Total score **85**

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T/F 7

1. [8%] General AI Knowledge and Application.

True or False: For each of the statements below, fill in the bubble T if the statement is always and unconditionally true, or fill in the bubble F if it is always false, sometimes false, or just does not make sense.

	T	F
1	T	●
2	T	●
3	●	F
4	●	F
5	T	●
6	●	F
7	T	●
8	●	F

1). [1%] $\neg(A \Leftrightarrow B) = (A \wedge (\neg B)) \vee (B \wedge A)$.

2). [1%] Every definite clause is a Horn clause.

3). [1%] KB *entails* α if and only if $KB \Rightarrow \alpha$.

4). [1%] $A \vee B$ is satisfiable.

5). [1%] $(A \Leftrightarrow B)$ *entails* $(A \vee B)$.

6). [1%] $\neg \forall x\ Likes(x, IceCream) \Leftrightarrow \exists x \neg Likes(x, IceCream)$.

7). [1%] Skolemization is the process of removing universal quantifiers by elimination.

8). [1%] $\neg \exists x$ (Friend(x) $\wedge$ Perfect(x)) is the logical translation of the statement: "None of my friends are perfect."

$-((A \Rightarrow B) \wedge (B \Rightarrow A))$

$-((-A \vee B) \wedge (-B \vee A))$

$(A \wedge -B) \vee (B \wedge -A)$

$\exists x$ -likes

$A \Leftrightarrow B$

A	B	$A \Leftrightarrow B$	$A \vee B$
T	T	T	T
T	F	F	T
F	T	F	T
F	F	T	F

A	B	
T	T	T
T	F	T
F	T	T
F	F	

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2.[16%] Multiple Choice

M-Choice 0

Write down the **best** answer for each question in the boxes:

C

1. [2%] Consider the statement p ⇒ q where p = "If Tom is Jane's father, then Jane is Bill's niece" and q = "Bill is Tom's brother." Which of the following statements is equivalent to this statement?

a If Bill is Tom's brother, then Tom is Jane's father and Jane is not Bill's niece.

b If Bill is not Tom's brother, then Tom is Jane's father and Jane is not Bill's niece.

c If Bill is not Tom's brother, then Tom is not Jane's father or Jane is not Bill's niece.

d If Bill is Tom's brother, then Tom is Jane's father and Jane is Bill's niece.

e If Bill is not Tom's brother, then Tom is not Jane's father and Jane is Bill's niece.

d

2. [2%] Which of the following statements is most likely to require a modal operator in its knowledge representation?

a All birds can fly.

b Everyone knows the world is round.

c Penguins are birds, but cannot fly.

d Superman's secret identity is Clark Kent.

e The melting point of butter is 30°C.

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$\alpha \Rightarrow \beta$ $\neg\beta \Rightarrow \neg\alpha$

$\Rightarrow \gamma$

M-Choice 2

a

3. [2%] Which of the following statements is the contrapositive of the statement, "You win the game if you know the rules but are not overconfident."

a If you lose the game, then you don't know the rules or you are overconfident.

b A sufficient condition that you win the game is that you know the rules or you are not overconfident.

c If you don't know the rules or are overconfident, you lose the game.

d If you know the rules and are overconfident, then you win the game.

e A necessary condition that you know the rules or you are not overconfident is that you win the game.

g

4. [2%] Which of the following statements is true?

a (P ⇒ (Q v R)) ⇒ ((P ^ Q) ⇒ R) is satisfiable and valid.

b Truth tables can be used to establish the truth or falsehood of any propositional sentence.

c UNIFY(Knows(John, x), Knows(x, Elizabeth)) = fail.

d Only (a), (b).

e Only (a), (c).

f Only (b), (c).

g Only (a), (b), (c).

John = x.
Elizabeth = x.

P Q R.

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M-Choice 0

f

5. [2%] Which of the following statements is true?

a Propositional logic does not scale to environments of unbounded size.

b "Grass is green" and "2 + 5 = 5" are propositions.

c Inference with Horn clauses can be done through the forward-chaining algorithm.

d Only (a), (b).

e Only (a), (c).

f Only (b), (c).

g Only (a), (b), (c)

a

6. [2%] When multiple copies of literals are removed during resolution, the process is called:

a Refutation

b Normalization

c Factoring

d All of the above.

e None of the above.

M-Choice 4 c

7. [2%] Which of the following categories is *least* likely to be a subcategory of *PhysicalObjects*?

a *Animal*

b *Horse*

c *Kilogram*

d *Oxygen*

e *Unicorn*

d

8. [2%] Which is not a type of First Order Logic (FOL) Sentence?

a Atomic sentence

b Complex sentence

c Quantified sentence

d Quality sentence

e Simple sentence

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3 | 8

3.[8%] First-Order Logic (FOL)

Translate the following sentences into first-order logic using the following predicates: IsWorker(*x*), IsHardworking(*x*), IsEvaluation(*x*) and Baffles(*x,y*) (meaning that *x* baffles *y*).

3A. [2%] Not all workers are hardworking.

$\neg \forall x\ IsWorker(x) \Rightarrow IsHardworking(x)$

3B. [2%] No hardworking worker is baffled by all evaluations.

$\neg \exists x\ IsWorker(x) \wedge IsHardworking(x) \wedge \forall y\ IsEvaluation(y) \Rightarrow Baffles(x,y)$

3C. [2%] All evaluations baffle some workers.

$\forall x\ Evaluation(x) \Rightarrow \exists y\ IsWorker(y) \wedge Baffles(x,y)$

3D. [2%] There are exactly two hardworking workers.

$\exists x \exists y\ IsWorker(x) \wedge IsHardworking(x) \wedge IsWorker(y) \wedge IsHardworking(y) \wedge \forall z\ (IsWorker(z) \wedge IsHardworking(z) \Rightarrow ((z=x) \vee (z=y)))$

4.[20%] Inference in First Order Logic

4A 10

Consider the following 5 facts that are added to a knowledge base in turn. Hobbit, Hero, Halfling, Journey and FinalBattle are predicates; Frodo and Mount Doom are constants; and *x* and *y* are variables that are universally quantified.

1. Journey(Frodo, Mount Doom)
2. Halfling(*x*) ⇒ Hobbit(*x*)
3. Journey(*x*, *y*) ⇒ FinalBattle(*x*, *y*)
4. Halfling(Frodo)
5. Hobbit(*x*) ∧ FinalBattle(*x*, Mount Doom) ⇒ Hero(*x*)

4A. [10%] Show how forward chaining can be used to infer whether Frodo is a Hero (i.e., Hero(Frodo)). Describe each step of the inference in detail in terms of unifications, rule firings, etc.

6. Final Battle (Frodo, MountDoom)
(By unifying 1 & 3 such x/Frodo & y/MountDoom ; Modus Ponens rule) ✓

7. Hobbit (Frodo) Modus Ponen rule
(By unifying 2 & 4. such that x/Frodo)

8. By applying values of 6 & 7 to 5 we get ✓
Hobbit (Frodo) ∧ FinalBattle (Frodo, Mount Doom)
⇒ $\boxed{\text{Hero (Frodo)}}$ ✓

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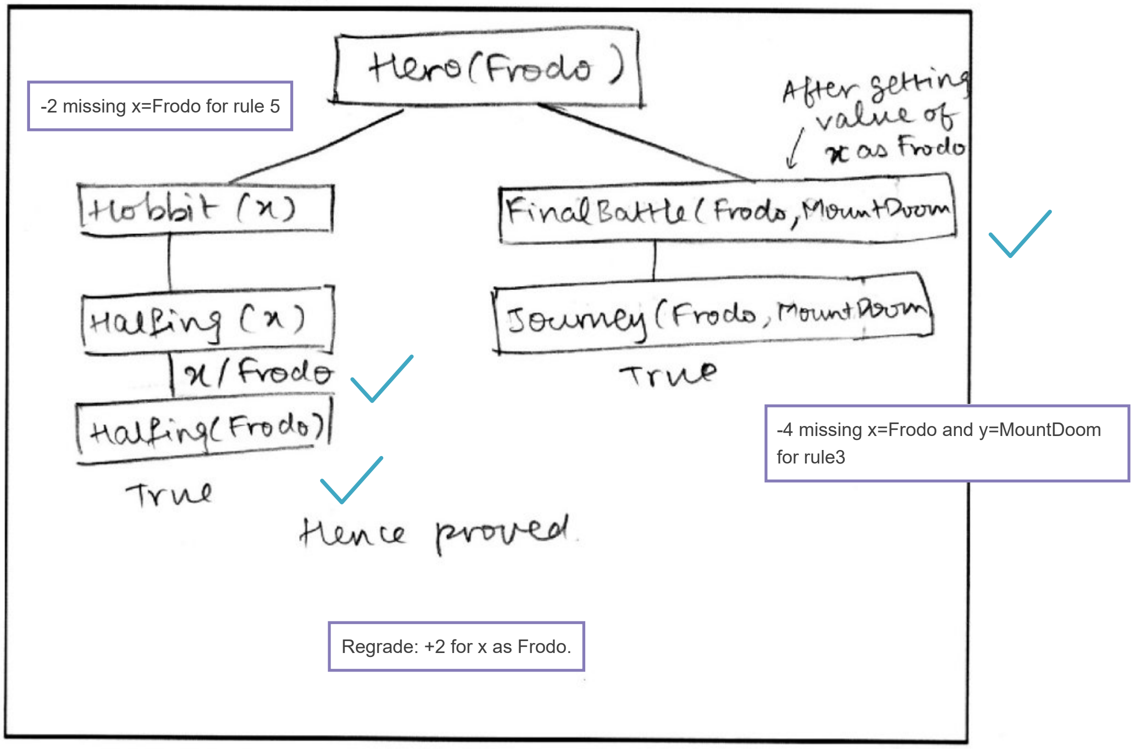
4B 6

4B. [10%] Show how backward chaining can be used to infer whether Frodo is a Hero (i.e. Hero(Frodo)). Describe each step of the inference in detail in terms of unifications, rule firings, etc.



5A 10

5.[23%] CNF and Resolution with FOL

5A.[10%] **Convert the following FOL formula to CNF showing all the steps involved.**

$\forall x[(\forall y P(x,y)) \Rightarrow \neg\forall y(Q(x,y) \Rightarrow R(x,y))]$

① Implication elimination

$\forall x\,[(\forall y\, P(x,y)) \Rightarrow \neg\forall y\,(\neg Q(x,y) \vee R(x,y))]$

$\forall x\,[\neg(\forall y\, P(x,y)) \vee \neg\forall y\,(\neg Q(x,y) \vee R(x,y))]$

② Moving ¬ inward

$\forall x\,[(\exists y\, \neg P(x,y)) \vee \exists y\,(Q(x,y) \wedge \neg R(x,y))]$

③ standardizing variables

$\forall x\,[(\exists y\, \neg P(x,y)) \vee \exists z\,(Q(x,z) \wedge \neg R(x,z))]$

④ skolemization

$\forall x\,[\neg P(x,F(x)) \vee (Q(x,F(x)) \wedge \neg R(x,F(x)))]$

⑤ Removing Universal Quantifier

$[\neg P(x,F(x)) \vee (Q(x,F(x)) \wedge \neg R(x,F(x)))]$

⑥ Distributing ∨ over ∧

$(\neg P(x,F(x)) \vee Q(x,F(x))) \wedge$
$(\neg P(x,F(x)) \vee \neg R(x,F(x)))$ ✓

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5B 13

5B. [13%] Given the following CNF knowledge base

① — $\neg Obtain(x,\ MBA) \vee \neg Graduate(x,\ CumLaude) \vee Successful(x)$
② — $Wealthy(Timmy)$
③ — $\neg Wealthy(x) \vee Graduate(x,\ CumLaude)$
④ — $\neg Invest(x) \vee Obtain(x,\ y)$
⑤ — $\neg Wealthy(x) \vee Obtain(x,\ y)$
⑥ — $\neg Invest(Timmy)$

-S(T)
-G(T, C) V -O(T, MBA)
G(T, C) -O(T, MBA)

Please demonstrate how one can prove *Successful*(*Timmy*) using resolution as the inference. Show all details of unification needed for each step of the inference process. You may assume that *MBA*, *CumLaude*, and *Timmy* are constants, and that *x* and *y* are variables.

To prove successful (Timmy)
we put -successfull (Timmy) into the KB

∴ we apply unification

-successful (Timmy) -obtain (x, MBA) V -Grad (x, Cumlaude) V successful (x)

x/Timmy

-wealth(x) V Grad(x, C) -obtain(Timmy, MBA) V -Grad (Timmy, MBA)

(x/Timmy)

wealth(Timmy) -obtain (Timmy, MBA) V -wealth (Timmy)

-Wealth(x) V obtain (x, y) -obtain (Timmy, MBA)

(x/Timmy ; y/MBA)

wealth(Timmy) -wealth (Timmy)

{} Hence Successful (Timmy) Proved.
(∵ -successful(Timmy) is unsatisfiable)

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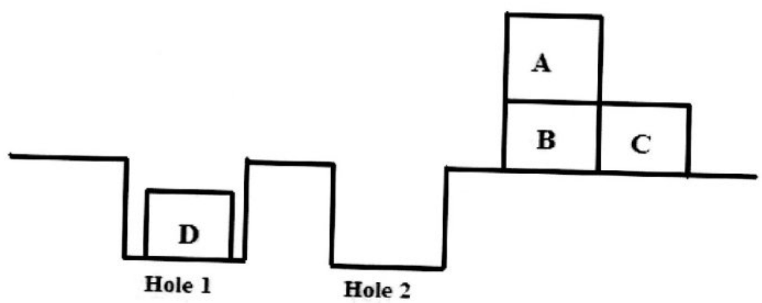
6.[17%] Planning

Consider the following block world shown below. The puzzle has four blocks (labeled A, B, C and D) and two holes. Initially, the blocks are positioned as shown with block D in one of the holes. The following rules apply:

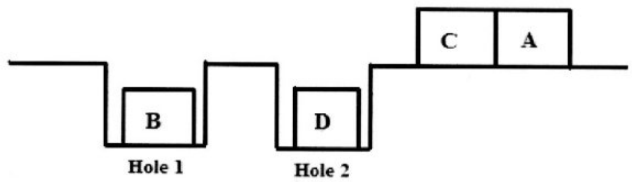
1. Only one block may be moved at a time.
2. Blocks can be moved onto the table, onto another block, or in/out of a hole.
3. A block may be placed inside a hole if there is not another block already inside.
4. In order to be moved, a block must be “clear”, meaning that there is not another block on top of it.



The above initial state is described as follows: Clear(A), On(A, B), On(B, Table), On(C, Table), InHole1(D), Clear(D), Clear(C), Empty(Hole 2)

6A,B 11

6A. [5%] Write down the description of the state of the blocks as shown below, using the closed-world assumption:



Clear(A), On(A, Table), Clear(C), On(C, Table), InHole1(B), clear(B), InHole2(D), clear(D)

6B. [6%] Write down the schema for the action MoveToHole2 that moves a block and places it inside Hole 2.

let the block be x

Precondition : Empty(Hole2), Clear(x)
Action : MoveToHole2 (x)
Effect : InHole2(x)

6C 6

6C. [6%] Write down the schema for the action MoveOntoA that moves a block that MUST be inside Hole 1 and places it on top of block A.

①. Precond : InHole 1 (x), Clear (x), Clear (A)
Action : MoveOnto A
Effect : Empty (Hole 1) , On (x, A) ,
clear (x)

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-- Not graded

7 [8%] Partial Order Planning

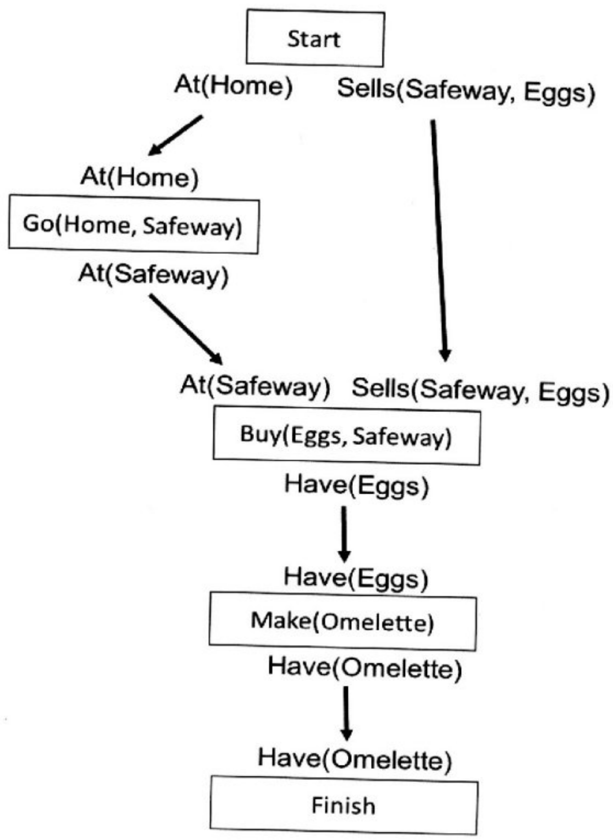
Consider using a partial-order planning system for making an omelette. Assume that in this domain there exist the following three actions:

Go(*a*, *b*) **PRECOND: At(*a*)** **EFFECT: At(*b*), ¬At(*a*)**	**Buy(*o*, *s*)** **PRECOND: At(*s*), Sells(*s*, *o*)** **EFFECT: Have(*o*)**	**Make(Omelette)** **PRECOND: At(Home), Have(Eggs)** **EFFECT: Have(Omelette), ¬Have(Eggs)**

Our initial state is:
At(Home),
Sells(Safeway, Eggs)

And the goal state is:
Have(Omelette)

Suppose we start with the partial plan shown in this figure. The partial plan currently contains no ordering constraints other than those implied by the partial order of the partial plan.



7 | 8

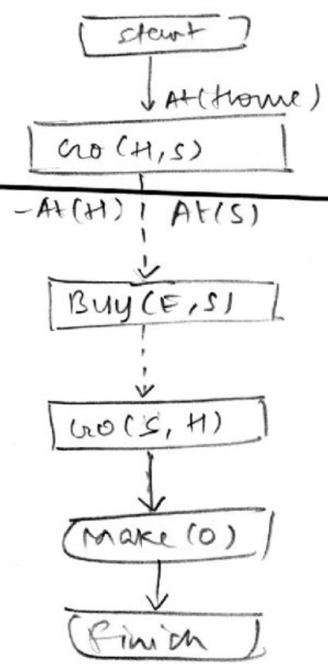
Describe the flaws in this partial plan, if any. Show how you would resolve each flaw. Feel free to propose adding operators if you feel you need to. If you see no flaws, justify your answer in terms of each causal link.

① · The effect of Go (Home, Safeway) should include ¬At (Home)

② After Buy (Eggs, Safeway) we should have action Go (Safeway, Home) because to make an omlette, we have a precondition At (Home)

③ · The effect of Make (omelette) should include ¬Have (Eggs).

So the final plan should be something like this



H → Home
S → Safeway
E → Eggs
O → Omlette