Problem 1. ***Supervised learning for 2D Ising ferromagnet***

In this exercise you will study the phase transition of the 2D Ising ferromagnet on a square lattice with supervised learning (Nature Physics, **13**, 431 (2017)):

$$H = -\sum_{\langle i,j \rangle} \sigma_i^z \sigma_j^z \,. \tag{1}$$

This model shows a phase transition at $T_c = \frac{2}{\log\left(1+\sqrt{2}\right)}$ between a paramagnetic and a ferromagnetic phase. We use a fully connected feed-forward neural network to classify these two phases.

1. Use the solution of exercise 6 to generate Monte-Carlo spin configurations both above and below the transition temperature for a lattice $L = 30$. These configurations will serve to train and validate the neural network.

2. Install TensorFlow and the library Keras. Step-by-step guides for the installation can be found at `www.tensorflow.org/install/` and `keras.io/installation`. In the exercise class we will provide help during the installation.

3. Implement a fully connected neural network with one input layer, one hidden layer with 100 neurons and an output layer. Use sigmoid neurons, cross entropy cost function and train using the Adam method for stochastic optimization. You can find a good tutorial to implement a fully connected neural network at this **link**.

4. Train the network with some of the configurations generated with Monte-Carlo algorithm. Validate the network with the remaining configurations. Study the output layer and the accuracy of the network. Experiment with the number of epochs and the batch size to obtain the best results.