Problem 5a: Entropy Equation for closed systems

1. A piston/cylinder setup containing air at 100 kPa and 400 K is compressed to a final pressure of 1000 kPa. Consider two different processes: (1) a reversible adiabatic process and (2) a reversible isothermal process. Show both processes in a *P–v* diagram and a *T–s* diagram. Find the final temperature and the specific work for both processes.

2. Consider a small air pistol with a cylinder volume of 1 cm^3 at 250 kPa and 27°C. The bullet acts as a piston initially held by a trigger, shown in Fig. P8.90. The bullet is released so that the air expands in an adiabatic process. If the pressure should be 100 kPa as the bullet leaves the cylinder, find the final volume and the work done by the air.

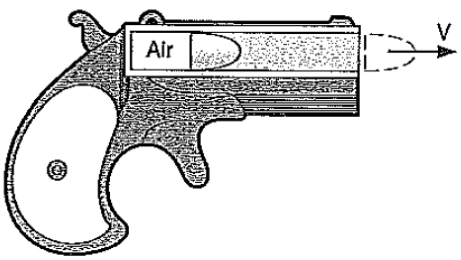
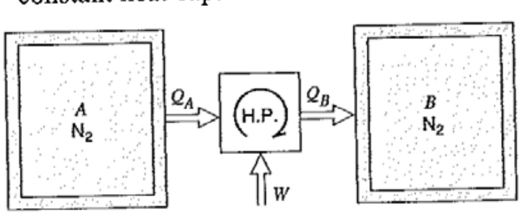


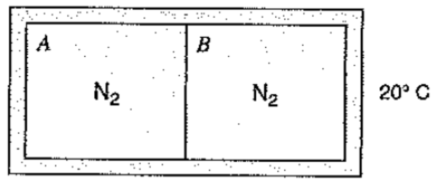
FIGURE P8.90

3. An insulated cylinder/piston setup contains carbon dioxide gas at 120 kPa and 400 K. The gas is compressed to 2.5 MPa in a reversible adiabatic process. Calculate the final temperature and the work per unit mass, assuming
   a. Variable specific heat (Table A.8).
   b. Constant specific heat (value from Table A.5).
   c. Constant specific heat (value at an intermediate temperature from Table A.6).

4. Two rigid tanks shown in Fig. P8.96 each contain 10 kg of N_2 gas at 1000 K and 500 kPa. They are now thermally connected to a reversible heat pump, which heats one and cools the other with no heat transfer to the surroundings. When one tank is heated to 1500 K the process stops. Find the final (*P*, *T*) in both tanks and the work input to the heat pump, assuming constant heat capacities.



5. A rigid container with a volume of 200 L is divided into two equal volumes by a partition, shown in Fig. P8.104. Both sides contain nitrogen; one side is at 2 MPa and 200°C, while the other is at 200 kPa and 100°C. The partition ruptures, and the nitrogen comes to a uniform state at 70°C. Assume the temperature of the surroundings to be 20°C. Determine the work done and the net entropy change for the process.



6. The power stroke in an internal combustion engine can be approximated with a polytropic expansion. Consider air in a cylinder volume of 0.2 L at 7 MPa and 1800 K, shown in Fig. 8.111. It now expands in a reversible polytropic process with an exponent *n* = 1.5, through a volume ratio 8:1. Show the process on p-v and T-s diagrams, and calculate the work and heat transfer for the process.

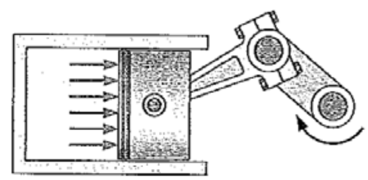


FIGURE P8.111

7. A reversible heat pump uses 1 kW of power input to heat a 25°C room, drawing energy from the outside at 15°C. Assuming every process is reversible, what are the total rates of entropy into the heat pump from the outside and from the heat pump to the room?

8. Room air at 23°C is heated by a 2000 W space heater with a surface filament temperature of 700 K, shown in Fig. P8.122. The room at steady state loses heat to the outside, which is at 7°C. Find the rate(s) of entropy generation and specify where it is made.

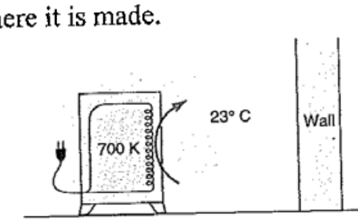
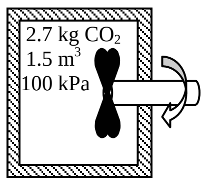


FIGURE P8.122

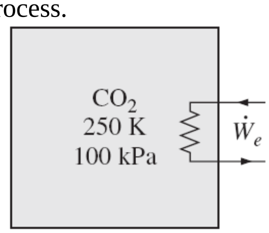
9. A 50-kg copper block initially at 80°C is dropped into an insulated tank that contains 120 L of water at 25°C. Determine the final equilibrium temperature and the total entropy change for this process. (Assume C_{Cu} = 0.385 kJ/kgK, and C_{water} = 4.2 kJ/kgK).

10. A 50-kg iron block and a 20-kg copper block, both initially at 80°C, are dropped into a large lake at 15°C. Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process. Specific heats of copper and iron are 385 and 434 J/kg K, respectively

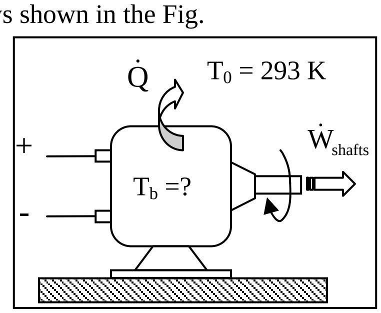
11. A 1.5m^3 insulated rigid tank contains 2.7 kg of carbon dioxide at 100 kPa. Now paddle-wheel work is done on the system until the pressure in the tank rises to 150 kPa. Determine the entropy change of carbon dioxide during this process. Use the specific heat polynomial of CO_2 from the book.



12. A 0.8-m^3 rigid tank contains carbon dioxide (CO2) gas at 250 K and 100 kPa. A 500-W electric resistance heater placed in the tank is now turned on and kept on for 40 min after which the pressure of CO2 is measured to be 175 kPa. Assuming the surroundings to be at 300 K and using constant specific heats, determine (*a*) the final temperature of CO2, (*b*) the net amount of heat transfer from the tank, and (*c*) the entropy generation during this process.



13. An electric motor operating at steady state draws a current of 10 A with a voltage of 220 V. The output shaft rotates at 900 rpm with a torque 16 N.m applied to an external load. The rate of heat transfer from the motor to its surroundings is related to the surface temperature T_b and the ambient temperature T_0 by the relationship $\dot{Q} = hA(T_b - T_0)$, where h = 100 W/m^{2}K, A = 0.2 m^2, and T_0 = 293 K. Energy transfers are indicted by the arrows shown in the Fig.
   i) Determine the temperature T_b in K
   ii) For just the motor as the system (i.e., its surface as the system boundary), calculate the rate of entropy generation within the system, and the rate of entropy transfer with heat.
   iii) Also, find out the entropy generated outside this system boundary



14. A computer chip consumes 2 kJ of electric work over time and rejects that as heat dissipation from its 47^o C surface to the surrounding air at 27^o C. How much entropy is generated within the chip, and how much outside?