1. A gas-turbine power plant operates with a two-stage compressor, a two-stage turbine, and a regenerator. The pressure ratio across each stage of compression and expansion is three. Both turbine inlets are at $1800\,\text{K}$ and both compressor inlets are at $300\,\text{K}$. The regenerator effectiveness is 75%, both compressor stages have an isentropic efficiency of 85%, and both turbine stages have an isentropic efficiency of 90%. Sketch the cycle on a $T - s$ diagram. Calculate the thermal efficiency of the cycle and the back work ratio. Use an air-standard analysis.

2. A converging-diverging nozzle is supplied by a plenum chamber where $P_o = 600\,\text{kPa}$. The throat diameter is $1\,\text{cm}$ and the exit diameter is $2\,\text{cm}$. The static temperature at the throat is $250\,\text{K}$. If a normal shock is observed at a diameter of $1.5\,\text{cm}$, what is the pressure in the region where the nozzle discharges? Assume $k = 1.4$.

3. A converging nozzle supplies a long, adiabatic pipe which discharges to a region where $P = 100\,\text{kPa}$. The pressure at the entrance of the pipe is $288\,\text{kPa}$ and the pressure at the exit of the pipe is $193\,\text{kPa}$. Find the new pressures at the inlet and exit of the pipe if the pressure in the plenum chamber supplying the converging nozzle is changed to $133\,\text{kPa}$. Assume $k = 1.4$.

4. A 4-cm diameter, frictionless, heated duct is connected to the exit of a converging-diverging nozzle. The converging-diverging nozzle has a design Mach number of 2. Heat is added in the heated duct at a rate of $386.1\,\text{kJ/kg}$. In the plenum chamber supplying the converging-diverging nozzle, $T_o = 300\,\text{K}$ and $P_o = 1\,\text{MPa}$. The duct discharges to a vacuum. Calculate the static pressure at the exit of the heated duct. Assume a constant $c_P = 1.007\,\text{kJ/(kg} \cdot \text{K)}$ and $k = 1.4$.

5. Gaseous propane (C_3H_8) at 25^oC and $1\,\text{atm}$ enters a well-insulated reactor, and reacts with air that enters the reactor at $400\,\text{K}$ and $1\,\text{atm}$. What percentage of theoretical air is used in this combustion reaction if the temperature of the products of combustion is $1200\,\text{K}$? Assume that the effects of kinetic and potential energy are negligible.

6. An air-standard dual cycle has a compression ratio of 9. At the beginning of compression, $p_1 = 100\,\text{kPa}$ and $T_1 = 300\,\text{K}$. The heat addition per unit mass of air is $1400\,\text{kJ/kg}$, with 40 percent added at constant volume and 60 percent added at constant pressure.

   (a) Sketch the cycle on a $p - v$ diagram.

   (b) Calculate the pressure at the end of the constant volume combustion process.

   (c) Calculate the cutoff ratio r_c.

   (d) Use a sketch on a $p - v$ diagram to explain so called *blowdown losses*.