Physics 123 Homework Solutions

Week #6 Unit T Thermodynamics

T9B.1

Yes, mechanical energy can be converted entirely into heat. This is essentially what a refrigerator does when it uses mechanical energy, converts it to heat energy, and then adds it to a hot reservoir. An electric space heater also coverts electrical energy entirely to heat. Complete conversion of mechanical energy into heat inevitably involves an increase in entropy and is thus fully allowed by the second law of thermodynamics, while complete conversion of heat into mechanical energy violates the second law.

T9B.2

The efficiency of the engine is given by $\varepsilon = 1 - \frac{T_C}{T_H} = 1 - \frac{295K}{1223K} = 76\%$. The efficiency is so high due to the large temperature difference.

T9B.5

The air conditioner needs to have access to the environment outside because it needs to have access to a hot reservoir where it can deposit waste heat (which includes the heat in the room.) Placing the air conditioner in the center of the room would mean that it would pump heat from the room back into the room, which wouldn't help.

T9B.6

Refrigerators essentially work by taking heat out of the cold reservoir (the inside of the refrigerator) and putting the heat into a hot reservoir (the kitchen). Leaving the door open will cause the refrigerator to put more heat into the kitchen, instead of cooling it, since any heat it extracts from the room is put back into the room with the refrigerators mechanical energy added. On the other hand, leaving the oven door open to heat a room will work though, since the hot air from the oven will satisfy the second law of thermodynamics by flowing out of the oven and into the cooler air of the kitchen.

T9S.2

A nuclear power plant generates heat which boils water and produces steam. This steam then turns the turbines that turn the generator to create electrical energy. The nuclear plant is fundamentally restricted by the second law of thermodynamics to an efficiency that depends on the temperatures if it's hot and cold reservoirs.

A hydroelectric plant, however, simply converts the kinetic energy of falling water (mechanical energy) to turn its turbines and generate electrical energy (another form of mechanical energy). This does not involve the conversion of heat to work, and thus is not restricted by the second law of thermodynamics. The only reason why a hydroelectric power plant is not 100% efficient is that some energy is unavoidably lost due to mechanical friction, in turning the turbines.

T9S.3

Heating a home can be considered 100% efficient if we focus on the fact that all of the electrical energy coming into the heater is indeed converted to heat. This statement is misleading because much less than 100% of the thermal energy produced by the fuel in the power pant is converted to electrical energy. You would get more heat out of a given amount of fuel if you were to burn the fuel directly in a furnace.

T9S.7

Assuming that $T_C = 100^oC$ (373 K), since the water cooled engine probably has been running long enough to bring water to its boiling point. If this is true then the maximum efficiency would be $\varepsilon = 1 - \frac{T_C}{T_H} = 1 - \frac{373K}{1500K} = 75\%$. A real engine would be less efficient.

T9S.14

This was done in class as a derivation of the efficiency of a *Carnot* engine.

T9S.15

This was done in class as an exercise and demonstration of a gasoline engine's efficiency and power output. For a compression ratio of 8, the efficiency is $\varepsilon = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1} = 1 - \left(\frac{1}{8}\right)^{1.4-1} = 0.56 = 56\%$.