CS 5060 **Name:** _____
Fall 2024
Midterm Exam
10/10/2024
Time Limit: 10/14/2024 By End of Day_____

This exam contains 3 pages (including this cover page) and 4 questions.
The total of points is 120.

This test is open notes but not open-neighbor. Please read each question carefully before deciding on an answer. A clear and concise statement or paragraph is much better than long answers with no focus on short written responses to these questions.

I have taken the liberty of organizing this as I would an assignment rather than a classical exam. I hope that you take the time to learn and understand this. I imagine this will be a moderately pleasant venture if you do so.

Mario Mercy Option: As long as you get 3 of these questions with 75%, the overall exam score will be at least 75%.

Grade Table

Question	Points	Score
1	20	
2	40	
3	20	
4	40	
Total:	120	

1. (20 points) Question 1: Algorithm Pseudocode (40 points)

   Write pseudocode to describe the following four algorithms:

   - **Optimal Stopping Problem**: Describe the process of stopping optimally to maximize the expected reward.
   - **Multi-Armed Bandit Problem**: Write pseudocode for exploring and exploiting multiple options to maximize cumulative reward.
   - **Option Valuation**: Provide pseudocode for calculating the value of a financial option, considering potential future prices.
   - **Insurance Algorithm**: Detail the pseudocode for pricing an insurance product based on probabilistic risk models.

   Each pseudocode description should include input, output, and a high-level explanation of key steps.

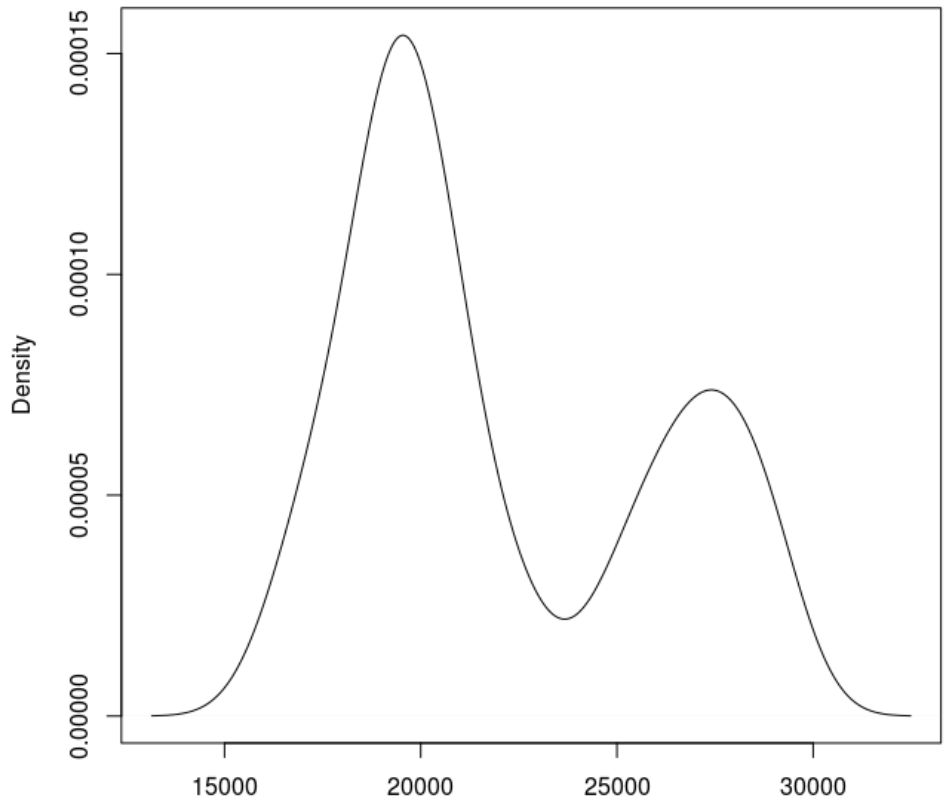

Figure 1: A distribution that is fairly common in a certain type of field we have discussed at some length in our course lectures.

2. (40 points) Question 2: Impact of Randomness on Algorithms (30 points)

   Consider how randomness affects each of the algorithms discussed in Question 1. For each algorithm, explain how the behavior changes when using different random distributions (uniform, normal, and beta with skew).

   - How would the **Optimal Stop** algorithm change with these distributions?
   - How does the **Multi-Armed Bandit** algorithm's decision-making change?
   - How does the randomness impact the **Option Valuation** algorithm?
   - How would randomness alter the performance of the **Insurance Algorithm**?

   Additionally, consider the following example of an interesting distribution (shown in Figure 1), and describe how you think it might impact these algorithms. Draw any connections between the shape of the distribution and potential algorithm behavior.

3. (20 points) Question 3: Nature of the Algorithms (20 points)

   Discuss the following properties of the algorithms:

   1. **Topology in the Optimal Stop Algorithm**: How does the state-space or topology of decisions evolve? How does this affect finding the optimal stopping point?

2. **Explore/Exploit Trade-offs in Multi-Armed Bandits**: How do different strategies (epsilon-greedy, Thompson sampling) handle the explore/exploit trade-off in various conditions?
3. **Option Valuation Model**: How do assumptions (e.g., volatility, time) change the option valuation model? What might happen under extreme assumptions?
4. **Effective Insurance Product Design**: What considerations improve the design of an insurance product? How does uncertainty and risk modeling influence pricing?

4. (40 points) Insurance: Value of Subdivision

   We are going to look at a simple insurance dataset (in the Canvas midterm module, a data file is provided named insurance.csv) where we only consider a few factors for 10,000 people:

   - age (INT age of claimant)
   - sex (BINARY As identified by the claimant)
   - bmi (FLOAT bmi of claimant, NA if not claimant that year)
   - children (INT children count per claimant, NA if not claimant that year)
   - smoker (BINARY smoking status of claimant, NA if not claimant that year)
   - region (STRING claimant regional ID, NA if not claimant that year)

   PART 1 - Calculate the basic insurance rate for this population if we are looking at zero deductible policies and we need an 11 % profit margin. What is the standard deviation and volatility of this portfolio?

   PART 2 - Calculate the tiered insurance rate (with the same 11% profit margin) for this population by breaking up the insurance product by age categories of [18-22, 23-30, 31-48, and 49+]. What is the standard deviation and volatility of this portfolio?

   PART 3 - Calculate the same in PART 2, but add sex to the calculation. Compare just using the sex parameter as compared to both age and sex.

   PART 4 - Comment on the change in risk for the portfolio and the anticipated benefits from subdividing the insurance product. Calculate what the prices would be if you could break the product into known claimants (ie: you know which people will be claimants and who will not be this year). What does the cost rise to for the annual rate on the claimants?