```
#Task 1
import numpy as np
#number of decision choices
Rm1=0
Lm1=0
Rm2=0
Lm2=0
k=20      #parameter
d=2       #parameter
ants=50
for z in range(0,2):
  for x in range(0,ants):
    r1=np.random.uniform(0,1)         #uniform distribution in the interval [
    Pr1=((Rm1+k)**d)/((Rm1+k)**d+(Lm1+k)**d)  #The probability with which the
    if r1<=Pr1:
      Rm1+=1
    else:
      Lm1+=1
    r2=np.random.uniform(0,1)
    Pr2=((Rm1+k)**d)/((Rm1+k)**d+(Lm1+k)**d)
    if r2<=Pr2:
      Rm2+=1
    else:
      Lm2+=1

print ('Right branch=',Rm1,'Left branch=',Lm1)
print ('Right branch=',Rm2,'Left branch=',Lm2)
```

```
Right branch= 46 Left branch= 54
Right branch= 50 Left branch= 50
```

```
#Task 2

#length of path
Rl1=7
Ll1=3

if Rl1<Ll1:
  print('1 Right path is shorter')
else:
  print('1 Left path is shorter')
Rl2=3
Ll2=7

if Rl2<Ll2:
  print('2 Right path is shorter')
```

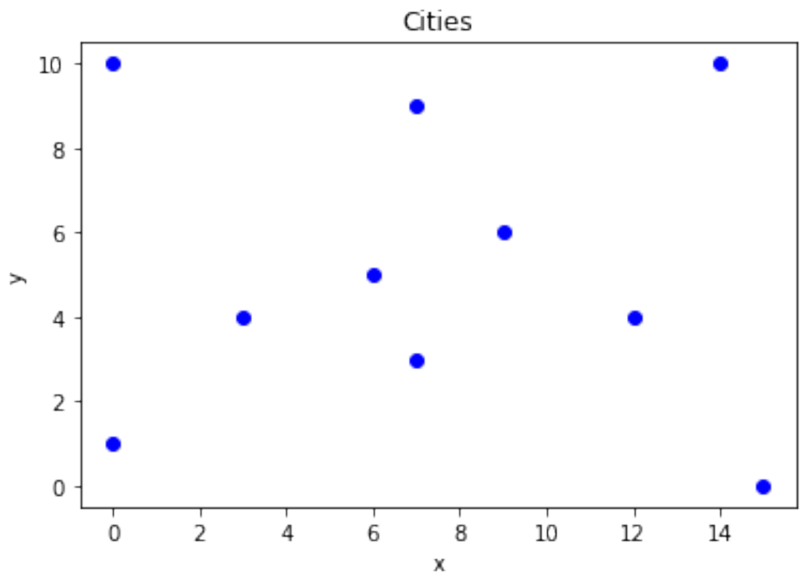
```
else:
  print('2 Left path is shorter')


Rm1=0
Lm1=0
Rm2=0
Lm2=0
#amount pheromone on paths
Rf1=0
Lf1=0
Rf2=0
Lf2=0

#amont pheromone, if the branch is longer ants put less amount of pheromon
Sum1=Rl1+Ll1
r1=1-Rl1/Sum1
l1=1-Ll1/Sum1

Sum2=Rl2+Ll2
r2=1-Rl2/Sum2
l2=1-Ll2/Sum2

for z in range(0,2):
  for x in range(0,ants):
    ra=np.random.uniform(0,1)            #uniform distribution in the interv
    Pr1=((Rf1+k)**d)/((Rf1+k)**d+(Lf1+k)**d)    #The probability with which t
    if ra<Pr1:
      Rm1=Rm1+1
      Rf1=Rf1+r1
    else:
      Lm1=Lm1+1
      Lf1=Lf1+l1

    rb=np.random.uniform(0,1)
    Pr2=((Rf2+k)**d)/((Rf2+k)**d+(Lf2+k)**d)
    if rb<Pr2:
      Rm2=Rm2+1
      Rf2=Rf2+r2
    else:
      Lm2=Lm2+1
      Lf2=Lf2+l2

print('1 Right path',Rm1,'1 Left path',Lm1)
print('2 Right path',Rm2,'2 Left path',Lm2)
```

```
1 Left path is shorter
2 Right path is shorter
1 Right path 30 1 Left path 70
2 Right path 69 2 Left path 31
```

```
#Task 3
import matplotlib.pyplot as plt
import numpy as np
import math
import pandas

# city 1
x = [0, 3, 6, 7, 15, 12, 14, 9, 7, 0]
y = [1, 4, 5, 3, 0, 4, 10, 6, 9, 10]

n=len(x)
ants=n

distance=np.zeros([n,n], dtype=float)
ni=np.zeros([n,n], dtype=float)
a=np.zeros([n,n], dtype=float)
T=np.zeros([n,n], dtype=int)
L=np.zeros(ants, dtype=float)

alfa=1
beta=5
Tmax=200
p=0.5

for i in range (0,n):
  for j in range (0,n):
    distance[i][j]=math.sqrt((x[j]-x[i])**2+(y[j]-y[i])**2)
    ni[i][j]=1/distance[i][j]

t0 = 1/np.amax(distance)
tau = np.full([n,n], t0)


plt.title('Cities')
plt.xlabel('x')
plt.ylabel('y')
plt.plot(x,y,'bo')
pandas.DataFrame(distance).reset_index(drop = True)

```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:27: RuntimeWarr
```

	0	1	2	3	4	5	6	
0	0.000000	4.242641	7.211103	7.280110	15.033296	12.369317	16.643317	10.2956
1	4.242641	0.000000	3.162278	4.123106	12.649111	9.000000	12.529964	6.3245
2	7.211103	3.162278	0.000000	2.236068	10.295630	6.082763	9.433981	3.1622
3	7.280110	4.123106	2.236068	0.000000	8.544004	5.099020	9.899495	3.6055
4	15.033296	12.649111	10.295630	8.544004	0.000000	5.000000	10.049876	8.4852
5	12.369317	9.000000	6.082763	5.099020	5.000000	0.000000	6.324555	3.6055
6	16.643317	12.529964	9.433981	9.899495	10.049876	6.324555	0.000000	6.4031
7	10.295630	6.324555	3.162278	3.605551	8.485281	3.605551	6.403124	0.0000
8	10.630146	6.403124	4.123106	6.000000	12.041595	7.071068	7.071068	3.6055
9	9.000000	6.708204	7.810250	9.899495	18.027756	13.416408	14.000000	9.8488




```
import copy
for przejscie in range(10):
  roads= [] #tablica drog
  road_lens = [] #tablica dystansow
  Delta_t = np.zeros((n,n)) #zmiana feromonu
  for mrowka in range(n): #kazda mrowka zaczyna podroz
    road_l = 0 #poczatkowa dlugosc drogi
    road = [] #miasta w ktorych mrowka byla
    delta_t = np.zeros((n,n)) #inicjacja zmiany feromonu dla danej mrowki
    curr_city = 0 #wszystkie mrowki
    for mrowka_decyzja in range(n-1): #wybor mrowki dla kazdego miasta
```

```
      #liczenie a (decyzje) kazdy wiersz osobno
      denominator = sum([0 if (j in road or curr_city==j) else (tau[curr_city
      d_res = 1/np.array(distance[curr_city])**beta #ni juz do bety
      d_res[curr_city] = 0
      decisions = np.array(tau[curr_city])
      #print(decisions)
      decisions = decisions**alfa
      #print(decisions)
      decisions = [0 if (j in road or curr_city == j) else (decisions[j]*d_re
      #print(decisions)

      #liczenie prawdopodobienstw
      prob = []
      for j in range(n):
        prob.append(decisions[j]/sum(decisions))
      prob = np.array(prob)
      #wybor miasta do ktorego mrowka sie porusza
      prob_pos = 0
      zmienna_wyboru = np.random.uniform(0,1)
      for d in range(n):
        prob_pos += prob[d]
        if zmienna_wyboru < prob_pos:
          wybor = d
          break
      road.append(curr_city)
      road_l += distance[curr_city][wybor]
      delta_t[curr_city][wybor] = 1
      delta_t[wybor][curr_city] = 1
      curr_city = wybor
    road.append(curr_city) #musimy dodac ostatnie miasto bo for idzie do prze
    road_l += distance[curr_city][wybor]
    road_l += distance[wybor][curr_city]
    road.append(0) #wracamy do poczatkowego miasta
    road_l += distance[curr_city][0]
    road_l += distance[0][curr_city]
    delta_t *= 1/road_l #feromon to 1/dlugoscDrogi tam gdzie mrowka sie porus
    Delta_t += delta_t
    roads.append(copy.deepcopy(road)) #dodajemy droge do tablicy drog w danej
    road_lens.append(road_l) #dlugosc tez
  tau = (1-0.5)*tau + Delta_t #update tau razem z ewaporacja

```

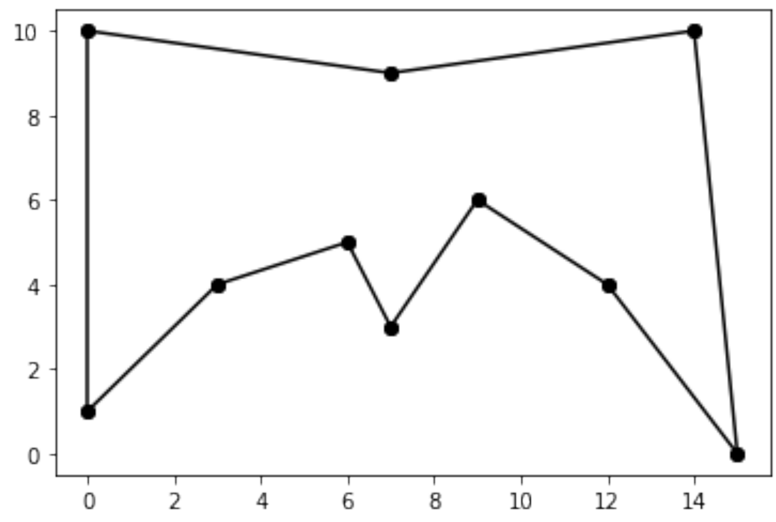
```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:14: RuntimeWarr
```

```
for i in range(n):
  print(roads[i],road_lens[i])
```

```
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 8, 9, 6, 5, 4, 0] 79.31430476466348
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
[0, 1, 2, 3, 7, 5, 4, 6, 8, 9, 0] 64.04410012056726
```

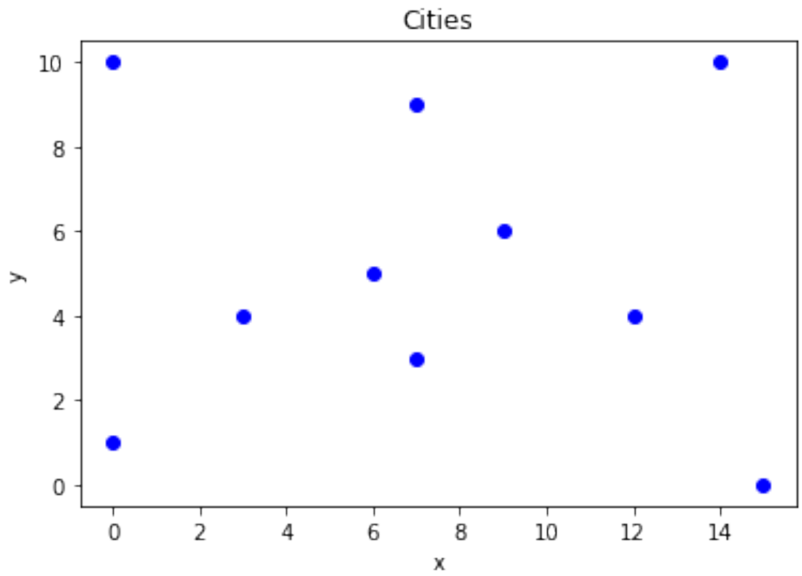
```
def connectpoints(x,y,p1,p2,colour = 'ko-'):
  x1, x2 = x[p1], x[p2]
  y1, y2 = y[p1], y[p2]
  plt.plot([x1,x2],[y1,y2],colour)

```

```

best_road =  min(road_lens)
best_road = roads[max([i if best_road == road_lens[i] else 0 for i in range(n
for i in range(len(best_road)-1):
    connectpoints(x,y,best_road[i],best_road[i+1])
plt.show()

```



```
plt.title('Cities')
plt.xlabel('x')
plt.ylabel('y')
plt.plot(x,y,'bo')
```

```
[<matplotlib.lines.Line2D at 0x7f9212adc908>]
```



For the testing purposes we checked different amount of iterations for the ants. We found out tl closest route possible. For lower amounts there were some roads that were not yet optimized.