1. [24=(6x4) points] *Getting Acquainted*. Consider the following axioms:

- **Horses are faster than dogs**
- **There is a greyhound that is faster than every rabbit**
- **Harry is a horse**
- **Ralph is a rabbit**

We would like to prove Harry is faster than Ralph

1a. Write each statement in FOL.

$\forall x, y Horse(x) \wedge Dog(y) \rightarrow Faster(x, y)$;

$\exists x Greyhound(x) \wedge (\forall y Rabbit(y) \rightarrow Faster(x, y))$;

$Horse(Harry)$;

$Rabbit(Ralph)$;

1b. Write additional assumptions needed in FOL.

$\forall x Greyhound(x) \rightarrow Dog(x)$;

$\forall x, y, z Faster(x, y) \wedge Faster(y, z) \rightarrow Faster(x, z)$;

1c. Convert each sentence into CNF.

FOL: $\forall x, y Horse(x) \wedge Dog(y) \rightarrow Faster(x, y)$

CNF: $\neg Horse(h) \vee \neg Dog(d) \vee Faster(h, d)$

FOL: $\exists x Greyhound(x) \wedge (\forall y Rabbit(y) \rightarrow Faster(x, y))$

CNF:

$Greyhound(G)$

$\neg Rabbit(r) \vee Faster(G, r)$

where G is a new skeolem constant

FOL: $Horse(Harry)$

CNF: $Horse(Harry)$

FOL: $Rabbit(Ralph)$

CNF: $Rabbit(Ralph)$

FOL: $\forall x Greyhound(x) \rightarrow Dog(x)$

CNF: $\neg Greyhound(g) \vee Dog(g)$

FOL: $\forall x, y, z Faster(x, y) \wedge Faster(y, z) \rightarrow Faster(x, z)$

CNF: $\neg Faster(x, y) \vee \neg Faster(y, z) \vee Faster(x, z)$

1d. Convert each sentence into dlv format

Horses are faster than dogs:

faster(X,Y) :- horse(X),dog(Y).

There's a greyhound that is faster than every rabbit:

greyhound(g).

faster(g,R) :- rabbit(R).

Harry is a horse:

horse(Harry).

Ralph is rabbit:

rabbit(Ralph).

A greyhound is a dog:

dog(X) :- greyhound(X).

X faster than y, y faster z then x also faster than z:

faster(X,Y) :- faster(X,Y), faster(Y,Z).

1e. Prove by hand Harry is faster than Ralph.

First construct refutation proofs and then refute the negation of the proposed theorem. Add $\neg Faster(Harry, Ralph)$ to KB.

Refutation Proofs:

$$\frac{Rabbit(Ralph), \neg Rabbit(r) \vee Faster(G,r)}{Faster(G, Ralph)} \{r / Ralph\}$$

$$\frac{Greyhound(G), \neg Greyhound(g) \vee \neg Dog(g)}{\neg Dog(G)} \{g / G\}$$

$$\frac{Horse(Harry), \neg Horse(h) \vee \neg Dog(d) \vee Faster(h,d)}{\neg Dog(d) \vee Faster(Harry, d)} \{h / Harry\}$$

$$\frac{Dog(G), \neg Dog(d) \vee Faster(Harry, d)}{Faster(Harry, G)} \{d / G\}$$

$$\frac{Faster(Harry, G), \neg Faster(x,y) \vee \neg Faster(y,z) \vee Faster(x,z)}{\neg Faster(G,z) \vee Faster(Harry, z)} \{x / Harry, y / G\}$$

$$\frac{Faster(G, Ralph), \neg Faster(G,z) \vee Faster(Harry, z)}{Faster(Harry, Ralph)} \{z / Ralph\}$$

$$\frac{Faster(Harry, Ralph), \neg Faster(Harry, Ralph)}{False}$$

Then we know Faster(Harry,Ralph) is true implies that Harry is faster than Ralph.

1f. User dlv to prove Harry is faster than Ralph

```
ubuntu@ip-172-31-53-199:~/ai/dlv$ cat god
faster(X,Y) :- horse(X),dog(Y).
greyhound(g).
faster(g,R) :- greyhound(g),rabbit(R).
horse(harry).
rabbit(ralph).
dog(X) :- greyhound(X).
faster(X,Z) :- faster(X,Y), faster(Y,Z).
ubuntu@ip-172-31-53-199:~/ai/dlv$ dlv god
{horse(harry), greyhound(g), rabbit(ralph), faster(g,ralph), faster(harry,g), faster(harry,ralph), dog(g)}
ubuntu@ip-172-31-53-199:~/ai/dlv$
```

ubuntu@ip-172-31-53-199:~/ai/dlv$ cat god

faster(X,Y) :- horse(X),dog(Y).

greyhound(g).

faster(g,R) :- greyhound(g),rabbit(R).

horse(harry).

rabbit(ralph).

dog(X) :- greyhound(X).

faster(X,Z) :- faster(X,Y), faster(Y,Z).

ubuntu@ip-172-31-53-199:~/ai/dlv$ dlv god

{horse(harry), greyhound(g), rabbit(ralph), faster(g,ralph), faster(harry,g), **faster(harry,ralph)**, dog(g)}

2. [20 points] Three people, Amy, Bob, and Cal, are each either a liar or a truth-teller. Assume that liars always lie, and truth-tellers always tell the truth.

- Amy says, "Cal is not honest."
- Bob says, "Amy and Cal never lie."
- Cal says, "Bob is correct."

What can you conclude about the truthfulness of each? [Hint: remember you will need to add "obvious" constraints, like "Amy is either telling the truth or lying". This problem can be done with propositional logic only.]

A: "Amy is truth-teller" ~A: "Amy is lying"
B: "Bob is truth-teller" ~B: "Bob is lying"
C: "Cal is truth-teller" ~C: "Cal is lying"
And suppose A is truth-teller, for the 3 sentences we have:

$$A \leftrightarrow \neg C$$

$$B \leftrightarrow (A \wedge C)$$

$$C \leftrightarrow B$$

Use resolution for the refutation proof:
After adding the negated goal, CNF:

$$(\neg A \vee \neg C) \wedge (A \vee C)$$

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

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

$$\neg A$$

Then apply the and-elimination:

$$----------KB-----------$$

$(1) \neg A \vee \neg C$

$(2) A \vee C$

$(3) A \vee \neg B$

$(4) \neg B \vee C$

$(5) \neg A \vee B \vee \neg C$

$(6) A \vee \neg C$

$$---------NEGATION------$$

$(7) \neg A$

$$---------DerivedClause--$$

$(8) A \cdots (2)(6)$

$(9) \{\} \cdots (7)(8) Contradiction!$

Then we know A is truth-teller, B and C are liar.

Also, we can prove the result according to truthfulness of B or C.

3. [26 points] Use DLV to solve problem 5 on HW#2. Hint: the tutorial shows one way to do this (of several). The command "`dlv filename -N=9 -filter=predicate`" will limit integers from 0 to 9, and only print the predicate named "`predicate`" in the model (might be helpful here). The section ***Built-in Predicates*** shows using =, !=, <, and `#succ(X,Y)` and `#prec(X,Y)` to do simple math (*"…scored one more goal than…"*)

The DLV source code is sort of long, so I don't paste it here. Please refer to the ship.dlv. I just translate the following rules into DLV:

Variables:

There are 3 types of variables in this problem:

Cruisers: Cory, Damon, Greg, Miranda, short for: C D G M

Destination: Barbados, Martinique, Saint Lucia, Trinidad: bs me sl td

Cruise: Azure Seas, Caprica, Farralon, Silver Shores: AS CA FA SS

Domain:

let's make the value of year as the domain.

Year: 1983, 1984, 1985, 1986 : 3 4 5 6

Constraints:

Unary constraints:

D!= 3 ; sl=6 ; SS=6

Binary constraints:

bs!=CA

td!=FA

sl!=FA

td!=FA

G-1=td

td>bs

me>C

FA-1=AS

sl=SS

Global constraints:

Alldiff(C,D,F,M) ; Alldiff(bs,me,sl,td) ; Alldiff(AS,CA,FA,SS)

The result is: (./dlv -slient -nofacts ship.dlv)

```
ubuntu@ip-172-31-53-199:~/ai/dlv$ dlv -nofacts ship.dlv
{take(as,3), take(fa,4), take(ca,5), take(ss,6), visited(bs,3), visited(me,4), visited(td,5), visited(sl,6), depart(c,3),
 depart(m,4), depart(d,5), depart(g,6)}
ubuntu@ip-172-31-53-199:~/ai/dlv$
```

dlv -nofacts ship.dlv

{

take(as,3), take(fa,4), take(ca,5), take(ss,6),

visited(bs,3), visited(me,4), visited(td,5), visited(sl,6),

depart(c,3), depart(m,4), depart(d,5), depart(g,6)}

4. [30 points] Use DLV to play the game Strimko [http://www.strimko.com/rules.htm], another sort of Sudoku variant.

The object of the puzzle is to fully fill in the given grid with missing numbers observing three simple rules. You may assume a 4x4 board (part of the problem is to develop a logical representation for an arbitrary 4x4 Strimko board).

1st The code please the attachment [strimko.dlv].

2nd If the stream is changed, then the results will be changed either.

3rd To change the stream, just modify the stream matrix. Here I use the middle example given in the problem. If we don't set the initial state, there are 24 legal results under the current stream constraints.

4th Also, the initial placed grid can be changed, it's just the last constraints in the source code. There's only one legal final result.

5th ./dlv -nofacts -silent strimko.dlv

Results:

```
{
res(1,1,3), res(2,1,2), res(3,1,1), res(4,1,4),
res(1,2,1), res(2,2,4), res(3,2,3), res(4,2,2),
res(1,3,4), res(2,3,1), res(3,3,2), res(4,3,3),
res(1,4,2), res(2,4,3), res(3,4,4), res(4,4,1)
}
```

EXTRA CREDIT: [10 pts] This is an actual LSAT question. From the LSAT board, this question is rated “difficult” (most future lawyers got it wrong).

> *Several critics have claimed that any contemporary poet who writes formal poetry — poetry that is rhymed and metered — is performing a politically conservative act. This is plainly false. Consider Molly Peacock and Marilyn Hacker, two contemporary poets whose poetry is almost exclusively formal and yet who are themselves politically progressive feminists.*

Question: The conclusion drawn above follows logically if which one of the following is assumed?

× A No one who is a feminist is also politically conservative.

× B No poet who writes unrhymed or unmetered poetry is politically conservative.

√ C No one who is politically progressive is capable of performing a politically conservative act.

× D Anyone who sometimes writes poetry that is not politically conservative never writes poetry that is politically conservative.

× E The content of a poet's work, not the work's form, is the most decisive factor in determining what political consequences, if any, the work will have.

I translate the premise into DLV :

```
poet(molly).
poet(marilyn).

write(molly,formally).
write(marilyn,formally).

progressive(X) v conservative(X):- poet(X).
conservative(X) :- write(X,formally),poet(X).
```

The results show an contradiction with the problem stated.
So we conclude that if an poet write formally that she can’t performs progressively:

```
ubuntu@ip-172-31-53-199:~/ai/dlv$ dlv -nofacts extra.dlv
{conservative(molly), conservative(marilyn)}
ubuntu@ip-172-31-53-199:~/ai/dlv$
```

So the my choice is C.