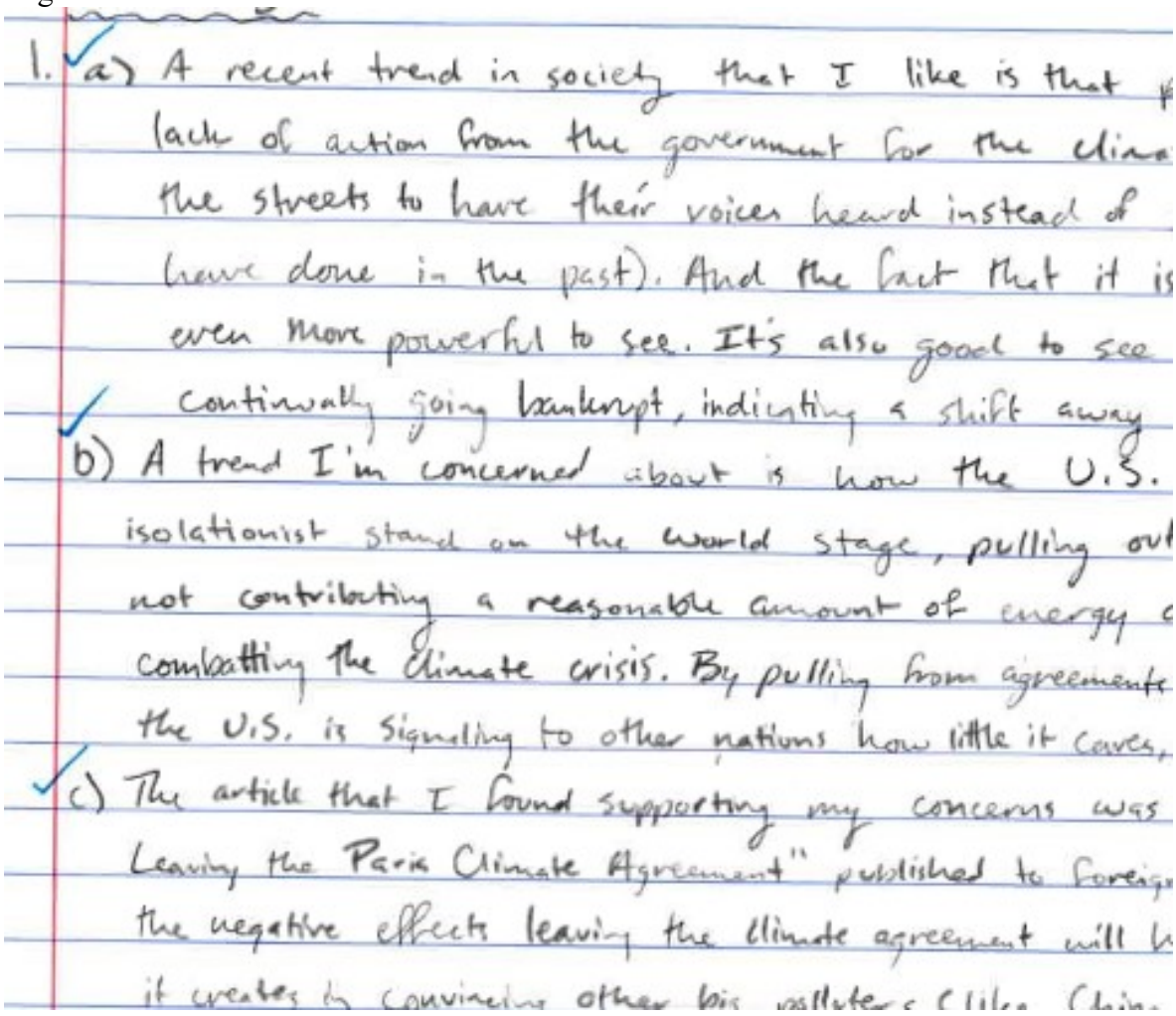
PHYS-320 Efficiency and Electricity
Schwartz Problem Set #3

1) Society, and Environment... What's going to happen?
   a) Identify something you like about a recent new trend in society and energy technologies.
   b) Identify something you are concerned about a recent new trend in society and energy technologies.
   c) Find an article supporting your position.
   d) Check the validity of your references and the bias that they may have. Did you reference a news agency? What is the priority of the news organization you referenced? Can you also find articles that do not agree with your statements above? Please see diagram on media bias: https://www.adfontesmedia.com/. However, we might wonder if ad fontes media is unbiased?

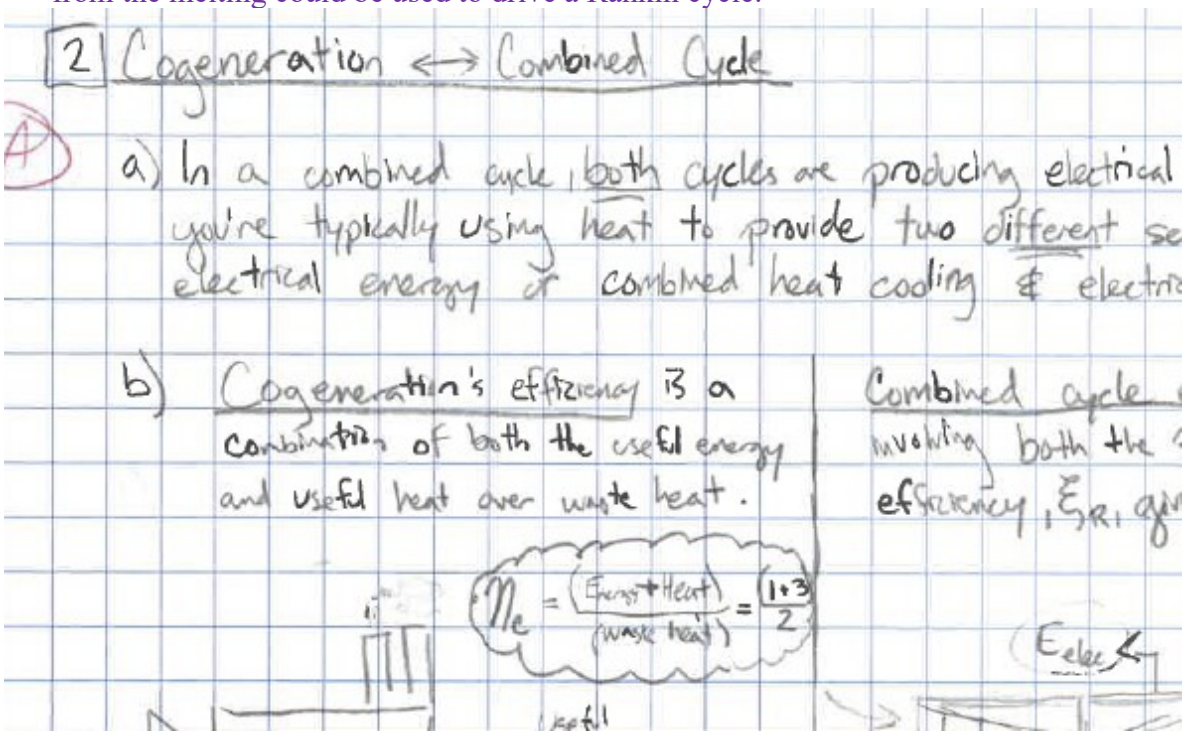

1. a) A recent trend in society that I like is that
lack of action from the government for the clima
the streets to have their voices heard instead of
(have done in the past). And the fact that it is
even more powerful to see. It's also good to see
continually going bankrupt, indicating a shift away
b) A trend I'm concerned about is how the U.S.
isolationist stand on the world stage, pulling out
not contributing a reasonable amount of energy c
combatting the climate crisis. By pulling from agreements
the U.S. is signaling to other nations how little it cares,
c) The article that I found supporting my concerns was
Leaving the Paris Climate Agreement" published to Foreign
the negative effects leaving the climate agreement will h
it creates by convincing other big polluters (like China

2) Cogeneration <–> Combined Cycle

a) What is the difference between Cogeneration and Combined Cycle?

b) Please state how each process increases efficiency.

Both Cogeneration and Combined Cycle involve two processes, fueled by a single combustion *in series*, that is the thermal energy of the second process uses the waste heat of the first process. In combined cycle, both processes generate electricity. In cogeneration only one process generates electricity, and the other process does something else. Usually, electricity is generated in the first process: One cogeneration example is that you could generate electricity with a Rankine cycle and use the waste heat to heat a greenhouse. However, an exception is if your industrial process needs really HOT heat, like melting steel. In this case, the waste heat from the melting could be used to drive a Rankin cycle.



3) Coal Power Production

Coal and natural gas are the two predominant forms of fossil fuels used for generating electricity in the world. Compared to the NGCC, coal is a worse polluter on two levels – criteria pollutants (like toxins), and in terms of greenhouse gas ($CO_2$) production.

a) Name a few criteria pollutants that you are most concerned about
Mercury is a big one. There is mercury in the ocean only because we burn coal to generate electricity. There is enough mercury in the ocean to make some fish at the top of the food chain (like tuna) toxic... especially for pregnant women. We've found that the toxicity of the Atlantic fish have decreased since we've stopped using so much coal in USA and Europe. Likely when China stops using so much coal, Pacific fish will also have less mercury. Additionally, sulfur results in $SO_2$ and $SO_3$, which result in very acid rain.

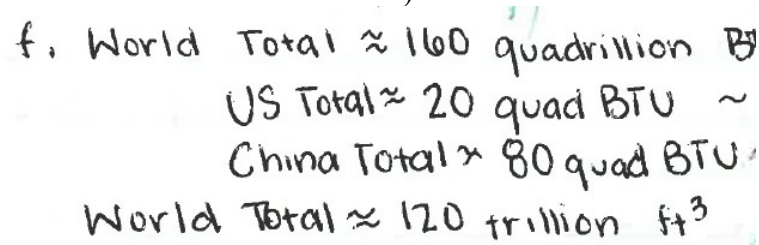
b) What does NGCC stand for?

c) Why does burning coal emit more toxins into the atmosphere and what are some of these toxins? Coal is a solid, so the impurities that are trapped in coal stay trapped in it, where natural gas and (to a lesser extent) petroleum percolate through layers of earth and are thereby purified.

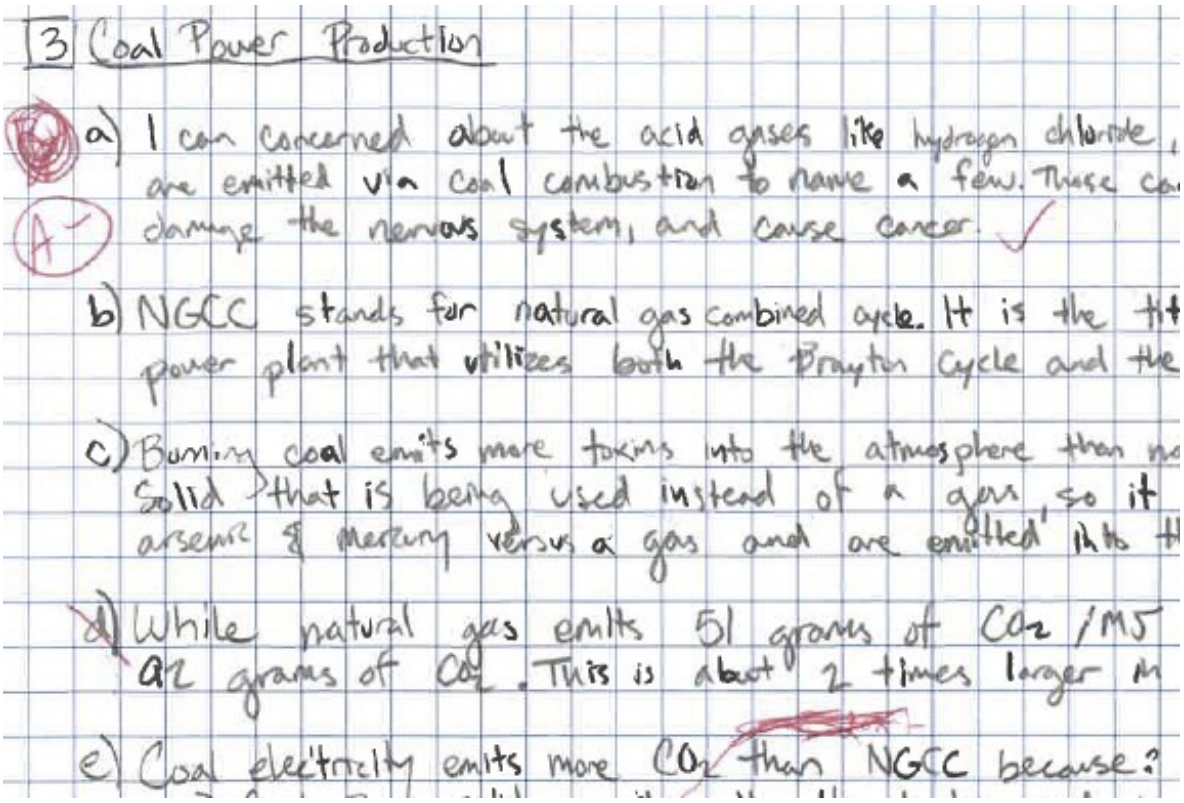
d) For the same amount of electricity, coal emits more $CO_2$ than the most efficient Natural Gas electricity generation – about how much more? About 3 times as much

e) Why is it that Coal Electricity emits more $CO_2$ than natural gas electricity generation? Please give two reasons. Coal has a higher thermal carbon intensity than NG – it produces more $CO_2$ than NG for the same amount of thermal output: 25 g(C) vs 15 g(C), or a ratio of about 5:3. Additionally, because NG can be put in a combined cycle, it can achieve close to twice the amount of electricity for the same amount of thermal input than the single cycle Rankine Cycle that coal uses. When you put the two together, coal facilities emit about three times as much $CO_2$ for the same amount of produced electricity.

f) What portion of the world's coal does the US consume? China? What portion of the world's NG does the US consume? China? You could start with the US EIA (Energy Information Administration):




Actually, the above is a little dated. According to the EIA website, US coal production has decreased steadily since 2006. China and India have grown. At present, USA is likely less than 10% of global use, and is less than India. China has ~50% global consumption.

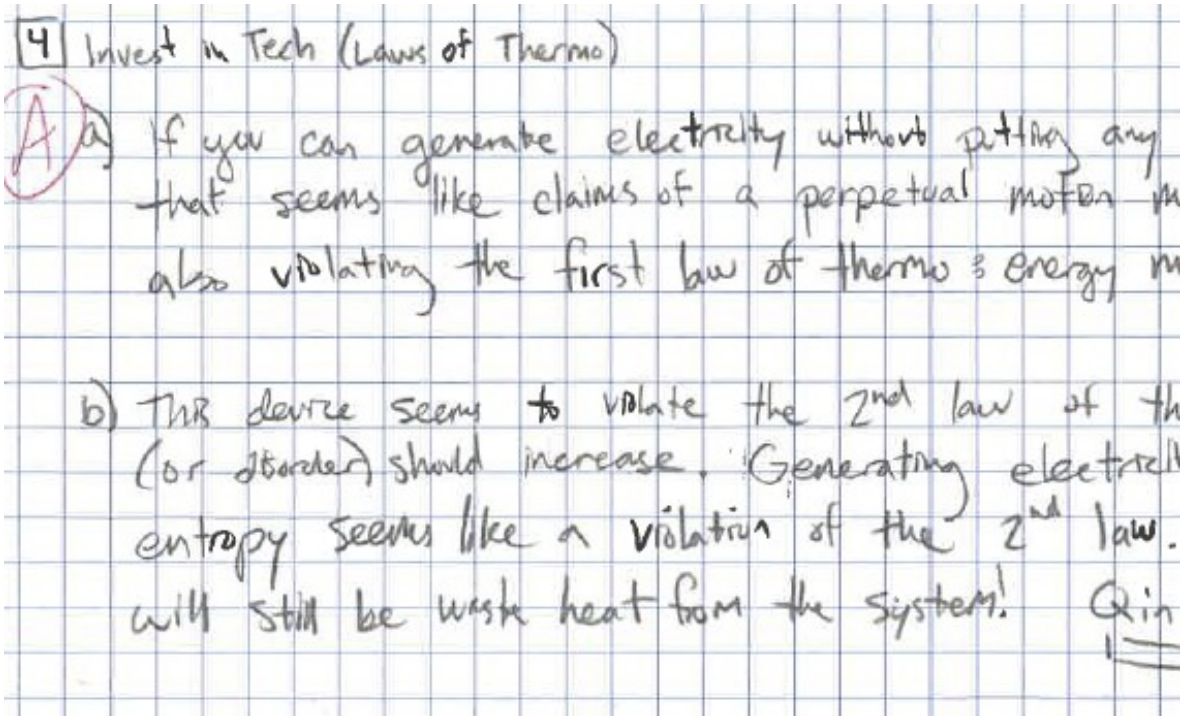



*4)* You meet three people, and each try to convince you to invest in their technologies. Please indicate how you would respond.

a) This person wants you to invest in a new invention that will power a car. It has many spinning magnets in it that generate electricity, which drives an electric motor. The beauty of this is that the device requires no fuels or external power supply. This is a perpetual motion machine of the 1st kind because it violates the 1st law of thermodynamics: conservation of energy. This means that all the heat and work that you get out of a machine must be equal to all the heat and energy flowing into the machine.

b) This person says that you can turn the thermal energy in your house directly into electricity. The result is that your house gets cooler as you generate electricity from the lost heat in your room. This will be particularly desirable in super-hot places such as Phoenix, Texas and LA in the summer. This is a perpetual motion machine of the 2nd kind because it violates the 2nd law of thermodynamics: entropy must increase, or for our purposes, it means that heat must flow from hot to cold. So this would work only if it was cold outside and heat flowing from your home could drive a heat engine and deposit some heat outside. However, on hot days it won't work. You could *make* heat flow from your warm house into the hot hot outside of Texas, but it would require you to put work (electricity) *into* the machine… it's called an air conditioner – we learn more about them later.

c) This person has designed a near frictionless motor that can turn fuel into electricity with almost 100% efficiency because there is no friction. As stated above, you must have heat flowing from hot *to* cold. The maximum efficiency you could hope for is the theoretical Carnot Efficiency: $(T_H - T_C)/T_H$. Where temperature is measured in absolute values (such as Kelvin). Frictional losses would *further* reduce your efficiency.




*5)* Remember we left all the balances on over the weekend (24 W, 72 hrs)? This choice resulted in the emission of how much mass of $CO_2$ into the atmosphere...:

This amounts to about 1.7 kWhr. We can calculate the carbon intensity of these two technologies, or we can just remember that coal usually produces about 1 kg $CO_2$ / kWhr, and that NGCC emits about 1/3 as much.

a) if the electricity was generated with a new NGCC power plant. ~ 0.6 kg
b) the electricity was generated with an old coal-fired Rankin Cycle facility. ~ 1.7 kg $CO_2$.

*6)* <u>Running a Natural Gas Combined Cycle</u>

Let's say you're in charge of a NGCC for Southern LA. You control the flow of NG to the Brayton Cycle turbine and you can monitor the (a) electrical current, (b) the torque (how hard the turbine has to push the generator to keep it going), (c) the spinning frequency of the turbine, and the (d) output voltage. At 5:30 PM, everyone gets home and turns on their electrical appliances – especially air conditioners.

a) When this happens, what do you notice about measurements in (a) – (d) above?

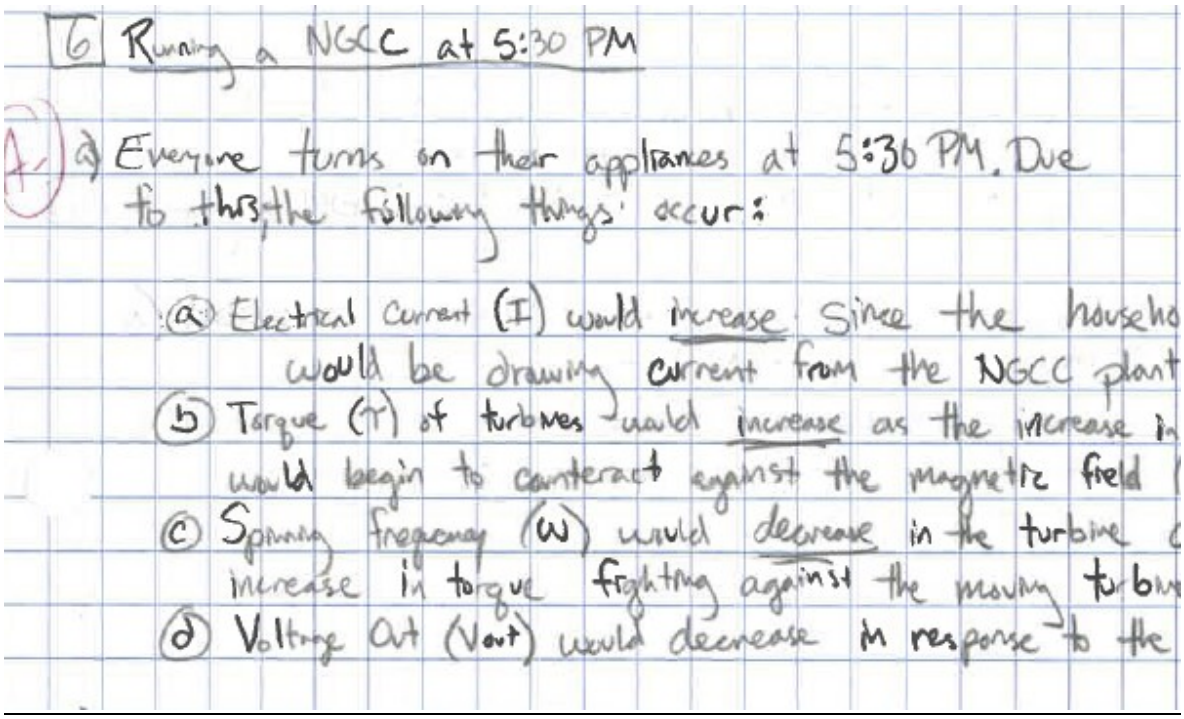
The current would increase because of the larger number of electrical appliances drawing current (power). This increase in current would make the turbine harder to turn, yes the torque would increase. Without increased input power, the spinning would slow and thus the voltage would drop… darn, you have a brownout!

b) How do you respond with the flow of NG to the Brayton Cycle Turbine?

You slam on more NG, to increase the flow and input power, increasing the torque the Brayton Cycle puts out.

c) After your action, how do measurements (a) – (d) change?

With the increased power that the Brayton cycle puts out, you're back to 60 Hertz (60 times per second), and the voltage is back where it should be, so there's even more current being put out, but you're providing the increased torque that it requires.



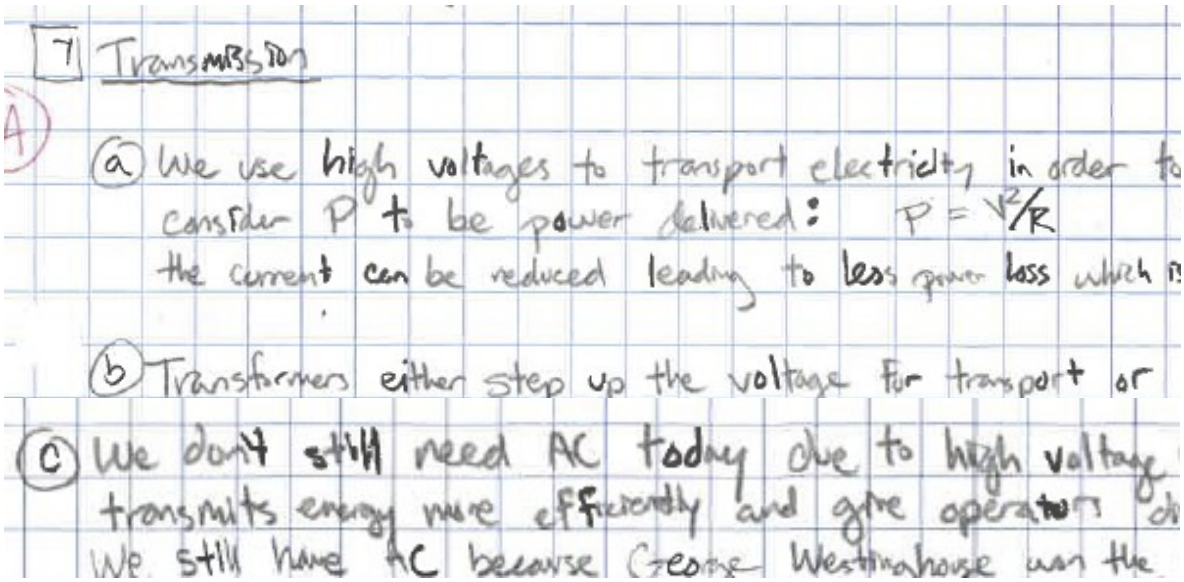

*7)* Transmission

Why do we need Transformers?

a)

What is the difference between AC and DC? How do the voltages look different on an oscilloscope? Where do you find AC (like in the wall socket), and DC (like a battery)?
We learned that we can generate electricity with a *changing* magnetic field. That's how generators work. However, we can also make a magnetic field with an electromagnet, but in order to make it change in time, the voltage driving the current for the electromagnet must be changing in time. So, a transformer is able to change from one voltage to the other voltage only if you use AC.
The full logic would look like this:

a) Why do we need HV to reduce line losses of electrical energy? Because if we raise voltage, we can lower current, and current is what causes resistive losses.
b) Why do we need to change electricity voltages from low to high to low again?
c) Why do transformers require AC? It's only the *changing* magnetic flux that results in electricity generation.
d) Do we *still* need to use AC to transport electricity long distances? (the answer is "no, not since we've developed solid state DC/DC convertors that change voltages of DC electricity)



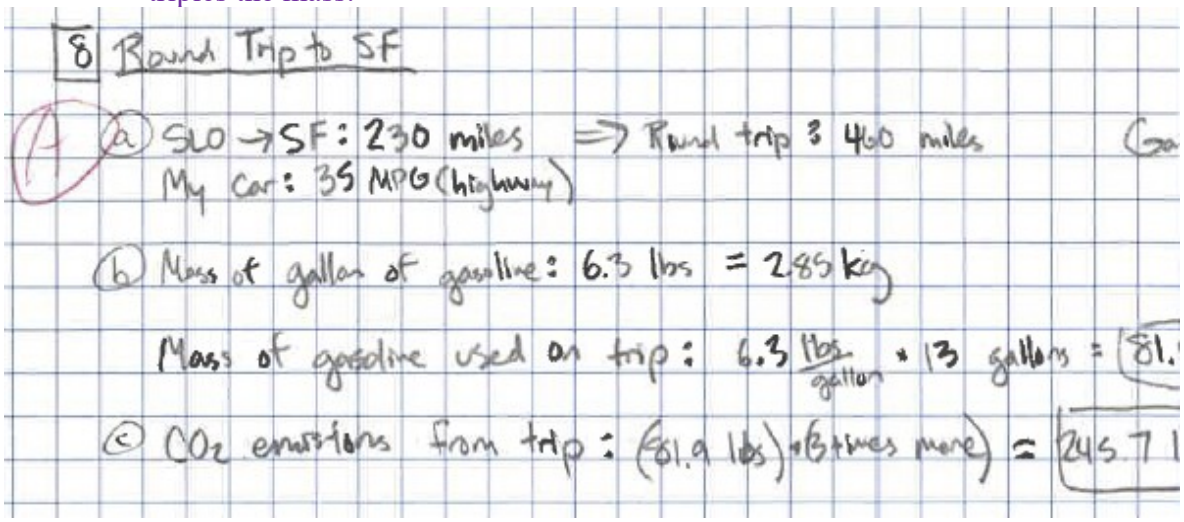

*8)* You take a weekend round trip to San Francisco.

a) Estimate the amount of gas the trip it requires. Likely you'll get 15-20 gallons for a car. Let's say 500 miles at 25 miles/gal for an inefficient car: 20 gallons.

b) Estimate the *mass* of gasoline the trip requires. A gallon is 4 quarts, or about 4 liters. A liter of water is 1 kg, so a gallon is a little less than 3 kg (gas has a lower density than water). So, we're looking at about 60 kg of gasoline.

c) The mass of $CO_2$ emitted into the atmosphere is about three times the mass of the gasoline consumed. How much is that? About 180 kg of $CO_2$…. Or almost 10 kg of $CO_2$ per gallon of gas used.

d) Why is the mass of $CO_2$ about three times the mass of the gasoline consumed? Where does the rest of the mass come from? Gasoline is just carbon and hydrogen (hydrocarbons), but the hydrogen has almost no mass. So as far as mass is concerned, you can think of gas as a tank of carbon. Then you add two oxygen atoms. This about triples the mass.




*9)* I read that Diablo Nuclear Power Plant* produces about 2 GW of electricity using a Rankine cycle that boils water at about 285 ºC (under pressure)**. The Pacific Ocean is about 15 ºC.

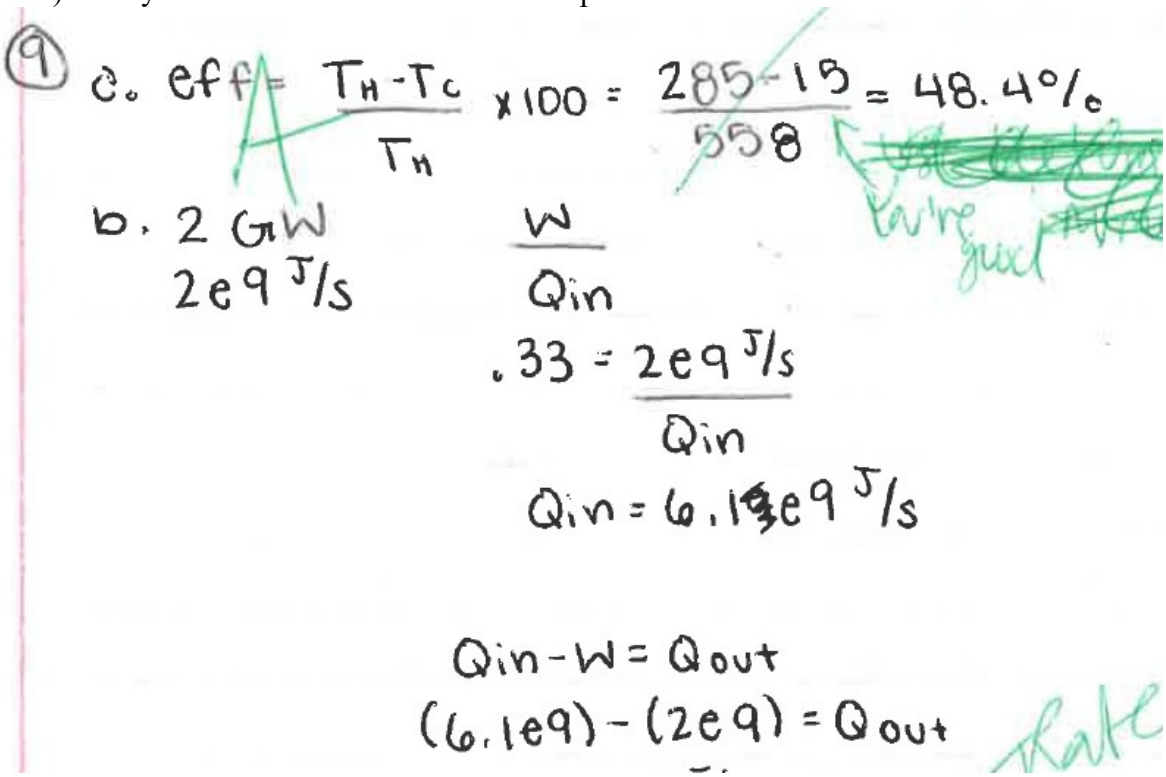
a) What is the maximum possible efficiency for this heat source? Notice below that the student didn't convert the temperatures to Celcius in the numerator, but it didn't matter

because the question requires only the *difference* in temperature, so you don't need to add the 273 to the two numbers you are subtracting from each other.

b) Diablo's actual efficiency is only about 33%. Estimate the rate at which Diablo dumps heat into the Pacific. Also notice that she got the right answer for thermal power into the ocean, but the grader didn't realize it.

c) The Pacific Coast is a lovely place to live. Consequently, we enjoy outrageous land prices! Why ever would someone put a *nuclear power facility* on this beautiful land? Why not in the desert somewhere, where no one wants to live***?

d) Did you remember to use absolute temperature?




(*) https://en.wikipedia.org/wiki/Diablo_Canyon_Power_Plant
(**)https://en.wikibooks.org/wiki/Diablo_Canyon_Nuclear_Power_Plant:_The_WikiBook/Boiling_water_reactor
(***) https://en.wikipedia.org/wiki/Palo_Verde_Nuclear_Generating_Station