a program in Python to implement Hopfield neural network

In [2]:
```python
import numpy as np
```

In [3]:
```python
x=np.array([[1,1,1,1,1],[1,-1,-1,1,-1],[-1,1,-1,-1,-1]])
```

In [4]:
```python
x1=np.transpose(x)
```

In [5]:
```python
t1=np.array([[1,1,1,-1,1]])
t2=np.array([[1,-1,-1,-1,-1]])
t3=np.array([[1,1,-1,-1,-1]])
```

In [6]:
```python
w=np.zeros((5,5))
i=0
j=0
k=0
```

In [12]:

```python
for i in range(len(x1)):
    for j in range(len(x[0])):
        for k in range(len(x)):
            w[i][j] += x1[i][k] * x[k][j]
        print('Weight Matrix:\n')
        for r in w:
            print(r)
            print('\n\nWeight Matrix with no self connection:\n')
```

Weight Matrix:

[4. -1. 1. 3. 1.]

Weight Matrix with no self connection:

[-1. 3. 1. -1. 1.]

Weight Matrix with no self connection:

[1. 1. 3. 1. 3.]

Weight Matrix with no self connection:

[3. -1. 1. 3. 1.]

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[5. -1. 1. 3. 1.]

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[-1. 3. 1. -1. 1.]

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[6. -1. 1. 3. 1.]

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[6. 0. 1. 3. 1.]

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[6. -1. 1. 3. 1.]

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[-1.  3.  1. -1.  1.]
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[1. 1. 3. 1. 3.]
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[ 6. -2.  2.  3.  1.]
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Weight Matrix with no self connection:

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[-1.  3.  1. -1.  1.]
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Weight Matrix with no self connection:

[1. 1. 3. 1. 3.]

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[6. -2. 2. 3. 1.]

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[-1. 3. 1. -1. 1.]

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[ 6. -2.  2.  4.  1.]
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[-1.  3.  1. -1.  1.]
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[1. 1. 3. 1. 3.]
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[1. 1. 3. 1. 3.]
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[ 6. -2.  2.  5.  1.]
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Weight Matrix with no self connection:

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[-1.  3.  1. -1.  1.]
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[1. 1. 3. 1. 3.]
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[ 6. -2.  2.  6.  2.]


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[6. -2. 2. 6. 2.]

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[6. -2. 2. 6. 2.]

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[0. 3. 1. -1. 1.]

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[-2. 6. 2. -2. 2.]

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[2. 2. 4. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 5. 1. 3.]

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[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[-2. 6. 2. -2. 2.]

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[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2.  6.  2. -2.  2.]
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Weight Matrix with no self connection:

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[2. 2. 6. 2. 4.]
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Weight Matrix with no self connection:

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[ 3. -1.  1.  3.  1.]
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Weight Matrix with no self connection:

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[1. 1. 3. 1. 3.]
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[ 6. -2.  2.  6.  2.]
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[-2.  6.  2. -2.  2.]
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Weight Matrix with no self connection:

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[2. 2. 6. 2. 5.]
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[ 3. -1.  1.  3.  1.]
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[1. 1. 3. 1. 3.]
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[ 6. -2.  2.  6.  2.]
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Weight Matrix with no self connection:

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[-2.  6.  2. -2.  2.]
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Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[3. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

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[4. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

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[5. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[2. 2. 6. 2. 6.]

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[6. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[-2. 6. 2. -2. 2.]

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[2. 2. 6. 2. 6.]

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[6. 0. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[2. 2. 6. 2. 6.]

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[6. -1. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[2. 2. 6. 2. 6.]

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[6. -2. 1. 3. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[6. -2. 2. 3. 1.]

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[-2. 6. 2. -2. 2.]

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[6. -2. 2. 4. 1.]

Weight Matrix with no self connection:

[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 5. 1.]

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[1. 1. 3. 1. 3.]

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[6. -2. 2. 6. 2.]

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[-2. 6. 2. -2. 2.]

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[6. -2. 2. 6. 1.]

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[-2. 6. 2. -2. 2.]

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[6. -2. 2. 6. 2.]

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[6. -2. 2. 6. 2.]

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```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[1. 1. 3. 1. 3.]
```

Weight Matrix with no self connection:

Weight Matrix:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[-2.  6.  2. -2.  2.]
```

Weight Matrix with no self connection:

```
[2. 2. 6. 2. 6.]
```

Weight Matrix with no self connection:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[2. 1. 3. 1. 3.]
```

Weight Matrix with no self connection:

Weight Matrix:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[-2.  6.  2. -2.  2.]
```

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 3. 1. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 3. 3. 1. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

```
[2. 2. 6. 2. 6.]
```

Weight Matrix with no self connection:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[2. 2. 3. 1. 3.]
```

Weight Matrix with no self connection:

Weight Matrix:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[-2.  6.  2. -2.  2.]
```

Weight Matrix with no self connection:

```
[2. 2. 6. 2. 6.]
```

Weight Matrix with no self connection:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[2. 2. 4. 1. 3.]
```

Weight Matrix with no self connection:

Weight Matrix:

```
[ 6. -2.  2.  6.  2.]
```

Weight Matrix with no self connection:

```
[-2.  6.  2. -2.  2.]
```

Weight Matrix with no self connection:

```
[2. 2. 6. 2. 6.]
```

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 5. 1. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 1. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 1. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 3.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 4.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 5.]

Weight Matrix with no self connection:

Weight Matrix:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[-2. 6. 2. -2. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

[6. -2. 2. 6. 2.]

Weight Matrix with no self connection:

[2. 2. 6. 2. 6.]

Weight Matrix with no self connection:

In [13]:
```python
i=0
j=0
for i in range(int(5)):
    for j in range(int(5)):
        if(i==j):
            w[i][j]=0
            for r in w:
                print(r)
```

```
[ 0. -2.  2.  6.  2.]
[-2.  6.  2. -2.  2.]
[2. 2. 6. 2. 6.]
[ 6. -2.  2.  6.  2.]
[2. 2. 6. 2. 6.]
[ 0. -2.  2.  6.  2.]
[-2.  0.  2. -2.  2.]
[2. 2. 6. 2. 6.]
[ 6. -2.  2.  6.  2.]
[2. 2. 6. 2. 6.]
[ 0. -2.  2.  6.  2.]
[-2.  0.  2. -2.  2.]
[2. 2. 0. 2. 6.]
[ 6. -2.  2.  6.  2.]
[2. 2. 6. 2. 6.]
[ 0. -2.  2.  6.  2.]
[-2.  0.  2. -2.  2.]
[2. 2. 0. 2. 6.]
[ 6. -2.  2.  0.  2.]
[2. 2. 6. 2. 6.]
[ 0. -2.  2.  6.  2.]
[-2.  0.  2. -2.  2.]
[2. 2. 0. 2. 6.]
[ 6. -2.  2.  0.  2.]
[2. 2. 6. 2. 0.]
```

In [14]:
```python
E1=0
E2=0
E3=0
x11= x[0].reshape(5,1)
x12=x[1].reshape(5,1)
x13=x[2].reshape(5,1)
E1= -0.5 * np.matmul(x[0],np.matmul(w,x11))
print('\n\nEnergy Calculations for pattern [1,1,1,1,1]:',E1)

E2= -0.5 * np.matmul(x[1],np.matmul(w,x12))
print('\n\nEnergy Calculations for pattern [1,-1,-1,1,-1]:',E2)
```

```
Energy Calculations for pattern [1,1,1,1,1]: [-20.]


Energy Calculations for pattern [1,-1,-1,1,-1]: [-12.]
```

In [15]:
```python
E3= -0.5 * np.matmul(x[2],np.matmul(w,x13))
print('\n\nEnergy Calculations for pattern [-1,1,-1,1,-1]:',E3)
```

Energy Calculations for pattern [-1,1,-1,1,-1]: [-20.]

In [16]:
```python
print('\n\nTESTING PHASE')
w_dash=np.transpose(w)
Yin1=t1[0][3]+ np.matmul(x[0],w_dash[3])
```

TESTING PHASE

In [25]:
```python
if(Yin1>0):
    t1[0][3]=1
else:
    t1[0][3]=-1
if((t1==x).any()):
        print('\nPattern [1,1,1,-1,1] Recognized ')
else:
        print('\nPattern [1,1,1,-1,1] not Recognized ')
Yin2=t2[0][3]+ np.matmul(x[1],w_dash[3])
if(Yin2>0):
    t2[0][3]=1
else:
    t2[0][3]=-1
if((t2==x).any()):
    print('\nPattern [1,-1,-1,-1,-1] Recognized ')
else:
    print('\nPattern [1,-1,-1,-1,-1] not Recognized ')
Yin3=t3[0][0]+ np.matmul(x[2],w_dash[0])
if(Yin3>0):
    t3[0][0]=1
else:
    t3[0][0]=-1
if((t3==x).any()):
    print('\nPattern [1,1,-1,-1,-1] Recognized ')
else:
    print('\nPattern [1,1,-1,-1,-1] not Recognized ')
```

Pattern [1,1,1,-1,1] Recognized

Pattern [1,-1,-1,-1,-1] Recognized

Pattern [1,1,-1,-1,-1] Recognized

In [ ]: