Physics 1215 – Spring 2008 - Exam #1
February 8, 2008

Name (Print): Key

My signature below is a statement that all work contained in this exam is my own work. I have not copied work from any other source, or used any material other than one 3 by 5 card and my calculator.

Name (Signature):______________________

DO NOT TURN THIS PAGE OVER UNTIL YOU ARE INSTRUCTED TO DO SO.

STOP WORKING ON THIS EXAM AS SOON AS YOU ARE INSTRUCTED TO DO SO.

You will have approximately 1 hour to do this exam

- The following exam consists of 4 multiple-choice questions and 3 worked problems.
  - Point values are assigned to each problem in the exam.
- It is a good idea to first skim through the entire test and begin with the problems that seem most familiar. If you get stuck on a problem, skip to another.
- For the computational problems, please show all problem solving steps and all your work.
  - All work must be done on the pages provided.
  - Please write neatly and put a BOX around your final answer.
  - Use significant figures in your answers.
- Calculators may be used only to do arithmetic. You cannot use your calculator for solving algebraic equations, for graphing, for vectors, etc.
- One 3 by 5 card with written notes may be used. No books or other notes are allowed.

Problem #	Max Points	Score	Problem #	Max Points	Score
1	5		5	25	
2	5		6	25	
3	5		7	30	
4	5		Total	100	

Constants

$R = 8.315$ J/(mol·K)

$k = 1.381 \times 10^{-23}$ J/K

For Water: $L_F = 3.335 \times 10^5$ J/kg

$c = 4186$ J/(kg·K)

$L_V = 2.256 \times 10^6$ J/kg

1. If 1.00 kg of ice at 273 K comes to equilibrium with 1 kg of steam at 373 K, the combination comes to thermal equilibrium as

$Q_1 = Q(\text{melt ice}) = (1\,kg)(3.335\times10^5\,\frac{J}{kg}) = 3.3\times10^5\,J$
$Q_2 = Q(\text{condense vapor}) = (1\,kg)(2.256\times10^6\,\frac{J}{kg}) = 2.2\times10^6\,J$
$Q_3 = Q(\text{warm ice to } 373) = (1\,kg)(4186\,\frac{J}{kg\,K})(100\,K) = 4.2\times10^5$
Since $Q_1 + Q_3 < Q_2$

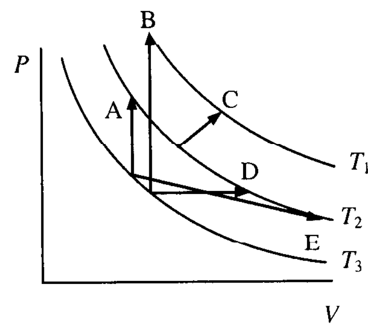
- ☐ a mixture of ice and water at 273 K
- ☐ water at 323 K
- ☒ a mixture of water and steam at 373 K
- ☐ water at 503 K
- ☐ none of the above

2. Ideal monatomic gas *A* is composed of molecules with mass *m* while ideal monatomic gas *B* is composed of molecules with mass 4*m*. The average molecular kinetic energies are the same if the ratio of temperatures T_A/T_B is:

☐ 1/4	☐ 1/2	☒ 1
☐ 2	☐ 4	

$K = \frac{1}{2} N_f kT$

3. The diagram shows five processes carried out for an ideal gas. For which of these processes is the change in the internal energy of the gas greatest?



- ☐ A
- ☒ B
- ☐ C
- ☐ D
- ☐ E

$\Delta U \propto \Delta T$

4. You have been asked to choose the most efficient engine available. Four proposals are presented all working between 600°C and 300°C. Which engine should you choose?

	Q_{in}	Q_{out}	*W*	1st	2nd
☐ Engine A	1000 J	-700 J	400 J	No	
☐ Engine B	1000 J	-600 J	400 J	OK	No
☒ Engine C	1000 J	-700 J	300 J	OK	OK
~~☐ Engine D~~	~~1000 J~~	~~-400 J~~	~~600 J~~	~~OK~~	~~No~~

- ☐ None of these engines will work
- ☐ More than one of these engines will work

1st LAW $Q_{in} + Q_{out} = W$

2nd Law $\frac{Q_{HIGH} - |Q_{LOW}|}{Q_{HIGH}} < 1 - \frac{T_L}{T_H}$

$< .34$

5. An ordinary glass is filled to the brim with 350.0 mL of water at a temperature of 100° C. If the temperature is decreased to 20° C, how much additional water can be added to the glass? The coefficient of linear expansion for glass is 9×10^{-6} $(C^o)^{-1}$ and the coefficient of volume expansion for water is 500×10^{-6} $(C^o)^{-1}$. (1 L = 10^{-3} m^3)

Find new volume of glass

$$V_g' = V_g + \Delta V_g = V_g(1 + 3\alpha_g(T_f - T_i)) = 350\text{ mL}(1 + 3(9\times10^{-6})(-80^\circ C))$$

$$= 349.2\text{ mL}$$

Find new volume of water

$$V_w' = V_w + \Delta V_w = V_w(1 + \beta_w(T_f - T_i)) = 350\text{ mL}(1 + (500\times10^{-6}\,C^{-1})(-80^\circ C))$$

$$= 336.0\text{ mL}$$

$$\Delta V = V_g' - V_w' = 349.2 - 336.0 = \boxed{13.2\text{ mL}}$$

6. Calculate the change in entropy for the following processes.
   a) Thirty five grams of water is heated from 25° C to 75° C.
   b) Thirty five grams of ice melts at a constant temperature of 0° C.
   c) A 2200 kg car traveling at 13 m/s crashes into a brick wall and comes to a stop when the car and the surroundings are at 19° C.
   d) Two dice are changed from showing a total number of seven on both dice to showing a total number of two (snake-eyes) on both dice.

a) $\Delta S = \int_i^f \frac{dQ}{T} = c_v m \int_{298}^{348} \frac{dT}{T} = c\, m \ln \frac{348}{298}$

$= \left(4186 \frac{J}{kg\,K}\right)(.035\ kg) \ln \frac{348}{298} = \boxed{22.7\ J/K}$

b) $\Delta S = \int_i^f \frac{dQ}{T} = \frac{1}{T}\int_i^f dQ = \frac{Q}{T} = \frac{m L_f}{T} = \frac{(.035\ kg)(3.335\times10^5\ J/kg)}{273\ K}$

$= \boxed{42.8\ J/K}$

c) $\Delta S = \frac{Q}{T} = \frac{\frac{1}{2}mv^2}{T} = \frac{\frac{1}{2}(2200\ kg)(13\ m/s)^2}{292\ K} = \boxed{637\ J/K}$

d) $k\,(\ln \omega_f/\omega_i) = 1.381\times10^{-23}\ J/K \ln 1/6 = \boxed{-2.47\times10^{-23}\ J/K}$

7. A certain heat engine uses 0.400 moles of monatomic gas and operates at a high temperature of ~~440°~~ C. (710 K) The engine follows a three step process. First it expands isothermally to four times its initial volume. Then it undergoes an isobaric contraction to its original volume. Finally it undergoes an isochoric pressure change back to its original temperature.

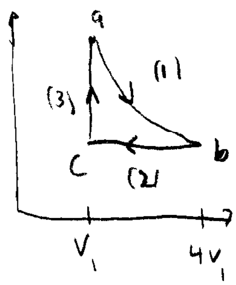
a) Draw a *P-V* diagram for this process.

b) Draw a chart showing *W*, ΔU and *Q* for all three processes. (Hint: To calculate work along the isobaric contraction you may need to use the ideal gas law to substitute for the product *PV*.)

c) Calculate the efficiency of this process.

$Q = W + \Delta U$

a)



b)

	W	ΔU	Q
1)	3270 J	0	3270 J
2)	−1780 J	−2650 J	−4430
3)	0	2650 J	2650 J

	T(K)	P	V
a	710	P_a	V_a
b	710		$4V_a$
c	178		V_a

From $a \to b$:

(1) $W = \int P\,dV = \int nRT \frac{dV}{V} = nRT_a \ln\frac{V_b}{V_a}$

$= (.400)(8.315\ \mathrm{J/mol\cdot K})(710\ \mathrm{K}) \ln 4$

$= 3270\ \mathrm{J}$

(2) From $b \to c$ $\quad P = \frac{nRT_b}{V_b} = \frac{nRT_c}{V_c} \Rightarrow T_c = T_b \frac{V_c}{V_b} = \frac{710\ \mathrm{K}}{4} = 178\ \mathrm{K}$

$W = \int P\,dV = P\Delta V = P(V_c - V_b) = PV_c\left(1 - \frac{V_b}{V_c}\right) = nRT_c\left(1 - \frac{V_b}{V_c}\right)$

$= (.400\ \mathrm{mol})(8.315\ \mathrm{J/mol\cdot K})(178\ \mathrm{K})(1-4) = -1780\ \mathrm{J}$

$\Delta U = \frac{1}{2} N_F Rn(T_c - T_b) = \frac{3}{2}(8.315\ \frac{\mathrm{J}}{\mathrm{mol\cdot K}})(.40\ \mathrm{mol})(178 - 710) = -2650\ \mathrm{J}$

$Q = W + \Delta U = 1780 - 2650 = -870$

3) $\Delta U = \frac{3}{2} Rn(T_a - T_c) = \frac{3}{2}(8.315)(.40)(710 - 178) = 2650\ \mathrm{J}$

$Q = \Delta U = 2650$

c) $\varepsilon = 1 - \frac{|Q_L|}{Q_H} = 1 - \frac{4430}{3270 + 2650} = .25 = \boxed{25\%}$