

Solutions Lecture 1 (Sections 3.1-3.5)

Make sure to import Numpy to be able to use all its functionality.

```
import numpy as np
```

Do not use for- or while-loops when answering the questions below.

Question 1

Create a 3×2 array M of ones. Make sure the elements have data type `int`.

```
# If you don't specify the dtype, then the array will have  
# dtype 'float64' (You can check this with the command: x.dtype)  
x = np.ones((3,2),dtype=int)
```

```
print(x)
```

```
[[1 1]  
 [1 1]  
 [1 1]]
```

Question 2

Create the array $x = [2, 4, 6, 8, \dots, 100]$ once with `np.arange()`, and once with `np.linspace()`.

```
# With arange()  
x = np.arange(2,101,2)  
print(x)
```

```
# With linspace()  
x = np.linspace(2,100,50)  
print(x)
```

```
[ 2  4  6  8 10 12 14 16 18 20 22 24 26 28 30 32 34 36  
 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72  
 74 76 78 80 82 84 86 88 90 92 94 96 98 100]  
[ 2.  4.  6.  8. 10. 12. 14. 16. 18. 20. 22. 24. 26. 28.  
 30. 32. 34. 36. 38. 40. 42. 44. 46. 48. 50. 52. 54. 56.  
 58. 60. 62. 64. 66. 68. 70. 72. 74. 76. 78. 80. 82. 84.]
```

86. 88. 90. 92. 94. 96. 98. 100.]

Question 3

Create the array $x = [-1, -0.9, \dots, -0.1, 0, 0.1, \dots, 0.9, 1]$.

```
# With arange()
x = np.arange(-1,1.1,0.1)
print(x)
```

```
# With linspace()
x = np.linspace(-1,1,21)
print(x)
```

```
[-1.00000000e+00 -9.00000000e-01 -8.00000000e-01 -7.00000000e-01
-6.00000000e-01 -5.00000000e-01 -4.00000000e-01 -3.00000000e-01
-2.00000000e-01 -1.00000000e-01 -2.22044605e-16  1.00000000e-01
 2.00000000e-01  3.00000000e-01  4.00000000e-01  5.00000000e-01
 6.00000000e-01  7.00000000e-01  8.00000000e-01  9.00000000e-01
 1.00000000e+00]
[-1.  -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1  0.   0.1  0.2  0.3
 0.4  0.5  0.6  0.7  0.8  0.9  1. ]
```

Question 4

Consider the two-dimensional array below and answer the questions below.

```
M = np.array([[1,1,1,1,1],[2,1,2,1,2],[2,1,2,1,2],[2,1,2,1,2],[2,1,2,1,2],[1,1,1,1,1]])
print(M)
```

```
[[1 1 1 1 1]
 [2 1 2 1 2]
 [2 1 2 1 2]
 [2 1 2 1 2]
 [2 1 2 1 2]
 [1 1 1 1 1]]
```

a) Index/access the odd-numbered rows of M .

```
M_odd = M[1::2]
print(M_odd)
```

```
[[2 1 2 1 2]
 [2 1 2 1 2]
 [1 1 1 1 1]]
```

b) Index/access the rows and columns that form the submatrix consisting of elements equal to 2.

```
M_2 = M[1:5,0::2]
```

```
print(M_2)
```

```
[[2 2 2]
 [2 2 2]
 [2 2 2]
 [2 2 2]]
```

c) Return the submatrix consisting of the rows 0,1,5 and columns 1,3,4.

```
i = [0,1,5]
```

```
j = [1,3,4]
```

```
print(M[np.ix_(i,j)])
```

```
[[1 1 1]
 [1 1 2]
 [1 1 1]]
```

Question 5

Consider the following array.

```
x = np.array([3,6,4,5,5,5,1,4,2,9,6,7,11,10])
```

```
print(x)
```

```
[ 3  6  4  5  5  5  1  4  2  9  6  7 11 10]
```

a) Use a Boolean mask to access all element whose value is smaller or equal than 4.

```
mask = x <= 4
```

```
print(x[mask])
```

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

b) Use a Boolean mask to access all element whose value is in the interval [5,10].

```
mask = (x >= 5) & (x <= 10)
```

```
print(x[mask])
```

```
[ 6  5  5  5  9  6  7 10]
```

c) Use a Boolean mask to access all element whose value is in the interval [2,4] or [6,9].

```
mask = ((x >= 2) & (x <= 4)) | ((x >= 6) & (x <= 9))
print(x[mask])
```

```
[3 6 4 4 2 9 6 7]
```

Question 6

Take the array $x = [0, 1, 2, 3]$ and convert it to

$$\begin{bmatrix} 0 & 1 & 2 & 3 & 0 & 1 & 2 & 3 \\ 0 & 1 & 2 & 3 & 0 & 1 & 2 & 3 \end{bmatrix}.$$

```
x = np.arange(0,4)
y = np.tile(x,(2,2))
print(y)
```

```
[[0 1 2 3 0 1 2 3]
 [0 1 2 3 0 1 2 3]]
```

Question 7

Construct the following matrix M using appropriate NumPy functions starting from the array $[1, 2, 4]$:

$$\begin{bmatrix} 1 & 1 & 2 & 2 & 4 & 4 \\ 1 & 1 & 2 & 2 & 4 & 4 \end{bmatrix}.$$

```
x = np.array([1,2,4])
x_repeat = np.repeat(x,2)
M = np.tile(x_repeat,(2,1))
print(M)
```

```
[[1 1 2 2 4 4]
 [1 1 2 2 4 4]]
```

Question 8

Write a function `blocks(m,n)` that, for given inputs n and m , returns an $(m+n) \times (m+n)$ matrix that contains an $m \times m$ block of ones on the top left, and an $n \times n$ block of ones on the bottom right (and zeros elsewhere). Use `np.hstack()` and `np.vstack()` in your solution.

For $m = 2$ and $n = 3$, this results in the matrix

$$\begin{bmatrix} 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

```
def blocks(m,n):
    X1 = np.ones((m,m),dtype='int')
    X2 = np.ones((n,n),dtype='int')
    Y1 = np.zeros((m,n),dtype='int')
    Y2 = np.zeros((n,m),dtype='int')
    return np.vstack((np.hstack((X1,Y1)),np.hstack((Y2,X2))))

#Testing
print(blocks(2,3))
```

```
[[1 1 0 0 0]
 [1 1 0 0 0]
 [0 0 1 1 1]
 [0 0 1 1 1]
 [0 0 1 1 1]]
```

Question 9

Write a function `checkerboard(n)` that returns a checkerboard pattern of zeros and ones of size $n \times n$ (see examples below; the top-left element is always a 1).

For $n = 5$ and $n = 6$, the matrix should look like this

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \end{bmatrix}.$$

```
def checkerboard(n):
    x = np.zeros((n,n),dtype=int)
    x[0::2,0::2] = 1
    x[1::2,1::2] = 1
    return x

#Testing
n = 5
print(checkerboard(n))
```

```
n = 6
print(checkerboard(n))
```

```
[[1 0 1 0 1]
 [0 1 0 1 0]
 [1 0 1 0 1]
 [0 1 0 1 0]
 [1 0 1 0 1]]
[[1 0 1 0 1 0]
 [0 1 0 1 0 1]
 [1 0 1 0 1 0]
 [0 1 0 1 0 1]
 [1 0 1 0 1 0]
 [0 1 0 1 0 1]]
```

Question 10

Compute the anti-diagonal of the matrix

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 5 & 6 & -7 \\ -9 & 10 & 11 \end{bmatrix}$$

using `np.rot90()`. The anti-diagonal is obtained by going from the bottom-left to the top-right element, i.e., $[-9, 6, 3]$ in this case (and not $[3, 6, -9]$). Have a look at the documentation of `np.rot90()` for details of how this function works.

```
A = np.array([
    [ 1,  2,  3],
    [ 5,  6, -7],
    [-9, 10, 11]])

# We first rotate the matrix 3*90 = 270 degrees
# and then take the diagonal.
d = np.diag(np.rot90(A,k=3))
print(d)
```

```
[-9  6  3]
```