University of California, Berkeley
Physics 7B, Lecture 001, Spring 2009 (*Xiaosheng Huang*)

Midterm 1
Monday, 2/23/2009
6:00-8:00 PM

Name:______________________

SID: ________________________

D/L Section:_______________

GSI: ________________________

Physical Constants:
Avogadro's number, N_A: 6.02×10^{23}
Gas Constant, R: 8.315J/mol·K
Boltmann's Constant, k_B: 1.38×10^{-23} J/K
Stefan-Boltzmann Constant, σ: 5.67×10^{-8} W/m²·K⁴
Specific heat for water: $c=4.19\times10^3$ J/kg·°C
Heat of vaporization for water: $L_V=22.6\times10^5$ J/kg
Heat of fusion for water: $L_F= 3.33\times10^5$ J/kg
Standard Temperature and Pressure (STP): T=273K, P=1atm=1.01×10^5 Pa
Atomic mass unit (1u): 1.6605×10^{-27} kg

Note: You are allowed one formula sheet (3½ by 5, double sided) and a calculator (without wireless capabilities). Do NOT just write down an answer in the answer box; show your steps. Formulaic answers may only involve the quantities given in a problem and constants. Good Luck!

#1	
#2	
#3	
#4	
Total	

1. (25 pts.) A spherical solid aluminum sphere with mass M, density ρ, specific heat c, and emissivity e, floats in the vacuum of intergalactic space. The sphere is initially (t=0) at temperature T_1.

a) How long does it take for the aluminum sphere to cool to the cosmic microwave background (CMB) temperature, T_0, assuming $T_1 > T_0$? (For this part, ignore the radiation energy that the aluminum sphere will absorb from the (CMB)).

Formulaic Answer:

If T_1 = 300K and T_0 = 2.7K at t=0 and the mass of the aluminum sphere is M= 100 kg, find the numerical value for the cooling time. For aluminum, e = 0.02, $\rho = 2.7\times10^3$ kg/m^3, and $c = 0.90\times10^3$ J/kg•K.

Numerical Answer:

For parts *b*) and *c*), take into consideration that the aluminum sphere will absorb radiation energy from the CMB.

b) If the temperature of the aluminum sphere at time t is T, what is the net heat loss ($|Q_{net\ loss}|$) of the aluminum sphere at this point?

Formulaic Answer:

$\|Q_{net\ loss}\| =$

c) Find a differential equation whose solution is $T(t)$, the temperature of the aluminum sphere as a function of time, t.

Formulaic Answer:

2. (25 pts.) The mint flavor comes from menthol, which has a molecular mass of M=156.27, in atomic units. A bottle of mint oil at thermal equilibrium with the air in a room at STP is opened at one end of the room at t=0. Assume the menthol molecule is spherical in shape with a radius of R=0.5nm. Also assume the air in the room consists only of N_2 (ignore the O_2 part) and treat the N_2 as a spherical molecule with radius r=0.3nm. Ignore all intermolecular interactions except elastic collisions.

a) Find the number density (number of molecules per unit volume, N/V) of the N_2 in the room.

<u>Numerical Answer:</u>

b) Find the rms average speed, v_{rms}, for menthol molecule.

<u>Formulaic Answer:</u>

c) Derive an expression for the mean free path l for the menthol molecule in terms of the quantities given in the problem and N/V. (You don't need to worry about factors of $\sqrt{2}$.)

Formulaic Answer:

d) Given $x^2 = sl^2$, where x is the displacement, l the mean free path, and s the number of collisions the molecule has suffered traveling through x, find the time, t, it takes for a menthol molecule to reach a displacement of x on average.

Formulaic Answer:

e) Suppose the room is x=20m across, find the numerical value for the average time, t, it takes for a menthol molecule to go from one end of the room to the other.

Numerical Answer:

f) (1 bonus pt.) Does your answer agree with what you know from experience? If not, why not?

3. (25 pts.) At a steam power plant, steam engines work in pairs, the heat output of the first one being the approximate heat input of the second. The operating temperatures of the first are $T_1 = 800\ ^0\text{C}$ and $T_2 = 410\ ^0\text{C}$, and of the second $T_3 = 400\ ^0\text{C}$ and $T_4 = 250\ ^0\text{C}$.

a) If the heat of combustion of coal is $b = 3.0\times10^7$ J/kg, at what rate must coal be burned if the plant is to put out p=1000 MW of power? Assume the efficiency of the engines is f = 50% of the ideal (Carnot) efficiency.

<u>Formulaic Answer</u>

<u>Numerical Answer</u>

b) Water is used to cool the power plant. How much heat per second ($\Delta Q_w/\Delta t$) does the water have to absorb?

Formulaic Answer

Numerical Answer

c) If the water temperature is allowed to increase by no more than $\Delta T = 6\ ^0$C, estimate how much water must pass through the plant per second. You may use $\Delta Q_w/\Delta t$ in your formulaic answer.

Formulaic Answer

Numerical Answer:

4. (25 pts.) An ideal gas in a thermally insulated box is separated by a thermally conducting partition into two parts. There are n moles of gas in each part. Initially, the gas in part A has temperature T_1 and volume V_1 and in B temperature T_2 and volume V_2. The partition can slide without friction and the two parts have the same pressure, P.

a) What is the final temperature when thermal equilibrium is reached?

<u>Formulaic Answer</u>

b) Calculate the entropy change for the gas in A and for the gas in B. (Please specify the reversible path that you choose for this calculation.)

<u>Formulaic Answer</u>

c) Calculate the entropy change of the combined system of A and B, ΔS_{total}.

Formulaic Answer

d) (4 bonus pts.) Show that $\Delta S_{total} \geq 0$.