Thermodynamics

Do two of the following three problems, each on a separate sheet (or sheets). Staple together the sheets for each problem, if using multiple sheets, but do not staple all problems together. Write at the top of the first sheet of each problem your name, subject, and problem number.

Problem 1

Consider one mole of an ideal monatomic gas with initial conditions of temperature, volume and pressure given by T_a, V_a and P_a, respectively. From this point a (on a PV diagram), the gas goes through a cycle with separate legs. First, it is isothermally compressed to half its initial volume at point b; then, the gas is kept at constant volume and the pressure is increased to twice the value it had at point b (point c). After the constant volume compression, the gas expands isothermally to its original volume (point d). Finally, pressure is reduced at constant volume, and the gas returns to its initial values of temperature, volume and pressure.

a) Draw a PV diagram showing these stages in the cycle of this gas. What is the temperature of the gas at point c in terms of T_a?

b) Determine the total work done in the cycle, making sure your answer includes both magnitude and sign (of course your answer will not be numerical). You should be able to express your answer in terms of temperature (and constants) only.

c) What is the value of Q for the entire process?

Problem 2

Apply the Clausius-Clapeyron relation to derive an equation describing the boiling temperature of a liquid as a function of altitude. Use this relation to estimate the boiling temperature of water in Las Cruces. The altitude of Las Cruces is approximately 1200 m above sea level. The molar mass of dry air is $M = 28.97$ g/mol and the latent heat of water vaporization is $L = 40.66$ kJ/mol.

Problem 3

Consider a free, ultrarelativistic, electron gas at zero temperature. Derive the relation between pressure and volume.