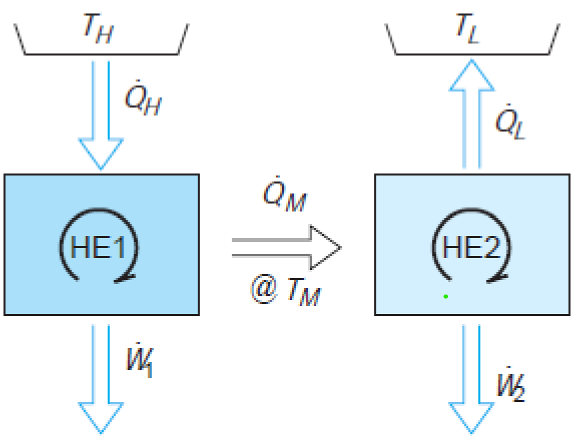
Tutorial-IV
Second law & Entropy (Closed Systems)

1. A farmer runs a heat pump with a 2 kW motor. It should keep a chicken hatchery at 30°C, which loses energy at a rate of 10 kW to the colder ambient T_{amb}. What is the minimum COP (heating) that will be acceptable for this heat pump?

2. A combination of two heat engines is shown in fig. Find the overall thermal efficiency (η_{th}) as a function of the two individual efficiencies (η_1 & η_2).



3. A cylinder having an initial volume of 3 m^3 contains 0.1 kg of water at 40°C. Water is then compressed through a reversible isothermal process until it has a quality of 50%. Calculate the work done in this process.

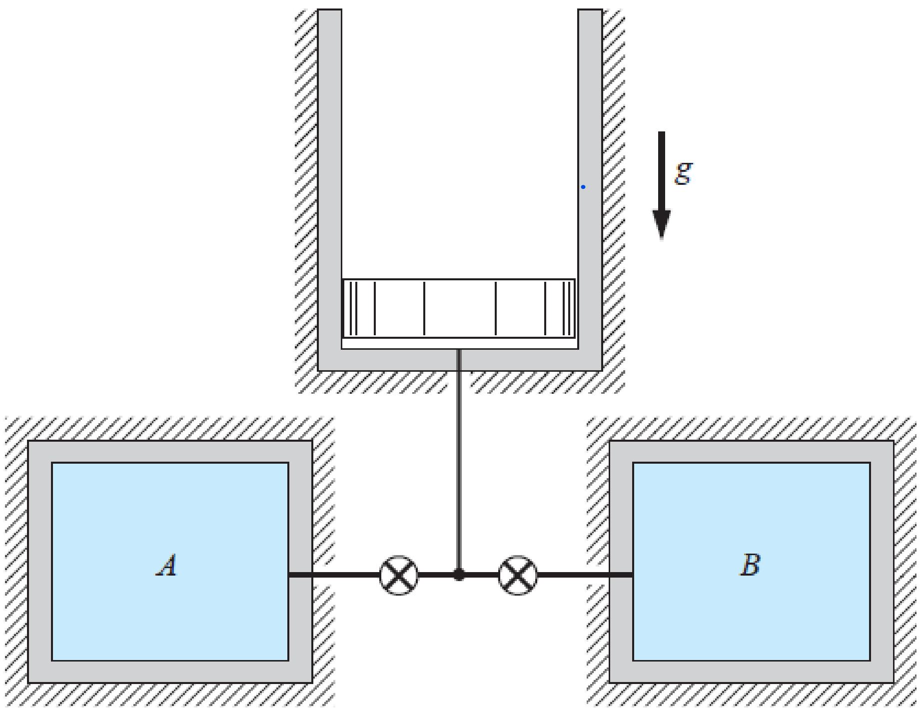
4. A piston cylinder compresses R-410a at 200 kPa, −20°C to a pressure of 1200 kPa in a reversible adiabatic process. Find the final temperature and the specific compression work.

5. A thermal storage device is made with a rock (granite) bed of 2 m^3 that is heated to 400 K using solar energy. A heat engine receives Q_H from the bed and rejects heat to the ambient surroundings at 290 K. The rock bed therefore cools down, and as it reaches 290 K the process stops. Find the energy the rock bed can give out. Find the total work the heat engine can give out as it receives energy from the rock bed. What is the heat engine's efficiency at the beginning of the process, and what is it at the end of the process?

6. A cylinder fitted with a movable piston contains water at 3 MPa with 50% quality, at which point the volume is 20 L. The water now expands to 1.2 MPa as a result of receiving 600 kJ of heat from a large source at 300°C. It is claimed that the water does 124 kJ of work during this process. Is this possible?

7. A piston/cylinder setup has 2.5 kg of ammonia at 50 kPa, -20°C. Now it is heated to 50°C at constant pressure through the bottom of the cylinder from external hot gas at 200°C. Find the heat transfer to the ammonia and the total entropy generation.

8. Two tanks contain steam, and they are both connected to a piston/cylinder, as shown in fig. Initially, the piston is at the bottom, and the mass of the piston is such that a pressure of 1.4 MPa below it will be able to lift it. Steam in A has a mass of 4 kg at 7 MPa, 700°C, and B has 2 kg at 3 MPa, 350°C. The two valves are opened, and the water comes to a uniform state. Find the final temperature and the total entropy generation, assuming no heat transfer.



9. An uninsulated cylinder fitted with a piston contains air at 500 kPa, 200 ◦ C, at which point the volume is 10 L. The external force on the piston is now varied in such a manner that the air expands to 150 kPa, 25 L volume. It is claimed that in this process the air produces 70% of the work that would have resulted from a reversible adiabatic expansion from the same initial pressure and temperature to the same final pressure. Room temperature is 20°C.

a. What is the amount of work claimed?

b. Is this claim possible?

10. A gas in a rigid vessel is at ambient temperature and at a pressure, P_1, slightly higher than ambient pressure, P_0. A valve on the vessel is opened, so gas escapes and the pressure drops quickly to ambient pressure. The valve is closed, and after a long time the remaining gas returns to ambient temperature, at which point the pressure is P_2. Develop an expression that allows a determination of the ratio of specific heats γ in terms of the pressures.

Entropy (Open Systems)

1. A Hilch tube has an air inlet flow at 20°C, 200 kPa and two exit flows of 100 kPa, one at 0°C and the other at 40°C. The tube has no external heat transfer and no work and all the flows are SSSF and have negligible kinetic energy. Find the fraction of the inlet flow that comes out at 0°C. Is this setup possible?

2. Two flow streams of water, one at 0.6 MPa, saturated vapor, and the other at 0.6 MPa, 600°C, mix adiabatically in a SSSF process to produce a single flow out at 0.6 MPa, 400°C. Find the total entropy generation for this process.

3. Carbon dioxide at 300 K, 200 kPa is brought through a SSSF device where it is heated to 500 K by a 600 K reservoir in a constant pressure process. Find the specific work, heat transfer and entropy generation.

4. A supply of 5 kg/s ammonia at 500 kPa, 20°C is needed. Two sources are available one is saturated liquid at 20°C and the other is at 500 kPa, 140°C. Flows from the two sources are fed through valves to an insulated SSSF mixing chamber, which then produces the desired output state. Find the two source mass flow rates and the total rate of entropy generation by this setup.

5. A large storage tank contains liquefied natural gas (LNG), which may be assumed to be pure methane. The tank contains saturated liquid at ambient pressure, 100 kPa; it is to be pumped to 500 kPa and fed to a pipeline at the rate of 0.5 kg/s. How much power input is required for the pump, assuming it to be reversible?

6. Air from a line at 12 MPa, 15°C, flows into a 500-L rigid tank that initially contained air at ambient conditions, 100 kPa, 15°C. The process occurs rapidly and is essentially adiabatic. The valve is closed when the pressure inside reaches some value, P_2. The tank eventually cools to room temperature, at which time the pressure inside is 5 MPa. What is the pressure P_2? What is the net entropy change for the overall process?

7. A 1-m^3 rigid tank contains 100 kg R-22 at ambient temperature, 15°C. A valve on top of the tank is opened, and saturated vapor is throttled to ambient pressure at 100 kPa. During the process the temperature inside the tank remains at 15°C. The valve is closed when no more liquid remains inside. Calculate the heat transfer to the tank and total entropy generation in the process.

8. An old abandoned salt-mine, 100000 m^3 in volume, contains air at 290 K, 100 kPa. The mine is used for energy storage so the local power plant pumps it up to 2.1 MPa using outside air at 290 K, 100 kPa. Assume the pump is ideal and the process is adiabatic. Find the final mass and temperature of the air and the required pump work. Overnight, the air in the mine cools down to 400 K. Find the final pressure and heat transfer.

9. A rigid steel bottle, V = 0.25 m^3, contains air at 100 kPa, 300 K. The bottle is now charged with air from a line at 260 K, 6 MPa to a bottle pressure of 5 MPa, state 2, and the valve is closed. Assume that the process is adiabatic, and the charge always is uniform. In storage, the bottle slowly returns to room temperature at 300 K, state 3. Find the final mass, the temperature T_2, the final pressure P_3, the heat transfer and the total entropy generation.

10. A rigid 1.0 m^3 tank contains water initially at 120°C, with 50 % liquid and 50% vapor, by volume. A pressure-relief valve on the top of the tank is set to 1.0 MPa (*the tank pressure cannot exceed 1.0 MPa - steam will be discharged to maintain this pressure*). Heat is now transferred to the tank from a 200°C heat source until the tank contains saturated vapor at 1.0 MPa. Calculate the heat transfer to the tank and show that this process does not violate the second law.