(25%) 1. A heat engine receives heat from a reservoir at 1500°C at a rate of 2000kJ/s and rejects the waste heat to the ambient air at 25°C. The work output is used to drive a refrigerator that removes heat from the refrigerated space at -20°C. and transfers it to the same ambient air. Please determine:

(a) The maximum work output of the heat engine.

(b) The maximum rate of heat removal from the refrigerated space.

(c) The total rate of heat rejection to the ambient air.

(d) Compare the efficiencies and heat rejections of the two machines.

(e) Please give your comments about the above results.

(25%) 2. (a) What is the entropy change of an adiabatic closed system which receives a compression work of 2000kJ during a thermodynamics process with pressure increasing from P_1 =1atm to P_2=8atm? Please show by an equation and in a T-S diagram.

(b) An insulated, rigid tank contains 4 kg of air at 450 kPa and 30°C. A valve is now opened and air is allowed to escape until the pressure inside drops to 150 kPa. Assuming that the air inside the tank has undergone a reversible, adiabatic process, please determine the final mass in the tank, the entropy change of the system, and the entropy change of the surroundings.

(25%) 3. If the compression ratio (r) and the heat addition (Q) are the same for both the Otto cycle and Diesel cycle, please :

(1) Draw these two cycles on the same T-S diagram. (8%)

(2) Compare their thermal efficiency η_{th}, which one is higher?(hint: not necessary to calculate them, comparing them by geometry) (7%)

(3) Discuss that the compression ratio in this comparison is assumed to be the same, is it fair for the Diesel engine? Why? (10%)

(25%) 4 Please derive the following equation and answer question

(a) $du = C_v dT + \left(T\left(\frac{\partial p}{\partial T}\right)_v - p\right)dv$ (8%)

(b) $k = 1 + \frac{v}{C_v}\frac{T\beta^2}{\kappa}$, (8%) [Hint: derive C_p- C_v first]

Where p is the pressure, T is absolute temperature, and v is specific volume, and $k = C_p/C_v$, is the specific heat ratio, β is the coefficient of volume expansion, and κ is the isothermal compressibility.

(c) If the ideal gas is applied, what is the internal energy expression for the ideal gas deriving from question (a). (4%)

(d) From eq. (b), what is relation of C_p and C_v for the water near 4℃ you can derive. (5%)

Following equation is the definition, or for reference only.

$$C_p = \left(\frac{\partial h}{\partial T}\right)_p, \quad C_v = \left(\frac{\partial u}{\partial T}\right)_v$$

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p, \quad \kappa = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$$

$$ds = \frac{C_v}{T}dT + \left(\frac{\partial p}{\partial T}\right)_v dv \qquad ds = \frac{C_p}{T}dT - \left(\frac{\partial v}{\partial T}\right)_p dp$$