Write True/False clearly and provide precise justification wherever applicable. Any instance of cheating is considered academic dishonesty. (**Question 01-07 and 09: 1 Marks Each and Questions 08: 2 Marks)**

Given the input dataset $X = [x_1, ...x_K], x_i \in \mathbb{R}^d$, a dictionary $D \in \mathbb{R}^{d*n}$ and representation $R = [r_1, ...r_K], r_i \in \mathbb{R}^n$

1. The dictionary D can be "under complete" if n<d or "overcomplete" in case n>d. **True**
2. Under complete dictionaries represent the setup in which the actual input data lies in a lower-dimensional space. **True** (Undercomplete dictionaries represent the setup in which the actual input data lies in a lower-dimensional space. This case is strongly related to dimensionality reduction and techniques like principal component analysis which require atoms $d_1, ..., d_n$ to be orthogonal.)
3. Overcomplete dictionaries do not require the atoms to be orthogonal. **True** (Overcomplete dictionaries, however, do not require the atoms to be orthogonal (they will never be a basis anyway) thus allowing for more flexible dictionaries and richer data representations.)
4. The objective function of dictionary learning is $min_{D,Z}||X - DZ||_F^2, s.t.||Z||_0 \geq \tau$? **False** It should be $min_{D,Z}||X - DZ||_F^2, s.t.||Z||_0 \leq \tau$
5. The optimization function of dictionary learning has been used only for Synthesis purpose not for Analysis purposes? **True**
6. Dictionary learning is a representation learning technique? **True**
7. Can dictionary learning algorithm be used for supervised and unsupervised tasks? **True**
8. What are the two steps of the K-SVD algorithm?

K-SVD is an algorithm that performs SVD at its core to update the atoms of the dictionary one by one and basically is a generalization of K-means. It enforces that each element of the input data $\{x_i\}$ is encoded by a linear combination of not more than $\{T_0\}$ elements in a way identical to the MOD approach:

(i) $min_{D,R}|X - DR|_F^2 \ s.t. \ \forall i \ ||r_i||_0 \leq T_0$

This algorithm's essence is to first fix the dictionary, find the best possible $\{R\}$ under the above constraint (using Orthogonal Matching Pursuit) and then iteratively update the atoms of

$$||X - DR||_F^2 = |X - \sum_{i=1}^{K} d_i x_T^i|_F^2$$

(ii) dictionary $\{\mathbf{D}\}$ in the following manner:

In Brief: K-SVD Algorithm: two steps

(i) Sparse Coding: Producing sparse representations matrix X, given the current dictionary D

(ii) Dictionary Update:(the main innovation) Updating dictionary atoms, given the current sparse representations

9. Out of the following which strategy is used by Dictionary Learning to shape the energy function?

a. Use a regularizer that limits the volume of space that has low energy **(Correct)**
b. Minimize the gradient and maximize the curvature around the data points
c. Build a mechanism so that the volume of low energy stuff is constant
d. Train the dynamical system so that the dynamics go to the data manifold.