Problem 1:

```
Black-Scholes Greeks (Closed-form):
Delta (call): 0.0830
Delta (put): -0.9165
Gamma: 0.0168
Vega: 6.9387
Theta (call): -8.2594
Theta (put): -0.4737
Rho (call): 1.1026
Rho (put): -13.7580


Comparison of Closed-form and Finite Difference Greeks:
Delta - Finite Difference(call): 0.0830
Delta - Finite Difference(put): -0.9165
Gamma - Closed-form: 0.0168, Finite Difference: 0.0168
Vega - Closed-form: 6.9387, Finite Difference: 6.9329
Theta - Finite Difference(call): -8.0480
Theta - Finite Difference(put): -1.8621
Rho - Finite Difference(call): 1.1026
Rho - Finite Difference(put): -13.7580
```

According to the graph, we can see that Greeks of European options from closed form and finite difference are close to each other. The difference is extremely small.

```
Binomial Tree American Option Prices (with dividend):
Call Price: 0.2978
Put Price: 14.5552

Binomial Tree Greeks for American Options:
Delta (Call): 0.0857, Delta (Put): -0.9555
Gamma (Call): 0.0120, Gamma (Put): 0.0185
Theta (Call): -7.9945, Theta (Put): -2.5761
Rho (Call): 1.1136, Rho (Put): -3.0877


Dividend: 0.50, Call Price: 0.3146, Put Price: 14.2038
Dividend: 0.88, Call Price: 0.2978, Put Price: 14.5552
Dividend: 1.20, Call Price: 0.2872, Put Price: 14.8515
```

When we changed the dividend amount, the price of call and put changed accordingly. Put option is more sensitive to the dividend change and dividend change has a positive effect on it.

Problem 2:

Result from last week:

	Portfolio	Mean	VaR	ES
0	Straddle	0.026828	0.152779	0.198406
1	SynLong	-2.611656	14.028682	16.929067
2	CallSpread	-0.151310	0.775118	0.933590
3	PutSpread	0.218425	0.685200	0.914758
4	Stock	-0.015514	0.085666	0.103488
5	Call	-0.165295	0.868317	1.046914
6	Put	0.251699	0.885189	1.174004
7	CoveredCall	-0.010950	0.061952	0.074909
8	ProtectedPut	-0.008321	0.045542	0.054997

Result from this week:

Normal distribution:

	Portfolio	Current Value	Mean Return	VaR (95%)	ES (95%)
0	Call	$15.11	-4.45%	$11.27	$12.74
1	CallSpread	$9.19	-12.16%	$5.69	$6.99
2	CoveredCall	$178.75	-0.50%	$5.91	$8.65
3	ProtectedPut	$189.00	-0.52%	$14.10	$16.66
4	Put	$0.04	909.31%	$0.04	$0.04
5	PutSpread	$0.04	851.31%	$0.04	$0.04
6	Stock	$188.99	-0.58%	$14.73	$18.13
7	Straddle	$15.15	-1.88%	$8.98	$9.31
8	SynLong	$15.07	-7.03%	$13.34	$16.44

Delta-Normal:

Portfolio: Call

Portfolio Delta: 82.5

Delta-Normal VaR (95%): $317.32

Delta-Normal ES (95%): $396.17

Portfolio: CallSpread

Portfolio Delta: 0.0

Delta-Normal VaR (95%): $0.00

Delta-Normal ES (95%): $0.00

Portfolio: CoveredCall

Portfolio Delta: 82.5

Delta-Normal VaR (95%): $317.32

Delta-Normal ES (95%): $396.17

Portfolio: ProtectedPut

Portfolio Delta: 82.5

Delta-Normal VaR (95%): $317.32

Delta-Normal ES (95%): $396.17

Portfolio: Put

Portfolio Delta: -82.5

Delta-Normal VaR (95%): $317.32

Delta-Normal ES (95%): $396.17

Portfolio: PutSpread

Portfolio Delta: 0.0

Delta-Normal VaR (95%): $0.00

Delta-Normal ES (95%): $0.00

Portfolio: Stock

Portfolio Delta: 165

Delta-Normal VaR (95%): $634.64

Delta-Normal ES (95%): $792.34

Portfolio: Straddle

Portfolio Delta: 0.0

Delta-Normal VaR (95%): $0.00

Delta-Normal ES (95%): $0.00

Portfolio: SynLong

Portfolio Delta: 165.0

Delta-Normal VaR (95%): $634.64

Delta-Normal ES (95%): $792.34

From the data, we can see that the mean return for Put, and PutSpread is significantly higher than others and also last week. This might be due to a steep stock price drop.

Problem 3:

```
4-Factor Model Portfolio Weights:
        AAPL  META  UNH   MA  MSFT  NVDA   HD    PFE   AMZN  BRK-B     PG  \
Weight   0.0   0.0  0.0  0.0   0.0   0.0  0.0  0.097  0.081  0.118  0.317

          XOM   TSLA  JPM    V    DIS  GOOGL    JNJ  BAC  CSCO
Weight  0.071  0.003  0.0  0.0  0.021    0.0  0.292  0.0   0.0

Optimal Portfolio Return (4-Factor Model): 76.8686
```

```
Ticker
AAPL     0.036448
META     0.027157
UNH      0.023623
MA       0.022486
MSFT     0.035327
NVDA     0.008086
HD       0.030626
PFE      0.038070
AMZN     0.015235
BRK-B    0.029606
PG       0.034370
XOM      0.025435
TSLA     0.004763
JPM      0.013709
V        0.014395
DIS      0.024049
GOOGL    0.020737
JNJ      0.035350
BAC      0.010954
CSCO     0.017190
dtype: float64
```

We’ve got the super-efficient portfolio which is only comprised of 8 stocks.