Problem 1: Rabbits and Chickens

1.A: Find the number of chickens and rabbits given total number of heads and legs

- Given the number of heads and number of legs, first find the number of rabbits.
- This can be found by solving the equations: 4*R + 2*C = Legs and R+C = Heads.
- Thus, I first found the number of rabbits using the first equation and found the number of chickens using the second equation.
- I Check if both the counts make sense. That is, check if both of them are integers and >=0.

Code:

```
% Farm yard. Chicken and rabbits
countRabbits(Heads, Legs, C) :-
   H is 2*Heads,
   C1 is Legs - H,
   C is C1 / 2.

% solution A
find_rabbits_and_chickens(Heads, Legs, RabbitCount,
ChickenCount):-
   % First find the number of rabbits
   countRabbits(Heads, Legs, RabbitCount),
   RabbitCount>=0, integer(RabbitCount),
   ChickenCount is Heads - RabbitCount,
   ChickenCount>=0, integer(ChickenCount).
```

Output:

```
abhijit@dwave ~/studies/logic_programming/exams/midterm (main)$ swipl
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?- consult("q1.pl").
true.

?- find_rabbits_and_chickens(2,6,R,C).
R = C, C = 1.

?- find_rabbits_and_chickens(14,48,R,C).
R = 10,
C = 4.

?- find_rabbits_and_chickens(7,64,R,C).
false.

?- find_rabbits_and_chickens(14,56,R,C).
R = 14,
C = 0.
```

1.B: Find the total number of animals with just the number of legs given

- I used the **generate and test** paradigm for the second part.
- First generate n heads in range [1, 40] and get the counts of rabbits and counts of chickens given by the 1.A function are valid.That is, check if both of them are integers and >=0.
- If yes, then add the chicken and rabbit counts to get the total counts.

Code:

```
% generate a list of numbers between M and N
range(M,N,[M|Ns]):- M<N, M1 is M+1, range(M1, N, Ns).
range(N,N,[N]).

% select
select(X, [X|Xs], Xs).
select(X, [Y|Ys], [Y|Zs]):- select(X,Ys,Zs).

% solution B
find_total_number_of_animals(Legs, TotalCount):-
   % generate a list of heads from 1 to 40
   range(1, 40, HeadList),
   % select each head: This is the generation part
   select(Heads, HeadList, _),
   % below is the test part
   % this is from the first part of the code
   find_rabbits_and_chickens(Heads, Legs, RabbitCount, ChickenCount),
   % make sure the Rabbit and chicken counts make sense
   integer(RabbitCount), integer(ChickenCount), RabbitCount>=0,
ChickenCount>=0,
   TotalCount is RabbitCount + ChickenCount.
```

Output:

```
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For built-in help, use ?- help(Topic). or ?- apropos(Word).

?- consult("q1.pl").
true.

?- find_total_number_of_animals(12, A).
A = 3 ;
A = 4 ;
A = 5 ;
A = 6 ;
false.

?- find_total_number_of_animals(14, A).
A = 4 ;
A = 5 ;
A = 6 ;
A = 7 ;
false.

?- find_total_number_of_animals(10, A).
A = 3 ;
A = 4 ;
A = 5 ;
false.
```

Problem 2: Weighted and Colored Blocks world

Approach:

- As given in the question I defined a new structure: **weight(block, weight, color)**.
- The only predicate that needs to be modified from the code given in the textbook is: **legal_action(to_block(Block1,Y,Block2),State).**
- In that predicate I added new predicates which checks if the weight of block1 > block2 and if it is, it checks if the weight difference is less than 3 ounces. I also made sure that the colors of block1 and block2 are different.

Code:

```
% block's world with weights
/*
   transform(State1,State2,Plan) :-
   Plan is a plan of actions to transform State1 into State2.
*/
block(a).
block(b).
block(c).
place(p).
place(q).
place(r).

weight(a, 2.2, green).
weight(b, 6.1, red).
weight(c, 8.2, blue).

% on(X,Y) -> where X is block and Y is block/place, means X is on Y
% initial states are: [on(a,b) ,on(b,p) ,on(c,r)]
% final states are: [on(a,b) ,on(b,c) ,on(c,r)]
% Actions is a list of
[to_place(block,Y,Place)|to_block(block,Y,block)]
transform(State1,State2,Plan) :-
   transform(State1,State2,[State1],Plan).
transform(State,State,Visited,[]).
transform(State1,State2,Visited,[Action|Actions]) :-
   choose_action(Action,State1, State2),
   update(Action,State1,State),
   \+ member(State,Visited),
   transform(State,State2,[State|Visited],Actions).
```

```
% two possible actions: moving to a place and moving to a block
% move block from Y(either a block or place) to place
legal_action(to_place(Block,Y,Place),State) :-
   on(Block,Y,State), % block must be on Y
   clear(Block,State), % block must be clear to move
   place(Place), % Place must be a place
   clear(Place,State). %

% check if moving Block1 to Block2 from Y is a legal action
% The predicate that needs to be modified
legal_action(to_block(Block1,Y,Block2),State) :-
   on(Block1,Y,State), % Block 1 is on Y
   clear(Block1,State), % Block 1 is clear to move
   block(Block2), % Block2 is a block
   Block1 \== Block2, % block1 and block2 are not same
   % incorporating the weight and color constraints
   weight(Block1, Weight1, Color1),
   weight(Block2, Weight2, Color2),
   % block 1 is going  on  top of block2
   % Thus  weight of block1 must not exceed the weight of  block1 by
3
   (Weight1>Weight2 -> WeightDiff is Weight1 - Weight2, WeightDiff <
3; true),
   Color1 \= Color2,
   clear(Block2,State). % Block2 is clear

% True if nothing is on top of A
clear(X,State) :- \+ member(on(A,X),State).
% True if X is on Y
on(X,Y,State) :- member(on(X,Y),State).
update(to_block(X,Y,Z),State,State1) :-
   substitute(on(X,Y),on(X,Z),State,State1).
update(to_place(X,Y,Z),State,State1) :-
   substitute(on(X,Y),on(X,Z),State,State1).


% substitute(X,Y,L1,L2), where L2 is the result of substituting Y for
all occurrences of X in L1, e.g., substitute(a,x,[a,b,a,c],[x,b,x,c])
% is true, whereas substitute (a, x, [a,b, a, cl , [a,b ,x, c] ) is
false
substitute(X,Y,[X|Xs],[Y|Xs]).
substitute(X,Y,[X1|Xs],[X1|Ys]) :- X \== X1, substitute(X,Y,Xs,Ys).
```

```
choose_action(Action,State1,State2) :-
   suggest(Action,State2), legal_action(Action,State1).

choose_action(Action,State1,State2) :-
   legal_action(Action,State1).

suggest(to_place(X,Y,Z), State) :-
   member(on(X,Z),State), place(Z).

suggest(to_block(X,Y,Z), State) :-
   member(on(X,Z),State), block(Z).
```

Output:

```
?- transform([on(a,b) ,on(b,p) ,on(c,r)], [on(a,b) ,on(b,c) ,on(c,r)],
Actions).
Actions = [to_place(a, b, q), to_block(b, p, c), to_block(a, q, b)] ;
Actions = [to_place(a, b, q), to_block(b, p, c), to_place(a, q, p), to_
block(a, p, b)] ;
Actions = [to_place(a, b, q), to_block(b, p, c), to_place(a, q, p), to_
block(a, p, b)] .

?- transform([on(a,p) ,on(b,q) ,on(c,r)], [on(a,c) ,on(b,q) ,on(c,b)],
Actions).
Actions = [to_block(a, p, c), to_place(b, q, p), to_place(a, c, q), to_
block(c, r, b), to_block(a, q, c), to_place(a, c, r), to_place(c, b, q)
, to_block(a, r, c), to_place(..., ..., ...)|...] [write]
Actions = [to_block(a, p, c), to_place(b, q, p), to_place(a, c, q), to_
block(c, r, b), to_block(a, q, c), to_place(a, c, r), to_place(c, b, q)
, to_block(a, r, c), to_place(b, p, r), to_place(a, c, p), to_block(c,
q, b), to_block(a, p, c), to_place(a, c, q), to_place(c, b, p), to_bloc
k(a, q, c), to_place(b, r, q), to_place(a, c, r), to_block(c, p, b), to
_block(a, r, c)] ;
Actions = [to_block(a, p, c), to_place(b, q, p), to_place(a, c, q), to_
block(c, r, b), to_block(a, q, c), to_place(a, c, r), to_place(c, b, q)
, to_block(a, r, c), to_place(b, p, r), to_place(a, c, p), to_block(c,
q, b), to_block(a, p, c), to_place(a, c, q), to_place(c, b, p), to_bloc
k(a, q, c), to_place(b, r, q), to_place(a, c, r), to_block(c, p, b), to
_place(a, r, p), to_block(a, p, c)] ;
Actions = [to_block(a, p, c), to_place(b, q, p), to_place(a, c, q), to_
block(c, r, b), to_block(a, q, c), to_place(a, c, r), to_place(c, b, q)
, to_block(a, r, c), to_place(b, p, r), to_place(a, c, p), to_block(c,
q, b), to_block(a, p, c), to_place(a, c, q), to_place(c, b, p), to_bloc
k(a, q, c), to_place(b, r, q), to_place(a, c, r), to_block(c, p, b), to
_place(a, r, p), to_block(a, p, c)] ;
Actions = [to_block(a, p, c), to_place(b, q, p), to_place(a, c, q), to_
block(c, r, b), to_block(a, q, c), to_place(a, c, r), to_place(c, b, q)
, to_block(a, r, c), to_place(b, p, r), to_place(a, c, p), to_block(c,
q, b), to_block(a, p, c), to_place(a, c, q), to_place(c, b, p), to_bloc
k(a, q, c), to_place(b, r, q), to_place(a, c, r), to_block(c, p, b), to
_block(a, r, c)] .

?- transform([on(a,p) ,on(b,q) ,on(c,r)], [on(a,p) ,on(b,a) ,on(c,b)],
Actions).
false.
```

Problem3: Change Maker

Approach:

- I used the generate test paradigm to solve this problem.
- First I generate a list of **[penny, nickel, dime, quarter]** with each value capped at the given max number of coins.
- Then for every list, I test if **P + 5*N + 10*D + 25*Q=Amount**.
- If yes, I accept this solution and print them in order **[penny, nickel, dime, quarter].**

Code:

```
/*
Change Maker
P=1, N=5, D=10, Q=25
*/
% generate a list of numbers between M and N
range(M,N,[M|Ns]):- M<N, M1 is M+1, range(M1, N, Ns).
range(N,N,[N]).

% select
select(X, [X|Xs], Xs).
select(X, [Y|Ys], [Y|Zs]):- select(X,Ys,Zs).

% create a list
generateChangesList(MaxCoins, ChangesList):-
   range(0, MaxCoins, PennyList), select(P, PennyList, _),
   range(0, MaxCoins, NickelList), select(N, NickelList, _),
   range(0, MaxCoins, DimeList), select(D, DimeList, _),
   range(0, MaxCoins, QuarterList), select(Q, QuarterList, _),
   P+N+D+Q=<MaxCoins,
   ChangesList = [P, N, D, Q].

validateChange([P,N,D,Q|_], Amount):-
   CurrAmount is P + 5*N + 10*D + 25*Q,
   CurrAmount == Amount.

% Generate Test Paradigm for finding the changes
calculate(Amount, MaxCoins, CoinList):-
   generateChangesList(MaxCoins, CoinList),
   validateChange(CoinList, Amount).
```

Output:

```
Terminal
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?- consult("./q3.pl").
true.

?- calculate(75, 6, Change).
Change = [0, 0, 0, 3] ;
Change = [0, 0, 5, 1] ;
Change = [0, 1, 2, 2] ;
Change = [0, 3, 1, 2] ;
false.

?- calculate(100, 5, Change).
Change = [0, 0, 0, 4] ;
false.

?- calculate(10, 7, Change).
Change = [0, 0, 1, 0] ;
Change = [0, 2, 0, 0] ;
Change = [5, 1, 0, 0] ;
false.

?-
```

Problem 4: MiniSudoku

Approach:

- I used the **generate and test** paradigm to solve this problem.
- I generate a list of lists for eg: **[[0,1,3,2], [2,3,1,0], [1,2,0,3], [3,0,2,1]]** to model minisudoku. I call this list of list as grid
- I made sure that the rows are generated using **permutations** of **[0,1,2,3].** This **ensures that the rows have no repeating elements**.
- I created helper predicates: **getColumnVectors** which when given the grid and the column index, it gives that corresponding columns as a list.
- I check if all the **4 column vectors are unique**.
- I accept the grid as a sudoku if the above test passes.
- I use write/1 to print each row line by line.

Code:

```
% Sudoku
% True if a list is unique
allDiff(L) :- \+ (select(X,L,R), member(X,R)).

% index into 2D list
index2D(Grid, RowIndex, ColIndex, Element):-
   nth0(RowIndex, Grid, Row),
   nth0(ColIndex, Row, Element).

% Given a column index, get the column vector as a list
getColVector(Grid, ColIndex, ColVector):-
   index2D(Grid, 0, ColIndex, A),
   index2D(Grid, 1, ColIndex, B),
   index2D(Grid, 2, ColIndex, C),
   index2D(Grid, 3, ColIndex, D),
   ColVector = [A, B, C, D].

% generate all possible permutations of the rows
generateRow(Row):-
   permutation([0,1,2,3], Row).

% generate all possible grids
generateGrid2X2(Grid):-
   generateRow(R1),
   generateRow(R2),
   generateRow(R3),
```

```
   generateRow(R4),
   Grid = [R1, R2, R3, R4].

% test if the given grid is a valid 2X2 sudoku
testGrid(Grid):-
   getColVector(Grid, 0, A), allDiff(A),
   getColVector(Grid, 1, B), allDiff(B),
   getColVector(Grid, 2, C), allDiff(C),
   getColVector(Grid, 3, D), allDiff(D).

% solution using generate test paradigm
minisudoku:-
   generateGrid2X2(Grid), testGrid(Grid), writeGrid(Grid).

% writes a given 2D grid to console
writeGrid([R1, R2, R3, R4|_]):-
   writeRow(R1),
   writeRow(R2),
   writeRow(R3),
   writeRow(R4).

% writes a given row to the console. This is used by write grid
writeRow([A,B,C,D|_]):-
   write(A), write(" "), write(B), write(" "), write(C), write(" "),
write(D), nl.
```

Output:

```
abhijit@dwave ~/studies/logic_programming/exams/midterm (main)$
 ls
cs6374.midterm.pdf  q1.pl  q2.pl  q3.pl  q4.pl  q5.pl
abhijit@dwave ~/studies/logic_programming/exams/midterm (main)$
 swipl
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g
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?- consult("q4.pl").
true.

?- minisudoku.
0 1 2 3
1 0 3 2
2 3 0 1
3 2 1 0
true ;
0 1 2 3
1 0 3 2
2 3 1 0
3 2 0 1
true ;
0 1 2 3
1 0 3 2
3 2 0 1
2 3 1 0
true ;
0 1 2 3
1 0 3 2
3 2 1 0
2 3 0 1
true ;
0 1 2 3
1 2 3 0
2 3 0 1
3 0 1 2
true ;
0 1 2 3
1 2 3 0
3 0 1 2
2 3 0 1
true ;
0 1 2 3
1 3 0 2
2 0 3 1
3 2 1 0
true
```

Problem 5: Decimal to AnyBase

Approach:

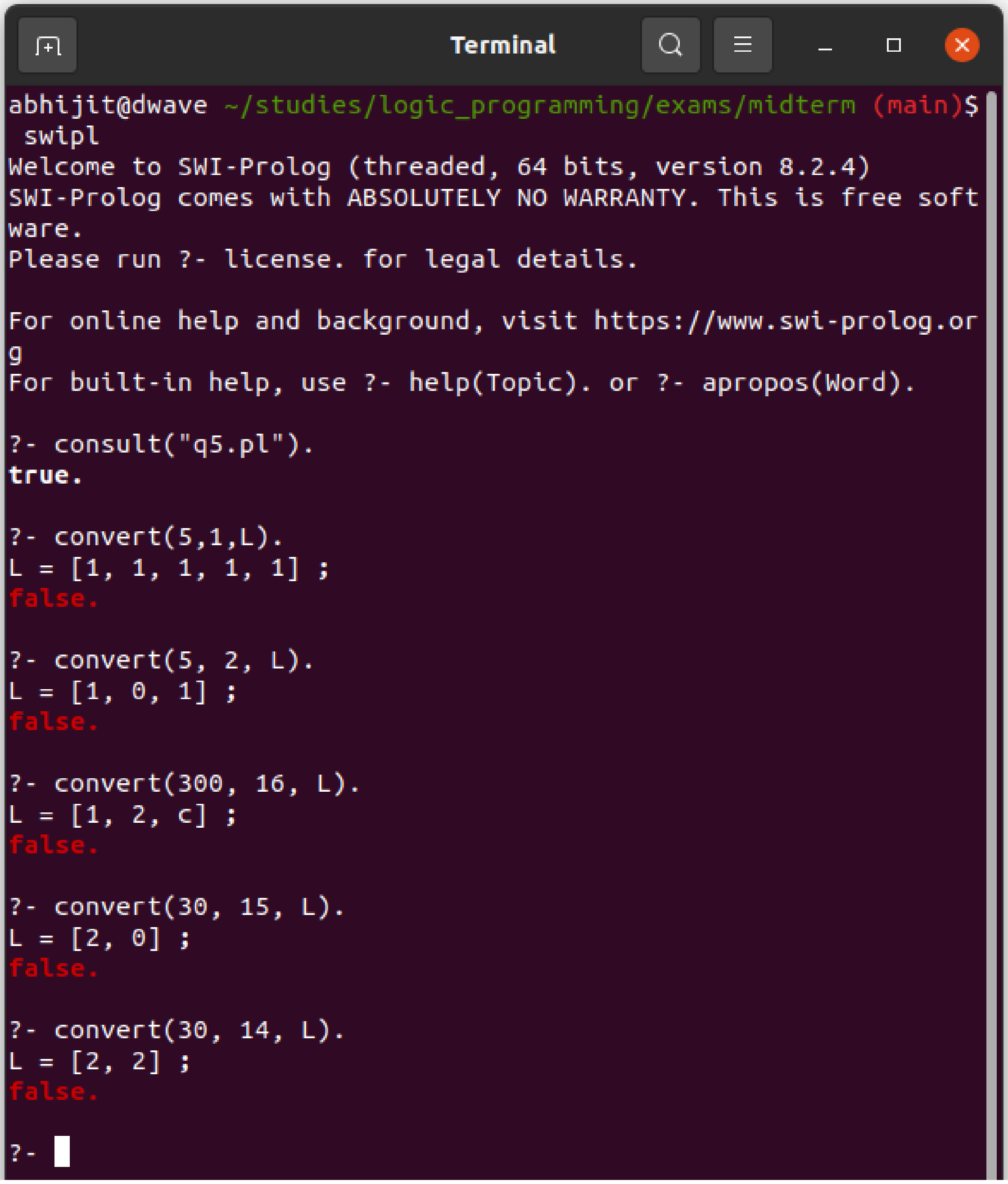
- The main **convert** predicate uses two predicates to solve the problem which are discussed below
- I separated the problem into two:
  - One predicate for Decimal to Base 1
  - Another for Decimal to Base [2,16]
- For Decimal to Base n where n in [2, 16]:
  - Remainder = Decimal Number mod Base
  - I append the Remainder to a list
  - I recurse this process using Decimal=Decimal // 2.
  - The recursion base case is when the Decimal is < Base.
  - Now I append the Decimal as such to the list
  - I reverse the list
  - This reversed list is the final answer
  - And for printing a...f instead of 10...15, I use if else predicates as shown in the code.
- For Decimal to base 1, The idea is simple. I append 1's to a list until the length of list = Decimal

Code:

```
% Decimal base conversion

% modified append to return a list when empty list is given
append([],L,[L]).
append([X|T], Y, [X|Z]) :- append(T,Y,Z).


% tail recursive rev
rev(L1, L2) :- rev(L1, [], L2).
rev([], P, P).
rev([H|T], P, R) :- rev(T, [H|P], R).


% handle base 1 separately and all other bases separately
convert(N, Base, FinalAns):- Base > 1, convertToBaseN(N, Base, [],
FinalAns).
convert(N, 1, FinalAns):- convertToBase1(N, [], FinalAns).
```

```
% handle base 1 separately
% recursive case
convertToBase1(N, CurrList, FinalAns):-
   length(CurrList, N1),
   N1<N,
   append(CurrList, 1, CurrList2),
   convertToBase1(N, CurrList2, FinalAns).
% base case
convertToBase1(N, FinalAns, FinalAns):- length(FinalAns, N1), N1 is
N.


% handle all other bases here
% recursive case
convertToBaseN(N, Base, CurrList, FinalAns):-
   N >= Base,
   N1 is N // Base,
   Value is N mod Base,
   (
   Value is 10 -> append(CurrList, 'a', CurrList2);
   Value is 11 -> append(CurrList, 'b', CurrList2);
   Value is 12 -> append(CurrList, 'c', CurrList2);
   Value is 13 -> append(CurrList, 'd', CurrList2);
   Value is 14 -> append(CurrList, 'e', CurrList2);
   Value is 16 -> append(CurrList, 'f', CurrList2);
   append(CurrList, Value, CurrList2)
   ),

   convertToBaseN(N1, Base, CurrList2, FinalAns).
% base case
convertToBaseN(N, Base, CurrList, FinalAns):- N<Base,
append(CurrList, N, Ans), rev(Ans, FinalAns).
```

Output:



```
abhijit@dwave ~/studies/logic_programming/exams/midterm (main)$
 swipl
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g
For built-in help, use ?- help(Topic). or ?- apropos(Word).

?- consult("q5.pl").
true.

?- convert(5,1,L).
L = [1, 1, 1, 1, 1] ;
false.

?- convert(5, 2, L).
L = [1, 0, 1] ;
false.

?- convert(300, 16, L).
L = [1, 2, c] ;
false.

?- convert(30, 15, L).
L = [2, 0] ;
false.

?- convert(30, 14, L).
L = [2, 2] ;
false.

?-
```