Thermodynamics

Do two of the following three problems, each on a separate page (or pages) and write your name on every page you turn in.

Problem 1

Refrigeration cycles have been developed for heating buildings. Heat is absorbed from the earth by a fluid circulating in buried pipes and heat is delivered at a higher temperature to the interior of the building. If a Carnot refrigerator were available for use in this way, operating between an outside temperature of 0 C and an interior temperature of 25 C, how many kilowatt-hours of heat would be supplied to the building for every kilowatt-hour of electrical energy needed to operate the refrigerator?

Problem 2

A system consists of N identical particles with zero intrinsic spin. Each particle may be in one of many possible states. The energies of those states are E_0, E_1, E_2, E_3, and so on, and they are related to each other like this:

$$E_m = mD$$

where D is a positive constant with units of energy.

The system is held at a fixed temperature of $T = 10D/k_B$. Calculate the expected total energy U of all the particles.

Problem 3

The universe is permeated by a microwave radiation with a spectrum corresponding to the emission of a black body; a remnant of the big bang. The peak of the spectrum is at a wavelength $\lambda = 1.06\,\mathrm{mm}$. Calculate the pressure exerted by this radiation.

Useful constants:

Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}\mathrm{W\,m^{-2}K^{-4}}$

Wien's displacement constant $b = 2.898 \times 10^{-3}\,\mathrm{m\,K}$