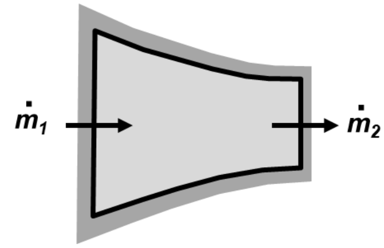
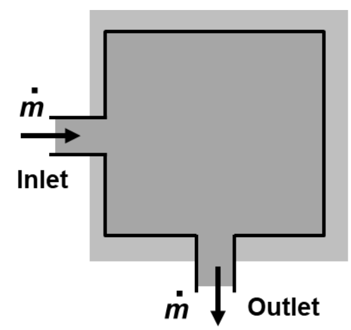
HW – 14: Open System Mass Balances

i) A nozzle is a device for increasing the velocity of a flow stream. Consider steady flow of air through a nozzle that is used for an electric hair dryer. Air enters the nozzle at a velocity of 3 m/s, pressure of 110 kPa, and temperature of 60°C, and exits at a velocity of 15 m/s, pressure of 100 kPa, and temperature of 60°C. Determine the ratio of inlet to exit area of the nozzle.



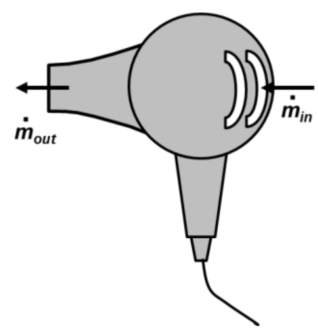
ii) A garden hose is attached to a nozzle is used to fill a 5-gallon bucket. The inner diameter of the hose is 2.54 cm and is reduced to 1.27 cm within the nozzle. The water is flowing through the hose at a velocity of 2 m/s and temperature of 20°C. Determine the a) volumetric flow rate (m^3/s) and mass flow rate (kg/s) of the water in the hose, b) velocity at the exit of the nozzle, and c) the time it takes to fill an empty bucket (minutes).

iii) A steady flow of saturated liquid water at 50°C enters a device that creates a pressure drop and exits as a homogeneous two-phase mixture at a pressure of 20 kPa and quality of 0.2. If the cross-sectional areas at the inlet and outlet of the device are equal, determine the ratio of the exit velocity to the inlet velocity.

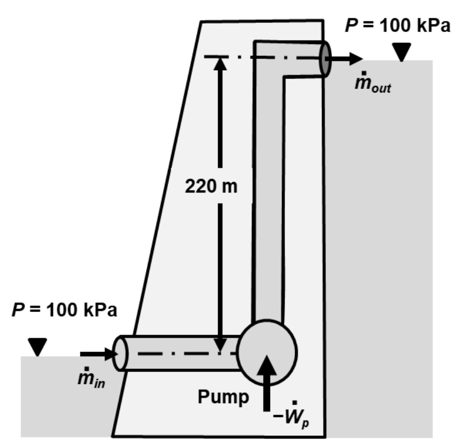


HW – 15: Open System Energy Balances

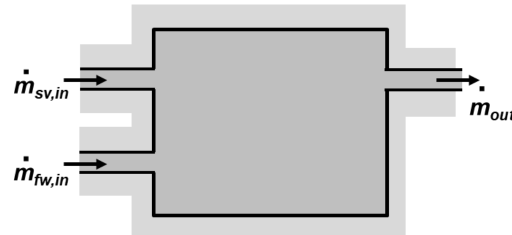
i) Consider the complete hair dryer and properties from HW-14(i). The electric hair dryer is drawing 60 cfm (cubic feet per minute) of air from the room at 20°C and 100 kPa with an inlet velocity of 1 m/s. For the given operating conditions, estimate the overall electrical power input to the hair dryer. You can neglect heat transfer from the dryer to the room. Based on the calculations, comment on whether it is reasonable to neglect kinetic energy changes.



ii) In order to store excess electricity generated during the day by solar PV, a utility in Nevada is considering using pumps to move water from below the Hoover Dam to its supply reservoir at the top of the dam for use later in the day. The height between the inlets and outlets for the Hoover Dam is 220 m. During peak solar availability, the utility operators would like to pump water at a volumetric flow rate of 850 m^3/s. Using this information and open system energy balances, determine the (a) minimum pump power requirement (MW) and (b) pressure at the pump outlet located at the bottom of the dam. Note that to determine the minimum pump power, you can assume frictionless/isothermal flow with a temperature of 20°C, ambient pressures at the inlet and outlet of 100 kPa, constant diameter piping, and negligible heat transfer.

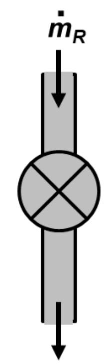


iii) In steam power plants, open feedwater heaters are used for heat recovery and operate by mixing steam bled off the turbine at some intermediate stage with water that is to be supplied to the boiler. Consider an open feedwater heater that operates at a pressure of 1000 kPa. Feedwater at 50°C and 1000 kPa is mixed with the superheated steam at 200°C and 1000 kPa. In an ideal feedwater heater, the mixture leaves the heater as saturated liquid at the feedwater pressure. Determine the ratio of the mass flow rates of the feedwater and the superheated vapor for this case.

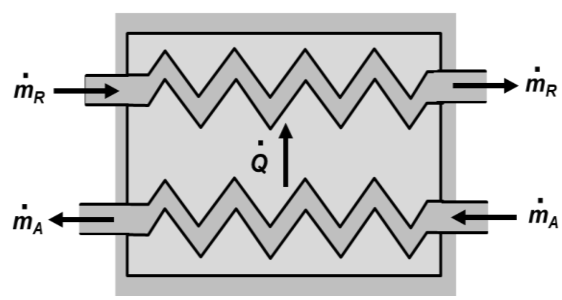


HW – 16: More Open System Energy Balances

i) A major U.S. manufacturer of HVAC equipment is considering the use of propane as a refrigerant for a residential air conditioner in a hot climate. As a first step, an engineer wants to understand the operating conditions for an adiabatic throttling device that would be used. The design inlet condition is a saturated liquid at a pressure of 18 bar. The engineer would like the throttle outlet condition to be a two-phase mixture at a temperature of 4°C. With this information, determine the exit pressure (kPa) and quality. Depict the process on a P-v diagram showing the dome and appropriate lines of constant temperature. Label the state points and show values of pressure and specific volume on the axes.



ii) Consider the indoor heat exchanger to be used for the propane air conditioner of problem 16(i). There is a heat transfer from an air flow stream to the propane refrigerant. The design engineer wants to determine the air flow and refrigerant flow rates necessary to achieve a target heat transfer rate of 10 kW at the following design conditions: 1) air inlet temperature from the house of 20°C, 2) air outlet temperature supplied to the house of 10°C, 3) entering propane refrigerant temperature of 4°C with a quality as determined in 16(i), and 4) leaving propane refrigerant temperature of 4°C with a saturated vapor. Determine the air mass flow (kg/s) and propane mass flow (kg/s) requirements. Depict the process for the propane on a T-v diagram showing the dome, appropriate lines of constant pressure, and labeled state points. Depict the air temperature variation from inlet to outlet on this plot in relation to the refrigerant temperature.



iii) Now consider the compressor power requirements for the propane air conditioner of problem 16(i). The design compressor inlet condition is a saturated vapor at a temperature of 4°C and the outlet pressure is 18 bar. The compressor exit temperature is estimated to be 60°C and the heat loss rate is expected to be 10% of the power input. Determine the required compressor inlet power (kW). Depict the process on a P-v diagram showing the dome and appropriate lines of constant temperature. Label the state points and show values of pressure and specific volume on the axes. What is the cooling COP of the cycle based on the cooling and compressor power?