Physics 161
Exam 1
MONDAY FEBRUARY 20

Directions: The exam consists of two parts. The first is multiple choice. In the second part you are to solve two problems; here it is important to show your work/thoughts. The maximum possible score is 100 points, but there is a bonus worth 5 more points. The value of each question are indicated; allocate your time wisely. The exam is closed book/notes.

Useful equations, conversions, and constants:

$$R = 8.314\ \tfrac{\text{J}}{\text{mole}\cdot\text{K}} = 0.08206 \tfrac{\text{ltr-atm}}{\text{mole}\cdot\text{K}}$$
$$1\text{ ltr-atm} = 101.3\text{ J}$$
$$1\text{ atm} = 1.01\times10^5\text{ N/m}^2$$
$$k = 1.38\times10^{-23}\tfrac{\text{J}}{\text{K}}$$
$$N_0 = 6.02\times10^{23}$$
$$C_p = C_V + nR\text{ (for ideal gas)}$$

$$T(^\circ\text{C})+273.15{=}T(\text{K})$$
$$\Delta U = Q - W$$
$$dU = TdS - PdV$$
$$H = U + PV$$
$$dH = TdS + VdP$$
$$A = U - TS$$
$$G = H - TS$$
$$S = k\ln W;$$
$$W_{\text{monatomic gas}} = \left(T^{3/2}V\cdot\text{const.}\right)^N/N!$$
$$\tfrac{1}{2}m\left\langle v^2\right\rangle = \tfrac{3}{2}kT$$
$$\wp(v) = \exp\left(-\tfrac{mv^2}{2kT}\right)4\pi v^2\left(\tfrac{m}{2\pi kT}\right)^{3/2}$$

Part 1

(1-5pts) The *second law* of thermodynamics is an assertion that
(a) the entropy of the universe increases for any spontaneous process.
(b) heat is added to a system reversibly.
(c) the energy of the universe is constant.
(d) heat is the same as the change in enthalpy.
(e) the free energy is constant at constant volume.

(2-5pts) What is $-V\left(dP/dV\right)_T$ for an ideal gas?
(a) P
(b) V
(c) nRT
(d) V/P
(e) V/T

(3-5pts) One mole of ideal gas at 300 K expands isothermally and reversibly from a pressure of 5 atm to a pressure of 1 atm. What is Q?
(a) 2.0 kJ.
(b) 3.0 kJ.
(c) 4.0 kJ.
(d) 5.0 kJ.
(e) 6.0 kJ.

(4-5pts) How much heat is required to raise the temperature of one mole of a *diatomic* ideal gas from 200 K to 300 K if the heating takes place at constant pressure?

(a) 1.66 kJ.
(b) 1.89 kJ.
(c) 2.04 kJ.
(d) 2.91 kJ.
(e) 2.45 kJ.

(5-5pts) 225 grams of hot coffee initially at 71 °C comes to equilibriuum with the surroundings at 21 °C at a constant pressure of 1 atm. What is ΔS for the coffee? Take $\bar{C}_p = 4.186$ J/(g·K) to be constant.

(a) −125 J/K.
(b) −148 J/K.
(c) 132 J/K.
(d) −175 J/K.
(e) 159 J/K.

(6-5pts) If a process takes place spontaneously at constant T and P, Gibbs's free energy G

(a) will decrease.
(b) will increase.
(c) will remain constant.
(d) will procede to a maximum.
(e) may increase or decrease.

(7-5pts) A reversible heat pump is used to cool a house in Albuquerque to a temperature of 21 °C (70 F) when the outdoor temperature is 38 °C (100 °F). For every 1 kJ of work performed on the compressor motor, how much heat is extracted *from the house*?

(a) 15.2 kJ
(b) 17.3 kJ
(c) 19.0 kJ
(d) 19.8 kJ
(e) 20.1 kJ

(8-5pts) A cup of 225 grams of ice-cold water initially at 273 K and 1 atm is placed in contact with the surroundings at 294 K, and 1 atm. What is the change in the entropy *of the surroundings* when the water warms up? Take $\bar{C}_p = 4.186$ J/(g·K) to be a constant.

(a) −38.2 J/K
(b) 45.0 J/K
(c) −54.3 J/K
(d) 65.6 J/K
(e) −67.3 J/K

(9-5pts) One mole of monatomic ideal gas initially at a pressure of 2 atm and a temperature of 300 K is compressed adiabatically to 5 atm by a constant external pressure of 5 atm. What is Q?

(a) 0 kJ
(b) −3.7 kJ
(c) −2.3 kJ
(d) −1.8 kJ
(e) −1.2 kJ

(10-5pts) Which of the following is false?

(a) The efficiency of the Carnot engine increases with increasing T_H.
(b) The Carnot cycle is reversible.
(c) A Carnot engine becomes 100% efficient as T_C approaches zero.
(d) The ideal gas Carnot engine is more efficient than the non-ideal gas Carnot engine.
(e) The Carnot efficiency is greater than or equal to the efficiency of an irreversible heat engine.

(11-5pts) A Carnot cycle consists of the following processes:
(a) two reversible isotherms and two reversible isochors.
(b) two reversible isobars and two reversible isochors.
(c) two reversible adiabats and two reversible isochors.
(d) two reversible isobars and two reversible isotherms.
(e) two reversible isotherms and two reversible adiabats.

(12-5pts) The first law of thermodynamics asserts that
(a) the entropy of the system will always increase.
(b) the energy of the universe remains constant.
(c) an increase in entropy may always be associated with a transfer of heat.
(d) energy increases for any spontaneous process.
(e) the entropy of the universe will procede to a maximum.

(13-5pts) One mole of monatomic ideal gas undergoes a reversible adiabatic expansion, from an initial state of 22.4 liters and 273 K to a final state of 207 K. What is ΔS?
(a) 0 J/K
(b) 5 J/K
(c) 6 J/K
(d) 8 J/K
(e) 10 J/K

(14-5pts) Who first patented a heat engine for powering underwater torpedoes?
(a) Carnot
(b) Boltzmann
(c) Stirling
(d) Maxwell
(e) Joule

(15-5pts) The equation $S = k \ln W$ is engraved on Boltzmann's tombstone in Vienna. What is k?
(a) The stiffness constant for free space.
(b) The gas constant divided by 6.02×10^{23}.
(c) The number of microscopic configurations a system may have while still being considered to be in the same macroscopic equilibrium state.
(d) The work.
(e) Boltzmann's first initial.

(16-5pts) What is the change in entropy for one mole of monatomic ideal gas whose volume decreases by a factor of 2 while the temperature remains the same?
(a) -3.4 J/K
(b) -8.6 J/K
(c) -1.9 J/K
(d) -5.8 J/K
(e) -2.8 J/K

(17-5pts) In a fluid in equilibrium at a temperature T, what is the RMS velocity of an atom having mass m?
(a) $v_{RMS} = (3kT/m)^{1/2}$.
(b) $v_{RMS} = 2kT/m$.
(c) $v_{RMS} = (m/2kT)^{1/3}$.
(d) $v_{RMS} = \sqrt{2m/3kT}$.
(e) $v_{RMS} = (3kT/2m)^{-1/2}$.
V. AA

Part 2 VAA (Show your work!)

Name:_____

(1-10pts) One mole of ideal gas initially at 250 K and 5 atm expands *adiabatically* against a *constant pressure* of 2 atm, to 2 atm. What is the final volume? Take $C_V = \frac{3}{2}nR$. (Note: This process is irreversible; see problem #2 for a reversible adiabatic process.).

(2-5pts) One mole of ideal gas initially at 250 K and 5 atm expands *adiabatically* and *reversibly* to 2 atm. What is the final volume? Take $C_V = \frac{3}{2}nR$. (Note: This process is reversible; see problem #1 for an irreversible expansion process.)

(Bonus: 5pts)

One mole of ideal gas is initially confined to a glass bulb having volume V. The bulb is connected to a second bulb with volume $2V$ by a small tube with a stopcock, and both are in contact with the surroundings at 250 K. The second bulb is initially evacuated. When the stopcock is opened, the gas expands to fill both bulbs. If the gas turns a paddle wheel while passing through the tube, what is the maximum work that can be extracted?