1	2	3	4	5	6	7	total
10	10	30	25	10	15	25	*125*

UMBC CMSC 471 Final Exam, 22 May 2017

with model answers and some explanations

Name:____

Please write all of your answers on this exam. The exam is closed book and has seven problems that add up to 125 points. You have the two hours to work on this exam. Good luck.

1. True/False (10 points) Circle ***T*** or ***F*** for each statement

T F Sound inference algorithms never infer false statements from true ones. T

T F Valid sentences are true in all models. F

T F Backpropogation is a technique for adjusting weights in a simple layer perceptron. F

T F A drawback of a naive bayes classifier is that it requires many joint probability tables. F

T F A Support Vector Machine classifier can only be used directly to do binary classification. T

T F A single layer perceptron is only capable of learning linearly separable patterns. T

T F The ID3 decision tree induction algorithm is guaranteed to find the optimal decision tree consistent with a given training set. F

T F Random variables A and B are independent if p(A ^ B) = p(A|B) * p(B) F

T F If the Blackbox planner finds a plan, it is guaranteed to be an optimal one, i.e., there is no other plan that has fewer steps. T

T F Situation calculus is a technique to adjust the weights in a neural network during learning. F

2. Short answers (10 points: 2;2;3;3)

2.1 Which of the following are classification tasks appropriate for a classification learning algorithm? Circle the letter for all that apply. **[2]**

(a) Predicting if a credit card transaction is fraudulent or legitimate

(b) Predicting how much it will rain tomorrow

(c) Predicting the letter of the alphabet represented by an image of a handwritten character

(d) Breaking a database of customers into clusters based on their buying patterns (where the nature of the clusters is determined automatically by the computer, not in any way provided by a human)

a c

2.2 Given a vocabulary with three propositions, A, B and C. How many models are there for the sentence (A⇔B) V B? [2]

a. 6	b. 8
c. 3	d. 2

2.3 Given a linear Support Vector Machine (SVM) that perfectly classifies a set of training data, which training examples, if any, could be removed and still produce the exact same SVM as derived for the original training set? [3]

All training examples that are not support vectors can be removed.

2.4 Under what condition, if any, would removal of exactly one training example cause the margin of a linear SVM to increase? [3]

Removal of a training example that is a support vector can cause the margin to increase if there is not another training example that also supports the initial Plus- or Minus-plane in the same way.

3. Resolution Proof in Propositional Logic (30)

A classmate believes (0) **UMBC** students are clever; (1) if you are **clever** and you **study**, you will **pass** the final; (2) if you are **lucky** and are either **clever** or you **study** you will **pass** the final.

A propositional sentence is in CNF if it is a set of one or more expressions where each is a disjunction of variables or negated variables.

(a) Construct a KB of propositional sentences using the five propositional variables (umbc, clever, study, lucky, pass) and logical connectives (∧, ∨, ¬, →). Encode each of the three sentences into one or more sentences in conjunctive normal form (CNF). We've done the first one for you. (10 pts)

#	English	CNF clauses
0	UMBC students are clever.	0.1 **¬UMBC ∨ clever**
1	If you are **clever** and you **study**, you will **pass** the final;	1.1 **¬clever ∨ ¬study ∨ pass**
		1.2
		1.3
2	if you are **lucky** and are either **clever** or you **study** you will **pass**	2.1 ¬lucky ∨ ¬clever ∨ pass
		2.2 **¬lucky ∨ ¬study ∨ pass**
		2.3

(b) How many models are there for this KB in which UMBC and pass are both True? Recall that a model is an assignment of true and false to each variable such that the KB is consistent? (5 points)

4

Here are the four models				
umbc	**clever**	**study**	**lucky**	**pass**
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

(c) Show a resolution refutation proof for "if you are a umbc student and you study, you will pass the final. That is, prove pass given your KB, and that both UMBC and study are true. Start with the negation of what's to be proved, add statements from your KB and use resolution to derive a contradiction (⊥). The table to the right shows an example proof (15 points).

step	action	result
1	assume	¬Q
2	given	¬P∨Q
3	given	P
4	resolve 2,3	Q
5	resolve 1,4	⊥

*Sample proof of **Q** given **P→Q** and **P***

step	action	result
1	assume	**¬ pass**
2	**Given**	**umbc**
3	**Given**	**study**
4	**Given**	**¬umbc ∨ clever**
5	**Resolve 2, 3**	**clever**
6	**Given 1.1**	**¬clever ∨ ¬study ∨ pass**
7	**Resolve 5, 6**	**¬study ∨ pass**
8	**Resolve 3, 7**	**pass**
9	**Resolve 1, 8**	⊥
10		
11		
12		
13		
14		
15		

4. English to logic (25 points, 3 each plus one freebie)

For each English sentence below, write the letter or letters corresponding to its best or closest sentence in first order logic. If none of the FOL sentences correspond to the English sentence, write ***none*** in the box.

D

4.1 Every person plays some game.

A. ∀x ∀y Person(x) ∧ Game(y) ∧ Plays(x, y)

B. ∀x ∃y Person(x) ∧ Game(y) ∧ Plays(x, y)

C. ∀x ∀y Person(x) ⇒ (Game(y) ∧ Plays(x, y))

D. ∀x ∃y Person(x) ⇒ (Game(y) ∧ Plays(x, y))

B

4.2 All games are fun.

A. ∀x Game(x) ∧ Fun(x)

B. ∀x Game(x) ⇒ Fun(x)

C. ∃x Game(x) ∧ Fun(x)

D. ∃x Game(x) ⇒ Fun(x)

C

4.3 For every game, there is a person that plays that game.

A. ∀x ∃y Game(x) ∧ Person(y) ∧ Plays(y, x)

B. ∀x ∃y [Game(x) ∧ Person(y)] ⇒ Plays(y, x)

C. ∀x ∃y Game(x) ⇒ [Person(y) ∧
Plays(y, x)]

D. ∀x ∀y Game(x) ∧ Person(y) ∧ Plays(y,
x)

A

4.4 Every person plays every game.

A. ∀x ∀y [Person(x) ∧ Game(y)] ⇒ Plays(x, y)

B. ∀x ∀y Person(x) ⇒ [Game(y) ∧ Plays(x, y)]

C. ∀x ∀y Person(x) ∧ Game(y) ∧ Plays(x, y)

D. ∀x ∃y [Person(x) ∧ Game(y)] ⇒ Plays(x, y)

B

4.5 There is some person in Pigtown who is smart.

A. ∀x Person(x) ∧ In(x, Pigtown) ∧ Smart(x)

B. ∃x Person(x) ∧ In(x, Pigtown) ∧ Smart(x)

C. ∀x [Person(x) ∧ In(x, Pigtown)] ⇒ Smart(x)

D. ∃x Person(x) ⇒ [In(x, Pigtown) ∧ Smart(x)]

4.6 Every person in Pigtown is smart.

C

A. $\forall x\ Person(x) \land In(x, Pigtown) \land Smart(x)$

B. $\exists x\ Person(x) \land In(x, Pigtown) \land Smart(x)$

C. $\forall x\ [\ Person(x) \land In(x, Pigtown)\ ] \Rightarrow Smart(x)$

D. $\exists x\ Person(x) \Rightarrow [\ In(x, Pigtown)\ ] \land Smart(x)$

4.7 Some person plays every game.

D

A. $\exists x\ \forall y\ [\ Person(x) \land Game(y)\ ] \Rightarrow Plays(x, y)$

B. $\exists x\ \forall y\ Person(x) \land Game(y) \land Plays(x, y)$

C. $\forall x\ \forall y\ Person(x) \land Game(y) \land Plays(x, y)$

D. $\exists x\ \forall y\ Person(x) \land [\ Game(y) \Rightarrow Plays(x, y)\ ]$

4.8 Some person plays some game.

A

A. $\exists x\ \exists y\ Person(x) \land Game(y) \land Plays(x, y)$

B. $\exists x\ \exists y\ [\ Person(x) \land Game(y)\ ] \Rightarrow Plays(x, y)$

C. $\exists x\ \exists y\ Person(x) \Rightarrow [\ Game(y) \land Plays(x, y)\ ]$

D. $\forall x\ \forall y\ Person(x) \land Game(y) \land Plays(x, y)$

5. Planning in the blocks world domain (10 points)

A friend says that the standard blocks world model could be simplified by modifying the **(on ?X ?Y)** predicate to mean says that block ?X is directly on top of ?Y where ?Y can either be another block or the table. She claims that we would no longer need the special **(on-table ?X)** predicate and could replace the **stack**, **unstack**, **pickup** and **putdown** actions with a single **move** action, which would be described in PDDL as follows.

```
(:action move
   :parameters (?obj ?from ?to)
   :precondition (and (on ?obj ?from)
                      (clear ?obj)
                      (clear ?to)
                      (arm-empty))
   :effect (and (not (on ?ob1 ?from))
                (on ?obj ?to)
                (not (clear ?to)))
```

Assuming that this is the only change made to the blocks world model we discussed in class and used in the homework, will her suggestion work? Explain why it will or why it won't.

This change will not work. While the standard model assumes that only one object can be on a block, it also assumes that any number of objects can be on the table. Once this action is used to move a block X to the table, the table will be asserted to not be clear. No other objects can then be moved to the table unless block X is put on anther block. SO it will not be possible to transform a scene where C is on the table, B is on C and A is on B to one where are three blocks are on the table.

6. Probabilistic Reasoning (20 pts: 5;5;5;5)

Prof. Dumbledore estimates that students who **finish** their homework **forget** to submit it 1% of the time and that half the students who have not finished their homework will tell him that they forgot to submit it. He estimates that 90% of the students in his classes complete their homework.

Recall that

P(a, b) = P(a|b) * P(b)
= P(b|a) * P(a)

so

P(a|b) = P(b|a) * P(a)/P(b)

6.1 [5] Let **Forgot** be a Boolean random variable indicating that the student reports that they forgot to submit their homework and **Finished** be a Boolean random variable indicating that the student's homework was finished. Fill in the boxes below with the probability values.

Probability of	value
P(Finished) =	**0.9**
P(Forgot | Finished) =	**0.01**
P(Forgot | ¬Finished) =	**0.5**

6.2 [5] What is the probability, P(Forgot), that a student says she forgot to submit their homework? Show your work.

.059

P(Forgot) = P(Forgot, Finished) + P(Forgot, ¬Finished)
= P(Forgot|Finished)*P(Finished) + P(Forgot|¬Finished)*P(¬Finished)
= 0.01 * 0.9 + 0.5 * 0.1 = 0.009 + 0.05 = 0.059

6.3 [5] What is the probability that a student who says she forgot to turn in their homework is telling the truth, i.e., P(Finished | Forgot)? Show your work.

.01525

P(Finished | Forgot) = P(Forgot | Finished) * P(Finished) / P(Forgot)
= 0.01 * 0.9 / 0.059 = 0.01525

6.4 [5] Fill in the missing values in the following joint probability table assuming that A and B are independent variables.

	A	¬A
B	3/12	6/12
¬B	**1/12**	**2/12**

We know that the values in the four boxes must sum to 1.0. Since we know that A and B are independent, we can conclude from the first row that ¬A is twice as likely than A. So in the second row the value for ¬A must be twice that for A also. Putting these constrains together gives us the answer.

7. Decision trees (25 points)

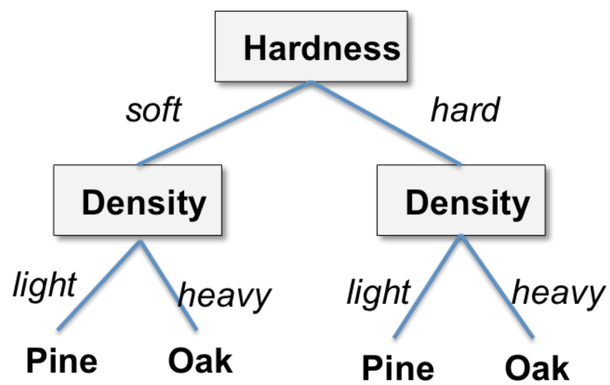
You are designing an automated system for a lumber mill to distinguish two kinds of wood, oak and pine, based on its sensed qualities. You decide to use a decision tree to do the classification using the ID3 algorithm that selects the variable at each level that maximizes the information gained. The training data is given in the table to the right.

Example	Density	Grain	Hardness	Class
Example#1	Heavy	Small	Hard	Oak
Example#2	Heavy	Large	Hard	Oak
Example#3	Heavy	Small	Hard	Oak
Example#4	Light	Large	Soft	Oak
Example#5	Light	Large	Hard	Pine
Example#6	Heavy	Small	Soft	Pine
Example#7	Heavy	Large	Soft	Pine
Example#8	Heavy	Small	Soft	Pine

7.1 Which attribute would information gain choose as the root of the tree? (5 pts)

hardness

7.2 Show the entire decision tree that would be constructed by ID3, i.e., by recursively applying information gain to select the roots of sub-trees after the initial decision. (10 pts)



7.3 Classify these new examples using your decision tree by finning in the last column (10)

Example	Density	Grain	Hardness	Class
Example#9	Light	Small	Hard	**Pine**
Example#10	Light	Small	Soft	**Oak**