CS561 Artificial Intelligence - Spring 2010
Midterm 2 Solutions

1. (25 points) First-order Logic / Knowledge Representation [Graded by Rohan]

Part a:

$\forall\ p Person(p) \land Person(Raymond) \Rightarrow Loves(p,Raymond)$
$\forall\ p Person(p) \Rightarrow Loves(p,Raymond)$
$\forall\ p Loves(p,Raymond)$

Part b:

$\forall\ c,d Cat(c) \land Dog(d) \land Day(Tuesday) \Rightarrow Rains(c,Tuesday) \land Rains(d,Tuesday)$
$\forall\ c,d Cat(c) \land Dog(d) \Rightarrow Rains(c,Tuesday) \land Rains(d,Tuesday)$

Part c:

$\exists\ d,o Dog(d) \land Owner(o,d) \Rightarrow \forall\ c Cat(c) \land Likes(o,c)$
$\exists\ d,o\ \forall\ c Dog(d) \land Owner(o,d) \Rightarrow Cat(c) \land Likes(o,c)$

Part d:

$\exists\ x Person(x) \Rightarrow Human(x) \equiv \exists\ x \neg\ Person(x) \lor Human(x)$
but what we want is $\exists\ x Person(x) \land Human(x)$
Hence, using implication and existential quantification may yield incorrect results.

Part e:

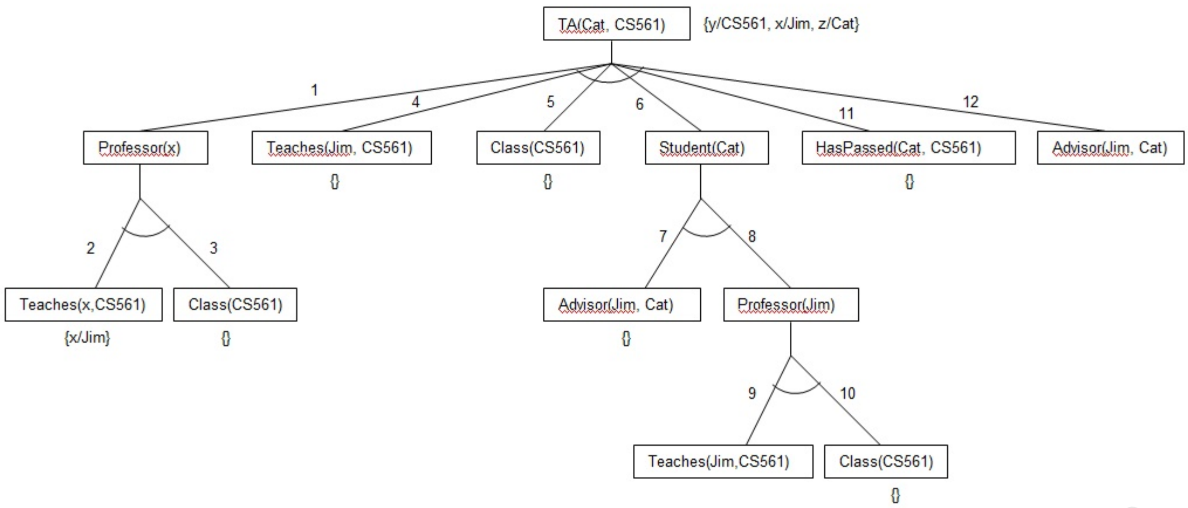
$\forall\ x Person(x) \Rightarrow Human(x) \equiv \forall\ x \neg\ Person(x) \lor Human(x)$
This means that if Person(x) is true, then Human(x) must be true. However $\forall\ x Person(x) \land Human(x)$ does not mean that if Person(x) is true that Human(x) must be true, therefore using and with universal quantification may yield incorrect results.
OR The key is using universal identifier, the predicate has to be universal truth. Forall x Person(x) ^ Human(x) . Since all objects in the universe are not necessarily human/person, therefore this predicate cannot represent the correct semantics.

Part f:

Yes, but it may require a large number of literals making it far less efficient, but easier to evaluate.

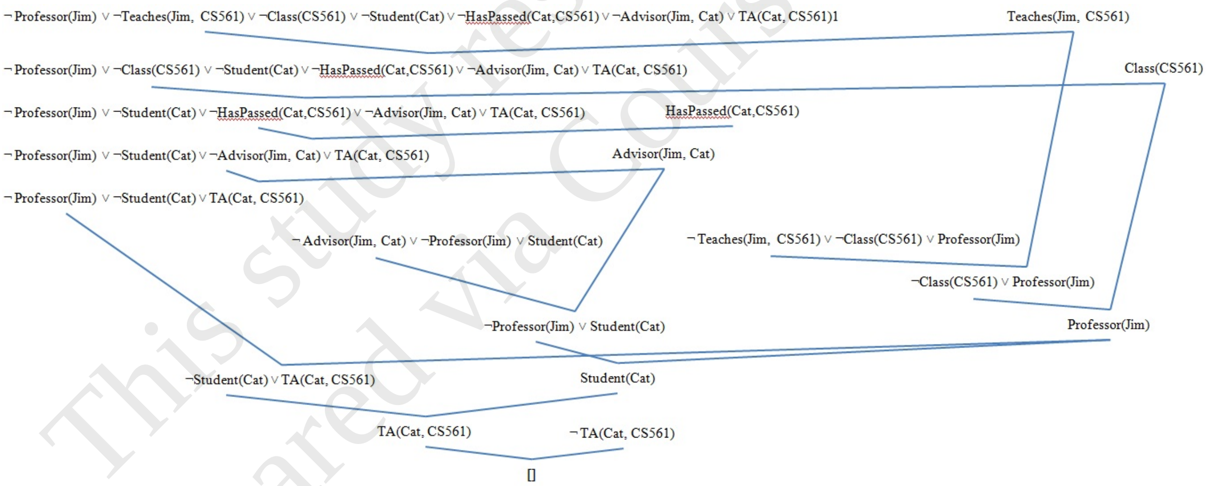
2. (40 points) First-order Inference [Solution by Nadeesha, Part a. graded by William, Part b. graded by Nadeesha]

Part a:



Grading key:
3 points: Show proof that backward chaining was attempted
1 point: Numbering the edges
1 point: Unifications
9 points: Clauses to imply TA(z,y) (1 point for each clause and 0.5 point for each edge)
3 points: Clauses to imply Professor(x) (1 point for each clause and 0.5 point for each edge)
3 points: Clauses to imply Student(y) (1 point for each clause and 0.5 point for each edge)

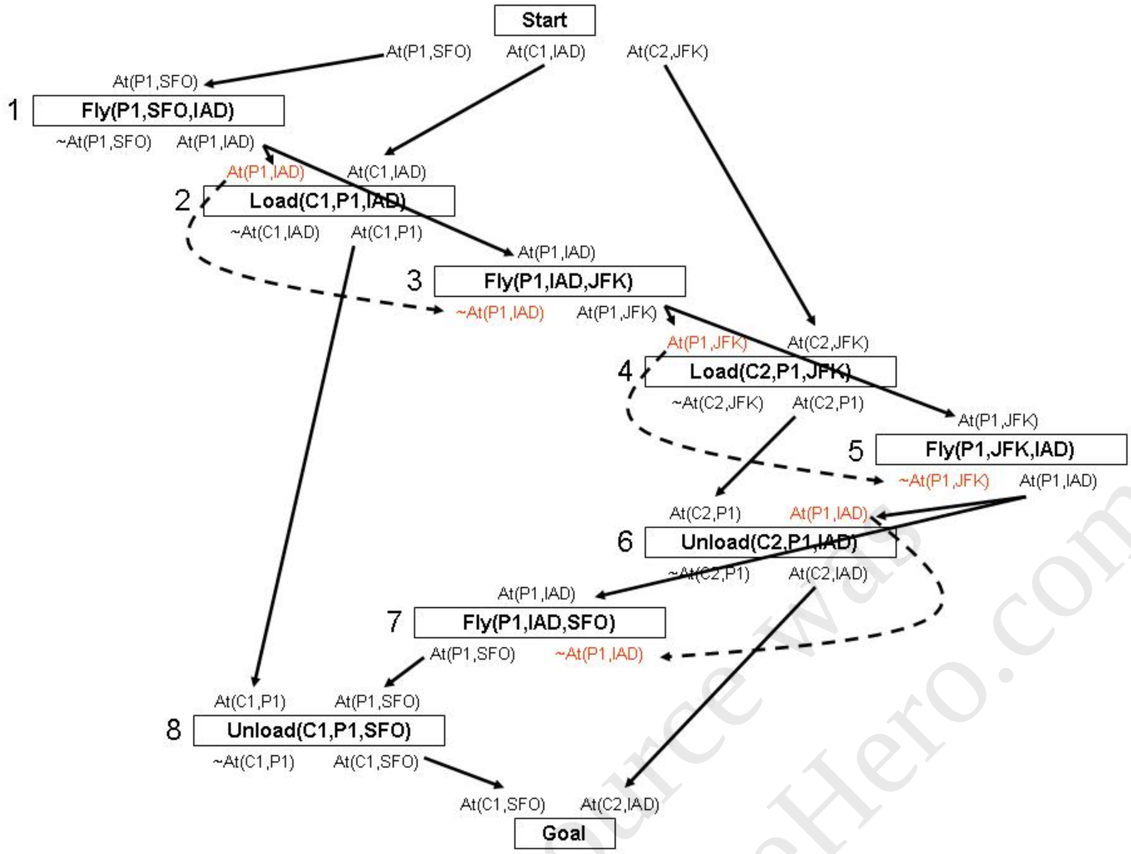
Part b:



Grading key:
-1 for each missing step towards the empty clause or each major error

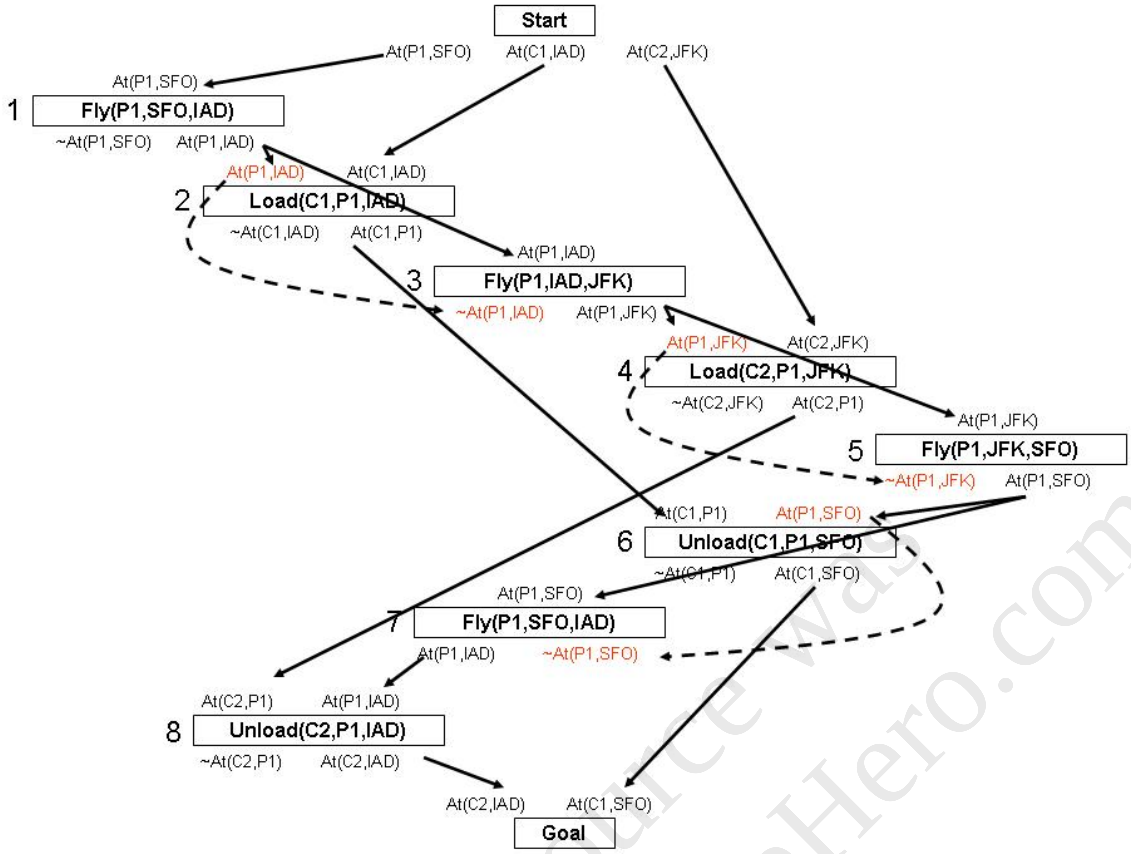
3. (25 points) Planning (STRIPS) [Solution by William, Graded by Guan]

Solution 1
Part a:



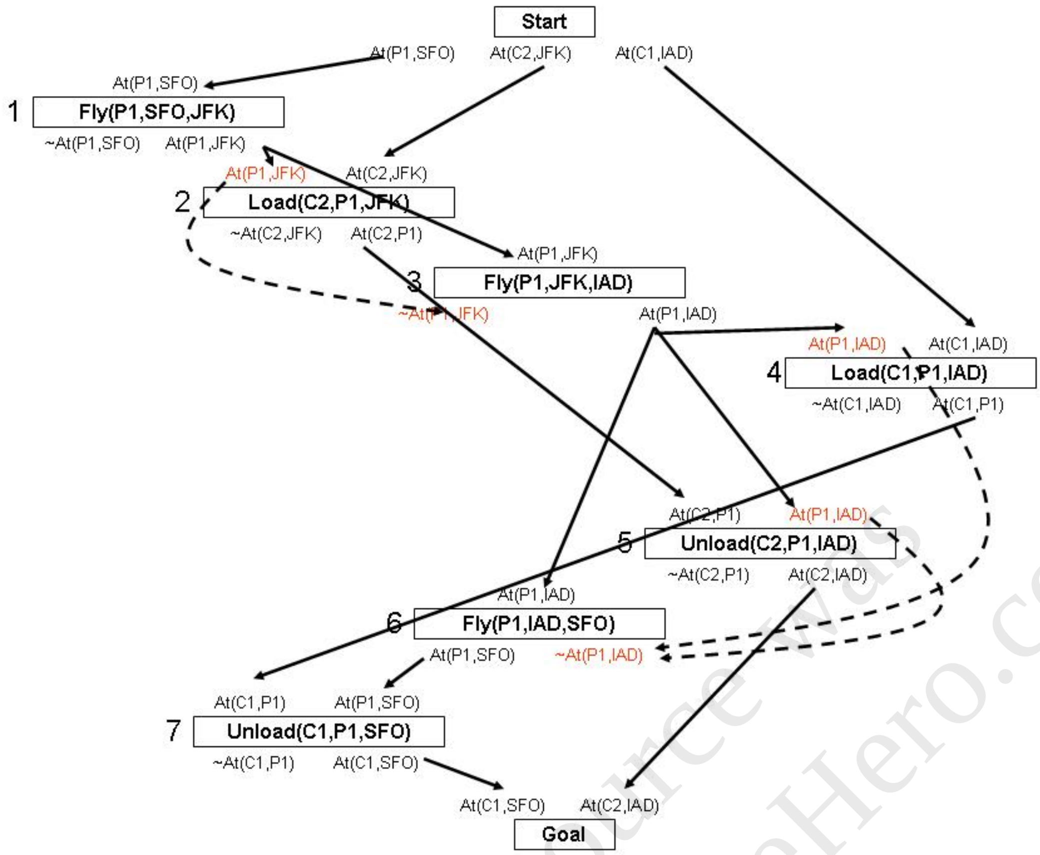
Part b:
1 possible linear solution.
Solution: Fly(P1,SFO,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Unload(C2,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO)

Solution 2
Part a:



Part b:
1 possible linear solution.
Solution: Fly(P1,SFO,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,IAD) -> Unload(C2,P1,IAD)

Solution 3
Part a:



Part b:

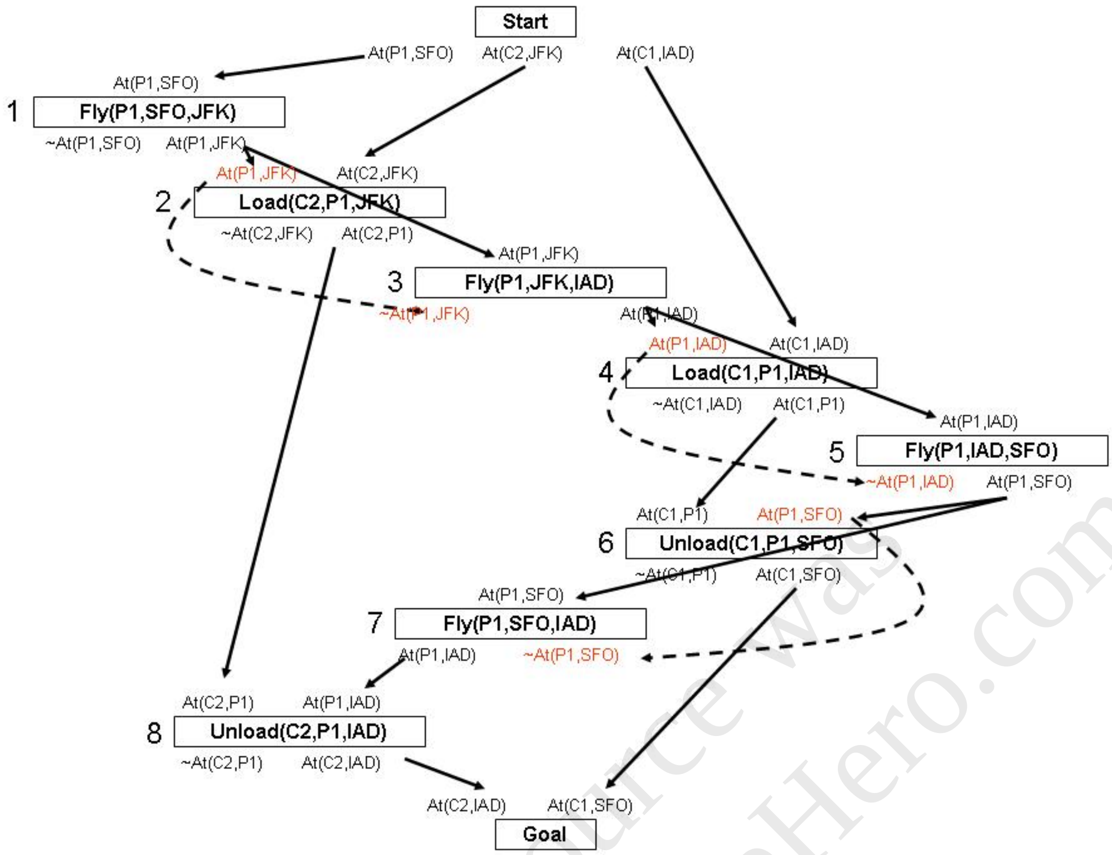
2 possible linear solutions.

Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Load(C1,P1,IAD) -> Unload(C2,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO)

Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Unload(C2,P1,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO)

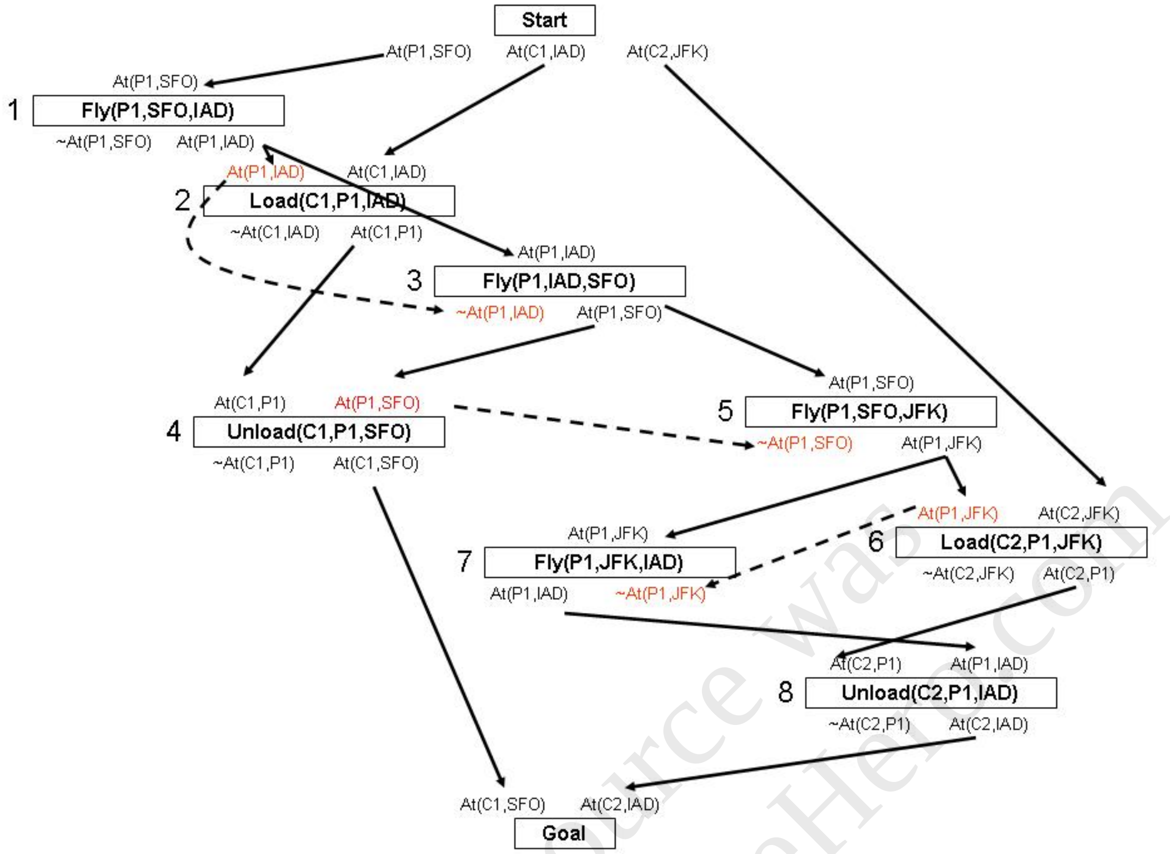
Solution 4

Part a:



Part b:
1 possible linear solutions.
Solution: Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,IAD) -> Unload(C2,P1,IAD)

Solution 5
Part a:



Part b:
1 possible linear solutions.
Solution: Fly(P1,SFO,IAD) -> Load(C1,P1,IAD) -> Fly(P1,IAD,SFO) -> Unload(C1,P1,SFO) -> Fly(P1,SFO,JFK) -> Load(C2,P1,JFK) -> Fly(P1,JFK,IAD) -> Unload(C2,P1,IAD)

Grading Key:

a)

write something	5 points
understanding of planning	5 points if answer contains states and links or 3 points
correct	2 points if answer is correct
finish	2 points if answer has a finish state
numbering actions	1 point
causal link	3 points if the line starts from the effect and ends at another precondition or 1 point if there's a line
clobbers	2 points if all the clobbers are correct or 1 point if the clobber are partially correct

b)

number of solutions	1 point
solution	4 points if correct or 1 or 2 or 3 points based on solution

4. (15 points) Probability [Solution by William, Graded by Rohan]

By definition, the variables are independent. Only give partial credit for people who decides they are not dependent, unless they explicitly state their dependence assumptions.

Part a:
If you assume that the variables are independent, then
P(x1=true,x2=true,x3=true,x4=true)
= P(x1=true) x P(x2=true) x P(x3=true) x P(x4=true)
= 0.75 x 0.75 x 0.25 x 0.25

Otherwise,
P(x1=true,x2=true,x3=true,x4=true)
= P(x1=true|x2=true,x3=true,x4=true) x P(x2=true|x3=true,x4=true) x P(x3=true|x4=true) x P(x4=true)
or some other combination of conditional probabilities

Part b:
If you assume that the variables are independent, then
P(x1=false,x2=false,x3=false,x4=false)
= P(x1=false) x P(x2=false) x P(x3=false) x P(x4=false)
= (1-0.75) x (1-0.75) x (1-0.25) x (1-0.25)
= 0.25 x 0.25 x 0.75 x 0.75

Otherwise,
P(x1=false,x2=false,x3=false,x4=false)
= P(x1=false|x2=false,x3=false,x4=false) x
P(x2=false|x3=false,x4=false) x P(x3=false|x4=false) x P(x4=false)
or some other combination of conditional probabilities

Part c:
If you assume that the variables are independent, then yes. Otherwise, no.

5. (45 points) Probabilistic Inference [Solution by Harris, Graded by Harris]

Part a:

$$P(A \wedge B \wedge C \wedge D \wedge E) = P(F|E,B)P(E|C,D)P(C|A)P(D|B)P(B|A)P(A)$$

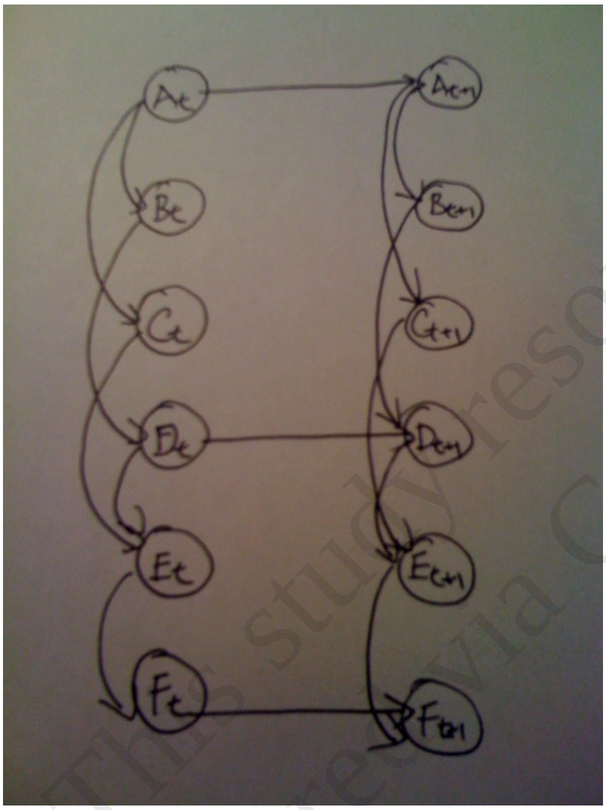
Part b:
As we know the truth value of A,B,C,E,F and according to the Bayesian Network, the probability of D depends on truth value of B.
Therefore, we only have to get the answer straight from the network P(D|B) for B is true and P(D|~B) for B is not true.

Part c:
Since D is independent of C, the observation of C will not affect the prob(D).
We can infer P(D| A) = P(D|B)P(B|A) + P(D|~B)P(~B|A)
P(D|~A) = P(D|B)P(B|~A) + P(D|~B)P(~B|~A)

Part d:
It includes its parent (B), its child (E) and its child's parent (C).

Part e:
For direct inference of E, we need the observations of C and D only.

Part f:



For this, it is enough if they just add the three temporal nodes (A_t, D_t and F_t).