The exam budgets 50 minutes, but you may have 60 minutes to finish it. Good answers can fit in the space provided.

Question values correspond to allotted time. Don't waste too much time on cheap questions.

Read each question carefully to see what it asks for (bold face is used to help highlight questions).

Make sure you are answering the question, not just saying something vaguely relevant to its topic.

1. The following structure is commonly drawn for the antihistamine Benadryl. This structure is misleading, because the HCl reacts with the organic molecule to form what used to be considered a “pentavalent” atom.

   A) (4 min) Scratch out the HCl and redraw its atoms to show a proper Lewis structure with lines for bonds. Write a few words to help explain the “pentavalence.”

   B) (3 min) Circle and name each functional group in your improved structure of Benadryl.

2. (4 min) Draw bond lines and necessary formal charges among the atoms below to show the two most reasonable “resonance structures” for formamide. Draw the proper arrow symbol between the two structures.
3. (2.5 min) **Who** said "I cannot bear the Thought of being made Master of a Jewell I know not how to wear"?

   **What did he mean?**

4. (2.5 min) Why did J. J. Thomson propose that negative corpuscles (or electrons) were arranged *inside* a cloud of positive charge density?

5. (3 minutes) Explain how a discovery by Chladni relates to the idea of “degenerate” orbital energies.

6. (5 minutes) **How and Why** does one hybridize atomic orbitals? Explain using the example of an H-like atom in an electric field.
7. (4 minutes) Explain how the average potential energy of a hydrogen-like atom scales with the nuclear charge. That is, if the nuclear charge is doubled, how much does the average potential energy change, and why?

8. (4 minutes) Which of the following techniques offers the best resolution (most detail), and which the least? Explain.

   Scanning Tunneling Microscopy

   Atomic Force Microscopy

   X-ray diffraction

9. (6 min) How is an electron difference (or deformation) density map prepared? Cite an example where it revealed “pathological” bonding. Be as specific as you can.
5. The diagram is part of an “Erwin Meets Goldilocks” plot with two trial wave functions for the potential energy, which is shown in gray.

A) (2 min) **Draw a horizontal line** showing the **TOTAL ENERGY** for the \( \psi \) curve that becomes horizontal at the right. Be as accurate as you can.

B) (2 min) Is the total energy for the other trial \( \psi \) (the one that has a value of 0 at the right) **higher or lower** than that the one you drew in A? **Explain your thinking.**

C) (3 min) Assuming that this is a Hooke’s Law single-minimum problem, **draw** in the **correct** lowest-energy \( \psi \) **function** (NOT its energy), and **extend all three \( \psi \) curves** to the right edge of the page.

D) (5 min) Now assume that this potential is in fact the left half of a symmetric double minimum, and the original two \( \psi \) traces are part of **correct** solutions. **Explain** how one \( \psi \) may be considered “bonding”, and the other “antibonding.”