Before-class Questions #6:

Question 1: Using a physical picture, describe spin-orbit coupling in a hydrogen atom.
Answer: In the electron's frame it looks like the proton is orbiting around the electron, generating a ring current and thus creating a magnetic field. This magnetic field (proportional to the electron's angular momentum) couples to the electron's magnetic moment (proportional to its spin), hence generating spin orbit coupling.

Question 2: When deriving the Darwin term, we assume the electron is smeared out over what wavelength? Why is this a good assumption?
Answer: It is smeared out over the Compton wavelength. This is the position uncertainty which corresponds to a momentum uncertainty (by Heisenberg) which corresponds to an energy uncertainty (from E = p^2/2m) which equals to the pair production threshold. Thus if we confine the particle into such a small space, the single particle picture breaks down.

Question 3: Does the fine structure energy splitting ultimately depend on J, or L and S separately?
Answer: Only J.

Question 4: What is the mechanism by which the Lamb shift arises?
Answer: Coupling of the atomic system/electrons to the vacuum modes of the electromagnetic field. EM modes have zero point fluctuations, which can shake the electrons similarly to the Darwin term.

Question 5: How does binding energy change for a finite mass nucleus isotope shift, compared to assuming an infinitely massive nucleus? Why?
Answer: Because we should replace the mass of the electron by the reduced mass, the kinetic energy increases (we can look at it as the kinetic energy due to the new motion of the nucleus). Thus the binding energy decreases.

Question 6: How does binding energy change for a finite volume nucleus compared to a zero volume nucleus? Why?
Answer: It weakens the binding energy of s electrons, since it effectively cuts off the Coulomb potential where it's the strongest, near the nucleus.

Question 7: What improvement was made in 2010 to improve the measurement of the proton radius? How did it help?
Answer: There was a big improvement in measuring the size of the proton by replacing the electron with a muon (heavy electron). And because the muon is much heavier, the Bohr orbit of the muon is much smaller. Therefore, the correction due to the finite size of the proton is much larger (more overlap of the muonic wave function with the proton than for the electron).

Optional: Please provide feedback and suggestions, including for improvements to the course material and for topics and questions for the in-class discussions.
Answer: Prof. Ketterle will respond in class