Questions before Exam 1

1. **When you look at a stick in water, it appears bent; objects underwater are not exact where we see them. What is going on?**

   We see an object in the direction of the light ray that makes it into our eye. If the light is refracted—if the light ray path is bent—we will receive false information about the location of the object.

   Question I could ask: Could a similar phenomenon happen with sound? How?

2. **You put a block of ice between the plates of a capacitor. How do the polar H_2O molecules align themselves?**

   The + end of each polar molecule will be repelled by the + plate and attracted to the − plate. So the polar molecules will become oriented, in a way very similar to the induced dipoles in dielectric materials as described in page 688 of your textbook. The total electric field inside the capacitor will be reduced in magnitude.

   Question I could ask: What is the role of friction in dipoles aligning themselves with an external electric field? (*Hint:* How would a dipole in a uniform external electric field behave if there was no friction?)

3. **The way synapses work involve migrating ions and resulting potential differences. Is an electric field also involved?**

   Voltage differences *always* result in electric fields. The different layers of ions that face each other across a synapse is very much like a capacitor. And just as in a capacitor, an electric field is set up in a synapse. Since the geometry of a synapse is not like an infinite-size parallel plate capacitor, however, the electric field will not be perfectly uniform.

   Question I could ask: Actual parallel plate capacitors do not have infinite areas. Say you set up two finite metal plates and imposed a voltage difference between them, much like you did in your equipotential lines lab. The size of the gap between the plates in the lab was comparable to the plate size. In this case, make a qualitative drawing of what the equipotential lines and the electric field lines look like for this more realistic capacitor. Be sure to show what happens outside the plates as well.

4. **What would happen if you built a capacitor out of antimatter plates?**

   Antimatter is just like matter, except that some of its properties such as electrical charge are exactly opposite. For example, the antimatter partner of a negatively charged electron is a positively charged anti-electron (positron). If, then, you replaced every particle that makes up a capacitor with its antiparticle, you'd have a capacitor where the $+q$ charge will have become $-q$ and vice versa.

   Question I could ask: Would the voltage difference between the plates also reverse sign or not?

5. **Interference effects such as diffraction happen with light waves. Can they also happen with electric fields?**

   If you had an electric field that varied up and down over space, and this pattern of variation travelled, you would have a wave in the electric field. And when you have any sort of wave, you can have interference effects such as diffraction.

   Later in the semester, we will see how a changing electric field generates a magnetic field, and how a changing magnetic field generates an electric field. As a result, if you start a wave in an electric field, you unavoidably also obtain a wave in a magnetic field. Therefore we call such waves electromagnetic waves. As it happens, light *is* an electromagnetic wave. Therefore, light is already the answer to this question.

   Question I could ask: Imagine a single-frequency electromagnetic wave (pure sine wave) going through an area in which there is an electron with initial position $x_e = y_e = 0$. Consider only the electric field: it points up and down (depending on what part of the sine wave is going through) along the y-axis, while the wave travels in the $+x$-direction. Make a qualitative graph of the electric force experienced by the electron, as a function of time t. Then make a qualitative graph of x_e and y_e vs. t.

6. **How can light be both a wave and a particle?**

   We will be addressing this question later in the semester, in some detail. But we need to get inso some quantum mechanics for its resolution, and it's a bit early for that. For now, however, we can concentrate on the differences between particles and waves. And here, the important point is that *interference* is a strictly wave phenomenon.

   Question I could ask: Imagine that in the lab I give you a black box which I say is a source of "Q-rays." I also provide you with an orange box which has a dial indicating the intensity of Q-rays incident on it. I then tell you that there are two theories about Q-rays. The first theory is that the Q-ray source emits a continual stream of tiny, invisible, and extremely numerous Q-particles. The detector registers the energy of each Q-particle colliding with it, and adds all the individual collision energies in a time interval up to give you $I = P/A$, with P the power and A the area. The second theory is that the source emits Q-waves, and the detector picks up the power $P \propto |a|^2$ proportional to the amplitude (a) squared of the Q-waves. What kind of experiment or experiments would you design to investigate which theory seems more accurate?

7. **How can you have multiple resonant frequencies for a single object?**

   An extremely simple oscillator like a mass on a spring is simple because it has only one "degree of freedom": the only thing the mass can do is go up and down along a single axis y. But real objects have very large numbers of degrees of freedom: not only can they oscillate in 3D, but all possible forms of distortion and deformation are also associated with vibrational frequencies. So depending on which degrees of freedom are in play, a real object will have lots of different possible resonant frequencies. In practice, all but a few of these frequencies will be too high or two low to practically access.

   Question I could ask: If you excited a badly-designed bridge at a resonant frequency (for example, with periodic wind gusts), you could cause it to collapse. Would such a bridge be at at any danger from sunlight? After all, light is also a wave that can act on the bridge by driving it at the wave frequency.

8. **What is the connection between resonance and echolocation?**

   As far as I know, there is no connection. Echolocation works by bouncing sound waves off of objects and detecting the reflecting waves. Resonance might make certain objects particularly detectable, but I don't think it would be very likely in practice.

   Question I could ask: Say you tried to do something like echolocation and image your surroundings by emitting audible sound waves and detecting the reflected echoes. Could you use this to distinguish between the facial features of various people, and tell them apart?

9. **What is happening with induced dipoles and Van der Waals interactions?**

   The presence of electric fields can distort the charge distribution in atoms and molecules. Since negative charges will be attracted toward the + end of the electric field and positive charges will behave in an opposite manner, the electrons will slightly move toward the higher voltage region, while the nuclei will move toward the lower voltage end. So the charge will become distributed such that there is more + charge at one end of a neutral molecule and more − charge at the other end. This is a dipole—induced by the external electric field.

   "Van der Waals interactions" is often a catch-all term used for electrical interactions involving dipoles and higher-order poles, which are weaker and fall off more rapidly in space compared to electrical interactions between bare charges.

   Question I could ask: You put a slab of some material between the plates of a capacitor. The electrical field of the capacitor induces dipoles in the material. Will the total electric field—due to the charged plates plus the induced dipoles—be larger, smaller, or equal in magnitude compared to the electrical field that would be there with only empty space between the capacitor plates?

10. **Is there any connection between earthquakes and electromagnetic waves?**

    Possibly. The extreme stresses on materials such as rock during earthquakes can produce weak electromagnetic effects as well. But they are incidental to what is happening in earthquakes.

Question I could ask: Since the only way you know of creating electric fields so far is through charges, and since an electromagnetic wave is a traveling oscillation in an electric field, can you think of a mechanism by which you could produce an electromagnetic wave?

11. **Is a light saber possible?**

    No, at least not exactly as in the movies.

    Question I could ask: In science fiction movies, you have spaceships exploding in outer space with lots of noise all the time. What is wrong with that picture?

12. **How does laser light result in heat? Could a laser work under water?**

    You have already learned that interactions involving lots of particles inevitably result in energy going into random microscopic movements—thermal energy. When you shine a laser on an object, which is made out of lots of particles, not all the light is reflected. Much of the energy in the beam is absorbed, and is transferred to the kinetic energies of the particles and the potential energies due to their mutual interactions—again, thermal energy.

    A laser could work under water. The beam couldn't travel as far, since water is not fully transparent, absorbing some of the energy as it passes through.

    Question I could ask: Could the same be said for ordinary sunlight or light from a light bulb? Or is there something special about a laser?

13. **How can a laser that can melt metal still be visible light?**

    The individual photons of visible light are energetic enough to strongly interact with ordinary matter (which is why they are visible). But melting metal is not just due to individual photon energies, but the intensity of the beam as a whole. The laser interacts with its target, and the usual heat transfer mechanisms do not act quickly enough to keep the target area cool. So it heats up and melts.

    Question I could ask: Say you shine a powerful laser on a near-perfect mirror. Would it melt?