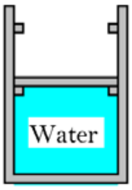
一 (Energy Equation and 1st Law of Thermodynamics)

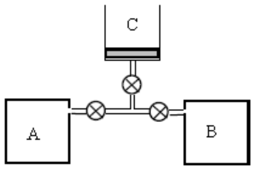
A frictionless piston is free to move between two sets of stops. When the piston rests on the lower stops, the enclosed volume is 400 L. When the piston reaches the upper stops, the volume is 600 L. The cylinder initially contains water at 100 kPa, 20% quality. It is heated until the water eventually exists as saturated vapor. The mass of the piston requires 300 kPa pressure to move it against the outside ambient pressure. Determine the final pressure in the cylinder, the heat transfer and the work for the overall process.

(提供水的熱力性質表)



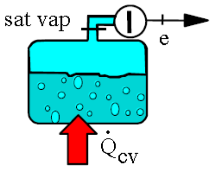
二 (Energy Equation and 1st Law of Thermodynamics)

A rigid tank A of volume 0.6 m^3 contains 3 kg water at 120 ^oC and the rigid tank B is 0.4 m^3 with water at 600 kPa, 200 ^oC. They are connected to a piston cylinder initially empty with closed valves. The pressure in the cylinder should be 800 kPa to float the piston. Now the valves are slowly opened and heat is transferred so the water reaches a uniform state at 250 ^oC with the valves open. Find the final volume and pressure and the work and heat transfer in the process. (提供水的熱力性質表)



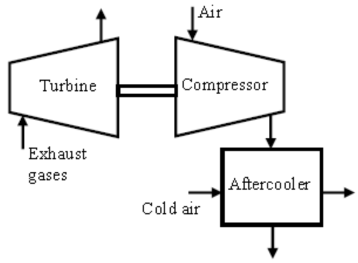
三 (Energy Analysis for a Control Volume)

A 200 liter tank initially contains water at 100 kPa and a quality of 1%. Heat is transferred to the water thereby raising its pressure and temperature. At a pressure of 2 MPa a safety valve opens and saturated vapor at 2 MPa flows out. The process continues, maintaining 2 MPa inside until the quality in the tank is 90%, then stops. Determine the total mass of water that flowed out and the total heat transfer. (提供水的熱力性質表)



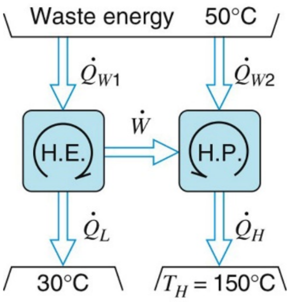
四 (Energy Analysis for a Control Volume)

In a turbocharger, exhaust gases enter the turbine at 400 ^oC and 120 kPa at a rate of 0.02 kg/s and leave at 350 ^oC. Air enters the compressor at 50 ^oC and 100 kPa and leaves at 130 kPa at a rate 0.018 kg/s. The air temperature leaves the aftercooler is 80 ^oC. The cold ambient air enters the aftercooler at 30 ^oC and leaves at 40 ^oC. Disregarding any frictional losses in the turbine and the compressor and treating the exhaust gases as air, determine (a) the temperature of the air at the compressor outlet and (b) the volume flow rate of ambient air. (C_p=1.008 kJ/kg-K, R=0.287 kJ/kg-K)



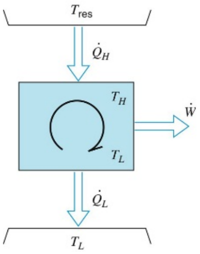
五 (The 2nd Law of Thermodynamics)

A combination of a heat engine driving a heat pump (see Fig. ?) takes waste energy Q_{w1} at 50 °C to the heat engine, rejecting heat at 30 °C. The remainder of waste energy, Q_{w2}, goes into the heat pump that delivers a Q_H at 150 °C. If the total waste energy is 5 MW, find the rate of energy delivered at the high temperature.



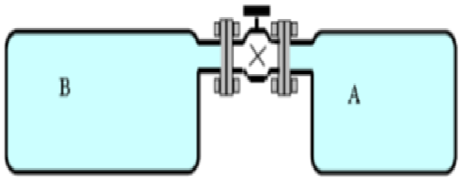
六 (The 2nd Law of Thermodynamics)

A Carnot heat engine, shown in Fig.?, receives energy from a reservoir at T_{res} through a heat exchanger where the heat transferred is proportional to the temperature difference as $\dot{Q}_H = K(T_{res} - T_H)$. It rejects heat at a given low temperature T_L. To design the heat engine for maximum work output show that the high temperature, T_H, in the cycle should be selected as $T_H = (T_{res}T_L)^{1/2}$



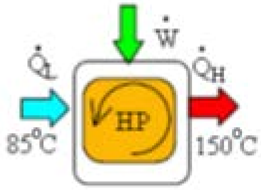
七 (Entropy)

Two rigid, insulated tanks, shown in Fig.?, are connected with a pipe and valve. One tank has 0.5 kg air at 200 kPa, 300 K and the other has 0.75 kg air at 100 kPa, 400 K. The valve is opened and the air comes to a single uniform state without any heat transfer. Find the final temperature and the change in entropy of the air. (C_p = 1.004 kJ/kg-K and R = 0.287 kJ/kg-K)



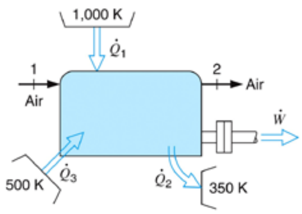
八 (Entropy)

A heat pump, shown in Fig.?, should upgrade 5 MW of heat at 85 °C to heat delivered at 150 °C. For a reversible heat pump what are the fluxes of entropy in and out of the heat pump? Reconsider the heat pump and assume it has a COP of 2.5. What are the fluxes of entropy in and out of the heat pump and the rate of entropy generation inside it?



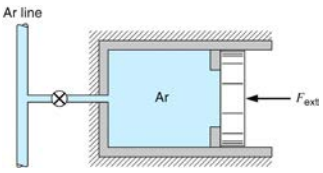
九 (Entropy Analysis for a Control Volume)

A reversible steady state device receives a flow of 1 kg/s air at 400 K, 450 kPa and the air leaves at 600 K, 100 kPa. Heat transfer of 900 kW is added from a 1000 K reservoir, 50 kW rejected at 350 K and some heat transfer takes place at 500 K. Find the heat transferred at 500 K and the rate of work produced.



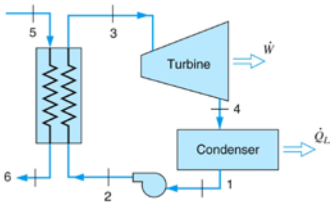
十 (Entropy Analysis for a Control Volume)

A horizontal, insulated cylinder has a frictionless piston held against stops by an external force of 500 kN. The piston cross-sectional area is 0.5 m^2, and the initial volume is 0.25 m^3. Argon gas in the cylinder is at 200 kPa, 100 ^oC. A valve is now opened to a line flowing argon at 1.2 MPa, 200 ^oC, and gas flows in until the cylinder pressure just balances the external force, at which point the valve is closed. (a) Use constant heat capacity to find the final temperature, (b) find the total entropy generation. (For Argon gas, R = 0.2081 kJ/kg-K, C_p = 0.52 kJ/kg-K)



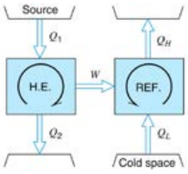
十一 (Power and Refrigeration Systems-With Phase Change)

A supply of geothermal hot water is to be used as the energy source in an ideal Rankine cycle (Shown in Fig. ?), with R-134a as the cycle working fluid. Saturated vapor R-134a leaves the boiler at a temperature of 85 °C, and the condenser temperature is 40 °C. (a) Plot the T-s diagram, (b) Calculate the thermal efficiency of this cycle. (提供 R-134a 熱力性質表)



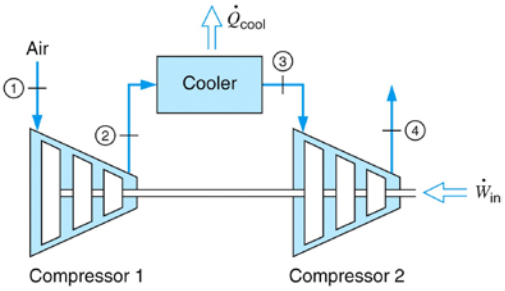
十二 (Power and Refrigeration Systems-With Phase Change)

A refrigerator using R-410A is powered by a small natural gas fired heat engine with a thermal efficiency of 25%, as shown in Fig.？. The R-410A condenses at 40 ^{o}C and it evaporates at -20 ^{o}C and the cycle is standard. (a) Plot the T-s diagram, (b) Find the two specific heat transfers (q_L and q_H) in the refrigeration cycle, (c) What is the overall coefficient of performance as Q_L / Q_1? (提供 R-410A 熱力性質表)



十三 (Power and Refrigeration Systems-Gaseous Working Fluids)

A two-stage air compressor has an intercooler between the two stages as shown in Fig. ?. The inlet state is 100 kPa, 290 K, and the final exit pressure is 1.6 MPa. Assume that the constant pressure intercooler cools the air to the inlet temperature, $T_3 = T_1$. (a) Show that the optimal pressure is $P_2 = (P_1 P_4)^{1/2}$ for minimum total compressor work, (b) Plot P-v and T-s diagrams, (c) Find the specific compressor works from process 1 to 4 and the intercooler specific heat transfer for the optimal P_2.



十四 (Power and Refrigeration Systems-Gaseous Working Fluids)

A four-stroke Otto cycle engine assume the heat input per unit mass is a given (it depends on the fuel-air mixture). The mean effective pressure of the engine scales with the net work and thus with the efficiency. How does the total power output vary with the inlet conditions (P_1, T_1)?

十五 (Thermodynamic Relations)

From $C_p = \left(\frac{\partial h}{\partial T}\right)_T = T\left(\frac{\partial s}{\partial T}\right)_P$ and $C_v = \left(\frac{\partial u}{\partial T}\right)_v = T\left(\frac{\partial s}{\partial T}\right)_v$ and the knowledge that $C_p > C_v$, what can you conclude about the slopes of constant *v* and constant *P* curves in a T-s diagram? Notice that we are looking at functions *T*(*s*, *P* or *v* given).

十六 (Thermodynamic Relations)

Use $ds = C_v \frac{dT}{T} + \left(\frac{\partial P}{\partial T}\right)_v dv$ to get an expression for the derivative $\left(\frac{\partial T}{\partial v}\right)_s$. For an ideal gas, show $\left(\frac{\partial T}{\partial v}\right)_s = -\frac{P}{C_v}$.

十七 (The 2nd Law of Thermodynamics)

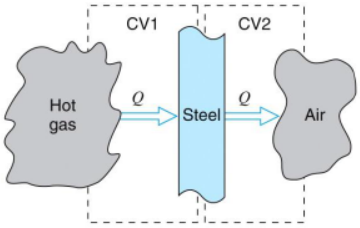
Consider a Carnot cycle heat engine operating in outer space. Heat can be rejected from this engine only by thermal radiation, which is proportional to the radiator area A and the fourth power of absolute temperature T, $\dot{Q}_{rad} = KAT^4$, and K is the proportion constant. Show that for a given engine work output and given T_H, the radiator area will be minimum when the ratio $T_L/T_H = 3/4$.

十八 (The 2^{nd} Law of Thermodynamics)

Use the inequality of Clausius to show that (a)heat transfer from a warm space towards a colder space without work is a possible process i.e. a heat engine with no work output.
(b) heat transfer from a cold space towards a warmer space without work is an impossible process i.e. a heat pump with no work input.

十九 (Entropy)

Consider a heat transfer of 100 kJ from 1500 K hot gases to a steel container at 750 K that has a heat transfer of the 100 kJ out to some air at 375 K. Determine the entropy generation in each of the control volumes indicated in Fig. ?.



二十 (Entropy Analysis for a Control Volume)

Stainless steel balls leaving the oven at a uniform temperature of 900°C at a rate of 1100 per minute are exposed to air and are cooled to 850°C before they are dropped into the water for quenching. Determine (a) the rate of heat transfer from the ball to the air and (b) the rate of entropy generation due to heat loss from the balls to the air. (For stainless steel, density ρ = 8085 kg/m^3, specific heat c = 0.480 kJ/kg-K)