1. A closed rigid-wall tank with volume $V = 0.1 \text{ m}^3$ contains 1 kg wet steam including liquid water and vapor phases in equilibrium, as shown below. The specific volumes of the liquid and vapor phases are $1.127 \times 10^{-3} \text{ m}^3/\text{kg}$ and $0.1943 \text{ m}^3/\text{kg}$, respectively. (Sketch is not to scale)
   a. Calculate the volume occupied by the vapor phase
   b. Calculate the mass fraction of liquid water in the water-steam mixture in the system.

2. The temperature, $T$ in °C on a thermometric scale is defined in terms of a property, $x$, by the relationship.

   \[ T = a \log_{10} x + b \]

   At the ice point, $x = 2.3$ and at the steam point, $x = 6.8$. Evaluate the temperature when $x = 3$.

3. A CU engineering student is tired of the fact that the ice point of water in existing absolute temperature scales is an awkward number. She proposes a new absolute temperature scale, called the Buff scale, with the Buff degree symbolized by B. The ice point of water is 500 B.
   a. Is this a valid temperature scale? Why/Why not?
   b. What is the boiling (steam) point of water in B?
   c. “Room temperature” is generally considered to be 20 degrees Celsius (°C). Calculate room temperature in B.

4. Calculate the work done by the systems (denoted in italics) in the following processes:
   a. A body of mass 10 kg falls freely through a vertical distance of 30 m in a gravitational field with $g = 9.81 \text{ m/s}^2$. The drag force of the atmosphere on the body is 4 N. (system consists of the body and the atmosphere)
b. A mechanical \textit{stirrer} driven by an electric motor mixes a fluid for 10 min. The motor exerts a torque of 0.006 N\textperiodcentered m and the stirrer rotates at 900 rpm. (The system is the stirrer and the fluid stirred.)

c. A 2-kW \textit{electric kettle} (includes heating element and water) is turned on for 5 min.

5. Specify:
   a. A closed system with a fixed boundary and define any two intensive thermodynamic properties of the system
   b. A closed system with a movable boundary and define any two extensive thermodynamic properties of the system
   c. An open system and define any two independent intensive properties of the system

6. Gas is trapped in two horizontal pistons by frictionless pistons, shown below. The cylinders are connected by a valve that is closed. The system is the gas in the cylinders. What is the magnitude of the force, \( F \), in kN, required to maintain static equilibrium in the system with the valve closed? (area of piston face = 0.03 m\(^2\))?

\[ F = \frac{(100 \text{ kPa} - 200 \text{ kPa}) \times 0.03 \text{ m}^2}{0.006 \text{ N\textperiodcentered m}} = \frac{-100 \text{ kPa} \times 0.03 \text{ m}^2}{0.006 \text{ N\textperiodcentered m}} = \frac{-3 \text{ N\textperiodcentered m}}{0.006 \text{ N\textperiodcentered m}} = -500 \text{ N} \]

7. The device below is used to raise the pressure of air in the rigid tank above the initial value of 100 kPa. When a force, \( F \), is applied to the frictionless piston and the pressure in the cylinder exceeds 200 kPa, the one-way valve opens and air is pushed into the rigid tank. Assume that during this process, the air pressure in the cylinder remains at just barely above 200 kPa while the piston moves 0.2 m to the right. Cross sectional area of the piston (face) is 0.03 m\(^2\). Consider the system as the cylinder and the rigid tank.
   a. Is this system open or closed? Justify your answer.
   b. Calculate the work of the system, applying the sign convention.
   c. Calculate the work of the surroundings, applying the sign convention.
8. Determine the atmospheric pressure at a location where the barometer reading is 750 mm Hg. (The density of mercury is 13,600 kg/m³).

9. The barometer of a mountain hiker reads 930 mbars at the beginning of the hike and 780 mbars at the end. Neglecting the effect of altitude on local gravitational acceleration, determine the vertical distance climbed, assuming an average air density of 1.2 kg/m³.

10. A pressure cooker cooks food a lot faster than an ordinary pan by maintaining higher pressure and temperature inside. The lid of a pressure cooker is well sealed during cooking and steam can escape only through a small opening in the middle of the lid. The opening is covered by a metal petcock. The weight of the petcock prevents steam from escaping until it reaches a pressure inside high enough to lift the petcock slightly releasing just enough steam until the opening is closed again by the weight force of the petcock, thus maintaining constant pressure inside the cooker. What is the mass of the petcock required to maintain 100 kPa gage pressure in the cooker when the opening has a cross-sectional area of 4 mm². Assume atmospheric pressure is 101 kPa. Include a free body diagram of the petcock in your solution showing all forces.