Q1 Score: **10.0** Total Score: **91.0**

1) General Concepts (20 points)

a) (1pt each) For each of the statements below, fill in the bubble T if the statement is always and unconditionally true, or fill in the bubble F if it is always false, sometimes false, or just does not make sense:

1	●	F
2	●	F
3	T	●
4	T	●
5	T	●
6	T	●
7	●	~~F~~
8	●	F
9	T	●
10	●	F
11	T	●
12	~~T~~	●

1- In FOL, constant symbols refer to objects, while predicate symbols refer to relations.

2- The truth table method of inference is complete for propositional logic.

3- Not every sentence of propositional logic can be converted to CNF.

4- ∀ is often used with ∧

5- Propositional logic is not monotonic but First order logic is.

6- Propositional logic has 2 quantifiers: for all and there exists.

7- Forward checking algorithm is sound but it is not complete for knowledge bases of definite clauses.

8- Cyc is an example application of a knowledge engineering.

9- The Semantic Web solves all of the problems of knowledge sharing

10- An upper ontology can be used for knowledge sharing.

11- Inheritance can occur from any subclass

12- Reification represents a category as an object

Q2 Score: **7.0**

b) (1 pt each) Fill in the blank for each sentence with the appropriate word or phrase.

13- A subclass hierarchy allows for an inference process called Inheritance.

14- An inference algorithm is sound if it entails only valid sentence.

15- An inference algorithm is complete if it entails all valid sentences.

16- A sentence is valid if it is true in all models.

17- α entails β if and only if $\alpha \wedge \neg\beta$ is unsatisfiable.

18- Generalized modus ponens requires sentences to be in positive form.

19- Prolog does inference using backward chaining.

20- Tnalogy is a sentence that is necessary true in all models.

Q3 Score: **8.0**

2) Truth Tables (10 points)

a) (8 points) Enumerate the truth table to discuss whether the sentence α is entailed by the knowledge base or not? Draw your table in the space below. There should be one row for each model. There should be columns for each propositional symbol. There should be sufficient number of additional columns to prove entailment.

α= (A ∧ B) ∨ C

KB= (A ∨ ¬C) ∧ (B ∨ C)

	A	¬C	A ∨ ¬C	B	C	B ∨ C	(A∨¬C)∧(B∨C)	A∧B	(A∧B)∨C
	T	F	T	T	T	T	T	T	T
	T	T	T	T	F	T	T	T	T
	T	F	T	F	T	T	T	F	T
	T	T	T	F	F	F	F	F	F
	F	F	F	T	T	T	F	F	T
1	F	T	T	T	F	T	T	F	F
	F	F	F	F	T	T	F	F	T
	F	T	T	F	F	F	F	F	F

Q4 Score: **2.0**

b) Does your table prove the entailment relationship? Explain how one can tell by examining your table.(2 points)

α is not entailed by KB.

Since when A is false, B is true, and C is false.

KB is true while α is false. That means $KB \land \neg\alpha$ is satisfiable. Thus α is not entailed by KB.

Q5 Score: **10.0**

3) Propositional Logic (30 points)

a) Convert the following propositional sentence into CNF. Your answer must be as simplified as much as possible and must exactly match the CNF form. (10 points)
~((A => B) => (((P^B) => Q) v R))

$\sim((\neg A \vee B) \Rightarrow ((\neg(P \wedge B) \vee Q) \vee R))$

$\sim(\neg(\neg A \vee B) \vee ((\neg(P \wedge B) \vee Q) \vee R))$

$\sim((A \wedge \neg B) \vee (\neg P \vee \neg B \vee Q \vee R))$

$(\neg A \vee B) \wedge (P \wedge B \wedge \neg Q \wedge \neg R)$

$(\neg A \vee B) \wedge P \wedge B \wedge \neg Q \wedge \neg R.$

Q6 Score: **10.0**

b) Consider the KB given below:

(1) ExamNextWeek => Study

(2) HomeworkDueNextWeek ^ HighWeightageOfHomework => WorkOnHW

(3) Study => GoodGrades

(4) ~GoodGrades

(5) StudyBreak => ExamNextWeek

(6) HomeworkDueNextWeek

(7) HighWeightageOfHomework

Are the following statements true? Mention which inference rule is used and to which sentences it was applied. If you need to perform intermediate steps, you can number the intermediate result and use it in your next step. (10 points)

(8) ~Study True

$\frac{\alpha \Rightarrow \beta, \neg\beta}{\neg\alpha}$ is used, (3), (4) are applied.

→ get result ~Study

(9) WorkOnHW True

① $\frac{\alpha, \beta}{\alpha \wedge \beta}$ is used. (6), (7) are applied.

intermediate result: HomeworkDueNextWork ∧ HighWeightageOfHomework ⋯(11)

② $\frac{\alpha \Rightarrow \beta, \alpha}{\beta}$ is used (2) and intermediate result (11) are applied.

get result WorkOnHW

(10) ~StudyBreak True.

① $\frac{\alpha \Rightarrow \beta, \neg\beta}{\neg\alpha}$ is used, (1), (8) are applied

intermediate result: ¬ExamNextWeek ⋯(12)

② $\frac{\alpha \Rightarrow \beta, \neg\beta}{\neg\alpha}$ is used. (5) and intermediate result (12) are used.

get result ¬StudyBreak

Q7 Score: **10.0**

c) Use resolution and proof by contradiction to prove W from the following knowledge base:

1. P
2. ¬ Q
3. P → R
4. ¬ Q v W
5. W → P
6. ¬ R v W

Please show the complete resolution proof, including all substitutions used. (10 points)

Negate goal W: 7. ¬W.

convert 3, 5 into CNF: 8. ¬P V R

9. ¬W V P

resolution:

$\dfrac{1,\ 8}{R}$ Add into KB: 10. R

resolution:

$\dfrac{10,\ 6}{W}$ Add into KB: 11. W

resolution:

$\dfrac{11,\ 7}{\{\ \}}$ ⇒ contradiction, i.e. ¬W is unsatisfiable.

∴ W is proved

Q8 Score: **11.0**

4) First-Order Logic (30 points)

1- Consider the following predicates:

Student(x) : x is a student.

Course(x) : x is a course.

Semester(x) : x is a semester.

Takes(x,y,z) : student 'x' has taken course 'y' in 'z' semester

Failed(x,y,z) : student 'x' has failed course 'y' in 'z' semester

Using the above predicates translate these English sentences into logic expressions (15 points)

a) Every student takes at least two courses in each semester.

$\forall x, s \;\; Student(x) \wedge Semester(s) \Rightarrow \exists y, z \;\; (Course(y) \wedge Course(z) \wedge y \neq z \wedge Takes(x, y, s) \wedge Takes(x, z, s))$

b) Only one student failed History in Spring2015.

$\exists x. \;\; Student(x) \wedge Failed(x, History, Spring2015) \wedge (\forall y. \;\; Student(y) \wedge x \neq y \Rightarrow \neg Failed(y, History, Spring2015))$

c) No student failed Chemistry in Spring2015 but at least one student failed History (in Spring2015).

$(\forall x. \;\; Student(x) \Rightarrow \neg Failed(x, Chemistry, Spring2015)) \wedge (\exists y. \;\; Student(y) \wedge Failed(y, History, Spring2015))$

d) Every student who takes Analysis also takes Geometry.

$\forall x, s_1, s_2 \;\; Student(x) \wedge Semester(s_1) \wedge Semester(s_2) \wedge Takes(x, Analysis, s_1) \Rightarrow Takes(x, Geometry, s_2)$

?

e) No student has Analysis and History simultaneously in one semester

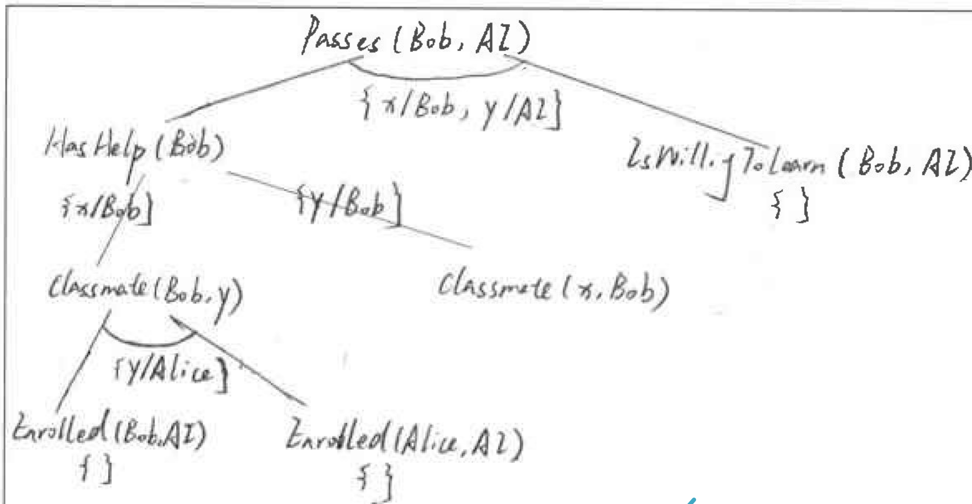
$\forall x, s \;\; Student(x) \wedge Semester(s) \Rightarrow \neg(Takes(x, Analysis, s) \wedge Takes(x, History, s))$

Q9 Score: **10.0**

2- Consider the following 8 sentences that are added to KB. Enrolled, Classmate, hasHel IsWillingToLearn, Passes are predicates. Bob, Alice, Susan and AI are constants. x, y, z are variables. Assume all sentences are universally quantifies over all variables.

- HasHelp(x) ∧ IsWillingToLearn(x,y) ⍰ Passes(x,y)
- Classmate(x,y) ⇒ HasHelp(x) ∧ HasHelp(y)
- Classmate(x,y) ∧ Classmate(y,z) ⍰ Classmate(x,z) ⇒ transition
- Enrolled(x,y) ∧ Enrolled(z,y) ⍰ Classmate(x,z)
- Enrolled(Bob, AI)
- Enrolled(Alice, AI)
- Classmate(Alice, Susan)
- IsWillingToLearn(Bob,AI)

Given the KB above, show how backward chaining with GMP can be used to infer whether Bob passes AI (ie. Passes(Bob, AI). Draw a backward chaining inference tree. Be sure to show all the substitutions used in unification at each stage, as relevant. (10 points)



Q10 Score: **5.0**

3- Is backward chaining a complete algorithm? If yes, why? If no, how can we make it complete? (3 points)

No. It may get stuck into infinite loop since it uses depth-frist search.

We can make it remember each subgoal, and when there exists duplicates of a subgoal, just terminate.

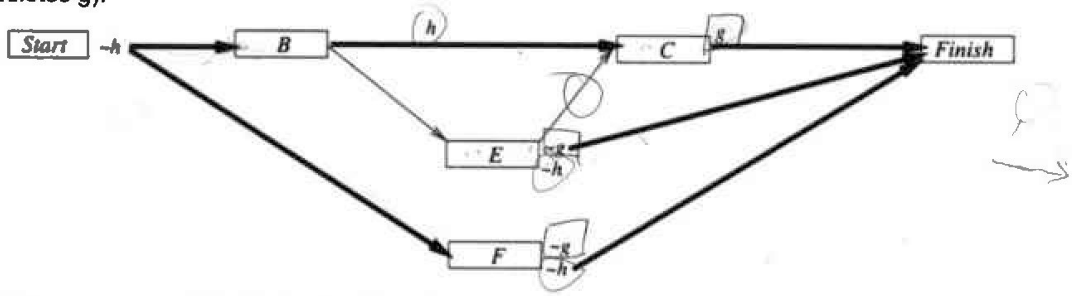
4- What does it mean to say that entailment for first-order logic is semidecidable? (2 points)

In first order logic. we can know it if one sentence is entailed from KB. But we will never know it if one sentence is not entailed from KB

Q11 Score: **8.0**

5) Planning (10 points)

Consider the following partial-order plan (a step followed by e.g. ~g means that the steps deletes g):



1- How many possible total-order plans does this partial-order plan have? (2 points)

3

2- Which step(s) may threaten the causal link between action B and action C? (2 points)

F

3- Which step(s) necessarily threaten the causal link between action B and action C? (2 points)

E

4- How can the plan be refined (by a standard partial-order planner) to remove a possible threat to the causal link between action B and action C ? (2 points)

Add ordering constraints to step F and C, that is, C must be befor F.

5- Is g necessarily true at the finish step? Justify your answer. (2 points)

No. Since both step C and step E can lead to goal, and step C add g, while step E delete g. So, g may or may not be true in Finish step's precondition. Thus g is not neassarily true.