

Physics 317

Homework #6 – *Due in class, Wed Oct 27*

Hint: Read about reversibility in Zemansky Chap 8 through Section 8.6.

1. A system has three energy levels, $\epsilon = 0 J$, $\epsilon = 273 c$, and $\epsilon = 546 c$, where $c = 1.38e - 23 J/K$ has the numerical value of Boltzmann's constant, but with units of Joules. The degeneracies of the levels are 1, 2, and 3, respectively.
 - a. Calculate the partition function, the relative populations of the energy levels, and the average energy, all at a temperature of 273 Kelvin.
 - b. At what temperature is the population of the energy level at $273 c$ equal to the population of the energy level at $546 c$.
2. 10 kg of water at 0°C must be frozen into ice. The refrigerator is in a room with ambient temperature of 20°C . The latent heat of fusion is 3×10^5 Joules per kilogram. What is the minimum power required to freeze the water in 30 minutes? *Assume your fridge is a Carnot and it has nothing else to do besides freeze the water.*
3. Which gives the greater increase in efficiency of a Carnot engine: increasing the temperature of the hot reservoir or lowering the temperature of the cold reservoir by the same amount?
4. Zemansky problem 7-6
5. Compute the single particle partition function for particles with energy only due to kinetic energy,

$$Z_1 = \int_0^\infty e^{-\epsilon/kT} D(\epsilon) d\epsilon = \frac{V}{\lambda_{th}^3}$$

where $D(\epsilon) = \frac{2\pi(2m)^{3/2}}{h^3} V \epsilon^{1/2}$ and

$\lambda_{th} \triangleq \frac{h}{\sqrt{2\pi mkT}}$ is the "thermal" de Broglie wavelength

Hints for #5: Make a change of variables to convert the messy integral into a cleaner one. Then use integration by parts to convert to the integral of a Gaussian. Finally, square that integral and use polar coordinates.