

PHYSICS 301

HOMEWORK #8

Due Monday November 10 at 5:00 in the front office.

1. To include quantum mechanics in the calculation of the translational degrees of freedom, one must use the partition function

$$Z = \frac{1}{N!} (n_Q V)^N.$$

- (a) Does this inclusion of quantum mechanics change the results of the equipartition theorem? Does it change the value of C_V ?
 - (b) Could this fact have been seen to be obvious from a plot of C_V versus temperature like **Figure 17.2** on page 305?
2. Problem 17-3 from **Stowe** on page 307. You can either repeat his derivation or use the partition function.
 3. In our calculation of the internal energy, we ignored the fact that these particles are located on earth and therefore experience a gravitational force. Assume that we have a gas with particles which are confined to a cube of side L . If this cube is oriented such that its top and bottom are perpendicular to the surface of the Earth, what is the average internal energy and specific heat, C_V ?

HINT: Assume that we can do a classical calculation and set the energy to

$$E = \frac{1}{2m} (p_x^2 + p_y^2 + p_z^2) + mgz$$

where g is the acceleration due to gravity and z is the height above the surface.

4. Certain scales work by using a spring which is suspended from a fixed support. When the spring become small (which is necessary for very precise measurements) or the temperature is large, the measurements can be destroyed by thermal fluctuations. Assume that the restoring force of the spring is given by α , and the acceleration due to gravity is g .
 - (a) What is the energy when an object of mass M is hung from the spring?
 - (b) What is the mean elongation of the spring, \bar{z} ?
 - (c) What is the magnitude of the thermal fluctuations, *i.e.*, the variance, $\sqrt{\overline{z^2} - (\bar{z})^2}$?

- (d) The scale becomes unusable when the magnitude of the thermal fluctuations become equal to the mean elongation of the spring. What is the minimum mass that can be measured using this type of spring scale?

HINT: This is a case where the partition function is not of much use. To find mean values, Either use the probabilities directly, $\bar{z} = \int dz P(z)z$, **OR** use a fact about this type of probability distribution that was proven way back in HW #1