Homework for Week 4

Due Friday Oct 25 at 5pm

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1. Term project - Step 1

Read the term project description on the class website (see the link on the sidebar).
http://physics.oregonstate.edu/~minote/COURSES/ph315

Identify three (3) subjects that you find interesting/intriguing (for example, solar energy, exoplanets…). Within each subject, pose a question that might have an interesting quantitative answer: "Since it requires energy to make a solar panel, how long does it take to recoup that energy?", "How far away could we see an Earth-like planet orbiting a Sun-like star?"… You should have 3 different subjects and 3 different questions.

Let your mind wander as broadly as possible. The class website has a list of ideas to spark your imagination. Subjects and questions are not restricted to the topics mentioned in this class. The instructor will read your answers and give you feedback about which ideas seem most promising for developing further.

2. Quantum corrections to the equipartition theorem

a) T5B.4 An atom of helium can store energy by bumping its electron from its lowest orbital energy level to a higher orbital energy level. In particular, moving an electron from the lowest state to the next-lowest state would store an energy of 24.6 eV. Explain why we can ignore this energy storage mode when calculating the heat capacity of helium gas at ordinary temperatures.

b) T5B.5 Calculate the approximate temperatures at which the following energy storage modes of a nitrogen molecule become "unfrozen" (i) The kinetic energy mode (energy quanta for this mode are about 10^{-7} eV). (ii) The rotational energy mode (energy quanta for this mode are about 0.00025 eV). (iii) The vibrational energy mode (energy quanta for this mode are about 0.29 eV).

Note: 1 eV = 1.6×10^{-19} J.

3. The physics of the medium affects the wave

a) In air at 293 K and atmospheric pressure, a disturbance in pressure travels at 340 m/s (this is called a sound wave). Humans can hear sound wave frequencies from 30 Hz to 15,000 Hz. At 293 K and atmospheric pressure, what wavelengths of sound correspond to the upper and lower limits of human hearing?

b) In air at 240 K and atmospheric pressure, a disturbance in pressure travels at 300 m/s. In these cold conditions, what wavelengths of sound correspond to the upper and lower limits of human hearing?

c) In vacuum, a disturbance in electric field travels at 3×10^8 m/s (this is a called electromagnetic radiation, or "light"). If the wavelength of light in vacuum is 633 nm (light generated by a red laser), what is the frequency of the disturbance (i.e. how many times per second does the electric field oscillate up and down at a fixed point in space?)

d) In diamond, a disturbance in electric field travels at 1.25×10^8 m/s. When you shine a red laser at a diamond, what is the wavelength of the light inside the diamond?

4. Boundary conditions and musical instruments (based on Q2M.1)

a) A concert flute, shown above, is about 2 ft long. Its lowest pitch is middle C (about 262 Hz). On the basis of this evidence, should we consider a flute to be a pipe that is open at both ends, or at just one end? (The end of the flute farthest from the mouth piece is clearly open. The other end of the flute seems to be clearly closed, so if you claim that the flute is open at both ends, you should try to explain where the other open end is.)

b) What are the lowest three resonant frequencies that can be played on a flute when all the finger holes are closed? Give you answer in units of Hz. Draw these frequencies on a frequency level diagram.

c) The orchestra is warming up their instruments. The flute starts at 290 K and increases temperature to 300 K. How seriously does this affect the pitch of the flute? For reference, each step on a chromatic musical scale has a frequency 1.06 times higher than the one below it ($1.06 = 2^{1/12}$). The conductor of the orchestra will be upset if the flute is detuned by a $^1/_6$ of a chromatic step. Remember that the speed of sound in a gas is $v = \text{sqrt}(\gamma P_0/\rho_0)$ where γ is a constant, P_0 is the ambient pressure and ρ_0 is the gas's density.

Extra question, not graded. I just thought it was interesting…

(Q2M.3) You may know that if you inhale helium, your voice sounds strange and high-pitched if you talk as you exhale the helium. Why is this? (Hints: Your sinuses are resonating chambers of air that emphasize certain pitches produced by your vocal chords. Remember that the speed of sound in a gas is $v = \text{sqrt}(\gamma P_0/\rho_0)$ where γ is a constant, P_0 is the ambient pressure and ρ_0 is the gas's density.) Obligatory safety note: Inhaling helium can be dangerous because while the helium is in your lungs, your body is not getting the oxygen that it needs.