ANSWERS Fall 2021 –

1) LOGIC

A) Logical equivalence: truth table. Satisfiable.

a	b	c	¬ *a*	b→ *c*	a ∨ *c*	¬a → (b → c)	b → (a ∨ c)
T	T	T	F	T	T	T	T
T	T	F	F	F	T	T	T
T	F	T	F	T	T	T	T
T	F	F	F	T	T	T	T
F	T	T	T	T	T	T	T
F	T	F	T	F	F	F	F
F	F	T	T	T	T	T	T
F	F	F	T	T	F	T	T

B)

- A ⇔ B
- (A ⇒ B) ∧ (B ⇒ A) by biconditional elimination
- (¬A ∨ B) ∧ (¬B ∨ A) by implication elimination
- (¬A ∧ (¬B ∨ A)) ∨ (B ∧ (¬B ∨ A)) by distribution
- (¬A ∧ ¬ B) ∨ (¬A ∨ A) ∨ (B ∧ ¬ B) ∨ (B ∧ A) by distribution
- (¬A ∧ ¬ B) ∨ (B ∧ A)
- ¬(A ∨ B) ∨ (B ∧ A) by de Morgan's Law
- (A ∨ B) ⇒ (B ∧ A) by implication elimination

C) Translation -here there may be alternative correct answers.

a. ∀xy. [Niece(x,y) ⇔ ∃z (Sibling(y,z) ∧ Daughter(x,z)

b. ∃x, ∃y: (Has(Anette, x) ∧ IsUmbrella(x) ∧ Has(Anette, y) AND IsUmbrella(y) ∧ NOT(x=y))
c. ∃x Professor(x) ∧ Teaches(x,EiT) ∧ Teaches(x,AI)

D) Convert to CNF

- Eliminate Implication
  - ∀x (¬R(x) ˅ (∀y (¬R(y) ˅ R(f(x, y))) ˄ ¬ ∀y (¬S(x, y) ˅ P(y))))
- Reduce scope of negation
  - ∀x (¬R(x) ˅ (∀y (¬R(y) ˅ R(f(x, y))) ˄ ∃y (S(x, y) ˄ ¬P(y))))
- Standardize variables
  - ∀x (¬R(x) ˅ (∀y (¬R(y) ˅ R(f(x, y))) ˄ ∃z (S(x, z) ˄ ¬P(z))))
- Eliminate existential quantification
  - ∀x (¬R(x) ˅(∀y (¬R(y) ˅ R(f(x, y))) ˄(S(x, g(x,g(x,y))) ˄ ¬P(g(x,y))))
- Drop universal quantification symbols
  - ¬R(x) ˅ ((¬R(y) ˅ R(f(x, y))) ˄ (S(x, g(x,y)) ˄ ¬P(g(x,y))))

E) Resolution Refutation

- First convert all sentences to CNF form.

1) ∀*x,y* (Father (x,y) → ¬Woman(x))
2) ∀*x,y* (Mother (x,y) → Woman(x))
3) Mother(Sophie, April)

- Now, Standardize apart the variables in 1 and 2:

1. ¬Father(x,y) ˅ ¬Woman(x)
2. ¬Mother(a,b)˅ Woman(a)

- Add negative of the question:

4. Father(Sophia, Edgar)

- Start resolution:

  - Resolving 1 and 2 gives:

  5. ¬ Father (a, y) ∨ ¬Mother (a,b). [with substitution: x/a]

- Resolving 5 and 3:
  6) ¬Father(Sophie, y). [with substitution a: Sophie, b: April]
- Resolve 6 with the 4 : ¬Father(Sophie Edgar). [with substitution y: Edgar]

Ends with Empty set meaning that the Question ¬Father(Sophie Edgar) is true.

2) SEARCH

1) Breadth first search expands A, S, Z, R, F, B returns A -> S -> F -> B which is the shortest path, but not cost-optimal. This is expected because breadth first search does not consider the weights but rather returns the first solution it finds.
2) DFS expands A, S, R, P, B . Returned solution A -> S -> R -> P -> B. This solution is optimal – in terms of length of the path. DFS alg is in general not optimal ; In this case it was just the luck.
3) Uniform cost: UC operates with weights (g). Returns ASRPB which is the path with optimal cost.
4) A* search alg:
    a. They are admissible
    b. It would return A -> S -> R -> P -> B. which is cost-optimal (418). The returned solution is optimal.
    c. With h(R)=228 , which is not admissible, it would still return the same cost-optimal solution.
    d. No, 4.c does not contradicts 4.a as admissibility is necessary for the cost-optimality. However, A* algorithm may still find optimal solutions sometimes when heuristic values are not admissible. See R&N textbook (page 107) which describes under which conditions A* alg can return cost-optimal solutions with inadmissible heuristic. Here, h(R) can go up to >32 of the actual cost to the goal node where A* alg still can return cost-optimal solutions. 32 is the difference between the optimal and next-best path cost (450, ASFB)

3) CSP

1) Variables are 1,2,3,4 corresponding to the nodes of G1.
   Each variable/node may correspond to any of the nodes in G2
   D(1)= {a,b,c,d,e}

   D(2)= {a,b,c,d,e}

   D(3)= {a,b,c,d,e}

   D(44)= {a,b,c,d,e}
2) Constraints:
   C1: Global. Alldiff{1, 2, 3, 4}, each node will match a different node in G2
   C2: C(X1 X2)={1e-2a, 1a,2c, 1c-2b, 1b-2d, 1-d,2c}

C3: C(X2 X3)={ea, ac,cb,bd,dc}
C4:C(X3 X4)={ea, ac, cb, bd, dc}
C5: C(X4 X2)={ea, ac, cb, bd, dc}

3)

X1=e , and forward checking
D(X2)={a}, because of C1 and C2
D(X3)= {a,b,c,d}
D(X4)= {a,b,c,d}

X1=e, X2=a
D(X3)= {c}
D(X4)= { } backtrack

X1=d
D(X2)={c},
D(X3)= {a,b,c,e}
D(X4)= {a,b,c,e}

X1=d, X2=c
D(X3)= {b}
D(X4)= { } Backtrack

X1=c
D(X2)={b},
D(X3)= { a,b,d,e }
D(X4)= { a,b,d,e }

X1=c, X2=b

D(X3)= { d }
D(X4)
= { } Backtrack

**
X1=b
D(X2)={d},
D(X3)= { a,c,d,e }
D(X4)= { a,c,d,e }

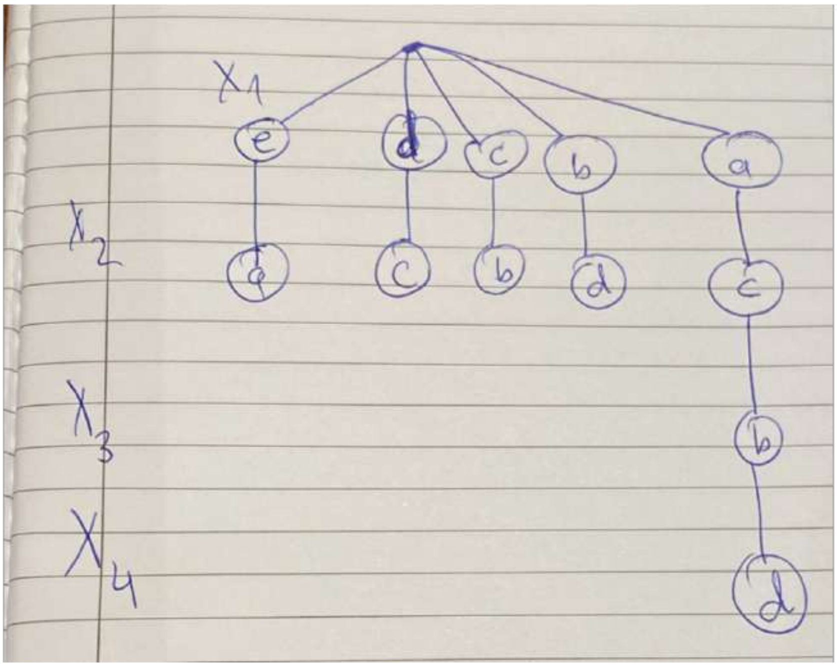
X1=b, X2=d
D(X3)= { c }
D(X4)= { } Backtrack

**
X1=a,forward checking:
D(X2)={c}, because of C1 and C2
D(X3)= {b,c,d,e}
D(X4)= {b,c,d,e}

X1=a, X2=c, FC:
D(X3)= {b}
D(X4)= {d}

X1=a, X2=c, X3=b, FC:
D(X4)={ d}

X4=d. OK



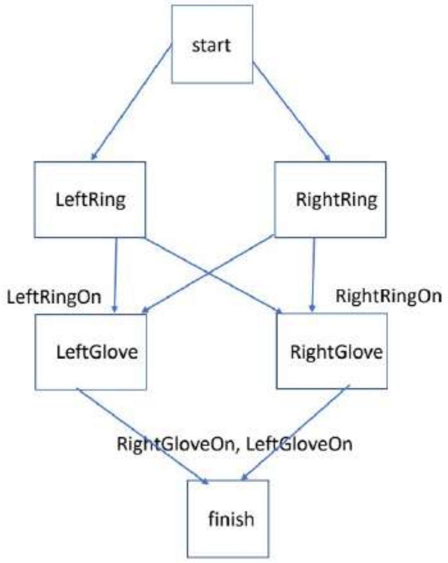
4) PLANNING

In this question there were 2 different interpretations. One is that both rings are before the gloves while the other is for each hand the ring is before the glove, i.e., left hand is finished first and then the right one. Both answers are accepted as correct.

a. PoP happens in plan-space while progressive and regressive planning methods are in state-space search. Starts with an initial plan consisting of the start and the finish states. The resultant plan is not a totally ordered, strictly sequential plan. Its key assumption is that the real world is nearly decomposable and subgoals are often independent.

b. 1. Actions with Precondition and effect components.

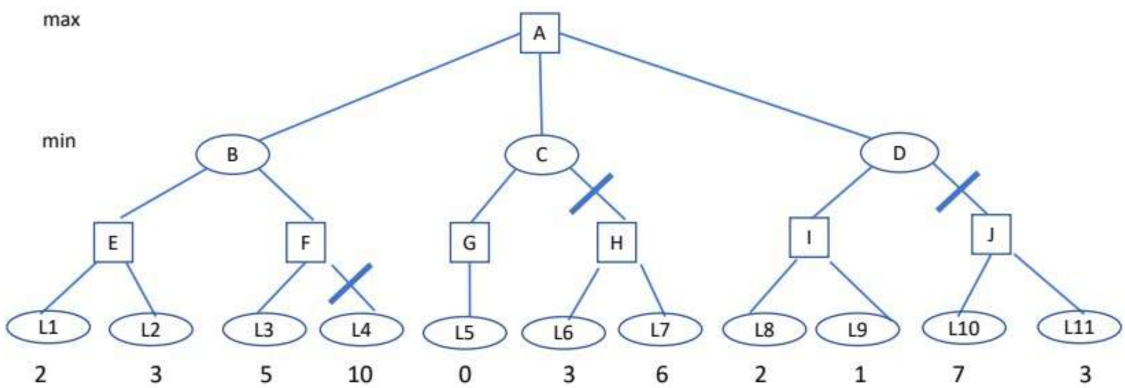
c. .



d. Plan: Start; (LeftRing, RightRing); (LeftGlove, RightGlove); Finish

5) ADVERSARIAL SEARCH

1) A= 3, B=3 , C=0 , D=2, E=3 , F=10 , G= 0, H=6 , I=2 , J=7



2) Alpha beta pruning: Prune L4 (because 5>3), H(0<3), J (2<3) pruned.

6) SHORT QUESTIONS

Here also there were different understanding of the sub-question 4 (the environment). Some students answered the environment is deterministic, some said stochastic and others it is strategic. Based on the given explanation any of these may be correct, and accepted so. I really enjoyed reading the answers to this one as well as the fairness question where most of the students collected full points because the arguments were very good and interesting. Note that the answers given below are not revised according to this note.

1) Game theory. Yes it is an instance of PD.

Canonical form of PD:

	Coop	Defect
Coop	R,R	S,T
Defect	T,S	P,P

Applies when this condition holds: $T > R > P > S$

In the question:

	Coop	Defect
Coop	4,4	-1,8
Defect	8,-1	2,2

T=8
R=4
P=2
S=-1

2) Atomic, factored and structured representation. See R&N textbook p.216-17. Examples are also there.

3) Fairness for example as a part of the objective function. Accuracy and fairness may contradict though. Some kind of trade-off should be found there- this is outside the scope of our course.

4) Environment is stochastic. By definition, if stochasticity is due to other agents, then the environment is called strategic. It depends on whether birds are defined/designed as agents or are part of the nature.