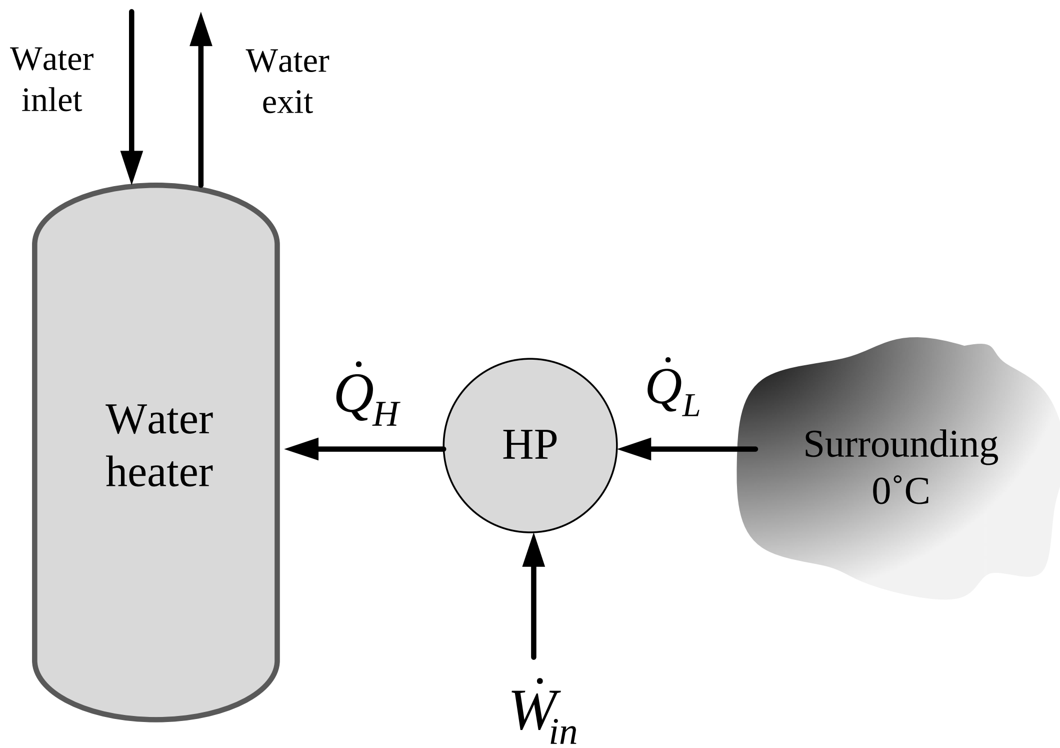
ENSC 388 Week # 6, Tutorial # 5– The Second Law of Thermodynamics

Problem 1: Cold water at *10°C* enters a water heater at the rate of *0.02* m^3/min and leaves the water heater at 5*0°C*. The water heater receives hest from a heat source at *0°C*.

a) Assuming the water to be an incompressible liquid that does not change phase during heat addition, determine the rate of heat supplied to the water, in *kJ/s*.
b) Assuming the water heater acts as a heat sink having an average temperature of 3*0°C*, determine the minimum power supplied to the heat pump, in *kW*.



<u>Solution</u>

Step 1: Write out what you are required to solve for (this is so you don't forget to answer everything the question is asking for)

Find:

a) $\dot{Q}_H$ - the rate of heat supplied to the water.

b) $\dot{W}_{in,\min}$ - the minimum power supplied to the heat pump.

Step 2: Prepare a data table

Data	Value	Unit
T_1	10	$[^{\circ}C]$
T_2	50	$[^{\circ}C]$
T_H	30	$[^{\circ}C]$
T_L	0	$[^{\circ}C]$
$\dot{\forall}$	0.02	$[m^3/\min]$

Step 3: State your assumptions (you may have to add to your list of assumptions as you proceed in the problem)

Assumptions:

1) Steady operating conditions exist.
2) The kinetic and potential energy changes are zero.
3) Constant properties are used for the water.

Step 4: Calculations

The specific heat and specific volume of water at room temperature are $c_p = 4.18\, kJ/kg$ and $\upsilon = 0.001\, m^3/kg$ (Table **A-3**).

a) An energy balance on the water heater gives the rate of heat supplied to the water.

$$\dot{Q}_H = \dot{m}\, c_p\, (T_2 - T_1) = \frac{\dot{\forall}}{\upsilon} c_p\, (T_2 - T_1) \quad \text{(Eq1)}$$

$$= \frac{(0.02/60)\,[m^3/s]}{0.001\,[m^3/kg]} (4.18\,[kJ/kg.^\circ C])\,(50-10)[^\circ C] = 55.73\,kW$$

b) The minimum power output is related to the maximum COP which is the COP of a reversible heat pump operating between the specified temperature limits.

$$COP_{\max} = \frac{1}{1 - T_L/T_H} = \frac{1}{1 - (0+273)/(30+273)} = 10.1 \quad \text{(Eq2)}$$

Note: Temperatures must be in Kelvin.

Then, the minimum power input would be

$$\dot{W}_{in,\min} = \frac{\dot{Q}_H}{COP_{\max}} = \frac{55.73\,kW}{10.1} = 5.52\,kW \quad \text{(Eq3)}$$