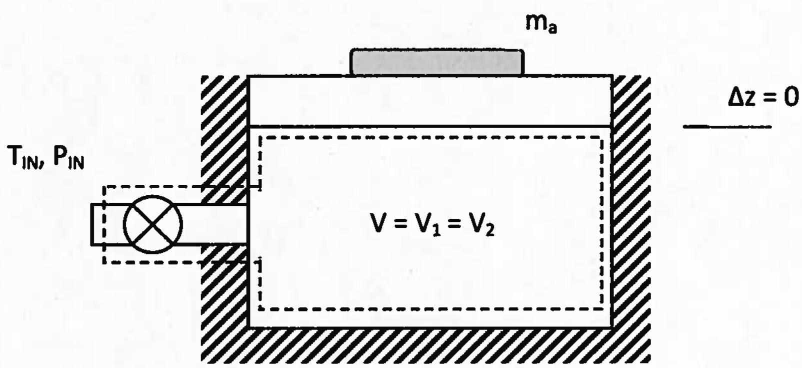
## Thermodynamics Qualifying Exam

### Problem 1

A pneumatic actuator is used to maintain the vertical height of a platform constant under a range of time-varying loads. The actuator is a piston-cylinder system with a piston diameter, $d_p$, and a piston mass of $m_p$. In response to an increase in the load that is imposed on the actuator, the actuator is supplied with an ideal gas at an inlet temperature of $T_{in}$ and pressure of $p_{in}$ through a control valve. The response of the control valve and actuator is very fast and can be assumed to be instantaneous and the entire assembly, including actuator and piston, are thermally insulated. The piston-cylinder system is initially in static equilibrium and the cylinder temperature is $T_1$ . An object with an known mass, $m_a$, is suddenly placed on the platform. Derive an expression for the final temperature, $T_2$, in the actuator cylinder.



**Problem 2**

1. Energy and entropy analysis of an adiabatic steady-state heat exchanger is to be conducted. First derive the following probably familiar formula for the change in entropy of an incompressible liquid. You may assume that the internal energy of a liquid is a function only of the temperature and that over a reasonable temperature range the specific heat is constant. Using one of the Gibbs (otherwise know as the *T- ds*) Equations, show that for this incompressible (i.e., constant density) liquid

(a) $s_2 - s_1 = C \ln\left(\frac{T_2}{T_1}\right)$

Now consider a heat exchanger that is said to operate in counterflow with 10 kg/s flow of hot high pressure water that is the heat source and 5.7 kg/s counterflow of similarly high pressure cooler inlet water that is the heat sink. The hot water enters at 120 C and leaves at 100 C. The cooler water enters at 90 C. Assume the specific heat of the pressurized water is constant 4.32 kJ/kg-K. Also assume that the viscous pressure drops in the heat exchanger flows are negligible. Assume the pressure is so high (several bar) that there is no chance of boiling.

Determine the following (**important**, please maintain at least 3 decimal places in calculations like "27.183" :

(b) the rate of entropy production in the proposed heat exchanger: __________ kW/K

(c) the outlet temperature of the cooler inlet water: __________ C

Answer the following questions:

(d) Does the calculated rate of entropy production make this proposed device seem to be possible? or alternatively impossible?

**(e) Is there any observation (other than the rate of entropy production) about the proposed device that makes it seem to be possible? or alternatively impossible?**

**(f) Is there is any apparent disagreement between the answers to the two questions above?**

**If so, please explain this discrepancy or disagreement.**

## Problem 3

A vapor-compression refrigeration system has two evaporators for cooling to two different temperatures. The system uses R-134a as the working fluid and operates at steady state. The low-temperature evaporator (1) operates at –18 °C and has a cooling capacity of 10 kW. The second evaporator (2) operates at 3.2 bar and has a cooling capacity of 7 kW. Saturated vapor exits both evaporators. The compressor is well insulated and isentropically compresses the refrigerant to 10 bar. Saturated liquid exits the condenser. Determine the mass flow rate of the refrigerant through each evaporator, the compressor power, the rate of energy transfer in the condenser, and the coefficient of performance of the cycle. Neglect any changes in kinetic and potential energy, pressure drop through the heat exchangers, and heat transfer to the surroundings from all valves and the mixing chamber. Assume that the states at points 4, 5, and 6 are identical.