Berkeley Physics H7B Spring 2015
Dr. Winoto - Midterm 1 Examination
Thursday, February 19th, 2015

Instruction for the examination (please read carefully):
- Topic: Thermodynamics
- There are 3 problems (in the order of length and difficulty), **do them in any order you prefer**.
- Total points for the exam = 100 points for a perfect score
- You have exactly (90-10=80) minutes to complete the test
- Please outline and explain in details all your physical and mathematical reasonings in a clear, step-by-step and logical manner.

1. (25 points):
In a 3D ideal gas,
(a). Sketch the Maxwell distribution f(v_x) versus v_x for two different temperatures T_1 and T_2, with $T_2 > T_1$;
(b). Sketch the Maxwell distribution f(v) versus v for two different temperatures T_1 and T_2, with $T_2 > T_1$;
where v_x is the velocity in the x direction, and v is the speed of the particle. Please show your mathematical reasoning clearly.

2. (35 points): (see Figure 2 on the board):
A cylindrical container, filled with n moles of a gas of Argon (monoatomic), is compressed using a spring loaded piston of mass m and area A, as shown in fig. 2; the spring has a spring constant, k_s. At equilibrium with the spring:
- the Argon gas is at a pressure of P_o and temperature T;
- the piston is at a distance L_o from the end wall, as shown in the figure;
- and the spring is compressed from its natural length d by x_o.
For simplicity, let's set the origin of the coordinate system x=0 to be at the position of the mass of the piston at this equilibrium.
(a). In an isothermal process, whereby the piston is displaced by a small amplitude, the piston will oscillate (simple harmonic oscillation). Please calculate the frequency of oscillation ω_1.
(b). In an adiabatic process, whereby the piston is displaced by a small amplitude, the piston will also oscillate (simple harmonic oscillation). Please calculate the frequency of oscillation ω_2
(c). Extra credit: which process has higher frequency? and briefly, explain why? physically and/or mathematically.
Hint: for small x, one may use: $(1 + x)^{-n} \approx 1 - n\,x$

3. (40 points): (see Figure 3 on the board):
A finite body B1 of mass m_1 with a constant specific heat per unit mass c_1, is initially at temperatures T_1. Another body B2 is an infinite reservoir heatbath at a constant temperature T_2. T_1 is greater than T_2.
(a). Suppose we bring B1 into thermal contact with B2. Eventually, they reach a thermal equilibrium. Please calculate the entropy change of B1, the entropy change of B2, and the total entropy change. (ONLY if you have time, show that the total entropy change is strictly greater than zero).
Now, suppose INSTEAD of (a):
we use B1 and B2 as a high temperature reservoir and a low temperature reservoir, respectively, to run a Carnot engine. Or in other words, we use the Carnot engine to transfer heat from B1 into B2 until they reach a thermal equilibrium, after an infinite number of infinitesimal cycles, and the engine comes to rest.
(b). Calculate the total final amount of work W done by the Carnot engine.

(c). Calculate the total entropy change for B1, B2, and for the whole system (B1 + B2 + Carnot engine)