Лабораторная работа №4

Вариант №7

Вид классов: `classification`

Random state: `55`

Class sep: `1.5`

Для всех:

`n_features = 2`

`n_redundant = 0`

`n_informative = 2`

`n_clusters_per_class = 1`

`n_classes = 4`

`n_samples = 100`

In [1]:
```python
from sklearn.datasets import make_classification
```

Загрузка выборки согласно варианту №7

In [2]:
```python
X, y = make_classification(n_samples=100,
                           n_features=2,
                           n_redundant=0,
                           n_informative=2,
                           n_clusters_per_class=1,
                           n_classes=4,
                           random_state=55,
                           class_sep=1.5)
```
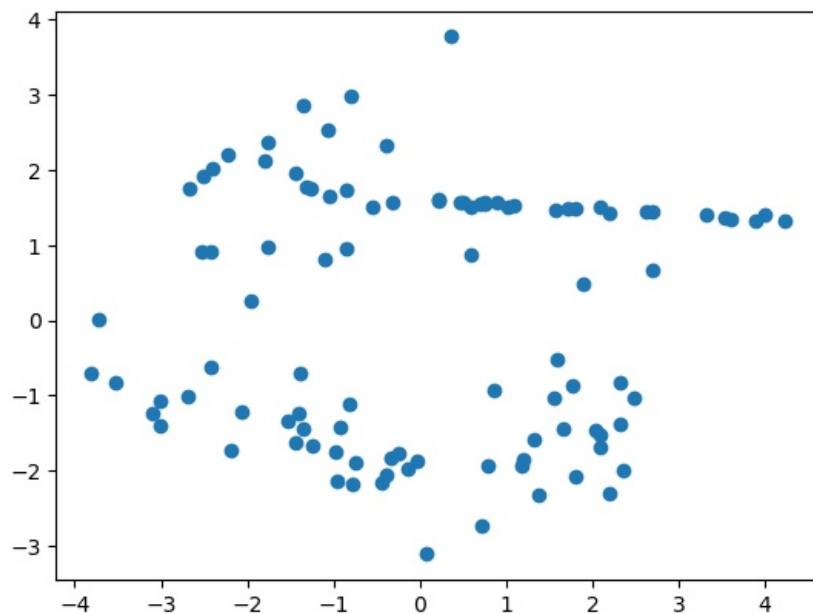
Отображение выборки на графике

In [3]:
```python
import matplotlib.pyplot as plt
```

In [4]:
```python
plt.scatter(X[:, 0], X[:, 1])
```

Out[4]: `<matplotlib.collections.PathCollection at 0x14507c790>`

Иерархическая кластеризация выборки

```python
from scipy.cluster.hierarchy import linkage, dendrogram
```

Расстояние ближайшего соседа (single)

```python
mergings_single = linkage(X, method='single')
mergings_single
```

```
array([[5.50000000e+01, 6.80000000e+01, 1.52210151e-02, 2.00000000e+00],
       [3.00000000e+00, 4.30000000e+01, 3.67553174e-02, 2.00000000e+00],
       [3.80000000e+01, 7.20000000e+01, 4.96617655e-02, 2.00000000e+00],
       [2.60000000e+01, 9.50000000e+01, 5.48418269e-02, 2.00000000e+00],
       [1.60000000e+01, 1.01000000e+02, 5.89391463e-02, 3.00000000e+00],
       [3.60000000e+01, 6.20000000e+01, 6.55950412e-02, 2.00000000e+00],
       [2.30000000e+01, 8.60000000e+01, 7.32334192e-02, 2.00000000e+00],
       [4.20000000e+01, 5.10000000e+01, 7.68651510e-02, 2.00000000e+00],
       [1.20000000e+01, 3.50000000e+01, 8.23646761e-02, 2.00000000e+00],
       [7.80000000e+01, 8.40000000e+01, 8.60879071e-02, 2.00000000e+00],
       [1.90000000e+01, 5.90000000e+01, 8.95418736e-02, 2.00000000e+00],
       [4.90000000e+01, 1.02000000e+02, 9.07691161e-02, 3.00000000e+00],
       [5.20000000e+01, 5.60000000e+01, 1.08135006e-01, 2.00000000e+00],
       [7.00000000e+00, 9.80000000e+01, 1.08767626e-01, 2.00000000e+00],
       [7.90000000e+01, 9.40000000e+01, 1.15887692e-01, 2.00000000e+00],
       [1.04000000e+02, 1.11000000e+02, 1.17926478e-01, 6.00000000e+00],
       [1.70000000e+01, 2.80000000e+01, 1.24046354e-01, 2.00000000e+00],
       [3.00000000e+01, 1.09000000e+02, 1.29410441e-01, 3.00000000e+00],
       [1.15000000e+02, 1.17000000e+02, 1.38853929e-01, 9.00000000e+00],
       [6.70000000e+01, 7.70000000e+01, 1.38861079e-01, 2.00000000e+00],
       [3.40000000e+01, 8.50000000e+01, 1.39770591e-01, 2.00000000e+00],
       [2.90000000e+01, 8.70000000e+01, 1.42955875e-01, 2.00000000e+00],
       [1.80000000e+01, 1.10000000e+02, 1.53935861e-01, 3.00000000e+00],
       [1.40000000e+01, 9.20000000e+01, 1.63194672e-01, 2.00000000e+00],
       [4.80000000e+01, 5.30000000e+01, 1.71764333e-01, 2.00000000e+00],
```

```
                   [4.50000000e+01, 1.06000000e+02, 1.73839874e-01, 3.00000000e+00],
                   [9.60000000e+01, 9.70000000e+01, 1.78584236e-01, 2.00000000e+00],
                   [1.10000000e+01, 1.26000000e+02, 1.84667553e-01, 3.00000000e+00],
                   [1.00000000e+01, 6.00000000e+01, 2.01646467e-01, 2.00000000e+00],
                   [9.00000000e+01, 1.28000000e+02, 2.03129422e-01, 3.00000000e+00],
                   [1.23000000e+02, 1.29000000e+02, 2.03403136e-01, 5.00000000e+00],
                   [4.60000000e+01, 6.50000000e+01, 2.03988132e-01, 2.00000000e+00],
                   [1.30000000e+01, 1.03000000e+02, 2.21150785e-01, 3.00000000e+00],
                   [1.00000000e+00, 1.05000000e+02, 2.26480932e-01, 3.00000000e+00],
                   [1.12000000e+02, 1.13000000e+02, 2.31916131e-01, 4.00000000e+00],
                   [1.21000000e+02, 1.34000000e+02, 2.33746871e-01, 6.00000000e+00],
                   [8.20000000e+01, 1.20000000e+02, 2.37165216e-01, 3.00000000e+00],
                   [6.10000000e+01, 7.50000000e+01, 2.38720376e-01, 2.00000000e+00],
                   [1.00000000e+02, 1.18000000e+02, 2.40288429e-01, 1.10000000e+01],
                   [9.10000000e+01, 1.16000000e+02, 2.47354324e-01, 3.00000000e+00],
                   [1.31000000e+02, 1.32000000e+02, 2.50656349e-01, 5.00000000e+00],
                   [4.70000000e+01, 1.36000000e+02, 2.56140076e-01, 4.00000000e+00],
                   [0.00000000e+00, 2.50000000e+01, 2.58167534e-01, 2.00000000e+00],
                   [2.70000000e+01, 4.10000000e+01, 2.59307900e-01, 2.00000000e+00],
                   [2.00000000e+00, 8.00000000e+01, 2.61372677e-01, 2.00000000e+00],
                   [2.20000000e+01, 8.30000000e+01, 2.64959259e-01, 2.00000000e+00],
                   [5.00000000e+00, 1.25000000e+02, 2.71317620e-01, 4.00000000e+00],
                   [2.40000000e+01, 9.30000000e+01, 2.86089825e-01, 2.00000000e+00],
                   [1.19000000e+02, 1.22000000e+02, 2.86338131e-01, 5.00000000e+00],
                   [1.30000000e+02, 1.44000000e+02, 2.94189477e-01, 7.00000000e+00],
                   [1.33000000e+02, 1.39000000e+02, 2.96073522e-01, 6.00000000e+00],
                   [8.10000000e+01, 1.07000000e+02, 3.00555570e-01, 3.00000000e+00],
                   [1.24000000e+02, 1.49000000e+02, 3.02273011e-01, 9.00000000e+00],
                   [7.60000000e+01, 8.90000000e+01, 3.17326525e-01, 2.00000000e+00],
                   [5.70000000e+01, 1.52000000e+02, 3.25657515e-01, 1.00000000e+01],
                   [7.40000000e+01, 1.27000000e+02, 3.38565070e-01, 4.00000000e+00],
                   [5.40000000e+01, 1.54000000e+02, 3.40568276e-01, 1.10000000e+01],
                   [3.70000000e+01, 6.90000000e+01, 3.42231437e-01, 2.00000000e+00],
                   [1.35000000e+02, 1.56000000e+02, 3.51067282e-01, 1.70000000e+01],
                   [1.45000000e+02, 1.46000000e+02, 3.68242285e-01, 6.00000000e+00],
                   [2.00000000e+01, 1.51000000e+02, 3.69982686e-01, 4.00000000e+00],
                   [1.59000000e+02, 1.60000000e+02, 3.74831997e-01, 1.00000000e+01],
                   [1.37000000e+02, 1.40000000e+02, 3.81552546e-01, 7.00000000e+00],
                   [3.30000000e+01, 1.43000000e+02, 3.81997234e-01, 3.00000000e+00],
                   [6.60000000e+01, 1.61000000e+02, 3.86256619e-01, 1.10000000e+01],
                   [1.42000000e+02, 1.62000000e+02, 3.93534393e-01, 9.00000000e+00],
                   [1.08000000e+02, 1.48000000e+02, 4.18779946e-01, 7.00000000e+00],
                   [1.63000000e+02, 1.64000000e+02, 4.19190656e-01, 1.40000000e+01],
                   [1.57000000e+02, 1.67000000e+02, 4.22926996e-01, 1.60000000e+01],
                   [1.41000000e+02, 1.65000000e+02, 4.32932052e-01, 1.30000000e+01],
                   [6.40000000e+01, 1.68000000e+02, 4.42797550e-01, 1.70000000e+01],
                   [4.40000000e+01, 9.90000000e+01, 4.46303338e-01, 2.00000000e+00],
                   [3.20000000e+01, 1.70000000e+02, 4.48594811e-01, 1.80000000e+01],
                   [5.00000000e+01, 1.55000000e+02, 4.64200659e-01, 5.00000000e+00],
                   [1.38000000e+02, 1.66000000e+02, 4.74616272e-01, 1.80000000e+01],
                   [3.10000000e+01, 5.80000000e+01, 5.28842124e-01, 2.00000000e+00],
                   [1.69000000e+02, 1.74000000e+02, 5.30814677e-01, 3.10000000e+01],
                   [8.00000000e+00, 1.58000000e+02, 5.33762742e-01, 1.80000000e+01],
                   [7.10000000e+01, 1.71000000e+02, 5.40246040e-01, 3.00000000e+00],
                   [1.75000000e+02, 1.77000000e+02, 5.46818875e-01, 2.00000000e+01],
                   [1.53000000e+02, 1.73000000e+02, 5.63926556e-01, 7.00000000e+00],
                   [1.50000000e+02, 1.76000000e+02, 6.16808377e-01, 3.70000000e+01],
                   [1.47000000e+02, 1.81000000e+02, 6.31629656e-01, 3.90000000e+01],
                   [7.00000000e+01, 1.82000000e+02, 6.42728930e-01, 4.00000000e+01],
                   [1.78000000e+02, 1.83000000e+02, 6.43317925e-01, 4.30000000e+01],
                   [1.79000000e+02, 1.80000000e+02, 6.53561127e-01, 2.70000000e+01],
                   [6.30000000e+01, 1.14000000e+02, 6.56161398e-01, 3.00000000e+00],
                   [1.84000000e+02, 1.86000000e+02, 6.72185490e-01, 4.60000000e+01],
                   [3.90000000e+01, 1.87000000e+02, 7.12658077e-01, 4.70000000e+01],
                   [2.10000000e+01, 1.72000000e+02, 7.17295386e-01, 1.90000000e+01],
                   [4.00000000e+01, 1.85000000e+02, 7.25623796e-01, 2.80000000e+01],
                   [7.30000000e+01, 8.80000000e+01, 7.35523341e-01, 2.00000000e+00],
                   [9.00000000e+00, 1.88000000e+02, 7.38881135e-01, 4.80000000e+01],
                   [1.50000000e+01, 1.92000000e+02, 7.79595716e-01, 4.90000000e+01],
                   [1.89000000e+02, 1.91000000e+02, 7.82422321e-01, 2.10000000e+01],
                   [4.00000000e+00, 1.93000000e+02, 8.22662818e-01, 5.00000000e+01],
                   [1.90000000e+02, 1.94000000e+02, 8.27034137e-01, 4.90000000e+01],
                   [1.95000000e+02, 1.96000000e+02, 1.00306315e+00, 9.90000000e+01],
                   [6.00000000e+00, 1.97000000e+02, 1.40154175e+00, 1.00000000e+02]])
```

In [7]:
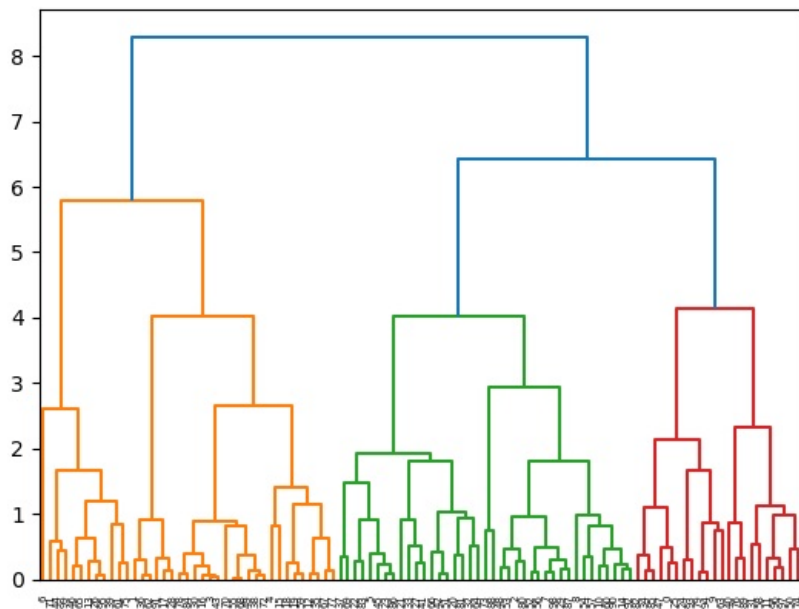```python
dendrogram(mergings_single)
plt.show()
```
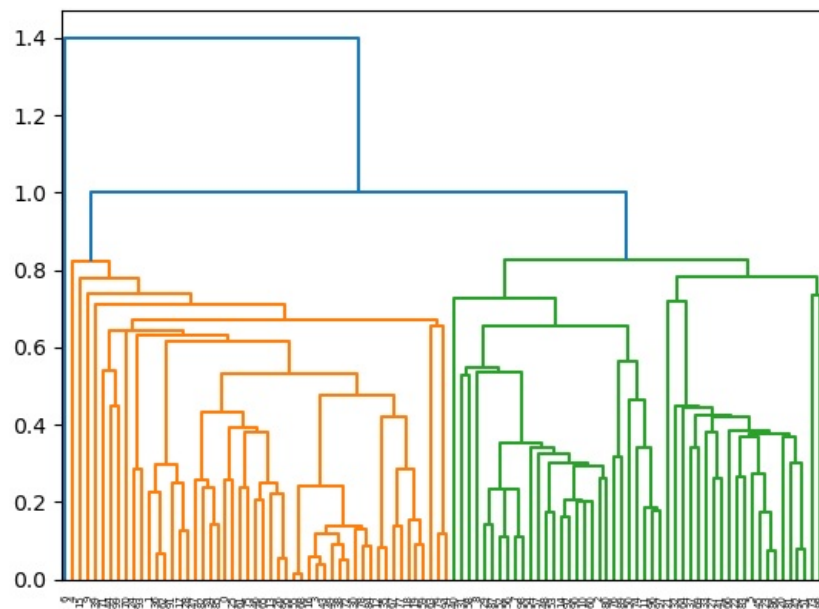
Расстояние дальнего соседа (complete)

```
In [8]:  mergings_complete = linkage(X, method='complete')
         mergings_complete

Out[8]:  array([[5.50000000e+01, 6.80000000e+01, 1.52210151e-02, 2.00000000e+00],
                [3.00000000e+00, 4.30000000e+01, 3.67553174e-02, 2.00000000e+00],
                [3.80000000e+01, 7.20000000e+01, 4.96617655e-02, 2.00000000e+00],
                [2.60000000e+01, 9.50000000e+01, 5.48418269e-02, 2.00000000e+00],
                [1.60000000e+01, 1.01000000e+02, 6.04297320e-02, 3.00000000e+00],
                [3.60000000e+01, 6.20000000e+01, 6.55950412e-02, 2.00000000e+00],
                [2.30000000e+01, 8.60000000e+01, 7.32334192e-02, 2.00000000e+00],
                [4.20000000e+01, 5.10000000e+01, 7.68651510e-02, 2.00000000e+00],
                [1.20000000e+01, 3.50000000e+01, 8.23646761e-02, 2.00000000e+00],
                [7.80000000e+01, 8.40000000e+01, 8.60879071e-02, 2.00000000e+00],
                [1.90000000e+01, 5.90000000e+01, 8.95418736e-02, 2.00000000e+00],
                [5.20000000e+01, 5.60000000e+01, 1.08135006e-01, 2.00000000e+00],
                [7.00000000e+00, 9.80000000e+01, 1.08767626e-01, 2.00000000e+00],
                [7.90000000e+01, 9.40000000e+01, 1.15887692e-01, 2.00000000e+00],
                [1.70000000e+01, 2.80000000e+01, 1.24046354e-01, 2.00000000e+00],
                [4.90000000e+01, 1.02000000e+02, 1.36751150e-01, 3.00000000e+00],
                [6.70000000e+01, 7.70000000e+01, 1.38861079e-01, 2.00000000e+00],
                [3.40000000e+01, 8.50000000e+01, 1.39770591e-01, 2.00000000e+00],
                [2.90000000e+01, 8.70000000e+01, 1.42955875e-01, 2.00000000e+00],
                [1.40000000e+01, 9.20000000e+01, 1.63194672e-01, 2.00000000e+00],
                [4.80000000e+01, 5.30000000e+01, 1.71764333e-01, 2.00000000e+00],
                [9.60000000e+01, 9.70000000e+01, 1.78584236e-01, 2.00000000e+00],
                [3.00000000e+01, 1.04000000e+02, 1.95418198e-01, 4.00000000e+00],
                [1.00000000e+01, 6.00000000e+01, 2.01646467e-01, 2.00000000e+00],
                [4.60000000e+01, 6.50000000e+01, 2.03988132e-01, 2.00000000e+00],
                [9.00000000e+01, 1.19000000e+02, 2.18468654e-01, 3.00000000e+00],
                [4.50000000e+01, 1.06000000e+02, 2.30748334e-01, 3.00000000e+00],
                [6.10000000e+01, 7.50000000e+01, 2.38720376e-01, 2.00000000e+00],
                [1.80000000e+01, 1.10000000e+02, 2.41752688e-01, 3.00000000e+00],
                [0.00000000e+00, 2.50000000e+01, 2.58167534e-01, 2.00000000e+00],
                [2.70000000e+01, 4.10000000e+01, 2.59307900e-01, 2.00000000e+00],
                [2.00000000e+00, 8.00000000e+01, 2.61372677e-01, 2.00000000e+00],
                [2.20000000e+01, 8.30000000e+01, 2.64959259e-01, 2.00000000e+00],
                [1.30000000e+01, 1.03000000e+02, 2.65312318e-01, 3.00000000e+00],
                [2.40000000e+01, 9.30000000e+01, 2.86089825e-01, 2.00000000e+00],
                [1.00000000e+00, 1.05000000e+02, 2.90449746e-01, 3.00000000e+00],
                [1.12000000e+02, 1.18000000e+02, 3.01621414e-01, 4.00000000e+00],
                [7.60000000e+01, 8.90000000e+01, 3.17326525e-01, 2.00000000e+00],
                [1.10000000e+01, 1.21000000e+02, 3.21681696e-01, 3.00000000e+00],
                [9.10000000e+01, 1.14000000e+02, 3.25547129e-01, 3.00000000e+00],
                [5.40000000e+01, 5.70000000e+01, 3.40568276e-01, 2.00000000e+00],
                [3.70000000e+01, 6.90000000e+01, 3.42231437e-01, 2.00000000e+00],
                [2.00000000e+01, 8.10000000e+01, 3.69982686e-01, 2.00000000e+00],
                [1.00000000e+02, 1.15000000e+02, 3.76628638e-01, 5.00000000e+00],
                [8.20000000e+01, 1.17000000e+02, 3.76840212e-01, 3.00000000e+00],
                [5.00000000e+00, 1.26000000e+02, 3.98255691e-01, 4.00000000e+00],
                [1.09000000e+02, 1.22000000e+02, 4.00769418e-01, 6.00000000e+00],
                [6.60000000e+01, 1.07000000e+02, 4.12078966e-01, 3.00000000e+00],
                [4.40000000e+01, 9.90000000e+01, 4.46303338e-01, 2.00000000e+00],
                [5.00000000e+01, 7.40000000e+01, 4.64200659e-01, 2.00000000e+00],
                [1.23000000e+02, 1.25000000e+02, 4.69096511e-01, 5.00000000e+00],
                [1.20000000e+02, 1.31000000e+02, 4.70692750e-01, 4.00000000e+00],
                [1.11000000e+02, 1.36000000e+02, 4.89589482e-01, 6.00000000e+00],
                [4.70000000e+01, 1.29000000e+02, 4.90071088e-01, 3.00000000e+00],
                [3.20000000e+01, 6.40000000e+01, 5.00997412e-01, 2.00000000e+00],
                [3.30000000e+01, 1.30000000e+02, 5.08696058e-01, 3.00000000e+00],
```

```
       [3.10000000e+01, 5.80000000e+01, 5.28842124e-01, 2.00000000e+00],
       [7.10000000e+01, 1.48000000e+02, 5.66875091e-01, 3.00000000e+00],
       [1.08000000e+02, 1.16000000e+02, 6.13749183e-01, 4.00000000e+00],
       [1.24000000e+02, 1.33000000e+02, 6.28500704e-01, 5.00000000e+00],
       [7.30000000e+01, 8.80000000e+01, 7.35523341e-01, 2.00000000e+00],
       [9.00000000e+00, 6.30000000e+01, 7.38881135e-01, 2.00000000e+00],
       [7.00000000e+01, 1.43000000e+02, 8.12548429e-01, 6.00000000e+00],
       [1.40000000e+02, 1.50000000e+02, 8.19579998e-01, 7.00000000e+00],
       [4.00000000e+00, 1.50000000e+01, 8.22662818e-01, 2.00000000e+00],
       [3.90000000e+01, 1.27000000e+02, 8.35591448e-01, 3.00000000e+00],
       [4.00000000e+00, 1.37000000e+02, 8.52735403e-01, 3.00000000e+00],
       [1.13000000e+02, 1.61000000e+02, 8.65135956e-01, 4.00000000e+00],
       [1.46000000e+02, 1.62000000e+02, 8.81593852e-01, 1.20000000e+01],
       [1.32000000e+02, 1.45000000e+02, 8.97913352e-01, 6.00000000e+00],
       [1.35000000e+02, 1.39000000e+02, 9.09307584e-01, 6.00000000e+00],
       [2.10000000e+01, 1.55000000e+02, 9.14270867e-01, 4.00000000e+00],
       [1.42000000e+02, 1.54000000e+02, 9.34910767e-01, 4.00000000e+00],
       [1.51000000e+02, 1.52000000e+02, 9.50203717e-01, 1.00000000e+01],
       [1.38000000e+02, 1.49000000e+02, 9.68046188e-01, 5.00000000e+00],
       [8.00000000e+00, 1.63000000e+02, 9.85271737e-01, 8.00000000e+00],
       [1.47000000e+02, 1.72000000e+02, 1.03272267e+00, 7.00000000e+00],
       [1.44000000e+02, 1.53000000e+02, 1.10120329e+00, 6.00000000e+00],
       [1.56000000e+02, 1.74000000e+02, 1.12365416e+00, 7.00000000e+00],
       [1.28000000e+02, 1.58000000e+02, 1.13715120e+00, 7.00000000e+00],
       [1.59000000e+02, 1.65000000e+02, 1.18758303e+00, 8.00000000e+00],
       [1.64000000e+02, 1.79000000e+02, 1.39168057e+00, 9.00000000e+00],
       [1.41000000e+02, 1.69000000e+02, 1.48379908e+00, 8.00000000e+00],
       [1.57000000e+02, 1.80000000e+02, 1.66472803e+00, 1.10000000e+01],
       [1.34000000e+02, 1.67000000e+02, 1.67009706e+00, 6.00000000e+00],
       [1.73000000e+02, 1.75000000e+02, 1.80466038e+00, 1.80000000e+01],
       [1.71000000e+02, 1.76000000e+02, 1.81466956e+00, 1.10000000e+01],
       [1.82000000e+02, 1.86000000e+02, 1.91504990e+00, 1.90000000e+01],
       [1.77000000e+02, 1.84000000e+02, 2.12260519e+00, 1.20000000e+01],
       [1.66000000e+02, 1.78000000e+02, 2.31516531e+00, 1.00000000e+01],
       [6.00000000e+00, 1.83000000e+02, 2.61101646e+00, 1.20000000e+01],
       [1.68000000e+02, 1.81000000e+02, 2.65214245e+00, 2.10000000e+01],
       [1.60000000e+02, 1.85000000e+02, 2.93164368e+00, 2.00000000e+01],
       [1.70000000e+02, 1.91000000e+02, 4.01628325e+00, 2.70000000e+01],
       [1.87000000e+02, 1.92000000e+02, 4.02196495e+00, 3.90000000e+01],
       [1.88000000e+02, 1.89000000e+02, 4.12859604e+00, 2.20000000e+01],
       [1.90000000e+02, 1.93000000e+02, 5.78545218e+00, 3.90000000e+01],
       [1.94000000e+02, 1.95000000e+02, 6.41138864e+00, 6.10000000e+01],
       [1.96000000e+02, 1.97000000e+02, 8.29563148e+00, 1.00000000e+02]])
```

In [9]:
```python
dendrogram(mergings_complete)
plt.show()
```


Расстояние Уорда (Ward)

In [10]:
```python
mergings_ward = linkage(X, method='ward')
mergings_ward
```
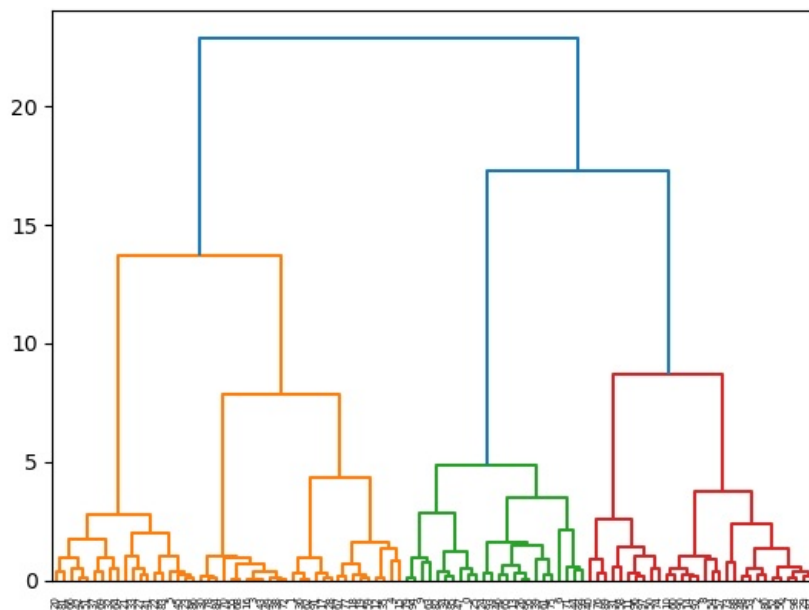
Out[10]:
```
array([[5.50000000e+01, 6.80000000e+01, 1.52210151e-02, 2.00000000e+00],
       [3.00000000e+00, 4.30000000e+01, 3.67553174e-02, 2.00000000e+00],
       [3.80000000e+01, 7.20000000e+01, 4.96617655e-02, 2.00000000e+00],
       [2.60000000e+01, 9.50000000e+01, 5.48418269e-02, 2.00000000e+00],
       [1.60000000e+01, 1.01000000e+02, 6.55748874e-02, 3.00000000e+00],
       [3.60000000e+01, 6.20000000e+01, 6.55950412e-02, 2.00000000e+00],
       [2.30000000e+01, 8.60000000e+01, 7.32334192e-02, 2.00000000e+00],
       [4.20000000e+01, 5.10000000e+01, 7.68651510e-02, 2.00000000e+00],
       [1.20000000e+01, 3.50000000e+01, 8.23646761e-02, 2.00000000e+00],
```

```
[7.80000000e+01, 8.40000000e+01, 8.60879071e-02, 2.00000000e+00],
[1.90000000e+01, 5.90000000e+01, 8.95418736e-02, 2.00000000e+00],
[5.20000000e+01, 5.60000000e+01, 1.08135006e-01, 2.00000000e+00],
[7.00000000e+00, 9.80000000e+01, 1.08767626e-01, 2.00000000e+00],
[7.90000000e+01, 9.40000000e+01, 1.15887692e-01, 2.00000000e+00],
[1.70000000e+01, 2.80000000e+01, 1.24046354e-01, 2.00000000e+00],
[4.90000000e+01, 1.02000000e+02, 1.30911584e-01, 3.00000000e+00],
[6.70000000e+01, 7.70000000e+01, 1.38861079e-01, 2.00000000e+00],
[3.40000000e+01, 8.50000000e+01, 1.39770591e-01, 2.00000000e+00],
[2.90000000e+01, 8.70000000e+01, 1.42955875e-01, 2.00000000e+00],
[1.40000000e+01, 9.20000000e+01, 1.63194672e-01, 2.00000000e+00],
[4.80000000e+01, 5.30000000e+01, 1.71764333e-01, 2.00000000e+00],
[9.60000000e+01, 9.70000000e+01, 1.78584236e-01, 2.00000000e+00],
[3.00000000e+01, 1.09000000e+02, 1.92298386e-01, 3.00000000e+00],
[1.00000000e+01, 6.00000000e+01, 2.01646467e-01, 2.00000000e+00],
[4.60000000e+01, 6.50000000e+01, 2.03988132e-01, 2.00000000e+00],
[9.00000000e+01, 1.19000000e+02, 2.24774165e-01, 3.00000000e+00],
[1.80000000e+01, 1.10000000e+02, 2.28227573e-01, 3.00000000e+00],
[4.50000000e+01, 1.06000000e+02, 2.32068278e-01, 3.00000000e+00],
[6.10000000e+01, 7.50000000e+01, 2.38720376e-01, 2.00000000e+00],
[0.00000000e+00, 2.50000000e+01, 2.58167534e-01, 2.00000000e+00],
[2.70000000e+01, 4.10000000e+01, 2.59307900e-01, 2.00000000e+00],
[2.00000000e+00, 8.00000000e+01, 2.61372677e-01, 2.00000000e+00],
[2.20000000e+01, 8.30000000e+01, 2.64959259e-01, 2.00000000e+00],
[1.30000000e+01, 1.03000000e+02, 2.80231432e-01, 3.00000000e+00],
[1.10000000e+01, 1.21000000e+02, 2.84763122e-01, 3.00000000e+00],
[2.40000000e+01, 9.30000000e+01, 2.86089825e-01, 2.00000000e+00],
[1.00000000e+00, 1.05000000e+02, 2.98332379e-01, 3.00000000e+00],
[7.60000000e+01, 8.90000000e+01, 3.17326525e-01, 2.00000000e+00],
[9.10000000e+01, 1.14000000e+02, 3.26058631e-01, 3.00000000e+00],
[1.12000000e+02, 1.18000000e+02, 3.37558829e-01, 4.00000000e+00],
[5.40000000e+01, 5.70000000e+01, 3.40568276e-01, 2.00000000e+00],
[3.70000000e+01, 6.90000000e+01, 3.42231437e-01, 2.00000000e+00],
[8.20000000e+01, 1.17000000e+02, 3.54483639e-01, 3.00000000e+00],
[2.00000000e+01, 8.10000000e+01, 3.69982686e-01, 2.00000000e+00],
[1.04000000e+02, 1.15000000e+02, 3.71013926e-01, 6.00000000e+00],
[5.00000000e+00, 1.27000000e+02, 3.80057362e-01, 4.00000000e+00],
[4.40000000e+01, 9.90000000e+01, 4.46303338e-01, 2.00000000e+00],
[6.60000000e+01, 1.07000000e+02, 4.59020061e-01, 3.00000000e+00],
[5.00000000e+01, 7.40000000e+01, 4.64200659e-01, 2.00000000e+00],
[1.20000000e+02, 1.31000000e+02, 4.79888904e-01, 4.00000000e+00],
[3.30000000e+01, 1.30000000e+02, 4.97375293e-01, 3.00000000e+00],
[1.23000000e+02, 1.25000000e+02, 4.97828546e-01, 5.00000000e+00],
[3.20000000e+01, 6.40000000e+01, 5.00997412e-01, 2.00000000e+00],
[4.70000000e+01, 1.29000000e+02, 5.12688727e-01, 3.00000000e+00],
[3.10000000e+01, 5.80000000e+01, 5.28842124e-01, 2.00000000e+00],
[1.11000000e+02, 1.39000000e+02, 5.39403913e-01, 6.00000000e+00],
[7.10000000e+01, 1.46000000e+02, 5.85160842e-01, 3.00000000e+00],
[1.24000000e+02, 1.33000000e+02, 6.48824113e-01, 5.00000000e+00],
[1.16000000e+02, 1.26000000e+02, 6.98944573e-01, 5.00000000e+00],
[1.00000000e+02, 1.44000000e+02, 7.08386548e-01, 8.00000000e+00],
[7.30000000e+01, 8.80000000e+01, 7.35523341e-01, 2.00000000e+00],
[9.00000000e+00, 6.30000000e+01, 7.38881135e-01, 2.00000000e+00],
[4.00000000e+00, 1.50000000e+01, 8.22662818e-01, 2.00000000e+00],
[4.00000000e+01, 1.37000000e+02, 8.95670884e-01, 3.00000000e+00],
[8.00000000e+00, 1.40000000e+02, 8.99708380e-01, 3.00000000e+00],
[3.90000000e+01, 1.28000000e+02, 9.10542587e-01, 3.00000000e+00],
[1.43000000e+02, 1.47000000e+02, 9.18175757e-01, 5.00000000e+00],
[7.00000000e+01, 1.59000000e+02, 9.25827262e-01, 9.00000000e+00],
[1.36000000e+02, 1.38000000e+02, 9.52496108e-01, 6.00000000e+00],
[1.13000000e+02, 1.61000000e+02, 9.61422118e-01, 4.00000000e+00],
[1.41000000e+02, 1.52000000e+02, 9.66234126e-01, 4.00000000e+00],
[2.10000000e+01, 1.50000000e+02, 9.79097482e-01, 4.00000000e+00],
[1.34000000e+02, 1.48000000e+02, 9.95604531e-01, 5.00000000e+00],
[1.22000000e+02, 1.67000000e+02, 9.99634645e-01, 1.20000000e+01],
[1.51000000e+02, 1.64000000e+02, 1.01565017e+00, 8.00000000e+00],
[1.32000000e+02, 1.45000000e+02, 1.03875248e+00, 6.00000000e+00],
[1.42000000e+02, 1.53000000e+02, 1.18985107e+00, 6.00000000e+00],
[1.49000000e+02, 1.55000000e+02, 1.31945184e+00, 1.00000000e+01],
[1.08000000e+02, 1.62000000e+02, 1.32751403e+00, 4.00000000e+00],
[1.54000000e+02, 1.72000000e+02, 1.38692714e+00, 7.00000000e+00],
[1.57000000e+02, 1.65000000e+02, 1.48693534e+00, 8.00000000e+00],
[1.58000000e+02, 1.78000000e+02, 1.60976753e+00, 9.00000000e+00],
[1.35000000e+02, 1.80000000e+02, 1.61905603e+00, 1.00000000e+01],
[1.66000000e+02, 1.70000000e+02, 1.73941959e+00, 9.00000000e+00],
[1.71000000e+02, 1.75000000e+02, 1.99750019e+00, 1.00000000e+01],
[6.00000000e+00, 1.56000000e+02, 2.13019401e+00, 4.00000000e+00],
[1.60000000e+02, 1.77000000e+02, 2.40152989e+00, 1.20000000e+01],
[1.63000000e+02, 1.79000000e+02, 2.55370371e+00, 1.00000000e+01],
[1.83000000e+02, 1.84000000e+02, 2.74289933e+00, 1.90000000e+01],
[1.69000000e+02, 1.76000000e+02, 2.84595144e+00, 1.00000000e+01],
[1.82000000e+02, 1.85000000e+02, 3.46604598e+00, 1.40000000e+01],
[1.74000000e+02, 1.86000000e+02, 3.77524844e+00, 2.00000000e+01],
[1.68000000e+02, 1.81000000e+02, 4.34835389e+00, 1.50000000e+01],
[1.89000000e+02, 1.90000000e+02, 4.87278370e+00, 2.40000000e+01],
[1.73000000e+02, 1.92000000e+02, 7.85744741e+00, 2.70000000e+01],
[1.87000000e+02, 1.91000000e+02, 8.69233528e+00, 3.00000000e+01],
[1.88000000e+02, 1.94000000e+02, 1.37321214e+01, 4.60000000e+01],
[1.93000000e+02, 1.95000000e+02, 1.72988918e+01, 5.40000000e+01],
```

```
                            [1.96000000e+02, 1.97000000e+02, 2.29068740e+01, 1.00000000e+02]])
```

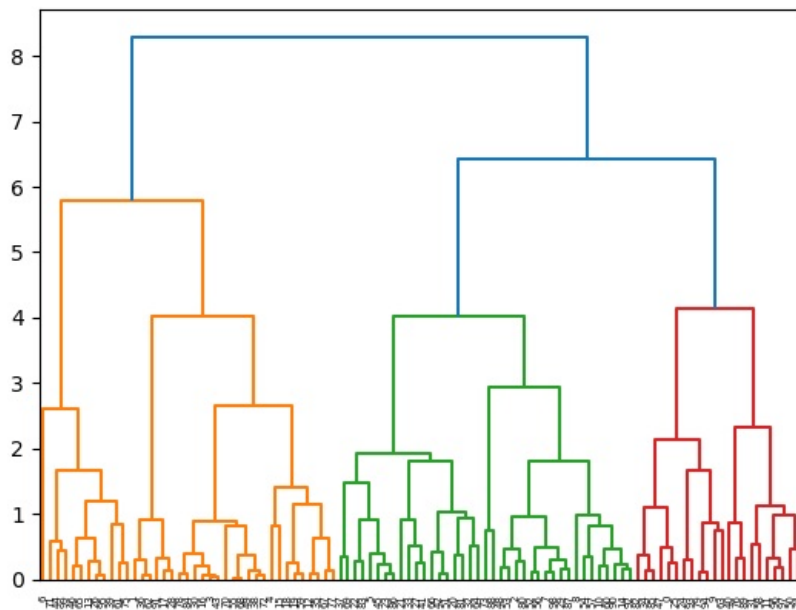In [11]:
```
dendrogram(mergings_ward)
plt.show()
```


Выбор лучшего разбиения

In [12]:
```
mergings_complete = linkage(X, method='complete')
mergings_complete
```

Out[12]:
```
array([[5.50000000e+01, 6.80000000e+01, 1.52210151e-02, 2.00000000e+00],
       [3.00000000e+00, 4.30000000e+01, 3.67553174e-02, 2.00000000e+00],
       [3.80000000e+01, 7.20000000e+01, 4.96617655e-02, 2.00000000e+00],
       [2.60000000e+01, 9.50000000e+01, 5.48418269e-02, 2.00000000e+00],
       [1.60000000e+01, 1.01000000e+02, 6.04297320e-02, 3.00000000e+00],
       [3.60000000e+01, 6.20000000e+01, 6.55950412e-02, 2.00000000e+00],
       [2.30000000e+01, 8.60000000e+01, 7.32334192e-02, 2.00000000e+00],
       [4.20000000e+01, 5.10000000e+01, 7.68651510e-02, 2.00000000e+00],
       [1.20000000e+01, 3.50000000e+01, 8.23646761e-02, 2.00000000e+00],
       [7.80000000e+01, 8.40000000e+01, 8.60879071e-02, 2.00000000e+00],
       [1.90000000e+01, 5.90000000e+01, 8.95418736e-02, 2.00000000e+00],
       [5.20000000e+01, 5.60000000e+01, 1.08135006e-01, 2.00000000e+00],
       [7.00000000e+00, 9.80000000e+01, 1.08767626e-01, 2.00000000e+00],
       [7.90000000e+01, 9.40000000e+01, 1.15887692e-01, 2.00000000e+00],
       [1.70000000e+01, 2.80000000e+01, 1.24046354e-01, 2.00000000e+00],
       [4.90000000e+01, 1.02000000e+02, 1.36751150e-01, 3.00000000e+00],
       [6.70000000e+01, 7.70000000e+01, 1.38861079e-01, 2.00000000e+00],
       [3.40000000e+01, 8.50000000e+01, 1.39770591e-01, 2.00000000e+00],
       [2.90000000e+01, 8.70000000e+01, 1.42955875e-01, 2.00000000e+00],
       [1.40000000e+01, 9.20000000e+01, 1.63194672e-01, 2.00000000e+00],
       [4.80000000e+01, 5.30000000e+01, 1.71764333e-01, 2.00000000e+00],
       [9.60000000e+01, 9.70000000e+01, 1.78584236e-01, 2.00000000e+00],
       [3.00000000e+01, 1.04000000e+02, 1.95418198e-01, 4.00000000e+00],
       [1.00000000e+01, 6.00000000e+01, 2.01646467e-01, 2.00000000e+00],
       [4.60000000e+01, 6.50000000e+01, 2.03988132e-01, 2.00000000e+00],
       [9.00000000e+01, 1.19000000e+02, 2.18468654e-01, 3.00000000e+00],
       [4.50000000e+01, 1.06000000e+02, 2.30748334e-01, 3.00000000e+00],
       [6.10000000e+01, 7.50000000e+01, 2.38720376e-01, 2.00000000e+00],
       [1.80000000e+01, 1.10000000e+02, 2.41752688e-01, 3.00000000e+00],
       [0.00000000e+00, 2.50000000e+01, 2.58167534e-01, 2.00000000e+00],
       [2.70000000e+01, 4.10000000e+01, 2.59307900e-01, 2.00000000e+00],
       [2.00000000e+00, 8.00000000e+01, 2.61372677e-01, 2.00000000e+00],
       [2.20000000e+01, 8.30000000e+01, 2.64959259e-01, 2.00000000e+00],
       [1.30000000e+01, 1.03000000e+02, 2.65312318e-01, 3.00000000e+00],
       [2.40000000e+01, 9.30000000e+01, 2.86089825e-01, 2.00000000e+00],
       [1.00000000e+00, 1.05000000e+02, 2.90449746e-01, 3.00000000e+00],
       [1.12000000e+02, 1.18000000e+02, 3.01621414e-01, 4.00000000e+00],
       [7.60000000e+01, 8.90000000e+01, 3.17326525e-01, 2.00000000e+00],
       [1.10000000e+01, 1.21000000e+02, 3.21681696e-01, 3.00000000e+00],
       [9.10000000e+01, 1.14000000e+02, 3.25547129e-01, 3.00000000e+00],
       [5.40000000e+01, 5.70000000e+01, 3.40568276e-01, 2.00000000e+00],
       [3.70000000e+01, 6.90000000e+01, 3.42231437e-01, 2.00000000e+00],
       [2.00000000e+01, 8.10000000e+01, 3.69982686e-01, 2.00000000e+00],
       [1.00000000e+02, 1.15000000e+02, 3.76628638e-01, 5.00000000e+00],
       [8.20000000e+01, 1.17000000e+02, 3.76840212e-01, 3.00000000e+00],
       [5.00000000e+00, 1.26000000e+02, 3.98255691e-01, 4.00000000e+00],
       [1.09000000e+02, 1.22000000e+02, 4.00769418e-01, 6.00000000e+00],
       [6.60000000e+01, 1.07000000e+02, 4.12078966e-01, 3.00000000e+00],
       [4.40000000e+01, 9.90000000e+01, 4.46303338e-01, 2.00000000e+00],
       [5.00000000e+01, 7.40000000e+01, 4.64200659e-01, 2.00000000e+00],
       [1.23000000e+02, 1.25000000e+02, 4.69096511e-01, 5.00000000e+00],
```

```
        [1.20000000e+02, 1.31000000e+02, 4.70692750e-01, 4.00000000e+00],
        [1.11000000e+02, 1.36000000e+02, 4.89589482e-01, 6.00000000e+00],
        [4.70000000e+01, 1.29000000e+02, 4.90071088e-01, 3.00000000e+00],
        [3.20000000e+01, 6.40000000e+01, 5.00997412e-01, 2.00000000e+00],
        [3.30000000e+01, 1.30000000e+02, 5.08696058e-01, 3.00000000e+00],
        [3.10000000e+01, 5.80000000e+01, 5.28842124e-01, 2.00000000e+00],
        [7.10000000e+01, 1.48000000e+02, 5.66875091e-01, 3.00000000e+00],
        [1.08000000e+02, 1.16000000e+02, 6.13749183e-01, 4.00000000e+00],
        [1.24000000e+02, 1.33000000e+02, 6.28500704e-01, 5.00000000e+00],
        [7.30000000e+01, 8.80000000e+01, 7.35523341e-01, 2.00000000e+00],
        [9.00000000e+00, 6.30000000e+01, 7.38881135e-01, 2.00000000e+00],
        [7.00000000e+01, 1.43000000e+02, 8.12548429e-01, 6.00000000e+00],
        [1.40000000e+02, 1.50000000e+02, 8.19579998e-01, 7.00000000e+00],
        [4.00000000e+00, 1.50000000e+01, 8.22662818e-01, 2.00000000e+00],
        [3.90000000e+01, 1.27000000e+02, 8.35591448e-01, 3.00000000e+00],
        [4.00000000e+01, 1.37000000e+02, 8.52735403e-01, 3.00000000e+00],
        [1.13000000e+02, 1.61000000e+02, 8.65135956e-01, 4.00000000e+00],
        [1.46000000e+02, 1.62000000e+02, 8.81593852e-01, 1.20000000e+01],
        [1.32000000e+02, 1.45000000e+02, 8.97913352e-01, 6.00000000e+00],
        [1.35000000e+02, 1.39000000e+02, 9.09307584e-01, 6.00000000e+00],
        [2.10000000e+01, 1.55000000e+02, 9.14270867e-01, 4.00000000e+00],
        [1.42000000e+02, 1.54000000e+02, 9.34910767e-01, 4.00000000e+00],
        [1.51000000e+02, 1.52000000e+02, 9.50203717e-01, 1.00000000e+01],
        [1.38000000e+02, 1.49000000e+02, 9.68046188e-01, 5.00000000e+00],
        [8.00000000e+00, 1.63000000e+02, 9.85271737e-01, 8.00000000e+00],
        [1.47000000e+02, 1.72000000e+02, 1.03272267e+00, 7.00000000e+00],
        [1.44000000e+02, 1.53000000e+02, 1.10120329e+00, 6.00000000e+00],
        [1.56000000e+02, 1.74000000e+02, 1.12365416e+00, 7.00000000e+00],
        [1.28000000e+02, 1.58000000e+02, 1.13715120e+00, 7.00000000e+00],
        [1.59000000e+02, 1.65000000e+02, 1.18758303e+00, 8.00000000e+00],
        [1.64000000e+02, 1.79000000e+02, 1.39168057e+00, 9.00000000e+00],
        [1.41000000e+02, 1.69000000e+02, 1.48379908e+00, 8.00000000e+00],
        [1.57000000e+02, 1.80000000e+02, 1.66472803e+00, 1.10000000e+01],
        [1.34000000e+02, 1.67000000e+02, 1.67009706e+00, 6.00000000e+00],
        [1.73000000e+02, 1.75000000e+02, 1.80466038e+00, 1.80000000e+01],
        [1.71000000e+02, 1.76000000e+02, 1.81466956e+00, 1.10000000e+01],
        [1.82000000e+02, 1.86000000e+02, 1.91504990e+00, 1.90000000e+01],
        [1.77000000e+02, 1.84000000e+02, 2.12260519e+00, 1.20000000e+01],
        [1.66000000e+02, 1.78000000e+02, 2.31516531e+00, 1.00000000e+01],
        [6.00000000e+00, 1.83000000e+02, 2.61101646e+00, 1.20000000e+01],
        [1.68000000e+02, 1.81000000e+02, 2.65214245e+00, 2.10000000e+01],
        [1.60000000e+02, 1.85000000e+02, 2.93164368e+00, 2.00000000e+01],
        [1.70000000e+02, 1.91000000e+02, 4.01628325e+00, 2.70000000e+01],
        [1.87000000e+02, 1.92000000e+02, 4.02196495e+00, 3.90000000e+01],
        [1.88000000e+02, 1.89000000e+02, 4.12859604e+00, 2.20000000e+01],
        [1.90000000e+02, 1.93000000e+02, 5.78545218e+00, 3.90000000e+01],
        [1.94000000e+02, 1.95000000e+02, 6.41138864e+00, 6.10000000e+01],
        [1.96000000e+02, 1.97000000e+02, 8.29563148e+00, 1.00000000e+02]])
```

In [13]:
```python
dendrogram(mergings_complete)
plt.show()
```


In [14]:
```python
import numpy as np

def update_cluster_centers(X, c):
    centers = np.zeros((4, 2))
    for i in range(1, 5):
        ix = np.where(c == i)
        centers[i - 1, :] = np.mean(X[ix, :], axis=1)
    return centers
```

In [15]:
```python
from scipy.cluster.hierarchy import fcluster
```
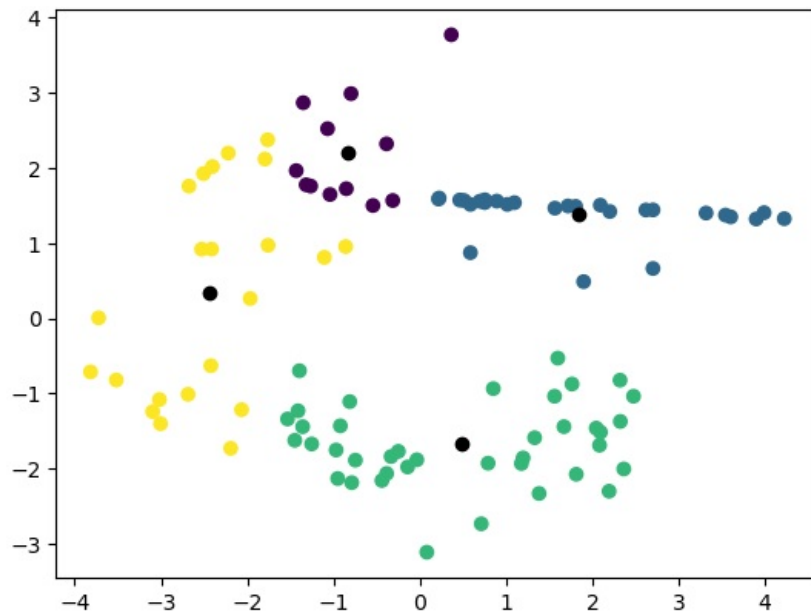
```
In [16]: T = fcluster(mergings_complete, 4, criterion='maxclust')
         clusters = update_cluster_centers(X, T)
         clusters

Out[16]: array([[-0.83398004,  2.20223549],
                [ 1.83982999,  1.39295948],
                [ 0.47828555, -1.66158024],
                [-2.4341005 ,  0.33631672]])

In [17]: plt.scatter(X[:, 0], X[:, 1], c=T)
         plt.scatter(clusters[:, 0], clusters[:, 1], c='black')

Out[17]: <matplotlib.collections.PathCollection at 0x145273650>
```


Вычисление характеристик

```
In [18]: from sklearn.metrics.pairwise import euclidean_distances

In [34]: # Сумма квадратов расстояний до центроида (inertia)
         sum_sq_dist = np.zeros(4)
         for i in range(1, 5):
             ix = np.where(T == i)
             sum_sq_dist[i - 1] = np.sum(euclidean_distances(*X[ix, :], [clusters[i - 1]]) ** 2)
         sum_sq_dist = np.sum(sum_sq_dist) / 4
         sum_sq_dist

Out[34]: 46.816598779185185

In [20]: # Сумма средних внутрикластерных расстояний
         sum_avg_intercluster_dist = np.zeros(4)
         for i in range(1, 5):
             ix = np.where(T == i)
             sum_avg_intercluster_dist[i - 1] = np.sum(euclidean_distances(*X[ix, :], [clusters[i - 1]]) ** 2) / len(*X[
         sum_avg_intercluster_dist = np.sum(sum_avg_intercluster_dist) / 4
         sum_avg_intercluster_dist

Out[20]: 1.708069605190309

In [21]: # Сумма межкластерных расстояний
         sum_intercluster_dist = np.sum(euclidean_distances(clusters, clusters))
         sum_intercluster_dist

Out[21]: 41.22177711444111
```

Кластеризация выборки методом k-средних

```
In [22]: from sklearn.cluster import KMeans

In [23]: models = []
         predicted_values = []

         for k in range(1, 11):
             kmeans = KMeans(n_clusters=k)
             kmeans.fit(X)
             models.append(kmeans)
             predicted_values.append(kmeans.predict(X))
```

```
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
/Users/alex/anaconda3/lib/python3.11/site-packages/sklearn/cluster/_kmeans.py:1412: FutureWarning: The default
value of `n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init` explicitly to suppress the wa
rning
  super()._check_params_vs_input(X, default_n_init=10)
```

In [24]:
```python
# Средней суммы квадратов расстояний до центроида
sum_sq_dist_avg = []
for it, kmean in enumerate(models):
    sum_sq_dist_avg.append(kmean.inertia_ / (it + 1))
sum_sq_dist_avg
```

Out[24]:
```
[646.3560779131652,
 189.2156519671821,
 73.24361867072788,
 33.804278557782894,
 20.06091255860947,
 11.025843176738787,
 8.177674127178951,
 6.137711546018515,
 4.592302738432533,
 3.6597898015447585]
```
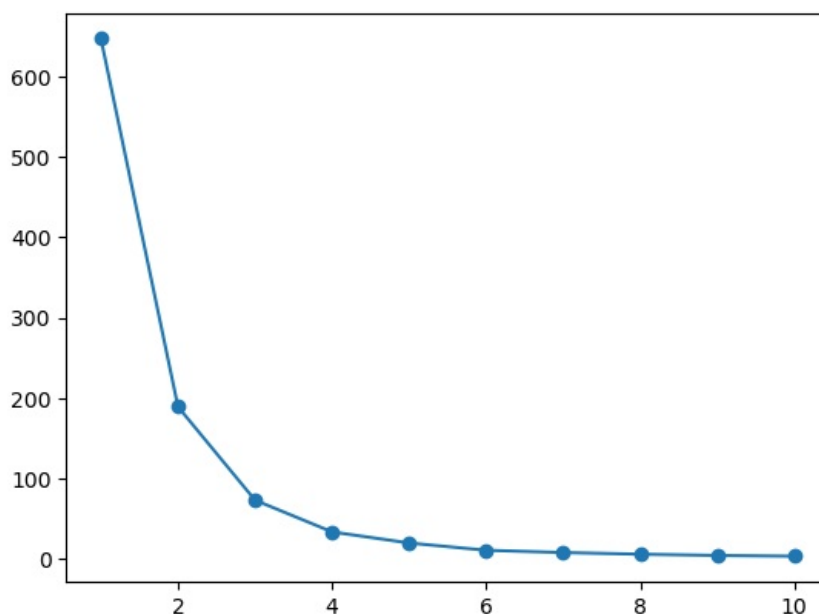
In [25]:
```python
plt.plot(range(1, 11), sum_sq_dist_avg, '-o')
```

Out[25]:
```
[<matplotlib.lines.Line2D at 0x15e3081d0>]
```


In [26]: # Средней суммы средних внутрикластерных расстояний

```
In [26]: # Средней суммы средних внутрикластерных расстояний
         new_centers = [kmean.cluster_centers_ for kmean in models]

         sum_avg_intercluster_dist_avg = []
         for k, kmean in enumerate(models):
             intercluster_sum = np.zeros(4)
             for i in range(4):
                 ix = np.where(predicted_values[k] == i)
                 if len(ix[0]) == 0:
                     intercluster_sum[i - 1] = 0
                 else:
                     intercluster_sum[i - 1] = np.sum(euclidean_distances(*X[ix, :], [kmean.cluster_centers_[i - 1]]) **
             sum_avg_intercluster_dist_avg.append(np.sum(intercluster_sum) / (k + 1))
         sum_avg_intercluster_dist_avg
```

```
Out[26]: [6.463560779131652,
          14.51201641242747,
          15.040195140980373,
          16.8298205683454,
          16.74816927126883,
          10.387129950728175,
          9.380204127185065,
          8.290426189777811,
          8.52405446812152,
          9.587885075326412]
```
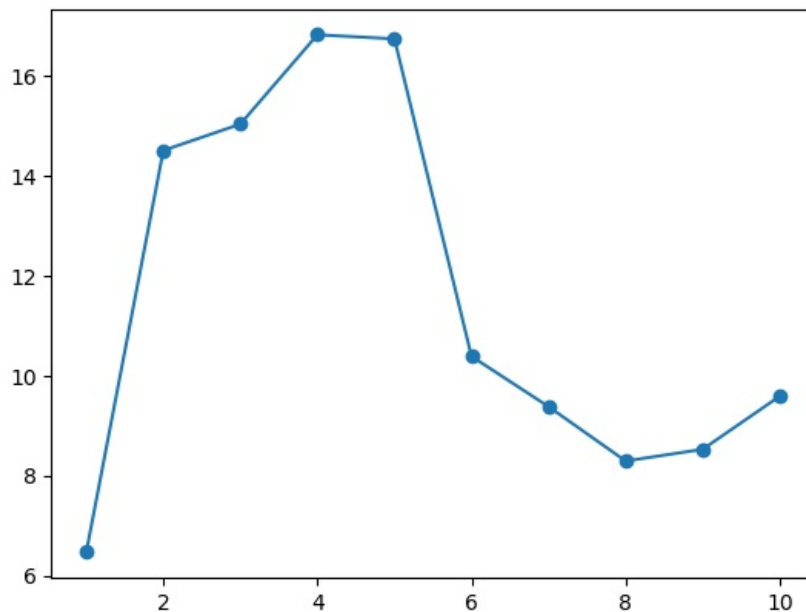
```
In [27]: plt.plot(range(1, 11), sum_avg_intercluster_dist_avg, '-o')
```

```
Out[27]: [<matplotlib.lines.Line2D at 0x15e2ddb90>]
```



```
In [28]: # Средней суммы межкластерных расстояний от количества кластеров
         sum_intercluster_dist_avg = []

         for k, kmean in enumerate(models):
             value = np.sum(euclidean_distances(kmean.cluster_centers_, kmean.cluster_centers_))
             sum_intercluster_dist_avg.append(value / (k + 1))
         sum_intercluster_dist_avg
```

```
Out[28]: [0.0,
          3.276303652616876,
          7.1540075209680625,
          10.929546574895468,
          14.574045430504816,
          18.582365920079223,
          22.39623761884071,
          25.52919592854157,
          29.677760874925777,
          33.95642870846736]
```
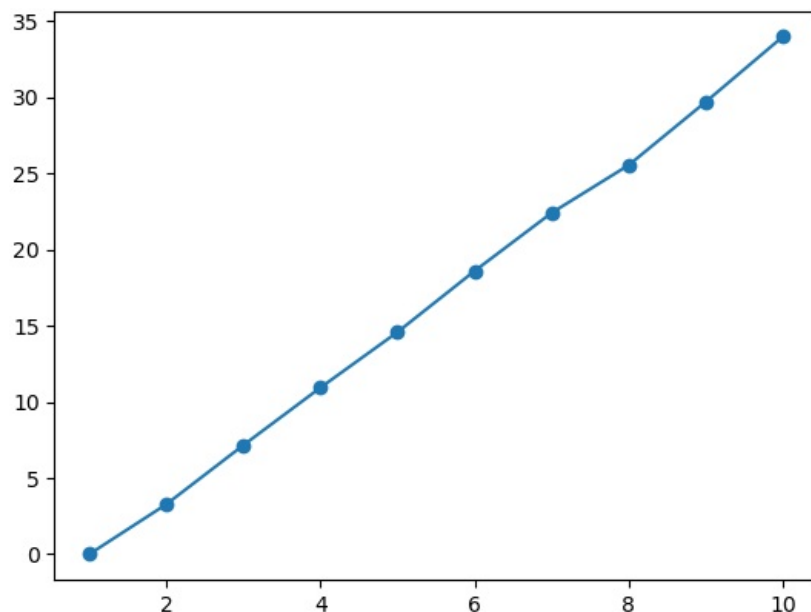
```
In [29]: plt.plot(range(1, 11), sum_intercluster_dist_avg, '-o')
```

```
Out[29]: [<matplotlib.lines.Line2D at 0x15e7d6290>]
```

Составление сравнительной таблицы

```
In [30]: import pandas as pd
```

```
In [31]: columns = pd.MultiIndex.from_product([['Иерархический метод', 'Метод k-средних'],
                                               ['Сумма квадратов расстояний до центроида', 'Сумма средних внутрикластерн
         df = pd.DataFrame(columns=columns)
         df
```

Out[31]:

	Иерархический метод			Метод k-средних		
	Сумма квадратов расстояний до центроида	Сумма средних внутрикластерных расстояний	Сумма межкластерных расстояний	Сумма квадратов расстояний до центроида	Сумма средних внутрикластерных расстояний	Сумма межкластерных расстояний

```
In [32]: df['Иерархический метод', 'Сумма квадратов расстояний до центроида'] = [sum_sq_dist for _ in range(len(sum_sq_d
         df['Иерархический метод', 'Сумма средних внутрикластерных расстояний'] = [sum_avg_intercluster_dist for _ in ra
         df['Иерархический метод', 'Сумма межкластерных расстояний'] = [sum_intercluster_dist for _ in range(len(sum_int

         df['Метод k-средних', 'Сумма квадратов расстояний до центроида'] = sum_sq_dist_avg
         df['Метод k-средних', 'Сумма средних внутрикластерных расстояний'] = sum_avg_intercluster_dist_avg
         df['Метод k-средних', 'Сумма межкластерных расстояний'] = sum_intercluster_dist_avg

         df
```

Out[32]:

	Иерархический метод			Метод k-средних		
	Сумма квадратов расстояний до центроида	Сумма средних внутрикластерных расстояний	Сумма межкластерных расстояний	Сумма квадратов расстояний до центроида	Сумма средних внутрикластерных расстояний	Сумма межкластерных расстояний
0	46.816599	1.70807	41.221777	646.356078	6.463561	0.000000
1	46.816599	1.70807	41.221777	189.215652	14.512016	3.276304
2	46.816599	1.70807	41.221777	73.243619	15.040195	7.154008
3	46.816599	1.70807	41.221777	33.804279	16.829821	10.929547
4	46.816599	1.70807	41.221777	20.060913	16.748169	14.574045
5	46.816599	1.70807	41.221777	11.025843	10.387130	18.582366
6	46.816599	1.70807	41.221777	8.177674	9.380204	22.396238
7	46.816599	1.70807	41.221777	6.137712	8.290426	25.529196
8	46.816599	1.70807	41.221777	4.592303	8.524054	29.677761
9	46.816599	1.70807	41.221777	3.659790	9.587885	33.956429

```
In [33]: df.to_excel('result.xlsx')
```