Topic 1

Topic 1: Motion

From Lecture

Newton's Laws

- What are the 3 ways to describe motion?
  - Position, velocity, and acceleration
- How can we describe **position**?
  - We use a vector, because it can tell us **direction** and **distance** (from some defined start point)
- What are the 2 parts of **velocity**?
  - How fast we are going (**speed**)
  - What direction we are going in (**direction**)
- What is **acceleration**?
  - It is how fast (and in what manner) our velocity is changing

- What is **Newton's first law**?
  - An object that is not subject to any net outside forces moves at constant velocity
- What is **Newton's second law**?
  - The force exerted on an object is equal to the product of the object's mass times its acceleration
  - The acceleration is in the same direction as the force
- What is **Newton's third law**?
  - For every force that one object exerts on a second object, there is an equal but oppositely directed force that the second object exerts on the first object

Gravity and Componential Motion

- What is **gravity**? What determines the effect we will experience due to gravity?
  - It is a downward force produced by the earth which acts on us, pulling us down
  - The gravitational effect we experience is always an acceleration of ~10 m/s2 -- REGARDLESS of our mass
    - This means that (neglecting air resistance) a feather falls just as fast as a brick
- Why doesn't gravity cause us to fall through the floor?
  - Because of the "**normal force**": an upward force produced by the surface we are standing on that counteracts the gravitational force so that we don't move

- Describe the motion of a projectile launched at some angle with respect to the horizontal.
  - We can break up its initial velocity into **horizontal** and **velocity components**
    - Its horizontal velocity will never change, because there are no forces present to change it (recall Newton's First Law)
    - Its vertical velocity will be subject to gravity, so its upward progress will slow, eventually become zero, then start to head downwards
- If you wanted to shoot a monkey in a tree, where should you aim? (Assume that the monkey will drop and fall downwards as soon as the shot is fired).
  - You should aim straight at the monkey (not above it or below it), because once the bullet is in the air and the monkey has dropped, both objects are subject to the same force (only gravity), and so they will meet at some point

Work and Energy

- What is the difference between kinetic and potential energy?
    - **Kinetic energy** is the energy of movement: the amount of this one possesses is related to one's velocity
    - **Potential energy** is stored: the amount of this one possesses is related to its ability to unleash energy
- Discuss energy conversions.
    - Energy cannot be created or destroyed, but it can be converted from one form into another
    - The types of conversions which occur and their efficiencies affect the things we see in the real world
        - For example, some materials bounce better than others because they do a better job of converting kinetic energy to elastic potential (while others just convert kinetic into heat)

- Discuss work, in particular the way it is related to potential energy.
    - To do **work** on something is to exert a force on it and cause it to move some distance in the direction of that force
    - Work is related to potential energy because we can give an object potential energy by doing work on it
        - For example, lifting a ball from the ground to a table

Friction

- Imagine a scenario where (with friction present) you are pushing a block horizontally across the floor. Describe the different forces acting on the box.
    - There is gravity acting downwards, and the normal force acting upwards
    - There is the human pushing force acting in the box's forward direction, and friction acting opposite to that
        - The pushing force must exceed the frictional force in order for the box to start moving from rest
- Discuss the 2 kinds of friction. What kind of energy is produced by friction?
    - **Static friction** is friction that opposes the initiation of movement
    - **Kinetic friction** is friction that slows down movement which has already started
    - The energy lost from friction (remember that we would expect a given amount of energy produced given the work we put into moving something…so when we have reduced energy due to friction, where does that energy go?) becomes **HEAT**
- Explain the "spiky" model of friction.
    - On a microscopic level, the two interacting surfaces are not smooth but rather have many small bumps and crevices, almost like interlocking teeth
        - Thus moving the surfaces across each other requires energy to overcome this interlocking mechanism
    - When starting from rest, more of the "teeth" are "locked together" and thus the frictional force experienced is greater
    - When already moving, there are fewer teeth interlocked and thus the force is smaller
    - If you press the two surfaces together (i.e. if the one on top is heavier), again the "teeth" "interlock" more, and so friction increases (this is why friction is related to the normal force)
- Explain why a tablecloth can be pulled out from beneath a dinner set.
    - It is simply a function of the frictional force between the tablecloth and the dinner plates: can we pull the tablecloth fast enough that it overcomes the frictional force which is causing the plates to stick to the cloth? If so, the cloth will come right out from beneath them...

Rotational Motion

- Describe the motion of a tennis ball connected to a string being flung around in the head in a CIRCULAR pattern.
  - Its **speed** is always the same, but its **velocity** changes since its direction is always changing
  - It has an **acceleration** that is always the *same in magnitude* but always *changing in direction* (though it is always pointed towards the middle)
    - The force creating this acceleration (since f = ma) is known as the "**centripetal force"**, and it is embodied in the tautness of the string
  - If at any time in the motion the ball was separated from the string, it would fly off in a line tangent to the circle (this is why we feel like we're falling out of the car when we go around curves)

- Recall the experiment where a water-filled bucket was rotated vertically in a circle. What determines whether the water falls out?
  - The relevant relationship here is that the **centripetal force** is related to the **velocity** of the motion
    - And the centripetal force is made up of the **tension** which swinging the bucket exerts on the arm **PLUS** the **gravitational force** - so if the necessary centripetal force isn't even as much as the gravitational force, then the remainder of the gravitational force will be used to allow the bucket to spill
- Why do figure skaters spin faster when they bring their arms close into their body?
  - Because something called **angular momentum** is conserved, which is a function of **rotational inertia** (analogous to mass) and **rotational speed** (analogous to velocity)
  - As long as **torque** (a force which affects rotational velocity) is not added to or removed from the system, angular momentum must stay constant - and so if we *reduce our rotational inertia by bringing our weight closer to the axis of rotation*, the rotational velocity must increase to counteract this
- Why did Idziak's tricks with the strings and the hourglass work better when the hourglass was spinning?
  - Because the hourglass wants *to conserve angular momentum*, and it does this by *continuing to spin on the same axis*
  - If it were to wobble (i.e. become unstable), this would constitute spinning on another axis and cause angular momentum to not be conserved - thus it tends to not do this

<u>From Textbook</u>
Chapter 1
Chapter 2

Topic 2

Topic 2: Resonance

<u>From Lecture</u>
Waves

- What is a *pulse* on a string? Describe some characteristics of it.
  - It is a "bump" that travels along a string
  - It has a defined direction and has the ability to be reflected off the ends of the string
  - It does not cause the string itself to move - it only causes sections of the string to be displaced vertically

- What is a **transverse wave**? Identify the following features of a transverse wave: **amplitude, node, antinode, velocity, wavelength.**
  - A transverse wave is one where the displacement created is vertical

- If we have a transverse wave on a string, what force causes the vertically-displaced portions of the string to oscillate "up and down"?
  - The **tension** on the string acts as a restoring force to bring it back to the middle, but it overshoots and goes to a maximum amplitude on the other side

- Explain how longitudinal waves work.
  - **Longitudinal waves** are those where the displacement is longitudinal - i.e. along the length of the wave
    - It is a series of compressions and stretches (aka **rarefactions**)
    - Longitudinal wave - a wave vibrating in the direction of propagation

- Discuss how sound is a longitudinal wave. What implications does this have for the necessary conditions for hearing sound?
  - **Sound waves** are simply **longitudinal** waves in air - and the analog of "compressions" and "rarefactions" are regions of high and low air pressure
  - The implication is that we must have air in order to hear sound - because to hear sound is simply for our ear to detect the pattern of air pressure changes
    - Recall the demo where a bell in a vacuum was rung, and no sound was heard

- How are the speed, frequency, and wavelength of a wave related? What implication does this have for sound in different mediums?
  - **Speed** = **frequency** x **wavelength**
  - The implication is that *sound travels at different speeds in different mediums*, and so when sound passes from one medium to another, the speed will change: thus either frequency or wavelength must change
    - Frequency does NOT change, and so wavelength does - thus the sound we hear is different
- Give an example of a wave traveling through different mediums.
  - If we pluck a guitar string, first the string vibrates in the form of a characteristic wave, and then it causes the air around it to vibrate - and we hear that in our ear

Doppler Effect

- Explain what the **Doppler Effect** is. Give an example.
  - It is the phenomenon where a sound will <u>sound different if its source is traveling either toward you or away from you</u> than it would if the source was stationary
  - This is why the siren from a police car or fire truck will appear to change in tone if you are standing on the side of the road and the car comes towards you, passes you, and continues on away from you
- How does the Doppler Effect work?
  - It is because the sound waves are either <u>compressed</u> (coming towards you) or <u>expanded</u> (going away from you), and thus the altered wavelengths are perceived differently
- How do **sonic booms** work?
  - This is an extreme application of the Doppler Effect whereby the source of sound created is so loud that the <u>waves are compressed so much that they all arrive at essentially the same time</u> at a single spot, and an extremely loud sound is created

Oscillations & Resonance

- Explain how a **pendulum** is an example of a simple harmonic oscillator.
  - It is because if we pull the mass to the left or right then let go, the tension in the string will cause the mass to swing back in the direction of the equilibrium position, and in fact surpass it and go to an extreme on the other side
  - The force that does this (and is definitive of simple harmonic oscillation) is a **"restoring force"**: a restoring force always tries to bring the mass to equilibrium

- Discuss the relationship which the restoring force has to the object's distance from the equilibrium point. What implication does this have for the period of a given pendulum?
  - The restoring force is linearly proportional to the object's distance from equilibrium: the further away the object is, the stronger the force is which wants the object to return
    - It consists of the force created by the tension of the string and gravity
  - The implication is that for a given pendulum, its period will always be the same…
    - Regardless of how far away you initially bring the pendulum
    - And also regardless of what the MASS of the swinging object is
  - The ONLY FACTOR that can change the pendulum's period is the length of the string

- Explain how **pendulum clocks** work.
  - There is a circle with 30 teeth (a gear), and an apparatus attached to a pendulum
  - The apparatus is positioned such that every time the pendulum completes an oscillation (period = 2 seconds), the apparatus clicks past one "tooth"
  - Thus, every time the gear completes a full revolution, we know that it has been one minute (60 seconds)

- Describe the motion of a mass on a spring, and why it is a harmonic oscillator.
  - Firstly, there is an **equilibrium point** - where the spring is neither stretched nor compressed
  - If we (for instance) pull the mass such that we are not at the equilibrium point and the spring is stretched, we will feel tension because the restoring force in the spring wants to return the mass to the equilibrium point
  - It is a harmonic oscillator because if we release the mass, it will accelerate back towards the equilibrium position and overshoot it to the other side, compressing the spring and creating another restoring force that pushes the mass again back to the equilibrium position from the other side
- How do we adjust the frequency of these things?
  - Bigger mass = lower frequency
  - Stiffer spring = higher frequency

- Explain what the concept of resonance is.
  - The **"resonance frequency"** is the frequency at which an oscillator "naturally" likes to oscillate
  - We can increase the amplitude of the oscillations if we add energy to the system at a frequency identical to this natural, "resonant" frequency
- How does resonance apply to shock absorbers in cars?
  - Well, here we want to REDUCE the amplitude of the oscillations (so we will go up and down less)
  - So the shock absorbers are designed to compress and expand at a frequency DIFFERENT than the one at which the car is bouncing up and down - this will reduce the amplitude of the movement and make the ride more comfortable
- How does resonance apply to pushing a child on a swing?
  - Here the relevant principle is that of pushing the child right when he gets to the apex of his swing - because when we do that, we are adding energy at the same frequency as the one at which he is oscillating

- That is why we can get him swinging very high in a relatively short time if we do this (as opposed to, say, pushing him back before he has reached the height of his swing)
- How does resonance apply to breaking a wine glass with sound?
    - It applies because if we play sound at a certain frequency, it will cause the air to (of course) also move at a certain frequency
    - Now, the sides of the wine glass also vibrate (ever so subtly) in response to the air
    - If we get the air to vibrate at the resonant frequency of the wine glass, the oscillations of the glass will increase until the glass breaks
- How can water have an effect on resonance?
    - [I forget which demo this was, but] if water was the medium in which energy was being added to some system at that system's resonant frequency, the water could potentially dampen its effects

Standing Waves and Sound

- Explain how a standing wave on a string works.
    - If we have a string that is stationary at both ends, we can pluck it and cause a wave to be created at (one of) the string's resonant frequency
    - The wave travels down to one end and is reflected -- and this pattern maintains itself for some period of time
    - We say it is a "standing" wave because a pattern of oscillation is produced such that there appears to be no movement
- Explain the concept of **harmonics**.
    - A string has many harmonics, and they are simply the term used for the frequencies associated with the natural "standing wave" conformations which the string can assume
    - Yes, that is right: a string can have more than one type of standing wave - theoretically, any number of wavelengths within the string is possible as long as the ends stay as nodes

- Why is a sound heard when we rub the top of a wine glass with our finger?
    - Because due to friction, when we rub our finger we are actually dragging it to some degree, and causing the glass to deform slightly
    - This deformation creates a wave in air which produces the sound we hear
    - Continuously rubbing the finger adds energy (helps the glass deform more) and thus makes the sound louder
- Why is a sound produced when we hit the end of a metal pole on the ground?
    - Because (again) the metal deforms ever so slightly, and we get a wave in air that makes the sound

- Explain why sound can be created by blowing into an organ pipe. What happened when we put this tube over a flame from a Bunsen burner, and why?
    - Blowing into a pipe creates a longitudinal standing wave using the air inside the tube
        - One end is closed (a **node**, where compression can take place) and the other is open (an **anti-node**)
        - The standing wave goes at a frequency that we can hear, and that is the sound we perceive
    - Note that the fundamental wavelength is TWICE the length of the tube, because only one end is a node
    - When we put this over a flame, we could see the flame moving around in the air because of the changes in air pressure coming out of the pipe
- Explain why sound can be created by blowing across the mouth of a beer bottle.
    - It is because when we blow, we are activating a mass-spring system such that the air in the neck of the bottle moves up and down due to the force we provide with our breath (by "pushing it down") vs. the restoring force of the air in the wide part of the bottle that pushes it back up

    - The frequency produced by this oscillation is perceived by our ears
- How do we show that sound is a compression/rarefaction wave?
    - Recall that we had a tube of (some gas), with holes in the top…and also a flame
    - We created a longitudinal sound wave in the tube, and where the regions of pressure were low (i.e. the nodes), the flames shot up higher because it was a stable environment for the flames to work
- Explain how a loudspeaker works.
    - There is an electromagnet, which consists of two magnets that can move towards or away from each other depending on the current in the coil
    - As the magnets move, they cause a paper cone to move, and this causes a pressure wave in air that we perceive as sound
- What happens when we mix up the red and black wires in a stereo system? What is the name for this phenomenon?
    - When we do that, we send the wrong signals to the speakers, and so the air pressure waves created cancel each other out by the time they reach us, and we perceive a very soft noise - this is called "**destructive interference**"
    - When the wires are correctly plugged in, the sound waves created are the same as each other, so "**constructive interference**" occurs and we hear a loud sound

<u>From Textbook</u>
Chapter 9

Topic 3
Sunday, October 08, 2006
12:28 AM

Topic 3: Balloons, Bubbles, and Pressure

<u>From Lecture</u>
Ideal Gas Law: Pressure, Density, Temperature, etc.
- Discuss the structural differences between a solid and a liquid.
    - A solid is structural and arranged in a periodic manner, such that if we know the location of one molecule, we can infer the location of all other molecules in that structure
    - Conversely, the molecules in gas are much farther apart from each other, and there is no defined structure
- What happened when we ran an air hose through liquid nitrogen? Why?
    - We caused some of the gases in the air to condense into liquids, while some others remained as gas
    - The result was that a combination of gas and liquid came out the other end
    - This is a property of gases - at certain temperatures, the molecules come together close enough that the substance takes on the consistency of a liquid

- Explain how the concept of **pressure** applies to a gas.
    - Recall that pressure = force / area
    - And the individual molecules in some sample of gas push against the walls of their container, and create pressure
- Explain how a steam engine works.
    - It's all about this pressure principle - you evaporate water and now we have lots of steam in a confined space
    - Thus it will create pressure against the walls, and this pressure can be used to crank an engine
- Why does a balloon make a loud sound when it pops?

- It is because there is a sudden <u>release of pressure</u> from the gas molecules which were previously inside, pushing out against the fabric of the balloon
  - When this pressure is suddenly released, a loud sound is made
- Note that the pressure inside is (definitely) greater than the pressure outside because the pressure inside needs to keep the balloon stretched out

- Explain gaseous temperature on a molecular level.
  - Temperature of some sample of gas is related to how quickly the molecules of gas are moving around
  - Note that if they move around faster, they will bump into the walls with more force and thus create greater pressure as well - that's why if a gas is in a container than can expand, heating the gas will cause the container to expand
- How do we apply the molecular explanation of temperature to making bombs and popcorn?
  - Both things involve the principle of heating something up so that it expands so much and so rapidly that an "explosion" is caused
    - Either the bursting of the kernel into a piece of popcorn
    - Or the bomb exploding

- Explain gaseous density on a molecular level.
  - **Density** is just how many gas molecules there are in a given area
  - Again, when the density is higher, the pressure will be higher because more gas molecules will be hitting the sides of the container
- How does this apply to using a straw?
  - We are basically sucking the air out of the straw, meaning that there is less pressure available to push the liquid down
  - Thus liquid is able to come up the straw and into our mouth :)

- What does the **Ideal Gas Law** tell us?
  - PV = nRT, or P = number density x R x T
  - Pressure is proportional to density of particles times temperature

Atmospheric Pressure and Buoyancy

- Explain the "box" model of atmospheric pressure.
  - If we are talking about the atmospheric pressure acting on a single person, imagine that the column of air above him is divided into boxes
  - Gravity acts (as it always does) on these boxes, and so there is a downward force on the person created by all this air
    - However, there are also air boxes which push up to counteract this (that is why we are not crushed)
  - As we get higher on this "pile" of boxes, there is more air pushing up and less air pushing down, so the air pressure we experience is less

- Why was it hard to pull those rubber disks apart when the air was removed from inside them?
  - Because removing the air meant that the air pressure in the "container" was reduced to zero, all the air from outside wanted to get in so that pressure could equilibrate
  - This air created a force which opposed the efforts to pull the discs apart
- Why does it not hurt to lie on a bed of nails?
  - Because the pain which we traditionally think nails cause is due to pressure, which (recall) is related to force and area
  - In this case, we are spreading out the area of the pressure source by putting many nails, and thus the total pressure is not too bad
- What would happen if the cabin of an airplane became de-pressurized, and I failed to put on my oxygen mask?

  - All the intestinal gas we have (which is now kept at a certain density because of the atmospheric pressure from outside) would now be subjected to less atmospheric pressure, and so it would expand (very uncomfortable!)

- What is **Archimedes' Principle of Buoyancy**?
  - "An object partially or wholly immersed in a fluid is acted on by an upward buoyant force equal to the weight of the fluid it displaces."
- What phenomenon was observed with the Playdoh boat, and why did this happen?
  - This is a demonstration of Archimedes' Principle: when it was shaped like a real boat, the volume of water it displaced was greater than the volume of water it displaced when we condensed it into a ball
  - Thus when we had the greater volume of water, the buoyant force supporting the boat (equivalent to the weight of this greater volume) was big enough to support the boat's weight
  - But when we had the smaller volume of water, the buoyant force was less, while the boat was the same weight - but this time it was insufficient to hold the boat up
- Why do we float higher in the Dead Sea than in our bathtubs?
  - It is because salt water is denser, so the weight of the volume of water we displace is greater than the same volume in regular water
  - Thus this greater weight means there is a greater buoyant force keeping us up
- How does our weight change when we are in water?
  - Our weight is essentially equivalent to the normal force that needs to be produced by the surface we are standing on in order for us to not fall through
  - When we are in water, this normal force is reduced because the downward force produced by gravity on our body is (partially) counteracted by the buoyant force

Balloons

- How does a hot air balloon work?
  - We have to think about PV = nRT, and the relationships which that equation represents
  - The idea is that we use a fire to warm the air inside the hot air balloon…and this increases the kinetic energy of the molecules, causing one of the following things to happen:
    - All molecules remain in the area and pressure increases (molecules hitting the wall more frequently and at greater speeds)
    - Some molecules leave the area and pressure remains the same (molecules hit the wall at the same rate even though they are moving faster, because there are fewer molecules)
  - **Since it is an open system**, pressure cannot be different and so the latter option occurs. This reduces the density of the balloon to the point where it rises (can you explain this using Archimedes' Principle?)

- Why did a balloon float when put at the top of a tube with dry ice at the bottom, yet outside the tube it sinks?
  - This is again an application of Archimedes' Principle: remember that the buoyant force depends on the weight of the air you have displaced
  - In regular air, this weight is not sufficient to keep the balloon afloat (it does have SOME weight!)
    - However, the gas evaporating from the dry ice is "heavy", so the buoyant force created is enough to keep the balloon afloat
- What is the source of the energy that causes a balloon to fly around the room when you suddenly let the air out of it?
  - It's because when we were blowing up the balloon, we added energy to the system because the elastic material resisted stretching

- Why do helium balloons act as they do?
    - Again, it's all about buoyancy. Think about the weight of the air displaced by the balloon. Now think about the weight of the balloon (plus, of course, the helium inside)
    - If the balloon is lighter, of course it will rise...

Bubbles

- How does soap work?
    - It is made up of molecules where one end of the molecule is hydrophobic (and thus can interact with oil) and the other is hydrophilic (and thus can interact with water)
        - This is why soap is good at removing oil - because it can cluster around the oil droplet, then the whole thing can be washed away with water
- How did he create that sheet of bubbles?
    - He created a very sheet-like balloon-like structure where there was water in the middle, and then soap on either side such that the hydrophilic end of the molecules were touching the water

Hydraulic Pump

- Explain the principle behind the hydraulic pump.
    - This takes advantage of the principle that within a body of fluid, the pressure is the same everywhere
    - So we can supply a lot of pressure at one location in the fluid with a medium force but very small area
        - At the other end of the fluid, we can put a pump with very large area, meaning that having equivalent pressure in this area would mean having an even greater force
    - **The "catch" is that the bigger weight will much less further than the smaller weight** because work must always be equal, and work = force x distance…thus if we have small force and big distance, the other end will have large force and small distance
        - **Basically, this allows us to move heavy things with little but prolonged effort, instead of much but instantaneous effort**

<u>From Textbook</u>
Section 5.1

Topic 4

Sunday, October 08, 2006
12:28 AM

Topic 4: Electricity

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<u>From Lecture</u>
Current

- Describe how electrons move in solids.
    - Think of the crystal lattice model of solids which was shown in class
    - There are spaces between the molecules where electrons can move freely - and since they carry negative charges, their movement constitutes a current
        - These electrons are known as conduction electrons
- What happens in non-ideal situations with respect to electron movement through metal?
    - Firstly, the entire metal is not a single crystal lattice, so an electron will not be able to travel through a single "corridor" all the way through the metal
    - Secondly, there are "crystalline defects" such that the lattices could be bent and again prevent the electrons from traveling very far in a straight path

- Describe a simple circuit consisting of a battery and a light bulb.
  - There are positive and negative terminals in the battery - the electrons leave (are repelled by) the negative terminal, go through the light bulb, then back to the positive terminal where they are "sucked in" (remember that positive attracts negative)
    - Note however that when we think about the path of current, we reverse this (it is as if we are thinking about the way POSITIVE charge moves, although no positive entities actually move -- it is instead the electrons)
    - Note also that the battery "pumps" charge - it does NOT store it in the sense of having a reserve of electrons
    - Note thirdly that the energy of the charges as they leave the battery is affected by the voltage of the battery (as a matter of fact, if it were not for resistance, voltage would equal **current**, which is the amount of charge passing a given spot per unit of time)
- If we take the same circuit but sever the line that connects the light bulb back to the positive terminal, what will happen?
  - No electrons will move and the bulb will not light up, because there is no positive terminal to attract the electrons through the circuit back to it
- Why does the bulb light up?
  - Because there is enough resistance in the light bulb wire that it becomes extremely hot, to the point where the wire glows

Resistance

- Explain the conceptual/molecular model of resistance.
  - Remember how there are crystalline imperfections (and such) that prevent electrons from moving through metal
  - The big-picture ultimate result of this is that electron movement (current) is slowed down to some degree
  - All this lost energy is converted to heat
- What is **Ohm's Law**, and how does it apply to resistance?
  - It is **voltage = current x resistance** : it means that the bigger the voltage is, the faster the current will move BUT this is tempered by the resistance of the material it is moving through
    - If the material has a very high resistance, the electrons will move slow (even with high voltage) and all that energy will be lost as heat
- Why did the light bulb dim when we put the wires in liquid nitrogen? Why did it brighten with another material?
  - It is because the coldness had different effects on the conductivity (i.e. resistance) of the wires
    - When resistance was decreased, more current was available to the light bulb and so it brightened
    - When resistance was increased, less current was available and so it dimmed

Power

- Give the 3 equations for power, and comment on each.
  - Power = energy / time : power is energy released per unit time
  - Power = voltage x current : power is increased by increasing voltage and/or current
  - Power = current^2 x resistance : this is just a consequence of the above equation
- Explain the term "kilowatt-hours".
  - It is the amount of energy consumed when you run a 1-kilowatt appliance (i.e. an appliance that draws power at a rate of 1 watt, or joule / sec) for 1 hour
    - Note: as said in parentheses, the units of power are watts (volts x amps)

AC vs. DC

- What is the difference between AC and DC?
  - AC (alternating current) is different from DC (direct current) in that the direction of the current is constantly changing
  - In order to accomplish this, the voltage source changes polarities as well - thus a voltage graph would form a sinusoidal curve
- Explain the strategy involved in bringing power from outside a city to the homes inside the city. How is this related to AC vs. DC?
  - The central problem is that we want to bring a LOT of power in from the country to the city - and so since P = IV, we can choose to either carry at high currents or high voltages
  - Since P = I^2R (current^2 x resistance), high currents are bad because we will lose power due to resistance at a squared rate
  - Thus we carry the power using lines with high voltage: and this is easier with alternating current than with direct current because AC at high V and low I (current) can more easily be converted to low V and high I (current) (which we want once we're inside the city)
- Why don't bulbs have to convert AC back to DC? Why do electric appliances have to do this?
  - Firstly, the central problem is that due to the sinusoidal voltage pattern of alternating current, there are times when there is absolutely no voltage
    - With bulbs, this is OK because although (yes) they turn on and off, this happens so rapidly that the human eye cannot tell
    - With electrical appliances, this is not OK because they will turn off and we will lose data - thus we have to convert AC to DC using **(?)**

Magnets and Electricity

- How do we create a magnetic field using electricity? How do we control the strength of this field?
  - When we put a current through a wire, a magnetic field is produced
    - Often we put current through a COIL to strengthen the magnetic field which is produced
  - The strength of the field depends on the current and the number of windings in the coil

- What advantage do we gain by placing a magnetic metal (such as iron) in the center of the coil?
  - The iron bar has magnetic domains which can be oriented by an external magnetic field (such as that produced by the coil), and thus create its own field that amplifies the total magnetic strength of the electromagnet
- What would happen if the individual coils were free to move? Which demo in class demonstrated this?
  - They would be attracted to each other because each individual coil creates a N-S magnet that causes it to be attracted to other magnets
  - Remember the coils wrapped loosely around the wooden cylinder - when electric current coursed through the coils, they clustered together in the middle

- Discuss the vice-versa situation. What effect does a magnetic field have on an electric field? Explain the demo which demonstrated this.
  - The overall principle is that a changing magnetic field creates an electric field
  - There were 2 demos which demonstrated this:
    - Firstly, recall the demo where you had to turn a crank very fast and light up a light bulb: here the theory is that turning the crank caused a changing magnetic field which created an electric field that caused current to flow through the wires and light the light bulb
    - Secondly, there was a demo with a large green coil and then a red coil that fit inside of it. An electric current was sent through the inner red coil, which created a magnetic field. This magnetic field acted on the outer coil and produced a current which went through it

Lenz's Law, Generators, and Transformers

- What is **Lenz's Law**? Explain how this describes the behavior we observe if we push a magnet into a coil.
    - Current induced by a changing magnetic field always produces a magnetic field that opposes the change.
    - So let's think - if we push a magnet into a coil, that magnetic is producing an electric field that causes voltage, which further causes current to go through the coil
        - But as we recall, this current is also going to create its own magnetic field - and Lenz's Law tells us that the new magnetic field will oppose the one created by the original magnet, and thus we will feel resistance as we attempt to push the magnet further down into the coil
        - Furthermore, where does the work that our hand is doing go? It becomes electrical energy (the current)
- What happens once the coil passes through the other side, and why?
    - The opposite occurs: now the magnetic fields are aligned such that the coil tries to suck the magnet back in
    - This happens because essentially the magnetic field created by the magnet wants to be constant

- How does a generator work?
    - We have two coils, and we connect them to a light bulb such that charge could flow from one coil through the light bulb, to the other coil, then back to the original coil
    - We put a magnet between the two coils and we spin it at a high rate
    - This causes a changing magnetic field in the vicinity of the coils, and (as we said earlier) causes current to flow through them
    - Since the "N" end of the magnet is always acting on one coil and the "S" on the other, current flows through the system (the coils act as the "+" and "-" terminals of a battery)
    - When the magnetic is flipped, the current just flips direction: thus we are essentially creating AC power
- Explain the modified guillotine, and what it demonstrated.
    - There was a guillotine created such that the "axe" is a magnet
    - The axe was made up a metal/coil sort of thing capable of holding an electric current, and then there was a magnet in the place where the head was supposed to be - thus as it swung through, a current was generated in the axe, which created a magnetic field that opposed the original magnetic field…and the axe stopped
        - Notably, if we replaced the axe with something that had spaces and therefore could not hold a current, the axe's motion was not stopped

- What does a transformer do, and how does it work?
    - A transformer can either convert current from one voltage to another, or keep it at the same voltage
        - In either scenario, transformers add a measure of safety because they isolate the source of AC power from the appliance that consumes it, so if there is ever a power surge, the appliance (and the person using it!) will not be damaged
    - A transformer works using magnetic induction - that is, the ability of a changing magnetic field to create electricity
        - We have two electric coils: a primary coil and a secondary coil
        - A magnetic material called the "transformer core" runs through both the coils
        - We put electric current from an outside source through the primary coil. What happens? The current creates a magnetic field, which is passed onto the transformer core so that it gets its own magnetic field
        - Now, what effect will this new magnetic field have on the secondary coil? Well, it is a changing magnetic field and so current will be produced in the coil
        - This current can be used to power appliances!

- The most useful aspect here is the fact that WE CAN CONTROL the voltages produced (which further affects the current in the coils)
  - This is because the voltage is affected by the number of turns in the coils, because the number of turns determines the magnetic field which will be produced
  - In fact, the following ratio exists:

Domestic Applications: House Power, Fuses, Circuit Breakers, Ground Fault Circuit Interrupters

- Describe the path of electricity from a power plant to a home.
  - We take electricity from the power plant to the edge of a city using a transmission line at about 500,000 V (remember that we want high V, not high I)
  - Then we transform the voltage to 5,000 V and use another transmission line to bring power to our street
  - Then we transform it again to 120 V and use another transmission line to bring it to our house
- Describe the roles of the different holes in a wall plug.
  - The two thin lines are for "live" and "neutral"
    - The neutral line stays around 0 V, and the live line alternates between a high positive and a high negative voltage (remember that it is AC)
    - Thus the path of current will either be neutral -> appliance -> high negative, or high positive -> appliance -> neutral
  - The rounded hole is the "ground" line, and it provides a path for electricity to go such that it cannot harm us in the case where a short circuit occurs and the electricity cannot pass through the appliance as it usually does
    - Because normally, what would happen? All that electricity would just keep going through the wire, the wire would get hot, then we would have a fire
    - The ground line allows us to send electricity through it (in emergency situations) and into the ground, so that there is no danger

- Describe what a fuse is, and how it works.
  - A fuse is something that prevents us from the dangers of short circuits
    - What is a short circuit? It is when we have a circuit with an appliance which is designed to let charge go through it, use the charge to power itself up, etc…but then for some reason the wiring messes up and a SECOND path is created for charge to go from the positive to negative terminal of the battery
    - Only this time, the new route was unplanned and so there are no appliances on this path which can use the energy. So what happens? The wire, which is not properly equipped to handle the heat which will be generated by all this current, will get hot and then dangerous things can happen
  - A fuse is made of a wire that melts very quickly should this case occur, and when it melts the circuit will be broken and then we are all safe

- Describe what a circuit breaker is, and how it works.
  - A circuit breaker performs a role similar to that of a fuse, only it does not have to be replaced
  - There are 2 strips of metal, one of which expands more quickly than the other
  - When there is lots of heat, the bottom one expands faster, causing a bending action - it bends so much that the metal is no longer connected to the wire, and again contact is broken and electricity stops moving

- Describe what a ground fault circuit interrupter is, and how it works.
  - GFCI's perform a role slightly different than fuses and circuit breakers: their job is not to detect an overload of current, but rather to detect current leaks

        - The idea is that usually current goes to an appliance, then comes back. If this fails but the current still has a way of leaving the system, the wires will not get hot - so circuit breakers won't help
        - However, this situation can still be dangerous because (for instance) if all that current is going into a body of water, anyone sitting in that water will be dead
        - So GFCI's have a way of detecting whether or not that current is returning
    - The way it works is that we have a coil, and two wires running through it - one of the wires has current going to the appliance, and the other has it coming back
        - So what happens due to the current going through these wires? A magnetic field is produced, which causes current to go through the coil, which will produce an opposing magnetic field, etc.
            - But wait! There are TWO wires in the coil, and current is going opposite ways. So in fact, the magnetic fields cancel out and the surrounding coil is unaffected
        - So what happens if the current coming back isn't the same as the current going away (i.e. there is a leak somewhere)? A magnetic field WILL be produced, and then the GFCI is designed such that a switch opens and the circuit is disrupted - everyone's safe!

<u>From Textbook</u>
Section 10.3

Section 11.1

Section 11.2

Section 11.3

Topic 5
Sunday, October 08, 2006
12:28 AM

<u>From Lecture</u>
Magnetism/Electricity Theory
- What are the ways in which magnetism and electricity differ?
    - A single given object must be both north and south magnetized, but in terms of electricity it can carry exclusively a negative charge or exclusively a positive charge
- What are the way in which they are the same?
    - They are both the same because there are two different states which they can be in (positively/negatively charged, and north/south pole)
    - Opposite poles/charges create magnetic or electric fields that can be described using electric field lines (or magnetic flux lines)
        - The idea is that if we were to throw an electrically charged particle (or a magnetized particle) in there, it would experience force along those lines
- Talk about some of the relationships between electricity and magnetism.
    - A changing electric field creates a magnetic field
    - A changing magnetic field creates an electric field (note that the magnetic field which this subsequently produces will be opposed to the original magnetic field, as per Lenz's Law)
    - Magnetism and electricity are different in that magnetic fields do not require any medium to move on, while electric fields do (they need electrons)!

Antennas, Tank Circuits, and Radios

- Explain how we send information using antennas.
    - OK, so the idea here is that charge moves up and down the antenna (it is vertically polarized), and the idea is that it sends an electric field out into space
    - And this electric field (vertically polarized) produces a horizontally polarized magnetic field (remember a changing electric field makes a magnetic field), and this travels out in the atmosphere to get to the antennas of the "receiving" radios
- Explain how a tank circuit and an antenna interact to send out signals from a radio transmitter.
    - OK, so for let's consider what a tank circuit is. It's very simple: we have a capacitor, where a coil of wire connects the two sides
        - So obviously, our start state is that all this negative charge is on one plate, and in going to the other plate it goes through this coil
        - As it goes through the coil, the changing electric field in the coil creates a magnetic field
        - This magnetic field grows to a maximum strength when all the charge has left the capacitor plate
        - But the magnetic field causes the charge to keep moving so that it accumulates on the other plate, and our end game is just like our start state except the charges are flipped
        - The take-home message: the capacitor switches states with a regular frequency - and we can use this to control the charge which it sends up an antenna
        - Lenz's Law is important here because the law is all about the desire of magnetic fields to remain constant - and so when the magnetic field builds up in the coil, it wants to release it and it does so by keeping the charge moving through
    - And then we connect the tank circuit to the antenna, and it causes charge to go up and down the antenna which forms an electric field in the air
- What degree of control do we have over this sent information?
    - We can control the frequency of the electrical "oscillations" in the tank circuit:
        - Changing the capacitance of the capacitor: the more charge it holds, the longer it takes to go to the other plate, the longer the period is
        - Also, we can change the inductor's inductance (i.e. how much the coil opposes the movement of charge through it)
- Explain how a tank circuit and an antenna interact to RECEIVE signals on a radio. How is this relevant to "tuning" our tank circuit?
    - So here the idea is that the radio receiver will sense the waves, and so a wave will go down the receiving antenna
    - The antenna is of course connected to another tank circuit, and so if we set the tank circuit at the right frequency, the electric waves coming off the antenna will BUILD THIS UP (resonant energy transfer), and it'll go crazy!

AM Radio

- What is the frequency range of AM radio? What is the significance of this?
    - The range is 550 kHz - 1600 kHz
        - OK, so this means that signals broadcasted for AM radio (i.e. those waves coming off the antenna) have to have frequencies in this range
    - Furthermore, of course there isn't just one AM station, so the stations have to share this range and they each have an even smaller amount of frequency to work with
        - And remember the pitch of sound that comes off the antenna will depend on the frequency, so if we are **restricted to a smaller range it means that we can't broadcast as good quality of sound**
    - Furthermore, the corresponding wavelength for these frequencies is approximately 300 m, which is HUGE
        - And note that the radio transmitters usually like their antenna to be exactly 1/4 of the wavelength, so it means they are 75 m high

        - On the other hand, the radio receivers don't have 75 m to work with, so instead they sense the magnetic part of the radio electromagnetic wave
- What is the meaning of amplitude modulation? What are the implications of this?
    - The idea is that AM radio encodes information by varying the amplitude of the waves it sends out - so perhaps greater amplitudes mean higher pitches, etc.
    - The consequences of this are that **we can listen to AM radio from farther away than FM radio** - it doesn't all cut out at once, rather as we go farther away we will still be able to hear the waves that originally had larger amplitudes

FM Radio

- What is the frequency range of FM radio? What is the significance of this?
    - It is 88 MHz - 108 Mhz
    - So this a bigger range than AM, which means that we can broadcast a wider range of frequencies for each station and so the sound quality is better
    - **It also means that the length of the antenna is smaller, because the corresponding wavelength to such a high frequency is very short**
- What is the meaning of frequency modulation?
    - OK, so this means that FM radio transmitters encode their sound information differently: instead of varying the amplitude of the waves they send out, they vary the frequency
    - This means that the amplitude will always be full (which also contributes to the better sound quality), but also means that when you get out of range of an FM station, ALL the frequencies of sound drop out

Television

- Give an overview of the path of electrons in a television
    - OK, so we warm up a cathode (negatively charged) so that electrons leave it
    - The first thing they run into is a negatively charged grid which repels most of the electrons coming off the cathode
    - However, the ones which are going straight and have enough energy get through
    - They are then attracted by an anode
    - After they get through the anode, they go through a focusing coil - a coil which is literally wrapped around the tube
        - This coil produces a magnetic field that causes the electrons to all go into a straight line
    - Then we get to the deflecting coils, which are placed all around the tube and produce fields to deflect the electrons to the precise part of the screen where they need to be
    - Then they hit the phosphor on the screen and make it glow white (or if there are less electrons, then maybe some gray) - and we get a picture
- Talk more about how the actual image is produced on the phosphor screen.
    - OK, well certain parts of the screen glow when we hit them with electrons
        - And the idea is we take the electron beam and we go across the screen really fast, filling in all the spots - either make the spot white, grey, black, etc.
    - We get through the total image 30 times per second (so stuff is fast!) -- however at this rate, it flickers
        - Or we can do "interlaced" where we only fill in every other line, but we get through 60 images per second

Color TV

- How do we create the appearance of color?
    - The idea is that for every individual spot of phosphor we used to have, we now have 3 different spots which glow either red, green, or blue when they are heated
        - And so we can hit one or several of these to make any color we want - and they are so close together that they appear to be a single color to our eyes

- We do this by having 3 electron guns and putting a "shadow mask" in front of the phosphor screen such that when electrons come out of the electron gun and go through the phosphor screen, it can only hit a certain color of phosphor, and so we know that **each electron gun will only make one color**
    - Magnets can really mess up the configuration of this shadow mask, so that's why you shouldn't bring magnets near a TV
    - Notably, the "degauss" button is supposed to fix any weirdness caused by magnetism

From Textbook
Section 13.1

Topic 6
Sunday, November 26, 2006
9:39 PM

Topic 6: Microwaves and CD's

From Lecture
Waves, Velocity, and Light
- What are the important units for the wave representation of light? Define them and explain how they are related.
    - Velocity = how fast the light is going (we know that this is 3 x 10^8 m/s in air)
    - Wavelength = the length of one "unit" in the wave
    - Frequency = how many wavelengths are traversed in one second
    - They are related as follows: Velocity = wavelength x frequency
- Comment on the constancy of the speed of light.
    - As stated earlier, we know it to be roughly 3 x 10^8 m/s in a vacuum
    - However, when light is going through other materials (such as glass), it is different
    - The idea is that the speed of the wave can change depending on the medium through which it travels
- Discuss the light spectrum.
    - So obviously light is going to look different to us depending on what the frequency of the wave is
        - In general, the frequencies for these waves are WAY higher than the frequencies for, say, AM radio
    - The frequencies range from (428,000 GHz) infrared -> visible light -> ultraviolet (750,000 GHz)
        - For the more hardcore of us, the full spectrum: radio -> microwave -> infrared -> visible -> UV -> X-ray -> Gamma ray

Microwaves
- Talk about microwaves generally, and also microwaves specifically (as in the ones which we will actually use).
    - General information: they range from 0.3 Ghz to 300 Ghz, and the associated wavelengths are 1 mm to 1 m
    - The ones which we use specifically (in real microwaves) are 2.45 Ghz frequency and 12 cm in wavelength
- How do microwaves heat food? What implications does this have for what we can and cannot heat in a microwave?
    - The idea is that we create an oscillating electric field within the microwave - meaning that the "plus" and "minus" ends flip back and forth rapidly

    - Since water molecules are polar, they will also flip back and forth because of the strength of this field, and this vigorous movement will create heat
    - Thus, we can heat things if…
        - The molecules are polar (so most commonly water) - all food has water in it
        - It is jello - because although it is a "solid", it is actually water within a matrix
            - The matrix is why it seems like a solid, but the free water molecules allow it to heat up
    - But we cannot heat things if…
        - The molecules are non-polar (such as a pure hydrocarbon like butane)
            - Note that vegetable oil does not work because it is impure
        - It is ice (because the molecules are frozen in place -- it's a solid! -- and cannot flip)
            - This is why frozen burritos sometimes heat up unevenly - because the ice in different parts of burrito is unequally subject to melting
                - The way we fix this is we make the defrost cycles in a microwave turn off occasionally to allow the heat to flow through the whole burrito
- Explain the mechanism through which the oscillating electric field is created within the microwave.
    - OK, so let's start off thinking about the big picture. What we basically need is to create an electric field within the microwave that changes polarities at a frequency of 2.45 GHz
    - Now let's think about a tank circuit - remember that this is basically a capacitor where the plates are connected by an inductor (something that allows charge to flow through), and thus all that happens is that the negative charge goes from one plate to another, then back again, etc.
    - But as the charges are moving from plate to plate, a magnetic field is created, and it differs based on what direction the charges are going in - and so we say that the field changes (or oscillates) at some frequency
    - So the idea is the same with microwaves - this time we use something called a "magnetron", which is just a curved piece of metal - the tips of the metal are the capacitor plates, and the other part just allows the electrons to go through
    - So what we actually do is we line up EIGHT of these guys so that they form a circle - and they are "sharing" tips, so the tips alternate negative, positive, negative, positive, etc.
    - And so there will be alternating magnetic fields produced between the tips, and they change at a 2.45 GHz rate…and so we are almost there
    - What we do next is we attach a coil to the magnetron - and thus there will be an alternating current in the coil
    - And then connect an antenna to the coil - and so we'll have microwaves coming off this antenna and into the microwave
- Explain what one problem with this is, and how we solve it.
    - OK, well since the inductor may be imperfect, and the energy of the waves is absorbed by the water molecules (making them flip), we have to give more energy to the inductor - and we do this by adding electrons to the negative terminals
    - The way we do this is in the middle of the magnetron, we have a hot cathode filament that will emit electrons
    - WAIT - when these electrons go free, they will just go to the positive terminals because of positive-negative force interaction, right? YES.
    - So we solve this by putting a magnetic field going straight up through the center that causes them to bend (remember what moving charge does in the presence of a magnetic field)
- Discuss the issue of metal with microwaves. What do we use it for?
    - Well the fundamental principle to remember here is that when electric current goes through any given material, the higher the resistance, the more it heats up. Whereas the lower the resistance, the less it heats up

- Metal Usage #1: think about the metal lining the edges of the microwave. It is very thick, so resistance is high and it does not get hot. In fact, it instead REFLECTS the waves back into the microwave
  - We have the same idea with the metal on the door - the holes in it which allow us to see through are acceptable because the hole is smaller than the wavelength of the microwave, so the waves will not go through
- Metal Usage #2: recall the Michelina's pizza thing. We were able to not make it soggy because it sat on a tin sheet which had high resistance, thus got very hot and baked the pizza while boiling off any water

- What are some of the safety issues we need to be aware of with microwaves?
  - Certain kinds of metal are DANGEROUS:
    - Near sharp point (like the crumples of a tin foil or the tines of a fork), the electric field can build up and we get sparks (maybe almost like a corona discharge?)
      - If a spark occurs near something combustible (like twist ties), we get a fire
    - Very thin metal, such as the gold rim of a plate or glass has large resistance and will heat up and melt
  - If there is nothing in the microwave but we turn it on, it'll just get really hot in there (nothing to absorb the energy) and bad things will happen - thus we have an auto-off switch for the magnetron
  - We don't allow the microwave to turn on if the door is open, because if we do - and someone puts their hand in there, they are TOAST - the whole hand will burn (not just the outside)

Geometrical Optics

- Explain what a convex lens does to light.
  - Think about its shape - it will focus parallel light to a spot at the focal point (this doesn't mean it makes objects smaller though!)
    - Although the wavelength of light limits how small that spot is
  - Thus it increases the energy density
  - It does this because as the light travels through the lens, the speed of light changes and so it curves
- Explain how a magnifying glass/projector lens works.
  - It bends the light such that the image produced by a given object is BIGGER (think about and draw the diagram)
  - However when we are thinking about light going the other way through the magnifying glass, it is parallel beams of light and so they get focused (that's why we can burn ants by holding a magnifying glass over them)
- Discuss the two kinds of mirrors.
  - Flat mirror - it reflects light "normally", where the incident angle is the same as the reflected angle
  - Parabolic mirror - it has a concave shape and so parallel rays of light will get focused to a point, and then diffused
- What do light polarizers do?
  - Firstly we have to realize that in our world, light doesn't come all neatly aligned - the wavelengths could be straight up and down, or left and right, or diagonal
  - So a light polarizer "selects" a certain alignment of wavelength and only lets that through
- Discuss two "real life" applications of polarization.
  - Polarizing sunglasses - these guys block horizontally polarized light, which is the main component of glare
  - Liquid crystal - this thing reorients light (i.e. changes its polarization), so let's think: if we put liquid crystal between a horizontal polarizer and a vertical polarizer, light which

would normally be blocked would get through because it goes through the vertical polarizer so that we only have vertical light, but then the LC re-orients to make it horizontal, and so it gets through the horizontal polarizer too

- We use this in liquid crystal displays with watches, where we use an electric field to turn the LC's re-orientation abilities on and off

Sound and Data Storage

- How could we store sound electronically, i.e. on a CD?
    - Let's imagine we are talking into a microphone. Throw a magnetic coil in there - it will vibrate in response to the sound waves which we create
    - The movement of the magnetic coil will create a corresponding electric waveform, which will have different voltages at different points
    - Now we measure the wave every so often and look at what voltage it is - then use binary to store these numbers
        - Note that the frequency (how often) we "take a measurement" will affect how faithfully we reproduce the sound - that's why MP3's have ratings such as 44 kHz
    - Throw that binary data onto a CD (will be explained later)
    - On the other end, we do everything in reverse to create sound!
- How might we use light to store and read data on a CD? Let's talk theory.
    - You have to remember the difference between constructive and destructive interference of the light waves
        - If two waves of light from the same source meet and their wavelengths are perfectly aligned, then they will "add" perfectly to each other (constructive)
        - However, if the wavelengths are 1/2 off, they will "cancel" perfectly (destructive)
    - So if we can put small pits on a CD such that they are 1/4 of a wavelength and then shine a light down into them, think about what the combination of light is going to be like for the wave that is reflected up from the pit and the light that is "newly" going downwards
        - The light going into the pit then back up will take up the equivalent of half a wavelength, so it will be perfectly out of phase with the "new" light - and they will cancel
    - But if there is no pit, then the two waves meeting each other will be "in phase" and so we are all good
    - From here we detect the "strength" of light we are getting and convert it into either 0 or 1
- What is some of the practical information that we have for CD's?
    - CD's are written in a long spiral and they are read from the inside to the outside
    - The pits are 110 nm high, 500 nm wide, and between 833-3560 nm long
        - Their dimensions depend on the wavelength of light, and that's why as we come up with better light sources (i.e. laser, then blu-ray), we can store more data on the same size disc because we make the pits smaller
    - The layers of the CD are as follows, from the "bottom" up: 1.2 mm of plastic, then the metal layer with the pits, then lacquer, then the label
        - That's why it is worse to scratch from the label side than the plastic side, because the label is actually much closer to the pits
- How does a CD player work? Talk about parts, now.
    - [Draw and learn the diagram!]

<u>From Textbook</u>

Section 13.2

Section 15.2

Topic 7

Monday, November 27, 2006
6:35 AM

Topic 7: Air Cleaners and Xerox

From Lecture

Electric Charges and Forces

- What is electric charge? How do we measure it (units)?
    - It is a theoretical concept which we use to describe the relative number of protons and electrons on a given material:
        - If there are more negative charges (electrons) than positive ones (protons), it is negatively charged
        - If there are more positive charges than negative ones, it is positively charged
    - We measure charge in coulombs - a proton is +1 C and an electron is -1 C
- What did Benjamin Franklin discover with glass and rubber that related to charge?
    - He discovered that rubbing glass with silk gave it the characteristics of a charged object (he called it positively charged)
    - Also, rubbing rubber with fur gave it the characteristics of a different kind of charged object (he called it negatively charged)
    - NOTABLY, he was wrong in terms of electrons - the glass actually gained electrons, so it should have been considered to be negatively charged (and vice versa with the rubber)
- Explain what Coulomb's Law is.
    - Coulomb's Law describes the nature of the attraction between two charged objects - like charges repel, opposite charges attract
    - Furthermore, the strength of this attraction is affected by:
        - Magnitude of charges on objects
        - Distance between objects (the square of it)
- Imagine two lightbulb-battery systems, where one battery is 1.5 V and the other is 100 V. What differences will we see in the lightbulbs, and why?
    - The lightbulb in the 100 V system will glow brighter - this is because the charges coming out of a 100 V battery have more potential energy than the 1.5 V battery, and so they can provide more of this energy to the lightbulb
- What if the systems were both 1.5 V batteries, except one of them had TWO batteries connected in series?
    - The one with the batteries connected in series would shine brighter because the idea is that whenever charge goes through a battery, it GAINS potential energy (it is like lifting a ball to a 2 m height, then lifting it 2 more m to a 4 m height)

Electric Charges and Forces - Selected Demonstrations

- What happened in class when we rubbed glass and rubber, then put them near the balls hanging from a string?
    - They caused the balls to move back and forth, due to the forces of attraction and repulsion created by the electric charges (recall Coulomb's Law)
- Explain how the machine worked where you turn a crank and every so often there would be a flash of "lightning".
    - Turning the crank was doing some rubbing so that charge built up on one plate of a capacitor
    - When there was too much charge on there for the capacitor to handle, it discharged through the air to the other plate
- How does the "electrostatic bell" work?

- It was a ball in the middle of two plates, one of which was positively charged and the other negative
- Thus when we set the ball on one plate (say negative), negative charge will be transferred onto there and it will swing towards the positive plate
- When it gets there, it will gain positive charged and be attracted back to the positive plate

Dust and Dust Filters

- What is dust? Discuss the 3 different types.
  - Dust is basically NEUTRAL particles floating in the air
  - There are 3 types:
    - Regular dust: rock, dirt, organic matter, etc.
    - Soot: carbon that has been burned imperfectly - oily, greasy, etc.
    - Ash: powdery non-combustible residue of a fire (which has been burned perfectly, I guess)
- Firstly, what kind of forces is the dust in the air subject to?
  - It is subject to all the traditional forces which any other material would experience: air resistance, air currents, gravity, buoyancy, etc.
- How do traditional air cleaners work? What are some drawbacks?
  - They are just a filter with very small holes so that when the air passes through, the large parts of dust contained in it are stopped
  - However, there are drawbacks:
    - The small particles of dust get through
    - The filter gets clogged eventually with the large particles
- Give a brief overview (more later) on how an electronic air cleaner might work.
  - The concept is very simple - if we can put negative charges onto the dust particles in the air, then force all the air through the electronic air cleaner where the WALLS of the cleaner are POSITIVELY charged, then the dust will stick to the walls due to electrostatic attraction

Electronic Air Filters in More Detail

- Explain what a corona discharge is (it will be important for later).
  - The idea is that if we can aggregate enough negative charge within a very confined area, the repulsion between the electrons will be so great that eventually the electrons will jump off on their own into the surrounding air
  - Some examples of this:
    - If we connect a power supply to a wire - they build up on the end of the wire
    - If we connect a power supply to a pin - the charges build up on the tip of the pin
    - The tops of ship masts can aggregate this charge and cause the phenomenon known as St. Elmo's Fire
- Explain the two things which a lightning rod does for us.
  - Firstly, realize that lightning happens when so much negative charge builds up in the clouds (or cloud layer) that it has to go somewhere, and often it discharges through the air into the earth below - and we see it going through the air (that is our "bolt")
  - As it goes down to the earth, it will try to take the path of least resistance - and so if we have a lightning rod on top of our house, it is easier for the lightning to go into that rod (and eventually into the ground) than it is for it to hit our house - so we have the rod there as protection, almost
  - However, the reverse also happens - as the house gathers charge (as it will tend to do when it is near lightning), the charge will ultimately build up on the tip of the lightning rod, and when there is too much we will just get a corona discharge of electrons off the tip, and everyone is safe
    - This will make our house less attractive to lightning, too!

- Now that we have all this theoretical information, how does an electrostatic precipitator (i.e. electronic air cleaner) work?
  - Recall the overview given earlier
  - We know now HOW the dust is negatively charged - because we have "corona wires" that get negative charges built up on them so they spew electrons off their tips
    - These electrons hit the dust particles and stick to them, making them negative
    - As the dust comes in, it sticks to the positively charged walls (overcoming any other forces such as air currents or gravity), and we are done!
- Explain the concept behind the Kelvin liquid drop generator.
  - The idea is that like everything, water has positive and negative charges
  - So as we drip water, if we can make it go through a ring that will separate the positively charged drops from the negatively charged ones, then the receiving buckets at the bottom will either be positively or negatively charged
  - When enough positive/negative charge builds up, it can't maintain itself for any longer and so it creates a spark as it discharges (or it goes through a wire and lights a lightbulb)
- Explain the concept behind ion generators.
  - These are another kind of electronic air filter - they still use corona discharge to charge dust particles in the air, but there is no positively charged wall to catch them
  - Instead, the negatively charged particles will tend to stick to the neutral walls or furniture in the room
    - Why? Because POLARIZATION occurs, which is when the dust particle re-organizes the charges on the neutral surface it is attached to - so that in its local area there are positive charges
- Where else do we see the concept of polarization?
  - When we stick the balloon to the wall - the wall is overall neutral so technically there should be no attraction between it and the negatively charged balloon, but the balloon polarizes the wall so that in the local area there is a charge
  - Same deal with the pendulum-like apparatus that rocked back and forth when a charged object was brought near it

Xerox Machines

- Firstly, explain what photoconductors are.
  - Photoconductors are objects which conduct electricity when they are exposed to light, but do NOT conduct electricity in the dark
  - Thus if we put two photoconductors on top of each other (in "parallel") and charge them one negative and one positive, then shine light on only certain parts of the photoconductor, then in those spots the charge will move from plate to plate until it is neutral
- Now give the overview of how a photocopier works.
  - Alright, so we have a belt that is made of those two parallel photoconductors, as previously discussed
  - Then we shine the image of the paper onto this belt - so there are places where it will be light (i.e. if the paper is white) and places where there will not be light (where the paper has black ink)
  - At the place where there is white, the belt will conduct charge and that region will become neutral
  - Then we put ink onto the belt - however the ink is ALSO charged, and so it will only stick to the belt at the places where there is charge (so, NOT the places which correspond to the white regions of the paper)
    - This ink is called "toner" - it is basically charged particles of ink
  - Then we erase the charge off the belt (but the ink is still there!) - we do this using an "erase lamp"
  - Then we press a piece of paper to the belt and since the paper is charged and so is the ink, the ink will transfer onto the paper - this is the "transfer charger"

   - Then we fuse the ink permanently to the paper using a "fuser"
- How do laser printers work?
   - We use a photoconductive DRUM instead of a belt - so where the belt had the whole image on there at once, the drum has only parts of the image on there at once and it is done by a laser
   - But from there it is similar - cover the drum with toner, transfer that onto a paper, and then we are done

<u>From Readings</u>
Section 10.1
Section 10.2
UW-ACE Reading

Topic 8
Wednesday, November 29, 2006
6:42 PM

Topic 8: Materials

<u>From Lecture</u>
States of Matter
- Talk about the 3 different states of matter, and how the positioning/separation of molecules in space differs for each.
   - Gas: randomly positioned molecules in space, very dilute
   - Liquid: randomly positioned molecules in space, very concentrated
   - Solid: periodic arrangement of molecules in space, very concentrated
- What were the 2 properties of a solid which we studied? Discuss them. Explain how they are different.
   - Hardness: this is a measure of a material's resistance to penetration, deformation, abrasion, and wear - it basically means that this material can absorb energy without breaking or changing
   - Brittleness: the tendency for a material to fracture while it is being deformed
   - The difference is in the fact that being NOT hard doesn't mean BRITTLE (they are not always related)
      - For example, playdoh is NOT hard, but it is not brittle because it doesn't break when we squeeze it (it just deforms)

Solids and Forces
- Explain what stress and strain are. What is the relationship between them?
   - OK, so stress is the application of a force to some material, and strain is what we call the effect on that material
   - There are 2 kinds of strain:
      - "Regular" strain is a change in length of some material - perhaps it is a compressing force or an elongating force
         - Formula: change in length / original length
      - "Shear" strain is a bend in the material as a result of the force - think about bending a wire hanger
         - Formula: amount bent (angle bent) / length
   - For each kind of material (at specific conditions, too!) there is a characteristic ratio of stress to strain - that is why the same force applied to a piece of paper and a brick will result in different strains being observed

- Explain what "slip" is. What condition makes it occur more easily? What condition makes it occur LESS easily?
    - To understand "slip", you have to consider the crystalline model of a material (let's say iron). So here we have iron atoms arranged in an orderly manner
        - When slip occurs, we have a SHEAR STRESS that causes sheets of atoms to slide past each other so that the crystalline structure is altered - maybe it is shaped differently, or atoms that used to be bonded to each other are no longer bonded thusly, etc.
        - There is a "slip plane" where the two sheets meet, and if we apply a shear stress along this plane, there will definitely be slippage
    - Slip happens EVEN more easily when there is a dislocation defect in the crystalline structure - this happens when we have a row of atoms in a sheet (let's say) and then the row suddenly ends - and so the sheet that is attached to this row's sheet has to stretch in order to maintain all the bonds, and it becomes NON-UNIFORM
        - We care about this because now the sheet can "slip" gradually, one row at a time - it does not have to go all at once
    - Slip happens LESS easily if the material is polycrystalline - the idea here is that instead of all being one crystal, the material is made up of many different crystals
        - The individual crystals are called grains, and the places where they contact each other are "grain boundaries"
        - This makes slip more difficult because remember that slip is SHEETS OF ATOMS moving past each other - and because it is the whole sheet, it will all be going in the same direction, etc.
        - However with grains, now the grains have to move along the grain boundaries - and this is more difficult because they are not aligned perfectly, they go in different directions, etc. - there is no neat "slip plane" that we can slip along
- Discuss the two types of deformation that can happen in solids, and a third term that mediates the relationship between the two.
    - Elastic deformation: this is a temporary deformation after stress - temporary meaning that when we cease the stress, it goes back to normal
    - Plastic deformation: this is a permanent deformation, which happens when atoms get rearranged
    - Yield strength: this is the maximum amount of stress that a solid can undergo before plastic deformation occurs
- Explain the 3 ways that we can use heat to alter the properties of a metal.
    - Annealing - this is when we heat metal to a high temperature, and then slowly cool it
        - This will cause the small crystallites to combine into larger ones (you know what annealing means)
        - This will make it ductile (easier to deform, have slip, etc.) - and think about why - because the more grain boundaries we have, the harder it is to have coordinated slip in one direction. But now that there are fewer, it will be easier to do slip
    - Quenching - this is when we heat metal to a high temperature and then rapidly cool it
        - This causes the formation of many small crystallites
        - Using the above principle, guess what happens? It becomes hard and brittle
    - Work hardening - we DON'T use heat here, but rather we bend the material back and forth
        - This breaks up the large crystallites and forms smaller ones
        - Again we know what happens - it becomes harder!

Knives

- What are the desirable properties of a knife?
    - Edge:
        - Hard: so the edge stays sharp

        - Not brittle: so the edge doesn't break
        - Toughness: ability to absorb energy during deformation
    - Blade:
        - Plastic deformation and ductility: so knife bends and does not snap
- How might we create these properties?
    - Edge:
        - We can use heat treatment to make it hard (we know how to do this from above)
        - We can use a flame and a laser beam to adjust the carbon content near the edge to make it harder (see next point)
        - We want to make it from martensite (see next point)
    - Blade:
        - We'll make it from pearlite
- Talk about what steel is, and how the different types of it are formed.
    - We add carbon to iron to form steel - the carbon goes into the interstitial areas, and then it dissolves
    - From here we get different kinds of steel, based on what percent of the entire material is occupied by carbon, and also by playing with heat
        - Some of these varieties include: ferrite, cementite, pearlite, austenite, fine pearlite, bainite, martensite
- Discuss stainless steel. What is it made of? What are its properties? Where might we use it?
    - Stainless steel is steel with chromium and nickel added (i.e. 18-8 stainless steel is 18% chromium and 8% nickel)
        - The added chromium (and thus less carbon) makes it corrosion (i.e. rust, stain, etc.) resistant
    - 18-8 stainless steel is cheap, ductile, and easy to work with
    - There are heating/hardening issues though:
        - For 18-8 stainless steel, we can only harden it by work hardening it (there is not enough carbon to form martensite, for example)
        - For other stainless steels, we CAN do work hardening, but it's hard
    - We use 18-8 stainless steel for cafeteria grade knives

Polarizers and Liquid Crystals

- What is a liquid crystal? What are the 3 ways in which they can be oriented? How does temperature affect this?
    - It is a rod-like molecule, and when you throw a bunch of them together they get oriented differently based on what the temperature is:
        - At higher temperatures, we have ISOTROPIC arrangement: no positional order (they are not lined up in rows or columns or anything) and no orientational order (they don't point in all the same direction)
        - At medium temperatures, we have NEMATIC arrangement: no positional order but they DO have orientational order (they all point the same way, but still no rows or columns)
        - At lower temperatures, they are in a SMECTIC arrangement: they have a quasi-one dimensional positional order (they are in columns but the rows are not that perfect) and they DO have orientational order
- What are polarizers? What can they allow us to see?
    - They are materials that only allow light to go through if the wave is aligned in a certain direction
    - We can use it for:
        - Sunglasses - because we make it so the alignment of the light waves in the glare that comes off the snow in winter (for example) is eliminated
        - Visualize defects in liquid crystals - because liquid crystals can be in different phases, with each phase affecting light in a different way

        - So there are phase transitions...
- How does a liquid crystal display work?
    - OK, so think about light going through 2 polarizing filters where the axis of polarity are perpendicular
        - The first filter would only let N-S light (for argument's sake) through, which would then be blocked by the second filter, which only allows W-E light through
    - Now think about putting a bunch of liquid crystals in there - they are going to be all chaotic but the ones near the filters will line up in the grooves of the filters due to charges
        - But since the filters and thus the grooves are perpendicular, we will see a DNA helix-type shape taking place with the crystals as they start pointing one way and then twist around to point in another way
    - Now as the light passes through the first filter, it hits these liquid crystals, which cause it to bend just as they are bending
        - By the time the light goes to the other end, it is facing in the direction which will allow it to go through the second polarizing filter, and so we're all good!
    - When we want to BLOCK the light, we just turn on an electric field that will cause the liquid crystals to line up in a straight line - so light goes through them still, but they do not TWIST the light and thus it gets blocked by the second filter

Polymers
- Talk about polymers of carbon, and how they can form different materials.
    - A lot of things are just (at their roots) hydrocarbon polymers: propane, diesel fuel, wax, high-density polyethylene (HDPE)
    - Their density and the length of the carbon chain comprising each molecule makes a difference, for example:
        - Wax is a hydrocarbon chain about 30 carbons long
        - Garbage bags are made of polyethylene (many 2-carbon groups) at a low density (thus they can stretch, etc.)
        - The plastic in 4L water jugs is made of polyethylene at high densities (that's why it is harder), with the crystalline (ordered) regions separated by amorphous regions
            - The amorphous regions give the plastic a "milky haziness" and also make it harder and have more tensile strength
    - Note that the longer carbon chains in wax and 4L plastic make them having higher melting points than wax
- Talk about how temperature can affect polymers.
    - Alright, so the deal is that it is very hard for polymers to be completely solid or completely liquid - so it occupies any of 5 states in between the two
        - At lower temperatures: it can't crystallize completely, and so that's why we can bend garbage bags (LDPE) easily
        - At higher temperatures: there are too many entanglements for it to completely become a liquid, and so that's why it doesn't flow like a liquid
    - Here are the "regimes", from lowest to highest temperature:
        - Glassy regime (i.e. Plexiglass) - atoms don't move and chains are entagled, so it is hard
        - Glass-rubber transition regime (i.e. latex paint) - atoms move but chains don't, so it is stiff but pliable
        - Rubbery plateau regime (i.e. garbage bags) - atoms move and chains move a bit, so it is rubbery, flexible, elastic, etc.
        - Rubbery flow regime (i.e. Silly Putty) - atoms and chains can move enough so that the chains can disentangle themselves, so it is very pliable, flexible, etc…
            - At slow speeds it almost even flows like a liquid
            - At high speeds it acts like a solid (bounces) i.e. Superball

        - Liquid flow regime (i.e. STP oil) - a VERY viscous liquid
- What is reptation?
    - Reptation is used to describe the movement of polymers as they attempt to disentangle itself - its almost like a snake - when it slithers, it "follows its own path"
    - That's why corn starch and water can be hard to stir - because you are trying to force the polymers to move in a direction that is not along their lengths - but if you just "let it go", it will move on its own
- What is the difference between a thermoplastic and a thermoset? How do we change one to another?
    - Comparison:
        - Thermoplastics behave like liquids when they are heated - the chains can separate from each other, the molecules get further apart, and we can reshape them at high temperatures
        - Thermosets have chemical bonds between the different chains, and so they do not come apart, act like a liquid, and so on - in fact when we heat them, they will burn before they melt
    - Conversion:
        - We can do a thing called vulcanization to create chemical bonds between the polymer chains in a thermoplastic, which will then turn it into a thermoset
        - This is really good to do when we want the thermoset to be in a certain shape, because remember that we can't shape it when it is a thermoset
            - So we make it as a thermoplastic in the shape that we want, then we vulcanize it

Real Life Examples

- What are 5 polymers which we discussed? Comment on each.
    - Rubber
        - It is elastic etc. because the molecules don't crystallize, but instead they coil
        - Natural rubber can go between different "regimes" at different temperatures, which is why a raincoat works very well on cold days but because sticky and "flowy" on hotter days
        - We can heat rubber to vulcanize it, which will make it stiffer but still elastic
    - Celluloid: this is a derivative of cellulose, which is stiff and cannot be shaped
        - We can combine it with acid to make nitrocellulose, which is flexible and can be shaped
            - This was the first practical synthetic plastic, and it was used to replace ivory on billiard balls
            - However, it is easily flammable because it is vulcanized and so it will burn instead of melting
        - We can also make cellulose acetate
            - This is used to make overhead transparencies
    - Nylon
        - We get this if we combine two carbon chain monomers where we have an acid group on one end and a base group on the other - they will combine and release water (neutralization)
            - The resulting product is strong, tough, elastic, and chemically inert (the H's block further attacks)
        - We can play with the nylon properties by changing the lengths of these carbon chain monomers with acids and bases on the end
            - i.e. Nylon 6,6 is stiffer than Nylon 6,12
    - Teflon
        - It is similar to poly-ethylene, except instead of hydrogen molecules around the chain, we have fluorine molecules

        - These fluorines are much bigger than hydrogen and so they block chemical attacks must better - thus they are inert
            - Thus it is good to cook frying pans with teflon because you know there won't be any chemical reactions happening
        - It is very slippery
    - Kevlar
        - This is similar to nylon in that you combine hydrocarbon chains with acid or base organic groups on the ends
            - However, the hydrocarbons are replaced by aromatic rings
        - And the thing with Kevlar is that the polymer chains don't coil - they stay in a straight line
            - That means if you want to break or bend them, you have to break ALL OF THEM - and this is very hard to do
- What are lyotropic liquid crystals, and why do we care?
    - A lyotropic liquid crystal is something whose ordering changes along with its concentration within whatever solvent
    - These guys can be surfactant molecules, where one end likes water and the other likes oil
        - There are many applications of this:
            - Soap
            - Cationic liposome complexes for getting DNA through a cell membrane

<u>From Textbook</u>
Reading #1 on UW-ACE
Reading #2 on UW-ACE

Topic 9

Thursday, November 30, 2006
9:44 AM

Topic 9: Rockets and the Bomb

<u>From Lecture</u>
Theoretical Concepts of Momentum and Collisions Behind Rockets

- What is momentum?
    - Momentum is a property that objects have: it is mass x velocity
- How is momentum significant during collisions?
    - It is significant because during collisions, the overall momentum of the system will be conserved - meaning that whatever the "final" state is (whether it is both objects stuck together or the two objects separately), the momentum of the objects will equal their original momentum, before the crash
- Explain how the concepts of momentum and collision inform our understanding of how a rocket works.
    - Well the idea of a rocket is that something (fire, water, etc.) spews out the back, and propels the rocket forward
    - If we think about "collisions" we can understand this - the overall momentum of the system before the fire comes out the back is considered 0, since the fire and the rest of the rocket are not moving relative to one another (they are both going "forward" at the same speed)
    - But now the fire gets ejected backwards out of the rocket, and so the fire on its own has some momentum

  - In order to maintain the "zero" momentum total, the rocket must move the OTHER way with a momentum equal to the fire, and so it is propelled forward
    - Realize that because their velocities are opposite directions, one of the momentums will be "negative", and that's how we get 0 when we add them
  - The other thing to consider is because the rocket is losing mass when the fuel goes out the back, it will go EVEN FASTER
- Explain why certain things cannot (and should not) be considered rockets.
  - Whenever the "bullets" are being "pushed" out of the thing (let's say, by one of the prof's Nerf guns), this is not a momentum thing - it is just applying a force

Rockets: Practical Applications

- Describe the two kinds of rocket engines, and explain the unique characteristics of each.
  - Solid fuel rocket engines (used in fireworks)
    - We have a bunch of solid fuel and we just ignite it
      - It comes out the back through a "converging-diverging" or "de Laval" nozzle
    - When these guys start, they DO NOT shut off - it will keep on burning until all the fuel is used up (think about it - how are you going to stop the burning?)
    - The "energy per mass" rate is not too good, however...
  - Liquid fuel rocket engines (used in rockets?)
    - So here you have separate tanks of fuel and an oxidizer (i.e. oxygen, which will allow for combustion)
      - And then you can turn the nozzle on and off which will allow the two things to mix and when combined with hot gas, we will get combustion
      - And again it all comes out the back
    - With these guys we can have "variable thrust" because we can use the valves to control how much comes out
    - The "energy per mass" rate is much better here

Theoretical Concepts of Atoms Behind Bombs

- First of all, what is that big chemical reaction that releases a lot of energy?
  - $2 H_2 + O_2 \rightarrow 2 H_2O$ + energy (not sure where this is applicable…)
- Give some data about the different particles in an atom.
  - There are 3 main particles
    - Proton: positive charge (mass of hydrogen nucleus)
    - Neutron: no charge (mass close to proton)
    - Electron: negative charge (mass 1/2000 that of proton)
  - The nucleus consists of protons and neutrons, and then furthermore the atom consists of nucleus and electrons
  - A neutral atom has as many electrons as protons
  - Some size-related issues:
    - Size of atom is 10-10 meters
    - Size of nucleus is 10-15 meters
    - Therefore, 99.9999999999999% of the atom is empty
- How do we relate these properties to the characteristics of different elements?
  - Well for reactivity, this is determined by the number of electrons in the atom
  - The elements of the periodic table are differentiated by the number of protons in the nucleus (hydrogen, helium, lithium, etc.)
- Discuss and explain the different isotopes of hydrogen.
  - OK, the idea is that as we explained with the previous point, your identity as an element is defined based on the number of protons that you have

        - So within that definition, there is still "wiggle" room to have different kinds of a single element (like hydrogen, let's say) because we can vary the number of neutrons
    - So regular hydrogen has no neutrons, and so we symbolize it as 1H: the "1" for the number of particles in the nucleus, which is 1 proton + 0 neutrons
    - But we can go from there and make other kinds of hydrogen which are heavier:
        - Deuterium: 2H - 1 proton + 1 neutron
        - Tritium: 3H - 1 proton + 2 neutrons
- Discuss some of the forces going on within a nucleus. What implications does this have for us if we were trying to "make" a nucleus?
    - Well remember that there are protons and neutrons - and also remember that since protons all have the same charge, so they will be pushing each other apart! (This is called the "electrostatic" force)
    - So how do we handle this? We handle it because there is another force there called the "strong nuclear force", which keeps the particles together (it is almost like gravitational attraction I guess…)
        - VERY important with this is the neutrons - the more neutrons in a nucleus, the stronger the "strong nuclear force" is, and thus the more stable the nucleus will be
    - The implication is that if we ever wanted to "make" a nucleus, we would need to put a lot of energy in at first (to overcome those electrostatic forces) but once we got it together, it would be fine (because of the strong nuclear force, which ONLY ACTS AT SHORT DISTANCES)
- Describe Einstein's famous equation. What are the implications of this?
    - His famous equation was E = mc2, which relates mass to energy
    - The implication is that we can turn mass into energy (and vice versa), and furthermore we can predict how much we are going to get when we convert it
- Describe and contrast nuclear fission from nuclear fusion. How is it that both of these things can (theoretically) create energy?
    - Nuclear fission: this is when a nucleus breaks apart
        - This happens when a neutron collides with a nucleus and breaks it apart - the particles get far enough apart that the strong nuclear force can't hold them together, and instead the electrostatic force pushes them apart with a vengeance
            - The result is the pieces of the nucleus, but also free neutrons and energy
        - Also some mass is just plain lost, and that gets converted into energy via Einstein's equation
    - Nuclear fusion: this is when two nuclei come together and make a bigger one
        - The roles of strong nuclear force and electrostatic force are flipped here: as we push them together the electrostatic force resists, but eventually we give way to the strong nuclear force, which brings them together and releases tons of energy
            - For example: 2H + 3H = 4He + neutron + energy
        - Again we have mass lost - some neutrons fly off and we get energy there too
- How does radiation play a role in the above processes? What is half-life?
    - OK, the deal with radiation and radioactivity is that sometimes nuclear fission happens spontaneously - and it happens when a nucleus is not stable (remember that we need a certain amount of neutrons to be stable, right?)
    - So when a nucleus is not stable, it may auto-fission - it may break apart itself in hopes of forming two products that are individually more stable
    - This can happen in (at least) 3 ways, and the reason why we care about them is that when they radioactively decay, different kinds of photons are produced that can do different things:

- Alpha decay produces alpha rays, which are stopped by the air (so no worries)
- Beta decay produces beta rays, which penetrate body tissue and can kill tumors
- Gamma decay produces gamma rays which are so high energy that they will go through us, only causing damage if there is something for it to react with (also used for radiation therapy)

  - Half-life is a related concept because it tells us about the speed with which some material spontaneously fissions: half-life is the amount of time it takes for half of some material to fission

Fission Bombs: Practical Applications

- What is a chain reaction?
  - OK, imagine we have a bunch of material together (say, uranium)
  - We throw one neutron in there and it causes one uranium to fission, releasing neutrons
  - These neutrons hit other uranium atoms and they do the same thin
  - And so we just started with one neutron, but because of the chain reaction we actually get a lot of stuff going up
  - This continues until there is either no more material to fission, or there is so much energy that it just blows everything up
    - Note that inefficiency here: if the whole thing just obliterates after only half the uranium has fissioned, we aren't getting good "value"
- OK, let's talk about uranium. What are some properties of it which are relevant to our objective of using it as a bomb?
  - Uranium contains 92 protons, and within this there are 2 isotopes: 235U and 238U
  - ^{235}U:
    - It has too many protons and not enough neutrons…
      - Firstly, this means that the electrostatic force is almost strong enough to rip the nucleus apart (marginally stable) because the strong nuclear force opposing it is not that good
      - Secondly, this means that it fissions easily when a neutron strikes it
      - Its critical mass is 52 kg (ball of diameter 17 cm)
    - So we want 235U and NOT 238U, because 235U is the one that fissions easily
      - However, it is only 0.72% of natural abundance so we have to purify it from normal uranium
      - We can do this by separating it based on mass (because they are different mass, duh) - sometimes we attach fluorines to it
    - Its half-life is 710 million years
  - ^{238}U:
    - It is more stable, half life 4.51 billion years
    - It absorbs most neutrons without fission, eventually becomes plutonium
- How would I go about making a uranium fission bomb?
  - Alright, so what I want to do is to have a sphere that altogether has enough critical mass
  - Then I cut some out so that neither piece on its own has enough
  - Then I fire the piece into the other piece when I want the bomb to go off, because now I provided energy (the cannon fire) and critical mass (it is all together now), and the chain reaction can start
    - I fire it in there FAST because I don't want any energy release until everything is all together
  - I contain the chain reaction until it is ready to do serious damage by putting this whole thing in a tungsten carbide and steel container
    - Because if neutrons leave, then they cannot contribute to further fission by hitting other uranium
- Now let's talk about plutonium. What are some properties of it which are relevant to our objective of using it as a bomb?
  - Plutonium has 93 protons: 239Pu

- Its half life is 24,400 years
- It fissions easily when struck by a neutron
- Its critical mass 10 kg (ball of diameter 10 cm)
- It is not found in nature - so we make it ourselves (note the above point about how uranium can turn into plutonium)
  - It COULD have been on earth before, but we don't know this because it would have all decayed
- It is very radioactive and poisonous - so this guy is a dirty bomb

- How would I go about making a plutonium fission bomb?
  - Well first of all, I have to realize that one problem exists with plutonium: it is SO radioactive and fissions on its own so much that I can't even assemble a critical mass of it, because it would fission and go off on its own (and we don't exactly want spontaneous bombs)
  - So what we do is we have a sub-critical mass of it, surrounded by a uranium "tamper", further surrounded by a high explosive
    - Note that this tamper is 238U, because we don't want it to blow up - we want it to stay together so that it can reflect those neutrons (recall that U-238 is more stable and less likely to fission than 235)
  - We explode the explosive and shockwaves are directed inwards, so all the plutonium is crushed together and then it is at a critical density which allows the chain reaction to occur
  - FURTHERMORE, when neutrons do try to escape, they hit the uranium and bounce back, so we get lots of "bang for the buck"

Fusion Bombs: Practical Applications

- Let's quickly review. What are the theoretical properties of hydrogen that allow us to use it in a fusion bomb?
  - Recall that: deuterium + tritium gives helium + neutron + energy
    - And from these products, the helium nucleus and neutron fly apart at incredible speed because so much energy is released
  - Note that this reaction does not occur naturally on earth because the hydrogen nuclei repel each other with great force
    - Thus the only way to get them close enough for fusion to occur is to make them move very fast so that when they collide, they can get very close to each other.
    - This also means has the implication that: very fast = high temperature
- How would I go about making a thermonuclear/hydrogen fusion bomb?
  - OK so let's think about it - the central issue is how to get the deuterium and tritium atoms heading towards each other so fast that they will fuse and give us energy - where are we going to get that much energy?
  - Well smart guy, why don't we just set off ANOTHER bomb right beside it - surely that will be enough energy
  - So that's what we do: we have a uranium tamper (again to keep neutrons inside) and within that we have a plutonium fission bomb (you know how that works) plus a whole crapload of the two hydrogens
    - And again it is U-238
  - Now let's think. We'll set off the plutonium bomb (fission), which will then set off the hydrogens (fusion)
    - BUT THEN…all that energy causes the surrounding uranium tamper to become plutonium (remember U-238 does that), which can then FISSION AGAIN
    - So all in all it is pretty beast…
- Explain what a neutron bomb is.
  - It is almost exactly like the thermonuclear/hydrogen fusion bomb, except there is no uranium tamper surrounding it
  - What are the implications of this?

        - It is no longer fission-fusion-fission: instead it will just be fission-fusion
        - Also, the neutrons produced can fly off because they are not kept in by the uranium
        - Also this is a "cleaner" bomb than the thermonuclear/hydrogen fusion bomb because with that bomb, the uranium was turned into plutonium and plutonium (as we know) is dirty
- So what is the result of this stuff?
    - Fireball - because the nuclei etc. are coming out so fast that they heat everything up
    - Light rays - these includes many wavelengths in the EM spectrum (not just visible) and so we can get damaged by X-rays, gamma rays, etc.
    - Pressure surge - this will knock stuff over
    - Mushroom cloud of hot air - the hot air rises due to its buoyancy
    - Fallout - lots of the new nuclei that are formed due to fission/fusion/etc. can get into our bodies and then radioactively decay, producing rays that screw us up

Peaceful Energy Generation: Practical Applications

- How does a thermal fission reactor work? What is an example of one, and what does it use as a moderator?
    - Alright, first of all we have to understand the difference between slow-moving and fast-moving neutrons, and how they affect U-235 and U-238
        - The difference is that U-235 likes slow-moving neutrons: it can capture them easily (even when U-238 is more abundant) and fission as a result…whereas U-238 works better with fast-moving neutrons
        - So in a fission bomb, that's why we have to use enriched uranium, because if we didn't have more U-235 than usual, then all the neutrons which were produced would just be absorbed by U-238 and we would have no explosion
    - So in a thermal fission reactor, what we have is U-235, U-238, and a moderator (either heavy water or graphite, which can catch on fire)
        - The moderator will remove energy and momentum from the neutrons without absorbing them, so that now when a nuclear reaction goes off, it can cause more U-235 to fission because the neutrons will be slower
            - In other words, if we did not have the moderator, than the fissioning of U-235 would produce FAST neurons which would be useless for setting off more U-235
        - Thus since the neutrons are slower, we can afford to have a not-as-high percentage of U-235…it turns out we only need to enrich it a bit, to 2-3%
    - Then we also put control rods in there which (unlike the moderators) DO absorb neutrons
        - The purpose of these guys is to slow down or stop the reaction by absorbing neutrons so that more U-235 does not go off
        - So we can make the reaction sub-critical, critical, or super-critical depending on how many rods we put in there
    - The CANDU reactor is a thermal fission reactor which is cooled with heavy water (D2O)
- Describe and compare a boiling water reactor and a pressurized water reactor.
    - First of all, the overall idea is that we can harness all the heat produced by the nuclear reaction by using it to boil water
        - This water will turn into steam and expand, so we can use it to turn a turbine and create energy
    - With a boiling water reactor, the water boils right in the reactor core and goes through pipes (as steam) to a turbine
        - Thus the water is "dirty" because it can absorb crap from the nuclear reaction
    - With a pressurized water reactor, the water is prevented from boiling in the reactor core because we keep the pressure very high there, and so it goes through pipes as

super-heated water to a heat exchanger, where it releases its heat to water going around in another system which DOES boil and subsequently turn a turbine
    - Here the water (at least the stuff that turns the turbine) is not "dirty" because it never touches the reactor nor the dirty water directly
- Explain what a "fast fission" or "breeder" reactor is, and how it works.
  - The idea here is that unlike "slow fission" in thermal fission reactors, where we WANT to slow down the neutrons due to the small percentage of U-235, we don't use a moderator and ENCOURAGE fast neutrons
    - This is only possible because we have WAY enriched U-235 here, to the point where it is 25-50%: this means that it doesn't matter that U-235 is "better" at receiving slow neutrons and U-238 is "better" at receiving fast neutrons, because there is enough U-235 to capture enough fast neutrons to maintain the chain reaction
  - So why would we ever want this? Because some fast neutrons are captured by U-238 as well, which promptly turns into Pu-239 (plutonium)
    - This is useful for us because we can use plutonium as the fuel later on (although admittedly we can also use it for bombs, so it is controversial)
  - Lastly, we use liquid sodium instead of water to cool down the reactor. We can't use water because that slows down neutrons - and we don't want that!
- How do nuclear fusion reactors work?
  - As we recall, the underlying principle is that we are smashing together deuterium and tritium to make helium
  - We do this in two ways:
    - Inertial confinement fusion: we have a ball of D and T, which we heat with lasers
      - They heat the surface of the sphere and cause the inside to mash together, which causes the D and T to fuse
      - We call this inertial confinement because the only reason that the D and T are mashed together is because the surface material goes outwards…and so (remember momentum) the inner part is compressed
    - Magnetic confinement: we localize the hydrogen atoms, neutrons, etc. using magnetic fields
      - The idea here is that when we heat hydrogen hot enough, it will dissolve into positively charged atoms and electrons
      - As we may or may not remember, charged particles' motion is affected by magnetic fields
      - So we can introduce a magnetic field that will attract the charged particles onto its path and prevent it from elaving
      - The "tokamak" is a setup where we have that magnetic field and it is shaped like a donut, so the charged particles just go around and around and do not touch the walls where it could transfer (and thus lose) heat
- Discuss some famous nuclear reactor accidents.
  - Windscale Pile 1 in Britain (1957)
    - Air cooled core with graphite moderator.
    - Structure of graphite changed by radiation during a routine shutdown, the core overheated, graphite caught fire and spread radiation throughout the countryside.
  - Three Mile Island, Pennsylvania (1979)
    - Pressurized water thermal reactor.
    - Water pump failure in generating loop.

        - Reactor shut down with control rods but fission products were still decaying and the core overheated, releasing radioactive steam through a pressure release valve.
    - Chernobyl Reactor Number 4, Ukraine (1986)
        - Water cooled, graphite moderator.
        - Test of emergency cooling system so operators slowed chain reaction down, slowed too much and so removed a large number of control rods to get it started again.
        - Then tested emergency cooling system which should have shut down the reactor by inserting control rods, except that the operators had overridden automatic controls so that the reactor would not have to be restarted.
        - No cooling, so the remaining water boiled, which removed some of the water moderator, which increased the chain reaction.
        - Operators tried manually insert control rods but this was too slow.
        - Fuel rods heated white hot and melted containers, graphite caught fire, explosions blew up the containment vessel.
        - 100,000 people evacuated.

<u>From Textbook</u>
Section 4.2
Section 16.1
Reading on UW-ACE

Topic 10

Friday, December 01, 2006
8:48 AM

Topic 10: Medical Imaging

<u>From Lecture</u>
X-Rays

- Give some information on the history of X-rays.
    - They were discovered accidentally by Roentgen, in 1895 when he was studying an element in a tube that was completely covered in paper, however it was still able to make a phosphor screen glow
    - He tried to put various things in the path of the light to stop the glow, but they were all unsuccessful
    - However when he tried to put his hand in the path, he saw an outline of the bones because his bones had absorbed the light rays - and so it was realized that they could be used to image the bones
    - Thus they were used clinically in 1896
- Describe the 2 ways that we can make X-rays.
    - Bremsstrahlung
        - This describes the effect that we see when a charged particle accelerates (more technically decelerates): it emits a high-energy photon (this essentially is our X-ray)
        - So if we can somehow "fire" an electron at a nucleus, it will be drawn into it quickly, then arc around it and be slowed greatly due to the positive nucleus - and this deceleration makes our photon for us
            - The photon can be light, UV, X-rays (what we want!), gamma rays, etc. - the energy is variable
    - Fluorescence

        - Now this time an electron comes and HITS another electron, causing it to completely leave the atom
        - So now there is an orbital that is missing an electron, and so an electron from a higher orbital drops down to fill its place - and when it does so, it releases a lot of energy
            - The photon/X-ray produced by this is more stable because it is always the same for the same distance in energy level drop
- How would we make an X-ray generator?
    - Alright, well the basic thing we have to do would be to get electrons to strike some metal at a high speed
    - The way we will do this is that we will have a hot cathode (negatively charged) which will emit electrons to hit an anode (positively charged), and the metal on that anode will make those photons/X-rays for us
        - In fact, the cathode filament is -V (a big negative number) and the anode is 0 V
    - The electrons will be charged because they are traveling through the electric field that is created between the anode and the cathode
        - 1 electron accelerated has 50,000 V of energy
    - Both Bremsstrahlung (variable energy) and fluorescent (characteristic energy) X-rays will be produced
    - A few modifications:
        - We spin the anode so that one part of it does not heat up and melt (we spread the heat around)
        - We have aluminum to absorb the really low energy X-rays, because they will INJURE our skin
            - Also note that the Bremsstrahlung rays are usually the low energy ones because a) they don't have a consistent energy and b) they only give off a high energy X-ray if they hit the nucleus exactly

X-Ray Practical Applications: X-Ray Imaging

- What are the 4 processes through which X-rays interact with bone and tissue?
    - Elastic scattering, the photoelectric effect, Compton scattering, electron-positron pair production
- Discuss elastic scattering.
    - OK, so the issue here is that when an X-ray hits an atom (because remember when an X-ray is EMITTED from an atom, it's going to encounter MORE atoms no matter what direction it goes), the atom will deflect the X-ray
    - So what are the implications:
        - If we're doing radiation therapy, there is no problem because the atom does not absorb any of the X-ray's energy
        - If we're doing a diagnostic X-ray, this is a problem because the path of the photon is deflected and so it will arrive on the screen from a weird angle, thus making the image hazy
            - We fix this by putting filters on the screen so that photons are only accepted if they hit it straight on
- Discuss the photoelectric effect.
    - Alright, this isn't a problem like elastic scattering is. Rather, it is the reason why X-rays work. Let's think about why a bone scan shows up the way it does
    - Recall the photoelectric effect: a photon hits an atom, which causes an electron to be ejected with some kinetic energy
        - The thing to realize is that the kinetic energy which it leaves with is basically the difference between the energy of the photon coming in, and the strength of the attraction between the electron and the nucleus of the atom it belongs to

    - But the thing is, when the electrons leaving the atom are at a REALLY HIGH kinetic energy, this is not preferred. An atom would "rather" have the photon go right through it than have it eject one of its electrons at high speed
        - So the implication is that basically, the photon will only get absorbed if the atom holds on strongly enough to its electrons that when they leave, they don't leave very fast
    - And so the trend we end up seeing is that large atoms absorb these photons, while small ones don't
        - And when we think about our bodies - our bones have the large atoms (i.e. Ca and P), whereas our skin has much smaller ones (C, H, O, N)
        - Another thing is that DYES (i.e. an iodine-based dye) can absorb X-rays, so putting dye in our body can allow us to see the activity at certain points
    - The photoelectric effect can be damaging because we have electrons flying all over our body
- What does a CT scanner do?
    - It is basically using X-rays in a new way: we take X-rays from many different angles around a given part of the body and thus create different "slices"
    - We assemble the slices to give us a 3D view of the organ

X-Ray Practical Applications: X-Ray Therapy

- Discuss Compton scattering.
    - This is similar to the photoelectric effect in that it involves photons coming near an atom, and then an electron leaving
    - But the difference is that this time, it's not that the ATOM absorbed the photon and ejected an electron, but rather that a photon hit one of the outlying electrons directly and caused it to leave - almost like two billiard balls hitting each other
        - This shows that photons have momentum, which is odd because they supposedly have 0 mass
    - In any case, the idea is that some energy can be left behind, which can be used to do damage (this is desirable with radiation therapy on tumors)
        - But the thing is, with a given stream of photons, only a few will hit electrons and cause this effect
        - This is actually a really good thing though because it means that if we shoot a tumor from a single angle, everything gets equally slightly damaged
        - However if we shoot the tumor from many different angles, the surrounding tissue will not get too much damage but the tumor will get a lot
- Discuss electron-positron pair production.
    - Alright, so the deal is that a photon (if it has enough energy) can spontaneously turn into an electron and a positron (this is an example of converting energy to matter)
        - The catch is that it requires 511,000 eV of energy to make an electron OR a positron, so the original photon must have a total of 1,022,000 eV
    - But then the positron doesn't last long because it soon collides with an electron and annihilates it, turning mass into energy again - the possibilities for radiation therapy are obvious
- Explain how we make gamma rays (another kind of light ray we can use for radiation therapy).
    - It's all about the radioactive decay of Cobalt-60 to Nickel-60
    - In changing from Cobalt-60 to Nickel-60, we have a beta decay and then two gamma decays
        - The beta decay means that a neutron in its nucleus turns into a proton, electron, and neutrino
        - The electron and neutrino leave but the proton stays, so now we have Nickel-60
    - However there is still some distance to go - the nickel-60 undergoes a gamma decay twice to become more stable

        - The first time, a gamma ray of 11.7 MeV is released
        - The second time, 1.33 MeV is released
    - And so we have these gamma rays, and we can collect and use them for radiation on our bodies
- Why are we talking about Particle Accelerators in the radiation therapy section? Explain how they work.
    - We are talking about particle accelerators because sometimes we can use the high speed electrons to attack tumors directly
    - So if we put electrons in a tube and put them between a positive and negative thing, they will accelerate towards the positive as they get attracted to it (and simultaneously pushed away from the negative)
        - And as it goes towards the positive, we now flip the charges so that it gets pushed further along
        - So the way we alternate the charges is with an idea similar to a tank circuit, where the positive and negative charges regularly flip
    - Note that at the beginning, the positive/negative things have to be further and further away from each other as the electron increases in velocity, but by the end we can keep them constant because the electron maintains the same speed as it nears the speed of light

MRI

- Explain the theoretical concepts necessary to understand Magnetic Resonance Imaging.
    - The idea is that a proton has "spin" (either "spin up" or "spin down"), which can be aligned by an external magnetic field
        - So if I apply a magnetic field to my body, a small majority of the protons in my body will be pointing in the direction of the field
    - Obviously the "spin" which is aligned with the field is of lower potential energy, so we can also consider a proton to have "ground state" and "excited state"
        - IMPORTANT: the difference between the two states is determined by the strength of the magnetic field (I guess this is intuitive because you would have to fight the field if you wanted to change your spin so you were going against it)
    - So let's think: if we applied a magnetic field to a person but varied it spatially (meaning that in different locations it is of different strength), the protons at different parts of the body would require different amounts of energy to flip their spins
    - So if we fire a radio wave of only a particular energy at the body, only protons in a certain area will respond and so this way we can see where the protons are
    - (Mmmm…not happy with this explanation…make sure you can do the questions!)

<u>From Textbook</u>
Section 16.2

Topic 11: Special Project

- What was the project?
    - Given: popsicle sticks, tape, string, manila envelope, Imprint, raw egg
    - Drop from upper level in CEIT
- How many eggs were broken?
    - LESS THAN 1O (perhaps 3?)

Midterm Notes (Devon)

Chapter 9
Resonance and Mechanical Waves

Natural resonance
- The energy in an isolated system causes it to perform a certain motion over and over again like a rocking chair or pendulum
- An object accelerates towards its natural equilibrium but overshoots it until there is no more excess energy in the system
- Resonances of objects that are extremely regular (like a pendulum) are called *harmonic oscillators*

Pendulums
- Transforming gravitational potential energy to kinetic energy (some potential energy is converted into thermal energy)
- Period doesn't depend on **amplitude** (its furthest displacement from equilibrium). Whether the amplitude is large or small the period remains exactly the same.
  - If you pull the mass of a pendulum higher before letting go, the period will still be the same.
- Increasing its mass doesn't increase the period because increasing the mass increases the pendulum's weight and stiffens its restoring force.
- A pendulum's period will decrease if the string is shorter and will increase if the string is longer.
- Thus a short pendulum swings more often than a long one, and any pendulum swings more often on Earth than it would on the moon.

Sound and Music
- When sound passes by, changes in air pressure in your ear fluctuate up and down about normal atmospheric pressure. When these fluctuations are repetitive you hear a *tone* with a pitch equal to the sound waves frequency.

Violin
- Violin strings are stretched to increase tension in the string
- The string is a harmonic oscillator
- The string retains the most important feature of a harmonic oscillator: the period of each vibrational mode is independent of its amplitude.
  - The violin's pitch doesn't depend on how hard it's vibrating!
- Shortening a string stiffens and reduces its mass so its pitch increases
  - Pressing your finger on a string effectively shortens it. Knowing where to press your finger to produce a particular note is the skill of playing a violin.

Waves
- **Mechanical waves** are natural motions of an extended object about its stable equilibrium -- like a violin string!
- A string's fundamental mode is a **standing wave**, which is a wave with fixed nodes and antinodes
  - A standing wave doesn't travel along the string
- Frequencies that are integer multiples of the fundamental pitch are called **harmonics**

Helium in a toy balloon has the same stiffness as ordinary air, but its density and inertia are smaller. How does this difference affect the speed of sound in helium?
- With its reduced density and inertia, helium vibrates faster than air, when the gasses carry sound waves of equal wavelength, so sound travels faster in helium than in air.

Questions

1. When you blow across the top of a beer bottle, how does the pitch change when
    a. Take a drink, reducing the amount of beer in the bottle
    b. Pour more beer into the bottle
2. When you blow across the bottom of an organ pipe or tube, how does the pitch change when
    a. The length of the tube is increased
    b. The length of the tube is decreased
3. How does the shape and diameter of wine glass change the pitch of sound produced by dragging your finger around the rim?
4. Suppose a guitar string is vibrating in the second harmonic (two antinodes). The wavelength of the standing wave being produced is equal to what proportion of the string length? What about the third harmonic?

Chapter 11

Magnetism and Electrodynamics

Magnets

- **North poles** carry positive amounts of magnetic pole and **south poles** carry negative amounts
- Iron and steel are made of up a bunch of tiny magnets called **magnetic domains**
- As you bring one pole of a magnet near a refrigerator, the tiny magnets in the steel reorient so that opposite poles shift closer to the magnet's pole and like poles shift farther. The steel develops a **magnetic polarization**.
    - The polarization remains strong as long as the magnet's pole is nearby. When the magnet is removed the magnetic domains in the steel reassume their random orientations.
    - No matter which pole or assortment of poles you bring near the refrigerator, its steel will polarize in just the right way to attract those poles.

Electromagnets

- Electric currents are magnetic. Moving electric charges produce an electric field!
- An **electromagnet** is a device that becomes magnet when it carries an electric current.
- The magnetic field around a current-carrying wire is very weak but wire wrapped in a **coil** strengthens the magnetic field.

Direct Current (DC)

- Direct current leaves the generator through one wire and returns to it through another.
    - Edison placed generators in central locations and moved current through copper wires to and from homes.
    - The farther a building was from the generator, the thicker the copper wires had to be. The wires wasted power is proportional to the square of the current passing through it! Thick wires increased the amount of charge passing through the wires.
    - Edison needed to provide **high-voltage DC electric power** to his customers (that is, the highest voltage that safety allowed)

Alternating Current (AC)

- DC power wastes much of its power in the wires connecting everything together
- Wires that carry power long distances have high-voltage, low-current circuits and waste little power.
- Alternating currents periodically reverses direction
- A **transformer** moves that power from the current in one coil of wire through a magnetic field to the current in a second coil of wire
    - Because a magnetic field that changes with time produces an electric field, the coil's alternating magnetic field produces an alternating electric field.

- This induced electric field pushes on the very alternating current that produces it!
- **Lenz's law**: when a changing magnetic field induces a current in a conductor, the magnetic field from that current opposes the change that induced it
- A transformer can transfer AC power from one coil to another with very little loss.
- I'm bored and confused now