1. Air enters a compressor operating at steady state with a pressure of 1 bar and a volumetric flow rate of $0.3 \text{m}^3/\text{s}$. The air velocity in the exit pipe is $70 \text{m/s}$ and the exit pressure is 10 bar. If each unit mass of air passing from inlet to exit undergoes a process described by $pv^{1.3} = \text{constant}$, determine the diameter of the exit pipe, in meters.

2. At steady state, air at 200 kPa, 325 K, and mass flow rate of $0.5 \text{kg/s}$ enters an insulated duct having differential inlet and exit cross-section areas. The inlet cross-sectional area is $6 \text{cm}^2$. At the duct exit, the pressure of the air is 100 kPa and the velocity is $250 \text{m/s}$. The inlet and the exit sections are kept at an elevation difference of 10 m, with the inlet section being at the top. Modeling air as an ideal gas with constant $c_p = 1 \text{kJ/(kgK)}$, determine 1) the velocity of the air at the inlet, in m/s, 2) the temperature of the air at the exit, in K and 3) the exit cross-sectional area, in cm$^2$.

3. Consider a horizontal constant-diameter pipe with a build-up of debris. Air modeled as an ideal gas enters at 320 K, 900 kPa, with a velocity of $30 \text{m/s}$ and exits at 305 K. Assuming steady state and neglecting stray heat transfer, determine for the air exiting the pipe 1) the velocity, in m/s, and 2) the pressure, in kPa. Take $c_p = 1 \text{kJ/(kgK)}$ for air.

4. a) Show that two reversible adiabatic lines cannot intersect for a real gas. Prove by contradiction. Hint: Try to violate Kelvin-Planck statement.
   b) Two kilograms of air within a piston-cylinder assembly execute a Carnot power cycle with maximum and minimum temperatures of 750 K and 300 K, respectively. The heat transfer to the air during the isothermal expansion is $60 \text{kJ}$. At the end of the isothermal expansion the volume is $0.4 \text{m}^3$. Assuming the ideal gas model for the air, determine b.1) the thermal efficiency
   b.2) the pressure and volume at the beginning of the isothermal expansion, in kPa and m$^3$, respectively
   b.3) the work and heat transfer for each of the four processes in kJ.

5. a) A heat engine receives 1163 $\text{kJ/kg}$ of heat per cycle from a reservoir at $540 ^\circ \text{F}$ and rejects heat to a reservoir at $40 ^\circ \text{F}$ in the hypothetical amounts of 1) $872 \text{kJ/kg}$ per cycle, 2) $582 \text{kJ/kg}$ per cycle, and 3) $125 \text{kJ/kg}$ per cycle. Which of these respective cases represent a reversible cycle, an irreversible cycle, and an impossible cycle?
   b) An engine with 28 per cent thermal efficiency is used to drive a refrigerator having a coefficient of performance of 5, both operating between the same reservoirs. No net work is obtained in the combined engine-refrigerator system. Determine the heat supplied to the engine for each $\text{kJ/kg}$ of heat removed from the cold body by the refrigerator.
   c) An inventor claims to have developed a power cycle operating between hot and cold reservoirs at 1175 K and 295 K, respectively, that provides a steady-state power output of 1) 28 kW, 2) 31.2 kW, while receiving energy by heat transfer from the hot reservoir at the rate 150,000 kJ/h. Evaluate each claim.

6. Determine the specific entropy change of perfect gas which is initially at 330 K, 9 atm, and is expanded irreversibly to 1 atm, 290 K.

7. For incompressible substance (density remains constant), $c_p(T) = c_v(T) = c(T)$. The following questions deal with incompressible substances and you can also assume $c$ to be independent of temperature. a) Show that the specific entropy change for a process between state 1 and 2 is
   \[ \Delta s = c \ln \frac{T_2}{T_1}. \]
b) Two identical bodies of mass \( m \) and \( c \) are at temperatures \( T_1 \) and \( T_2 \). They are used as source and sink for a heat engine, respectively. Show that the maximum work obtainable is given by \( mc(\sqrt{T_1} - \sqrt{T_2})^2 \).