Name: Key

Student ID #: ____________

Examination 4 Spring 2008 Physics 211 Professor Philip L. Cole
Date April 25, 2008

Test Time: 50 minutes

Write your name on each page. Do the easier problems first. If a problem seems too difficult, skip it, and return to it once you have completed all of the other problems first. There are five pages to this test. An extra sheet is provided for scratch.

You must show all work. No credit will be assigned for answers without the appropriate work. Be very careful with significant figures.

Problem 1	____________	**(30 pts)**
Problem 2	____________	**(25 pts)**
Problem 3	____________	**(20 pts)**
Problem 4	____________	**(35 pts)**
Maximum	____________	**(100 pts)**

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Problem 1 SHM: back and forth, back and forth, and back again.

Imagine we have a pendulum formed of a heavy plumb bob of mass m at the end of a thin, very light rigid rod of length l, which is executing simple harmonic motion.

From the equation we derived in class ($\frac{d^2\theta}{dt^2} + \frac{g}{l}\theta = 0$), determine the following:

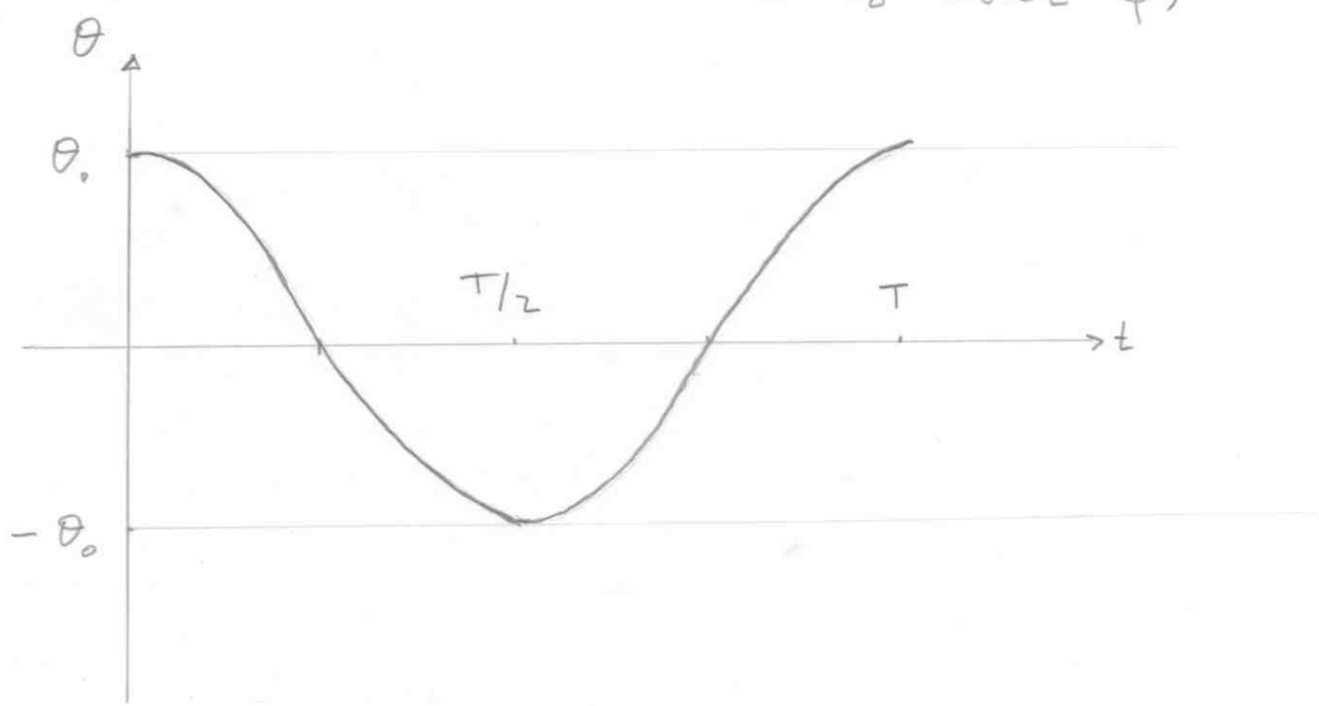
1. Find the angular frequency ω in terms of g and l.
2. What is the period? Would the period increase or decrease if the string length were doubled?
3. What is the condition on the maximum θ_0 (i.e. amplitude) so that simple harmonic motion ensues?
4. What the solution to $\theta = \theta(t)$ in the equation above?
5. Plot θ as a function of time over one period. At time $t = 0$, the pendulum is released from rest at an angle θ_0 with respect to the vertical (i.e. $\theta(t=0) = \theta_0$ and $d\theta(t=0)/dt = 0$).

1. For SHM $\frac{d^2\theta}{dt^2} + \omega^2\theta \Rightarrow \omega = \sqrt{g/l}$

2. $T = \frac{1}{f}$; $f = \frac{\omega}{2\pi} \Rightarrow T = 2\pi\sqrt{l/g}$ If $l \to 2l$, T increases by $\sqrt{2}$

3. $\sin\theta \simeq \theta$. For this to be true $\theta_0 \lesssim 0.18$ rad (~10.3°)
[To be within ~5%. $\left|\frac{\theta - \sin\theta}{\theta}\right| = 0.5\%$

4. The solutions are harmonic $\theta = \theta_0 \cos(\omega t + \varphi)$



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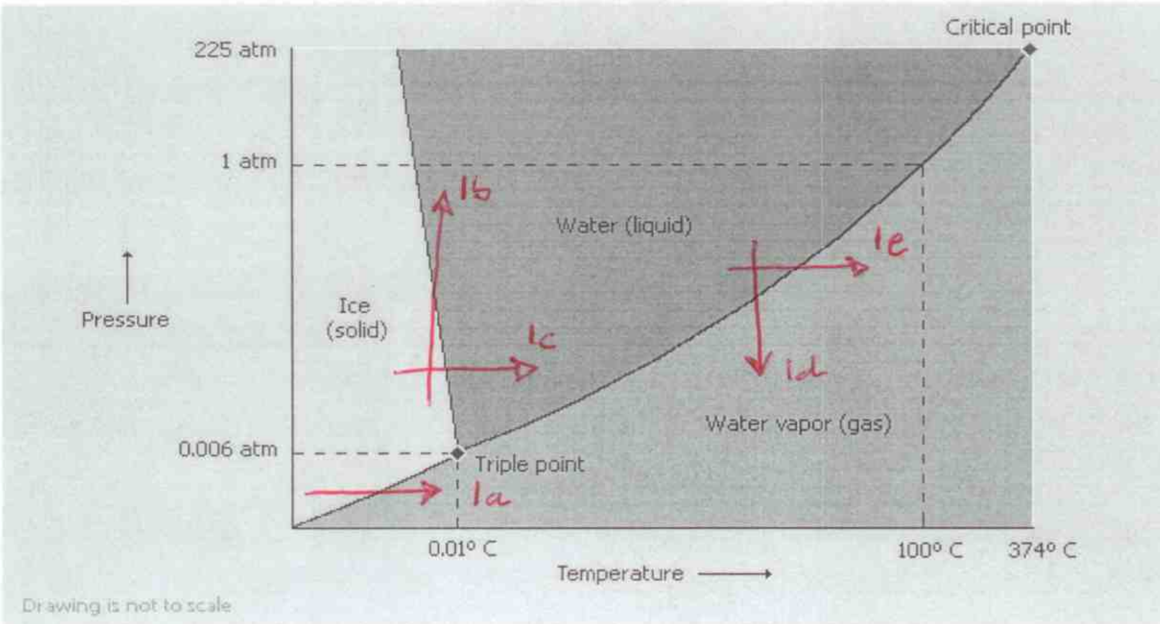
Problem 2. Water, Water, Everywhere



1. On the above Phase Diagram show (have the arrow pointing in the correct direction):
   a. Sublimation under constant pressure as a function of temperature.
   b. Melting under constant temperature as a function of pressure.
   c. Melting under constant pressure as a function of temperature.
   d. Boiling under constant temperature as a function of pressure.
   e. Boiling under constant pressure as a function of temperature.
2. Temperature matters.
   a. At what temperature does water boil in New York City?
   b. Would you expect water to boil at a higher or lower temperature in Pocatello, Idaho?
   c. At what temperature does water freeze in New York City?
   d. Would you expect water to freeze at a higher or lower temperature in Pocatello, Idaho?
3. Based on the physical significance of the negative slope for the liquid-solid phase for water as well as from your experience and readings:
   a. Does ice float? Why? And why would you think this is bizarre behavior for a solid?
   b. Why do freshwater lakes not freeze from the bottom up?
   c. Conjecture on why skate blades are narrow instead of wide.
4. Can you liquefy steam if it is above 380°C? Why or why not?

2. NYC: sea level   Pocatello: >1300 m above sea level
[Pressure decreases with height]

a. $P = 1$ atm $\Rightarrow$ 100°C
b. $P < 1$ atm $\Rightarrow$ Less than 100°C
c. $P = 1$ atm $\Rightarrow$ 0°C
d. $P < 1$ atm $\rightarrow$ Greater than 0°C

$P_{Poky} < P_{NYC}$

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Problem 2 con't

3. a) Yes, ice does float because it is less dense than water. For a liquid to solid phase transition one would expect the solid state to be denser than the liquid state

b) Water is the most dense at 3.98 °C. A parcel of this water will drop to the bottom and be replaced by less dense water. This process repeats until cooler water is on top. As the top layer freezes, it forms an insulating layer of ice. Hence the warmer water is on the bottom, and water freezes from the top down.

c.) The blades of the ice skates behave as "Pressure Amplifiers" Since $P = F/A$, for the same amount of force (here mg), the pressure goes up as the area gets smaller. Hence narrow skates are good.

4. You cannot liquify a substance once its temperature exceeds the CRITICAL POINT.

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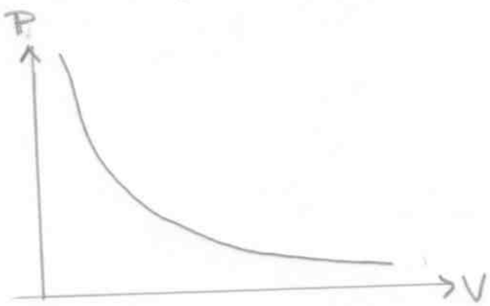
Problem 3 Ideally speaking….

For an ideal gas of n moles.

1. Plot the relationship of pressure vs. volume for a fixed amount of gas held at a constant temperature.
2. If you were to double the temperature while holding the volume and the amount of gas fixed, by how much would you increase the pressure?
3. Determine the volume in liters of 1.00 mol of any gas at STP (273 K and 1.013 x 10^5 Pa). Note that one liter is equal to 1000 cubic centimeters.

1. 

For $nRT = \text{const} \Rightarrow P \propto \frac{1}{V}$

2. $$P_1V_1 = nRT_1, \quad P_2V_2 = nRT_2 \Rightarrow \frac{P_2V_2}{P_1V_1} = \frac{T_2}{T_1} \Rightarrow P_2 = P_1\left(\frac{T_2}{T_1}\right)\left(\frac{V_1}{V_2}\right)$$

If $T_2 = 2T_1$ and $V_2 = V_1$ then $P_2 = 2P_1$

$\Rightarrow$ it doubles

3. $$PV = nRT \Rightarrow V = \frac{nRT}{P} =$$

$$= \frac{(1.00\,\text{mol})(8.314\,\text{J/mol}\cdot\text{K})(273\,\text{K})}{1.013 \times 10^5\,\text{N/m}^2}$$

$$= 0.0224\,\text{m}^3 \times \frac{(100\,\text{cm})^3}{1\,\text{m}^3} \times \frac{1\,\text{L}}{1000\,\text{cm}^3}$$

$$= \underline{22.4\ \text{Liters}}$$

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Problem 4 Many moving molecules making Mr. Maxwell mighty merry.

A gas containing 15,000 molecules, each of mass 2.00 x 10^{-26} kg, has the following distribution of speeds, which crudely follows the Maxwell distribution. Hint: $v_{rms} = \sqrt{\frac{1}{N}\sum n_i v_i^2}$

Number of Molecules	Speed (m/s)	n_i v_i (m/s)	v_i^2 $(m/s)^2$	n_i v_i^2 $(m/s)^2$
1500	200.0	300,000	40,000	6.000×10^7
4000	500.0	2,000,000	250,000	1.000×10^9
5000	800.0	4,000,000	640,000	3.200×10^9
2750	1200.0	3,300,000	1,440,000	3.960×10^9
1250	1400.0	1,750,000	1,960,000	2.450×10^9
500	1600.0	800,000	2,560,000	1.280×10^9
N = 15000		$\sum n_i v_i = 1.215 \times 10^7$		$\sum n_i v_i^2 = 1.195 \times 10^{10}$

1. Determine the v_{rms} characterizing this distribution of speeds from the tabulated values above.
2. Calculate the effective temperature of this gas.
3. Plot this information as a function of speed versus the relative number of molecules.
4. Sketch a rough curve through these data points.
5. On this plot indicate, v_{rms}, v_{avg}, and v_p, where v_p is the most probable speed.
6. If instead, the mass of the molecules were increased by a factor of two, by how much then would the corresponding kinetic energy increase if the temperature stayed the same?

1. $V_{rms} = \left[\frac{1}{N}\sum n_i v_i^2\right]^{1/2} = \left[\frac{1}{15{,}000}\left(1.195\times10^{10}\,m^2/s^2\right)\right]^{1/2}$

$\boxed{V_{rms} = 892.6\,m/s}$

Let's compare this to V_{avg}:

$V_{avg} = \bar{V} = \frac{1}{N}\sum n_i v_i = \frac{1.215\times10^7\,m/s}{15{,}000}$

$\boxed{\bar{V} = 810.0\,m/s}$

2. $\bar{K} = \frac{1}{2}m\overline{V^2} = \frac{3}{2}kT$

$T = \frac{m\overline{V^2}}{3k} = \frac{(2.00\times10^{-26}\,kg)(892.6\,m/s)^2}{3(1.38\times10^{-23}\,J/k)}$

$\boxed{T = 385\,k}$

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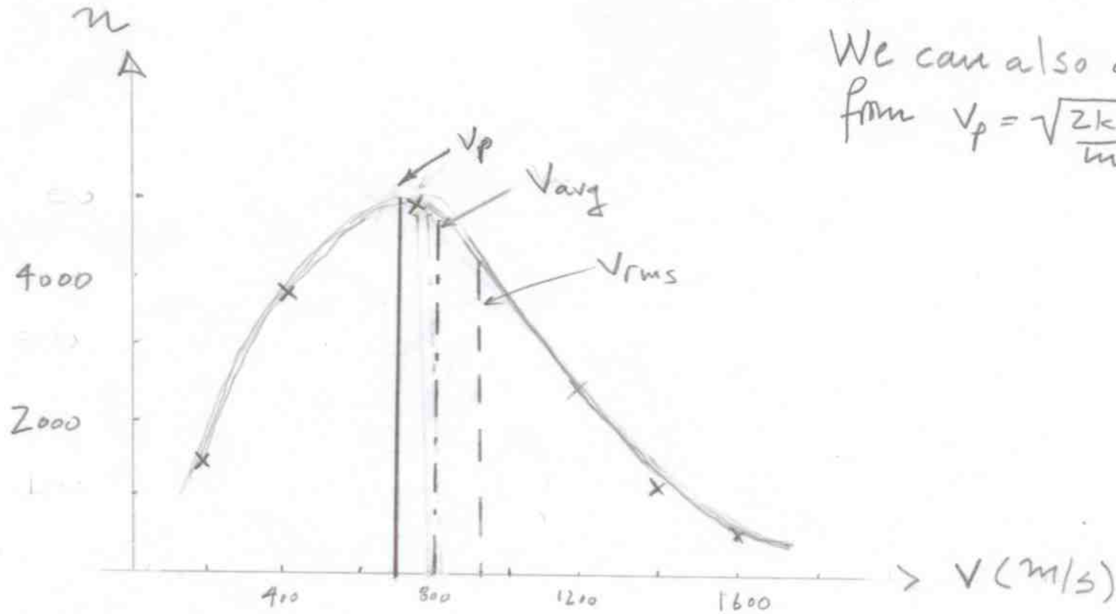
$V_{rms} = 892.6 \, m/s$

$V_{avg} = 810.0 \, m/s$

$V_p \simeq 700 \, m/s$ (by inspection)

We can also calculate this from $v_p = \sqrt{\frac{2kT}{m}} = 729 \, m/s$.



6. $\bar{K} \propto T$

If T is fixed then $\bar{K}$ does not change. This is true for all molecular species.

$\boxed{\text{NO CHANGE}}$!

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