CS 6601 Midterm – Fall 2021

Please read the following instructions thoroughly.

Fill out this PDF form and submit it on **Gradescope**. Remember to also submit on Canvas. **You will be penalized 5 points on this exam if you don't submit on both the platforms.**

You have unlimited resubmissions until the deadline. You can: **(a)** type directly into the form – we highly recommend using Adobe Reader DC (or Master PDF on Linux). Other programs may **not** save your answers (**very important**), so **please keep a backup**; or **(b)** print, hand-write & scan. You can combine the methods as well.

Submit only a single PDF – no phone pictures, please! (You may use an app like CamScanner or Office Lens if you do not have scanner access.) Do not add pages unless absolutely necessary; if you do, please add them at the end of the exam **only**, and clearly label **both** the extra page and the original question page. Submit **ALL** pages of the exam, not only the completed ones.

Do not forget to fill the checklist at the end before turning in the exam. The exam may not be graded if it is left blank.

The exam is open-book, open-note, open video lectures, with no time limit aside from the open period. No internet use is allowed, except for e-text versions of the textbook, this semester's CS6601 course materials, Piazza, and any links provided in the PDF itself. No resources outside this semester's 6601 class should be used. Do not discuss the exam on Piazza, Slack, or any other form of communication. More generally, do not post **publicly** about the exam. If there is a question for the teaching staff, **please make it private on Piazza and tag it as Midterm Exam with the question number in the subject line** (for example, a question on Search would be "Midterm Exam #2"). Please make **different posts for different questions.**

Please round all your final answers to 6 decimal places, don't round intermediate results. You can use `round(your_number, 6)` function in Python for help.
You may not receive full credit if your answers are not given to the specified precision.

Point breakdown (Each question has sub-parts with varying points):

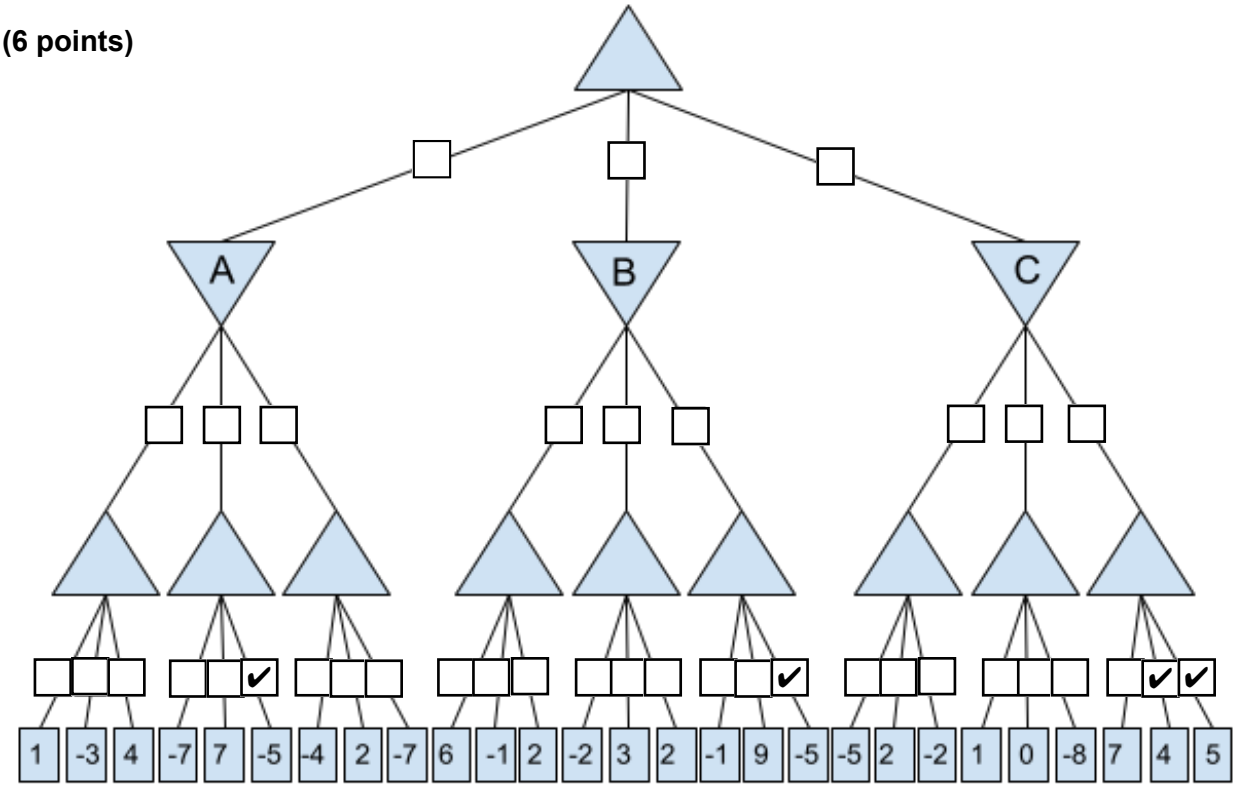
	Q1	Q2	Q3	Q4	Q5	Q6	Total
Pts	**16**	**20**	**14**	**16**	**18**	**16**	**100**

1. Game Playing

(16 points)

Part A

(6 points)



With the minimax tree given above, answer the following questions:

Q1.A.1 Mark all branches that are to be pruned using alpha-beta pruning and give the number of branches that were pruned below: **(4 points)**
NOTE: If one branch is pruned, all the sub branches would be pruned as well. For example, if the whole branch C connected to the root node is pruned, then a total of 1 + 3 + 9 = 13 branches would be counted as pruned

4

Q1.A.2 Which of the branches will be chosen by the root node to maximize the score? If there is a tie, the preference is given to A, then B, then C. **(2 points)**

- (•) A
- ( ) B
- ( ) C

Part B

(10 points)

A game will have the following rules:

There will be two players A and B with each player holding an initial balance of 50 points. The game will be played for **2** rounds where in each round, either A or B will be making a choice between the following two options:

a. Gain 50 points
b. Steal 80 percent of the opponent's balance with a success rate of 40 percent, and add the stolen balance to own balance

Alice and Bob are playing the game, where the order of players to make choices is specified as:

1st Round: Alice will make a choice
2nd Round: Bob will make a choice

For the following questions, use your knowledge of expectimax and assume that the strategies of Alice and Bob are public.

Assuming both Alice and Bob would like to maximize the difference of their own balances to that of the opponent's, and they will try to play optimally:

Q1.B.1 What is the best option for Alice to choose for round 1? **(4 points)**

- (•) Option a
- (•) Option b
- ( ) Both options would lead to the optimal result

Q1.B.2 What is the expected difference between the balance of Alice and the balance of Bob (i.e. expected value of *balance(A)* - *balance(B))* at the end of the game? Please follow the guideline when rounding your result. **(6 points)**

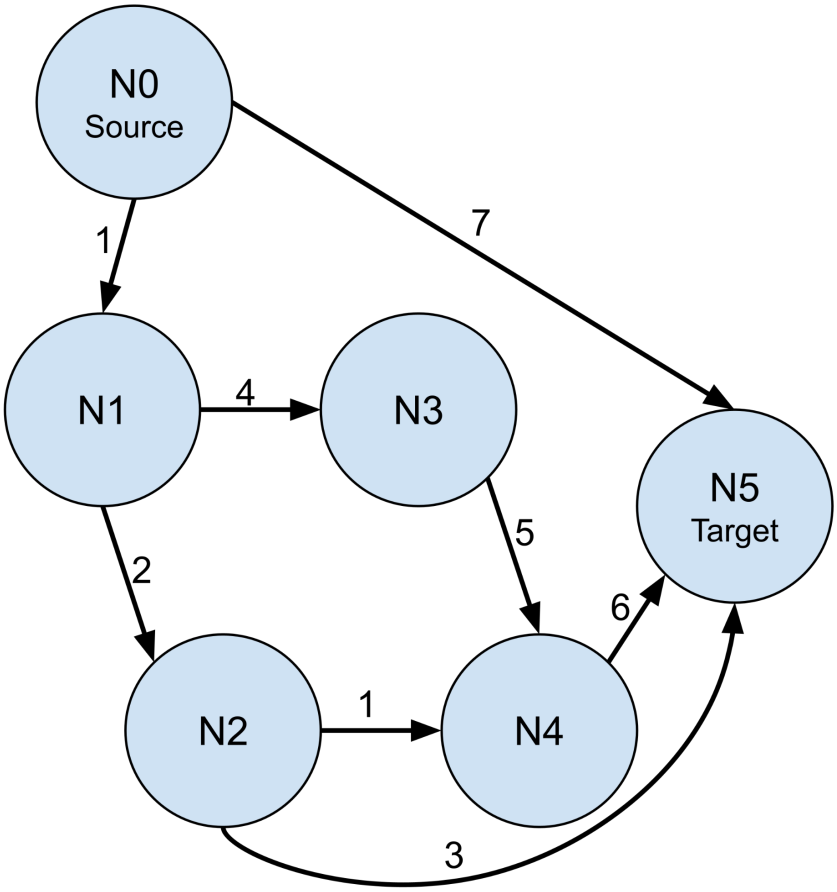
-14

2. Search

(20 points)

Part A: Search Algorithms

(11 points)



Consider the graph above. We are interested in searching for a path from the ‘source’ node (N0) to the ‘target’ node (N5). The edges in the graph are directed and weighted, which means you can only move along the direction of an edge. Edge weights can only take real positive values. While executing the search algorithm(s) in questions 1-2, break any ties in ascending order of the node numbering provided (for example if choosing between N1 and N2, choose N1 because 1 goes before 2). Note that we always start the search from the source node (N0).

Q2.A.1 What is the total path cost (sum of all the edge weights from source to target node) of the path obtained from **Breadth-First Search (BFS)**? Fill in the below blank with the total path cost obtained. **(5 points)**

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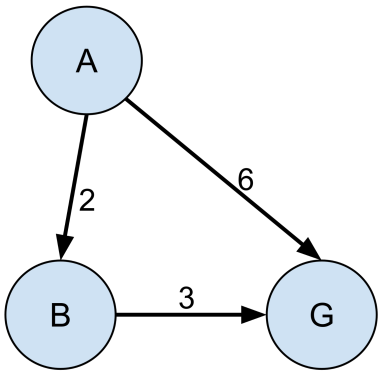
Q2.A.2 We want to modify the edge weight of edge (**N4-N5**) such that **A* graph search** would return **N0-N1-N2-N4-N5** as the source to the target path using a consistent heuristic and admissible heuristic. With these requirements, what is the longest permissible interval of edge weight for edge N4-N5?
Note: An *open interval* does not include its endpoints and is indicated with parentheses. For example, (0, 1) describes an interval greater than 0 and less than 1. A *closed interval* includes its endpoints and is denoted with square brackets. For example, [0, 1] describes an interval greater than or equal to 0 and less than or equal to 1. **(6 points)**

- (●) (0, 2)
- ( ) (0, 2]
- ( ) [2, 3)
- ( ) (2, 3)
- ( ) (0, 3)
- ( ) Such a path is not possible using A*

Part B: Heuristic functions

(9 points)

Consider a three-node directed graph shown below. G is the goal node. We define three heuristic functions f1, f2, and f3. The table shows the value that each of the heuristics functions takes corresponding to each node in the graph. For instance, a cell corresponding to f1 and A determines the value of the heuristic function f1 for node A (here the value is 3).



	A	B	G
f1	3	1	0
f2	5	5	0
f3	5	2	0

Q2.B.1 Which of the following is true for the heuristic function f1? **(3 points)**

- (●) It is admissible and consistent
- ( ) It is admissible but not consistent
- ( ) It is not admissible but consistent
- ( ) It is neither admissible nor consistent
- ( ) Cannot determine with the given information

Q2.B.2 Which of the following is true for the heuristic function f2? **(3 points)**

- ( ) It is admissible and consistent
- ( ) It is admissible but not consistent
- ( ) It is not admissible but consistent
- (●) It is neither admissible nor consistent
- ( ) Cannot determine with the given information

Q2.B.3 Which of the following is true for the heuristic function f3? **(3 points)**

- ○ It is admissible and consistent
- ◉ It is admissible but not consistent
- ○ It is not admissible but consistent
- ○ It is neither admissible nor consistent
- ○ Cannot determine with the given information

3. Genetic Algorithms

(14 points)

Note: No partial credit will be allowed for this question. Please note that a partial solution has been provided to you in Q3, such that it can be used to verify your computations.

Secret Encryption

Assume you are running a company for message encryption. You are given a certain kind of text message from your clients, and your job is to encrypt the given messages by using the secret encryption function of your company. The text message is divided into 4 parts, A, B, C, and D. Your task here is to discover how many rounds of the secret encryption function you apply to the text will give you the best security level.

Example individual:

{3, 2, 4, 2}	You are doing 3, 2, 4, and 2 rounds on A, B, C, and D respectively

The security level is described as Fitness Function:

$$Fitness(text) = A^2 + 2B + C \times D$$

A, B, C, D are the number of rounds of encryption on the 4 parts of the text message.

Suppose we have the following 4 individuals with the corresponding fitness values:

Individual	Fitness Score
{1, 5, 6, 2}	23
{4, 1, 7, 3}	39
{3, 2, 1, 6}	19
{2, 5, 4, 7}	42

Crossover

In order for a genetic algorithm to generate offspring from the existing population, a procedure must be defined to ‘mate’ members together to form new ones. We use an operation called crossover and define it as follows:

$Child_1 = \{A_1, B_1, C_2, D_2\}$
$Child_2 = \{A_2, B_2, C_1, D_1\}$

Q3.1 Using the initial population, perform the crossover procedure defined above on the pair of individuals that have the best fitness (highest and second-highest) and on the other pair of individuals (lowest and second-lowest). Sort the resultant children in decreasing order of fitness, and add them to the table. We have filled out two cells for you, to help you check your math. **(7 points)**

Rank	Individual	Fitness Score
1	{4,1,4,7}	46
2	{2,5,7,3}	**35**
3	**{3, 2, 6, 2}**	25
4	{1,5,1,6}	17

Genetic algorithms rely on mutation procedures to introduce some diversity in the population and to continually produce different solutions. In order to introduce new characteristics into a population, the crossover operation is often not enough. Thus, we need to 'mutate' children in a small but potentially impactful manner to traverse our search space efficiently. This method allows children to have characteristics that their parents do not have, and in this way the population as a whole avoids homogeneity.

Assume we are given an array for each child, and the mutation is defined as follows:

[X, x], mutate the X part of the individual to x round(s).

For example:

Individual	Mutation Array	Mutated # of round
{3, 2, 4, 2}	[A, 4]	{**4**, 2, 4, 2}

Q3.2 Using the resultant children from Question 1, calculate the fitness scores of the children after mutation. Note that child #1, #2, #3, and #4 are exactly the same as question 1, you don't have to reorder them based on the fitness score. **(5 points)**

Rank (Q1)	Mutation Array	(Mutated) Individual	New Fitness Score
1	[C, 1]		25
2	[B, 6]		
3	[A, 4]		
4	[D, 4]		15

Q3.3 Select the top 4 individuals for the next generation of the genetic algorithm (after crossover and mutation) and sort them in decreasing fitness order. **(2 points)**

Rank	Individual	New Fitness Score
1		
2		**37**
3		**35**
4	**{4, 2, 6, 2}**	

4. Constraint Satisfaction

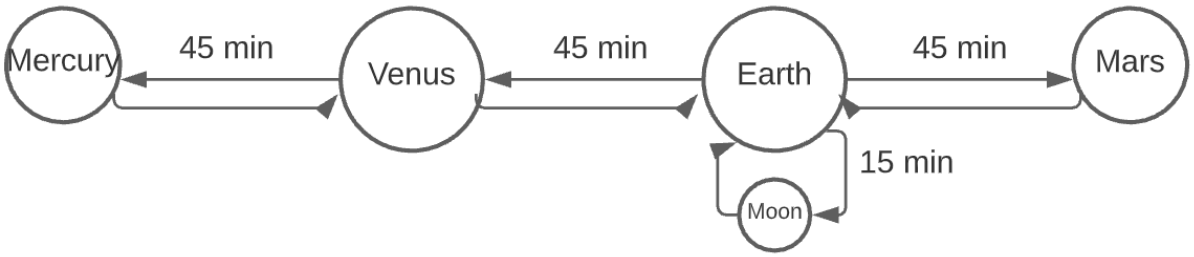
(16 points)

This is the year 2222. You have been employed as an interstellar delivery manager. Your job is to oversee an automatic delivery system that delivers goods to different planets in the solar system. You begin each day on Earth. Your orders today are:

Location	Goods	Weight
Mercury	Ice cream from Earth	5 lbs
Venus	Metals from Mars	200 lbs
the Moon	The newest edition of Artificial Intelligence A Modern Approach from Earth	10 lbs
Earth	Moon Crystals	250 lbs
Mars	Domino's Pizza from Earth	10 lbs

Usually these goods are delivered by robots. However, there are a few things to consider when scheduling the delivery task:

1. Sending robots for interstellar affairs is considered offensive in Martian culture so you'd have to deliver the goods to Mars in person. Due to safety concerns, the automatic delivery system has to be put on pause when you are away from the control center on Earth.
2. Mercury is the closest planet to the Sun and is therefore the hottest, so the Mercurians are crazy for ice cream from Earth. However, because it's the hottest planet and the farthest terrestrial planet from Earth, it's imperative that you deliver the ice cream as soon as possible before it melts. The ice cream melts in 1.5 hours after leaving its manufacturing facility on Earth.
3. The Mercurians will give you a tip if their ice cream is delivered first thing in the day.
4. You can't wait too long before you deliver pizza. Martians have high standards when it comes to interstellar etiquette. In the Interstellar Peace Contract with Earth, Martians have agreed to never attack Earth for human brains and to eat pizzas instead of human brains as long as Earth supplies them with good quality pizzas. If you deliver cold pizza, they might get angry and eat your brain as a side. The pizza gets cold in 45 minutes after leaving the oven.
5. The delivery spacecraft can only hold up to 300 lbs when entering or leaving Earth's atmosphere. And you weigh 160 lbs. But the delivery craft is part of the automatic delivery system and normally runs on autopilot.
6. Currently, you have 2 delivery craft running in the entire delivery system.



The figure above shows the route map of the delivery system. The time it takes to go from Earth to Mercury is the time it takes to go from Earth to Venus + the time it takes to go from Venus to Mercury. You don't need to take into account the time you spend dropping off and picking up goods between deliveries.

You need to figure out a schedule for delivering the goods, and you want to finish delivering the goods as fast as possible (use as few runs as possible and use as many early runs as possible).

delivery run1
delivery run2
delivery run3
delivery run4
delivery run5

The delivery run number represents the order in which you are going to be on the run to deliver the goods. Goods scheduled at delivery run1 will be on route before goods scheduled at delivery run2 and so on. For example, if you want spacecraft1 to deliver goods to Mercury(takes 90 minutes) and want spacecraft2 to delivery goods to the Mars(takes 45 minutes) and then deliver goods from Mars to Earth(takes another 45 minutes), you should assign delivery run1 to Mercury and Mars, and assign delivery run2 to Earth even though the delivery to Mercury will be finished at the same time as the delivery to Earth.

The set of variables is {Mercury, Venus, Moon, Earth, Mars} where the name of the variable indicates the destination to which the order needs to be delivered, and the set of domains is {run1, run2, run3, run4, run5} for each variable.

*Every variable needs a run, but not every run has to be assigned to a variable. There are 2 delivery spacecraft, both capable of running on autopilot so up to 2 orders can be delivered during the same delivery run. In other words, since there are only 2 spacecraft, a maximum of 2 variables can be assigned the same delivery run number. You need to pick up the goods before you can deliver them.

Q4.1 Which ones of the following are preference constraints? Check all that apply. **(3 points)**

- [ ] Mercury = run1
- [ ] Moon < Earth
- [ ] Mars < Venus
- [ ] None of the Above

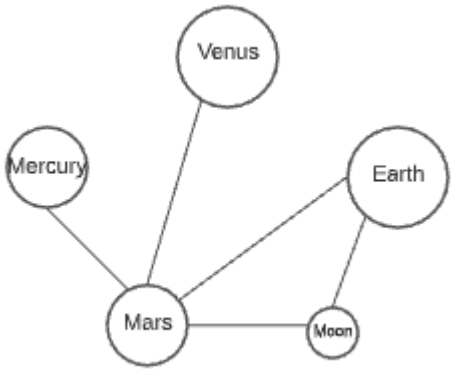
Q4.2 Which ones of the following are binary constraints? Check all that apply. **(3 points)**

- [ ] Mars ≠ Venus, Earth, Mercury, Moon
- [ ] Moon < Earth
- [ ] Mercury = run1
- [ ] None of the Above

Q4.3 What kind of constraint is constraint 6 (having only 2 spacecraft in the delivery system)? **(1.5 points)**

- ◯ global constraint
- ◯ resource constraint
- ◯ unary constraint
- ◯ binary constraint
- ◯ preference constraint

Q4.4 The constraint graph below represents the following constraints: Mars < Venus, Mars ≠ Venus, Earth, Mercury, Moon, and Moon < Earth. **(3 points)**



Using the degree heuristic, what's the order in which you should try to assign values to the variables in order to reduce the branching factor in the search tree? If there's a tie between two variables, use alphabetical ordering. Separate the variable names with commas.

Q4.5 Find a consistent and complete solution to this scheduling problem. **(5.5 points)**

Variable	Delivery Run number
Mercury	
Venus	
the Moon	
Earth	
Mars	

5. Probability

(18 points)

In a popular TV series, there are superheroes (also called supes) who are created by injecting a gene-modifying serum called Compound_V when they are infants. Now, imagine if there are some supes in the show, who got their powers not from Compound_V but because they were part-aliens. They can still be injected with Compound_V, but the source of their power would either be Compound_V or their alien genes.

Let us assume the people who inject Compound_V into people are not aware of whether the infant has alien genes or not. So, having alien genes is **independent** of injection of Compound_V.

The lead character Starlight is a supe. In this question, we will investigate the source of their superpower.

We know that 20% of the population has been injected with Compound_V at birth, and 10% of the population has alien genes.

We also know the following from our study of superheroes:
If a person with alien genes is injected with Compound_V, they have superpowers for sure. If a person without alien genes is injected with Compound_V, half of such people get superpowers. Seven out of ten people with alien genes exhibit superpowers when they are not injected with Compound_V. A person without alien genes cannot have superpowers if not injected with Compound_V

Let us denote the probability of being a supe as P(S). '~' symbol denotes negation.

Q5.1 Fill in the blanks: **(2.5 points)**

P(injection of compound_V) = P(V) = 0.2
P(alien genes) = P(A) = 0.1
P(S|V,A) = 1.0
P(S|~V,A) = 0.7
P(S|V,~A) = 0.5
P(S|~V,~A)= 0.0

Q5.2 Given that a person is a supe, is having alien genes independent of having been injected with Compound_V? (Yes/No) **(1 point)**

No

Q5.3 Without the knowledge of whether the person is a supe, calculate the probability of having alien genes given that you are injected with Compound_V, i.e., **(1 point)**

P(A|V) = 0.02

Q5.4 Calculate the probability that Starlight (a supe) was injected with Compound_V. **(5.5 points)**

0.6627

Q5.5 A close friend of Starlight told you that Starlight has no aliens in their family tree. If you completely believe Starlight's friend, calculate the probability that Starlight (a supe) was injected with Compound_V. **(4.5 points)**

1.0

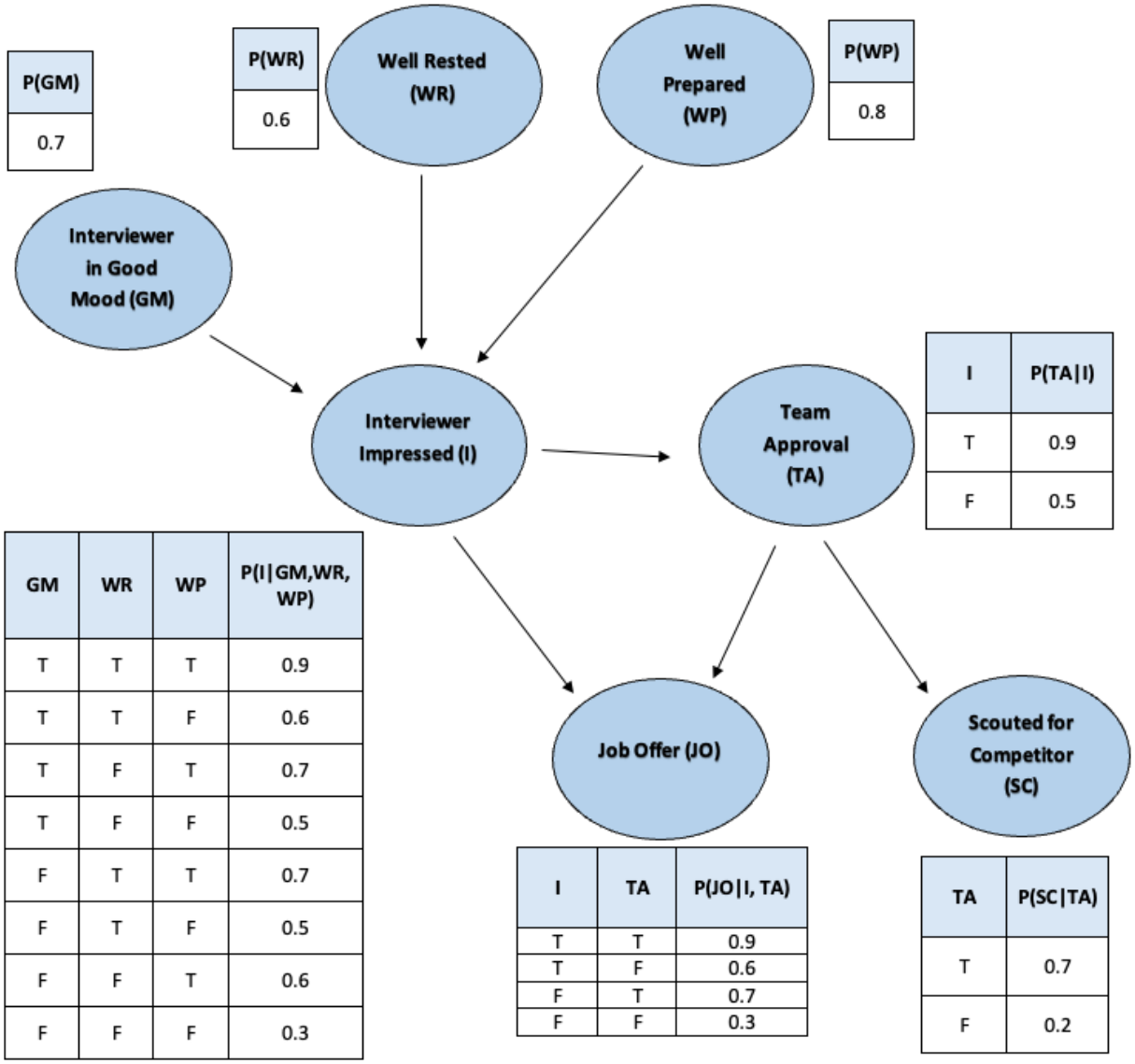
Q5.6 Sceptical of Starlight's friend, you decide to hire a private investigator to look into the matter, and you find that one of Starlight's grandparents was an alien. So, Starlight has alien genes. With this new knowledge about Starlight, calculate the probability that Starlight was injected with Compound_V. **(3.5 points)**

0.2631

6. Bayes Nets

(16 points)

You have applied to an up-and-coming startup in hopes of receiving a nice job offer after working tirelessly at GT for the last few years. You know that if you are well rested and prepared, you are more likely to impress your interviewer. You also know, however, that your chances to impress the interviewer also vary depending on how the interviewer is feeling on the day of your interview. The team that you applied to will do an inspection of your background and qualifications and will also take into account the interviewer's feedback on your interview to determine their approval. Both the interviewer and the team will have a say into whether you receive the job or not. Additionally, there are some members of the team you applied to that plan on leaving the company and creating their own rival startup. If you impress these team members, they may offer you a position at their new company. The following Bayes Net and probability tables outline this situation.



P(GM)
0.7

P(WR)
0.6

P(WP)
0.8

I	P(TA|I)
T	0.9
F	0.5

GM	WR	WP	P(I|GM,WR, WP)
T	T	T	0.9
T	T	F	0.6
T	F	T	0.7
T	F	F	0.5
F	T	T	0.7
F	T	F	0.5
F	F	T	0.6
F	F	F	0.3

I	TA	P(JO|I, TA)
T	T	0.9
T	F	0.6
F	T	0.7
F	F	0.3

TA	P(SC|TA)
T	0.7
F	0.2

Using the Bayes Net and probability tables given, calculate the following probabilities. Please follow the exam rounding guidelines.

Q6.1 What is the probability the interviewer will be impressed given you are well rested and well prepared, P(I|WR, WP)? **(2 points)**

_____

Provide brief reasoning for your answer to Q6.1

Q6.2 What is the probability you will be scouted for the competitor given you have been offered a job and impressed the interviewer, P(SC|I, JO)? **(3.5 points)**

Provide brief reasoning for your answer to Q6.2

Q6.3 What is the probability that the team does not approve given you are well prepared and well rested, P(¬TA|WP, WR)? **(6 points)**

Provide brief reasoning for your answer to Q6.3

Q6.4 Which of the following are true? Mark all that apply. (Independence is represented as in the format in this example: A $\perp$ B | C implies that A is independent of B given C). **(4.5 points)**

- ☐ JO $\perp$ WR | TA
- ☐ GM is in the Markov Blanket of WP.
- ☐ P(JO|I) = P(JO|¬I)
- ☐ SC $\perp$ WP | I
- ☐ P(TA|I, GM) = P(TA|I)
- ☐ SC in the Markov Blanket of I.

Checklist

And now mark the checklist below making sure you have taken care of each of the points mentioned:

- ☐ I have read the pinned Piazza post with the title Final Exam Clarifications Thread', and I am familiar with all of the clarifications made by the Teaching staff.
- ☐ All answers with more than 6 digits after the decimal point have been rounded to 6 decimal places.
- ☐ All pages are being uploaded in the correct order that they were presented to me, and none of the pages are missing/removed.
- ☐ Any extra pages **(including blanks)** are only attached at the END of this exam, after page 61 with clear pointers to wherever the actual answer is in the PDF (reference properly).
- ☐ I am submitting only one PDF and nothing else (no docx, doc, etc.).
- ☐ The PDF I am submitting is not blank (unless I want it to be).
- ☐ **I will go over the uploaded pictures on Gradescope and make sure that all the answers are clearly visible. I acknowledge that I am aware that dull / illegible / uneven scans will not be graded.**
- ☐ I have submitted a copy of the PDF to Canvas.