

Problem 1:

1.1:

	GBSM Call	GBSM Put	Diff Call	Diff Put
delta	0.510071	-0.489450	0.510071	-0.489450
gamma	0.040173	0.040173	0.040173	0.040173
vega	19.776582	19.776582	19.776582	19.776582
theta	-21.628607	-22.090281	-21.628942	-22.090616
rho	7.253304	-7.661132	7.253304	-7.661133
carry rho	-7.609135	7.301527	-7.609135	7.301527

From the above, we see that the values between two methods for both a call and a put are the same, which indicates that our implementation for both methods is correct. Black Scholes method can provide the most accurate Greeks, but the finite difference method is able to give a good approximation on Greeks given small enough changes of impact. It can be used as an alternative while it is not possible to use Black Scholes method.

1.2:

	BT_Call	BT_Put
delta	0.510500	-0.531187
gamma	0.041285	0.039790
vega	19.349184	19.607574
theta	-13.425310	-21.528016
rho	6.538935	-7.746206
carry rho	-0.095796	0.531082

call price: 3.8147

put price: 4.4469

The graph above shows Greeks for BT call and BT put, the call price is 3.8147 and the put price is 4.4469. The carry rho represents the sensitivity. As the dividend of the

underlying asset increase by \$1, the American call price decrease by \$0.095796, and the American put price increase by \$0.531082.

Problem 2:

	Mean	VaR	ES
Straddle	-0.001046	0.348438	0.443939
SynLong	0.037428	14.561353	18.051492
CallSpread	-0.006262	5.501462	6.893154
PutSpread	-0.020329	5.823678	7.308101
Stock	0.037973	13.840549	17.161336
Call	0.017439	7.048001	8.783879
Put	0.097430	7.151996	9.110660
CoveredCall	0.045495	6.683588	8.432616
ProtectedPut	0.023511	6.432256	7.958029

	Mean	VaR	ES
Portfolio			
Call	-0.030997	0.970262	0.985859
CallSpread	-0.093097	0.964677	0.983190
CoveredCall	-0.002014	0.058050	0.078658
ProtectedPut	-0.000089	0.024480	0.024790
Put	0.101693	0.957305	0.978478
PutSpread	0.173506	0.941960	0.970655
Stock	-0.002805	0.082951	0.103422
Straddle	0.034603	0.274430	0.275518
SynLong	-5.869339	138.975409	172.897045

The left graph is from this week's project, and the right graph is from last week's project. As we can see, most of the values in the two graphs are like each other. But it seems that portfolios created from American Options tend to be riskier than portfolios created from European Options.

Problem 3:

	AAPL	FB	UNH	MA	MSFT	NVDA	HD	PFE	AMZN	BRK_B	PG	XOM	TSLA	JPM
AAPL	0.065441	0.031073	0.020744	0.010865	0.039993	0.081306	0.020419	-0.021341	0.041714	0.000136	-0.002699	0.008210	0.081903	0.005251
FB	0.031073	0.104613	0.008503	0.040435	0.037940	0.071235	0.007342	-0.034076	0.039219	0.009335	0.000548	0.016634	0.070407	0.003429
UNH	0.020744	0.008503	0.044678	0.025495	0.022884	0.037212	0.016155	-0.006501	0.018861	0.002269	0.011324	0.009566	0.024662	0.003660
MA	0.010865	0.040435	0.025495	0.129913	0.008331	0.032840	0.013766	-0.025942	0.018757	0.020274	0.012592	0.047964	0.042987	0.027444
MSFT	0.039993	0.037940	0.022884	0.008331	0.065237	0.089283	0.022864	-0.018821	0.033346	-0.001568	0.002797	0.004023	0.078434	-0.003993
NVDA	0.081306	0.071235	0.037212	0.032840	0.089283	0.354876	0.052871	-0.048652	0.100484	-0.003756	-0.009097	0.033804	0.188497	0.007134
HD	0.020419	0.007342	0.016155	0.013766	0.022864	0.052871	0.058241	-0.022702	0.014528	0.000238	0.006162	0.005143	0.028978	0.014535
PFE	-0.021341	-0.034076	-0.006501	-0.025942	-0.018821	-0.048652	-0.022702	0.177019	-0.027410	-0.012057	0.005692	-0.036887	-0.055088	-0.022267
AMZN	0.041714	0.039219	0.018861	0.018757	0.033346	0.100484	0.014528	-0.027410	0.066280	-0.001549	-0.003372	0.013645	0.041839	-0.001034
BRK_B	0.000136	0.009335	0.002269	0.020274	-0.001568	-0.003756	0.000238	-0.012057	-0.001549	0.022978	0.009790	0.023074	-0.005053	0.022736
PG	-0.002699	0.000548	0.011324	0.012592	0.002797	-0.009097	0.006162	0.005692	-0.003372	0.009790	0.020747	0.008562	-0.014879	0.005781
XOM	0.008210	0.016634	0.009566	0.047964	0.004023	0.033804	0.005143	-0.036887	0.013645	0.023074	0.008562	0.076084	0.020601	0.032106
TSLA	0.081903	0.070407	0.024662	0.042987	0.078434	0.188497	0.028978	-0.055088	0.041839	-0.005053	-0.014879	0.020601	0.515711	0.012343
JPM	0.005251	0.003429	0.003660	0.027444	-0.003993	0.007134	0.014535	-0.022267	-0.001034	0.022736	0.005781	0.032106	0.012343	0.056659
V	0.010712	0.034626	0.018395	0.098294	0.003577	0.041099	0.013316	-0.015947	0.010257	0.018162	0.007860	0.042525	0.039617	0.025793
DIS	0.012826	0.029683	0.010282	0.044054	0.010030	0.023697	0.011541	-0.023313	0.017323	0.010155	0.002047	0.024406	0.052436	0.018758
GOOGL	0.031423	0.036417	0.021946	0.010899	0.051307	0.083843	0.022639	-0.021314	0.039699	0.001378	0.002965	0.007619	0.043748	0.003235
JNJ	-0.003238	0.005036	0.008787	0.013416	-0.001555	-0.013139	0.002178	0.006779	-0.003340	0.009128	0.014588	0.002300	-0.017519	0.006472
BAC	0.005305	0.008607	0.003671	0.040533	-0.000343	0.017036	0.007904	-0.034283	0.002833	0.028815	0.008013	0.047495	0.027099	0.051533
CSCO	0.011880	0.016598	0.015559	0.017995	0.022863	0.013277	0.003715	-0.002152	0.002798	0.007915	0.008888	0.014596	0.013973	0.012274

V	DIS	GOOGL	JNJ	BAC	CSCO
0.010712	0.012826	0.031423	-0.003238	0.005305	0.011880
0.034626	0.029683	0.036417	0.005036	0.008607	0.016598
0.018395	0.010282	0.021946	0.008787	0.003671	0.015559
0.098294	0.044054	0.010899	0.013416	0.040533	0.017995
0.003577	0.010030	0.051307	-0.001555	-0.000343	0.022863
0.041099	0.023697	0.083843	-0.013139	0.017036	0.013277
0.013316	0.011541	0.022639	0.002178	0.007904	0.003715
-0.015947	-0.023313	-0.021314	0.006779	-0.034283	-0.002152
0.010257	0.017323	0.039699	-0.003340	0.002833	0.002798
0.018162	0.010155	0.001378	0.009128	0.028815	0.007915
0.007860	0.002047	0.002965	0.014588	0.008013	0.008888
0.042525	0.024406	0.007619	0.002300	0.047495	0.014596
0.039617	0.052436	0.043748	-0.017519	0.027099	0.013973
0.025793	0.018758	0.003235	0.006472	0.051533	0.012274
0.097985	0.044888	0.004174	0.007931	0.034852	0.012377
0.044888	0.064854	0.011925	0.003500	0.019232	0.019587
0.004174	0.011925	0.063281	0.001318	0.005473	0.019005
0.007931	0.003500	0.001318	0.022242	0.005681	0.005765
0.034852	0.019232	0.005473	0.005681	0.064756	0.014238
0.012377	0.019587	0.019005	0.005765	0.014238	0.054527

The graphs above shows the annual covariance matrix for the 10 stock
The graph below shows the optimal portfolio on the efficient frontier graph

