

PHY294, Winter 2016, QUIZ IV.

Answer all questions on the exam paper. Duration: 25 minutes.

Name: the prof; Student #: _____; Tutorial group: _____

I. Consider two monatomic ideal gases. Both gases have the same number of particles and their respective containers have the same volume. The atoms of one gas are roughly 4 times heavier than the other. Imagine that the two gases are initially at the same temperature and that at that temperature both of them obey equipartition and the usual ideal gas law. Which gas will you have to cool more in order for quantum effects to become important and for the ideal gas law to break down?

the heavier gas has a shorter thermal de Broglie wavelength (@ same T)
so to increase it (to make gas quantum)
it has to be cooled more
(really, roughly 4x more)

3 points

II. A paramagnet of N spins, each with magnetic moment μ , is placed in magnetic field B and is kept at some temperature T . There are two characteristic regimes of temperatures. In one regime, the magnetization is large, while in the other regime it tends to be very small. What value of T (expressed in terms of the parameters of the magnet μ , and B and any relevant fundamental constants) separates the two regimes? Which temperature regime corresponds to increasing order and which to increasing disorder?

"high" T	$kT \gg \mu B$	disordered
"low" T	$kT \ll \mu B$	ordered

3 points

Turn over, please \rightarrow

III. Can one build a heat engine that converts the entire amount of heat from burning the fuel to work? Explain your answer.

no. - This would decrease the entropy of the "universe" (as the heat source loses entropy) & is forbidden by 2nd law

3 points

IV. What is the free energy of a quantum harmonic oscillator in the $T \rightarrow 0$ limit? (Take the quantum oscillator's ground state energy to be zero.)

$$F = 0 \text{ @ } T = 0$$

a) ✓

$$Z \rightarrow 1 \text{ as } T \rightarrow 0$$

$$\therefore F = -kT \log Z \rightarrow 0$$

or

$$b) F = U - TS$$

$$\rightarrow U_0 \text{ as } T \rightarrow 0$$

$$\text{but } U_0 = 0 \quad \square \quad 3 \text{ points}$$

Total number of points: $3 + 3 + 3 + 3 = 12$.