**Output (page 1-5) and Justification (page 6) of Group A&B**

Hanlin WANG

**Output**

# GROUP A: EXACT SOLUTIONS

a) Options Pricing

The call option's price of batch 1 is 2.13337

The put option's price of batch 1 is 5.84628

The call option's price of batch 2 is 7.96557

The put option's price of batch 2 is 7.96557

The call option's price of batch 3 is 0.204058

The put option's price of batch 3 is 4.07326

The call option's price of batch 4 is 92.1757

The put option's price of batch 4 is 1.2475

b) Check Put-Call parity

By parity, the put price should be 5.84628

While the put price is 5.84628

Parity is satisfied

Parity is satisfied

c) Option Prices for Different Values of S

call price of batch 1 is 7.792e-36 1.88964e-32 1.64204e-29 6.19303e-27 1.17207e-24 1.24529e-22 8.11387e-21 3.47944e-19 1.03991e-17 2.27042e-16 3.76503e-15 4.89964e-14 5.1436e-13 4.45934e-12 3.25772e-11 2.0405e-10 1.11246e-09 5.34891e-09 2.29454e-08 8.8713e-08 3.11926e-07 1.00545e-06 2.99241e-06 8.27565e-06 2.13896e-05 5.19359e-05 0.000119024 0.000258548 0.000534403 0.00105474 0.00199417 0.00362244 0.00633924 0.010714 0.0175282 0.0278174 0.0429083 0.0644467 0.0944125 0.135117

d) Option Prices for matrix

Call price

Price s = 10 s = 11 s = 12 s = 13 s = 14 s = 15 s = 16 s = 17 s = 18 s = 19 s = 20 s = 21 s = 22

s = 23 s = 24 s = 25 s = 26 s = 27 s = 28 s = 29 s = 30 s = 31 s = 32 s = 33 s = 34 s = 35 s = 36 s = 37 s = 38 s = 39 s = 40 s = 41 s = 42 s = 43 s = 44 s = 45 s = 46 s = 47 s = 48 s = 49

batch1 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00001 0.00002 0.00005 0.00012 0.00026 0.00053 0.00105 0.00199 0.00362 0.00634 0.01071 0.01753 0.02782 0.04291 0.06445 0.09441 0.13512

batch2 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00001 0.00001 0.00002 0.00003 0.00006 0.00010 0.00016 0.00026 0.00041 0.00062

batch3 2.48011 3.20115 3.97989 4.80493 5.66680 6.55778 7.47169 8.40362 9.34971 10.30693 11.27290 12.24577 13.22408

14.20669 15.19272 16.18145 17.17235 18.16498 19.15898 20.15410 21.15011 22.14684 23.14416 24.14195 25.14013 26.13862 27.13738 28.13634 29.13547 30.13475 31.13415 32.13364 33.13321 34.13286 35.13255 36.13230 37.13208 38.13190 39.13175 40.13161

batch4 6.08558 6.90422 7.73711 8.58239 9.43856 10.30437 11.17876 12.06085 12.94986 13.84514 14.74613 15.65231 16.56326

17.47859 18.39794 19.32103 20.24757 21.17731 22.11004 23.04556 23.98368 24.92424 25.86708 26.81207 27.75909 28.70801 29.65873 30.61115 31.56517 32.52073 33.47772 34.43609 35.39577 36.35668 37.31878 38.28200 39.24630 40.21163 41.17794 42.14518

# GROUP A: SENSATIVITIES

a) Greeks

Exact delta call 0.59463

Exact delta put -0.3566

Exact gamma 0.013494

b) Delta fot Different Values of S

Calll delta of batch1: 1.3688e-31,1.0382e-28,3.4475e-26,5.7877e-24,5.4895e-22,3.2107e-20,1.2419e-18,3.3624e-17,6.675e-16,1.0099e-14,1.2025e-13,1.1583e-12,9.2358e-12,6.219e-11,3.5974e-10,1.8145e-09,8.0847e-09,3.2185e-08,1.1563e-07,3.7825e-07,1.1356e-06,3.1508e-06,8.1309e-06,1.9625e-05,4.4533e-05,9.5441e-05,0.00019399,0.00037538,0.00069391,0.0012293,0.0020932,0.0034346,0.0054444,0.008356,0.012443,0.018013,0.025394,0.034923,0.046923,

c) Deltas fot Matrix

Call Delta

Price s = 10 s = 11 s = 12 s = 13 s = 14 s = 15 s = 16 s = 17 s = 18 s = 19 s = 20 s = 21 s = 22

s = 23 s = 24 s = 25 s = 26 s = 27 s = 28 s = 29 s = 30 s = 31 s = 32 s = 33 s = 34 s = 35 s = 36 s = 37 s = 38 s = 39 s = 40 s = 41 s = 42 s = 43 s = 44 s = 45 s = 46 s = 47 s = 48 s = 49

batch1 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00001 0.00002 0.00004 0.00010 0.00019 0.00038 0.00069 0.00123 0.00209 0.00343 0.00544 0.00836 0.01244 0.01801 0.02539 0.03492 0.04692

batch2 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00001 0.00001 0.00002 0.00003 0.00005 0.00008 0.00012 0.00018 0.00026

batch3 0.68793 0.75194 0.80363 0.84488 0.87757 0.90336 0.92364 0.93958 0.95210 0.96194 0.96969 0.97580 0.98063

0.98445 0.98748 0.98990 0.99183 0.99337 0.99460 0.99560 0.99640 0.99705 0.99757 0.99800 0.99835 0.99863 0.99886 0.99905 0.99921 0.99934 0.99945 0.99954 0.99961 0.99967 0.99972 0.99977 0.99980 0.99983 0.99986 0.99988

batch4 0.81081 0.82610 0.83936 0.85096 0.86118 0.87026 0.87838 0.88567 0.89225 0.89822 0.90366 0.90864 0.91320

0.91740 0.92127 0.92485 0.92818 0.93127 0.93416 0.93685 0.93936 0.94172 0.94394 0.94602 0.94799 0.94984 0.95159 0.95324 0.95480 0.95629 0.95769 0.95903 0.96030 0.96152 0.96267 0.96377 0.96482 0.96582 0.96678 0.96770

Put Delta

Price s = 10 s = 11 s = 12 s = 13 s = 14 s = 15 s = 16 s = 17 s = 18 s = 19 s = 20 s = 21 s = 22

s = 23 s = 24 s = 25 s = 26 s = 27 s = 28 s = 29 s = 30 s = 31 s = 32 s = 33 s = 34 s = 35 s = 36 s = 37 s = 38 s = 39 s = 40 s = 41 s = 42 s = 43 s = 44 s = 45 s = 46 s = 47 s = 48 s = 49

batch1 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000

-1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -0.99999 -0.99998 -0.99996 -0.99990 -0.99981 -0.99962 -0.99931 -0.99877 -0.99791 -0.99657 -0.99456 -0.99164 -0.98756 -0.98199 -0.97461 -0.96508 -0.95308

batch2 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000

-1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -1.00000 -0.99999 -0.99999 -0.99998 -0.99997 -0.99995 -0.99992 -0.99988 -0.99982 -0.99974

batch3 -0.31207 -0.24806 -0.19637 -0.15512 -0.12243 -0.09664 -0.07636 -0.06042 -0.04790 -0.03806 -0.03031 -0.02420 -0.01937

-0.01555 -0.01252 -0.01010 -0.00817 -0.00663 -0.00540 -0.00440 -0.00360 -0.00295 -0.00243 -0.00200 -0.00165 -0.00137 -0.00114 -0.00095 -0.00079 -0.00066 -0.00055 -0.00046 -0.00039 -0.00033 -0.00028 -0.00023 -0.00020 -0.00017 -0.00014 -0.00012

batch4 -0.18919 -0.17390 -0.16064 -0.14904 -0.13882 -0.12974 -0.12162 -0.11433 -0.10775 -0.10178 -0.09634 -0.09136 -0.08680

-0.08260 -0.07873 -0.07515 -0.07182 -0.06873 -0.06584 -0.06315 -0.06064 -0.05828 -0.05606 -0.05398 -0.05201 -0.05016 -0.04841 -0.04676 -0.04520 -0.04371 -0.04231 -0.04097 -0.03970 -0.03848 -0.03733 -0.03623 -0.03518 -0.03418 -0.03322 -0.03230

d) Numerical Method

When h = 0.001, call delta = 0.5946286597

When h = 0.01, call delta = 0.5946286549

Exact call delta = 0.5946286597

Smaller values of h produce better approximation.

When h = 0.001, gamma = 0.0134936471

When h = 0.01, gamma = 0.0134936371

Exact gamma = 0.0134936371

Larger values of h produce better approximation.

# GROUP B

b) Test the Delta

The price of call option is 18.50350

The price of put option is 3.03106

c) Prices for Different Values of S

Call price of batch1: 0.00826 0.01123 0.01485 0.01922 0.02439 0.03045 0.03748 0.04555 0.05474 0.06514 0.07683 0.08988 0.10439 0.12044 0.13811 0.15750 0.17868 0.20174 0.22678 0.25388 0.28314 0.31464 0.34847 0.38473 0.42351 0.46491 0.50901 0.55591 0.60571 0.65850 0.71437 0.77343 0.83578 0.90150 0.97070 1.04347 1.11993 1.20015 1.28425 1.37233

d) Prices for Matrix

Call price

Price s = 10.00000 s = 11.00000 s = 12.00000 s = 13.00000 s = 14.00000 s = 15.00000 s = 16.00000 s = 17.00000

s = 18.00000 s = 19.00000 s = 20.00000 s = 21.00000 s = 22.00000 s = 23.00000 s = 24.00000 s = 25.00000 s = 26.00000 s = 27.00000 s = 28.00000 s = 29.00000 s = 30.00000 s = 31.00000 s = 32.00000 s = 33.00000 s = 34.00000 s =

35.00000 s = 36.00000 s = 37.00000 s = 38.00000 s = 39.00000 s = 40.00000 s = 41.00000 s = 42.00000 s = 43.00000

s = 44.00000 s = 45.00000 s = 46.00000 s = 47.00000 s = 48.00000 s = 49.00000

batch1 0.00826 0.01123 0.01485 0.01922 0.02439 0.03045 0.03748 0.04555 0.05474 0.06514 0.07683 0.08988 0.10439

0.12044 0.13811 0.15750 0.17868 0.20174 0.22678 0.25388 0.28314 0.31464 0.34847 0.38473 0.42351 0.46491 0.50901 0.55591 0.60571 0.65850 0.71437 0.77343 0.83578 0.90150 0.97070 1.04347 1.11993 1.20015 1.28425 1.37233

batch2 0.14216 0.17593 0.21372 0.25561 0.30168 0.35200 0.40665 0.46568 0.52917 0.59718 0.66975 0.74695 0.82884

0.91546 1.00686 1.10309 1.20420 1.31023 1.42123 1.53725 1.65831 1.78446 1.91575 2.05221 2.19388 2.34079 2.49299 2.65050 2.81336 2.98161 3.15527 3.33439 3.51899 3.70910 3.90475 4.10599 4.31282 4.52529 4.74342 4.96724

batch3 0.00028 0.00049 0.00082 0.00131 0.00203 0.00303 0.00442 0.00630 0.00880 0.01207 0.01628 0.02166 0.02842

0.03685 0.04726 0.05999 0.07545 0.09407 0.11635 0.14283 0.17413 0.21091 0.25391 0.30394 0.36187 0.42868 0.50539 0.59316 0.69320 0.80685 0.93551 1.08075 1.24419 1.42761 1.63291 1.86209 2.11732 2.40089 2.71524 3.06298

batch4 0.41837 0.51000 0.61108 0.72167 0.84182 0.97159 1.11104 1.26020 1.41914 1.58789 1.76649 1.95499 2.15342

2.36181 2.58021 2.80864 3.04714 3.29573 3.55446 3.82334 4.10240 4.39168 4.69119 5.00097 5.32104 5.65141 5.99213 6.34320 6.70464 7.07650 7.45877 7.85149 8.25467 8.66833 9.09250 9.52719 9.97242 10.42820 10.89457 11.37152

**OutputJustification**

**Overall**

1. Define option class and inheritation (Option, EuropeanOption and AmericanOption)

2. Pricing and computing Greeks (by formula)

3. Define matrix option class and inheritation (MatrixOption, EuropeanMatrixOption and AmericanMatrixOption) for multi-dimensional computing

**Detail**

**Group A**

Part 1:

a) Input all the arguments of batch1234, call function Price() separately when the option is call and put (transformed by toggle())

b) Check put-call parity, the result is that the parity is corresponded

c) Test the Price() overloading with a vector of different S as parameter

d) Test MatrixOption’s subclass and its member function

Part 2:

a) Define function to calculate Greeks, the output of my code is the same as the answer

b) Similar to c) in Part 1

c) Similar to d) in Part 1

d) Result shows that the smaller the h, the more accurate the numerical method is

**Group B**

a) Create AmericanOption derieved from Option

b) Call the Price() function and get the output same as the answer

c) Similar to c in Group A Part 1

d) Similar to d in Group A Part 1