Thermodynamics

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

Problem 1

What color is the sun? Estimate the wavelength at the peak of the solar radiation spectrum by using only the fact that the sun's angular diameter (apparent size) as seen from the earth is approximately $0.5°$ and making the following assumptions and approximations:

- Earth and sun are perfect black bodies
- The earth is in thermal equilibrium with the radiation it receives from the sun
- The earth is at a uniform temperature of $15°\,\mathrm{C}$

The Wien displacement law constant is to a good approximation equal to $3 \times 10^{-3}\mathrm{m\,K}$.

Problem 2

El Paso Electric operates a set of steam and gas turbines at its Newman plant. The largest system at the Newman plant is the Newman-5, consisting of two gas-fired turbines and a steam turbine. The hot exhaust gases from the gas turbines are used to heat water in the steam turbine. The total power output of the combined system is 288 MW. It is claimed that the thermal efficiency of a combined gas- and steam- turbine system of this kind can be approximately 60%.

(a) Is it possible for the plant to operate at 60% thermal efficiency? Make a quantitative argument to explain your answer.

(b) Assuming that the 60% thermal efficiency is correct, then how much natural gas (in m^3/s) is needed to operate the Newman-5 at full power?

Additional information:

- 2.74 m^3 of natural gas can produce 105.5 MJ of energy.
- Natural gas burns at a temperature of 1960 °C.

Problem 3

A system consists of N particles, each of which may independently be in one of three states labeled $i = 1, 2, 3$. The energies of these states are $\epsilon_1 = -a$, $\epsilon_2 = 0$, and $\epsilon_3 = a$, where $a > 0$. The system is in thermal equilibrium with a reservoir at temperature T.

(a) Write the partition function for this system.

(b) What is the average total energy of the system $\langle U \rangle$, as a function of T?

(c) What temperature is required to find the system in a state with $\langle U \rangle = -Na$? $\langle U \rangle = 0$? $\langle U \rangle = +Na$?