Problems from Moran Shapiro (5th Ed.)

4.17 Air enters a control volume operating at steady state at 1.05 bar, 300 K, with a volumetric flow rate of 12 m^3/min and exits at 12 bar, 400 K. Heat transfer occurs at a rate of 20 kW from the control volume to the surroundings. Neglecting kinetic and potential energy effects, determine the power, in kW. Ans: -44.6

4.19 Methane (CH_4) gas enters a horizontal, well-insulated nozzle operating at steady state at 80°C and a velocity of 10 m/s. Assuming ideal gas behavior for the methane, plot the temperature of the gas exiting the nozzle, in °C, versus the exit velocity ranging from 500 to 600 m/s.

4.21 Air enters an insulated diffuser operating at steady state with a pressure of 1 bar, a temperature of 300 K, and a velocity of 250 m/s. At the exit, the pressure is 1.13 bar and the velocity is 140 m/s. Potential energy effects can be neglected. Using the ideal gas model, determine

(a) the ratio of the exit flow area to the inlet flow area.
(b) the exit temperature, in K.

4.26 Nitrogen gas enters a turbine operating at steady state with a velocity of 60 m/s, a pressure of 0.345 Mpa, and a temperature of 700 K. At the exit, the velocity is 0.6 m/s, the pressure is 0.14 Mpa, and the temperature is 390 K. Heat transfer from the surface of the turbine to the surroundings occurs at a rate of 36 kJ per kg of nitrogen flowing. Neglecting potential energy effects and using the ideal gas model, determine the power developed by the turbine, in kW.

4.30 Air is compressed at steady state from 1 bar, 300 K, to 6 bar with a mass flow rate of 4 kg/s. Each unit of mass passing from inlet to exit undergoes a process described by $pv^{1.27} = constant$. Heat transfer occurs at a rate of 46.95 kJ per kg of air flowing to cooling water circulating in a water jacket enclosing the compressor. If kinetic and potential energy changes of the air from inlet to exit are negligible, calculate the compressor power, in kW.

4.40 Carbon dioxide gas is heated as it flows steadily through a 2.5-cm-diameter pipe. At the inlet, the pressure is 2 bar, the temperature is 300 K, and the velocity is 100 m/s. At the exit, the pressure and velocity are 0.9413 bar and 400 m/s, respectively. The gas can be treated as an ideal gas with constant specific heat $c_p = 0.94$ kJ/kg · K. Neglecting potential energy effects, determine the rate of heat transfer to the carbon dioxide, in kW. Ans: 56.1

4.51 Electronic components are mounted on the inner surface of a horizontal cylindrical duct whose inner diameter is 0.2 m, as shown in Fig. P4.51. To prevent overheating of the electronics, the cylinder is cooled by a stream of air flowing through it and by convection from its outer surface. Air enters the duct at 25°C, 1 bar and a velocity of 0.3 m/s and exits with negligible changes in kinetic energy and pressure at a temperature that cannot exceed 40°C. If the electronic components require 0.20 kW of electric power at steady state, determine the minimum rate of heat transfer by convection from the cylinder's outer surface, in kW, for which the limit on the temperature of the exiting air is met.