• Please read all instructions (including these) carefully.

• The exam is closed book, closed notes, and closed internet.

• The exam consists of 7 pages including this page. The last page is a reference sheets for the Fitch rules of inference. There are 5 questions. Each question is worth 10 points.

• Time limit: one hour. Budget your time accordingly.

• Please write your solutions in the spaces provided on the exam. Make sure that your solutions are neat and clearly marked. You may use the blank areas and backs of the exam pages for scratch work.

In accordance with both the letter and spirit of the Honor Code, I have neither given nor received assistance on this examination.

NAME: __________________________________________

SUNETID (username): ________________________________

SIGNATURE: ______________________________________

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1
Question 1 [10 points]

Please circle exactly one of the provided answers for each question, and provide a brief justification (no more than 1 sentence)

a. Is the following sentence valid, contingent, or unsatisfiable? (4 points)

\[ p \land (p \leftrightarrow q) \land q \land (p \Rightarrow \neg q) \]

VALID CONTINGENT UNSATISFIABLE

b. Suppose that you are given the following premises:

\[ p \\
\quad p \Rightarrow \neg q \\
\quad p \lor r \]

The sentence \( p \Rightarrow q \) is consistent with the supplied premises. (3 points)

TRUE FALSE

The sentence \( p \land \neg q \land r \) is logically entailed by the supplied premises. (3 points)

TRUE FALSE
Question 2 [10 points]

Please circle exactly one of true or false for each of the following statements. No explanation is required.

1. In Propositional Logic, for any set of sentences $\Delta$ and a sentence $\phi$ such that $\phi$ is provable from $\Delta$ using the Fitch system, then $\Delta$ logically entails $\phi$. (3 points)

   TRUE  FALSE

2. Propositional Resolution is complete; that is, if a set of clauses $\Delta$ is unsatisfiable, then there is guaranteed to be a resolution derivation of the empty clause from $\Delta$. (3 points)

   TRUE  FALSE

3. Propositional Resolution is not generatively complete; that is, it is not possible to find resolution derivations for all clauses that are logically entailed by a set of premise clauses. (4 points)

   TRUE  FALSE
Question 3 [10 points]

Assume that $\Gamma$ and $\Delta$ are sets of sentences in Propositional Logic, and $\phi$ and $\psi$ are sentences in Propositional Logic. Please circle true or false for each of the following statements. No justification is required.

a. If $\Delta \models \phi$ and $\Delta \models \neg \phi$, then $\Delta \models \psi$. (2 points)
   
   TRUE          FALSE

b. If $\Gamma \not\models \phi$ and $\Delta \not\models \phi$, then $\Gamma \cup \Delta \not\models \phi$. (2 points)
   
   TRUE          FALSE

c. If $\Gamma \cap \Delta \models \phi$, then $\Gamma \models \phi$ and $\Delta \models \phi$. (2 points)

   TRUE          FALSE

d. If $\Gamma \cap \Delta \not\models \phi$, then $\Gamma \not\models \phi$ and $\Delta \not\models \phi$. (2 points)

   TRUE          FALSE

e. If $\Gamma \subseteq \Delta$ and $\Gamma \models \phi$, then $\Delta \models \phi$. (2 points)

   TRUE          FALSE
Question 4 [10 points]

Use the Fitch System to prove $p \Rightarrow \neg q$ from the premise $\neg(p \land q)$.

Please annotate your proof by writing the rule and line number for each step in your proof (abbreviations are fine). Clearly mark any assumptions and subproofs within your proof in the same format as the exercises and notes.
Question 5 [10 points]

Prove \((p \Rightarrow q \land w) \Rightarrow ((\neg w \land \neg p) \lor q)\) using Propositional Resolution given the premises \(w \Rightarrow p\) and \(\neg w \Rightarrow (q \Rightarrow p)\).
Fitch Rules of Inference

**And Introduction**

\[ \phi_1 \]
\[ \ldots \]
\[ \phi_n \]

\[ \phi_1 \land \cdots \land \phi_n \]

**And Elimination**

\[ \phi_1 \land \cdots \land \phi_n \]

\[ \phi_i \]

**Or Introduction**

\[ \phi_1 \]

\[ \phi_1 \lor \cdots \lor \phi_n \]

**Or Elimination**

\[ \phi_1 \lor \cdots \lor \phi_n \]

\[ \phi_1 \implies \psi \]
\[ \ldots \]
\[ \phi_n \implies \psi \]

\[ \psi \]

**Negation Introduction**

\[ \phi \implies \psi \]
\[ \phi \implies \neg \psi \]

\[ \neg \phi \]

**Negation Elimination**

\[ \neg \neg \phi \]

\[ \phi \]

**Implication Introduction**

\[ \phi \models \psi \]

\[ \phi \implies \psi \]

**Implication Elimination**

\[ \phi \implies \psi \]
\[ \phi \]

\[ \psi \]

**Biconditional Introduction**

\[ \phi \implies \psi \]
\[ \psi \implies \phi \]

\[ \phi \iff \psi \]

**Biconditional Elimination**

\[ \phi \iff \psi \]
\[ \phi \implies \psi \]
\[ \psi \implies \phi \]

In addition to these rules of inference, you may make **assumptions** within subproofs and use **reiteration** to reproduce an earlier conclusion in your proof.