Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*? Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete. Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them. Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$. Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \to b) \wedge c$ is equivalent to $(a \wedge c) \to (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \to b) \wedge (\neg a \to c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \to b, \quad \neg(b \vee c), \quad a \vee d, \quad d \to a\}$.

(ii) $\{\neg(a \to b), \quad b \vee c, \quad a \to c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \to b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \to a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \to b) \wedge c$ is equivalent to $(a \wedge c) \to (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \to b) \wedge (\neg a \to c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \to b, \quad \neg(b \vee c), \quad a \vee d, \quad d \to a\}$.

(ii) $\{\neg(a \to b), \quad b \vee c, \quad a \to c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \to b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \to a)$.

Q1. (a) What is a “half adder”? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called “*if-then-else*” or “$ifte$”) shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*? Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete. Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them. Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$. Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "*ifte*") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "*ifte*") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*? Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete. Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them. Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$. Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "*ifte*") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q1. (a) What is a "half adder"? Show how to express it

(i) using logic tables;

(ii) using the operators $\{\wedge, \vee, \neg\}$.

(b) What does it mean for a set of operators to be *functionally complete*?
Show that the set $\{\wedge, \vee, \neg\}$ is functionally complete.
Give an example of a set consisting of a single operator but which is functionally complete. Express the half adder from Part (i) using it.

Q2. (a) State de Morgan's laws, and prove either of them.
Establish that the following distributive law is correct: $(a \vee b) \wedge c \equiv (a \wedge c) \vee (b \wedge c)$.
Is it true that $(a \rightarrow b) \wedge c$ is equivalent to $(a \wedge c) \rightarrow (b \wedge c)$? Explain your answer.

(b) Consider the logic table for the ternary operator (sometimes called "*if-then-else*" or "$ifte$") shown below.

a	b	c	$ifte(a, b, c)$
F	F	F	F
F	F	T	T
F	T	F	F
F	T	T	T
T	F	F	F
T	F	T	F
T	T	F	T
T	T	T	T

(i) Show that $ifte(a, b, c) \equiv (a \rightarrow b) \wedge (\neg a \rightarrow c)$.

(ii) Write $ifte(a, b, c)$ in Disjunctive Normal Form, and sketch a Venn diagram for the operator.

Q3. (a) Show that $\{A_1, A_2, \ldots, A_n\} \models C$ if and only if the set $\{A_1, A_2, \ldots, A_n, \neg C\}$ is inconsistent as a collection.

(b) For each of the following sets, use the tableau method to either find a model, or to show that the set is inconsistent.

(i) $\{a \rightarrow b, \quad \neg(b \vee c), \quad a \vee d, \quad d \rightarrow a\}$.

(ii) $\{\neg(a \rightarrow b), \quad b \vee c, \quad a \rightarrow c\}$.

(c) For each of the following, use the tableau method to establish if it is a correct logical consequence.

(i) $\{a \vee \neg b, \neg a \rightarrow b\} \models b$.

(ii) $\{a \oplus b, b \uparrow c\} \models (c \rightarrow a)$.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x\big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x\big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x\big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x\big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x,y) \rightarrow P(a,a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x\big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x\big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \lor \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \lor b, \neg a \lor c, \neg(b \lor c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \lor \forall x Q(x)$, and $B = \forall x \big(P(x) \lor Q(x)\big)$.

(ii) $A = \forall x P(x) \land \forall x Q(x)$, and $B = \forall x \big(P(x) \land Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \to c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \to P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.

Q4. (a) Express the following proposition in Conjunctive Normal Form:

$$(a \downarrow b) \vee \neg(a \rightarrow c).$$

Furthermore, show how to write it in Clause Form.

(b) Recall that, for sets of clauses U and V, when we write

$$U \approx V,$$

we mean that U is satisfiable if and only if V is satisfiable.

Suppose that U contains the unit clause $\{a\}$. Furthermore, suppose that V is formed by deleting every clause containing a in U, and deleting $\neg a$ from every remaining clause in U. Explain why $U \approx V$.

(c) Use the resolution procedure to determine if the set $\{a \vee b, \neg a \vee c, \neg(b \vee c)\}$ is satisfiable.

Q5. (a) For each of the following pairs of expressions, determine if A is equivalent to B. Explain your answer.

(i) $A = \forall x P(x) \vee \forall x Q(x)$, and $B = \forall x \big(P(x) \vee Q(x)\big)$.

(ii) $A = \forall x P(x) \wedge \forall x Q(x)$, and $B = \forall x \big(P(x) \wedge Q(x)\big)$.

(b) Use a semantic tableau to show that $\forall x \forall y P(x, y) \rightarrow P(a, a)$ is valid.

(c) For each of the following, determine if it is a valid argument.

(i) All roses have thorns. This flower has thorns. Therefore this flower is a rose.

(ii) No student is lazy. Anyone who is not lazy and is intelligent will pass this exam. I am an intelligent student. Therefore I will pass this exam.