Problem 1 **(20%)**

Answer the following question.

(a) What is the difference between a refrigerator and a heat pump?

(b) Why is the Carnot Cycle not a realistic model for steam power plants?

(c) How are the combustion and exhaust processes model under the air-standard assumptions?

(d) Prove that a cyclic device that violates the Kelvin-Planck statement of the second law also violates the Clausius statement of the second law.

Problem 2 **(20%)**

In an air-standard Brayton cycle the air enters the compressor at 0.1 MPa, 15℃. The pressure leaving the compressor is 1.0 MPa, and the maximum temperature in the cycle is 1100℃.

(a) Show the P-v and T-s diagram. (4%)

(b) Determine the pressure and temperature at each point in the cycle. (8%)

(c) Determine the compressor work, turbine work, and cycle efficiency. (8%)

Problem 3 **(30%)**

A piston-cylinder assembly maintained at a constant pressure of 100 kPa (weightless piston) initially contains 0.0010 kmol of air at 27℃. The assembly is connected to an air line maintained at 700 kPa and 400 K. Air is allowed to flow from the line to the assembly until the volume is doubled. During this process heat enters the cylinder in the amount of 1000 kJ/kmol of gas finally in the tank. For air, let u = 20.9T and h = 29.2T, both expressed in kJ/kmol and with T in kelvins.

(a) Use a control-volume energy analysis to derive an equation in the form $C_1 N_f T_f + C_2 N_f + C_3 = 0$, where C_1, C_2, and C_3 are numerical values and the subscript f stands for the final state in the cylinder.

(b) Derive another independent equation which shows that $N_f T_f = C_4$, where C_4 is some numerical value.

(c) Determine the value of the mass which has entered the assembly, in kilomoles, and the final temperature in the cylinder, in kelvins.

Problem 4 **(30%)**

(a) Show that the Joule-Thomson coefficient of an ideal gas is zero.

(b) Develop an expression for the change in internal energy of a gas which follows the equation of state

$$P = \frac{RT}{v-b} - \frac{a}{v^2}$$