1. Calculate the following quantities for the "Protein_structure_1AOR.txt":
   - the average degree $\langle k \rangle$,
   - the average shortest path length $\langle l \rangle$,
   - the average clustering coefficient $\langle C \rangle$.

   (Hand in the results on paper).

2. Visualize the "Protein_structure_1AOR.txt" network in the following way:
   - apply a layout algorithm,
   - prepare an image in which the nodes are colored according to their clustering coefficient,
   - prepare another image in which the nodes are colored according to their closeness.

   (Accepted formats: .pdf, .cys, .gephi)

3. Treat the "Protein_structure_1AOR.txt" network as directed and calculate both the in-degree and out-degree distribution. Plot the two **normalized** distribution on one chart, export the image to a file.

   (Accepted formats: .jpg, .png, .ps, .gnu).

4. a) How many weakly and strongly connected components are in the following chain?
   $A \to B \to C \to D \to E \to F \to A$

   b) Do these quantities change if the direction of one link is reversed?

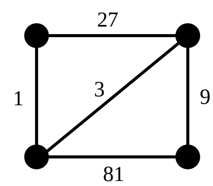
   (Hand in the result on paper).

5. Draw a small network in which the node with the highest betweenness has the highest degree! Draw an other network, in which the node with the highest betweenness has the lowest degree!

6. What is the average clustering coefficient in an Erdős-Rényi graph with $N = 100$ nodes and $M = 990$ edges? Please derive the exact value. (Generating a sample can help checking the result).

   (Hand in the result on paper).

7. What is the intensity of the following weighted graph?



(Hand in the result on paper).

8. Construct a Watts-Strogatz graph in the following way:
Take $N >> 1$ nodes on a ring, the links connect first and second neighbors. In addition, distribute evenly $N/2$ shortcuts among the nodes, connecting random pairs, (i.e., one shortcut per node). Calculate the average clustering coefficient.

(Hand in the result on paper).

9. What is the degree distribution for the following networks?

   a) chain of 100 nodes,
   b) clique of 100 nodes,
   c) balanced binary tree of 127 nodes. (In this tree we find always two "children" linked under a given node, except for the leafs at the bottom of the tree, which have no descendants at all.)

(Hand in the result on paper).

10. What is the maximal length of the shortest paths in a balanced binary tree of N nodes?

(Hand in the result on paper).

11. What is the in-strength of node 3 in the graph characterized by the following weight matrix?

$$W = \begin{pmatrix} 1.2 & 3.5 & 0.4 & 0 \\ 0 & 0 & 1.7 & 1.4 \\ 3.2 & 0 & 2.1 & 0 \\ 1.7 & 0.7 & 0 & 0.9 \end{pmatrix}$$

(Hand in the result on paper).

12. Modularity maximum is a global criterion for the partition of a graph to find communities:

$$Q = \frac{1}{2M}\sum_{ij}\left(A_{ij} - \frac{k_i k_j}{2M}\right)\delta(C_i, C_j)$$

Here the adjacency matrix is compared to the probability of having a link between nodes i and j in the configuration graph. How would Q look like if the the Erdős-Rényi graph was chosen as a reference system?

(Hand in the result on paper).

13. Suppose we turn an assortative network into disassortative by applying a stochastic rewiring procedure which otherwise keeps the degree of the nodes fixed. How does the clustering coefficient of the hubs change under the rewiring?

(Hand in the result on paper).

14. What are the three basic properties of most natural and human made large networks?

(Hand in the result on paper).