1. At what temperature will a system have the same numerical value on the Centigrade (or Celsius) and the Fahrenheit scale? Express your result on the Kelvin and the Rankine scale.

2. A gas within a piston-cylinder assembly undergoes a thermodynamic cycle consisting of three processes: **Process 1-2:** Compression with \( pV \) = constant, from \( p_1 = 1 \) bar, \( V_1 = 2 \text{ m}^3 \) to \( V_2 = 0.2 \text{ m}^3 \), \( U_2 - U_1 = 100 \text{ kJ} \). **Process 2-3:** Constant volume to \( p_3 = p_1 \). **Process 3-1:** Constant pressure and adiabatic process.

Sketch the cycle in \( pV \) diagram and determine the net work of the cycle in \( kJ \) and the heat transfer for process 2 – 3 in \( kJ \).

3. Helium gas is contained in a closed rigid tank. An electric resistor in the tank transfers energy to the gas by heating at a constant rate of 1 \( \text{kW} \). Heat transfer from the gas to its surroundings occurs at a rate of 5 \( \text{twatts} \), where \( t \) is time, in minutes. Plot the change in internal energy of the helium, in \( kJ \), for \( t \geq 0 \). At what time, does the gas return to its initial value of the internal energy?

4. Steam in a piston-cylinder assembly undergoes a polytropic process. The initial and final state are \( p_1 = 690 \text{kN/m}^2 \), \( v_1 = 0.3 \text{ m}^3/\text{kg} \), \( u_1 = 2643 \text{kJ/kg} \) and \( p_2 = 276 \text{kN/m}^2 \), \( v_2 = 0.7 \text{ m}^3/\text{kg} \), \( u_2 = 2615 \text{kJ/kg} \), respectively. For the process, determine the work and heat transfer, each in \( kJ/kg \) of steam.

5. Air at 1 bar and 25\(^\circ\)C with specific volume 1 \( \text{m}^3/\text{kg} \) is compressed to 5 bar and 25\(^\circ\)C by two reversible processes: a) cooling at constant pressure followed by heating at constant volume and b) heating at constant volume followed by cooling at constant pressure. Assume \( c_p = 1 \text{kJ/(kg K)} \) to be constant. The molecular weight of air can be taken as \( M = 28 \text{g/mol} \). With the ideal-gas model, calculate the heat and work requirements and \( \Delta u \) and \( \Delta h \) of the air for both cases expressing in the units of \( kJ/kg \).

6. For an ideal gas, show that

\[
\int_1^2 \frac{\delta q}{T} = c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}
\]

by assuming \( c_v = \text{constant} \).

7. Find the work done per unit mass by a gas during an isothermal expansion from an initial specific volume \( v_1 \) to a final specific volume \( v_2 \) if the equation of state is

\[
\frac{pv}{RT} = 1 + \frac{B(T)}{v} + \frac{C(T)}{v^2}.
\]