1. [10 points] What is a Bayesian Network (BN)? What are its advantages over a tabular representation of the joint distribution of the system variables? Explain both the representational and the computational advantages. What is a Dynamic BN (DBN)? Describe Markov Models (MMs) and Hidden Markov Models (HMMs). Pick a problem of interest in Data Science that can be modeled using HMMs. Describe the problem and the application of HMM techniques on it.

2. [10 points] What is a Weighted Constraint Satisfaction Problem (WCSP)? Pick two problems of interest in Graph Theory and explain how they can be modeled as WCSPs. Explain how the MAP query on a BN is equivalent to a WCSP. How can a WCSP on Boolean variables be translated to the Minimum Weighted Vertex Cover (MWVC) problem? In what cases can the substrate MWVC problem be solved efficiently?

3. [10 points] What is the Variable Interaction (VI) graph associated with a combinatorial problem? Explain how the Variable Elimination (VE) algorithm uses the VI graph to solve the combinatorial problem via Dynamic Programming. In this context, explain the notion of the treewidth of the VI graph. Is computing the treewidth NP-hard? In what cases is it easy?

4. [10 points] Describe the architecture of a Feed-Forward Neural Network (NN). Explain the Backpropagation (BP) algorithm used to train it. What are the key algorithmic principles used in BP? Pick a problem of interest in Data Science that can be solved efficiently using a Feed-Forward NN and BP. Describe the problem and the application of these techniques on it.

5. [10 points] What is Polynomial Identity Checking (PIC)? Describe the randomized algorithm standardly used for PIC. Pick a problem of interest in Data Science that can be solved efficiently using PIC. Describe the problem and the application of PIC on it. What are heavy-tailed distributions and where do they occur? Describe a situation where the runtime behavior of an algorithm on a combinatorial problem can exhibit a heavy-tailed distribution. In such a situation, what can be done to boost the performance of the algorithm?