



# NumPy

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# Numpy

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NumPy is a Python package for general-purpose array-processing. It provides a high-performance multidimensional array object, and tools for working with these arrays.

It is the fundamental package for scientific computing with Python. It contains various features but the most important feature is **vectorization**.

The vectorization results in more “Pythonic” code. Without vectorization, our code would be littered with inefficient and difficult to read for loops.

# Numpy

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Vectorization describes the absence of any explicit looping, indexing, etc., in the code - these things are taking place, of course, just “behind the scenes” in optimized, pre-compiled C code. Vectorized code has many advantages, among which are:

vectorized code is more concise and easier to read

fewer lines of code generally means fewer bugs

the code more closely resembles standard mathematical notation (making it easier, typically, to correctly code mathematical constructs)

# np.array()

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The screenshot shows the PyCharm IDE interface. The main editor window displays a Python script named `np1.py` with the following code:

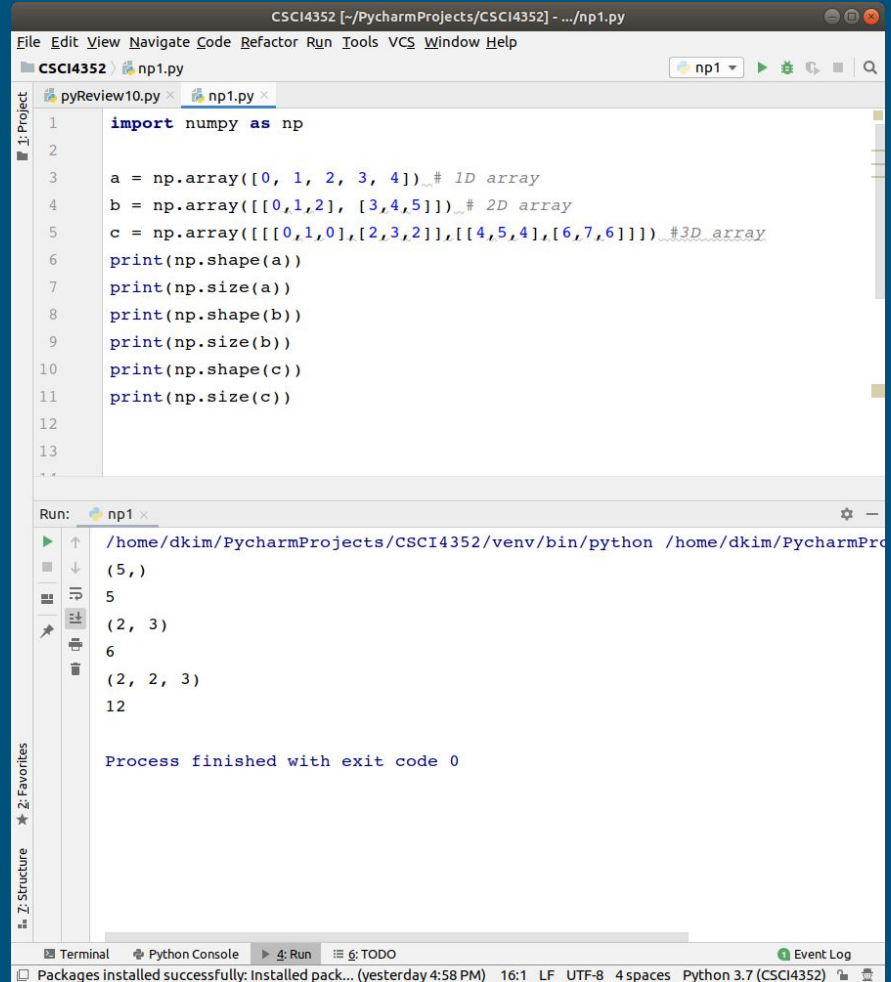
```
1 import numpy as np
2
3 a = np.array([0, 1, 2, 3, 4]) # 1D array
4 print(a)
5 b = np.array([[0,1,2], [3,4,5]]) # 2D array
6 print(b)
7 c = np.array([[[0,1],[2,3]],[[4,5],[6,7]]]) # 3D array
8 print(c)
9
10
11
12
13
14
```

The Run window below the editor shows the output of the script:

```
np1
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/PycharmPro
[0 1 2 3 4]
[[0 1 2]
 [3 4 5]]
[[[0 1]
 [2 3]]
 [[4 5]
 [6 7]]]
Process finished with exit code 0
```

The status bar at the bottom indicates the package installation status: "Packages installed successfully: Installed packages... (today 4:58 PM) 12:1 LF UTF-8 4 spaces Python 3.7 (CSCI4352)".

```
np.shape()
np.size()
```



The screenshot shows a PyCharm IDE window titled "CSCI4352 [-/PycharmProjects/CSCI4352] - .../np1.py". The editor displays a Python script with the following code:

```
1 import numpy as np
2
3 a = np.array([0, 1, 2, 3, 4]) # 1D array
4 b = np.array([[0,1,2], [3,4,5]]) # 2D array
5 c = np.array([[[0,1,0],[2,3,2]],[[4,5,4],[6,7,6]]) #3D array
6 print(np.shape(a))
7 print(np.size(a))
8 print(np.shape(b))
9 print(np.size(b))
10 print(np.shape(c))
11 print(np.size(c))
12
13
```

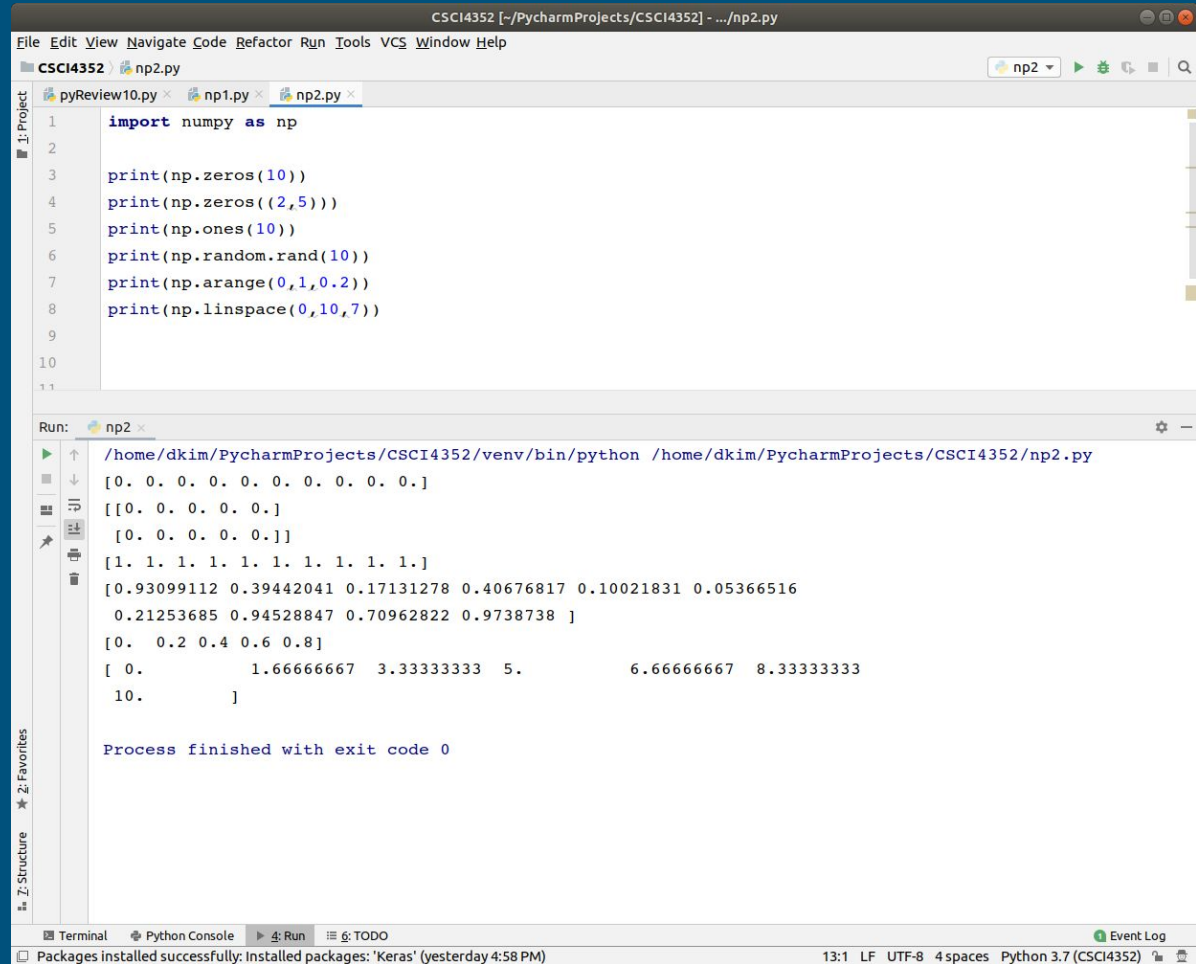
The Run window below the editor shows the execution output for the script:

```
Run: np1 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/PycharmPro
(5,)
5
(2, 3)
6
(2, 2, 3)
12

Process finished with exit code 0
```

The status bar at the bottom of the IDE indicates "Packages installed successfully: Installed pack... (yesterday 4:58 PM) 16:1 LF UTF-8 4 spaces Python 3.7 (CSCI4352)".

```
np.zeros()
np.ones()
np.random.rand()
np.arange()
np.linspace()
```



The screenshot shows the PyCharm IDE interface. The main editor window displays a Python script named `np2.py` with the following code:

```
1 import numpy as np
2
3 print(np.zeros(10))
4 print(np.zeros((2,5)))
5 print(np.ones(10))
6 print(np.random.rand(10))
7 print(np.arange(0,1,0.2))
8 print(np.linspace(0,10,7))
9
10
11
```

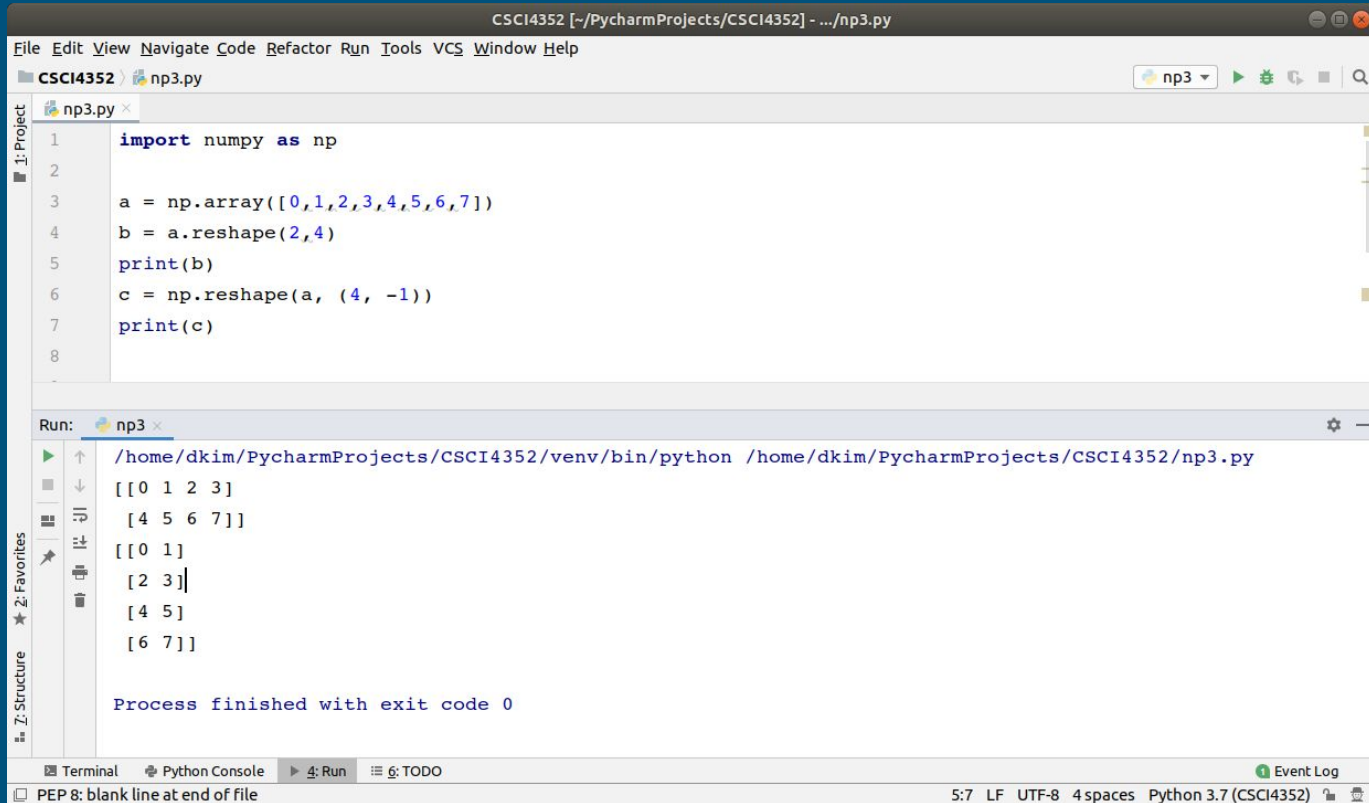
The Run window below the editor shows the execution output for the script:

```
Run: np2
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/PycharmProjects/CSCI4352/np2.py
[0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
[[0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0.]]
[1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]
[0.93099112 0.39442041 0.17131278 0.40676817 0.10021831 0.05366516
 0.21253685 0.94528847 0.70962822 0.9738738 ]
[0. 0.2 0.4 0.6 0.8]
[ 0.          1.66666667  3.33333333  5.          6.66666667  8.33333333
 10.         ]

Process finished with exit code 0
```

The bottom status bar of the IDE indicates the following information: Terminal, Python Console, Run, TODO, Packages installed successfully: Installed packages: 'Keras' (yesterday 4:58 PM), 13:1, LF, UTF-8, 4 spaces, Python 3.7 (CSCI4352), and Event Log.

# reshape ()



The screenshot shows the PyCharm IDE interface. The main editor window displays a Python script named `np3.py` with the following code:

```
1 import numpy as np
2
3 a = np.array([0,1,2,3,4,5,6,7])
4 b = a.reshape(2,4)
5 print(b)
6 c = np.reshape(a, (4, -1))
7 print(c)
8
```

The Run console at the bottom shows the execution output:

```
Run: np3 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/PycharmProjects/CSCI4352/np3.py
[[0 1 2 3]
 [4 5 6 7]]
[[0 1]
 [2 3]
 [4 5]
 [6 7]]
Process finished with exit code 0
```

The status bar at the bottom indicates the file encoding is UTF-8 with 4 spaces, and the Python version is 3.7 (CSCI4352).

## Addition of two vectors (1D array)

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$$A+B = [a_1, a_2]^T + [b_1, b_2]^T = [a_1+b_1, a_2+b_2]^T$$

## Scalar product

$$A \cdot c = [a_1, a_2]^T \cdot c = [a_1 \cdot c, a_2 \cdot c]^T$$



CSCI4352 [~/PycharmProjects/CSCI4352] - .../np3.py

File Edit View Navigate Code Refactor Run Tools VCS Window Help

CSCI4352 > np3.py

```
1 import numpy as np
2
3 a = np.array([0,1,2,3])
4 b = np.array([2,3,1,3])
5 print(a+b)
6
```

Run: np3

```
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python3
[2 4 3 6]

Process finished with exit code 0
```

Terminal Python Console Run TODO Event Log

5:1 LF UTF-8 4 spaces Python 3.7 (CSCI4352)

CSCI4352 [~/PycharmProjects/CSCI4352] - .../np3.py

File Edit View Navigate Code Refactor Run Tools VCS Window Help

CSCI4352 > np3.py

```
1 import numpy as np
2
3 a = np.array([0,1,2,3])
4 b = 3
5 print(a*b)
6
```

Run: np3

```
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python3
[0 3 6 9]

Process finished with exit code 0
```

Terminal Python Console Run TODO Event Log

9:1 LF UTF-8 4 spaces Python 3.7 (CSCI4352)

# Dot product

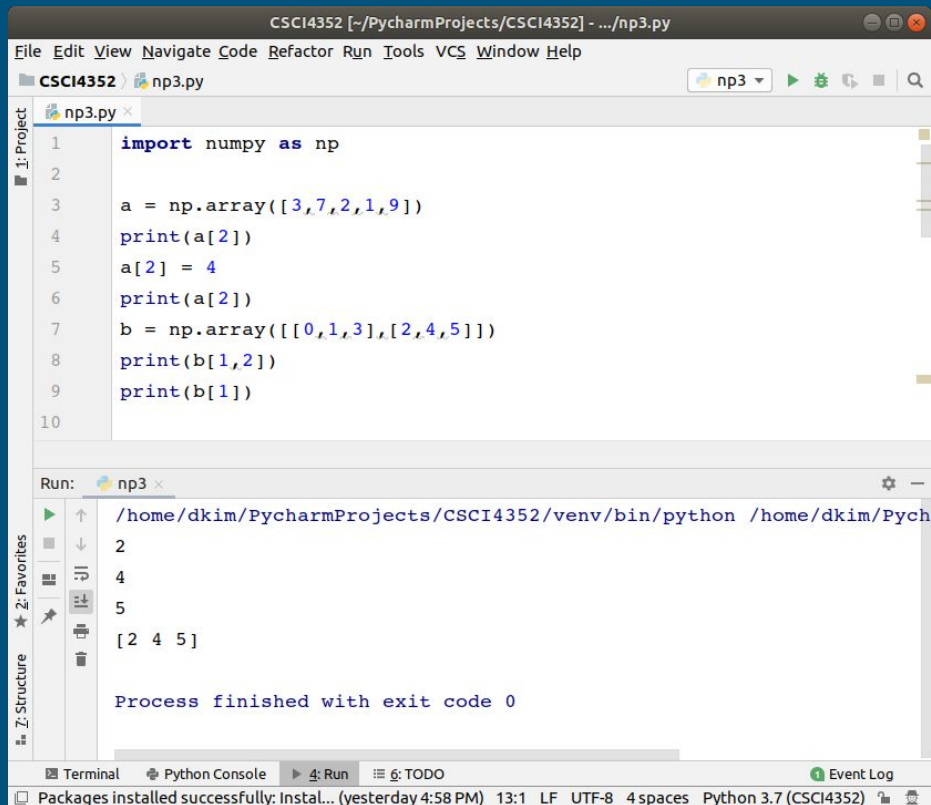
$$a \cdot b = \begin{bmatrix} a_1 & a_2 & a_3 & a_4 & a_5 \end{bmatrix}_{(1 \times n)} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix}_{(n \times 1)} = \left\{ a_1 b_1 + a_2 b_2 + a_3 b_3 + a_4 b_4 + a_5 b_5 \right\}$$

**Dot Product**

```
1 import numpy as np
2
3 a = np.array([0,1,2,3])
4 b = np.array([2,3,1,3])
5 print(np.dot(a,b))
6 c = np.array([0,1,2,3,4,5]).reshape(2,3)
7 d = np.array([0,1,2,3,4,5]).reshape(3,2)
8 print(np.dot(c,d))
9
```

```
▶ ↑ /home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/Pych
◻ ↓ 14
◻ ↺ [[ 10 13]
◻ ↻ [ 28 40]]
▶ ↻
◻ 🗑️ Process finished with exit code 0
```

# Access to elements



The screenshot shows the PyCharm IDE interface. The main editor window displays the following Python code in a file named `np3.py`:

```
1 import numpy as np
2
3 a = np.array([3,7,2,1,9])
4 print(a[2])
5 a[2] = 4
6 print(a[2])
7 b = np.array([[0,1,3],[2,4,5]])
8 print(b[1,2])
9 print(b[1])
10
```

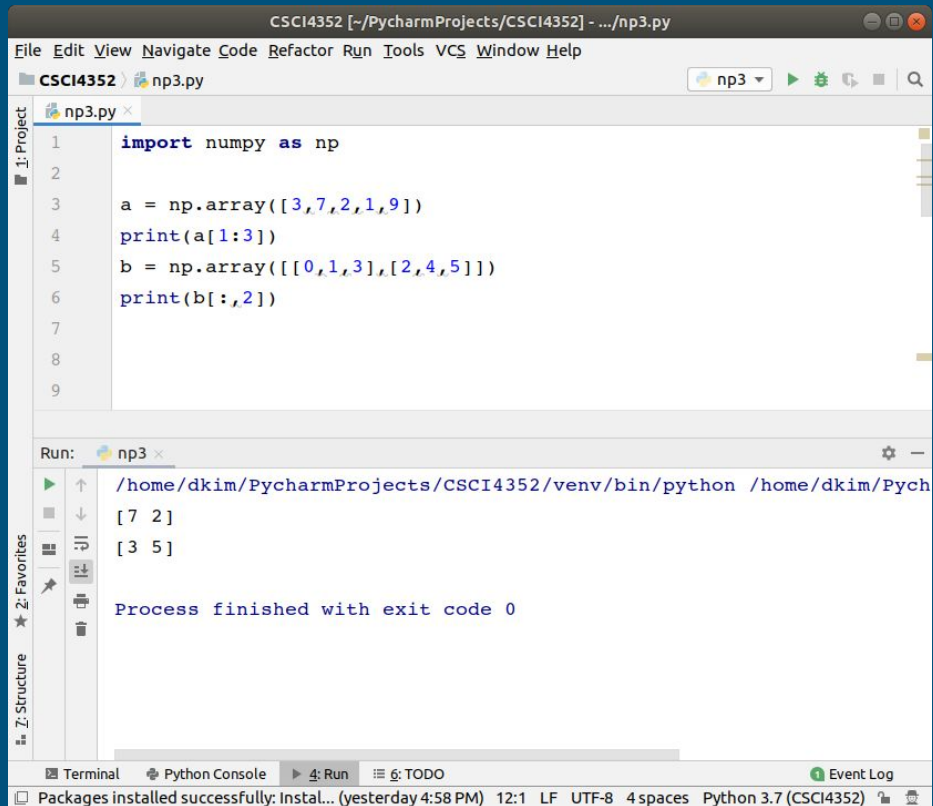
Below the code editor, the Run window shows the execution output for the script:

```
Run: np3 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/Py...
2
4
5
[2 4 5]

Process finished with exit code 0
```

The status bar at the bottom of the IDE indicates: Packages installed successfully: Instal... (yesterday 4:58 PM) 13:1 LF UTF-8 4 spaces Python 3.7 (CSCI4352)

# Slicing



The screenshot shows the PyCharm IDE interface. The main editor window displays a Python script named `np3.py` with the following code:

```
1 import numpy as np
2
3 a = np.array([3,7,2,1,9])
4 print(a[1:3])
5 b = np.array([[0,1,3],[2,4,5]])
6 print(b[:,2])
7
8
9
```

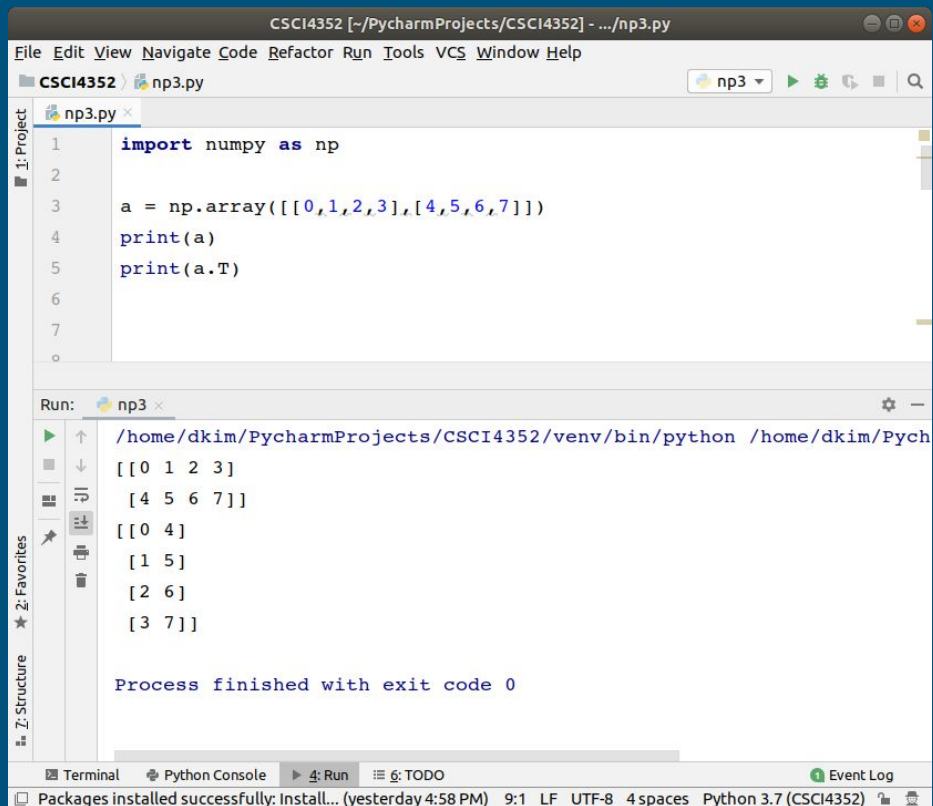
Below the editor, the Run console shows the output of the script:

```
Run: np3 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/Pych
[ 7 2]
[ 3 5]

Process finished with exit code 0
```

The status bar at the bottom indicates the file encoding is UTF-8, the font size is 12:1, and the Python version is 3.7 (CSCI4352).

# Transpose



The screenshot shows the PyCharm IDE interface. The main editor window displays a Python script named `np3.py` with the following code:

```
1 import numpy as np
2
3 a = np.array([[0,1,2,3],[4,5,6,7]])
4 print(a)
5 print(a.T)
6
7
8
```

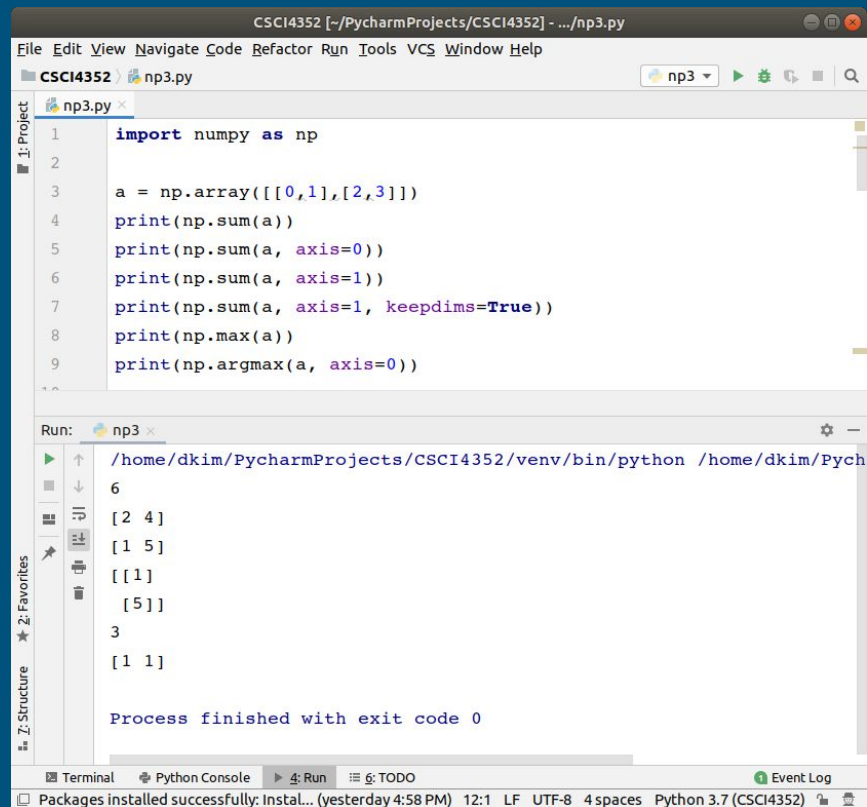
Below the editor, the Run console shows the output of the script:

```
Run: np3 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/Pych
[[0 1 2 3]
 [4 5 6 7]]
[[0 4]
 [1 5]
 [2 6]
 [3 7]]

Process finished with exit code 0
```

The status bar at the bottom indicates that packages were installed successfully and shows the Python version as 3.7 (CSCI4352).

# Numpy functions



The screenshot shows a PyCharm IDE window titled "CSCI4352 [~/PycharmProjects/CSCI4352] - .../np3.py". The editor displays the following Python code:

```
1 import numpy as np
2
3 a = np.array([[0,1],[2,3]])
4 print(np.sum(a))
5 print(np.sum(a, axis=0))
6 print(np.sum(a, axis=1))
7 print(np.sum(a, axis=1, keepdims=True))
8 print(np.max(a))
9 print(np.argmax(a, axis=0))
```

The Run window below the editor shows the execution output:

```
Run: np3 x
/home/dkim/PycharmProjects/CSCI4352/venv/bin/python /home/dkim/Pych
6
[2 4]
[1 5]
[[1]
 [5]]
3
[1 1]

Process finished with exit code 0
```

The status bar at the bottom indicates "Python 3.7 (CSCI4352)" and "Packages installed successfully: Instal... (yesterday 4:58 PM)".

# Lab 5

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Run the example codes and capture screens with outputs.

Submit python files (.py or .ipynb) and captured images of outputs and codes in blackboard.