Physics 132-1 Test 1

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Signature ________________________________

Questions (6 for 8 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. Consider a mass of ice that is being heated. There are regions of the heating curve in which the temperature is not changing. What is happening to the added heat in these regions?

2. A known mass m_w of warm water is placed in a calorimeter cup and its temperature T_0 recorded. The specific heat of water is given. A known mass m_i of ice at $T_1 = 0°\text{C}$ (with no water) is added to the water and allowed to melt and come to equilibrium. The final temperature of the mixture after the ice has melted T_2 is recorded. Is there any additional information needed to determine the latent heat of fusion of the ice? Explain.

3. In our development of the kinetic theory we showed that for a single-particle 'gas', the force exerted on the wall of the cubic container of side ℓ was $F_x = mv_x^2/\ell$. We also showed $P = mv_x^2/V$. Explain the steps needed to go from the equation for F_x to the one for P.

DO NOT WRITE BELOW THIS LINE.

4. The table below has the results of a calculation of the multiplicities of an Einstein solid with $N_A = 80$, $N_B = 120$, and $q = 30$. What is the probability P_1 there are no energy quanta in solid A? What is the ratio of this probability to the most probable macrostate? How does this result validate or invalidate the notion of irreversibility? Explain.

U(A)	U(B)	U(A)/U	U(B)/U	Ω(A)	Ω(B)	Ω(AB)	Probability
0	20	0.000000	1.000000	1	9.228e+32	9.228e+32	0.000045
1	19	0.050000	0.950000	240	4.870e+31	1.169e+34	0.000569
2	18	0.100000	0.900000	28920	2.448e+30	7.079e+34	0.003443
3	17	0.150000	0.850000	2332880	1.169e+29	2.726e+35	0.013262
4	16	0.200000	0.800000	141722460	5.284e+27	7.488e+35	0.036427
5	15	0.250000	0.750000	6916056048	2.254e+26	1.559e+36	0.075847
6	14	0.300000	0.700000	2.824e+11	9.042e+24	2.553e+36	0.124214
7	13	0.350000	0.650000	9.925e+12	3.394e+23	3.368e+36	0.163843
8	12	0.400000	0.600000	3.064e+14	1.186e+22	3.634e+36	0.176781
9	11	0.450000	0.550000	8.444e+15	3.836e+20	3.239e+36	0.157562
10	10	0.500000	0.500000	2.102e+17	1.140e+19	2.398e+36	0.116639
11	9	0.550000	0.450000	4.778e+18	3.091e+17	1.477e+36	0.071840
12	8	0.600000	0.400000	9.995e+19	7.559e+15	7.555e+35	0.036749
13	7	0.650000	0.350000	1.937e+21	1.648e+14	3.192e+35	0.015529
14	6	0.700000	0.300000	3.501e+22	3.151e+12	1.103e+35	0.005367
15	5	0.750000	0.250000	5.929e+23	5.180e+10	3.071e+34	0.001494
16	4	0.800000	0.200000	9.449e+24	711563490	6.723e+33	0.000327
17	3	0.850000	0.150000	1.423e+26	7840920	1.116e+33	0.000054
18	2	0.900000	0.100000	2.032e+27	64980	1.320e+32	0.000006
19	1	0.950000	0.050000	2.759e+28	360	9.931e+30	4.831e-7
20	0	1.000000	0.000000	3.572e+29	1	3.572e+29	1.738e-8
					Ω(Total) =	2.0557e+37	1.000000

5. Starting with the equation for the entropy $S = k_B \ln \Omega$, use the chain rule to clearly show all the steps that lead to the following result.

$$\frac{dS}{dE} = k_B \frac{1}{\Omega} \frac{d\Omega}{dE}$$

6. Two identical rooms are sealed so they don't leak and are connected by an open door. The temperatures in the two rooms are maintained at different values. Does one room contain more air than the other? Explain.

DO NOT WRITE BELOW THIS LINE.

Problems (3). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

1. 15 pts. Two identical cars collide head-on while each is traveling at a speed $v = 20\ m/s$. Suppose all their kinetic energy is transformed into the thermal energy of the wrecks. What is the temperature increase ΔT of each car? You can assume that each cars specific heat is that of iron which is $c = 450\ J/kg -^{\circ}$ C.

2. 17 pts. A newly-created material has a multiplicity

$$\Omega = \alpha N E^{3/2}$$

where N is the number of atoms in the solid, E is the total internal energy in the solid, and α is a constant. How is the energy E of the material related to the temperature T? What is the molar specific heat? Does this result make sense? Explain.

3. 20 pts. The Universe was created about twelve billion years ago in a cataclysmic explosion known as the Big Bang. As the Universe expanded after the explosion it cooled and its current temperature has been measured to be $T_b = 2.7\ K$. Its number density is $N/V = 10^6\ particles/m^3$ which is primarily due to protons (H nuclei of mass $m_p = 1.67 \times 10^{-27}\ kg$) and its radius is $r = 10^{26}\ m$. Let's treat the Universe as a spherical, ideal gas of protons. What is the root-mean-square speed of the protons in this 'gas'? What is the total thermal energy in the gas? How does this compare with the energy output of all the stars in the universe $E_{stars} = 10^{65}\ J$?

Physics 132-1 Equations

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt} \qquad KE = \frac{1}{2}mv^2 \qquad ME_0 = ME_1 \qquad \vec{p} = m\vec{v} \qquad \vec{p}_0 = \vec{p}_1$$

$$Q = C\Delta T = cm\Delta T = nC_v\Delta T \qquad Q_{f,v} = mL_{f,v}$$

$$\Delta E_{int} = Q+W \qquad W = \text{force}\times\text{distance} = \int \vec{F}\cdot d\vec{s} \to P\Delta V \qquad \vec{F} = m\vec{a} = \frac{d\vec{p}}{dt} \qquad \langle\vec{F}\rangle = \frac{\Delta\vec{p}}{\Delta t}$$

$$\vec{I} = \int \vec{F}dt = \langle\vec{F}\rangle\Delta t = \Delta\vec{p} \qquad P = \frac{|\vec{F}|}{A} \qquad PV = Nk_BT = nRT$$

$$\langle KE\rangle = \langle E_{kin}\rangle = \frac{1}{2}m\overline{v^2} \qquad \langle E_{kin}\rangle = \frac{3}{2}k_BT \qquad E_{int} = N\langle E_{kin}\rangle = \frac{3}{2}Nk_BT$$

$$v_{rms} = \sqrt{\overline{v^2}} \qquad C_V = \frac{f}{2}N_Ak_B \qquad E_f = \frac{k_BT}{2} \qquad E_{int} = \frac{f}{2}Nk_BT$$

$f \equiv$ number of degrees of freedom

$$E_{atom} = (n_x + n_y + n_z + \frac{3}{2})\hbar\omega_0 \qquad E = \sum_{i=1}^{3N} n_i\epsilon = q\hbar\omega_0 \qquad \Omega(N,q) = \frac{(q+3N-1)!}{q!(3N-1)!}$$

$$S = k_B \ln\Omega \qquad \frac{1}{T} = \frac{dS}{dE} \qquad q = \frac{E}{\hbar\omega_0} \qquad C = \frac{1}{n}\frac{dE}{dT} \qquad E = 3Nk_BT$$

$$\langle x\rangle = \frac{1}{N}\sum_i x_i \qquad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x\rangle)^2}{N-1}}$$

$$A = 4\pi r^2 \qquad V = Ah \qquad V = \frac{4}{3}\pi r^3 \qquad \frac{d}{dx}x^n = nx^{n-1} \qquad \frac{d}{dx}(u\cdot v) = u\frac{dv}{dx}+v\frac{du}{dx} \qquad \frac{d}{dx}\ln x = \frac{1}{x}$$

$$\frac{df(x)}{dx} = \lim_{\Delta x\to 0}\frac{f(x+\Delta x) - f(x)}{\Delta x} \qquad \int_a^b f(x)dx = \lim_{\Delta x\to 0}\sum_{n=1}^{N} f(x)\Delta x \qquad \frac{d}{dy}f(x) = \frac{df}{dx}\frac{dx}{dy}$$

Physics 132-1 Constants

$T_{boiling}$ (N_2)	$77\ K$	$T_{freezing}$ (N_2)	$63\ K$
$T_{boiling}$ (water)	$373\ K$ or 100°C	$T_{freezing}$ (water)	$273\ K$ or 0°C
L_v(water)	$2.26 \times 10^6\ J/kg$	L_f (water)	$3.33 \times 10^5\ J/kg$
L_v(N_2)	$2.01 \times 10^5\ J/kg$	c (copper)	$3.87 \times 10^2\ J/kg -^\circ$ C
c (water)	$4.19 \times 10^3\ J/kg - K$	c (steam)	$0.69\ J/kg - K$
c (iron(	$4.5 \times 10^2\ J/kg - k$	c (aluminum)	$9.0 \times 10^2\ J/kg - K$
ρ (water)	$1.0 \times 10^3 kg/m^3$	P_{atm}	$1.05 \times 10^5\ N/m^2$
k_B	$1.38 \times 10^{-23}\ J/K$	proton/neutron mass	$1.67 \times 10^{-27}\ kg$
R	$8.31 J/K - mole$	g	$9.8\ m/s^2$
$0\ K$	-273° C	$1\ u$	$1.67 \times 10^{-27}\ kg$
Gravitation constant	$6.67 \times 10^{-11}\ N - m^2/kg^2$	Earth's radius	$6.37 \times 10^6\ m$
e electronic charge	$1.6 \times 10^{-19}\ C$	$k_e = 1/4\pi\epsilon_0$	$8.99 \times 10^9\ N - m^2/C^2$