Name _____

COMPSCI 348 **Practice Exam 3 Answer Sheet (v.2)** Spring 2019

Instructions (for the actual exam)

- *Do not open the exam until directed to by the instructor or TA*
- *Do not use books, notes, electronic devices, or other aids.*
- *Please avoid wrinkling the exam because that makes it difficult to scan.*
- *Your answers must be your own, so keep your eyes on your exam. Do not look at other students' exams.*
- *Answer each question. Note the point values and allocate your time accordingly.*
- *Be clear in marking your answers, and please place your answers in the designated spaces.*
- *Only the final answer in the designated space will be graded. However, other markings and calculations will be reviewed in support of regrade requests.*

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1. **Goals of data science** — For each statement below, mark it either True or False by filling in the appropriate circle. (10 points)

True	False	Question
○	●	Methods that model univariate probability distributions are primarily used for predictive analytics.
●	○	Methods for causal modeling are primary used for prescriptive analytics.
○	●	To perform well at predictive analytics, it is usually necessary for a model to accurately represent the internal structure of the underlying data generating process (DGP).
○	●	Simple Bayesian classifiers are often used for causal modeling.
●	○	Methods for exploratory data analysis and visualization are typically used in descriptive analytics.

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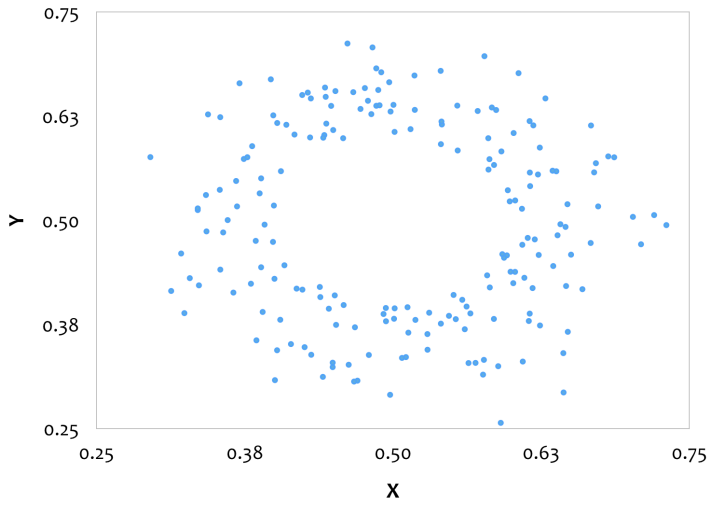
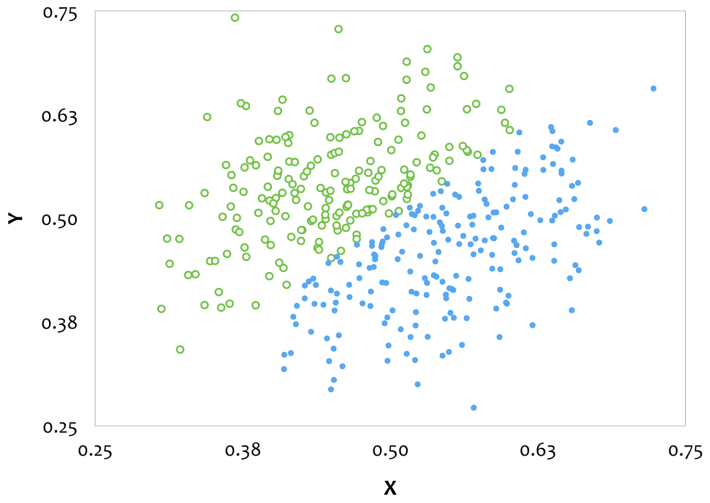
2. Independence and dependence — Answer each question below.

a. Below is a scatterplot of data instances sampled from the joint distribution of two variables, X and Y. The horizontal and vertical axes show the values of X and Y, respectively. State in words how you would determine whether X and Y are marginally independent. (5 points)



X and Y are dependent. How can you tell? If X and Y are independent, then knowing the value of X should tell me nothing about the probability distribution of Y. However (for example), different values of X appear to produce very different distributions of Y. If X=0.5, then the distribution of Y is "bimodal" (with two dense regions near 0.35 and 0.65). If X=0.35, then the distribution of Y is unimodal (with a single dense region near 0.5).

b. Below is a scatterplot of data instances sampled from the joint distribution of three variables, X, Y, and Z. The horizontal and vertical axes show the values of X and Y, respectively. The value of a third variable, Z, is shown as the symbol and color of the plotted point. State in words how you would determine whether X and Y are conditionally independent given Z. (5 points)



X and Y are marginally independent, but conditionally dependent. How can you tell? If X and Y are conditionally independent, then knowing the value of X should tell me nothing about the probability distribution of Y for any given value of Z. However (for example), different values of X appear to produce very different distributions of Y, given Z (green unfilled points). This is not the case if you ignore Z.

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3. **Assumptions** — In your own words, briefly define each of the assumptions below. (10 points)

   a. Causal Markov assumption

   Every variable in a causal graphical model is conditionally independent of its non-descendants given its parents.

   b. Causal sufficiency

   Every common cause of two or more a variables in model is also included in the model.

   c. Faithfulness

   If a conditional independence statement is true of a probability distribution generated by a causal structure, it is entailed by the causal structure and not just for particular parameter values.

   d. Positivity

   All possible treatments X are observed for all possible situations (values of the covariates Z).

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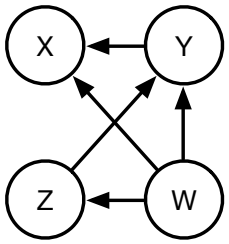
4. Semantics of Bayesian networks — Answer each question below.

a. For the Bayesian network at right, use probability notation to write the equation for the joint probability distribution as a product of conditional distributions. (4 points)



$$P(X,Y,Z,W) = \prod P(X|Y,W)P(Y|Z,W)P(Z|W)P(W)$$

b. Can two Bayesian networks with different structure represent the same joint probability distribution? Say "yes" or "no" and briefly describe why or why not. (2 points)

Yes. Networks with the same edges, but different direction, can represent the same joint probability distribution. That is the basis of Markov equivalence classes.

c. Can a graph with N variables (nodes) and N^2 dependencies (edges) be a valid Bayesian network? Say "yes" or "no" and briefly explain why or why not. (4 points)

No. The maximum number of possible edges in a valid Bayesian network would be a single edge connecting each pair of variables, and this corresponds to N(N-1)/2 edges. A larger number of edges implies that multiple edges join the same pair of variables. This either implies a cycle or multiple edges in the same direction, neither of which is a valid Bayesian network.

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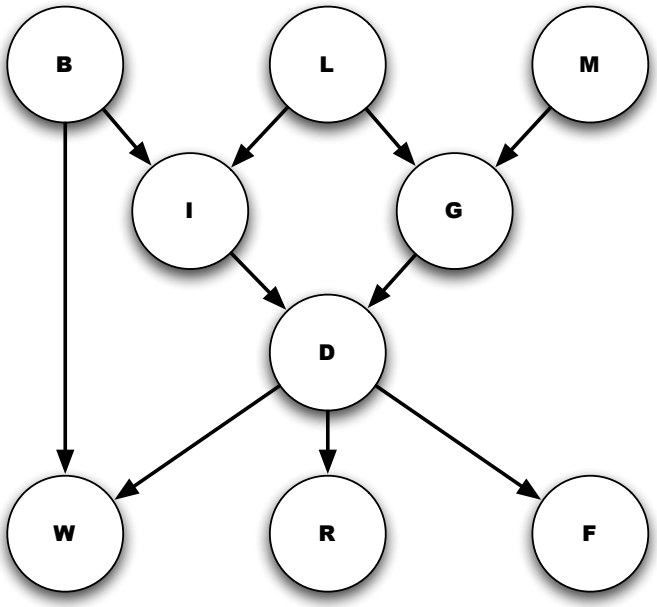
5. **Bayesian networks** — Draw the graphical structure of the Bayesian network that represents the full joint distribution P(D,R,F,W,G,I,M,B,L) corresponding to the situation described below. (10 points)

   "Ghoulisitis is a disease (D) that can cause your eyes to turn red (R), your hair to fall out (F), and your skin to turn pasty white (W). The disease has both a genetic component (G) and an infectious component (I). Persons afflicted with the disease usually have a single recessive gene, inherited from their mother's genome (M), and they have suffered an infectious bite of a ghoul-rat (B). Initially, epidemiologists studying ghoulisitis were baffled by many cases of genetically susceptible individuals being bitten by ghoul-rats and not contracting the disease. However, recent research has revealed one additional influence on disease transmission, rat-bites that occur under the light of a full moon (L) help activate the ghoulisitis gene and make the rat-bite more infectious. Also, diagnosing the disease is complicated by the fact that being bitten by a ghoul-rat is so frightening that some individuals who have been bitten by one acquire a pasty white complexion even though they do not contract the disease."



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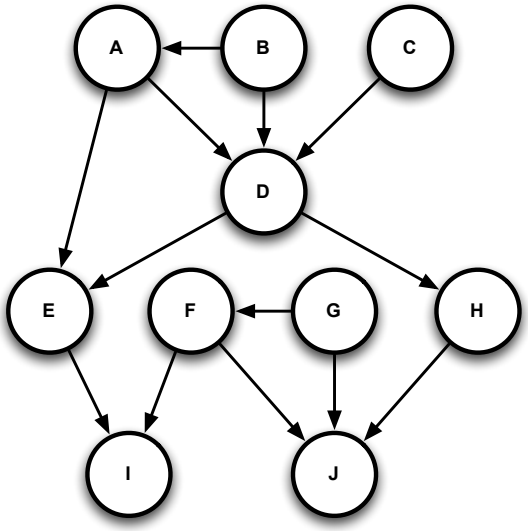
6. d-separation — In the Bayesian network below, use d-separation to decide whether X is conditionally independent of Y given Z. If X and Y are not conditionally independent, provide one d-connecting path by naming the sequence of nodes (e.g., ABD). The answer to the first query is provided. (2 points each)



X	Y	Z	X ⫫ Y | Z? (Circle one)	*d*-connecting path (if False)
A	C	{D}	True **False**	ADC
A	C	{B,D,E}	True **False**	ADC
E	J	{}	True **False**	EDHJ, EADHJ, or EABDHJ
A	H	{D,I}	**True** False	
I	J	{F,G,D}	**True** False	
A	G	{E}	**True** False	

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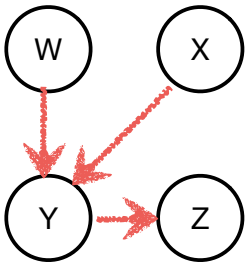
7. Inferring model structure — The conditional independence statements below provide the minimum-sized conditioning sets necessary to make any two variables in {W,X,Y,Z} conditionally independent. If no such statement is made for a given set of variables, then the variables cannot be made conditionally independent by conditioning on any set of the other variables. Use these statements to infer the structure of a graphical model consistent with the statements and draw in the directed edges between the nodes below. (10 points)

$W \perp\!\!\!\perp X$
$X \perp\!\!\!\perp Z \mid Y$
$W \perp\!\!\!\perp Z \mid Y$



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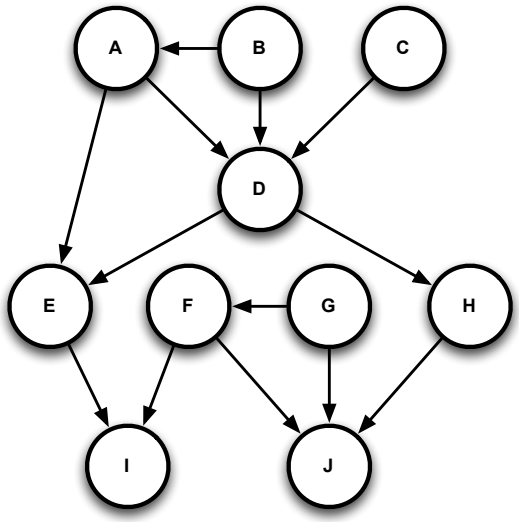
8. Causal graphical models — For the Bayesian network at right, answer each of the questions below and briefly explain your answer. (2 points each)



a. Does A cause H?

Yes. There is a causal path from A to D to H

b. Does E cause H?

No. There is no directed path from E to H.

c. Suppose that we intervene on E, then does C cause I?

No, because intervening on E deletes all incoming edges to E, and then there is no directed path from C to I.

d. Suppose that we intervene on both A and D, do the variables B and C provide us any information about the other variables in the network?

No, because intervening on A and D delete all edges from B and C, disconnecting them from all other nodes in the network.

e. Suppose we try to intervene on D, but aren't sure we have been successful. If you can collect data after the (potential) intervention, name one conditional independence test on that data that would help you verify whether your intervention has been successful.

Intervening on D should delete all incoming edges to D. Any conditional independence test that differs between the network before and after intervention will help test whether your intervention has been successful. For example:

$$C \perp\!\!\!\perp E \mid \{\}$$
$$C \perp\!\!\!\perp H \mid \{\}$$
$$B \perp\!\!\!\perp C \mid \{D\}$$
$$A \perp\!\!\!\perp C \mid \{D\}$$

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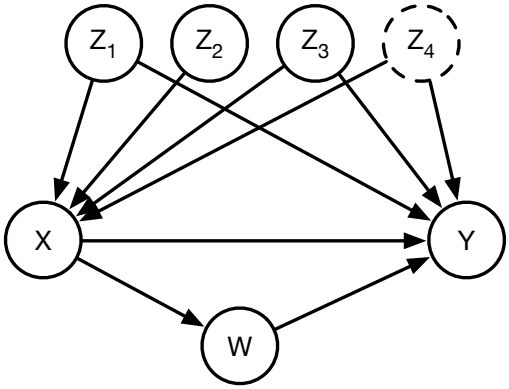
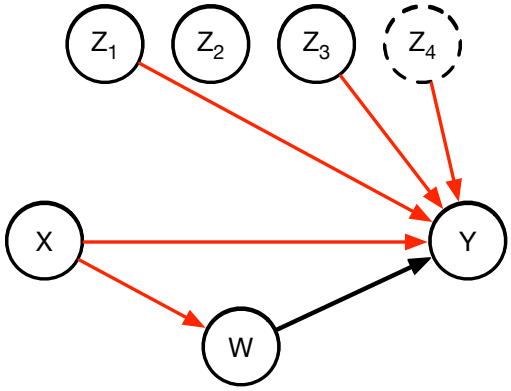
9. Experiments and quasi-experiments — Answer each question below.

a. The model in the figure below at left represents the ordinary behavior of a causal system. Assume you can perform an experiment on this system that randomly assigns the value of X. Add directed edges to figure below at right so that it represents the new causal system after random assignment of X. One valid edge (from W to Y) has already been added. (5 points)





b. Below is a brief description of an analysis that uses observational data and a propensity scores approach to determine whether consuming eggplant (E) prevents heart disease (H), given a set of possible confounding variables, including the country you were born in (C), age (A), and income (I). Fill in the missing words or letters denoting variables so that the description is complete and accurate. (5 points)

A propensity score design constructs a model that predicts the probability of ___E__ using the variables ____C, A, I_____. Then, it partitions the distribution of the __predicted probability of E or P(E)__ into categories with nearly equal values. Using these partitions, it then determines if __E__ is conditionally independent of __H__ given ___P(E)___. If it is, then E is not causal for H.

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10. Miscellaneous — For each statement below, mark it either True or False by filling in the appropriate circle. (10 points)

True	False	Question
○	●	Two variables X and Y are considered to be conditionally independent given Z if X and Y are independent for at least one value of Z.
○	●	In general, when used as a representation of the conditional probability distributions in a Bayesian network, simple Bayesian classifiers and classification trees would be equally accurate.
○	●	If two variables are d-connected in a Bayesian network, then they are guaranteed to be dependent.
○	●	A directed graphical model can be completely specified by a set of nodes (corresponding to random variables) and a set of edges (corresponding to direct causal dependence) that form a directed acyclic graph.
○	●	If X causes Y, then any manipulation of X will produce a change in the value of Y.