Physics CS 33 **Spring 2011**

Set #7 - for Wd May 18

Read K&K	Ch. 11, Ch.12, Sects. 12.1 - 12.4
Read Ohanian	Ch. 2, Sects. 2.1-2.6
Read HR&K	Ch. 20, Sects. 20.1 - 20.7
Feynman Vol. I	Ch. 15

From K&K:

Ch. 11 Problem 11.4.

Ch. 12 Problems 12.1, 12.2, 12.3, 12.4, 12.9

From Ohanian:

Ch. 2 Problems 6, 11, 13.

1. Consider a system of N particles in thermal equilibrium. The energy of each particle can be expressed as

$$E = \sum_{i=1}^{n} E_i$$

with $E_i = a_i w_i^2$. The constants a_i are all positive and w_i are continuous variables such that $0 \leq w_i^2 \leq \infty$, that is, a classical system. Thus this system obeys the Boltzmann distribution $f = Ce^{-E/k_B T}$ and with n thermal degrees of freedom (n quadratic terms).

a) Give physical examples for systems with $n = 3, n = 5$, and $n = 6$.

b) Evaluate the average value of each individual term E_i and show that $\overline{E_i} = \frac{1}{2} k_B T$. (*The Equipartition Theorem*).

c) Next consider a system where the particles can be found either in a state of energy E or in a state of energy $-E$. This is a so called two-level system which appears in quantum physics. Would you say that you can apply the *equipartition theorem* to this system and thus say $\overline{E} = \frac{1}{2} k_B T$ for the average energy of a particle? If not, work out the correct formula for $\overline{E}$. Assume the statistical weight of each energy state is $g = 1$.

d) Evaluate the internal energy of one mole of this quantum system and its molar heat capacity. Evaluate the high and low temperature expressions for the heat capacity.

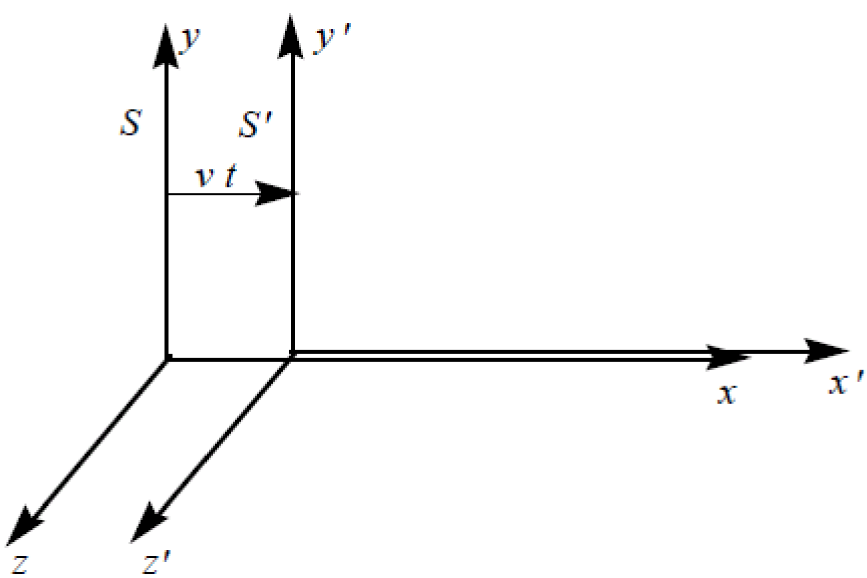
2. The equation describing the propagation of electromagnetic waves (light) in vacuum according to an inertial observer is of the form of the familiar wave equation:

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} = 0,$$

where c is the speed of light in vacuum. Find the form of this equation according to a relativistic observer traveling along the positive x-axis with velocity v relative to the first observer. Use the Lorentz transformation equations to relate the space and time coordinates for each observer.

3. *The Lorentz transformation (alternative derivation):* Consider the interial frame S' moving at velocity v relative to frame S. Consider the linear transformation

$$x' = Ax + Bt$$
$$y' = y$$
$$z' = z$$
$$t' = Cx + Dt$$



a) Consider points with $x' = 0$ and thus with $x = vt$. Show that the transformation above then implies $v = -\frac{B}{A}$.

b) Consider points with $x = 0$ and thus with $x' = -vt'$. Show $v = -\frac{B}{D}$.

c) Next consider a spherical wave emitted at the origin at $t = t' = 0$ and explanding at the speed of light c as seen from S. Require that S' sees also a spherical wave expanding from the origin at the speed of light c. Thus determine the coefficients of the linear transformation above.

Extra Credit **Tipler** Chapter 2 Problem 13.