Assignment 3 - Variational-Autoencoders

1. Why is the KL Divergence term important in the VAE loss function?

Ans: The KL Divergence term in the Variational Autoencoder (VAE) loss function is important because it regularizes the latent space. It measures the difference between the learned posterior distribution (from the encoder) and the prior distribution (typically a standard normal distribution). By minimizing this divergence, the model is encouraged to keep the learned latent space close to the prior, preventing overfitting. This helps the model learn a more meaningful, generalizable latent representation, which can improve the quality of generated samples.

2. How does the reparameterization trick enable backpropagation through the stochastic layers of a VAE?

Ans: The reparameterization trick enables backpropagation through the stochastic layers of a VAE by transforming the sampling process into a differentiable operation. Instead of directly sampling the latent variable z from the encoder's output distribution,
it is reparametrized as $\boldsymbol{z} = \boldsymbol{\mu} + \boldsymbol{\sigma} * \in$

Where, $\boldsymbol{\mu}$ and $\boldsymbol{\sigma}$ are the mean and standard deviation, and ∈ is sampled from a standard normal distribution and does not depend on learnable parameters ($\boldsymbol{\mu}$ and $\boldsymbol{\sigma}$), gradients can flow through these parameters, allowing backpropagation during training.

3. Why does a VAE use a probabilistic latent space instead of a fixed latent space?

Ans: A VAE uses a probabilistic latent space instead of a fixed latent space to create smooth and continuous latent representations allowing for more flexible and expressive modeling of data. A fixed latent space would constrain the model to a deterministic mapping between the data and the latent space, which limits the model's ability to handle variations and uncertainties in the data. The probabilistic latent space, on the other hand, encourages smooth interpolation and better generalization by sampling from distributions, rather than fixed points. This allows the VAE to generate diverse and coherent outputs, even for unseen or noisy inputs.

4. What role does KL Divergence play in ensuring a smooth latent space?

Ans: KL Divergence plays a crucial role in ensuring a smooth latent space by preventing it from collapsing into a disjoint or sparse representation. By minimizing the KL divergence between the approximate posterior $q(z|x)$ and the prior $p(z)$, the VAE encourages the encoder to map similar inputs to nearby points in the latent space. This regularization creates a structured, continuous, and interpolatable representation, facilitating smooth transitions between data points. As a result, the model learns a latent space that captures the underlying data distribution effectively while allowing for meaningful interpolation and generation of new samples.