

problem1:

code output:

```
[[ 2.14851331 -1.38946985 -0.51646635 -0.12932743 -1.05681437]
 [-1.38946985  1.03534243  0.3399928  0.19388784  0.62687597]
 [-0.51646635  0.3399928  0.94238795  0.94788729  0.05178794]
 [-0.12932743  0.19388784  0.94788729  1.11343622 -0.20473118]
 [-1.05681437  0.62687597  0.05178794 -0.20473118  0.59202693]]
```

1.1 Test passed!

```
[[ 1.          -0.93161849 -0.36295948 -0.08361591 -0.93704179]
 [-0.93161849  1.          0.34420158  0.1805826  0.80069826]
 [-0.36295948  0.34420158  1.          0.92535668  0.06933349]
 [-0.08361591  0.1805826  0.92535668  1.          -0.25216254]
 [-0.93704179  0.80069826  0.06933349 -0.25216254  1.          ]]
```

1.2 Test passed!

```
[[ 1.17398583 -0.62963106 -0.27893199 -0.081448  -0.73513969]
 [-0.62963106  1.3181973  0.01808963  0.44604714  0.13930939]
 [-0.27893199  0.01808963  0.91810185  0.36083562  0.25861288]
 [-0.081448  0.44604714  0.36083562  0.89476398 -0.23519021]
 [-0.73513969  0.13930939  0.25861288 -0.23519021  0.52260731]]
```

1.3 Test passed!

```
[[ 1.          -0.48319932 -0.24178663 -0.06776693 -0.71476123]
 [-0.48319932  1.          0.01544631  0.40565982  0.17828625]
 [-0.24178663  0.01544631  1.          0.48824985  0.33624763]
 [-0.06776693  0.40565982  0.48824985  1.          -0.32213624]
 [-0.71476123  0.17828625  0.33624763 -0.32213624  1.          ]]
```

1.4 Test passed!

2.1 Test passed!

2.2 Test passed!

```
[[ 1.17398583 -0.61798867 -0.284559  -0.06515152 -0.68828687]
 [-0.61798867  1.3181973  0.01709196  0.44569555  0.13917594]
 [-0.284559  0.01709196  0.91810185  0.35414666  0.24605561]
 [-0.06515152  0.44569555  0.35414666  0.89476398 -0.21871734]
 [-0.68828687  0.13917594  0.24605561 -0.21871734  0.52260731]]
```

3.1 Test passed!

```
[[ 1.          -0.48319932 -0.24178663 -0.06776693 -0.71476123]
 [-0.48319932  1.          0.01544631  0.40565982  0.17828625]
 [-0.24178663  0.01544631  1.          0.48824985  0.33624763]
 [-0.06776693  0.40565982  0.48824985  1.          -0.32213624]
 [-0.71476123  0.17828625  0.33624763 -0.32213624  1.          ]]
```

3.2 Test passed!

```
[[ 1.18671354 -0.62832088 -0.28371877 -0.07391597 -0.71401651]
 [-0.62832088  1.31833217  0.01759688  0.44682248  0.14148379]
 [-0.28371877  0.01759688  0.91990212  0.35800289  0.25066863]
 [-0.07391597  0.44682248  0.35800289  0.8992213  -0.22268989]]
```

[-0.71401651 0.14148379 0.25066863 -0.22268989 0.55766378]]

3.3 Test passed!

```
[[ 1.          -0.48319932 -0.24178663 -0.06776693 -0.71476123]
 [-0.48319932  1.          0.01544631  0.40565982  0.17828625]
 [-0.24178663  0.01544631  1.          0.48824985  0.33624763]
 [-0.06776693  0.40565982  0.48824985  1.          -0.32213624]
 [-0.71476123  0.17828625  0.33624763 -0.32213624  1.          ]]
```

3.4 Test passed!

```
[[ 1.08350627e+00  0.00000000e+00  0.00000000e+00  0.00000000e+00
  0.00000000e+00]
 [-5.70360031e-01  9.96437019e-01  0.00000000e+00  0.00000000e+00
  0.00000000e+00]
 [-2.62627924e-01 -1.33175007e-01  9.11807458e-01  0.00000000e+00
  0.00000000e+00]
 [-6.01302681e-02  4.12870700e-01  4.31383647e-01  7.31159534e-01
  0.00000000e+00]
 [-6.35240325e-01 -2.23937642e-01  5.41790569e-02 -2.56892194e-01
  1.49011612e-08]]
```

3.4 Test passed!

```
[[0.08509187 0.08728343 0.04227439 0.00899644 0.00387718]
 [0.08728343 0.15987801 0.05789903 0.0123237 0.00530774]
 [0.04227439 0.05789903 0.03746491 0.00595388 0.00257236]
 [0.00899644 0.0123237 0.00595388 0.00168983 0.00054637]
 [0.00387718 0.00530774 0.00257236 0.00054637 0.00031375]]
```

5.1 Test passed!

```
[[0.08509187 0.11693613 0.04236111 0.0090158 0.00388588]
 [0.11693613 0.16069758 0.05821406 0.01238982 0.00534011]
 [0.04236111 0.05821406 0.03757588 0.00597408 0.00258284]
 [0.0090158 0.01238982 0.00597408 0.00169292 0.00054819]
 [0.00388588 0.00534011 0.00258284 0.00054819 0.0003147 ]]
```

5.2 Test passed!

```
[[0.08509187 0.00810277 0.03769477 0.00801642 0.00344845]
 [0.00810277 0.16066675 0.05176521 0.0110067 0.00474394]
 [0.03769477 0.05176521 0.03734547 0.00598114 0.00257938]
 [0.00801642 0.0110067 0.00598114 0.00168799 0.00054856]
 [0.00344845 0.00474394 0.00257938 0.00054856 0.00031276]]
```

5.3 Test passed!

```
[[ 8.58420083e-02 -7.67145578e-05  4.07486781e-02  8.15103166e-03
  3.48223524e-03]
 [-7.67145578e-05  1.61206666e-01  5.69011799e-02  1.17212163e-02
  5.03403823e-03]
 [ 4.07486781e-02  5.69011799e-02  3.98499384e-02  7.41465937e-03
  3.23943898e-03]
 [ 8.15103166e-03  1.17212163e-02  7.41465937e-03  2.54796440e-03
  ]]
```

```

9.39620837e-04]
[ 3.48223524e-03  5.03403823e-03  3.23943898e-03  9.39620837e-04
 4.95077454e-04]]

```

5.4 Test passed!

```

[[0.08490465 0.11667884 0.04496958 0.00926454 0.00397027]
 [0.11667884 0.16034401 0.06179872 0.01273164 0.00545608]
 [0.04496958 0.06179872 0.02381805 0.00490694 0.00210285]
 [0.00926454 0.01273164 0.00490694 0.00101092 0.00043322]
 [0.00397027 0.00545608 0.00210285 0.00043322 0.00018566]]

```

5.5 Test passed!

	Date	SPY	AAPL	...	C	BSX	AMT
1	2022-09-02	-0.010544	-0.013611	...	0.001846	-0.012198	-0.026355
2	2022-09-06	-0.003773	-0.008215	...	-0.012695	-0.002717	0.013275
3	2022-09-07	0.017965	0.009254	...	0.008503	0.026994	0.020930
4	2022-09-08	0.006536	-0.009618	...	0.026116	0.029901	0.008362
5	2022-09-09	0.015535	0.018840	...	0.015431	0.005385	-0.000306
..
261	2023-09-18	0.000586	0.016913	...	-0.001639	0.001890	-0.003386
262	2023-09-19	-0.002074	0.006181	...	0.000938	0.000566	-0.012087
263	2023-09-20	-0.009193	-0.019992	...	-0.008903	0.020177	0.000282
264	2023-09-21	-0.016528	-0.008889	...	-0.013948	-0.002403	-0.045601
265	2023-09-22	-0.002249	0.004945	...	-0.018940	-0.006856	-0.018368

[265 rows x 102 columns]

	Date	SPY	AAPL	...	C	BSX	AMT
1	2022-09-02	-0.010600	-0.013705	...	0.001844	-0.012273	-0.026708
2	2022-09-06	-0.003780	-0.008249	...	-0.012776	-0.002720	0.013187
3	2022-09-07	0.017806	0.009211	...	0.008467	0.026636	0.020714
4	2022-09-08	0.006515	-0.009664	...	0.025780	0.029463	0.008327
5	2022-09-09	0.015416	0.018664	...	0.015313	0.005371	-0.000306
..
261	2023-09-18	0.000586	0.016772	...	-0.001640	0.001889	-0.003392
262	2023-09-19	-0.002076	0.006162	...	0.000938	0.000566	-0.012161
263	2023-09-20	-0.009236	-0.020195	...	-0.008943	0.019976	0.000282
264	2023-09-21	-0.016666	-0.008929	...	-0.014046	-0.002406	-0.046673
265	2023-09-22	-0.002251	0.004932	...	-0.019122	-0.006879	-0.018538

[265 rows x 102 columns]

```

      mu      sigma
0 0.046026 0.046545

```

7.1 Test passed!

```

      mu      sigma      nu
0 0.04594 0.045443 6.336775

```

7.2 Test passed!

	mu	sigma	nu	Alpha	B1	B2	B3
0	0.000532	0.048549	4.598678	0.042103	0.974963	2.041181	3.154816

7.3 Test passed!
-0.030534719374794843

	VaR Absolute	VaR Diff from Mean
0	0.030535	0.07656

8.1 Test passed!

	VaR Absolute	VaR Diff from Mean
0	0.04153	0.08747

8.2 Test passed!

	VaR Absolute	VaR Diff from Mean
0	0.041441	0.087025

8.3 Test passed!

	ES Absolute	ES Diff from Mean
0	0.049984	0.09601

8.4 Test passed!

	ES Absolute	ES Diff from Mean
0	0.075232	0.121173

8.5 Test passed!
0.04363309590876207 0.07732223761661139

	ES Absolute	ES Diff from Mean
0	0.077322	0.122595

8.6 Test passed!

problem2

code output:

normal distribution's ES and VaR: 0.11411909995199543 0.09117937291393813

t distribution's ES and VaR: 0.11321752956203937 0.07647567329365701

historical's ES and VaR: 0.11677669788562187 0.07598069069686242

values are similar, but stock return is not normal so t will be more accurate, historical's ES is a rough approximate so it's a little bit far from t's result

problem3:

we can see the copula portfolio VaR and ES from output below, and the bottom matrix is using method from last week, clearly we can see the VaR decrease.

Matrix is PSD

	Portfolio	VaR95	ES95
0	A	288.719123	460.466703
1	B	265.955626	492.589022
2	C	241.334004	328.359953

	Portfolio	VaR95	ES95
0	A	359.317945	518.262046
1	B	302.051281	545.021004
2	C	262.080967	373.889432