Assignment-1

2021101113

Science - II

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> **All these commands are tested on Ubuntu Version 20.04.3 LTS (Focal Fossa)**

```
Q3
├── Q3-Bonus.py
├── Q3-c.py
├── Q3.pdf
└── Q3.py
```

> - Q3

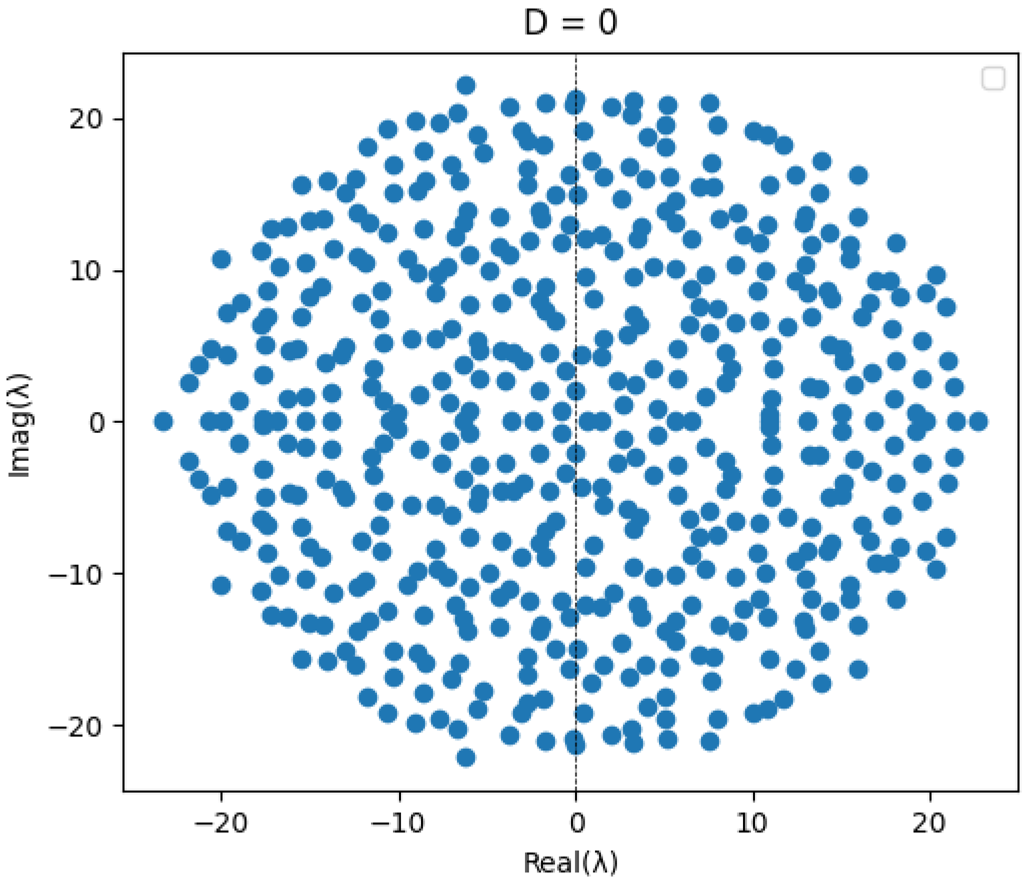
`$ python3 Q3.py`

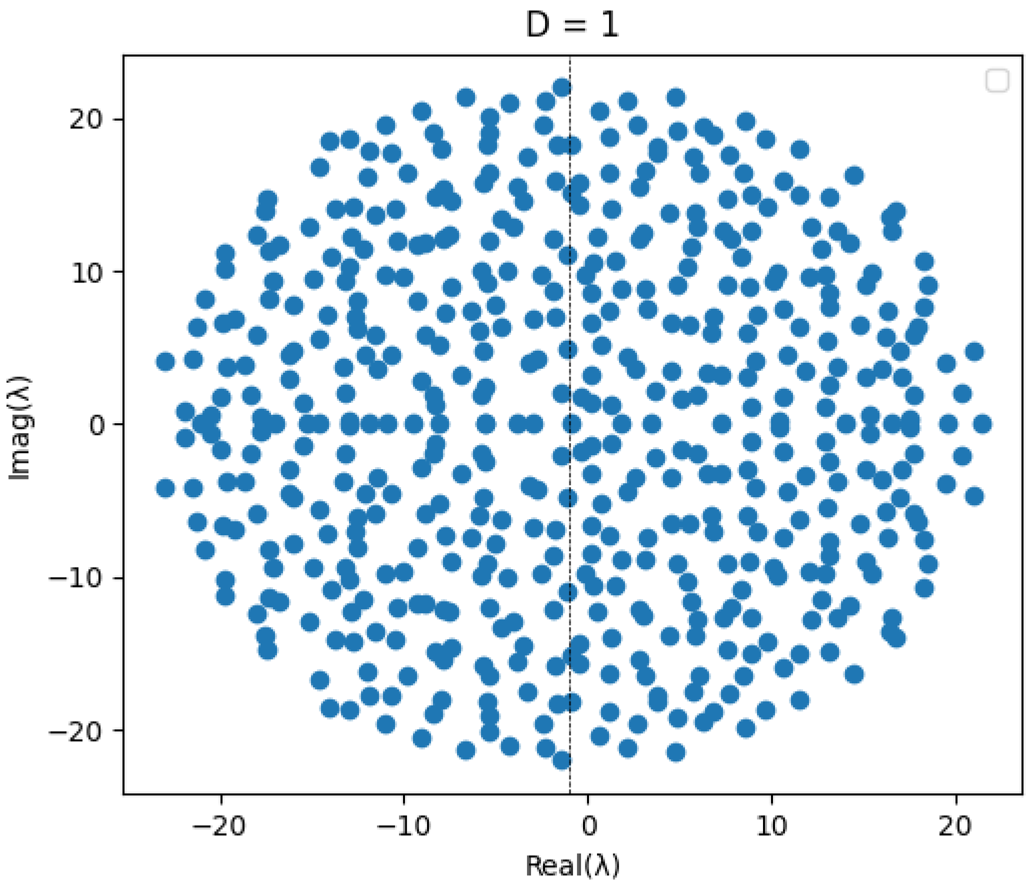
```
// code for eigen value plot for D = 0,1,5,10
import numpy as np
import matplotlib.pyplot as plt
M = np.random.normal(loc=0, scale=1, size=(500, 500))
for D in [0,1,5,10]:
    # Add diagonal elements to matrix
    np.fill_diagonal(M, -D)
    eigenvalues = np.linalg.eigvals(M)
    plt.scatter(np.real(eigenvalues), np.imag(eigenvalues))

plt.xlabel("Real(λ)")
plt.ylabel("Imag(λ)")
plt.show()
```

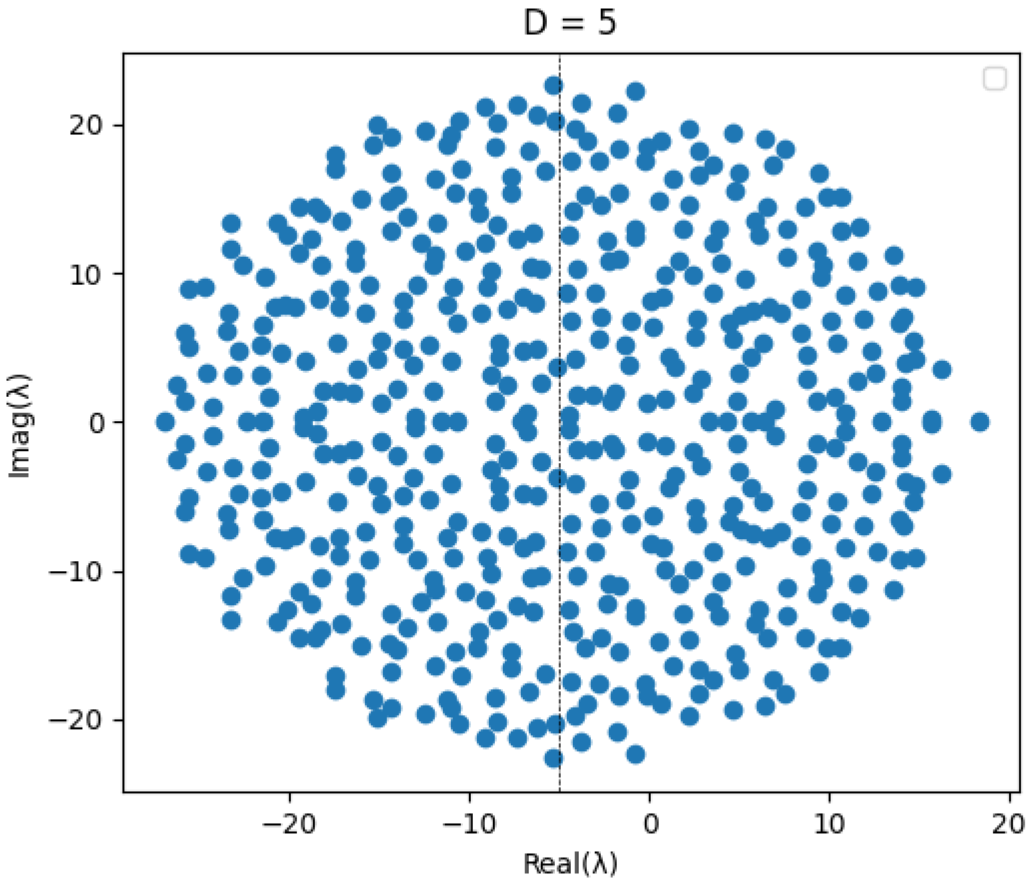
```
// code for part c
import numpy as np
import matplotlib.pyplot as plt
N = 500
M = np.random.normal(loc=0, scale=1, size=(500, 500))

# Plot eigenvalues for different values of D
# for D in [1]:
```

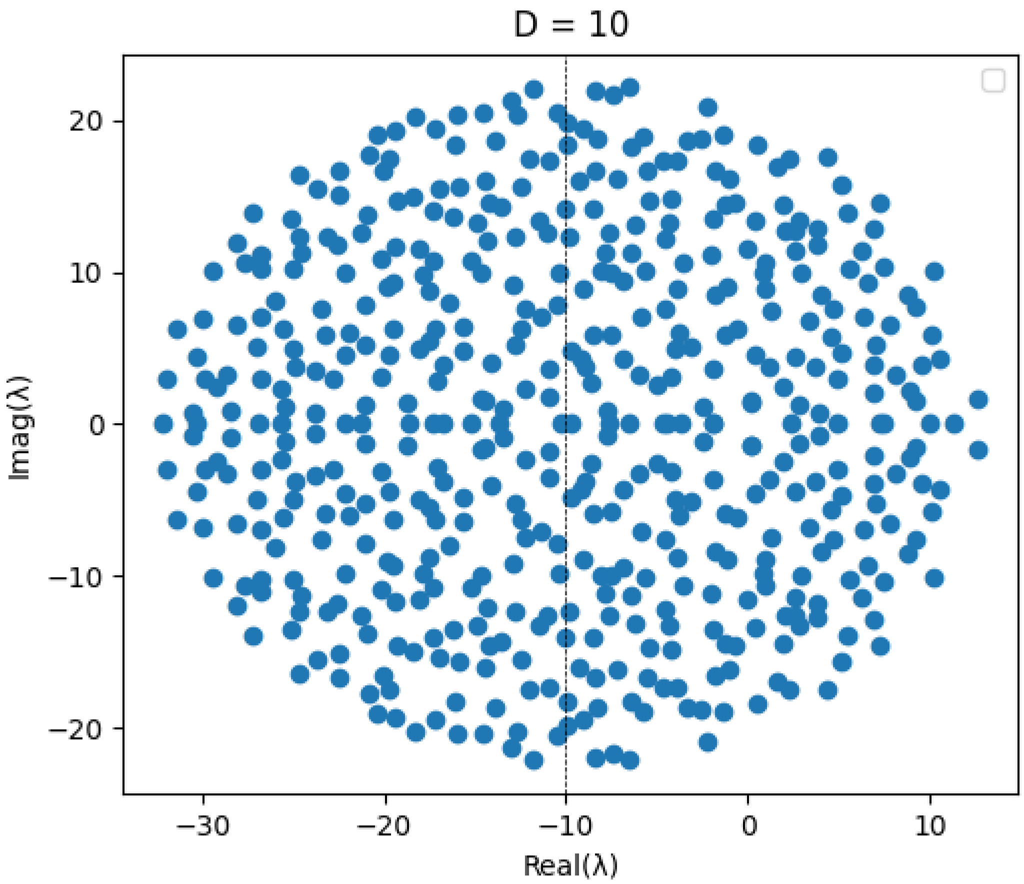
```
    # Add diagonal elements to matrix
D = 1
np.fill_diagonal(M, -D)
M = (M + M.T)/2
eigenvalues = np.linalg.eigvals(M)
plt.scatter(np.real(eigenvalues), np.imag(eigenvalues))
plt.xlabel("Real(λ)")
plt.ylabel("Imag(λ)")
plt.show()
```

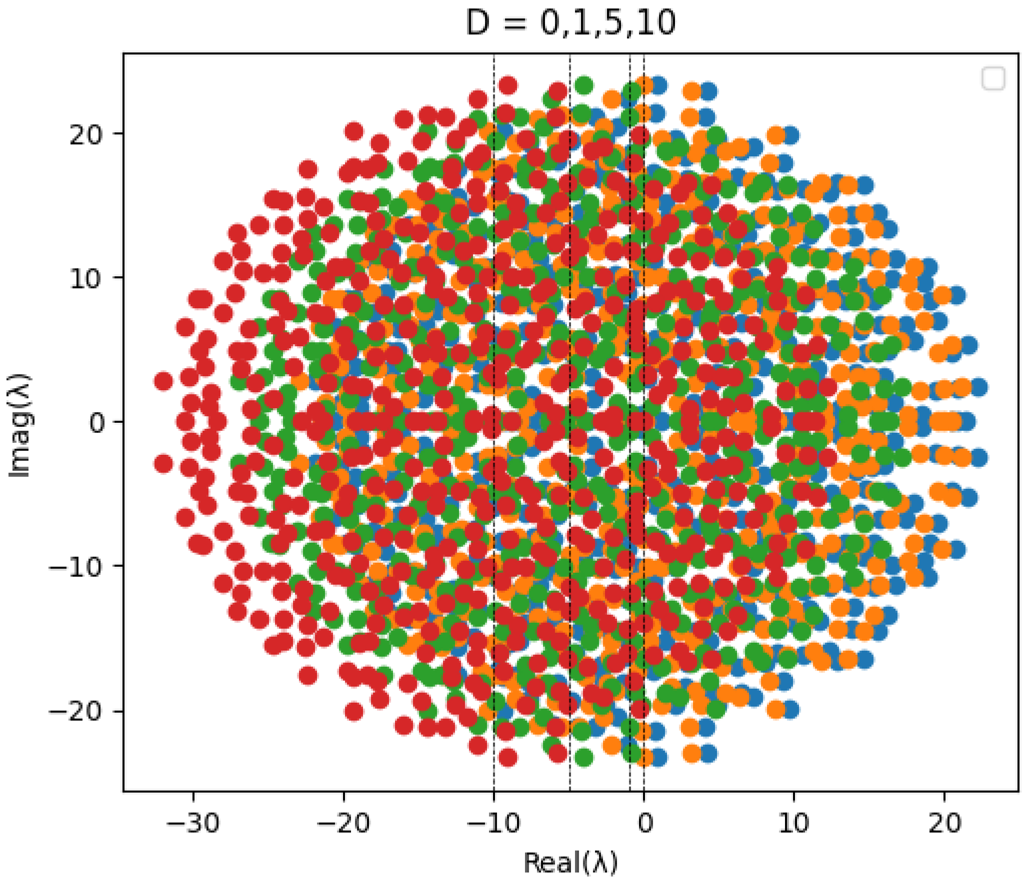
```
// code for bonus part
import numpy as np
import matplotlib.pyplot as plt
N = 500
M = np.random.normal(loc=0, scale=1, size=(500, 500))
for D in [0,1,5,10]:
    N = (M - M.T)/2
    np.fill_diagonal(N, -D)
    eigenvalues = np.linalg.eigvals(N)
    plt.scatter(np.real(eigenvalues), np.imag(eigenvalues))
plt.xlabel("Real(λ)")
plt.ylabel("Imag(λ)")
plt.show()
```


D = 0
Imag(λ)
Real(λ)
20
10
0
−10
−20
−20
−10
0
10
20


D = 1
Imag(λ)
Real(λ)
20
10
0
−10
−20
−20
−10
0
10
20

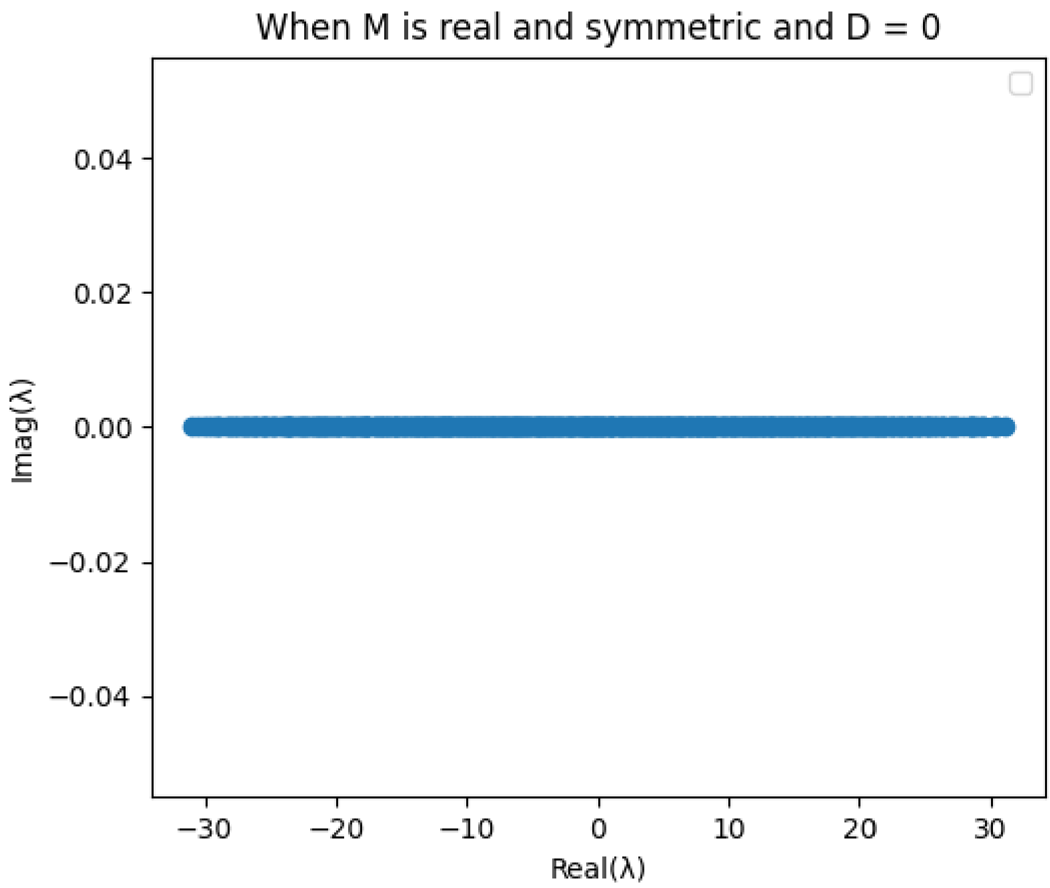

D = 5
Imag(λ)
Real(λ)
20
10
0
−10
−20
−20
−10
0
10
20


D = 10
Imag(λ)
Real(λ)
20
10
0
−10
−20
−30
−20
−10
0
10



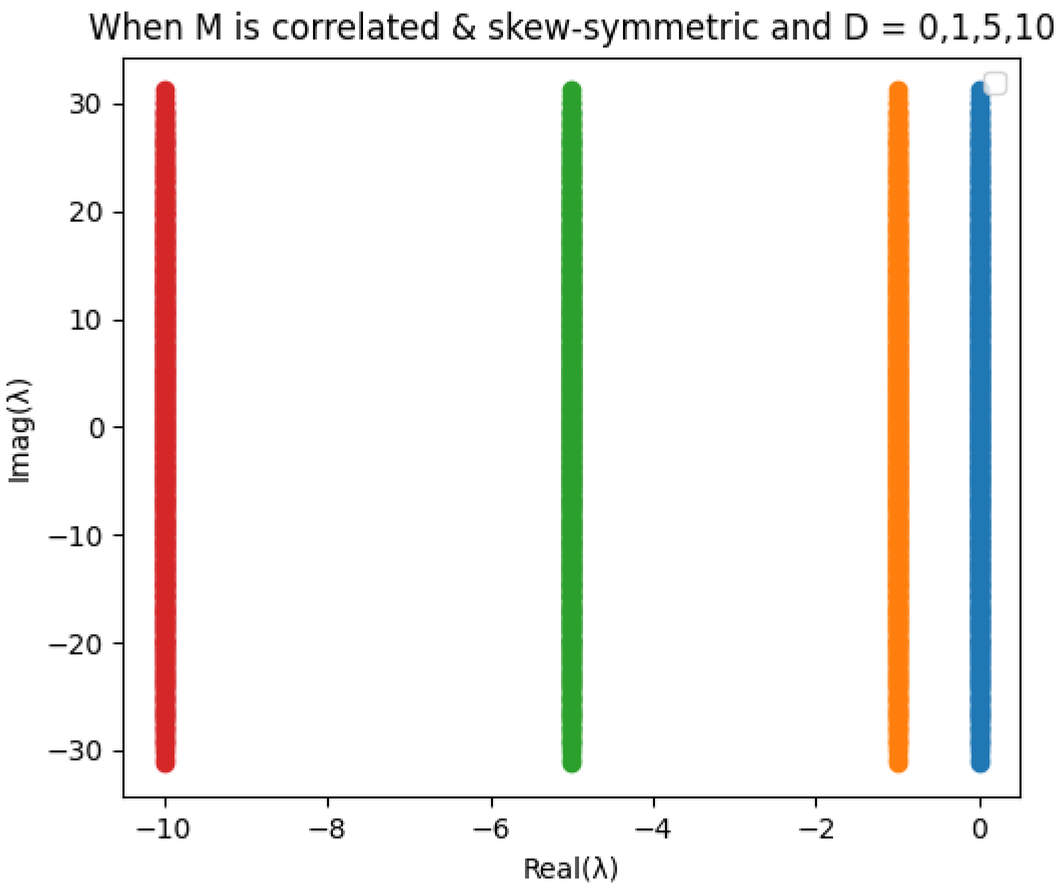

```
a) The shape in the plot is likely to be a cloud of scattered points , as
the eigen values are complex numbers
b) As the value of D increases , the eigen values will move away from the
origin of complex plane (-D is used in the matrix)
```

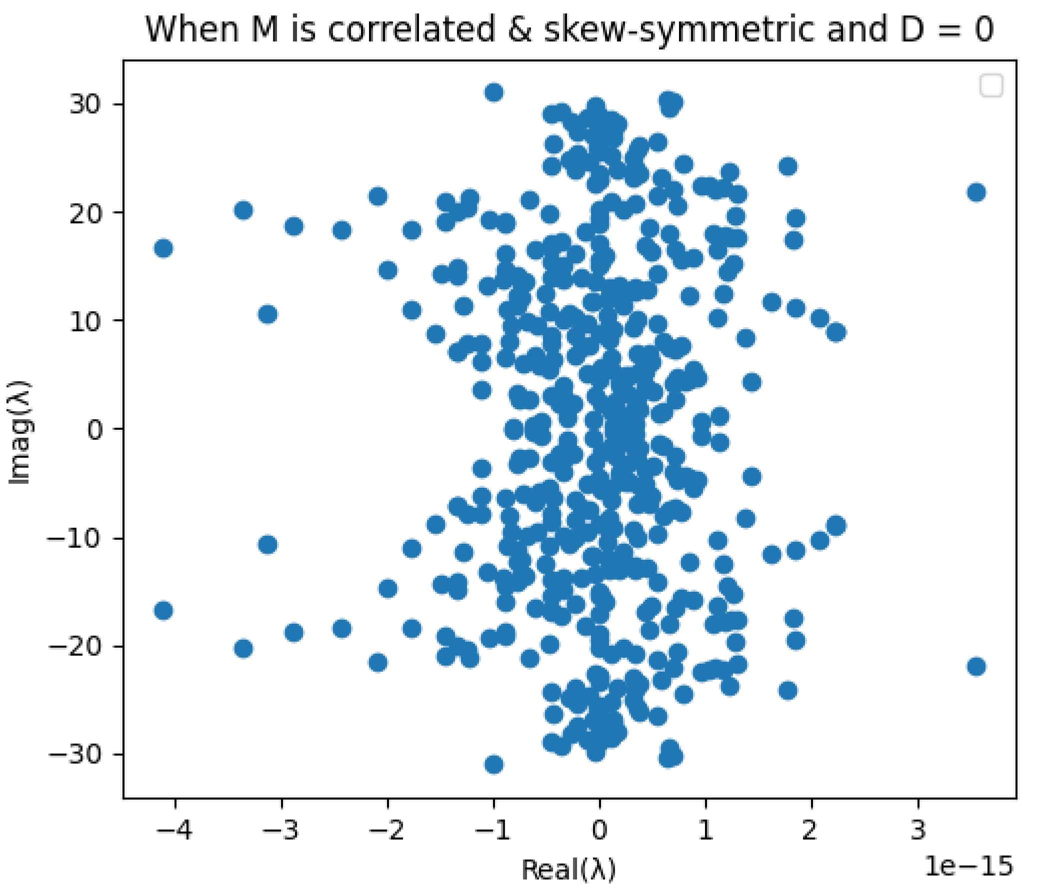
```
c) If the matrix is real and symmetric , then all eigen values will be real
numbers and the plot will show a scatter of points along the real axis only
```




```
What will happen if the random elements in the matrix are correlated? E.g
if M ij >0 then Mji <0.
1. Large complex systems which are assembled (connected) at random may be
expected to be stable up to a certain critical level of connectance, and
then, as this increases, to suddenly become unstable
2. If the random elements in the matrix are correlated (Consider the
example where if Mij > 0 and Mji<0) , then the matrix will be skew-
symmetric . A skew symmetric matrix is a square matrix whose transpose is
equal to its negative . If A is skew-symmetric , then A^T = -A
3. Skew symmetric matrices have some special properties , one of them is
that their eigen values will have zero real part and the plot will show a
scatter of points along the imaginary axis only and they are always
orthogonal matrices and hence their eigenvectors form an orthogonal basis
```

```
// ! Here the matrices are obtained after fetching a skew-symmetric matrix
and then replacing the Diagonal matrix with -D
```


When M is correlated & skew-symmetric and D = 0,1,5,10
Imag(λ)
Real(λ)
30
20
10
0
−10
−20
−30
−10
−8
−6
−4
−2
0


When M is correlated & skew-symmetric and D = 0
Imag(λ)
Real(λ)
1e−15
30
20
10
0
−10
−20
−30
−4
−3
−2
−1
0
1
2
3