Midterm 1 Sample Exam

Physics 7B (Section 1) Spring 2002
(Prof. Young-Kee Kim)

Name :

Student ID Number :

Discussion Section :

Name of Teaching Assistant :

DO NOT OPEN THIS EXAM
UNTIL YOU ARE TOLD TO DO SO !!

Problem	Points	Score
1	8	
2	34	
3	12	
4	12	
5	34	
Total	100	

Some equations and numbers that might be useful.

- Ideal Gas Law :

$$PV = nRT$$

  - Universal gas constant, R

$$\begin{aligned} R &= 8.315\ J/(mol \cdot K) \\ &= 0.0821\ (L \cdot atm)/(mol \cdot K) \\ &= 1.99\ calories/(mol \cdot K) \end{aligned}$$

  - the number of moles, $n = N/N_A$
  - the number of molecules, N
  - Avogadro's number, $N_A = 6.02 \times 10^{23}$
  - Boltzmann's constant : $k = R/N_A$

- Internal Energy of an Ideal Gas :

$$U = \frac{3}{2}NkT = \frac{3}{2}nRT$$

- Specific Heat, c = amount of heat required to raise the temperature of unit mass by 1 C^o.

$$Q = mc\Delta T$$

  Q = Amount of Heat required to change the temperature of a given material with the mass m by ΔT.

- Molar Specific Heats for Gases, C_V and C_P, heat required to raise 1 mol of the gas by 1 C^o at constant volume and at constant pressure, repectively.

$$\begin{aligned} Q &= nC_V\Delta T \text{ (volume constant)} \\ Q &= nC_P\Delta T \text{ (pressure constant)} \\ C_P &= C_V + R \\ \gamma &= \frac{C_P}{C_V} \end{aligned}$$

- Adiabatic Expansion of a Gas

$$PV^\gamma = \text{constant} \tag{0.1}$$

- Heat Transfer: Conduction, Convection, Radiation

$$\begin{aligned} \frac{\Delta Q}{\Delta t} &= kA\frac{T_1 - T_2}{l} \text{ (conduction)} \\ \frac{\Delta Q}{\Delta t} &= e\sigma A(T_1^4 - T_2^4) \text{ (radiation)} \end{aligned}$$

- Entropy Change of Irreversible Heat Transfer
  e.g. an Entropy change ΔS of an object with mass m and specific heat c whose intitial temperature is T_i and whose final temperature is T_f :

$$\Delta S = mc \ln \frac{T_f}{T_i}$$

Problem #1 (8 points)

A steel metric scale is to be ruled so that the millimeter intervals are accurate to within 5×10^{-5} mm at a certain temperature. What is the maximum temperature variation allowable during the ruling ?

Problem #2 (34 points)

A sample of gas consisting of 0.11 mol is compressed from a volume of $V_i = 4.0$ m^3 to $V_f = 1.0$ m^3 along two paths (path 1 and path 2) while its pressure increases from 10 to 40 Pa. Path 1 represents an isothermal process. Path 2 consists of two processes, one at constant pressure followed by another at constant volume. Assume that the gas is ideal.

1. (8 points) Calculate the work done by the gas along the two different paths.

   (a) path 1 :

   (b) path 2 :

2. (6 points) What is the heat added to or removed from the gas in the two paths ? You should clarify the direction of heat.

   (a) path 1 :

   (b) path 2 :

3. (8 points) Let the cylinder be removed from the thermal resorvior and let us compress the gas reversely and adiabatically until its volume is $V_f = 1.0$ m^3. Calculate the pressure at $V_f = 1.0$ m^3 ? Assume the gas to be Helium (a monatomic gas with $\gamma = 1.66$).

4. (4 points) Sketch the P-V diagram of part 3.

5. (8 points) What is the change in internal energy of the gas in part 3 ?

Problem #3 (12 points)

You wish to increase the efficiency of an ideal gas engine. Is it better to raise the temperature of the high-temperature reservoir by a certain amount, or lower the temperature of the low-temperature resevoir by the same amount ? Explain your logic.

Problem #4 (12 points)

A Carnot engine works between temperatures T_1 and T_2 with $T_1 > T_2$. It drives a Carnot refrigerator that works between two different temperatures T_3 and T_4 with $T_3 > T_4$. Find the ratio $|Q_3|/|Q_1|$ in terms of the four temperatures.

Problem #5 (34 points)

A hot iron horseshoe with mass of 0.40 kg which has just been forged, is dropped into 1.35 L of water in a 0.30-kg iron pot initially at 20^oC. Ignore any heat transfer between the environment (air) and these objects.

1. (10 points) If the final equilibrium temperature is 25^oC, what is the initial temperature of the hot horseshoe ?

2. (20 points) Calculate the entropy change of the entire system.

3. (4 points) Does this process violate the 2nd law of thermodynamics ? Explain your reasons in a couple of sentenses.