Problem 1:

1. Arithmetic Returns (Last 5 Rows):

```
                 SPY      AAPL      EQIX
Date
2024-12-27 -0.011492 -0.014678 -0.006966
2024-12-30 -0.012377 -0.014699 -0.008064
2024-12-31 -0.004603 -0.008493  0.006512
2025-01-02 -0.003422 -0.027671  0.000497
2025-01-03  0.011538 -0.003445  0.015745
SPY     0.008077
AAPL    0.013483
EQIX    0.015361
```

2. Log Returns (Last 5 Rows):

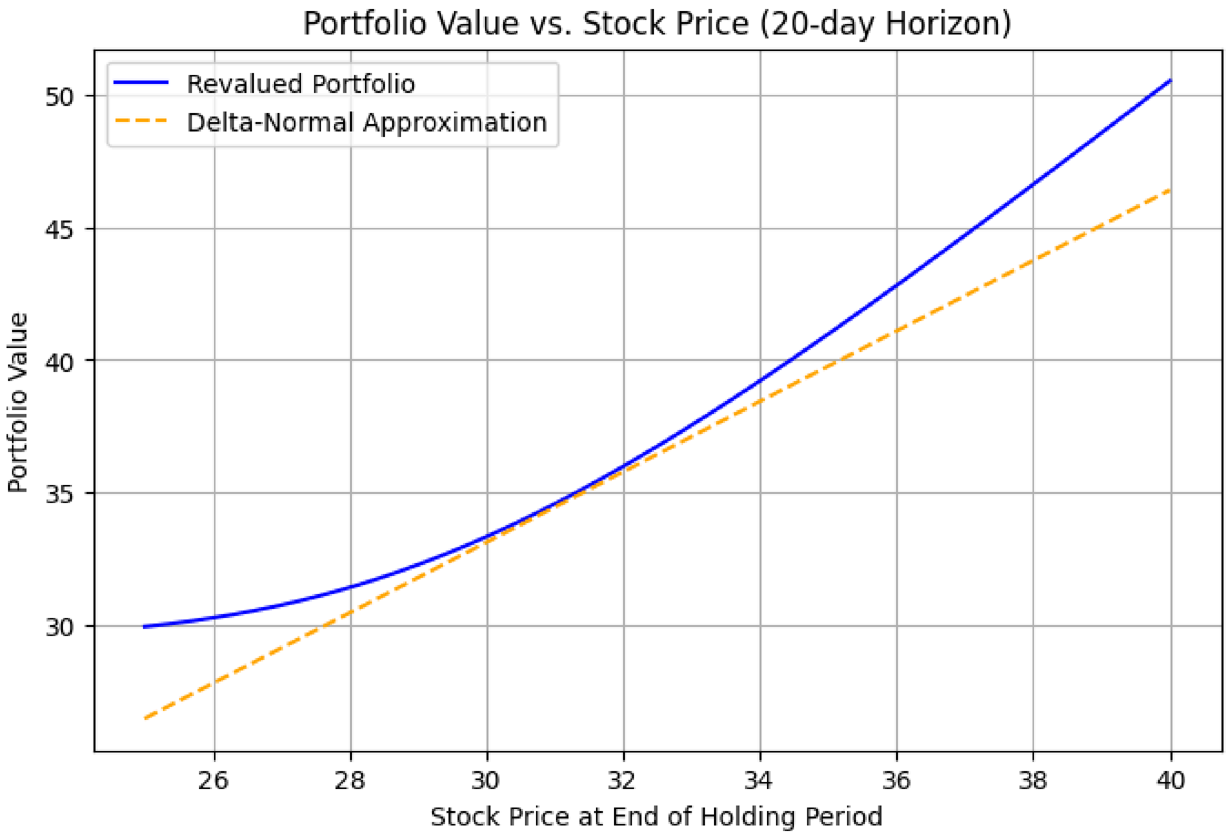
```
                 SPY      AAPL      EQIX
Date
2024-12-27 -0.011515 -0.014675 -0.006867
2024-12-30 -0.012410 -0.014696 -0.007972
2024-12-31 -0.004577 -0.008427  0.006602
2025-01-02 -0.003392 -0.027930  0.000613
2025-01-03  0.011494 -0.003356  0.015725
SPY     0.008078
AAPL    0.013446
EQIX    0.015270
```

Problem 2:

1. Current Value of Portfolio given today is 1/3/2025: $251862.50
2. VAR and ES
    a. *Method 2a (Normal EW Covariance):*
    b. VaR 5%: $3886.02
    c. ES 5%: $4873.23
    d. *Method 2b (Copula):*
    e. VaR (T-distribution with Gaussian Copula, 5%): $4379.51
    f. ES (T-distribution with Gaussian Copula, 5%): $6123.02
    g. *Method 2c (Historical):*
    h. VaR (Historical, 5%): $4575.03
    i. ES (Historical, 5%): $6059.39
3. The three VaR and ES estimation methods differ in their assumptions and risk sensitivity. Normal EW Covariance assumes normally distributed returns, making it computationally efficient but prone to underestimating extreme losses, resulting in the lowest VaR ($3,886.02) and ES ($4,873.23). T-distribution with Gaussian Copula captures fat tails and dependencies better, producing a higher VaR ($4,379.51) and the highest ES ($6,123.02), but is more complex. Historical Simulation relies on past market data, providing the highest VaR ($4,575.03) and ES ($6,059.39), though it assumes historical patterns persist. For accurate risk assessment, a combination of these methods is ideal.

Problem 3:

1. Implied Volatility: 0.3351
2. Delta: 0.6659, Vega: 5.6407, Theta: -5.5446
   Estimated Option Price Change for 1% Volatility Increase: $0.0564
3. Put Price (BSM Model): $1.2593 Put-Call Parity Difference: 0.0000; Given that the Put-Call Parity Difference is 0.0000, it confirms that the parity relationship holds exactly, as expected in a theoretically efficient market. This result indicates that the calculated put price aligns perfectly with the put-call parity condition, suggesting no arbitrage opportunities.
4. Delta–Normal Approximation: VaR(5%) = 5.5773, ES(5%) = 5.1403
5. Monte Carlo Simulation: VaR(5%) = 4.1738, ES(5%) = 4.6119



6.
7. The Delta-Normal Approximation and Monte Carlo Simulation methods differ in how they estimate Value at Risk (VaR) and Expected Shortfall (ES). The Delta-Normal method assumes that portfolio returns follow a normal distribution, using the portfolio's delta and theta to approximate risk linearly. This method is computationally efficient but ignores the nonlinearity of options, which becomes evident for larger stock price movements. In contrast, the Monte Carlo Simulation revalues the portfolio using the full Black-Scholes model, allowing it to capture convexity and path-dependent risks. As shown in the graph, the Delta-Normal approximation (orange dashed line) deviates from the actual portfolio value (blue curve) at extreme stock prices, highlighting its limitations in capturing nonlinear option behavior. The Monte Carlo approach provides a more accurate risk

estimate, as reflected in the lower VaR and ES values, since it considers the full distribution of future stock prices rather than assuming a simple normal distribution.