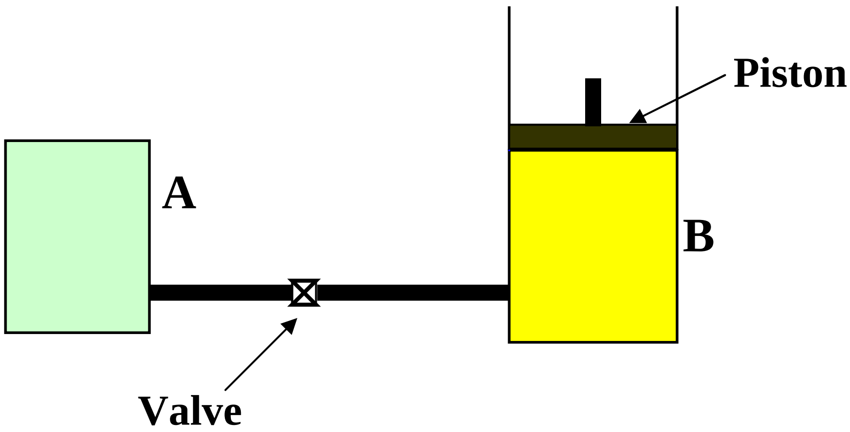
GWW School of Mechanical Engineering
Ph.D. Qualifier Exam, Fall 2005
Thermodynamics

Problem 1

In the piston-cylinder arrangement shown in the figure, both tanks contain H_2O. Tank *A* is $1\ m^3$ in volume. The two tanks are connected by a line and a valve. Initially Tank A contains saturated vapor at *150 kPa*, and Tank B contains $2\ m^3$ of H_2O at *400ºC* and *300 kPa*. The piston in Tank B maintains its pressure constant. The valve is opened, and water reaches *200 ºC* when equilibrium is achieved. Calculate:

a) The initial mass content of each tank.
b) The work and heat exchanged with the surroundings during the process.

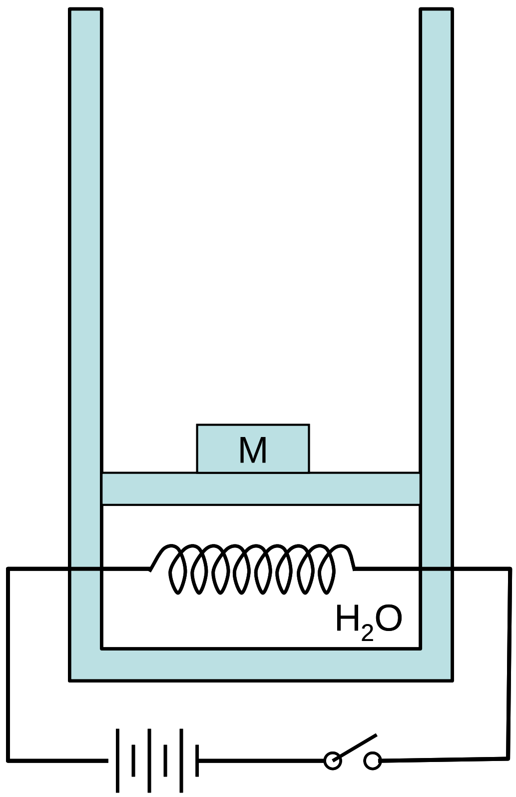


Problem 2

The figure below shows a cylinder containing 3 kg water, whose pressure is maintained at 200 kPa by a weight on a frictionless piston and the atmosphere. The cylinder walls are well insulated. An electric resistor is fed through and powered by a 30 V battery. Assume that initially the cylinder contains saturated liquid only. When the circuit is closed, an electric current of 1 A goes through the resistor for 15 minutes before the circuit is open again.

Find the following:

(a) The final volume inside the cylinder.
(b) The work done on the piston.
(c) The entropy generation if any in this process.



Problem 3

A refrigeration system for a household refrigerator is depicted below. It uses R-134a as the working fluid. The evaporator is located inside the refrigerator, and is required to absorb a 150 W heat transfer rate, in order to maintain the refrigerated space at a desired temperature. The refrigeration system is designed to provide an evaporating (saturation) temperature of -20°C and a condensing (saturation) temperature of 34°C. The refrigeration system uses a long, small diameter capillary tube as the expansion (throttling) device. In the "base system", the tube (suction line) connecting the evaporator to the compressor is insulated, so the state of the refrigerant is the same at the evaporator outlet and the compressor inlet. Also in the base system, the heat loss from the capillary tube is negligible. The refrigeration designer is concerned that operation of the base system at "off-design" conditions could sometimes allow liquid slugs to enter the compressor (not desirable). Therefore, a modified system design, in which the capillary tube and the suction line are soldered together along a part of their length, is being considered. The resulting heat transfer will cause the refrigerant vapor to have 20°C of superheat at the compressor inlet (i.e., the temperature there will be 0°C).

Determine the impact of this change on the refrigeration system performance by calculating two ratios:

- $Ratio_m$ = mass flow rate for modified system/mass flow rate for base system
- $Ratio_W$ = power input for modified system/power input for base system

Briefly comment on (interpret) the results.

Assume that, in both systems, the evaporator outlet state is saturated vapor at -20°C and the condenser outlet state is saturated liquid at 34°C. Neglect pressure drops in the evaporator, condenser and suction line. Assume that the compression process is internally reversible and adiabatic.