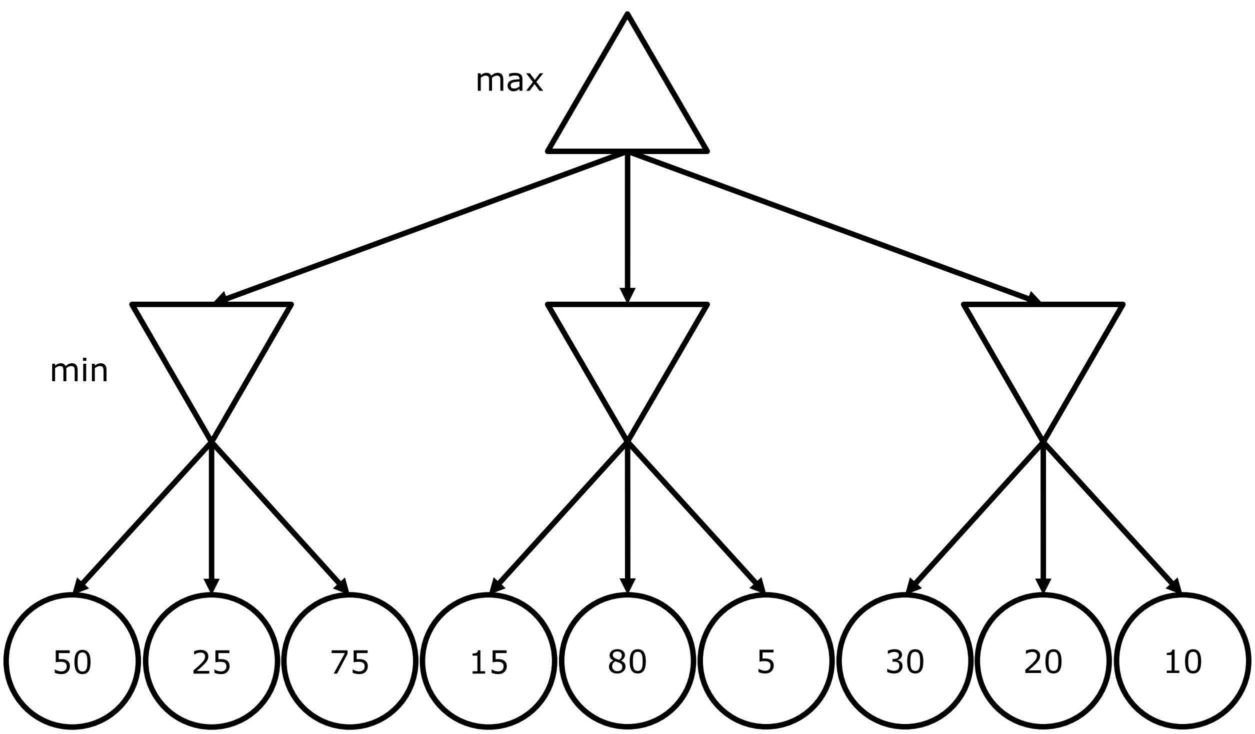
Name:
Course: CAP 4601
Semester: Summer 2013
Assignment: Assignment 06
Date: 08 JUL 2013

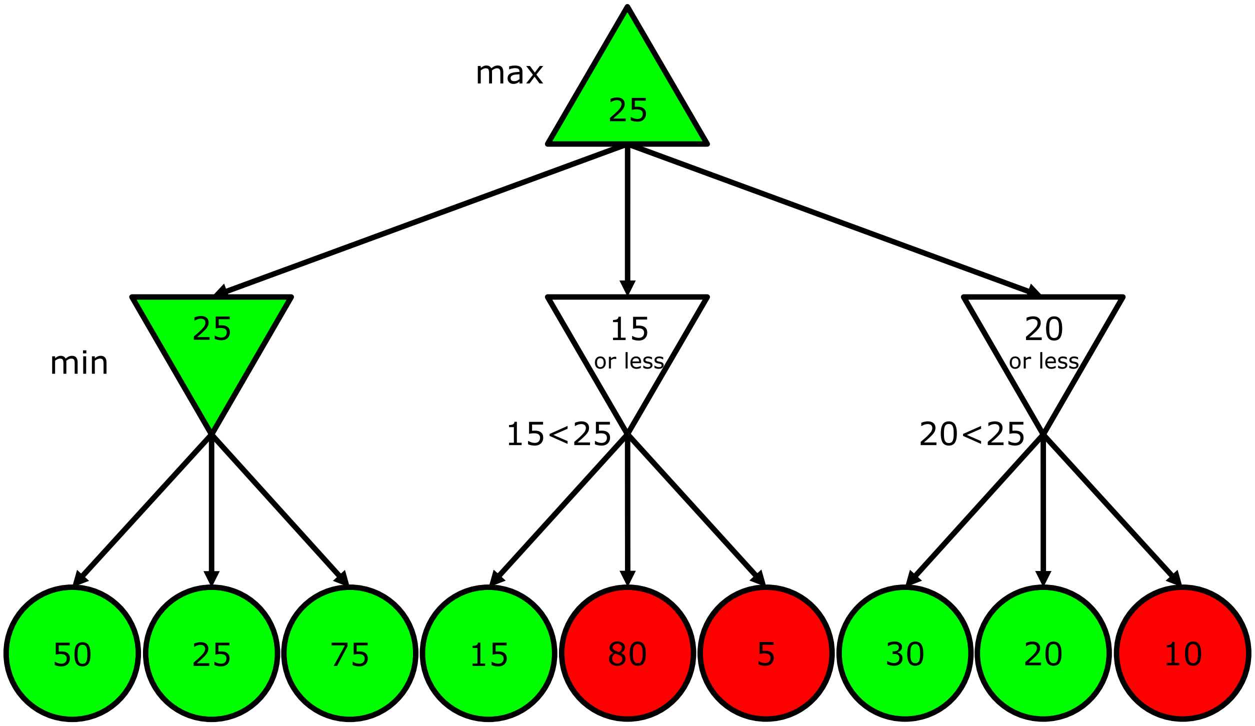
Complete the following written problems:

1. Alpha-Beta Pruning (40 Points).

Consider the following min-max tree.



a. Given that we search depth first from left to right, list all leaf nodes above that we need to search/expand. (35 Points)



Therefore, the leaf nodes that are search/expanded are 50, 25, 75, 15, 30, and 20.

b. What is the final value at the top of the tree? (5 Points)

The final value at the top of the tree is 25.

2. The Wumpus World (70 Points).

Suppose that an agent in the Wumpus World has perceived nothing in (1,1), a breeze in (2,1), and a stench in (1,2):

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2 S V OK	2,2	3,2	4,2
1,1 V OK	2,1 B V OK	3,1	4,1

A	= Agent
B	= Breeze
G	= Glitter, Gold
OK	= Safe Square
P	= Pit
S	= Stench
V	= Visited
W	= Wumpus

Given this Knowledge Base, the agent now concerns itself with the contents of (1,3), (2,2), and (3,1). Each of these locations can contain a pit (P). At most, one location can contain a Wumpus (W). A location can contain nothing (N).

Construct the set of all possible worlds. Each possible world should be represented by a list representing the contents of each location in the following order: (1,3), (2,2), and (3,1). Example: N,P,W means that there is nothing in (1,3), a pit in (2,2), and a Wumpus in (3,1). Hint: There are 32 possible worlds. Mark the worlds in which the Knowledge Base (KB) is true and those in which each of the following sentences is true:

$$\text{A2} = \text{"There is not pit in } (2,2)\text{."}$$

$$\text{A3} = \text{"There is a Wumpus in } (1,3)\text{."}$$

Hence, show that $\text{KB} \models \text{A2}$ and $\text{KB} \models \text{A3}$.

If the world is not supported by the KB, then mark the world False for "KB?". If the world does not support A2, then mark the world False for "A2?". If the world does not support A3, then mark the world False for "A3?".

Number	World	KB?	A2?	A3?
1.	N,N,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
2.	N,N,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	True	False
3.	N,P,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	False
4.	N,P,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	False
5.	P,N,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
6.	P,N,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	True	False
7.	P,P,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	False
8.	P,P,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	False
9.	N,N,W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
10.	N,N,P&W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
11.	N,P,W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
12.	N,P,P&W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
13.	P,N,W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
14.	P,N,P&W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
15.	P,P,W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
16.	P,P,P&W	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
17.	N,W,N	In (1,2), stench and no breeze: True and, in (2,1), no stench and breeze: False; ∴ , False	True	False
18.	N,W,P	In (1,2), stench and no breeze: True and, in (2,1), no stench and breeze: False; ∴ , False	True	False
19.	N,P&W,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
20.	N,P&W,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
21.	P,W,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
22.	P,W,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	False
23.	P,P&W,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
24.	P,P&W,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	False	False
25.	W,N,N	In (1,2), stench and no breeze: True and, in (2,1), no stench and breeze: False; ∴ , False	True	True
26.	W,N,P	In (1,2), stench and no breeze: True and, in (2,1), no stench and breeze: True; ∴ , True	True	True
27.	W,P,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	True
28.	W,P,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	True
29.	P&W,N,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: False; ∴ , False	True	True
30.	P&W,N,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	True	True
31.	P&W,P,N	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	True
32.	P&W,P,P	In (1,2), stench and no breeze: False and, in (2,1), no stench and breeze: True; ∴ , False	False	True

Note: From Page 237, the agent will perceive a Stench in the square containing the wumpus and in directly (not diagonally) adjacent squares. Additionally, the agent will perceive a Breeze in the squares directly adjacent to a pit. If there were a pit in either (1,3) or (2,2), then we would perceive a Breeze in (1,2); however, we do not. If there were a wumpus in either (2,2) or (3,1), the we would perceive a Stench in (2,1); however, we do not. Therefore, we must have a wumpus only in (1,3), nothing in (2,2), and a pit only in (3,1).

3. Propositional Logic (60 Points).

Given the following paragraph:

If the unicorn is mythical, then it is immortal, but if it is not mythical, then it is a mortal mammal. If the unicorn is either immortal or a mammal, then it is horned. The unicorn is magical if it is horned.

And the following propositions:
UnicornIsMythical: The unicorn is mythical.
UnicornIsMortal: The unicorn is mortal.
UnicornIsMammal: The unicorn is a mammal.
UnicornIsHorned: The unicorn is horned.
UnicornIsMagical: The unicorn is magical.

Note: The names for the following rules are based on Figure 7.11 on Page 249 and Section 7.5 (Propositional Theorem Proving; Pages 249-254).

Below are two of the many ways these can be proved.

a. Use propositional logic to prove that the unicorn is magical. List each premise and indicate each inference rule used in your proof. You may use more or less lines than in the table below. (30 Points)

Line	**Sentence**	**Rule**
1.	$UnicornIsMythical \Rightarrow \neg UnicornIsMortal$	Premise
2.	$\neg UnicornIsMythical \Rightarrow UnicornIsMortal \wedge UnicornIsMammal$	Premise
3.	$\neg UnicornIsMortal \vee UnicornIsMammal \Rightarrow UnicornIsHorned$	Premise
4.	$UnicornIsHorned \Rightarrow UnicornIsMagical$	Premise
5.	$\neg UnicornIsMythical \vee \neg UnicornIsMortal$	From 1 by Implication Elimination
6.	$\neg(\neg UnicornIsMythical) \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 2 by Implication Elimination
7.	$UnicornIsMythical \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 6 by Double Negation Elimination
8.	$\neg UnicornIsMortal \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 5 and 7 by Resolution
9.	$(\neg UnicornIsMortal \vee UnicornIsMortal) \wedge (\neg UnicornIsMortal \wedge UnicornIsMammal)$	From 8 by Distributivity of $\vee$ over $\wedge$
10.	$\neg UnicornIsMortal \wedge UnicornIsMammal$	From 9 by Tautology

11.	$\neg UnicornIsMortal$	From 10 by And Elimination
13.	$\neg(\neg UnicornIsMortal \lor UnicornIsMammal) \lor UnicornIsHorned$	From 3 by Implication Elimination
14.	$(\neg(\neg UnicornIsMortal) \land \neg UnicornIsMammal) \lor UnicornIsHorned$	From 13 by De Morgan
15.	$(UnicornIsMortal \land \neg UnicornIsMammal) \lor UnicornIsHorned$	From 14 by Double Negation Elimination
16.	$(UnicornIsMortal \lor UnicornIsHorned) \land (\neg UnicornIsMammal \lor UnicornIsHorned)$	From 15 by Distributivity of $\lor$ over $\land$
17.	$UnicornIsMortal \lor UnicornIsHorned$	From 16 by And Elimination
18.	$\neg(\neg UnicornIsMortal) \lor UnicornIsHorned$	From 17 by Double Negation Elimination
19.	$\neg UnicornIsMortal \Rightarrow UnicornIsHorned$	From 18 by Implication Elimination
20.	$UnicornIsHorned$	From 11 and 19 by Modus Ponens
21.	$UnicornIsMagical$	From 4 and 20 by Modus Ponens

b. Use propositional logic to prove that the unicorn is horned. List each premise and indicate each inference rule used in your proof. You may use more or less lines than in the table below. (30 Points)

Line	**Sentence**	**Rule**
1.	$UnicornIsMythical \Rightarrow \neg UnicornIsMortal$	Premise
2.	$\neg UnicornIsMythical \Rightarrow UnicornIsMortal \land UnicornIsMammal$	Premise
3.	$\neg UnicornIsMortal \lor UnicornIsMammal \Rightarrow UnicornIsHorned$	Premise
4.	$UnicornIsHorned \Rightarrow UnicornIsMagical$	Premise
5.	$\neg UnicornIsMythical \lor \neg UnicornIsMortal$	From 1 by Implication Elimination

6.	$\neg(\neg UnicornIsMythical) \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 2 by Implication Elimination
7.	$UnicornIsMythical \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 6 by Double Negation Elimination
8.	$\neg UnicornIsMortal \vee (UnicornIsMortal \wedge UnicornIsMammal)$	From 5 and 7 by Resolution
9.	$(\neg UnicornIsMortal \vee UnicornIsMortal) \wedge (\neg UnicornIsMortal \wedge UnicornIsMammal)$	From 8 by Distributivity of $\vee$ over $\wedge$
10.	$\neg UnicornIsMortal \wedge UnicornIsMammal$	From 9 by Tautology
11.	$\neg UnicornIsMortal$	From 10 by And Elimination
13.	$\neg(\neg UnicornIsMortal \vee UnicornIsMammal) \vee UnicornIsHorned$	From 3 by Implication Elimination
14.	$(\neg(\neg UnicornIsMortal) \wedge \neg UnicornIsMammal) \vee UnicornIsHorned$	From 13 by De Morgan
15.	$(UnicornIsMortal \wedge \neg UnicornIsMammal) \vee UnicornIsHorned$	From 14 by Double Negation Elimination
16.	$(UnicornIsMortal \vee UnicornIsHorned) \wedge (\neg UnicornIsMammal \vee UnicornIsHorned)$	From 15 by Distributivity of $\vee$ over $\wedge$
17.	$UnicornIsMortal \vee UnicornIsHorned$	From 16 by And Elimination
18.	$\neg(\neg UnicornIsMortal) \vee UnicornIsHorned$	From 17 by Double Negation Elimination
19.	$\neg UnicornIsMortal \Rightarrow UnicornIsHorned$	From 18 by Implication Elimination
20.	$UnicornIsHorned$	From 11 and 19 by Modus Ponens

4. Conjunctive Normal Form (50 Points).

Consider the following sentence:

$$\left[(Food \Rightarrow Party) \vee (Drinks \Rightarrow Party)\right] \Rightarrow \left[(Food \wedge Drinks) \Rightarrow Party\right]$$

a. Using the procedure starting on page 253, convert this sentence into Conjunctive Normal Form showing each step. (Points 40)

(1) Eliminate $\Leftrightarrow$, replacing with $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$:

$$\left[(Food \Rightarrow Party) \vee (Drinks \Rightarrow Party)\right] \Rightarrow \left[(Food \wedge Drinks) \Rightarrow Party\right]$$

(2) Eliminate $\Rightarrow$, replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$:

$$\left[(Food \Rightarrow Party) \vee (Drinks \Rightarrow Party)\right] \Rightarrow \left[(Food \wedge Drinks) \Rightarrow Party\right]$$

$$\left[\left(\boxed{\neg Food \vee Party}\right) \vee (Drinks \Rightarrow Party)\right] \Rightarrow \left[(Food \wedge Drinks) \Rightarrow Party\right]$$

$$\left[(\neg Food \vee Party) \vee \left(\boxed{\neg Drinks \vee Party}\right)\right] \Rightarrow \left[(Food \wedge Drinks) \Rightarrow Party\right]$$

$$\left[(\neg Food \vee Party) \vee (\neg Drinks \vee Party)\right] \Rightarrow \left[\boxed{\neg(Food \wedge Drinks) \vee Party}\right]$$

$$\boxed{\neg\left[(\neg Food \vee Party) \vee (\neg Drinks \vee Party)\right] \vee \left[\neg(Food \wedge Drinks) \vee Party\right]}$$

(3) CNF requires $\neg$ to appear only in literals, so we "move $\neg$ inwards" by repeated application of the following equivalences: $\neg(\neg\alpha) \equiv \alpha$, $\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$, and $\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$.

$$\neg\left[(\neg Food \vee Party) \vee (\neg Drinks \vee Party)\right] \vee \left[\neg(Food \wedge Drinks) \vee Party\right]$$

$$\neg\left[(\neg Food \vee Party) \vee (\neg Drinks \vee Party)\right] \vee \left[\boxed{(\neg Food \vee \neg Drinks)} \vee Party\right]$$

$$\boxed{\left[\neg(\neg Food \vee Party) \wedge \neg(\neg Drinks \vee Party)\right]} \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

$$\left[\boxed{(\neg\neg Food \wedge \neg Party)} \wedge \neg(\neg Drinks \vee Party)\right] \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

$$\left[\boxed{(Food \wedge \neg Party)} \wedge \neg(\neg Drinks \vee Party)\right] \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

$$\left[(Food \wedge \neg Party) \wedge \boxed{(\neg\neg Drinks \wedge \neg Party)}\right] \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

$$\left[(Food \wedge \neg Party) \wedge \boxed{(Drinks \wedge \neg Party)}\right] \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

(4) Now we have a sentence containing nested $\wedge$ and $\vee$ operators applied to literals. We apply the distributivity law (distributing $\vee$ over $\wedge$ wherever possible):

$$\left[(Food \wedge \neg Party) \wedge (Drinks \wedge \neg Party)\right] \vee \left[\neg Food \vee \neg Drinks \vee Party\right]$$

$$(Food \wedge \neg Party \wedge Drinks \wedge \neg Party) \vee (\neg Food \vee \neg Drinks \vee Party)$$

$$\begin{pmatrix} (Food \vee (\neg Food \vee \neg Drinks \vee Party)) \\ \wedge \\ (\neg Party \vee (\neg Food \vee \neg Drinks \vee Party)) \\ \wedge \\ (Drinks \vee (\neg Food \vee \neg Drinks \vee Party)) \\ \wedge \\ (\neg Party \vee (\neg Food \vee \neg Drinks \vee Party)) \end{pmatrix}$$

$$\begin{pmatrix} (Food \vee \neg Food \vee \neg Drinks \vee Party) \\ \wedge \\ (\neg Party \vee \neg Food \vee \neg Drinks \vee Party) \\ \wedge \\ (Drinks \vee \neg Food \vee \neg Drinks \vee Party) \\ \wedge \\ (\neg Party \vee \neg Food \vee \neg Drinks \vee Party) \end{pmatrix}$$

$$\begin{pmatrix} (Food \vee \neg Food \vee \neg Drinks \vee Party) \\ \wedge \\ (\neg Party \vee Party \vee \neg Food \vee \neg Drinks) \\ \wedge \\ (Drinks \vee \neg Drinks \vee \neg Food \vee Party) \\ \wedge \\ (\neg Party \vee Party \vee \neg Food \vee \neg Drinks) \end{pmatrix}$$

b. Using resolution, determine if this sentence is valid, satisfiable (but not valid), or unsatisfiable. (Points 10)

$$\begin{pmatrix} (Food \vee \neg Food \vee \neg Drinks \vee Party) \\ \wedge \\ (\neg Party \vee Party \vee \neg Food \vee \neg Drinks) \\ \wedge \\ (Drinks \vee \neg Drinks \vee \neg Food \vee Party) \\ \wedge \\ (\neg Party \vee Party \vee \neg Food \vee \neg Drinks) \end{pmatrix}$$

$$\begin{pmatrix} \left(\boxed{Food \vee \neg Food} \vee \neg Drinks \vee Party\right) \\ \wedge \\ \left(\boxed{\neg Party \vee Party} \vee \neg Food \vee \neg Drinks\right) \\ \wedge \\ \left(\boxed{Drinks \vee \neg Drinks} \vee \neg Food \vee Party\right) \\ \wedge \\ \left(\boxed{\neg Party \vee Party} \vee \neg Food \vee \neg Drinks\right) \end{pmatrix}$$

$$\begin{pmatrix} \left(\boxed{True} \vee \neg Drinks \vee Party\right) \\ \wedge \\ \left(\boxed{True} \vee \neg Food \vee \neg Drinks\right) \\ \wedge \\ \left(\boxed{True} \vee \neg Food \vee Party\right) \\ \wedge \\ \left(\boxed{True} \vee \neg Food \vee \neg Drinks\right) \end{pmatrix}$$

$$\left(\boxed{True} \wedge \boxed{True} \wedge \boxed{True} \wedge \boxed{True}\right)$$

$$\boxed{True}$$

Therefore, this sentence is valid.

5. Resolution (40 Points).

A propositional 2-CNF expression is a conjunction of clauses, each containing exactly 2 literals, e.g.,

$$(A \vee B) \wedge (\neg A \vee C) \wedge (\neg B \vee D) \wedge (\neg C \vee G) \wedge (\neg D \vee G)$$

Prove using resolution that the above sentence entails G.

Line	**Sentence**	**Rule**
1.	$(A \vee B) \wedge (\neg A \vee C) \wedge (\neg B \vee D) \wedge (\neg C \vee G) \wedge (\neg D \vee G)$	
2.	$A \vee B$	From 1 by And Elimination
3.	$\neg A \vee C$	From 1 by And Elimination
4.	$B \vee C$	From 2 and 3 by Resolution
5.	$\neg B \vee D$	From 1 by And Elimination
6.	$C \vee D$	From 4 and 5 by Resolution
7.	$\neg C \vee G$	From 1 by And Elimination
8.	$D \vee G$	From 6 and 7 by Resolution
9.	$\neg D \vee G$	From 1 by And Elimination
10.	$G \vee G$	From 8 and 9 by Resolution
11.	G	From 10 by Logical Equivalence

6. First Order Logic (100 Points).

Given the following vocabulary with the following symbols:

$Student(x)$: Predicate. **Person** x is a **student**.

$Knows(x, y)$: Predicate. **Student** x knows **concept** y.

$Course(x)$: Predicate. Subject x is a **course**.

$Takes(x, y)$: Predicate. **Student** x takes **course** y.

$Covers(x, y)$: Predicate. Course x covers **concept** y.

Amy, $Brian$: Constants denoting **people**.

$MAC1140$: Constants denoting the **course** College Algebra.

$MatrixMethods$: Constant denoting the **concept** of matrix methods.

Convert the following sentences to first-order logic:

a. Amy is a student and knows matrix methods. (5 Points)

$$\boxed{Student(Amy) \wedge Knows(Amy, MatrixMethods)}$$

b. Some student knows matrix methods. (10 Points)

$$\boxed{\exists x, Student(x) \wedge Knows(x, MatrixMethods)}$$

c. Every student takes MAC 1140. (10 Points)

$$\boxed{\forall x, Student(x) \Rightarrow Takes(x, MAC1140)}$$

d. MAC 1140 is a course that the student, Brian, has not taken. (10 Points)

$$\boxed{Student(Brian) \wedge \neg Taken(Brian, MAC1140)}$$

e. There is some course that every student has not taken. (20 Points)

$$\boxed{\exists x, Course(x) \wedge \left[\forall y, Student(y) \Rightarrow \neg Taken(y, x)\right]}$$

f. If Brian is a student, takes the course MAC 1140, and MAC 1140 covers matrix methods, then Brian knows matrix methods. (15 Points)

$$\boxed{Student(Brian) \wedge Takes(Brian, MAC1140) \wedge Covers(MAC1140, MatrixMethods) \Rightarrow Knows(Brian, MatrixMethods)}$$

g. If a student takes a course and the course covers some concept, then the student knows that concept. (30 Points)

$$\boxed{\forall x, \forall y, \forall z, Student(x) \wedge Course(y) \wedge Takes(x,y) \wedge Covers(y,z) \Rightarrow Knows(x,z)}$$

7. First Order Logic (90 Points).

This exercise uses the function $MapColor$ and predicates $In(x,y)$, $Borders(x,y)$, and $Country(x)$, whose arguments are geographical regions, along with constant symbols for various regions. In each of the following, we give an English sentence and a number of candidate logical expressions. For each of the logical expressions, state whether it (1) correctly expresses the English sentence, (2) is syntactically invalid and therefore meaningless, or (3) is syntactically valid but does not express the meaning of the English sentence.

a. Paris and Marseilles are both in France.

(i) $In(Paris \wedge Marseilles, France)$ (10 Points)

(2) syntactically invalid and therefore meaningless

(ii) $In(Paris, France) \wedge In(Marseilles, France)$ (10 Points)

(1) correctly expresses the English sentence

(iii) $In(Paris, France) \vee In(Marseilles, France)$ (10 Points)

(3) is syntactically valid but does not express the meaning of the English sentence

NOTE: This incorrectly reads: Either Paris is in France, Marseilles is in France, or both are in France.

b. There is a country that borders both Iraq and Pakistan.

(i) $\exists c \quad Country(c) \wedge Border(c, Iraq) \wedge Border(c, Pakistan)$ (10 Points)

(1) correctly expresses the English sentence

(ii) $\exists c \quad Country(c) \Rightarrow [Border(c, Iraq) \wedge Border(c, Pakistan)]$ (10 Points)

(3) is syntactically valid but does not express the meaning of the English sentence

NOTE: This incorrectly reads: If there is a country, then that country borders Iraq and Pakistan.

(iii) $\left[\exists c \quad Country(c)\right] \Rightarrow \left[Border(c, Iraq) \wedge Border(c, Pakistan)\right]$ (10 Points)

(2) syntactically invalid and therefore meaningless

c. All countries that border Ecuador are in South America.

(i) $\forall c \quad Country(c) \wedge Border(c, Ecuador) \wedge In(c, SouthAmerica)$ (10 Points)

3) is syntactically valid but does not express the meaning of the English sentence

NOTE: This reads: Every country borders Ecuador and is in South America.

(ii) $\forall c \quad Country(c) \Rightarrow \left[Border(c, Ecuador) \Rightarrow In(c, SouthAmerica)\right]$ (10 points)

(1) correctly expresses the English sentence

NOTE: This translates to:

$$\forall c \quad Country(c) \Rightarrow \left[Border(c, Ecuador) \Rightarrow In(c, SouthAmerica)\right]$$
$$\forall c \quad \neg Country(c) \vee \left[\neg Border(c, Ecuador) \vee In(c, SouthAmerica)\right]$$
$$\forall c \quad \left[\neg Country(c) \vee \neg Border(c, Ecuador)\right] \vee In(c, SouthAmerica)$$
$$\forall c \quad \neg\left[Country(c) \wedge Border(c, Ecuador)\right] \vee In(c, SouthAmerica)$$
$$\forall c \quad Country(c) \wedge Border(c, Ecuador) \Rightarrow In(c, SouthAmerica)$$

(iii) $\forall c \quad Country(c) \wedge Border(c, Ecuador) \Rightarrow In(c, SouthAmerica)$ (10 Points)

(1) correctly expresses the English sentence

8. Research Project (50 Points).

a. Write a rough draft of the title of your research project. (10 Points)

b. Write a rough draft of the abstract of your research project. (40 Points)

This assignment has no programming problems.

After completing Assignment 06, create an `assignment_06_`*`lastname`*`.pdf` file for your written assignment.

Upload your `assignment_06_`*`lastname`*`.pdf` file for your written assignment to the Assignment 06 location on the BlackBoard site: https://campus.fsu.edu.