Exercise 1 (6 Points, LTL Semantics)
Consider the following transition system over the set of atomic propositions \( \varphi \{a, b\} \):

![Transition System Diagram]

In which states are the following LTL formulae true:
(a) \( Xa \)  
(b) \( XXXa \)  
(c) \( Gb \)  
(d) \( GFa \)  
(e) \( G(bUUa) \)  
(f) \( F(aUb) \)  

Exercise 2 (10 Points, LTL properties)
Suppose we have two users, Peter and Betsy, and a single printer device Printer. Both users perform several tasks, and every now and then they want to print their results on the Printer. Since there is only a single printer, only one user can print a job at a time. Suppose we have the following atomic propositions for Peter at our disposal:

- \( \text{Peter.request} ::= \) indicates that Peter requests usage of the printer;
- \( \text{Peter.use} ::= \) indicates that Peter uses the printer;
- \( \text{Peter.release} ::= \) indicates that Peter releases the printer.

For Betsy, similar predicates are defined. Specify in LTL the following properties:
(a) Mutual exclusion, i.e., only one user at a time can use the printer.
(b) Finite time of usage, i.e., a user can print only for a finite amount of time.
(c) Absence of individual starvation, i.e., if a user wants to print something, he/she is eventually able to do so.
(d) Absence of blocking, i.e., a user can always request to use the printer.
(e) Alternating access, i.e., users must strictly alternate in printing.
Exercise 3 (6 Points, LTL operators)
Let \( \varphi \) and \( \psi \) be LTL formulae. Consider the following new operators:

1. “At next” \( \varphi N \psi \): at the next time where \( \psi \) holds, \( \varphi \) also holds.
2. “While” \( \varphi W \psi \): \( \varphi \) holds at least as long as \( \psi \) does.
3. “Before” \( \varphi B \psi \): if \( \psi \) holds sometime, \( \varphi \) does so before.

Make the definitions of these informally explained operators precise by providing LTL formulae that formalize their intuitive meanings.

Exercise 4 (8 Points, LTL formulae)
Are the following LTL formulae, valid, not valid but satisfiable or unsatisfiable?

1. \( X(a \lor Fa) \rightarrow Fa \),
2. \( (Ga) U (Fb) \rightarrow G(a U (Fb)) \),
3. \( GG(\varphi \lor \neg \psi) \leftrightarrow \neg (F(\neg \varphi \land \psi)) \),
4. \( ((\varphi U \psi) U \psi) \leftrightarrow (\varphi U \psi) \).