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14. Football Tackles, Concussions, and Systemic Racism - students do a 1-D momentum conservation problem. A conceptual question asks whether helmets prevent concussions. Then students read about the NFL's recent court case on race-norming and are asked to come up with another example of a system which perpetuates racism.
15. Billionaires in Space - the rocket propulsion equations from Knight's Physics for Scientists and Engineers, 4th ed are used to find the top speed of 1- and 2-stage rockets. Questions about billionaires and the US tax system are posed.
16. Biomechanics and Prosthetics - biomechanics problems finding the force needed by a muscle to hold up the arm and to hold a 1-liter soda. Some questions exploring prosthetics and health insurance.
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18. Green Energy Efficiency - students research and compare efficiency of different energy generation methods. Questions about how to speed up the social switch to green energy.
19. Simple harmonic motion: Earthquake safety - students use resonance frequency of springs to model the shaking of building in earthquakes and compare the most recent large Seattle earthquake frequency to that of a campus building.
20. Simple Harmonic Motion: Pendulums and Prosthetics - students answer some concept questions about physical pendulum-nature of the leg and how to adjust a prosthetic leg for a more natural gait. Some questions exploring prosthetics and health insurance.
21. Hydrostatic Pressure and the Ocean Gate implosion - students calculate the pressure at the depth of the Ocean Gate Titan's implosion and reflect on engineering ethics.
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23. Thermodynamics and Phase Changes: Global Warming and sequestering CO2 - calculate the energy it would take to store the world's excess CO2 in liquid phase, calculate how long it would take to generate that energy using renewables, and prompts to consider other ways to sequester CO2.
24. Heat transfer: Redlining and Heat Islands - concept questions about heat transfer and asphalt. Students read about redlining and look at a heat map to see if there is evidence that heat islands correlate to redlined zones and review Seattle's recent policy changes around this issue.
25. Redlining and Heat Islands (v2) - Students calculate solar intensity using trig and then typical asphalt temperatures. They learn about heat islands and redlining and evaluate King County's heat mitigation strategy plan.
26. Energy Efficiency - calculate the efficiency of a coal-fired power plant. Use online infor to find the dominant form of energy generation in each state. For states primarily using non-renewable fuels, what is a renewable option that might be available but underutilized?

27. Efficiency vs Efficacy - students look at how inefficient many green energy sources are. Then they read about the racial bias in who is impacted by pollution and reflect on why environmental justice is important.
28. Fluid Dynamics: How Income and Diet Impact Cardiac Health - fluid dynamics problem about carotid arteries and blood pressure. Students connect this to diet and read about how healthy food is inaccessible to low-income families and reflect on policy changes that could fix this.
29. Sound: Noise Pollution and Health - students find an apartment complex near the freeway and calculate the ambient noise level. They read an article about noise pollution and stress and consider what changes could improve the situation and who should be responsible for those changes.
30. Waves: Sound Harmonics and Perceived Gender in Voices - Concept questions about the parts of the human vocal system that dominate in men and women. Students consider what adjustments trans people try to make in their vocal training to pass as their identified gender. Students also consider how to make conversation spaces more welcoming for trans people.
31. Wave Guides and Debunking Conspiracy Theories - Students read a portion of a book chapter that explains how wave reflection due to changes in a medium create the sound channels in the ocean and atmosphere. The reading also explains the now-declassified Roswell project that made Area 51 famous. Students are asked which explanation seems most plausible and are asked to reflect on how to change a conspiracy theorist's mind.
32. Hair types and hair discrimination - students use a laser to measure the width of their hair and to see if it has a round or oval cross section. They read about the link between race and hair type and also about hair discrimination. They reflect on workplace hair policies.
33. Optics/Ray Tracing: Retroreflectors and Bicycle Safety - students do a simple ray tracing to understand how retroreflectors work. They google the fatality rate of day time versus night time accidents and are asked to reflect on why we don't have a mandatory bike helmet law in our city.
34. Optics: Lenses and Access to Glasses - students estimate the focal length of some extreme reading glasses. They read an article about the lack of eye glasses in Benin and consider what benefit better optometry services would create and what can be done for developing countries.
35. Optics: Microscopes and Frugal Science - concept questions about a very cheap portable microscope. Students consider the impact of scientific developments like this and are asked to share another impactful invention in medical science.
36. Telescopes, Sacred Places, and Indigenous Ways of Knowing - wave optics calculation of the resolution of HST. Students then read about the controversy over the Thirty Meter Telescope and also read about Indigenous Ways of Knowing and reflect on both.
37. Electric Fields: Electrophoresis and HeLa cells - an electric field problem about electrophoresis. Then students read about HeLa cells and look up how much they cost and discuss whether Henrietta Lacks' descendents should benefit from the wide-spread use of this cell line.

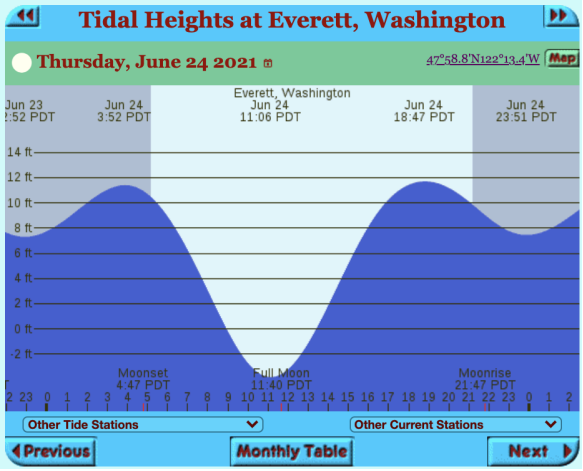
38. Electrostatics: Soot Removal and Environmental Racism - Coulomb's law problem about electrostatic precipitators. Students look up the Clean Air Act and reflect on progress that came from that. They read about environmental racism and reflect.
39. Electric Potential Difference: EKGs and Gender Bias in Heart Disease Diagnosis - concept questions about potential difference between electrodes in an EKG based on equipotential maps. Students read about gender bias in heart attack diagnosis and look into other parts of medicine that have a gender bias.
40. Basic Circuits: Electric Cars and the complexities of battery production - students calculate power and current for an electric car. They read about lithium mining and reflect on the broader impact of electric cars on the environment.
41. RC Circuits, Multiple Sclerosis, and Invisible Illnesses - concept question and calculation about nerves as RC circuits and connection to MS. Students read about invisible illnesses and reflect on access.
42. Magnetic Fields: Save the Bees - students calculate the magnetic field near the ground under a high voltage power line. They read about bees and reflect on what can be done to protect them.
43. Solenoids and MRIs - calculate the current needed to generate a 1 Tesla magnetic field in an MRI, and explain why we need superconductors to carry that current. Follow up questions about access to MRIs for diagnostics.
44. Lenz's Law: Generators and Renewable Energy - concept question where students graph magnetic flux and emf for a simple motor. Students use online info to find the dominant form of energy generation in each state. For states primarily using non-renewable fuels, what is a renewable option that might be available but underutilized? (same reflection as the "Energy vs Efficacy question).
45. Rail guns and the military industrial complex - students derive an equation for acceleration of a projectile in a rail gun and think about what design components maximize kinetic energy for the projectile. They read about military spending and the military-industrial complex and reflect on US military spending.

Preamble at the top of every discussion board problem:

Discussion Board Problems are more open-ended problems that ask you to start with some physics from class but then tie that into bigger issues. Each is worth 5 points: 4pts for your response to all parts of the prompt (including correct answers in terms of Physics problem solving and concepts) and 1 pt for responding to another students' response (more than 10 words, please). Many of these discussion prompts are political in nature but I am not grading you on your opinion. My main goal here is for you to connect physics to real life issues. Though many of your answers may start with a google search, remember to put things in your own words.

Tides and Indigenous Fishing Technologies

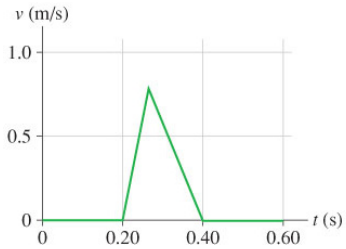
Tidal forces from the moon and sun cause the earth's oceans to increase and decrease in height throughout the day. This change in vertical height causes a change in horizontal speed of ocean water. Each day has two high tides and two low tides, whose timing changes with the phases of the moon. I like to consult a tide chart whenever I go kayaking around Jetty Island in Everett. The tide chart below shows the average ocean water height in Everett on June 24, 2021.



1. What times were the high tides that day? What times were the low tides?
2. Because this is a graph of position versus time we can infer velocity information from it to some extent. Recall that velocity is the derivative of position. When paddling in a channel, like the one between Jetty Island and the Everett Marina, experienced kayakers avoid trying to paddle against strong tidal currents because the horizontal speed of the water flowing in or out with the tide may be faster than a person can paddle. What times of day on June 24, 2021 were the best for paddling?
3. Crabbing on the other hand, is best when the currents are fast. Since crabs are slow underwater walkers, a fast current will help more crabs to walk past your crab pot and possibly be caught. What times of day on June 24, 2021 were the best for crabbing?
4. Let's shift gears to salmon. Read the article "Indigenous Fishing Practices Hold Promise for Future". Or for the TL;DR version, look at the diagram describing several indigenous fishing technologies. If you built a tidal fish trap like the one shown in the diagram in the mud flats of the Snohomish River, when on June 24, 2021 would be a good time to go out and check the trap?
5. Compare indigenous methods for fishing salmon to the most common commercial method (net fishing in the ocean). Why are indigenous methods more sustainable?

Heart Health and Microaggressions

A somewhat idealized graph of the speed of the blood in the ascending aorta during one beat of the heart appears as shown below.



1. Approximately how far, in cm, does the blood move during one beat?
2. Assume similar data for the motion of the blood in your aorta, and make a rough estimate of the distance from your heart to your brain. Estimate how many beats of the heart it takes for blood to travel from your heart to your brain.
3. Many of you will go on to careers in Health and Science that might involve using, designing, testing, or writing software for medical sensors. STEM workers in the Health sector take pride in that their work has a positive impact on the health of millions of people. But as STEM professionals, we should be aware that social issues can undermine our efforts to create a healthier world. Read the article Microaggressions: How and why do they impact health? from Medical News Today. What are some of the health impacts of microaggressions?
4. Why is it hard to stop microaggressions from happening?
5. While some people might tell others to “grow a tougher skin”, the data on microaggressions and health imply that is not a viable solution. It’s also not a humane solution. What can people do to help stop microaggressions from happening?

Tesla Ludicrous Mode and Corporate Surveillance

Tesla cars generally have a smooth, constant acceleration because they are electric and do not have gears. However, a software feature is available for certain high performance Tesla models (Ludicrous Mode) that increases power output and acceleration. If a Tesla Model S P100D in "Ludicrous mode" is pushed to its limit, the first 3.0 s of acceleration can be modeled as

$$a_x = \begin{cases} \left(35\ \mathrm{m/s^3}\right) t & 0\ \mathrm{s} \le t \le 0.40\ \mathrm{s} \\ 14.6\ \mathrm{m/s^2} - \left(1.5\ \mathrm{m/s^3}\right) t & 0.40\ \mathrm{s} \le t \le 3.0\ \mathrm{s} \end{cases}$$

1. How long does it take to accelerate to 60 mph? Your answer, which seems impossibly short, is confirmed by track tests.
2. What acceleration would be needed to achieve the same speed in the same time at constant acceleration? Give your answer as a multiple of *g*.
3. Accelerating quickly in a sports car is really fun. But more recently, there may be a price to pay for accelerating too fast. Read the article from the New York Times *Your Driving, Tracked*. To what extent does your car and your insurance use telematics (automatic tracking through car hardware or a phone app) to track your driving? Don't guess -- go google this or go look at your insurance policy. This is information you will want to know. If you don't drive, answer for someone else in your family or household who does.
4. What are some ways that telematics make insurance pricing more fair for low income drivers? What are some ways telematics make insurance pricing less fair?
5. Do you think this use of personal data tracking is ok? Explain your position.
6. Corporations are often desperate for this kind of personal data on people for a variety of reasons. Thinking beyond just car insurance, what are situations where you think this kind of surveillance is ok? What are situations where it is not ok?

Ballistics and War

1. A bullet is shot horizontally from a rifle at 300 m/s and hits a target 50 meters away. The person shooting is holding the gun 5 feet (1.5 meters) above the ground. How long is the bullet in the air?
2. How far from the ground is the bullet hole in the tree?
3. It's important when we learn about science to think about the places and ways it is used. Physics is strongly connected to the military. In fact, ballistics (ie, projectile motion) is a common Physics topic formally taught to many service men and women. The military trains soldiers on ballistics in case they need that information in an armed conflict. Give an example of a specific war/conflict the US has been involved in (just name of conflict and approximate years for this question). If you don't know much US history you might have to read a little about a war/conflict before you can answer this question.
4. Watch the 5 minute video
   How Do Countries Decide Whether to Go to War? | World101. In your example, was there a balance or imbalance of power between the groups involved in the conflict? What benefit/cause/national interest was the US fighting for? Explain.
5. At any given moment, there are many conflicts happening around the globe. What's an example of a current conflict? Why is the US involved/not involved in that conflict?

Paperfuge and Frugal Science

Watch the video below about the Foldscope and the Paperfuge, inventions of physicist Manu Prakash and colleagues at Stanford.

How to save 51 billion lives for 68 cents with simple Engineering

You can see the size scale of the Paperfuge in the video at 6:32. It's about 4" wide. You can also see at about 7:05 in the video that when a tube of blood is in the Paperfuge, one end is about ¼" from the end and the other is ¼" from the center. If you watch the Paperfuge work at about 7:09 in the video, you can see that it goes from rest to full speed (100,000 rpm) back to rest in about 1 second.

1. What is 100,000 rpm in radians/sec?
2. What is the angular acceleration of the Paperfuge while it is spinning up?
3. During the spin up, how many revolutions does the Paperfuge make?
4. Why is this cheap, disposable device so important for global health?
5. Do some web surfing. Post a link to another article about an invention or technology that has the potential to massively impact global health and give a one sentence description of the invention/technology.

Gender Bias in Automobile Safety

1. Whiplash injuries during an automobile accident are caused by the inertia of the head. If someone is wearing a seatbelt, their body will tend to move with the car seat. However, their head is free to move until the neck restrains it, causing damage to the neck. Brain damage can also occur. The figure below shows two sequences of head and neck motion for a passenger in an auto accident. One corresponds to a head-on collision, the other to a rear-end collision. Which is which? Explain.

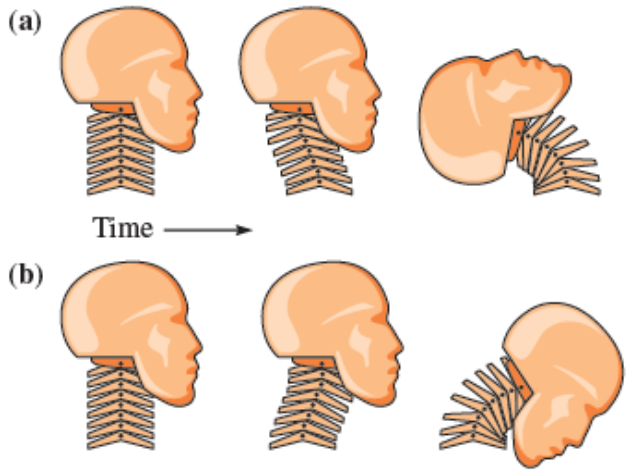


FIGURE P4.1

2. KOMO news did a piece on Vehicle Crash Test Gender Bias. Go to the link and either read the article or watch the piece. How accurately are female bodies represented in current car safety test standards? Explain.
3. Who else is not well represented in these safety studies?
4. The automotive industry is predominantly run by men at every level, including safety testing. Do you think this bias would have happened if the automotive industry were not male-dominated? Explain.

Why the Mask?

Scientists have gone back and forth over what the dominant form of transmission is for COVID-19: water droplets like you would get from a cough, sneeze, or loud talking/singing, or tiny aerosol particles like you would get from normal talking and breathing. It's important because the two main government policies for slowing COVID-19 transmission (social distancing and mask wearing) depend on which is the dominant form.

Very small objects, such as aerosols and tiny water droplets, experience a linear drag force, D = bv, in the direction opposite their motion, where b is a constant. For a sphere of radius R, the drag constant can be shown to be

$b=6\pi\eta R$, where η is the viscosity of the air the particle is traveling through.

1. Derive an expression for the terminal speed vterm of a spherical particle of radius R and mass m falling through a gas of viscosity η.
2. Suppose an eddy has carried a 5-μm-diameter aerosol particle to a height of 2 m. If the aerosol particle only encounters calm air afterwards, how long will it take it to settle to the ground? Assume a mass density of 1000 kg/m^3, the viscosity of 25oC air is 2.0x10-5 N $\cdot$ s/m^2, and you can assume that the falling particle reaches terminal speed almost instantly and then falls at a constant speed.
3. It was earlier thought that coughs and sneezes, which produce larger droplets that fall with negligible drag, were the main culprits for COVID transmission. How long would it take a large droplet to fall 2 meters?
4. Social distancing, as a policy, was based on COVID spread due to large droplets that move through the air like projectiles. If COVID is transmitted more often by tiny aerosol particles, why is social distancing ineffective?
5. Read the article As US COVID-19 death toll reaches 600,000, racial gaps persist. What are some of the reasons listed for the existing racial gaps in COVID deaths?
6. Which policy would reduce those racial gaps: mandatory masking or social distancing? Explain.

Inclined Planes and Wheelchair Ramps

1. In construction, slopes are published in units of percent. A 15% slope means the slope rises 15 feet over the course of 100 horizontal feet. This means that a 45 degree angle would be labeled as a 100% slope. The city of Everett publishes their guidelines for sidewalk wheelchair ramps online via a set of CAD drawings. Have a look specifically at drawings 318-321, and in particular the main ramp dimensions (not the side slopes). What is the maximum allowed slope for a wheelchair sidewalk ramp in percent? What is it in degrees?
2. A person using a wheelchair needs to move up the incline at a constant speed. Draw a free-body diagram for this situation. Rolling friction and drag can be neglected but the incline should not be ignored.
3. What force would it take a 75kg adult using a 10kg wheelchair to move up the ramp? Note: you will need trig for this.
4. Look back at the CAD drawings from the City of Everett. What are some corners in your neighborhood that do not have the proper ADA compliant sidewalk ramps?
5. Folks using wheelchairs clearly need to use these ramps. Who else needs and/or benefits from these sidewalk ramps? When an individual uses the sidewalk to commute, what is the impact when needed sidewalk ramps aren't consistently available along their commute route?

Gun Recoil

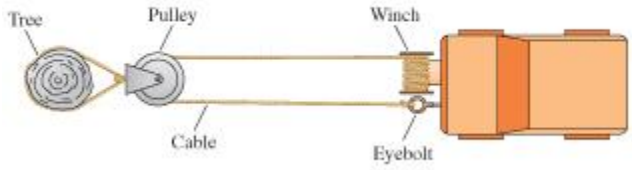
The AR-15 assault rifle is the "most beloved and most vilified rifle" in America. A typical AR-15 semi-automatic rifle has a mass of 6.3 pounds, a 16" long barrel, and a barrel speed of about 2800 ft/s for 4 g bullets. In general, a bullet is a chunk of metal that sits at the end of a cartridge of explosive. When the trigger of the gun is pulled, a metal pin taps a spot on the bottom of the bullet that causes a spark and ignites the explosive. The heat of the gun powder's combustion accelerates the bullet forward in the barrel.

1. What's the average force on the bullet as it is accelerated in the barrel of an AR-15? What average force does the bullet apply to the AR-15?
2. How long does it take the bullet to exit the barrel?
3. If you hold the gun loosely, how fast will the gun recoil? That is, how fast will the gun be moving after the bullet leaves? Convert this value to mph so you have a sense for how fast this is.
4. You should not hold a gun like this loosely when firing it. Instead, you should brace it against your body, typically at the shoulder. If a 75 kg person holds this gun firmly against their shoulder when firing, what will their recoil speed be?
5. Let's talk about gun control. Ok, I know we all have extremely strong feelings about gun control. I would appreciate if you don't go on a crazy rant in either direction. It's only a 5 point assignment and this part is just graded on effort. Instead, I would like to challenge you to see the other side. Even though I have my own opinions on guns I've been fortunate to have thoughtful friends with different opinions who help me understand that these issues are not entirely black and white. There is supportive data on either side of the gun control debate. Please find a bit of data to support the side of the gun control debate that is counter to where you stand. That means if you are pro-gun control you find some data about why it's bad. If you are anti-gun control you find some data about why it would be good. This can involve historical data, data from other countries, and of course data from the US, including homicide and suicide rates and mass shooting stats, or anything else you think might be relevant. Provide the link to where you got that data.

In your responses to other students, please refrain from judging other people on the basis of their stance on this one subject. We don't have to all agree but we should practice listening to each other.

The Hazards of Living in a Rural Forested Area

1. One of the hazards of living in a rural forested area is getting stuck in the mud. Rural roads are often unpaved and are not always set up for good drainage. People who live in rural areas adapt by driving more rugged vehicles and sometimes install winches. Below is a top down view of a Jeep stuck in the mud. The driver has a winch that can pull on its cable with a force of 40,000N. The driver loops the cable through a pulley attached to a tree, as seen below. What is the maximum force that can be exerted on the Jeep by this cable arrangement?



2. If this isn't enough to pull the Jeep out of the mud, what can the driver do to get more force?

3. Another hazard of living in rural forested areas is wildfires. Wildfires are becoming much more common with the rise in global temperatures due to global warming. Read the article Wildfires Impact Minorities. What is the difference between an area with high Wildfire Hazard versus an area with high Wildfire Vulnerability?

4. Use the slider in the map to flip between Wildfire Hazard and Wildfire Vulnerability. Who lives in the places with high Wildfire Hazard but low Wildfire Vulnerability?

5. Who lives in the places with the highest Wildfire Vulnerability? What makes them highly vulnerable? You might find this map of tribal lands in Washington state handy.

6. The article offers suggestions of ways the devastation of wildfires in high vulnerability areas can be mitigated. Given that many of those most impacted are Indigenous peoples who were forcefully relocated by the US government to reservations, what role should the US government play in minimizing and mitigating wildfire risks?

Froude's Number and Trans Athletes

The physics of circular motion sets an upper limit to the speed of human walking: to go faster, your gait changes from a walk to a run. If you take a few steps and watch what's happening, you'll see that your body pivots in circular motion over your forward foot as you bring your rear foot forward for the next step. As you do so, the normal force of the ground on your foot decreases and your body tries to "lift off" from the ground. If you're curious about the technical difference between walking and running, read about Froude number.

1. A person's center of mass is very near the hips, at the top of the legs. Model a person as a particle of mass m at the top of a leg of length L. Find an expression for the person's maximum walking speed v_{max}.
2. Evaluate your expression for the maximum walking speed of a 70 kg person with a typical leg length of 70 cm. Give your answer in m/s.
3. Speed walking is an Olympic Sport. What physical attribute(s) would make someone naturally better at speed walking?
4. Let's switch from speed walking to sports in general. Name a sport and suggest a physical attribute that might make someone naturally better at that sport.
5. Read the article "How high school sports became the latest battleground over transgender rights". Why are some states trying to ban trans women from competing in high school sports?
6. Why might a transgender person prefer to do sports with athletes of the gender with which they identify?
7. Title IX was meant to create gender equality in athletics. What are some of the ways it's failed?

HYDROELECTRICITY AND THE EXTINCTION OF IDAHO SALMON

Hydroelectric dams use water in rivers that naturally changes altitude as it flows to the sea to turn turbines that generate electricity. This process is about 90% efficient at turning potential energy of water into electrical energy. The dams are needed to back up the river so that the drop in potential energy at the turbines is larger. This changes the landscape around the dams by creating a reservoir/lake behind the dam. It creates a bigger altitude drop near the dam that fish need to navigate when traversing upstream to spawn. It also makes the downstream river's flow different because it is regulated by the dam's flow release and not just snow melt.
The four dams on the lower Snake River have the following characteristics:

Dam	Dam Height [m]	Flow rate [ft3/s]
Lower Granite	30	17,000
Little Goose	30	19,000
Lower Monumental	30	20,000
Ice Harbor	30	21,000

1. If 90% of the potential energy of this falling water is turned into electricity, how much energy will these four dams generate in a year? Note, you will need to turn those flow rates into kg/yr.
2. The average Washingtonian uses 273 million BTUs of power in a year. There are 7.615 million people in Washington. How much power do the people of Washington consume?
3. What percent of this is produced by those four dams?
4. Read the article "Inslee, Murray plan new report on breaching Snake River dams. 'We need an answer ...'". What are the benefits of hydroelectric power?
5. What are the negative impacts of hydroelectric power to the local people? To the residents of Washington state? To local species of animals along the river?
6. Do you think it's a good idea to remove these four hydroelectric plants? Explain.

HOW MUCH ENERGY DOES AI USE?

In Physics, all of our energy calculations end up in units of Joules. But in the world of energy utilities the common unit is the kiloWatt-hour. 1 kWh is 1000 J/s * 3600 s, or the number of Joules a kW power supply consumes in 1 hour. For lower amounts of energy consumption, Watt-hours is a common unit. Those are a factor of 1000 less than a kWh.

1. How much energy is a typical full cell phone charge? Report your answer in both kWh and in Joules.
2. What is a typical household's energy use in one year? Report your answer in both kWh and in Joules.
3. Read the 3-page article **How much energy will AI really consume?** Why is it hard to estimate how much energy AI uses?
4. How much energy, in Joules, does it take to train an AI model? How many times the annual energy consumption of a typical American household is that?
5. In places like Virginia, where does the additional energy needed for data centers come from?
6. What is the projected energy consumption for AI in the near future? Do you think AI is important enough to merit this amount of resources? Explain.
7. How will the growth needed to support AI affect communities where Data Centers are located?

Football Tackles, Concussions, and Systemic Racism

1. A 110 kg linebacker running at 2.0 m/s and an 82 kg quarterback running at 3.0 m/s have a head-on collision in midair. The linebacker grabs and holds onto the quarterback. Who ends up moving forward after they hit?
2. How fast are the two going just after they hit?
3. A concussion happens when the brain, which is floating in cerebrospinal fluid, hits the side of its container, the skull. Do football helmets prevent concussions? Explain your reasoning based on Physics we've covered in this class.
4. The average professional NFL player only last about 3.3 years before health reasons cause them to retire. Repeated concussions are a common cause for retirement. Watch the 4-minute long video How use of race-norming resulted in denial of former NFL players' concussion claims. What is "race-based norming"? How was it used in the NFL settlement for former players who suffered concussions?
5. People often think of racism as being cruel and unfair to someone based on their race. While that does still happen, a larger issue is the systemic nature of modern racism: many policies and practices have racist thinking at their foundation. The NFL's use of race-norming was a prime example of systemic racism. What's another example of a policy or practice that has the effect of creating racially biased outcomes? If nothing pops immediately to mind, do a google search and include any good sites/articles you find in your answer.

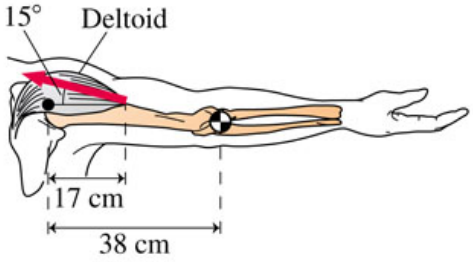
BILLIONAIRES IN SPACE

For the Physics portion of this assignment you will definitely want to refer to section 11.6 in Knight, especially equation 11.44. The problems here are directly from the textbook: Problem 11.74.

1. To understand why rockets often have multiple stages, first consider a single-stage rocket with an empty mass of 200 kg, 800 kg of fuel, and a 2000 m/s exhaust speed. If fired in deep space (where gravity is negligible), what is the rocket's maximum speed?
2. Now divide the rocket into two stages, each with an empty mass of 100 kg, 400 kg of fuel, and a 2000 m/s exhaust speed. The first stage is released after it runs out of fuel. What is the top speed of the second stage? You'll need to consider how the equation for vmax should be altered when a rocket is not starting from rest.
3. How big is the 2022 proposed budget for NASA? (Just Google this one)
4. Read the article "Richest Americans...Paid Federal Income Taxes Equaling Just 3.4% of $401 Billion In New Wealth" and also watch this 1:52 video on "How America's Ultrawealthy Stay That Way". Is the US tax system fair? Explain.
5. Space exploration has shifted from government to private industry in part because of a lack of money to fund such endeavors. How many times over could NASA be funded by the tax gap?
6. Should tax be levied on income, wealth, both, or neither? Explain.

Biomechanics and Prosthetics

If you hold your arm outstretched with palm upward, the force to keep your arm from falling comes from your deltoid muscle. Assume that the arm has mass 4.0 kg and the distances and angles shown. The arm's center of mass is marked in the figure at approximately the elbow.



1. What force must the deltoid muscle provide to keep the arm in this position? By what factor does this force exceed the weight of the arm?
2. What force must the deltoid muscle provide if the person is also holding a 1-liter soda in their hand while their arm is outstretched? The closed hand with soda is about 25 cm further than the elbow.
3. Prosthetics, which people use to replace missing limbs for either aesthetic or functional purposes, can range from very basic to very advanced. A standard prosthetic arm with no functionality will cost you around $5,000. One with a hook would allow you to pick a few things that have just the right shape and will cost you $10,000. A myoelectric arm, which uses contractions in nearby muscles to trigger electronics to open and close an artificial hand, will cost $20,000-$100,000, though there are some researchers trying to get this cost lower. A myoelectric model would allow you to pick up a beverage and eat a meal, though the motion is a full-fisted grasp. A fully robotic arm, which taps directly into nerves, can control each individual finger and offer dexterity, strength, and in some cases sensation almost on par with a biological arm. These are still in development and presently cost upwards of $500,000 because of all the time needed to work with an occupational therapist and software engineer to train neural network software to interpret nerve signals. Read up on what insurance coverage for prosthetics is like in the US. If you are missing an arm, what kind of prosthetic are you likely to have? How often will you need to replace it? How much will you pay out of pocket?
4. Fully functional hands can be the difference between being a permanently disabled person who has limited job options to being a productive tax-paying member of society. Sadly, our policies and practices do not use compassion or altruism to determine who gets what resources. Instead, money is the driving factor. Is a fully functional robotic arm worth the price? Clearly it is to the person receiving the prosthesis. But is it worth the price to society as a whole? Explain your reasoning, including some relevant number estimates.
5. Are there changes to insurance and/or government policies that could help folks with missing limbs live up to their full unencumbered potential? Explain.

Jocelyn Bell Burnell's Nobel Prize

During most of its lifetime, a star maintains an equilibrium size in which the inward force of gravity on each atom is balanced by an outward pressure force due to the heat of the nuclear reactions in the core. But after all the hydrogen "fuel" is consumed by nuclear fusion, the pressure force drops and the star undergoes a gravitational collapse until it becomes a neutron star. In a neutron star, the electrons and protons of the atoms are squeezed together by gravity until they fuse into neutrons. Neutron stars spin very rapidly and emit intense pulses of radio and light waves, one pulse per rotation. These "pulsing stars" are called pulsars and were discovered in 1967 by Jocelyn Bell Burnell.

1. A star like our sun with the mass M=2.0x1030 kg and size R=3.5x108 m rotates once every 31.0 days. After undergoing gravitational collapse, the star forms a pulsar that is observed by astronomers to emit radio pulses every 0.200 s. By treating the neutron star as a solid sphere, deduce its radius.
2. What is the speed of a point on the equator of the neutron star? Your answer will be somewhat too large because a star cannot be accurately modeled as a solid sphere.
3. Read the article "She made the discovery, but a man got the Nobel...". Was it fair that Bell was not recognized as the discoverer of pulsars? What are some of the historical factors that went into this? Should the Nobel committee, who award the Nobel Prizes, do anything to correct for situations like this? Explain.
4. Some say history is written by the winners. This is to say that what is documented and carried forward from the past is dictated by those in power at that time. What are some examples of where history was written in a one-sided way that cast those in power as the "heroes"?
5. What should be done about the bias that exists in what we teach as history? How do we represent the past fairly?

Energy: Green Energy Efficiency

1. For each of the following forms of commercially available energy (coal, nuclear, solar, wind, hydro, geothermal), what is the typical efficiency? When you google this be sure you are finding the efficiency as defined in physics (useful output energy / input energy). The word efficiency is often used in non-physics ways. I had to google each type of energy individually ("how efficient is coal energy?") If you find a range of values, quote the most typical one, not the best one. Also don't confuse geothermal house heaters for geothermal energy plants.
2. Why might people choose an energy source with a low efficiency?
3. Why do you think the US has been slow to switch to greener forms of energy production?
4. What could be done to speed up America's switch to green energy? For this you might want to read a bit about subsidies, tax credits, and rebates, or maybe read up on another country that is doing better with green energy. Think both at the individual level and the county/state/national level.

Simple Harmonic Motion: Earthquake Safety

Watch this short video on why buildings shake apart during earthquakes.
https://youtu.be/H4VQul_SmCg

All things act like springs. When an earthquake jiggles buildings, their subsequent motion is related to their stiffness, k, which is a sort of spring constant, and their mass, m. Buildings have a natural frequency, just like a mass on a spring or a pendulum. When the building is jiggled with a frequency that is close to that natural frequency it can sway far more than the magnitude of the ground's movement.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

1. Why did mid-size buildings collapse in the 1985 Mexico City earthquake while taller buildings remained in tact?
2. What is the natural frequency for a two story building whose mass is about 4000 metric tons and whose stiffness is about 200 kN/mm? You will need to convert units before using the equation given.
3. The Nisqually earthquake of 2001 in Seattle had ground movement of about 1 Hz. How would the building in question 2 have fared in such an earthquake?
4. The ideas mentioned in the video for dampening earthquake vibrations are relatively new innovations. Everett Community College has some buildings built decades ago with approximately the specs given in question 2. Though the state gave the college funding to replace or retrofit one of these buildings for earthquake safety, the college elected to instead build a new building and keep the old one without retrofitting in order to increase the facility space on campus. The college's solution for the earthquake risk was to only use four of the original classrooms for instruction and use the rest of the space for support programs for low-income, first generation, and disabled students and students of color. As students, what are your thoughts on this administrative decision?

Simple Harmonic Motion: Pendulums and Prosthetics

A prosthesis can change the life of someone who is missing a limb. There are all different types, many of which need to be replaced regularly, and only some of which insurance will cover. A good prothesis needs to mimic the original limb as much as possible to avoid straining joints, muscles, and ligaments and provide for more natural movement.

1. You have a single-amputee patient who is being fitted with a prosthetic leg. You have the patient sit on a tall chair and swing their legs below the knee. The prosthetic leg swings more slowly than the other leg. What should you modify about the leg so that they can walk more naturally? As you look at equations from this chapter keep in mind that moment of inertia is not always equal to $I=\frac{1}{3}mL^2$ and the distance from the center of mass to the pivot is not always d=L/2.

2. Athletes who are missing a leg often opt for a prosthetic made of a sort of spring. Instead of being a traditional coil of wire, these are bent rods of carbon fiber that store elastic potential when bent and release that to spring a runner forward, much like a muscle does. If a running prosthetic is made to have about the same spring constant as human leg muscles (about 18000 N/m), how much does the running prosthetic have to bend to achieve the 1000 N typical of a human foot pushing off the ground while running at full speed?

3. For arm prosthetics, the big issue is not strength and speed so much as functionality. A standard prosthetic with no functionality will cost you around $5,000. One with a hook would allow you to pick a few things that have just the right shape and will cost you $10,000. A myoelectric arm, which uses contractions in nearby muscles to trigger electronics to open and close an artificial hand, will cost $20,000-$100,000, though there are some researchers trying to get this cost lower. A myoelectric model would allow you to pick up a beverage and eat a meal, though the motion is a full-fisted grasp. A fully robotic arm, which taps directly into nerves, can control each individual finger and offer dexterity, strength, and in some cases sensation almost on par with a biological arm. These are still in development and presently cost upwards of $500,000 because of all the time needed to work with an occupational therapist and software engineer to train neural network software to interpret nerve signals. Read up on what insurance coverage for prosthetics is like in the US. If you are missing an arm, what kind of prosthetic are

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Hydrostatic Pressure and the Ocean Gate Implosion

OceanGate, a small company in North Everett, provided seats on its Titan submersible to visit the remains of the Titanic on the bottom of the ocean for $250,000 per passenger. In June of 2023, with 4 paying passengers and the captain onboard, who was the CEO of OceanGate, the submersible experienced catastrophic failure at a depth of about 3500 m.

1. What is the pressure at that depth?
2. The submersible had a single window that had a diameter of 38 cm. What was the force on the window at a depth of 3500 m? Which direction was that force pointing?
3. The two founders of OceanGate were not marine engineers but rather aerospace engineers. If this same submersible were put up in space, what would the force on the window be? Which direction would that force point? The pressure inside the sub was maintained at 1 atm.
4. The world was shocked when the Titan imploded. Though the Marine Board of Investigation has not yet released their final report on the Titan, there has been much speculation as to what happened. Read of listen to Wired article The *Titan* Submersible Hearings End With Few Solid Answers. What are some of the possible reasons the Titan experienced catastrophic failure?
5. Many of you are working towards becoming professional engineers. In your opinion, what is an engineer's responsibility in regards to safety?
6. The reason the Titan was not required to conduct thorough and repeated safety testing was because the submersible was classified as an "experimental vessel". Do you believe OceanGate's business of selling rides on the Titan was unethical? Explain.
7. While some would argue that the US imposes too many safety regulations, their intent is to prevent or reduce injury. Engineers interact heavily with this type of legislation. Give an example of a safety regulation related to your intended career and why it was created.

Climate Change and CO_2 Emission

On average, each person in the industrialized world is responsible for the emission of 10,000 kg of carbon dioxide (CO_2) every year. This includes CO_2 that you generate directly, by burning fossil fuels to operate your car or your furnace, as well as CO_2 generated on your behalf by electric generating stations and manufacturing plants. CO_2 is a greenhouse gas that contributes to global warming.

1. If you were to store your yearly CO_2 emissions in a cube at STP, how long would each edge of the cube be?
2. How does this volume compare to the volume of your home?
3. Read through NASA's abridged inventory of the Effects of Climate Change. Have you noticed any of these effects increasing in frequency or severity throughout your life? Which one(s)?
4. Read the EPA's webpage providing data on the Sources of Green House Gases. Based on this data, what changes could the US make to significantly reduce our green house gas emissions?
5. Morality doesn't seem to be working to get people and industries to slow their green house gas emissions. The Inflation Reduction Act (IRA) was intended to address climate change. What's an example of a program under the IRA that aims to reduce greenhouse gas emissions? Describe the program and what Source of Green House Gases (from the link in question 4) it will reduce.
6. Propose another policy change that could push the US to reduce green house gas emissions faster. Policies come in many forms: laws that ban, tax credits that encourage, regulations that limit, etc.

Thermodynamics and Phase Changes: Global Warming and sequestering CO_2

It is no longer debated that the Earth is getting warmer. And what's more, it's becoming clear that it will not be enough for humans to merely stop producing excess CO_2. At some point soon we will need to consider ways to actively remove CO_2 from our atmosphere.

1. Estimate how much energy it would take to remove all the excess CO_2 in Earth's atmosphere by turning it into dry ice and storing it underground. That's a big task so let's take it in steps.
    a. First, you will need an equation. To turn CO_2 into dry ice we will need to first cool it to the point where it turns from gas to solid (deposition point) and then remove energy so it can change phase. For now, let's just figure out how much energy it takes to turn 1 mole of CO_2 at 1.1oC (the global average temperature) into dry ice. Write down an equation for this using stuff from Chapter 12.
    b. Next, we'll need numbers to put in our equation. You might want to check out the wikipedia page on Dry Ice for all the various constants you'll need that are related to CO_2. Assume we change the CO_2 into dry ice at 1 atm of pressure. Take the molar specific heat of CO_2 gas to be 37.35 J/mol*K.
    c. After you figure out how much energy it would take to change 1 mole of CO_2 into dry ice the last step is to multiply that by the total amount of CO_2 we want to sequester. I'll save you the web search and unit conversion and just tell you that since the start of the Industrial Age humans have put 2.3x1016 extra moles of CO_2 into Earth's atmosphere.
2. Clearly we can't use coal, oil, or natural gas powered plants to make the energy we need for this. That just defeats the purpose. Go to https://ourworldindata.org/renewable-energy and look at the "Renewable Energy Generation" chart (either one with that name will work). How much energy did the world make via renewable resources (wind, solar, hydro, and other renewables) in 2019? The website gives this in units of TeraWatt-hours but you should convert that to Joules.
3. If the world could use all renewable energy at the rate it was produced in 2019 to sequester CO_2, how many years would it take all these resources to generate enough power to sequester all the excess CO_2?
4. Is this a reasonable thing to do? Explain your reasoning.
5. What are some other ways to remove CO_2 from the atmosphere? Are there better options to underground storage? This question is a little more open-ended and may involve some web research.

Side note: in reality we wouldn't turn the CO_2 into dry ice to store it. We would probably just store it as pressurized gas which would take about 1/10 the amount of energy you calculated.

Heat transfer: Redlining and Heat Islands

This week's prompt is about how redlining led to increased temperatures in low-income neighborhoods. Start by reading the article "Racist Housing Practices From The 1930s Linked To Hotter Neighborhoods Today" from NPR, and watching the video "Housing Segregation and Redlining in America: A Short History | Code Switch" that is embedded in the article.

1. Why are some parts of cities hotter than others? What form(s) of heat transfer are these reasons connected to?
2. The sun's light has an intensity of 1366 W/m^2 at the equator. What would that intensity be at our latitude? To calculate this, consider that the sun is nearly directly overhead at the equator and the sun's light shines straight down. At higher latitudes, the sun's light strikes at an angle related to our latitude and is spread out and thus less intense.
3. Asphalt has an emissivity of around 0.95. On a hot summer day when the ambient temperature is 80°F, what would be the equilibrium temperature of asphalt? Assume that the only incoming energy sources are the sun's light and the environment, and the asphalt loses energy only by radiation. Note that the temperature you get here will be a bit on the unreasonable side because in reality the asphalt will lose heat into the ground and through convection with the air as well as radiation.
4. Read the NPR article and watch the video on redlining. What policy choices and practices led to the racially-based heat island problem?
5. What about locally? The article, As Rising Heat Bakes U.S. Cities, The Poor Often Feel It Most, also from NPR, has a tool about ⅓ of the way down where you can choose a city near you and see how well temperatures and income correlate. Do you see evidence that the heat island problem is related to low-income neighborhoods? Explain.
6. King County in Washington state is actively working to address the heat island problem. Read the (short) article and rate their plans, which are in the second half of the article.

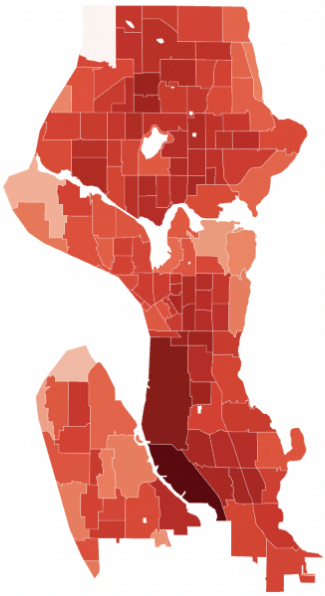
Heat And Income In **Seattle**

Census tracts in **Seattle** displayed a **MODERATE** correlation between heat and income.

Washington

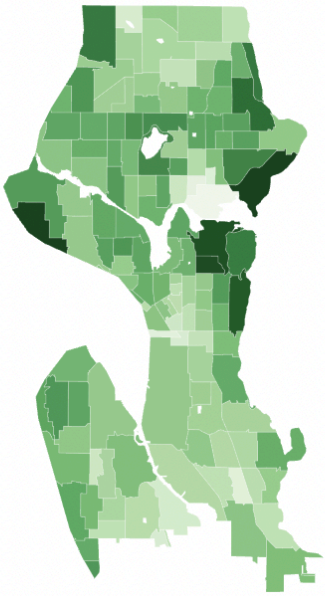
Seattle

SURFACE TEMP.



Cooler — Hotter

INCOME



Minimum $11K — Median $81K — Maximum $168K

Redlining and Heat Islands (v2)

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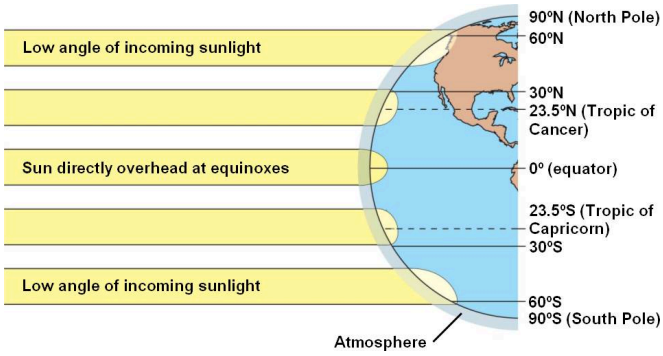
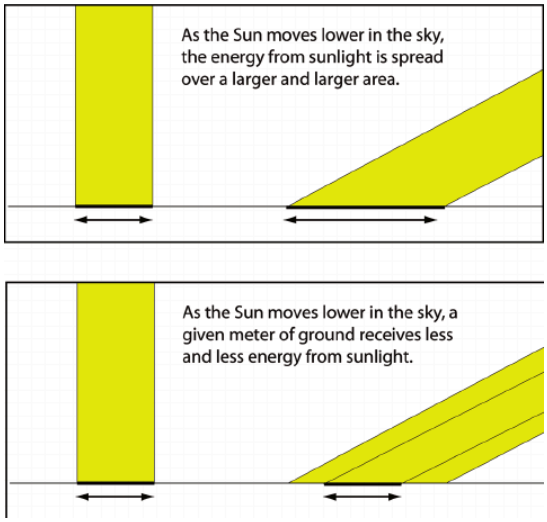




2. Asphalt has an emissivity of around 0.95. On a hot summer day when the ambient temperature is 80oF, what would be the equilibrium temperature of asphalt? Assume that the only incoming energy sources are the sun's light and the environment, and the asphalt loses energy only by radiation. Note that the temperature you get here will be a bit on the unreasonable side because in reality the asphalt will lose heat into the ground and through convection with the air as well as radiation.

3. Watch this PBS video on heat islands. What policy choices and practices led to the racially-based heat island problem? What are some proposed solutions? If you're curious about local history of redlining, here is an interactive map of historical racial restrictions in Snohomish County property sales.

4. King County is actively working to address the heat island problem. This webpage briefly lists their strategy for extreme heat mitigation. Comment on their plans: how well do you think they will combat the racial disparities in who is affected by heat waves?

Energy Efficiency

1. A typical coal-fired power plant burns 350 metric tons of coal every hour to generate 750 MW of electricity. 1 metric ton = 1000 kg. The density of coal is 1500 kg/m3 and its heat of combustion is 28 MJ/kg. Suppose the coal is piled up in a 11m x 11m room. How tall must the pile be to operate the plant for one day?
2. What is the efficiency of this power plant?
3. Go to https://www.eia.gov/state/maps.php. The map starts out looking a little overwhelming but is more manageable when you zoom in. What is the predominant form of energy generation used in our state?
4. Think of a friend or family member who lives in another state. What is the predominant form of energy generation in their state? Is this form of energy generation considered renewable or non-renewable?
5. While some folks still debate about how much of global warming is man-made versus natural, no one contests that the earth is getting warmer and causing a lot of bad changes. Find a state that is predominantly dependent on non-renewable energy. Consider things like geology, weather, etc. and suggest what the best renewable option would probably be for that state.

Efficiency vs Efficacy

This week we'll start by considering the energy yields of various different modes of energy generation and then move on to discuss why efficiency is not always the most important attribute of your energy source.

1. There has long been an interest in using the vast quantities of thermal energy in the oceans to run heat engines. A heat engine needs a temperature difference, a hot side and a cold side. Conveniently, the ocean surface waters are warmer than the deep ocean waters. Suppose you build a floating power plant in the tropics where the surface water temperature is ~35oC. This would be the hot reservoir of the engine. For the cold reservoir, water would be pumped up from the ocean bottom where it is always ~6oC. What is the maximum possible efficiency of such a power plant?
2. For each of the following forms of commercially available energy (coal, nuclear, solar, wind, hydro, geothermal), what is the typical efficiency? When you google this be sure you are finding the efficiency as defined in physics (useful output energy / input energy). The word efficiency is often used in non-physics ways. I had to google each type of energy individually ("how efficient is coal energy?") If you find a range of values, quote the most typical one, not the best one. Also don't confuse geothermal house heaters for geothermal energy plants.
3. Why might people choose an energy source with a low efficiency?
4. Read the article Black Americans Hit Hardest By Deadly Air Pollution. What are some reasons why Black Americans are more impacted by pollution than white Americans?
5. Read online about Environmental Justice. What is environmental justice and why is it an especially important issue in urban areas?

Fluid Dynamics: How Income and Diet Impact Cardiac Health

Arteriosclerotic plaques forming on the inner walls of arteries can decrease the effective cross-sectional area of an artery. Even small changes in the effective area of an artery can lead to very large changes in the blood pressure in the artery and possibly to the collapse of the blood vessel.

Imagine a healthy artery, with blood flow velocity of v_o=0.14 m/s and mass per unit volume of ϱ = 1050 kg/m^3. The kinetic energy per unit volume of blood is given by

$$K_o = ½ \varrho v^2$$

This is one of the terms in Bernoulli's equation. Imagine that plaque has narrowed an artery to one-tenth of its normal cross-sectional area (an 90% blockage).

1. Compared to normal blood flow velocity, v_o, what is the velocity of blood as it passes through this blockage?
2. By what factor does the kinetic energy per unit of blood volume change as the blood passes through this blockage?
3. Using Bernoulli's equation, as the blood passes through this blockage, what happens to the blood pressure?

When this happens, blood vessels can collapse and completely cut blood flow to all down stream organs and tissues. Blockages like this are caused by plaque build up along blood vessel walls. Foods high in saturated fats are a big contributor to this effect. While theoretically a lot of heart disease can be avoided through diet, there are many restricting factors that cause certain populations to be unable to do that. Read the article "Can Low-Income Americans Afford a Healthy Diet?"

4. What are some of the reasons the article gives to explain why low-income families might not eat healthy?
5. What are some policy changes that could happen to improve this situation?

Sound: Noise Pollution and Health

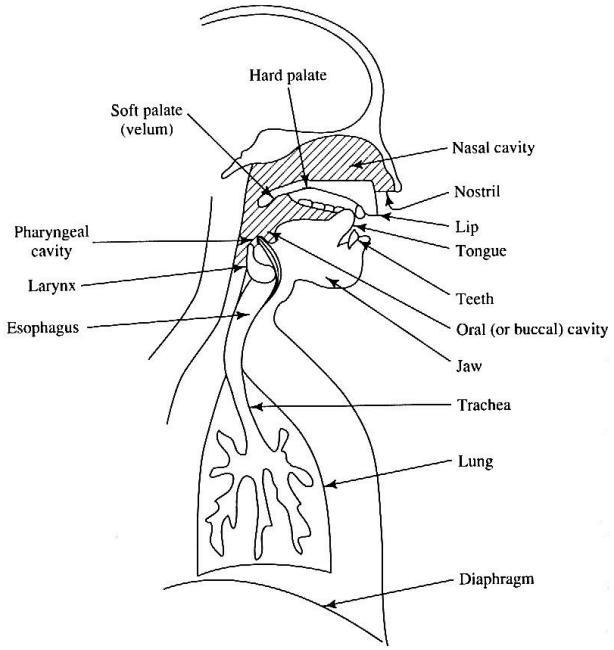
Noise pollution is a legitimate public health concern. Start by watching this 2:15 video and answer the questions below.

Transportation Noise may be Hazardous to Your Health

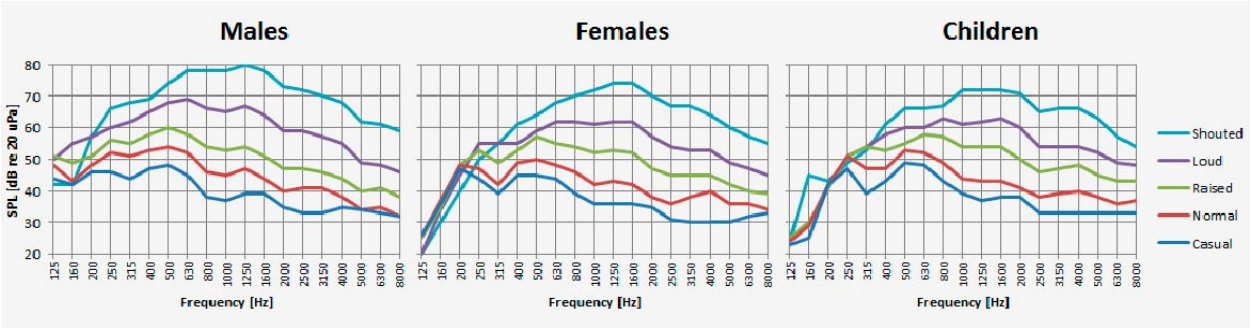
1. Traffic noise can be up to 80 dB at a distance of 15 meters from a noisy interstate like I-5. What power does that correspond to?
2. Go to Google maps and find one of the many apartment complexes located right beside I-5. Which one did you choose? Use the map to estimate the distance from the center of the apartment complex to the center of I-5. Using the power you got from question 1, what's the sound intensity level at one of those apartment complexes?
3. How far away would you have to move in order for the highway to be a much more palatable 40 dB?
4. What are some of the health concerns that arise from noise pollution?
5. Read either How Interstate Highways Gutted Communities (History Channel) or How the Interstate Highway System Connected America (American Society of Civil Engineers). The first article is shorter, but future civil engineers might like the latter article more. What determined where the American interstate highways were built in major cities?
6. Is highway noise an example of environmental racism? That is, are minority communities more impacted by the negative environmental outcomes of having freeways than majority communities? What evidence from the video and article(s) support your opinion?

Waves: Sound Harmonics and Perceived Gender in Voices

The human body's system for producing speech consists of many different cavities whose geometries determine the sounds we make. Some of these can be modified to favor different frequencies (especially the tongue, mouth, and larynx). An image of the parts of the speech system is below.



Speech is strongly tied to biological sex. Below are some frequency spectra for men, women, and children. These graphs are a little different than the ones we saw in class because instead of showing several peaks they have connected those peaks with a line. But they are still conveying the same information about which frequencies are loudest.



1. What differences from the graphs do you notice between male and female voices?
2. How do people's voice frequencies change when they are shouting versus speaking casually?
3. Based on the diagram of the speech system, which parts of the body are used more in male speech? Female speech? How do you know?
4. Gender and biological sex are not the same thing, though society often treats them as the same. A transgender person is someone who identifies with the gender that does not match their biological sex at birth. Being able to pass for the gender you identify with greatly reduces body dysmorphia and is validating for a trans person. It also reduces the

amount of stress one has to endure from society. Speech can be an especially challenging issue. Trans-women will sometimes do voice training to adapt their speech to something that sounds more akin to what we think of as female speech. Part of that training involves shifting frequencies and part involves vocal patterns of speech. If a trans woman wanted to adapt her speech more to match the female gender she identifies with, what parts of her physical speech system would she have to work to train? That is, which resonance chambers would she need to try to shift sounds to?

Note that though this question focused on pitch because it relates to the physics we're covering, the speech patterns have a more pronounced effect on how gender manifests in speech.

5. Many people, most specifically cis-gender people, feel a sense of confusion when they interact with a person whose voice doesn't match their gender expression. This can often manifest in behaviors and responses that are invalidating or demeaning to transgender individuals, making a conversation space an unwelcoming environment. What are some ways we can work to create conversation spaces that are inclusive of all individuals?

Wave Guides and Debunking Conspiracy Theories

Read the excerpt from "Physics and Technology for Future Presidents" by Richard Muller. Though this file is an entire chapter of the book, you're welcome to just read the highlighted sections to cut down on the overall amount of reading.

1. How does the oceanic sound channel work?
2. Why is there also a sound channel in the atmosphere?
3. What was the government using the atmospheric sound channel for?
4. Americans have for decades been obsessed with the conspiracy theory that the government recovered UFOs from a crash in Roswell, New Mexico and has been hiding spacecraft and aliens from this incident at Area 51. This article uses Physics that we have learned and evidence from declassified files to provide a different explanation for Roswell than what you may have heard. Which do you believe to be true and why?
5. There has been a noticeable increase in conspiracy theories in America in the past several years: the flat earth theory, Q-Anon, and conspiracy theories about COVID-19 to name a few. When someone you know believes deeply in one of these theories that you do not agree with, what can be done to persuade them to see reason?

Hair types and hair discrimination

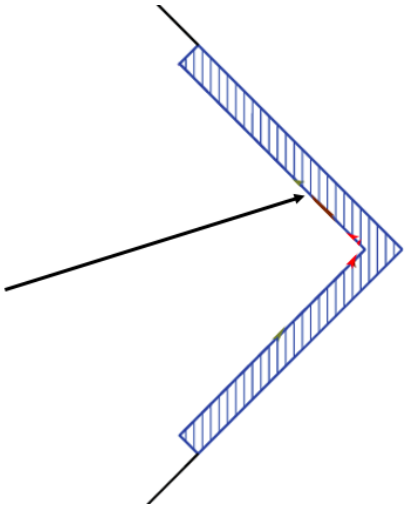
This week's topic: Hair types and hair discrimination

1. Use a laser to measure the width of your hair. There is an example of how to do this in the Week 8 Lecture 2 video. Show your work and all measured quantities. If you need a laser, borrow one from a friend with a cat or from the school.
2. After you've measured your hair's width, try rotating the hair to see if the diffraction pattern changes. That is, is your hair circular in cross section or oval? If you can, measure the thinnest and thickest widths of your hair.
3. Read this short article with helpful diagrams. How do you expect your hair might be different than other people in the class?
4. Read this article from USA Today on Race-based Hair Discrimination. Have people ever given you a hard time for the way you wear your hair? Have you ever seen others treated differently because of the way they wear their hair? Explain.
5. Is hair-based discrimination racist? Explain.
6. What is an example of a reasonable hair policy for an employer or institution to have? What is an example of a potentially biased hair policy?

Optics/Ray Tracing: Retroreflectors and Bicycle Safety

Have you ever noticed that at night some things are far more reflective than others? You can have two surfaces that are both white, like in the the inset image below, that are very different brightnesses at night. Why is this?

This is because one surface is using retroreflectors and the other is reflecting the light in random directions. For the purposes of this question, think of retroreflectors as reflective surfaces at right angles to each other, ie--a pair of mirrors that form a 90o angle together. In reality, reflective paints use spherical glass beads to create retroreflection, but we don't cover that topic until next week.



1. Redraw the image above on paper and sketch light hitting and bouncing out of a retroreflector so it's clear which way the light will end up going. Separately, sketch light hitting and bouncing off a normal white painted surface. You might want to refer to Figure 18.11 in the textbook for reference. Upload your images into your discussion board post.
2. Why does the retroreflector look brighter at night than the white surface?
3. Bicyclists are urged to wear reflective clothing and to put reflectors and lights on their bikes so they are more visible to motorists. Do a quick google search. How does the fatality rate for bicyclists hit by cars vary in the night versus daytime?
4. Safety organizations have lobbied for laws requiring not only that bike helmets be worn, but that they have reflective paint or tape on them. While this seems like a very obvious solution to a problem, it's not a law in Everett or in many other places. What do you think are the barriers to safety standards like this?

Optics: Lenses and Access to Glasses

This week's problem focuses on eye glasses. Consider Professor Sybil Trelawney, seen in the image below. Her glasses are lenses. At the distance of the camera, we observe an image of her eyes.

1. Are the glasses she's wearing converging or diverging lenses? Is this a real or virtual image?
2. Is the magnification of these glasses positive or negative? Explain how you know.
3. Her eyes are about 1 cm away from the lenses. They appear to be twice as big as normal eyes. What is the focal length of these lenses?

Access to glasses is a huge problem in some parts of the world. Next week we'll talk at length about glasses and prescriptions. But for now, read the short article on "Providing Spectacles in Developing Countries

4. What are some of the barriers to getting glasses in Benin?
5. What are some ways these barriers can be improved, either within Benin or through global cooperation?
6. What would the benefits to society be if the access to eye glasses in third world countries was improved?

Optics: Microscopes and Frugal Science

Watch the video below about the Foldscope, an invention of physicist Manu Prakash and colleagues at Stanford.

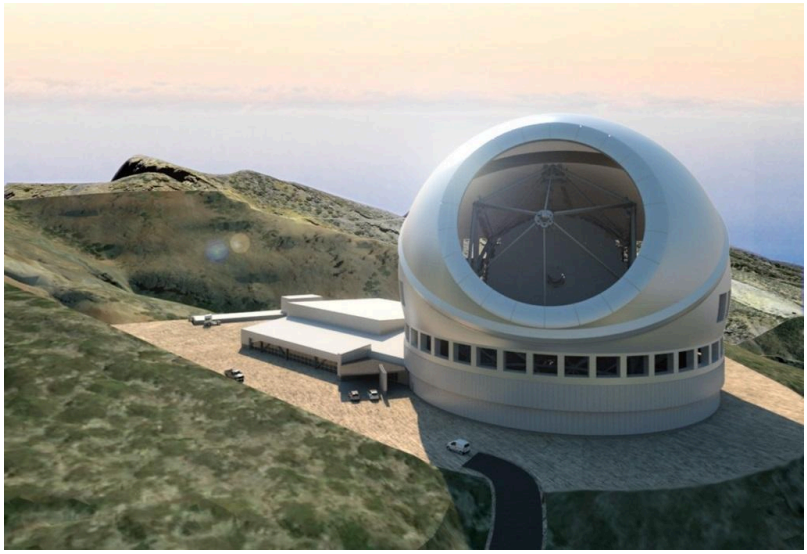
How to save 51 billion lives for 68 cents with simple Engineering

The Wikipedia article on the Foldscope shows a schematic of the actual device. Here's a link to the image.

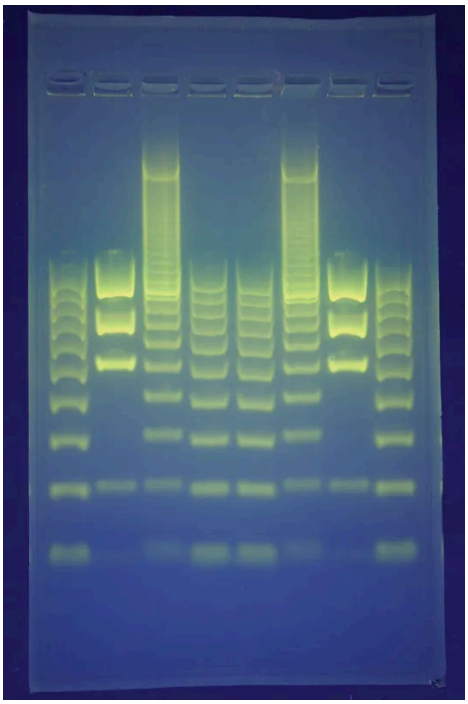
1. From what you see in the schematic, how many lenses does the Foldscope use?
2. Based on your answer to the previous question, what type of instrument does this most resemble: a microscope, a telescope, or a magnifying glass?
3. The Foldscope was designed so that you can project the magnified image on a screen. Based on this, is the specimen slide inside or outside the lens' focal point?
4. Why is this cheap, disposable device so important for global health?
5. Do some web surfing. Post a link to another article about an invention or technology that has the potential to massively impact global health and give a one sentence description of the invention/technology.

Telescopes, Sacred Places, and Indigenous Ways of Knowing

1. The Hubble Space Telescope has a mirror diameter of 2.4 m. Suppose the Hubble is used to photograph stars near the center of our galaxy, 30,000 light years away, using red light with a wavelength of 650 nm. What's the distance (in km) between two stars that are marginally resolved? The resolution of a reflecting telescope is calculated exactly the same as for a refracting telescope.
2. For comparison, what is this distance as a multiple of the distance of Jupiter from the sun?
3. The Hubble Space Telescope is actually not considered a large telescope by professional standards. Its size was chosen because that was the largest telescope we could fit in the space shuttle's payload bay. Since Hubble, professional astronomers have built ground-based telescopes that far surpass the abilities of Hubble using a technique called Adaptive Optics that cancels the turbulence of the atmosphere. We can now make optical telescopes that can see fainter objects and resolve much smaller details than Hubble. The problem is that we need to put them somewhere extremely dark with mostly cloudless weather. There are few places in the world that are ideal for a very large telescope. Read the article The Fight Over the Thirty Meter Telescope Reveals Science's Shortcomings. Be sure to click the down arrow and read the "Go deeper" part of the article. What are the issues with the construction of the Thirty Meter Telescope (TMT)? What are the main points of each opposing side?
4. Read the article Native Hawaiian Culture is Science. Though the article is about the Hokulea, a traditional Polynesian boat built in the 1970's to recreate traditional ways of navigating, the author talks at length about Hawaiian culture and learning. How does traditional Hawaiian learning differ from the more western approach we're familiar with? What are some of the benefits to indigenous Hawaiians' approach to learning?
5. Why do many indigenous Hawaiians oppose the construction of the TMT? What are western scientists and the NSF doing wrong from their perspective? What do you think should be done about the TMT?



Electric Fields: Electrophoresis and HeLa cells



Electrophoresis is a laboratory technique used to separate DNA fragments based on their size and charge. To do it, DNA is broken into fragments using enzymes. The fragments are different sizes and form ions in solution with typical charges between -100e and +100e. Each DNA molecule forms its own unique set of fragments. Separating the fragments by mass allows a fingerprint of the DNA to be taken. An electric field is applied to the gel, pushing the fragments.The fragments to quickly settle into different constant velocities due to a drag force from the gel:

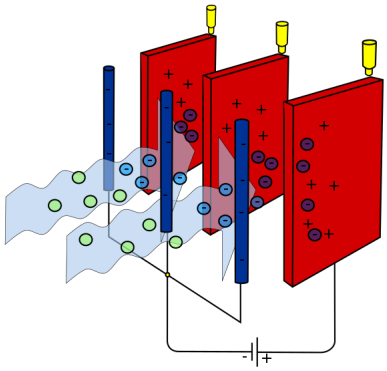
$$D = -C\ r\ v$$

where D is the drag force, C is a constant that characterizes the gel, r is the fragment radius, and v is the fragment's velocity through the gel.

1. Consider two fragments of DNA that have radius r1=30nm and r2=35nm when they are coiled up as they move through a gel with C = 5.0×10^{-5} kg/m*s. Assume each fragment has a charge of -10e. If the field has a magnitude of 1.0 N/C, what is the speed of each fragment in the gel?
2. How long will it take the smaller fragment to move a distance of 1 cm (a typical distance in DNA fingerprinting)?
3. After the time in the previous question, what is the separation of the two different-size fragments in the electrophoresis gel?
4. Read this article in Nature about the questionable origins of HeLa cells, the most important cell line in medical research. What is the controversy surrounding HeLa cells? https://www.nature.com/articles/d41586-020-02494-z
5. Go online and look up the price for a starting sample of HeLa cells and whether that vendor donates money to the Lacks Foundation. You can sometimes figure that out by searching for the phrase "Lacks Foundation" on their website. How much does it cost to buy HeLa cells? Does the vendor you found donate money to the Lacks Foundation?
6. What do you think would be a fair and just resolution for Lacks' descendents?

Electrostatics: Soot Removal and Environmental Racism

This week's Discussion Board Problem is about clean air. An electrostatic precipitator uses electric fields to remove fine particles like dust and soot from a flowing gas. Smoke and soot consists of tiny particles that are given a small negative charge (around -10 nC) by some electrodes as it rises up the smoke stack of a factory. Further up, some positive metal plates collect up the particles. These devices can be up to 99% effective at removing particulate matter from the exhaust of factories. A schematic that shows how this work is shown below along with an image of a disassembled electrostatic precipitator. The precipitator is laying on its side and is usually oriented with the honeycomb tubes vertical.

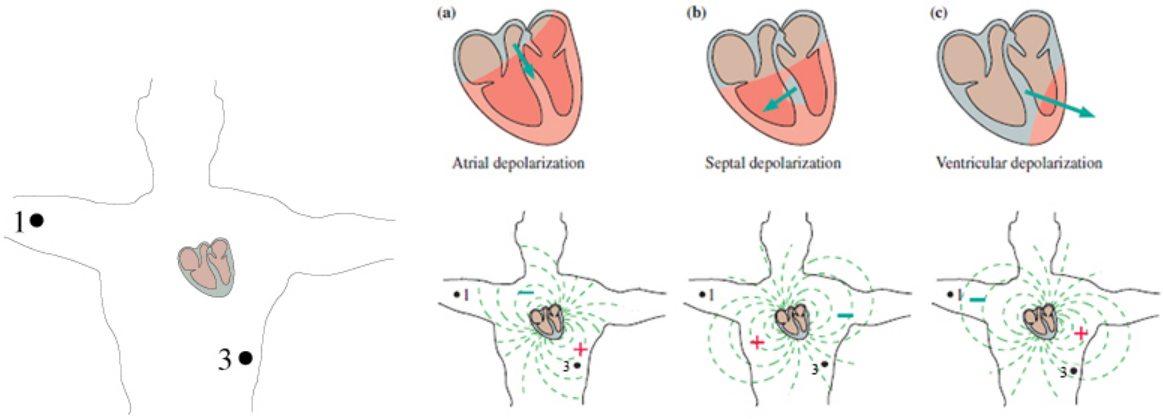


1. The precipitator you see in the image above is about 3 meters long. Each tube/honeycomb is 25 cm wide. If soot is rising at about 10 m/s, how long does it take the soot to get all the way through the precipitator tube?
2. A typical soot particle has a density of 1800 kg/m^3 and a typical size of 18 nm in diameter. What is the mass of a typical soot particle in kg?
3. The precipitator uses a constant electric field to pull soot to the sides and stick it to the walls, instead of letting it out into the air you breathe. For soot particles charged to -10nC, what electric field is needed to pull the particles to the sides of the precipitator from the middle (a distance of 12.5 cm) during the time it's rising up through the tube? (You should get a tiny answer for this. In reality, the electric field has to be much higher to hold the soot in place while hot air continues blowing through.)
4. Look up the Clean Air Act. This is legislation from the 1970's. What are some of the positive changes that have happened in the last 50 years as a result of this legislation?
5. While the Clean Air Act has had many successes, not all places have seen the full positive effects. Read this article from The Atlantic about Environmental Racism. What evidence given in the article supports the claim that there is a racial effect to air pollution? What can be done to stop this?

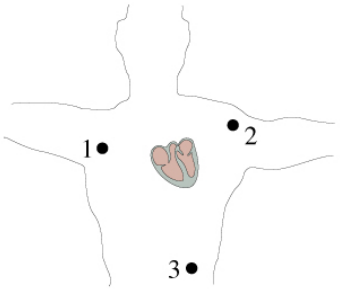
Electric Potential Difference: EKGs and Gender Bias in Heart Disease Diagnosis

This week's Discussion Board Problem is about heart disease.

1. One standard location for a pair of electrodes during an EKG is shown below. The potential difference $\Delta V31 = V3 - V1$ is recorded. For each of the three instants a, b, and c during the heart's cycle shown in the figure below, will $\Delta V31$ be positive or negative? Explain.



2. Three electrodes, 1 - 3, are attached to a patient as shown below. During ventricular depolarization (see the figure above right), across which pair of electrodes is the magnitude of the potential difference likely to be the smallest? Explain.



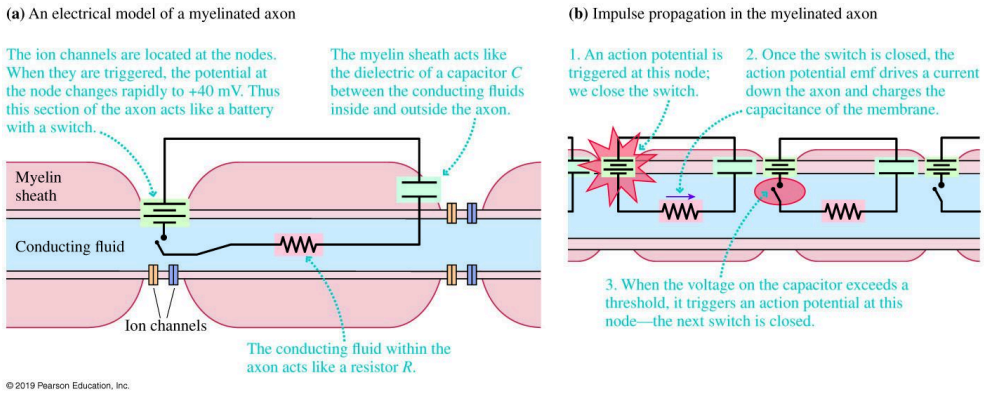
3. Heart disease is the number one killer of women in America. But the outcomes for men and women with heart disease are very different. Read the article Why Doctors Still Misunderstand Heart Disease in Women. What are some of the reasons women have worse outcomes for heart disease than men?
4. What are ways the medical profession can address these issues? That is, what actions, policies or practices can be put in place to create more equitable outcomes for women with heart disease?
5. Do a bit more reading on gender bias in medicine. Share an interesting article you find and give a 1-2 sentence summary of the article. It's really fascinating to read about the history of medical science as it pertains to gender.

Basic Circuits: Electric Cars and the complexities of battery production

1. The 400 V battery of a Tesla Model S electric car stores 3.0×10^8 J of energy. At 65 mph, the car can drive 250 miles before the battery is depleted. What is the power supplied by the battery while driving?
2. At this speed, what is the current delivered by the battery?
3. What is the effective resistance of the entire electrical motor system?
4. Hybrid and electric cars (as well as many electronic devices we all know and love, such as phones and laptops) rely on lithium-ion rechargeable batteries. As production of electric cars ramps up, more lithium is needed to make rechargeable batteries. Read the article about Lithium Mining. After reading the article, what are some of the environmental and societal pro's and con's to electric cars?
5. After having read the article, what are your thoughts on whether or not electric cars are good for the planet?

RC Circuits, Multiple Sclerosis, and Invisible Illnesses

1. A myelinated nerve fiber has a conduction speed of 40 m/s. If the spacing between nodes is 1.0 mm and the resistance of segments between nodes is 25 MΩ, what is the capacitance of each segment? To a good approximation, the time it takes from one node trigger to the next is equal to τ.
2. What is the signal speed if the thickness of the myelin sheath is halved but no other changes are made to the axon?
3. Read about Multiple Sclerosis on the Mayo Clinic website. Briefly describe what MS is in terms of the circuits topics of this chapter and what those electrical changes look like in terms of symptoms. The Mayo clinic article describes this well further down the page.
4. Read about Invisible Illnesses. An article I found on the top of my google search was https://www.nwpc.com/supporting-people-with-invisible-illness/. A list of examples is given for invisible illnesses. We all know people suffering some of these illnesses. Think of someone you know who suffers from an invisible illness. You don't need to name the person; I just want you to be able to draw from experiences you've had or interacting with someone with an invisible illness. What is the illness and what are some of the challenges the person faces navigating day-to-day life with their illness?
5. What are some things schools/businesses/society do that improve access for someone with this illness?
6. What are some things schools/businesses/society don't yet do that would improve access for someone with this illness?



Solenoids and MRIs

Magnetic Resonance Imaging often uses a giant solenoid to generate huge uniform magnetic fields. The solenoid in a typical MRI creates a magnetic field strength of 1.5 Tesla.

1. If the solenoid is 1.7m long and 60cm in diameter with a single layer of tightly wound 1.0mm-diameter superconducting wire, what current is needed? (Note: you can find N knowing the width the wire and the length of the tube with the wrapped wires.)
2. MRIs need to use superconducting wire (R = 0 Ω). Why? What power would be radiated by the MRI machine if it had even 1 Ω of resistance?
3. What are some health issues that an MRI is used to diagnose? You might want to google this one.
4. Choose a small rural town in your state. What's the name of the town? What's its population? Where is the nearest MRI for someone who lives in this town?
5. Look at your insurance plan. How much would it cost for you to get an MRI?
6. What are some things happening in industry to make MRIs both more affordable and more accessible?

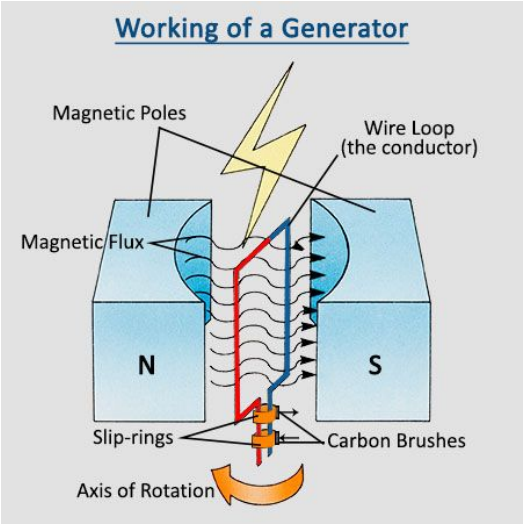
Image courtesy of pixabay.com

Magnetic Fields: Save the Bees

1. There has been concern in recent years over possible effects from the magnetic fields generated by transmission lines on honey bees. A typical high-voltage transmission line is 20 m off the ground and carries a current of 200 A. Estimate the field strength on the ground underneath such a line.
2. How does this number compare with the strength of the Earth's magnetic field?
3. Read the article from Science News about how honeybees may be affected by power lines. Look up what foods we eat that rely on pollination by bees. Is it worthwhile to invest effort into maintaining bee populations?
4. What could farmers who bring in bees during pollination season do to help keep bee colonies healthier?

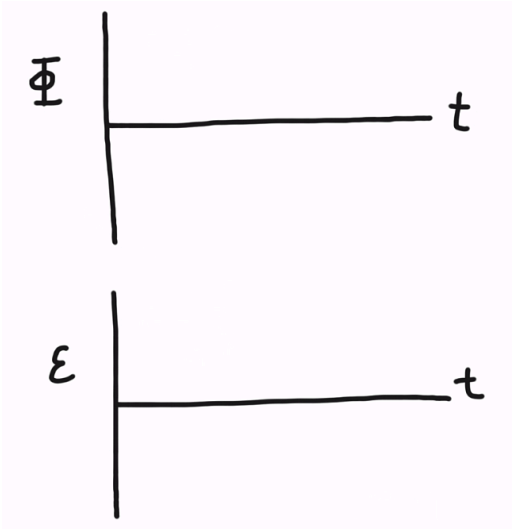
Lenz's Law: Generators and Environmental Racism

Some generator designs will have magnets moving past a coil of wire, some will have a coil of wire spinning between magnets. But generators are all fundamentally the same in that they use Lenz's law to turn motion into potential.



1. We will use the image above as the starting point for this question. Sketch the graphs below and add in what the flux and emf (voltage) will do as the coil spins through one rotation. Define t =0 and positive flux to be the situation in the instant shown above. Define positive emf as the situation that would have current flowing up the red side of the wire.

(Hint: for me, it helped to think about whether the flux was increasing or decreasing and then using the right hand rule to determine the current that will flow as a result.)



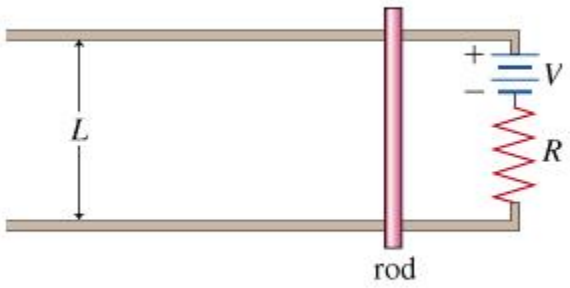
2. Does a generator create an alternating current or a direct (constant) current? Explain.
3. If you took Phys& 242 with me, we read about Red Lining. But in case you didn't or you need a refresher, go read up on it. What is **red lining** in terms of housing?

4. Read the article **Historical red-lining is associated with fossil fuel power plant siting and present-day inequalities in air pollutant emissions**. The entire article is worth reading but if you're pinched for time the abstract and graphics will suffice, as with any well-written paper. Which came first: BIPOC folks moving to certain areas or fossil fuel plants being constructed in those areas?
5. Most power plants are owned by private corporations. A smaller proportion are publicly owned. All power plants must secure extensive government approval for site selection of power plants. Did the US government exhibit racial bias when choosing and/or approving sites for fossil fuel power plants? What evidence did you see in the article for this?
6. As many of us know, people often cannot just choose to live somewhere farther from a power plant. There are real health impacts to siting fossil fuel power plants upwind of BIPOC neighborhoods. Should reparations be made for these impacts? If so, what should those look like and should they come from the corporations or the government? What other changes should be made to reduce inequitable environmental impacts?

Rail guns and the military industrial complex

I'd just like to note beforehand, that the last couple discussion questions are in no way a criticism of the people who serve in the military. But we should always be critical of people in power and the decisions they make, especially when it comes to human lives.

Rail guns use magnetic force to accelerate projectiles to extremely high speeds. While they're a novelty in a physics lab, the US military has been actively researching the use of rail guns as weapons because they can accelerate projectiles well beyond Mach 8 and use no chemical propellant. The destruction is caused only by the kinetic energy of the projectile.



1. A conducting rod is free to slide on two parallel rails with negligible friction. At the right end of the rails, a voltage source of strength V, in series with a resistor of resistance R, makes a closed circuit together with the rails and the rod. The rails and the rod are taken to be perfect conductors. The rails extend to infinity on the left. The arrangement is shown in the figure. There is a uniform magnetic field of magnitude B pervading all space, perpendicular to the plane of rod and rails. The rod is released from rest, and it accelerates to the left. In what direction does the magnetic field point?
2. What is the acceleration of the rod, a, in terms of the rod's mass (m), the power source voltage (V), the magnetic field strength (B), the velocity of the rod (v), the length of the rod (L), and resistance of the circuit (R)? Assume the rails have negligible friction and that drag can be ignored.
3. The projectile will not accelerate forever because of Lenz's law. Set acceleration from your previous equation equal to zero and derive an equation for the terminal speed of the projectile.
4. When designing a rail gun, do you want a long or short projectile? Large or small magnetic field? High or low voltage source?
5. The US has spent half a billion dollars on rail gun research. The US spends a lot of money on defense. Watch this 1 minute long video on the Military Industrial Complex and read this page of data graphics on military spending. Dwight Eisenhower, a Republican whose presidency happened near the start of the cold war, strongly

cautioned America about the dangers of a Military-Industrial complex. What is the Military-Industrial complex?

6. Does America spend too much on defense? Explain. This is a complex question. Consider things like jobs and opportunity the military creates (educational benefits, home and small business loans, job training), active global threats, risks to soldiers' lives, risks that might be mitigated by the military, and the amount and way money is spent on defense.