Midterm 2 Exam

CSCI 561 Spring 2018: Artificial Intelligence

Please print neatly.

Instructions:

1. Date: **03/20/2018 from 5:00 pm to 6:20 pm**
2. Maximum credits/points/percentage for this midterm: 100
3. The percentages for each question are indicated in square brackets [ ] near the question.
4. **No books** (or any other material) are allowed.
5. **Write down your name, student ID and USC email address.**
6. **Your exam will be scanned and uploaded online.**
7. **Write within the boxes provided for your answers.**
8. **Do NOT write on the 2D barcode.**
9. **The back of the pages will NOT be graded. You may use it for scratch paper.**
10. No questions during the exam. **If something is unclear to you, write that in your exam.**
11. **Be brief: a few words are often enough if they are precise and use the correct vocabulary studied in class.**
12. When finished, raise completed exam sheets until approached by proctor.
13. **Adhere to the Academic Integrity code.**

Problems	**100 Percent total**
General AI Knowledge 1 (TF)	10
General AI Knowledge 2 (MC)	10
Propositional Logic	26
First Order Logic	10
Inference	24
Classical Planning	20

1. [10%] General AI Knowledge: True/False

For each of the statements below, answer **T** if the statement is **always true**, or **F** otherwise.

T	1. $(A \lor B) \land \neg(A \Rightarrow B)$ is satisfiable.
F	2. Propositional logic is not monotonic, but first-order logic is.
T	3.The completeness theorem states that any sentence entailed by a set of sentences can be proven from that set.
F	4. The part-of relation is composite and transitive, but not reflexive.
F	5. Procedure *i* is sound if whenever $KB \models \alpha$, it is also true that $KB \vdash_i \alpha$.
T	6. Every first-order knowledge base can be propositionalized.
T	7. After applying Skolemization to a sentence, the resulting formula is satisfiable if and only if the original sentence is satisfiable.
T	8. Totally ordered plans are created by a search through the space of plans rather than through the state space.
F	9. Backward chaining is a breadth-first algorithm.
F	10. Entailment in first-order logic is semidecidable. No algorithm can verify the correctness of every entailed sentence.

2. [10%] General Knowledge: Multiple Choice

Each question is worth 2% and has one or more correct choices. Circle all correct choices. Please note that there will be no partial credit and you will receive full credit if and only if you choose all of the correct choices and none of the wrong choices.

1. An AI student wanted a new iPhone. Upon arrival at the Verizon store, the student was informed that quantities were limited. The salesperson recognized that the prospective customer is an astute AI student and wrote down on a piece of paper the propositional logic in DNF form using *Bj* as the proposition symbols.

$$(\boldsymbol{B1} \land \neg \boldsymbol{B2} \land \neg \boldsymbol{B3}) \lor (\neg \boldsymbol{B1} \land \boldsymbol{B2} \land \neg \boldsymbol{B3}) \lor (\neg \boldsymbol{B1} \land \neg \boldsymbol{B2} \land \boldsymbol{B3})$$

If *Bj* is a white iPhone and ¬*Bj* is a black iPhone, which of the following most accurately reflects the salesperson's message?

a. The store has only 3 iPhones of 3 different models.
b. The store has only 3 iPhones of 2 different models.
c. The store has only 2 iPhones of 2 different models.
d. The store has only 3 iPhones and all are of the same model.
e. The store has only 2 iPhones and all are of the same model.

2. If an agent knows that 3 + 3 = 6 and that 6 < 8, the property by which the agent also knows that 3 + 3 < 8 is:

a. backward chaining
b. modal logic
c. referential transparency
d. forward chaining
e. deductive reasoning

3. Which of the following sentence pairs cannot be unified?

a. *Knows(Bob, x)* and *Knows(x, Alice)*
b. *Knows(Bob, x)* and *Knows(y, Alice)*
c. *Knows(Bob, x)* and *Knows(Brother(Alice), Alice)*
d. *Knows(Bob, x)* and *Knows(x, y)*
e. None of the above

4. Consider *p* = "If Nikhil is Alice's father, then Alice is Bob's niece" and *q* = "Bob is Nikhil's brother." Which of the following statements is equivalent to $p \Rightarrow q$?

a. If Bob is Nikhil’s brother, then Nikhil is Alice’s father and Alice is not Bob’s niece.
b. If Bob is not Nikhil’s brother, then Nikhil is Alice’s father and Alice is not Bob’s niece.
c. If Bob is not Nikhil’s brother, then Nikhil is not Alice’s father or Alice is not Bob’s niece.
d. If Bob is Nikhil’s brother, then Nikhil is Alice’s father and Alice is Bob’s niece.
e. If Bob is not Nikhil’s brother, then Nikhil is not Alice’s father and Alice is Bob’s niece.

5. Which of the following inferences is an example of inheritance?

a. If all dogs bark, and all wolves howl, then a greyhound is a dog and not a wolf.
b. If all birds can fly, and a penguin is a bird, then we can conclude that all penguins can fly.
c. If all cats eat mice, and Jerry is a mouse and Tom does not eat Jerry, then we can conclude Tom is not a cat.
d. If object A1 is a member of the category Square, Square is a subclass of Rectangle, and Rectangle is a subclass of Shape, then A1 is a shape.
e. None of the above

3. [26%] Propositional Logic

1. Given the following logic statement: $[\neg(A \Rightarrow B) \vee (C \wedge D)] \vDash \neg(B \vee C)$

a. [2%] If this statement is valid, what implication must be valid too?

$[\neg(A \Rightarrow B) \vee (C \wedge D)] \Rightarrow \neg(B \vee C)$

b. [6%] Convert the implication from 1a to CNF with only two clauses.

(1) $\neg [\neg(A \Rightarrow B) \vee (C \wedge D)] \vee \neg(B \vee C)$
(2) $[(A \Rightarrow B) \wedge \neg(C \wedge D)] \vee \neg(B \vee C)$
(3) $[(\neg A \vee B) \wedge (\neg C \vee \neg D)] \vee (\neg B \wedge \neg C)$
(4) $(\neg A \vee B \vee \neg B) \wedge (\neg B \vee \neg C \vee \neg D) \wedge (\neg A \vee B \vee \neg C) \wedge (\neg C \vee \neg C \vee \neg D)$
(5) $(\neg B \vee \neg C \vee \neg D) \wedge (\neg A \vee B \vee \neg C) \wedge (\neg C \vee \neg D)$
(6) $(\neg A \vee B \vee \neg C) \wedge (\neg C \vee \neg D)$

2. Given the following logic statement: $(P \Rightarrow Q) \vDash Q$

a. [2%] If this statement is valid, what statement must be unsatisfiable?

$(P \Rightarrow Q) \wedge \neg Q$ must be unsatisfiable.

b. [6%] Fill in the truth table, including headings for any (if necessary) new columns used, for the statement from 2a.

P	Q	xxx	P ⇒ Q	(P ⇒ Q) ∧ ¬ Q
T	T	x	T	F
T	F	x	F	F
F	T	x	T	F
F	F	x	T	T

Subtract 1 point for each incorrect answer until 0. Answer must include "(P ⇒ Q)" and "(P ⇒ Q) ∧ ¬ Q" and their corresponding truth values for credit. If students use an extra column "xxx" as an extra step, do not deduct points.

c. [4%] Is $(P \Rightarrow Q) \models Q$ valid? Why or why not?

No. If $(P \Rightarrow Q) \models Q$ is valid, $(P \Rightarrow Q) \land \neg Q$ must be unsatisfiable. However, when P is False, Q is False, the truth table shows that it's True. This is a contradiction.

d. [6%] Use inference to prove whether the statement from question 2a is satisfiable or not. Be sure to state the rule for each step.

$(\neg P \lor Q) \land \neg Q$.	Implication elimination
$(\neg P \land \neg Q) \lor (Q \land \neg Q)$	Distributive of $\land$ over $\lor$
$(\neg P \land \neg Q) \lor$ False	By definition.
$(\neg P \land \neg Q)$	By definition.

When P is False, Q is False, $(P \Rightarrow Q) \land \neg Q$ is satisfiable.

4. [10%] First-Order Logic

Using the predicates defined in each problem, convert the following sentences from English to logic expressions.

1. [2%] Not everything that is white is milk, but milk is always white.

White(*x*): *x* is white.
Milk(*x*): *x* is milk.

One possible answer: $\exists x(White(x) \land \neg Milk(x)) \land \forall x(Milk(x) \rightarrow White(x))$
One possibile answer: $\neg(\forall x(White(x) \rightarrow Milk(x)) \land \forall x(Milk(x) \rightarrow White(x))$

2. [2%] Not all boys are unintelligent.

Boy(*x*): *x* is a boy.
Intelligent(*x*): x is intelligent.

One possible answer: $\neg\forall x(Boy(x) \rightarrow \neg Intelligent(x))$
One possible answer: $\exists x(Boy(x) \land Intelligent(x))$

3. [2%] Some millenials will eat anything.

Millennial(*x*): *x* is a millennial.
Food(*x*): *x* is food.
Eat(*x*,*y*): *x* eats *y*.

$\exists x(Millennial(x) \land \forall y(Eat(x,y)))$

4. [2%] A surgeon is happy when she has no patients.

Surgeon(*x*): *x* is a surgeon.
Patient(*x*, *y*): *x* is a patient of *y*.
Happy(*x*): *x* is happy.

One possible answer: $\forall(x)\ ((Surgeon(x) \land \neg\exists y\ Patient(y,x)) \rightarrow Happy(x))$
One possible answer: $(Surgeon(x) \rightarrow (\neg\exists\ y\ Patient(y,x) \rightarrow Happy(x)))$
One possible answer: $\forall(x)\ ((Surgeon(x) \land \forall y\ \neg Patient(y,x)) \rightarrow Happy(x))$

5. [2%] There are at least two mountains in California.

Mountain(x): x is a mountain.
InCal(x): x is in California.

$\exists x, y, (Mountain(x) \land Mountain(y) \land InCal(x) \land InCal(y) \land x \neq y)$

5. [24%] Inference

Given the knowledge base below, can we infer that F is *true*? Use inference (not truth tables), and state which rule and/or statement you use in each step.

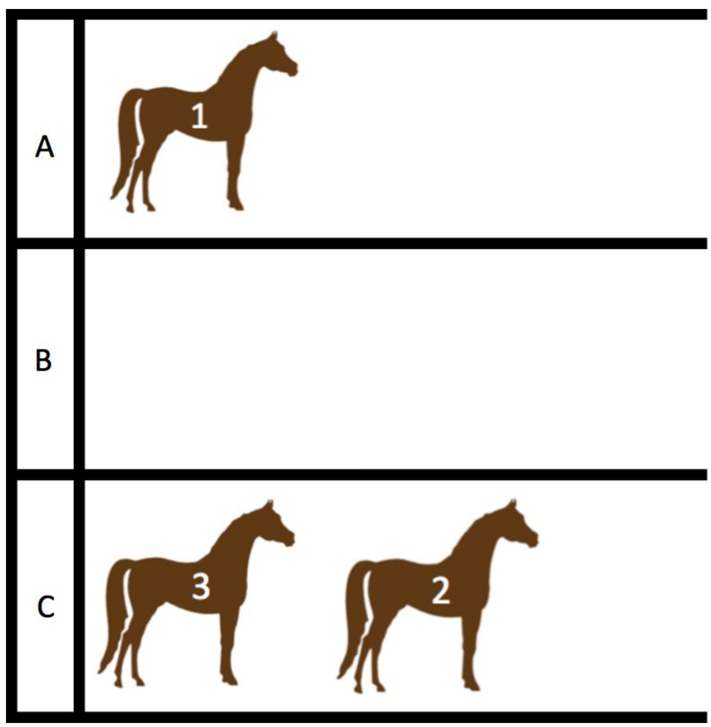
Number	Sentence	Justification
1	$\neg A \wedge B$	given
2	$(\neg C \wedge G) \vee (A)$	given
3	$E \vee D$	given
4	$\neg(D \wedge E) \Rightarrow A$	given
5	$(\neg A \wedge E) \Rightarrow (F \vee C)$	given

(1)	$\neg A$ ^ B	given
(2)	$\neg A$	and elimination from (1)
(3)	$(\neg C \wedge G) \vee (A)$	given
(4)	$(\neg C \wedge G)$	get from (2) and (3)
(5)	$\neg C$	and elimination from (4)
(6)	$\neg(D \wedge E) \Rightarrow A$	given
(7)	$(D \wedge E)$	Modus tollens from (2)
(8)	E	and elimination from (7)
(9)	$(\neg A \wedge E)$	get from (2) (8)
(10)	$(\neg A \wedge E) \Rightarrow (F \vee C)$	given
(11)	$(F \vee C)$	Modus ponens from (9)
(12)	F	get from (5)

Subtract 1 point for each incorrect sentence and 1 point for each incorrect reason/justification. It's possible that the student might answer this question out-of-order or sequence. Therefore, step numbers might not match up; so, be careful to adjust accordingly, i.e. do not deduct student's grade unnecessarily.

6. [20%] Classical Planning

Consider a planning problem where there are three horses in a three-stall stable. These horses are known to be friendly and therefore can be arranged such that there could be more than one horse in a stall at the same time. However, because the stable is narrow, the horses can only be moved one at a time and in the opposite order in which they were ushered into or out of the stall, i.e. last in, first out (LIFO). For example, in the figure below, horse 2 must be moved out of C before horse 3 can be moved.



iTommy, a Los Angeles-based AI company, has teamed up with Amazon to build a robotic horse trainer that can move horses one at a time from stall to stall, obviously through the use of Alexa. In fact, “Alexa, move horse 1 from stall A to stall B” translates to the system’s STRIPS code **moveFromTo(Horse1, A, B)** or “Alexa, move horse 3 from stall C to stall B” would elicit a response, “Precondition not met. Sorry it’s being blocked.”

1. [6%] STRIPS actions: define the STRIPS actions, as well as their preconditions and postconditions,required for the robotic horse trainer to rearrange the horses as shown in the figure above.

Action: moveFromTo(h1,s1,s2) (alternative: moveTo(h1,s2))

Pre: rightmost(s1,h1), rightOf(h1,h2), rightmost(s2,h3)
Post: not rightmost(s1,h1), not in(h1,s1), not rightOf(h1,h2),
not rightmost(s2,h3),
rightmost(s2,h1), in(h1,s2), rightOf(h1,h3), rightmost(s1,h2)

rightmost(stall,horse): horse is the rightmost horse in the stall
in(horse,stall): horse is in the stall
rightOf(h1,h2): h1 is to the right of h2 in the same stall (h2 could be a horse or the special Fence object)

Different kinds of actions and their pre-/postconditions are acceptable as long as they take into account that the trainer can only grab the outermost horse and is not a smart (intelligent) trainer.

2. [6%] Initial Plan: if the robotic horse trainer plans to rearrange the horses from the starting state in the figure above so that Horse 3 goes into stall A, Horse 2 into stall B, and Horse 1 into stall C, write down the initial condition and goal of this planning problem using the STRIPS definitions from 6.1.

Initial conditions:

- in(Horse1,A)
- in(Horse2,C)
- in(Horse3,C)

- rightmost(A,Horse1)
- rightmost(B,Fence)
- rightmost(C,Horse2)

- rightOf(Horse1,Fence)
- rightOf(Horse2,Horse3)
- rightOf(Horse3,Fence)

Goal condition:

- in(Horse1,C)
- in(Horse2,B)
- in(Horse3,A)

Partial credit: 2 points each for the initial condition and the goal.

3. [8%] Complete Plan: write down the plan to reach the goal from the initial condition, using the condition and goal specified in 6.2.

Plan using moveFromTo:

moveFromTo(Horse2,C,B)
moveFromTo(Horse3,C,B)
moveFromTo(Horse1,A,C)
moveFromTo(Horse3,B,A)

or

moveFromTo(Horse2,C,B)
moveFromTo(Horse1,A,B)
moveFromTo(Horse3,C,A)
moveFromTo(Horse1,B,C)

Plan using moveTo:

moveTo(Horse2,B)
moveTo(Horse3,B)
moveTo(Horse1,C)
moveTo(Horse3,A)

or

alternative: moveTo(Horse2,B)
alternative: moveTo(Horse1,B)
alternative: moveTo(Horse3,A)
alternative: moveTo(Horse1,C)

Partial credit: 2 points for each step.