Problem 1 (15%)
A bottle containing 100 liters air at 5 bars and 25°C is filled with compressed air at 25°C until a pressure of 50 bars is reached. Suppose the process is adiabatic and air is an ideal gas with constant heat capacity, find the amount of air injected into the bottle. The heat capacity of air is \( c_p = 1.0045 \text{ kJ/kg } \text{K} \).

Problem 2 (15%)
An insulated chamber with a volume of 100 liters is filled with air at 100 kPa and 25°C. A peddle rotates inside the chamber, doing work on the air until its temperature has been raised to 50°C. Suppose air is an ideal gas with constant specific heat, find the amount of work being done and the net entropy change of the system. The atmospheric temperature is 25 °C.

Problem 3 (20%)
What is the minimum work that has to be done to cool down 1 kg of water at 25°C to the temperature of -10°C. The heat capacity of water is 4.186 kJ/kg-K and that of ice is 2.11 kJ/kg-K. The enthalpy of melting of ice at 0°C is \( \Delta h_{fs} = 333.4 \text{ kJ/kg} \), and the atmospheric temperature is 25 °C. (Hint: The minimum work is the work of a process in which net entropy change is zero.)
Problem 4 (25%) (Thermal resistance for steady 1-D conduction)
A house has a composite wall of wool ($k_w = 2.0$ W/m•K), fiberglass insulation ($k_b = 0.2$ W/m•K), and plaster board ($k_p = 4.0$ W/m•K), as shown below. On a cold winter day the convection heat transfer coefficients are $h_p = 60$ W/m$^2$•K and $h_l = 20$ W/m$^2$•K. The total wall surface area is 250 m$^2$.
(a) Draw the thermal circuit for the system and determine the total thermal resistance of the wall, including inside and outside convection effects. (b) Determine the total heat loss through the wall. (c) Find the temperatures at the inside surface A of the plaster board and at the interface B between the glass fiber blanket and plywood siding.

Problem 5 (25%) (Parameters in convection heat transfer)
Experimental measurements of the convection heat transfer coefficient for a square bar with characteristic length $L = 0.5$ m in cross flow yielded the following values:
\[ h_1 = 60 \text{ W/m}^2 \cdot \text{K} \quad \text{when flow velocity } V_1 = 18 \text{ m/s} \]
\[ h_2 = 40 \text{ W/m}^2 \cdot \text{K} \quad \text{when flow velocity } V_2 = 12 \text{ m/s} \]

Assume that the functional form of the Nusselt number is $Nu = CRe^m Pr^n$, where $C$, $m$, and $n$ are constants, and $Re$ and $Pr$ denote the Reynolds number and Prandtl number, respectively. (a) What will be the convection heat transfer coefficient for a similar bar with $L = 1.0$ m when $V = 12$ m/s? (b) If we want to maintain the convection heat transfer coefficient at 120 W/m$^2$•K for a similar bar with $L = 1.0$ m, what will be the velocity $V$?