BASIC QUESTION FOR SPRING 1998 QUAL

(70 pts) I. One of the most valuable tools that a physicist can have is the ability to make rough estimates of physical quantities, based on some reasonable assumptions that approximate the physical conditions which are present. This conscious effort should be a prelude to any detailed calculation or measurement which one attempts to do. With this in mind, make a reasonable estimate of the following quantities. In each case, describe what are your reasonable assumptions and use sound physical arguments to make your estimate whenever possible. If a model is required, describe that as well. (In some instances, you may need to "guess" some parameter, but try to develop basic arguments which would lead you to the approximate value of the parameter that you need in your estimate.)

(14 pts) (a.) Estimate the frequency of radiation that is used in a microwave oven.

(14 pts) (b.) Estimate the energy yield of a fission bomb with a 20 kg uranium core.

(14 pts) (c.) Estimate the energy of impact with the Earth of a dense meteorite (with a 10-meter diameter) that survives entry into the atmosphere.

(14 pts) (d.) Estimate the total number of air molecules in the earth's atmosphere.

(14 pts) (e.) Estimate the speed of sound in helium gas at STP.

(30 pts.) II. A common problem encountered in the laboratory is the need to pump down some large vacuum chamber. Assume that you have a pump that is capable of maintaining a base pressure of $P_p = 1.0 \times 10^{-7}$ Pa (where "Pa" is a $\mathrm{N/m^2}$). Further, assume that the previously evacuated chamber, with a volume $V = 1.0\ \mathrm{m^3}$, has had enough gas evolve from the wall surfaces to cause the chamber pressure to rise to $P_0 = 1.0 \times 10^{-3}$ Pa of air. It is then connected to the vacuum pump (i.e. a valve is opened) by a flange with a circular aperture of radius $R = 1.0$ cm.

(10 pts) (a.) The total flux of particles that strike a unit area per sec is $\frac{1}{4} n \overline{v}$ where n is the density of particles in the volume and $\overline{v}$ is the mean speed of the molecules. Justify by plausible physical arguments why this equation is valid under the prevailing conditions (to within a factor near unity).

(10 pts) (b.) What basic assumption or condition needs to be met (for the pump aperture) in order to use the above relationship? You may assume that the mean free path of air molecules at STP is ≈ 100 nm.

(10 pts) (c.) How long does it take for the pressure in the large vacuum chamber to fall to 2.0×10^{-7} Pa?