Physics 132-1 Test 1

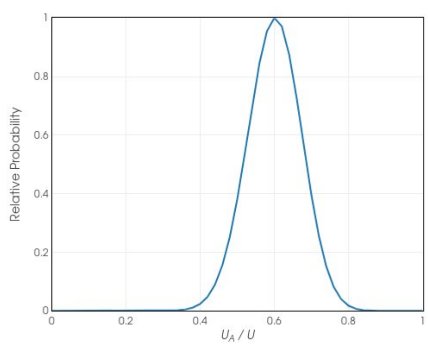
I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Signature ________________________________

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

1. What evidence can you cite from this course so far that would support the kinetic theory of gases? Give at least two pieces of evidence.

2. The plot below shows the results of a calculation of the multiplicities of two Einstein solids A and B in thermal contact with $N_A = 120$, $N_B = 80$, and $q = 50$. The horizontal axis is the fraction of the total energy in A (E_A/E). What is the width of the probability distribution? What is the most probable energy in terms of $\epsilon = \hbar\omega$, the energy quantum? Show your reasoning for full credit.



3. A piece of ice of mass m_i at T_0 is tossed into water of mass m_w in a calorimeter cup of mass m_c at room temperature T_1 and melts completely. The calorimeter cup is thermally isolated from its surroundings so no heat escapes. Suppose you knew all the masses (ice (m_i), water (m_w), cup(m_c)) at the start, specific heats (ice (c_i), water (c_w), cup(c_c)), and latent heats (ice (L_{fi}, L_{vi}), water (L_{fw} , L_{vw}), cup(L_{fc} , L_{vc})) What is the equation you would start from and solve in order to calculate the final temperature of the system? Ice melts at $T_f = 0$°C.

4. Our calculation of the molar specific heat of an elemental solid was 24.9 $J/K - mole$. The accepted value for tin is 27.0 ± 0.6 $J/K - mole$. Does our calculation agree with the accepted value? Explain.

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. The force exerted by a gas on the walls of a container is constant in time (think about a balloon). Someone challenging the atomic picture of gases claims that you should see fluctuations in the pressure exerted on the walls like the fluctuations in the motion of small particles observed in Brownian motion. How would you respond?

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

1. 14 pts. A certain macropartition of two Einstein solids has an entropy of $307.2k_b$. The next macropartition closer to the most probable one has an entropy of $330.5k_b$. If the system is initially in the first macropartition and we check it again later, how many times more likely is it to have moved to the other than to have stayed in the first?

2. 20 pts. Two speeding lead bullets, each of mass $m_0 = 0.005\ kg$ and at temperature $T_0 = 20.0°$C, collide head-on at speeds of $v_0 = 250\ m/s$ each. Assume a perfectly inelastic collision and no loss of energy by heat to the atmosphere. Does the lead melt?

melting point of lead	$T_f = 325.7°$ C
latent head of fusion	$L_f = 23kJ/kg$
Specific heat of solid lead	$c_{Pb-s} = 130J/kg\ K$
Specific heat of molten lead	$c_{Pb-l} = 1340J/kg\ K$

3. 24 pts. Water standing in the open at $T_w = 32°$C evaporates because of the escape of some of the surface molecules. The heat of vaporization of water ($L_V = 2.253 \times 10^6\ J/kg$) is approximately equal to $n\langle E_{escape}\rangle$ where $\langle E_{escape}\rangle$ is the average energy of the escaping molecules and n is the number of molecules per kilogram. What is the molar mass of H_2O? What is $\langle E_{escape}\rangle$? What is the ratio of E_{escape} to the average kinetic energy of the H_2O molecules assuming the molecules in the liquid are related to the temperature the same way they are related to temperature in a gas?

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)	$3.87 \times 10^2\ J/kg -°$ 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	$1.6 \times 10^{-19}\ C$	$k_e = 1/4\pi\epsilon_0$	$8.99 \times 10^9\ N - m^2/C^2$

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

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

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

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

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

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

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