on, fuck all happens

- If you decrease the distance between them, capacitance increases
- If you increase the area of the plates, capacitance goes up
- What does capacitance depend on? the geometry and material makeup, we *do not give a singular iota of a damn* as to the voltage or charge, even though $C = \frac{Q}{\Delta V}$ exists.

Energy Stored in Capacity

- Uh, you can do the derivation, or just

$$U = \frac{1}{2}C\Delta V^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}Q\Delta V$$

- Energy density is energy over volume, and for a parallel plate we use

$$u_E = \frac{\text{Energy}}{\text{Volume}} = \frac{1}{2}\epsilon_0 E^2$$

Capacitors in Series

- Fuck you, it's the opposite of resistors. You add them in inverse.

$$\Delta V_{Total} = \sum \Delta V_i = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$$

Capacitors in Parallel

- Still the opposite of resistors, you just add them together.

$$Q_{total} = \sum_i Q_i = C_1\Delta V_1 + C_2\Delta V_2 + C_3\Delta V_3$$

This is because of elements in parallel having the same voltage drop across them, which pops that out

PHGN 200 - 2024-10-01

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Clicker~~(s?)~~

- Inserting a dielectric into a charged capacitor, causes:
    - Capacitance goes up, but charge stays the same
        - So this makes the energy go down, as the dielectric needs to be polarized
        - (and like, the math just works out)

Simple RC Circuit

- Reduced into having, at most, one resistor and one capacitor.

$$R_{eq} = \frac{1}{\frac{1}{2} + \frac{1}{3}}, C_{eq} = \frac{1}{\frac{1}{10*10^{-6}} + \frac{1}{5*10^{-6}}}$$

$$R_{eq} = 1.2\Omega, C_{eq} = 3.33\mu F$$

Kirchhoff's Rules - More Sign Conventions

- Battery from negative to positive is positive, battery from pos to pos is negative
    - There was, frankly, a lot more words on this slide

Recognizing Changes

Identifying time-dependent behavior

- When a quantity starts low and ends high, $A(t) = A_{\text{final}}(1 - e^{-t/\tau})$
- When a quantity starts high and ends low, $A(t) = A_{\text{initial}}e^{-t/\tau}$

Identifying time-dependent behavior: Current

- Uncharged capacitor hooked up to a battery, what happens to current over time?
    - It should go *down*, right?
        - Let's fucking go, eat shit most clicker-answerers, get better, skill issue, L + no voltage + uncharged + no potential (difference)

Identifying time-dependent behavior: Charge

- Uncharged capacitor hooked up to a battery, charge goes up over time
-

Identifying time-dependent behavior: Charge (but again)

- Current is going to *decrease* over time. Fuck.
  - This is essentially like pouring out a cup. That makes perfect god damn sense. How did I fuck this up?

$$I(t) = Ie^{-t/RC}$$

$$I(t=2s) = \frac{V}{R_{eq}} e^{-2s/R_{eq}C_{eq}}$$

- This is just a dash of $v = ir$ and plugging stuff in

$A(t) = A_{\text{initial}} e^{-t/\tau}$

$$I(5) = I(i) * 0.9$$

$$0.9 = e^{-t/RC}$$

$$\ln(0.9) = \frac{-t}{RC}$$

$$C = \frac{-5}{R - 1\ln(0.9)}$$

PHGN 200 - 2024-10-03

#notes #phgn200 #physics

Average of the function $V_0(\frac{t}{t_0})^2$ from $t = 0$ to $t = t_0$
$V_m = \frac{1}{t_0 - 0} \int_0^{t_0} V_0(\frac{t}{t_0})^2 dt$
$= \frac{V_0 t^3}{3t_0^3}$

$V_0^2(\frac{t}{t_0})^4$

- Blah blah blah, some root mean square stuff (you square the function, do the mean, and then root it) (shit's crazy)

Most of what we've done so far is DC

- Steady voltage, common in digital electronics

A lot of other things though use *alternating* current

- Comes out the wall, is oscillating and sine-y and all that other fun stuff
- AC signals get two parameters:
    - Frequency, which is $\omega = 2\pi f$
    - We have the amplitude, either I_0 or V_0
        - For instance, $V(t) = V_0 \cos(\omega t)$
- Funny story about resistors:
    - They still work the exact same!
    - Voltage and current are going to be, how you say, uh, fucked up, but resistance is just fine!
    - $V = IR$ still applies, you just gotta plug in your fucked up values
- Capacitors though are morally compromised and refuse to hold to a reasonable standard.
    - With a DC current (low frequency), they prevent current flow, exactly as expected
    - With a high frequency input (read: AC power) the capacitor is going to charge and discharge quickly, dumping current through.
        - This is because it's going to oscillate between being charged and not, so it is somewhere between a straight piece of wire and infinite resistor, so it essentially works as resistor (less straightforward though)
    - The "reactance" of a capacitor, which is essentially the resistance, is represented by X and is represented by $\frac{1}{\omega C}$
        - This also uses ohms!
- Unfortunately, voltages across our resistor and our capacitor are not in phase, so we can't just slap them together straight away
  - What we *can* do is add them together in quadrature ie $Z = \sqrt{R^2 + X^2}$, which is the "impedance" of our circuit

$$V_{rms,C} = \frac{V_{rms,in}}{\sqrt{\omega^2 R^2 C^2 + 1}}$$

  - that shit's fucked up, for the record. I don't like that at *all*

exampling or something

- Finding resistance and capacitance
- $$R_{tot} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

  $$C_{tot} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$

$$X = \frac{1}{\omega(\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}})}$$

$$X = \frac{1}{\frac{\omega}{\frac{1}{c_1}+\frac{1}{c_2}}}$$

$$X = \frac{\frac{1}{C_1}+\frac{1}{C_2}}{\omega} = \frac{1}{\omega C_1}+\frac{1}{\omega C_2}$$

$$Z = \sqrt{R^2+X^2}$$

$$Z = \sqrt{\left(\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}\right)^2 + \left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}\right)^2}$$

PHGN 200 - 2024-10-08

#notes #phgn200 #physics

We doing topic three, magnetic shit

- Static charges do jack squat to magnets, but a *moving* charge does produce a magnetic field
- Also taught by Pat Kohl. Holy shit. I'm shaking in my flip flops.

So, magnetic fields

- Are a vector quantity $\vec{B}$
- Fields are measured using Teslas, which are $\frac{kg}{s^2A}$
  > - Just for reference, teslas are pretty big. An MRI is 1-2 teslas, and those are BIG.

Biot-Savart Law

- Is unfortunately French.
- Governs how current makes magnetic field

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{\ell}\times\vec{r}}{r^3}$$

- This is fundamentally not *that* different from coulomb's law, which was, to recap

$$d\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{dQ\vec{r}}{r^3}$$

- The bit out front? Still a constant of proportionality, which exists to make the units work.
- Our little chunk of source is where we have a difference
  - Coulomb's law is just a tiny little chunk of dQ
  - When we're dealing with magnetic fields though, we care about how much it's moving, and therefore it's $Id\vec{\ell}$
    - Which is because it's a vector
  - And because it's a vector, we can't just multiply, we need to do the cross product.
  - $\mu_0 = 4\pi * 10^{-7}\frac{Tm}{A}$
    - This is the permeability of free space.
- Around a nice cylindrical wire, it makes little loops
  - This is where the $_{\text{first}}$ curly right hand rule comes into play.
- In a loop of charged material, they're all going to point the same way!
  - We actually get a fascinating little bit of behavior:
    - Straight wire makes loops of field, loops of wire make straight fields.
      - (ignoring the dipole that's spewing out the top)
  - If you invert the behavior of the curly rule (ie, curl your fingers in the direction of current, your thumb is going to point in the direction of the field)

- Example, where we have a line of charge and we're finding what's happening at a point away from a line of current

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{\ell} \times \vec{r}}{r^3}$$

$$\frac{\mu_0}{4\pi}\int_{-b}^{a}$$

- Plugging in our things, $d\vec{\ell} = dy\hat{\jmath}$
  - $\vec{r} = -y\hat{\jmath} + x\hat{\imath}$
  - This then gives $|\vec{r}\sqrt{y^2 + x^2}$
- We want the cross product of $dy\hat{\jmath} \times (x\hat{\imath} - y\hat{\jmath})$
  - You can actually do a little distributing, and the $\hat{\jmath}$ part actually doesn't matter
  - So we're actually just doing $dy\hat{\jmath} \times x\hat{\imath} = -xdy\hat{k}$
  - If you're going in alphabetical order, you're positive, if you're not in alphabetical order, you're negative

- Alphabetical... but you can go around the corner.

$$\vec{B} = \int d\vec{B} = \frac{\mu_0}{4\pi}\int_{-b}^{a} \frac{I * xdy\hat{k}}{(y^2+x^2)^{\frac{3}{2}}}$$

$$\frac{-\mu_0 Ix\hat{k}}{4\pi}\int_{-b}^{a}\frac{dy}{(y^2+x^2)^{\frac{3}{2}}}$$

- You have to do some icky trig sub thing because this is is icky.
- If you have an infinite wire, you'd actually end up with

$$\frac{\mu_0 I}{2\pi x}$$

- That's also on the equation sheet, and comes up all the damn time and is vaguely worth remembering.
- Similarly on the equation sheet is the equation for the magnetic field along the axis of a current loop, which is

$$\frac{\mu_0 NIR^2}{2(x^2+R^2)^{\frac{3}{2}}}$$

PHGN 200 - 2024-10-17

#notes #phgn200 #physics

Ok, so like, what do magnetic fields *do?*

- Like, we can calculate them, but one of the things they can do is exert forces on moving charges

$$\vec{F}_{\text{mag}} = q\vec{v}\times\vec{B}$$

- There's a couple fairly interesting conclusions to be drawn from this
  - If there's no charge, there's no force
  - If said charge has no velocity, there's no force
  - If the velocity is parallel to the magnetic field, there is *also* no force.
- Whole pile of clickers I probably should've written down, but my general takeaway was pay attention to your right hand rule and the charges involved.

Cyclotron Cases

1. $\vec{V} \perp \vec{B}$ actually produces circular motion
2. $\vec{V} \parallel \vec{B}$ is going to do all of fuck all. Magnets don't do jack shit.
3. $\vec{V}$ is neither $\parallel$ or $\perp$, you have what we call a problem.
    1. It's actually a helix, it ends up spiraling around some center line.

Cyclotron Examples

- For a charge q and mass m traveling with speed v, what is the cyclotron frequency in a magnetic field with magnitude B
    - We're expecting circular motion, where $a_c = \frac{v^2}{r}$
    - And circular motion is that $F_b = \frac{mv^2}{r}$
    - We set our forces equal, where $mv_r = qBr$
    - and $v_t = \omega r$
    - $m\omega r = qBr -> \omega \frac{qB}{m} -> f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\frac{qB}{m}$

Magnetic Force on a Current-carrying Wire

- So, using the good ol' drift velocity equation, and our new magnetic force equation, we get some shenanigans along the lines of $\vec{F_B} = q\vec{v} \times \vec{B} => Q\vec{v} \times \vec{B}$, where $Q = nqA\ell$, so $\vec{F_b} = nqa\ell\vec{v} \times \vec{B}$
- Which, where $I = nqAv_d$ means that $\vec{F_b} = I\vec{\ell} \times \vec{B}$
- We, quite annoyingly, often end up integrating over this, where $d\vec{F} = Id\vec{\ell} \times \vec{B}$

Example problem (attempt)

- $Rd\theta I \times B_0$? maybe
- wrong, actually, it's $d\vec{\ell} = Rd\theta(-\sin\theta\hat{\imath} + \cos\theta\hat{\jmath})$
- which then gives $\vec{B} = B_0\hat{k}$
- So the cross product of $Rd\theta(-\sin\theta\hat{\imath} + \cos\theta\hat{\jmath}) \times B_0\hat{k}$
- $= (\cos\theta\hat{\jmath}Rd\theta * B_0)\hat{\imath} + (Rd\theta\sin\theta)B_0\hat{\jmath} + 0\hat{k}$
- $$B_0Rd\theta(\cos\theta\hat{\imath} + \sin\theta\hat{\jmath})$$
  $$= IB_0R\int(\cos\theta\hat{\imath} + \sin\theta\hat{\jmath})d\theta$$

PHGN 200 - 2024-10-22

#notes #phgn200 #physics

- Electric field in hall effect shenanigans because we need the upward force from the electric field to be balanced from the downward force from the magnetic field, which is just saying $|q\vec{E}| = |q\vec{v} \times \vec{B}| \rightarrow E = vB$
- Oh hey, now that we know our electric, field, we can find the voltage difference, $\Delta V = \int \vec{E} \cdot d\vec{l} \approx ED = vBd$
- You only end up with an induced hall voltage when you're not going the same direction as your electric field (airplane example)

torque time

- this came up in the webwork before in lecture, just for the record
- $\vec{\tau} = \vec{r} \times \vec{F}$, where $\vec{r}$ is the radius from the axis of rotation to the point of application, and $\vec{F}$ is the applied force
- CCW is positive, for convention's sake

there are two ways:

the safe way

- Which is just going to be $\vec{\tau} = \int \vec{r} \times d\vec{F}$
  - where $d\vec{F} = Id\vec{l} \times \vec{B}$

the less safe way

- This only works with a full loop of current, in this case we can say $\vec{\tau} = \vec{\mu} \times \vec{B}$
  - where μ is a magnetic moment, defined by $NI\vec{A}$
    - Area vector of a current loop can be found using the right hand rule, ie if you have a counterclockwise loop of current, we can point up and call it good.
    - $\vec{A}$ is the area vector, in that equation
    - N is our number of loops

Para and Ferro magnetism

- An electron has spin (an intrinsic magnetic moment)
- Paramagnetic materials have net electron spins that are just kind of a crapshoot and are all over the palce
  - Applying a magnetic (B-field) aligns the spins (juuust a little bit), which reinforces the original field (juuuust a little bit)
    - Examples include aluminum, magnesium, and tungsten
- Ferromagnetic materials, on the other hand, have chunks of spin domains
  - When you shove a ferromagnetic material in a big old magnetic field, they end up all facing the same way, doing so at high temperature tends to lock magnets in place
- "Permanent" magnets are made of ferromagnetic materials

PHGN 200 - 2024-10-29

#notes #phgn200 #physics

Faraday's Law

- The magnitude of emf (voltage) induced in a conducting loop is equal to the rate at which the magnetic flux through that loop changes with time.

$$\epsilon = \frac{d\Phi_B}{dt} = \frac{-d}{dt}\int \vec{B} \cdot d\vec{A} = -\frac{d}{dt}\int \vec{B} * \cos\theta * d\vec{A}$$

Lenz's Law

- An induced current has a direction such that the magnetic field due to the current opposes the change in the magnetic flux that induces that current.

How to find the direction of current

1. Decide if Flux is increasing or decreasing
2. Recognize that the induced B-field will change the flux in the *opposite* way
3. Use the right hand rule to find the direction of the current that will produce the induced B-field from 2
   For that right hand rule bit:

1. Curl your fingers around said loop
2. Your thumb will point in the direction of the magnetic field

-

Big Note: Nature hates changes in flux!

- this means that most of the time we're somehow keeping flux constant. Nature *HATES* changes in flux.

Finding EMF

If we have a loop

Use the one earlier of

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

If you do not have a loop

$$|\epsilon| = |\Delta V| = \int \vec{E} \cdot d\vec{l}$$

$$\vec{F}_E = q\vec{E}, F_B \text{ yadayada I lost it.}$$

---

example attempt

$$B\cos(\omega * t) * \pi a^2$$

$$\Phi_B = \vec{B} \cdot \vec{A} = -B(\pi a^2)\cos(\omega t)$$

$$|\epsilon| = \frac{d\Phi_B}{dt} = \frac{d}{dt}(-B(\pi a^2)\cos(\omega t)) = \omega B(\pi a^2)\sin(\omega t)$$

$$\epsilon = IR \rightarrow I = \frac{\epsilon}{R} = \frac{\omega B(\pi a^2)\sin(\omega t)}{R}$$

- They just asked for the magnitude is where the negative goes

- A square of current of length L moves into a region with a B-field of magntitude B. What voltage is induced in the loop

$$\epsilon = BLv$$

- Direction is going to be out of the page, due to CCW current.

Eddy Currents

- If you have plates of conductive material as opposed to loops of wire, we get neat little eddies of electrons that cause a braking force

PHGN 200 - 2024-10-31

#notes #phgn200 #physics

Autobots! Roll out!

- A transformer is a device with two coils in which a current through one coil induces a voltage in a second coil.

$$\mu_0 I_0 N_1 = B_1$$

$$= \mu_0 \frac{N_1}{L} I(t)$$

$$(\mu_0 \frac{N_1}{L} I(t)) \pi R_2^2 N_2$$

So the *maximum* induced EMF is when $\sin = 1$, so that'll just be $\mu_0 \frac{N_1}{L} I_0 \pi R_2^2 N_2 * \omega$

- totally forgot about needing to do the time derivative? So that's where the ω on the end gets slapped on from
- Fun fact, the flux through one loop in Coil One is the same as the change in flux through one loop in Coil 2

$$emf_2 = \frac{N_2}{N_1} emf_1$$

Mutual Inductance

- The mutual inductance M is the proportion between the magnetic flux in coil 2 and the change in current in coil 1, which isn't relevant for this class but exists as a fun little bit.

Self Inductance

- If the current in a wire changes, there will be an EMF *in said wire*. Inductance, represented by L, is the flux linkage (flux times number of loops) produced by a unit of current,

$$L = \frac{N\Phi_{B,\text{single loop}}}{I}$$

- Inductors produce a magnetic field when we have a changing current, and then basically end up working as the magnetic version of a capacitor
  - (in that sense than an inductor produces an electric field due to stored charges. it kinda makes sense and works out? Don't worry about it too much.)
- Induced EMF in an inductor is always acting opposite to the change in current. Everyone's a contrarian these days.
- Inductance can be given by

$$L = \frac{\Phi}{I}$$

  - Draw your system, shove a current through it
  - Find your flux
  - Divide flux by current to get self inductance
- Essentially, we're finding capacitance. More or less.
  - Flux should just be $\pi r^2 * \mu_0 I$
  - $\Phi = \vec{B} \cdot \vec{A} = (\mu_0 \frac{N}{\ell} I)(\pi R^2 N) = \frac{\mu_0 N^2 \pi R^2}{\ell}$
  - Which then just gives $\mu_0 n^2 A\ell$

Inductors are always backwards

- Same as a resistor - if it's the same as current flow, it's negative contribution
- Opposite direction though is positive contribution.

Inductors Store Energy

- $U = \frac{1}{2}LI^2$

- And $L_{\text{solenoid}} = \mu_0 n^2 A \ell$
- An "energized" inductor has a steady current, which means that it basically acts like a wire
  - An un-energized inductor acts like an open switch, so you get fuck all current.
  - Somewhere inbetween the two is where you get like, actual behavior
- If you hav ea simple circuit, you can use

$$I(t) = I_f(1 - e^{-t/\tau})$$

  - That's for exponential growth, and all of these equations work for both current and voltage change over time

$$I(t) = I_0 e^{-t/\tau}$$

  - The only major difference here is that

$$\tau = \frac{L}{R}$$

  -

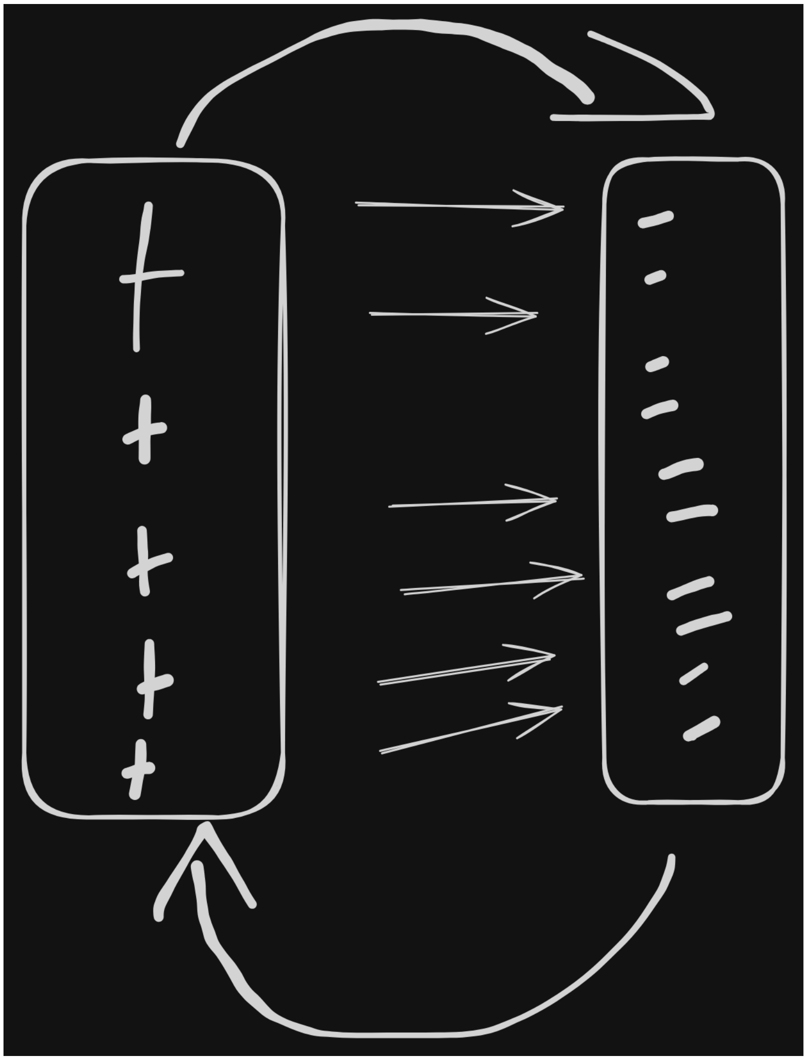
PHGN 200 - 2024-11-05

#notes #phgn200 #physics

Displacement Currents

- When we have two charged plates, ie, like a capacitor, you end up with some fascinating shenanigans

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{\text{thru}}$$



$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0(I_{thru} + I_{disp}) = \mu_0 I_{thru} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

- Displacement current is in the direction of the changing electric flux, ie $\Delta\Phi_E$

brief aside

- Maxwell was deeply wrong about a great deal of things, including when he thought the ether was a thing that existed and was the electromagnetic equivalent of air. Ie, like how sound waves move through air, surely EM must move through an equivalent
- A parallel plate capacitor with circular plates of radius R and a separation distance d is being charged at a rate of 2 C/s. What is the magnitude of the displacement current through a loop with radius a where $a > R$?
- Example problem with some loop that I should embed a picture of later. #toDo type beat.
- Rate of change of charge over time, $\frac{dq}{dt}$ is 2 C/S
- At what radius is the electric field non-zero?

    - Only between the plates, so $r < R$
- Uh, finding Φ_E

$$\Phi_E = \int \vec{E} \cdot d\vec{A} = EA$$

$$E_{\infty\text{ sheet}} = \frac{\sigma}{2\epsilon_0} = \frac{q}{\pi R^2}(2\epsilon_0)$$

$$E_{2\,\infty\text{ sheets}} = \frac{q}{\epsilon_0 \pi R^2}$$

$$EA = \frac{q}{\epsilon_0 \pi R^2} * \pi R^2 = \frac{q}{\epsilon_0}$$

- Now finding how flux changes with time

$$I_{disp} = \epsilon_0 \frac{d\Phi_E}{dt} = \frac{dq}{dt} = 2$$

---

moving on, light as an electromagnetic wave or something

- Uh, these equations make sense. Mhm.

$$\frac{d^2 E_x}{dx^2} = \epsilon_0 \mu_0 \frac{d^2 E_x}{dt^2}$$

$$\frac{d^2 B_x}{dx^2} = \epsilon_0 \mu_0 \frac{d^2 B_x}{dt^2}$$

- There's some wave bullshit going on here.

$$y = y_0 \sin(kx \mp \omega t)$$

- Holy shit, minus-plus ($\mp$) is a real symbol. I didn't expect that to work
    - $y_0 =$ max amplitude
    - $k =$ wavelengths per unit distance
        - $k = \frac{2\pi}{\lambda}$
            - Lambda here is the distance from peak to peak - one full unit of wavelength
    - $\omega =$ angular frequency (rad/s)
- Standing wave, ie one hooked to a wall, not moving in space, etc, you don't have to worry about the $\mp$

> - If you're moving in space though, it's going to be $-\omega t$ if it's moving in the positive direction, and $+\omega t$ if it's moving in the negative direction, hence the $\mp$

$$E = E_{max}\sin(ky - \omega t + \Delta)$$

- Wave number $k = \frac{2\pi}{\lambda}$
- Angular frequency: $\omega = 2\pi f$
- Phase constant Δ is just shifting where it "starts"

- What do you to make it magnetic? You just change the name!

$$B = B_{max}\sin(ky - \omega t + \Delta)$$

- A charged particle makes an electric field
- A moving charged particle makes a magnetic field
- An *accelerating* charged particle makes an electromagnetic wave

energy stored in fields

$$uE = \frac{1}{2}\epsilon_0 E^2 = \text{Energy density of electric field}$$

$$u_B = \frac{1}{2\mu_0}B^2 = \text{Energy density of magnetic field}$$

Total energy of an EM wave is $u = u_E + u_B = \epsilon_0 E^2$

$$c = \frac{1}{\sqrt{\epsilon_0\mu_0}}$$

- useful little cutesy discovery/derivation thing

example

- Magnetic field is given by $B = B_0\sin(\alpha\pi x - \alpha\pi\beta t)$
- Do the RMS
  > - Square: $B^2 = B_0^2\sin^2(\alpha\pi x - \alpha\pi\beta t)$
  > - Mean: $B_{av}^2 = B_0^2\frac{1}{2}$
  > - Root: $B_{av} = \frac{B_0}{\sqrt{2}}$
- So $u_{B_{av}} = \frac{B_0^2}{4\mu_0}$

PHGN 200 - 2024-11-06

#notes #phgn200 #physics

$$u = u_e + u_b$$

$$u_e = \frac{1}{2}\epsilon_0 E^2$$

$$u_b = \frac{B^2}{2\mu_0}$$

$$u = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

$$E = \frac{B}{\epsilon_0 \mu_0 c}$$

$$E = \frac{B}{\epsilon_0 \mu_0 (\sqrt{\epsilon_0 \mu_0})}$$

$$\frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\epsilon_0 (\frac{B^2}{\epsilon_0^2 \mu_0^2 \epsilon_0 \mu_0})$$

$$\frac{1B^2}{2\epsilon_0^2 \mu_0^3} + \frac{B^2}{2\mu_0}$$

$$I_{avg} = u_{rms} c$$

$$u = E^2 \epsilon_0$$

$$u = \left(\frac{E_0}{\sqrt{2}}\right)^2 \epsilon_0 * c$$

PHGN 200 - 2024-11-12

#notes #phgn200 #physics

final bit

- December 9th from (time to time), last name based, yadayada
- Has not been written yet, but:
  - Will be 20 multiple choice questions, roughly 15 of which are going to be from homework, the other five from studio/discussion.
  - Extra credit stuff that adds 1% to your grade each, grand total of.. +2%.

- The phys 2 equivalent of a course review is from December 2nd-4th, and will give ya +1%.

ok back to waves

- We don't.... really care about the energy in a wave at a given point, we care more about how much it's delivering(power)
  - Intensity is going to be how spread out this power is, which is going to be $I = \frac{P}{A}$
    - It's *way* easier to measure intensity than actual power, so that's what we measure.
  - Poynting (pronounced pointing, not a typo) Vector is the intensity, represented by $\vec{S}$

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

Radiation Pressure

$$F_{absorb} = \frac{EBA}{\mu_0 c}, P_{absorb} = \frac{I}{c}, P_{reflect} = \frac{2I}{c}$$

- In this case, the P we're solving for is pressure, not power. Fuck you. Apparently, you can even get the same letter representing up to three different things. Fuck you too, physics. We couldn't get like a rho or something at the very least?

Solar Sail Problem

- We're some distance D from the sun, and unfurl a circular solar sail of radius R, oriented to capture the most sunlight possible. If the sun radiates a power of P_{rad}, find the total force.
  - First up is finding intensity, which should just be power/surface area, or $\frac{P_{rad}}{4\pi D^2}$
  - To find radiation pressure, we're reflected, so it becomes $P = \frac{2I}{c}$, or $P = \frac{P_{rad}}{2\pi D^2 c}$

Antennas

- Linear antennas pick up the electric field of a wave directly, or $V = -\int \vec{E} \cdot d\vec{\ell}$
- Circular antennas have voltages induced by way of Faraday's law, where EMF = $-\frac{d\Phi_B}{dt}$

- Total antenna radiation can be measured in watts, or Joules / second, and the signal strength at a location is intensity, watts / area.

Handy support equations

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}} = \frac{1}{2}c\epsilon_0 E^2$$

$$\omega = 2\pi f$$

$$I = \frac{P}{4\pi D^2}$$

- Quick little reminder that $E = cB$

- So we have that

$$B(t) = \frac{1}{c}\sqrt{\frac{P}{2\pi\epsilon_0 cD^2}}\sin(kx - \omega t)$$

$$\phi_B = \left(\frac{1}{c}\sqrt{\frac{P}{2\pi\epsilon_0 cD^2}}\sin(kx - \omega t)\right) * (\pi R^2)$$

$$\text{Quick } \frac{d}{dt} = 1(\text{ all that}))$$

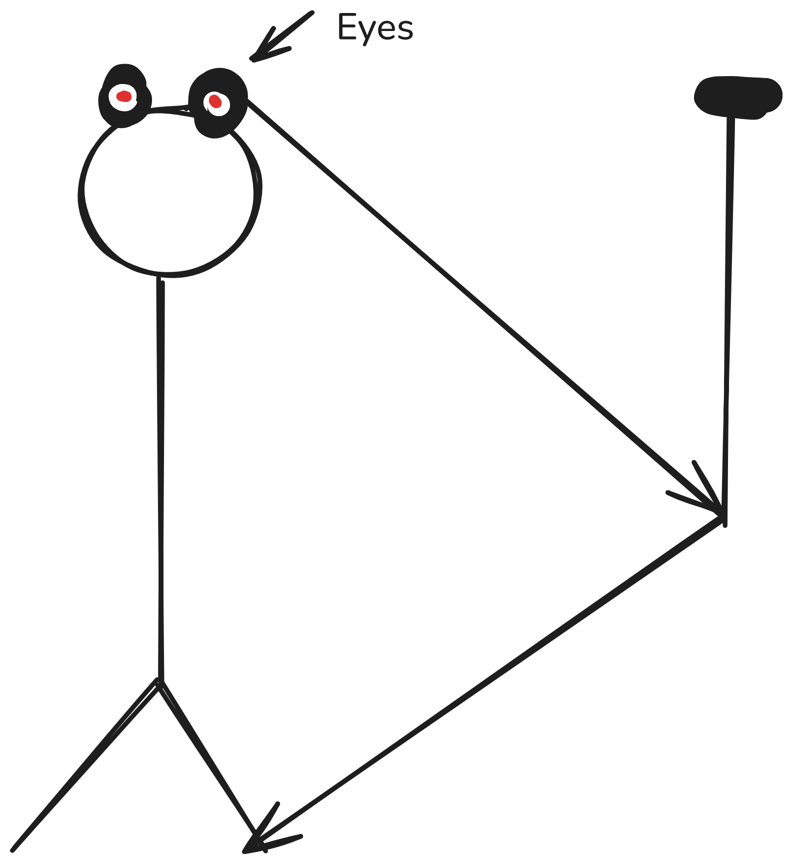
PHGN 200 - 2024-11-14

#notes #phgn200 #physics

Reflection

- When EM radiation hits a surface, some of it will be reflected, at an angle equivalent to the incident angle (ie, comes in at 45 degrees, will go back out at 45 degrees)

What is the minimum height of a wall mirror that allows a 4ft tall child to see her entire reflection



- Alright well that was reflection, the child doesn't care about distance from the mirror.

Refraction time

- Light travels at a speed less than c going through not empty space.

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

- That's for empty space, but when moving through not empty space, we end up with

$$c = \frac{1}{\sqrt{\kappa \epsilon_0 \mu_0}}$$

- Where that κ is based on the material. μ_0 stays the same, because it only really changes for metals, and metals don't exactly let light through.
  - The index of refraction, $n = \frac{c}{v} > 1$ is a thing that exists but like, not really clear what's what.
- What's actually going to change is some part of our $v = \lambda f$, where the frequency of our light is going to stay constant(due to some mild conservation of energy shenanigans since frequency determines the energy of waves), where wavelength is then going to change.

- Some typical indices of refraction
  - Air: $n = 1$
  - Water: $n = 1.33$
  - Glass: $n = 1.5$
- Quirky bit is that $n = \frac{c}{\lambda f}$, which is how you get rainbows and such
- As light goes from one material to the other, it'll refract according to Snell's law, which states that

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

  - Where n_1 and n_2 are properties of the materials, defined by $n = \frac{c}{v}$

- $$1 \sin\theta = n_2 \sin\theta$$

- $$\sin\theta = \frac{\sin\theta_1}{n}$$

$$n \arcsin(\frac{\sin_1}{n}) = \sin\theta_3$$

$$\arcsin(n \arcsin(\frac{\sin}{n}))$$

$$\cos(\theta_r) = \frac{t}{\ell}, \ell = \frac{t}{\cos(\theta_r)}$$

$$\sin(\theta - \theta_r) = \frac{d}{\ell}$$

$$d = \sin(\theta - \theta_r) * \ell = \sin(\theta - \theta_r) * \frac{t}{\cos(\theta_r)}$$

Total Internal Reflection

- At a critical angle (or greater), all light incident on a surface is completely reflected without losses. We call this total internal reflection

$$\sin\theta_1 = \frac{4}{3}$$

$$\theta_1 = \arcsin(\frac{4}{3})$$

- Which is, uh, not possible? I think?

- TO keep something inside though, we just end up needing

$$\theta = \arcsin(1/n_{material})$$

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PHGN 200 - 2024-11-19

#notes #phgn200 #physics

phymsics

- In a lot of cases, treating light as a ray (read: doing optics) works just fine
- However, it is a wave, and as such we have to deal with some bullshit.
- If light was a ray, then we'd just add sources together and call it good
  - However, it's not! So we end up with either 4x as bright or jack didley squat if we shine two similar sources at the same point.

interference

- If you have two waves in phase, ie if we just had two $\sin(x)$ kinda looking waves, adding them together would give you a wave with the same phase, just double the amplitude
- If they're *out* of phase, we get destructive interference, where if you were to add, say $\sin(x)$ and $\cos(x)$ together, the net would be a fat ol' 0.

Cool interference applications

- Light in a material is going to be

$$\lambda_n = \frac{\lambda_v}{n}$$

- Where λ_v is the wavelength in a vacuum

Path Length Differences

- If there's a path length difference of $n\lambda$, where n is some integer, we get constructive interference in the spots where it lines up and jack squat elsewhere.
  - Similar for destructive, just if we have a path length difference of $n + \frac{1}{2}$

- You get them when it's the same except some leftover, which is $\frac{\Delta L}{\lambda} = m$, and destructive is $\frac{\Delta L}{\lambda} = (m + \frac{1}{2})$
- Also of note is the phase angle thing
    - The difference of two waves with the same phase, just offset is δ, where one wavelength is 2π radians of phase. For constructive interference, $\delta = 2\pi m$, and destructive is $\delta = 2\pi\left(m + \frac{1}{2}\right)$

Clicker time

- Two radiation sources, some distance D above and below the axis. Our observation point is L away, along said axis - what's the difference in path lengths?

$$\sqrt{D^2 + L^2} - \sqrt{D^2 + L^2} = 0$$

Thin Film Interference

- When light waves reflect off thin films of materials (oil, water, soap, etc) their waves will produce interference
- Refraction never causes a phase change, but reflection can, based on n shenanigans of the materials.
- When we hit something with a higher index of refraction, the reflected wave has a phase shift of π relative to the incident wave, (π phase shift is like sine to cosine)
    - When bouncing off something with a low index of refraction, there is no phase shift.
    - So the interesting stuff ONLY HAPPENS with low to high.

X-Ray Diffraction