PHYS-310 Heat Transfer, Efficiency, Electricity, Problem Set #3:

1) Humans put out about 100 W while at rest. I build a house that is a cube in the air on stilts. The walls are insulated with 25 cm of rice hulls (~ 0.05 W/m-K), and I stay inside.
   a) What is the free temperature from me living in the house? That is, what is the equilibrium temperature difference between the inside and outside of the building when I'm living inside?
   b) This house (without any sunlight) is placed in Minneapolis with 8000° F-degree days. How many barrels of oil (5.8 M BTU/bbl) are consumed in the year.? State any reasonable assumptions.
   c) What's the "R-value" of this 25 cm of this wall material in English units of ft^2-F-h/Btu.
   d) Let's say that one of the walls is a sheet of glass that is very thin and perfectly transparent. Repeat calculation a for this consideration.

2) Entropy is created when heat flows from hot to cold. In the idealized Sterling Engine, and in the idealized Carnot Cycle, one can imagine that no heat flows from hot to cold. Therefore, these engines create no entropy. No heat is lost without doing work! Work turns heat to energy, reducing entropy, while heat flowing from hot to cold increases entropy. So, if work is created (reducing entropy) we must have som waste heat (to create that much entropy). Starting with a change of entropy of zero and the conservation of energy, please derive the Carnot efficiency.

3) Remember our Bugatti Veyron? http://www.youtube.com/watch?v=LO0PgyPWE3o Please reconsider the subject of efficiency:
   a) What was the efficiency you calculated? This is called the "first law efficiency" because it follows directly from the first law of thermal physics. This is also of course the *actual* efficiency of the vehicle.
   b) What is the maximum possible efficiency (Carnot Efficiency) you could hope for given the extremes of temperature between ambient outside temperature and the hottest hot of the combustion (you'll have to look this up… but I wasn't able to find it for a Veyron. You could look it up for the general Otto Cycle.)
   c) What portion of this maximum theoretical efficiency did you achieve? This portion is called the "second law efficiency" because the Carnot Efficiency comes from adhering the second law of thermal physics.
   d) Even a perfect, frictionless Otto Cycle doesn't achieve the Carnot Efficiency. Please see: http://web.mit.edu/16.unified/www/SPRING/propulsion/notes/node25.html and investigate the efficiency of the Otto Cycle – what is the key factor? Why are diesel engines a little more efficient than the Otto Cycle? Well, there are a few reasons we will investigate later, but please find one of them now.
   e) What is the second law efficiency for a perfect Otto Cycle (achieving perfect Otto Cycle efficiency for the temperatures and compression ratios you find)?
   f) What portion of the maximum possible Otto Cycle efficiency does your Veyron actually achieve?

4) Running a Natural Gas Combined Cycle
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?
   b) How do you respond with the flow of NG to the Brayton Cycle Turbine? What does this do?
   c) After your action, how do measurements (a) – (b) compare to how they were before everyone came home?

5) Transmission
Why do we need Transformers?
   a) Please explain how transformers reduce transmission losses, and include consideration of High Voltage, AC/DC, and resistive heat losses in a wire.

   Let's say you're on a task force to address the power loss to Bakersfield from Diablo. The power lines were made a long time ago and since then, Bakersfield's demand for electricity during peak hours has doubled.
   b) If the power use has doubled, by what factor will the amount of heat loss in the cables increase?
   c) On extra hot days, there will be an extra thermal load on the wires. What problem occurs when the wires heat up? How would this change the transmission losses?
   d) Long wires have considerable inductance and capacitance. How does this affect heating loses?
   e) You find a way to increase the transmission voltage by a factor of 5. By what factor will this change the transmission losses?

Please read more about what transmission lines are made of at
http://en.wikipedia.org/wiki/Electric_power_transmission