**Examples of exercises you should be able to solve**

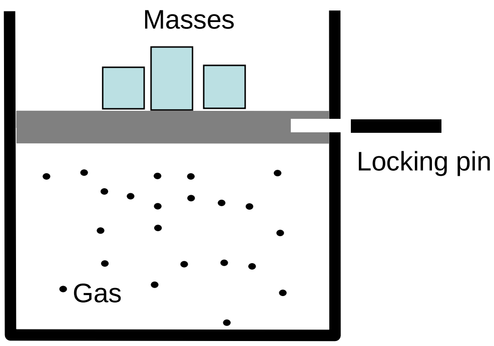
## a. Ideal gas law

Consider a piston chamber which is undergoing an expansion at constant temperature. The fluid within the chamber is helium, which behaves as ideal gas, and has molar mass of 4 kg/kmol and R = 2.07 kJ/kgK. The temperature is 100 °C, the initial pressure 30 bar, and the final pressure 1 bar. Calculate:

a) The specific expansion work [kJ/kg] and the specific heat that has to be transferred in order to have an isothermal process. Is the heat supplied or released?
b) The change of entropy in the piston chamber.

The cylinder of gas shown in the figure has a piston that can float up and down. You can:

lock or unlock the piston in place with a pin,
add or remove masses from the piston, or
place the entire cylinder in either a hot or a cold liquid.




a) Can you decrease the volume without changing the pressure? If so, how?

b) Can you decrease the volume without changing the temperature? If so, how?

c) Can you decrease the pressure without changing the temperature? If so, how?

d) Can you decrease the pressure without changing the volume? If so, how?

## b. Mass and Energy balances

Water (200 kPa, 10 °C) enters a mixing chamber at a mass flow rate of 150 kg/minute together with steam (200 kPa, 150 °C). The mixture leaves the mixing chamber at 200 kPa and 70 °C. The mixing chamber has a heat loss of 190 kJ/minute to the environment which has a temperature of 20 °C.

The following properties are given:

| | *h* (kJ/kg) | *s* (kJ/(kg·K)) |
|---|---|---|
| Water | 42.022 | 0.1511 |
| Steam | 2769.1 | 7.2810 |
| Mixture | 293.07 | 0.9551 |

<u>Determine</u>:

a. The mass flow rate of the input steam in kg/minute.
b. The exergy loss of the mixing chamber in kJ/minute (if you could not find a value for the mass flow rate of the steam, use 15 kg/minute).

## c. Entropy balance

In a stationary steam turbine, steam expands adiabatically from 500 °C and 10 bar to a final pressure of 2 bar. Assume that the steam can be treated as an ideal gas with a constant specific heat $c_p$=1.846 $kJ \cdot kg^{-1} \cdot K^{-1}$. The gas constant of steam is 0.4615 $kJ \cdot kg^{-1} \cdot K^{-1}$.

a. Draw in an *h-s* diagram a sketch of the adiabatic expansion of steam, with two isobars at 2 and 10 bar and an isentropic turbine efficiency of 90% and 100%, respectively.
b. Calculate the final temperature at an isentropic turbine efficiency of 100%.
c. Calculate the final temperature at an isentropic turbine efficiency of 90%.
d. Calculate the irreversible entropy production in $kJ \cdot kg^{-1} \cdot K^{-1}$ at an isentropic turbine efficiency of 90%.