Thermodynamics Qualifier Spring 2009
three (3) equally weighted problems

P.1 The gas turbine power plant (shown in Figure below) operates in steady-state regime with the constant mass flow rate $\dot{m}$ =15 kg/s. The atmospheric air (P = 101 kPa) is first fed into the compressor, then, it flows through the heat exchanger to be heated and, eventually, it flows through the gas turbine to produce the work. The shaft of the turbine is connected to the shaft of the compressor, so that 60% of the turbine power output is utilized as a power input to the compressor (i.e., $|\dot{W}_C| = 0.6 \times |\dot{W}_T|$). The remaining 40% of the turbine power output is used to drive an electric generator connected to the turbine shaft. By assuming that (1) both the compressor and the turbine are adiabatic, (2) kinetic and potential energy changes through each component of the power plant are negligible, (3) negligible pressure drop through heat exchanger, and by using information from Table 1 below → determine the following information: **(Do not assume constant specific heats.)**

(a) Could you use the Carnot principles to determine the maximum possible efficiency of this power plant, yes or not? Briefly explain why? [1pt]

(b) List your assumptions/observations? [1pt]

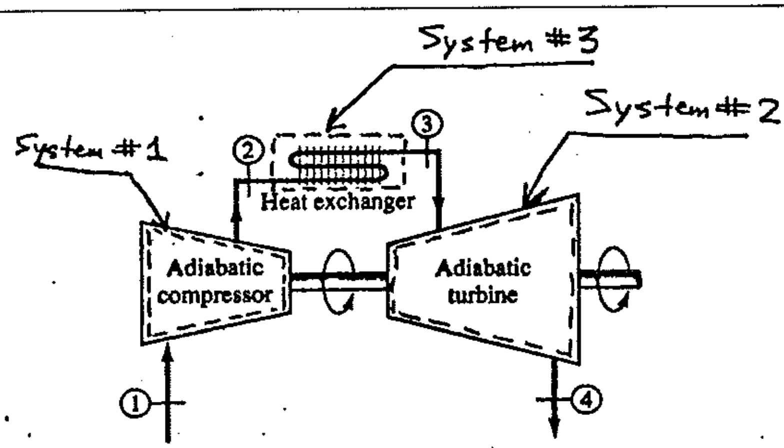
(c) Power input to the compressor [kW]? [3pt]

(d) Power output of the turbine [kW]? [3pt]

(e) Net power output of the power plant [kW]? [2pt]

(f) Magnitude and direction of heat transfer in the heat exchanger [kW]? [4pt]

(a) Fill the missing information in the Table below? [1pt]



	Pressure, kPa	Temperature, °C
Location 1	101	20
Location 2	400	400
Location 3		
Location 4	130	700

P.2 A rigid but **not** adiabatic tank of volume V contains an ideal gas, with constant specific heats, at initial pressure p_1. An exhaust valve is opened, and the gas escapes until the pressure has dropped to a final pressure p_2. During this time, the gas within the tank undergoes a polytropic process, $pv^n = \text{constant}$. (The exponent n is also a constant.)

Determine the total heat transfer, Q, to the tank during the process, as a function of V, p_1, p_2, n, and the familiar constant properties of the gas such as R, C_p, C_v, or k..

Hint: Start with an expression for $\dot{Q}$.

P.3 Consider the steady, adiabatic flow of some fluid through a turbine. It is given that the inlet temperature and pressure are T_i and p_i (i.e., prescribed values), respectively, and that the exit pressure is given as p_e.

Show analytically (i.e., using a $T\,ds$ equation), for the given conditions, that the power generated is greatest when the flow process is internally reversible.