Physics 132-1 Test 1

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

Signature ____________________ Name ____________________

Questions (6 for 7 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided. Show your reasoning.

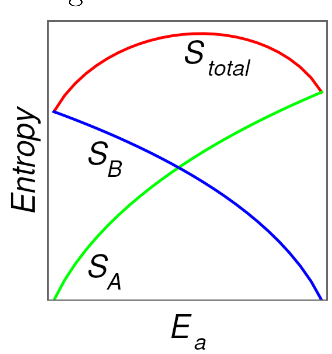
1. In our development of kinetic theory we claimed that on average $\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$ for a large number of particles in a box. Why?

2. 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?

3. The figure shows the entropy of two solids S_A and S_B and their combined entropy S_{AB} as a function of the internal energy in solid A E_a. The solids are in thermal contact. At the most probable macrostate we showed that

$$\frac{dS_A}{dE_A} = \frac{dS_B}{dE_B}$$

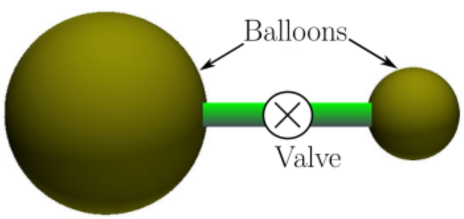
and we require that $T_A = T_B$ at thermal equilibrium. Make a guess about the relationship between dS/dE and the temperature T. Justify your choice. Consider using the figure below.



4. When you measured the latent heat of vaporization of nitrogen in lab you made some measurements with the power to the resistor turned off. Why?

5. Consider a strange solid whose multiplicity is always one ($\Omega_A = 1$) no matter how much energy you put in it. If you put lots of energy in solid A and then put it into thermal contact with a 'normal' Einstein solid (solid B) that has the same number of atoms ($N_A = N_B$), but far less energy ($q_A >> q_B$), what happens? Explain.

6. You may have noticed that when you blow up a balloon it is difficult at the start, but becomes easier once you get enough air into the balloon. In other words you have to exert more pressure when you start blowing it up. Consider two, air-filled balloons connected by a straight tube with a closed valve as shown below. If the valve is opened what will happen to the sizes of each balloon? 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. 14 pts. How many times more likely is it that the combined system of solids described in the table below will not be found in macropartition 3:4 than it is to be found in macropartition 0:7, if the fundamental assumption is true?

Macropartition	E_A	E_B	Ω_A	Ω_B	Ω_{AB}
0:7	0	7	1	36	36
1:6	1	6	3	28	84
2:5	2	5	6	21	126
3:4	3	4	10	15	150
4:3	4	3	15	10	150
5:2	5	2	21	6	126
6:1	6	1	28	3	84
7:0	7	0	36	1	36
				Total=	792

2. 20 pts. The Universe was created almost fourteen 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 $E_{stars} = 10^{65}\ J$?

3. 24 pts. A newly-created material has a multiplicity

$$\Omega = Ne^{-NE/\hbar\omega}$$

where N is the number of atoms in the solid, E is the total internal energy in the solid, and $\hbar\omega$ is the energy of a single quantum. 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.

DO NOT WRITE BELOW THIS LINE.

Physics 132 Equations

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt} \quad KE = \frac{1}{2}mv^2 \quad ME_0 = ME_1 \quad PE_g = mgh \quad \vec{p} = m\vec{v} \quad \vec{p}_0 = \vec{p}_1 \quad W = \int \vec{F}\cdot d\vec{s} \rightarrow P\Delta V$$

$$Q = C\Delta T = cm\Delta T = nC_v\Delta T \quad Q_{f,v} = mL_{f,v} \quad \Delta E_{int} = Q + W \quad \vec{J} = \int \vec{F}dt = \langle\vec{F}\rangle\Delta t = \Delta\vec{p}$$

$$P = \frac{|\vec{F}|}{A} \quad PV = Nk_BT = nRT \quad \langle KE\rangle = \langle E_{kin}\rangle = \frac{1}{2}m\langle v^2\rangle \quad \langle E_{kin}\rangle = \frac{3}{2}k_BT$$

$$E_{int} = N\langle E_{kin}\rangle = \frac{3}{2}Nk_BT \quad v_{rms} = \sqrt{\langle v^2\rangle} \quad f = \#\text{dof} \quad C_V = \frac{f}{2}N_Ak_B \quad E_f = \frac{k_BT}{2} \quad E_{int} = \frac{f}{2}Nk_BT$$

$$\epsilon = \hbar\omega \quad E_{atom} = (n_x + n_y + n_z)\epsilon \quad E = \sum_{i=1}^{3N} n_i\epsilon = q\epsilon \quad \Omega(N,q) = \frac{(q+3N-1)!}{q!(3N-1)!} \quad q = \frac{E}{\epsilon} \quad S = k_B\ln\Omega$$

$$\frac{dS}{dE} = \frac{1}{T} \quad E = 3Nk_BT \quad C_n = \frac{1}{n}\frac{dE}{dT} \quad \langle x\rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x\rangle)^2}{N-1}}$$

$$\ln(ab) = \ln a + \ln b \quad \ln\left(\frac{a}{b}\right) = \ln a - \ln b \quad \ln x^n = n\ln x \quad x = e^{\ln x} = \ln(e^x)$$

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

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

Physics 132 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}	$1.01 \times 10^5\ N/m^2$
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	$6.37 \times 10^6\ m$

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

The Periodic Chart.