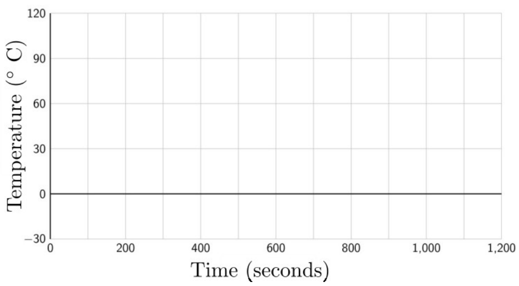
Physics 132-2 Test 1

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. Suppose you were to add heat at a constant rate to a container of ice water at 0°C until the water begins to boil. Sketch the predicted shape of the heating curve on the graph below using a dashed line. Mark the point at which the water begins to boil. Explain your reasoning.



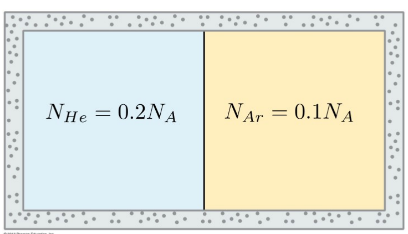
2. In the lab entitled *The Heat of Vaporization of Nitrogen* you measured the power P (J/s) going into the liquid nitrogen and the mass loss rate R_{loss} (kg/s). Are these quantities related to the latent heat of vaporization of nitrogen? If so, how? If not, why not? Explain your reasoning.

3. 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 $T_1 = 0°C$ (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.

4. An Einstein solid has 3 atoms (so $N_A = 3$) with 4 quanta. What is its multiplicity? Explain your reasoning.

5. In the lab on kinetic theory the collisions of the particles with the wall perpendicular to the x direction are elastic. Show that the average force exerted on the wall for each collision is $\langle F_x \rangle = 2m\frac{v_x}{\Delta t_x}$ where m is the mass of the particles. What is Δt_x? (Hint: Think of the form of Newton's second law in which force is defined in terms of the change in momentum per unit time so that $\vec{F} = \frac{\vec{\Delta p}}{\Delta t}$.)

6. The two containers of monatomic gas in the figure (helium (He) on the left and Argon (Ar) on the right) are separated by a fixed barrier, are in good thermal contact with each other, and well insulated from the surrounding environment. They are in thermal equilibrium. Is v_{rms} of the helium great than, less than, or equal to v_{rms} of the argon? 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. One mole ($N = 6.022 \times 10^{23}$) of oxygen gas is at a pressure $P = 6\ atm = 6.01 \times 10^5 N/m^2$ and a temperature $T = 30°$C. If the gas is heated so that both the pressure and volume are doubled, what is the final temperature T_g?

2. 20 pts. A certain macropartition of two Einstein solids has an entropy of $250k_b$. The next macropartition closer to the most probable one has an entropy of $305k_b$. 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?

3. 24 pts. A possible way to measure time very accurately is to use atoms and molecules falling under gravity in very deep, evacuated, vertical boreholes. The boreholes have to be kept very cold to reduce the effect of collisions with any remaining gas particles. Consider a diatomic oxygen molecule O_2 and a hydrogen atom H in such a very long, vertical vacuum tube.

    1. From what height must the diatomic oxygen molecule fall from rest in vacuum so that that its kinetic energy at the bottom is equal to the average energy of an oxygen molecule at 100 K?
    2. How far would a single hydrogen atom have to fall from rest in the same vaccum so that that its kinetic energy at the bottom equals the average energy of a hydrogen atom at 100 K?
    3. Which one (O_2 or H) would be better/easier to build and use? Why?

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Physics 132 Equations

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

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

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

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

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

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

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

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

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

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.