Instructions:
Be verbose. Explain clearly your reasoning, methods, and results in your written work.

No code is necessary, but including it in your answer could result in partial credit.

Written answers are worth 10 points per question. 10 questions total – 100 possible points.

2 extra credit problems at the end are worth 10 points each.

Total available points on this exam is 120.

1. Answers should be formatted as a PDF.
2. Restate the question along with the question number before each answer
3. When finished, email your PDF directly to me.

All work needs to be in my inbox by 8pm on 4/24.

Data for problems can be found in CSV files with this document in the class repository.

1. Why do we need risk management?
2. Use data in question2.csv.
    a. What are the first 4 moments of this data?
    b. If this represented the Profit and Loss from an investment, what would you say about its risk and reward?
3. Use data in question3.csv.
    a. This data has missing values. Calculate the pairwise correlation matrix.
    b. Is this matrix PSD?
    c. If the matrix is not PSD, use Higham 2002 to calculate the nearest PSD matrix.
4. Assume you have 3 variables

    Y_1, Y_2, X

    Each are assumed to be distributed normally.

    Further assume you have a structural model:

    $Y_1 = \alpha_1 + \beta_1 X + \epsilon_1$

    $Y_2 = \alpha_2 + \beta_2 X + \epsilon_2$

    And $\epsilon_1 \& \epsilon_2$ are assumed to be independent and normally distributed.

    Describe how you would jointly simulate $Y_1, Y_2, \& X$.

5. Assume the have the same three variables and structural model as in Question #4. However, now we assume that $\epsilon_1 \& \epsilon_2$ are independent and distributed by a generalized Student T distribution.

    Describe how you would jointly simulate $Y_1, Y_2, \& X$.

6. Assume

   - European Put, value = 7.18
   - Risk Free Rate = 2%, no dividend payment
   - Stock Price $100, Strike Price $100
   - 1 Year to maturity

   a. What is the implied volatility?

   b. Assume the stock returns are normally distributed, Expected annual return = 4%, with an annual volatility equal to the implied volatility, and 255 trading days in a year. The implied volatility does not change. A market maker has sold this option. What is her 1-day VaR and ES expressed in $ terms?

7. The market maker from question #6 wishes to hedge her position by buying or selling stock. How many shares should she buy/sell for each option she has sold?

8. Given 3 Assets, A, B, and C. The risk free rate is 0%. The correlation matrix is:

```
3×3 Matrix{Float64}:
 1.0  0.5  0.5
 0.5  1.0  0.5
 0.5  0.5  1.0
```

   Volatilities are

```
3-element Vector{Float64}:
 0.1
 0.2
 0.3
```

   Expected Returns are

```
3-element Vector{Float64}:
 0.03
 0.06
 0.09
```

   What is the maximum sharpe ratio portfolio with no constraints on negative weights?

9. Given the covariance structure in #8,

   a. if we have an equal weight on each asset (33.3…%), what is the risk contribution of each asset?

   b. What are the risk parity portfolio weights?

10. Use Data in question10.csv for assets A, B, & C, and given a starting weight of [0.55, 0.27, 0.18]

    a. Calculate the ex-post return contribution of each asset

Extra Credit. Each of these questions are worth an additional 10 points. They are completely optional.

EC1. Using the data in ec1.csv for assets A and B. This is output from a simulation of asset values.

a. Calculate the covariance of the assets. Use the expected value from the series. Assume the risk free rate is 2%. Weights must be >=-1.0. Find the maximum sharpe ratio portfolio.

   (**HINT**: Because you have 2 Assets, you can quickly sweep the potential weights to find maximum values instead of using an optimizer)

b. Using the simulated values in the CSV file, calculate the portfolio that maximizes

   $$\frac{\mu - rf}{ES}$$

   Where ES is the portfolio expected shortfall.

c. Why are these two portfolios so different?

EC2. Using the data in ec2.csv.

a. $X \sim N(\mu, \sigma)$
b. $Y_i = \alpha_i + \beta_i X + \epsilon_i \quad for\ i\ \in [1, 2]$
c. $\epsilon_i \sim T(0, \sigma_i, \nu_i)\ for\ i\ \in [1, 2]$
d. Initial price of Y1 = $10.
e. Initial price of Y2 = $50.
f. You hold a portfolio of 100 shares of both Y1 and Y2

What is the VaR and ES of the portfolio, given the information above, expressed as a $ profit and loss?