1. [20 points] You are given this action schema to move object \( o \) from \( x \) to \( y \):
\[
\text{Action (Transfer}(o, x, y),
\]
\[
\text{Precond: } \neg \text{At(Robot, } x) \land \text{At}(o, x) \land (x \neq y)
\]
\[
\text{Effect: } \neg \text{At}(o, x) \land \text{At(Robot, } y) \land \text{At}(o, y)
\]
1. Create new action schemas by decomposing the given action schema into three schemas, one to grasp the object, one to move it to the destination, and one to drop it at the destination.
2. Describe in general how action schemas can be created by splitting existing schemas. Explain when this is a good idea and when not.

2. [15 points] Your goal is to have \( \text{RightShoeOn} \land \text{LeftShoeOn} \), using these actions:
\[
\text{Action(RightShoe),}
\]
\[
\text{Precond: } \text{RightSockOn}
\]
\[
\text{Effect: } \text{RightShoeOn}
\]
\[
\text{Action(RightSock),}
\]
\[
\text{Precond: }
\]
\[
\text{Effect: } \text{RightSockOn}
\]
\[
\text{Action(LeftShoe),}
\]
\[
\text{Precond: } \text{LeftSockOn}
\]
\[
\text{Effect: } \text{LeftShoeOn}
\]
\[
\text{Action(LeftSock),}
\]
\[
\text{Precond: }
\]
\[
\text{Effect: } \text{LeftSockOn}
\]
Show the planning graph marking the mutexes. At what level is the problem solved? Show a solution.

3. [20 points] You are given the following propositional actions:
\[
\text{Action(Sell),}
\]
\[
\text{Precond: } \text{HaveFood}
\]
\[
\text{Effect: } \text{HaveMoney} \land \neg \text{HaveFood}
\]
\[
\text{Action(Eat),}
\]
\[
\text{Precond: } \text{HaveFood}
\]
\[
\text{Effect: } \text{Happy} \land \neg \text{HaveFood}
\]
\[
\text{Action(Run),}
\]
\[
\text{Precond: }
\]
\[
\text{Effect: } \text{AreTired}
\]
\[
\text{Action(Sleep),}
\]

TURN TO THE NEXT PAGE FOR MORE QUESTIONS
**Precond:** AreTired
**Effect:** Happy

**Action(Enjoy,**

- **Precond:** HaveMoney \(\land\) Happy
- **Effect:** HaveFriends)

Initial state: HaveFood. Goal: HaveFriends

Draw the planning graph up to where it finds the goal. Mark the mutexes. At what level is the problem solved? Show a solution.

4. **[20 points]** Represent the following information using a semantic network: “Clyde crossed the Alps with the army of Hannibal. Hannibal was a military commander. Hannibal was an enemy of the Romans. Clyde is an elephant. Elephants are grey. They can carry large loads. Clyde helped Hannibal in his fight against the Romans. Clyde did not like the cold weather in the Alps.”

5. **[25 points]** Answer these questions briefly but precisely, Explain your reasoning.
   
   1. When writing an action schema in propositional calculus, can we assume that in the effect there is no proposition that is included both as positive and as negative? why? or why not?
   2. When writing an action schema in propositional calculus, can we assume positive propositions in the effect do not appear in the preconditions? why? or why not?
   3. Explain why dropping negative effects from every action schema results in a relaxed problem.
   4. Explain why if an action appears in a planning graph at one level, it will appear at every subsequent level.
   5. Why the distinction between disjoint categories and an exhaustive decomposition is important when representing categories and objects?

6. **[20 points – extra credit]** You are given a train engine and three boxcars which are all at the Saint Paul station. There are two more boxcars in Milwaukee. There is a track connecting Saint Paul to Milwaukee and one connecting Milwaukee to Chicago. Your goal is to move the five boxcars to Chicago and take the engine back to Saint Paul.

   Boxcars can be moved if coupled with an engine. You can couple a boxcar with an engine if they are both at the same train station. You can couple one boxcar at a time with an engine. You can connect as many boxcars as you want to an engine. An engine can move from a station to another as long as there is a track connecting the stations, either directly or indirectly through another city.

   1. Write the initial state and the goal state. Provide a description of the predicates you used sufficient to understand them unequivocally.
   2. Write the planning action schemas needed for this train domain.

YOU REACHED THE END OF THE EXAM