General Instructions:

(i) Do not open exam until 9:55 (when bell rings).
(ii) Use blank paper on the back of each page to work out answers. Final answers must be written legibly in the space provided.
(iii) Print your name on each page.

***No credit will be given for illegible and/or ambiguous answers.***

(Substantiated evidence for cheating or other misconduct is grounds for automatic course failure and subject to further prosecution.)
1. [15 points] Provide skeletal structures for the following compounds. It's not necessary to include hydrogen atoms. Include wedged and dashed bonds where appropriate to indicate three-dimensional orientation.

(a) (4 pts) 2-bromo-4-isopropyl-1-heptene

(b) (6 pts) trans-1-fluoro-3-propylcyclohexane (your drawing should clearly indicate the most stable three-dimensional conformation of this molecule)

(c) (5 pts) trans-2-bromo-3-chloro-1,1-diethylcyclopropane
2. [10 points] Provide the IUPAC name for the following molecules.
   (a) (4 pts)
   \[\text{cis-1-chloro-2-ethyl cyclobutene}\]
   
   (b) (6 pts)
   \[\text{(E)-2-butyl-1-fluoro-1,3-butadiene}\]

3. [10 pts] In the following structure...
   (a) (3.5 pts) Indicate the orbital hybridization at each carbon.
   
   (b) (3.5 pts) What is the angle between each of the substituents at each of the carbon centers.
   
   (c) (3 pts) Redraw the structure with the correct bonds angles (include hydrogen atoms) and indicate the direction of the molecular dipole, if any exists.

Correct drawing 1 pt
Dipole 2 pts
4. [20 pts] The following molecules are unstable as drawn because they contain both nucleophilic and electrophilic sites in the same molecule.

(a) Draw partial charges (i.e., $\delta^+$, $\delta^-$) in the molecules.

(i) (4 pts)

(ii) (4 pts)

(b) These molecules react to produce the initial products shown below. Draw an arrow pushing mechanism that leads to the products shown.

(i) (4 pts)

(ii) (4 pts)

(c) (4 pts) Based on the initial products arising from reactivity, indicate the primary nucleophilic and electrophilic sites in the molecules.
5. [19 pts] The following molecules are constitutional isomers.

(a) (4 pts) What is the molecular formula for each of these molecules?

\[ C_8H_{16} \]

(b) (8 pts) Which molecule do you predict is more stable? Indicate the three most important sources of instability (i.e., strain) in these molecules (one in the cyclohexane and two in the cyclopropane).

- A is more stable than B

1) B has significant angle strain
2) B has significant torsional strain (eclipsing alkyl groups)
3) A has strain arising from a 1,3 di axial interactions with the methyl group

(c) (7 pts) As clearly as possible, describe how we could experimentally determine the relative energies of these molecules. (If a chemical method is used, provide a balanced reaction).

- Burn them and measure the heat given off

\[ C_8H_{16} + 12O_2 \rightarrow 8CO_2 + 8H_2O + \text{heat} \]

\[ \Delta H_{\text{cyclohexane}} < \Delta H_{\text{cyclopropane}} \]
6. [24 pts] Electrophilic addition to alkynes occurs in a manner very similar to that described for alkenes in class. The overall reaction between 2-butyne and HCl is shown below.

\[
\text{H}_3\text{C} = \equiv \text{CH}_3 + \text{HCl} \rightarrow \text{Cl} = \equiv \text{CH}_2 \text{H} \text{CH}_3
\]

This reaction involves the formation of a cationic intermediate, which subsequently converts to the product. An energy diagram for this reaction is shown below.

(a) (6 pts) Indicate on the diagram, the \( \Delta G^\circ \) for the above reaction and the \( \Delta G^1 \) for the rate-determining step.

\[
\begin{align*}
\text{H}_3\text{C} & = \equiv \text{CH}_3 + \text{HCl} \\
\text{C} & \quad \text{B} \\
\text{A} & \quad \Delta G^* \\
\text{H}_3\text{C} & = \equiv \text{CH}_2 \text{H} \text{CH}_3
\end{align*}
\]
(b) (18 pts) Provide clearly drawn structures for species A, B, and C from the energy diagram, specifying three-dimensional orientation where appropriate. Clearly indicate whether the structure is an intermediate or a transition state; appropriately label the transition states with the \( \dagger \) symbol. Indicate any full or partial charges in the structures.