

Diffusion Models

Week 15 · December 1, 2026

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Reading Prince, *Understanding Deep Learning*, Chapter 18

 These notes are still being written. The reading above is authoritative until this banner disappears.

1 Learning Objectives

By the end of this week you should be able to:

1. Describe the forward diffusion process and its closed-form marginal at any timestep.

2. Explain the reparameterization that lets a network predict noise instead of the clean image.
3. Write the training objective for a denoising diffusion probabilistic model.
4. Describe ancestral sampling and the speed/quality trade-off of the sampler.
5. Explain classifier-free guidance and conditional generation.
6. Relate diffusion models to score matching and to VAEs.

```
import numpy as np
import matplotlib.pyplot as plt
import torch

torch.manual_seed(774)
np.random.seed(774)

plt.rcParams.update({
    "figure.figsize": (7, 4),
    "figure.dpi": 130,
    "axes.spines.top": False,
    "axes.spines.right": False,
    "axes.grid": True,
    "grid.alpha": 0.25,
    "font.size": 10,
    "legend.frameon": False,
})

NDSU_GREEN = "#005643"
NDSU_GOLD = "#FFC72C"
ACCENT = "#C1121F"
```

2 The Forward Process

TODO

3 Closed Form at Arbitrary Timesteps

TODO

4 The Reverse Process

TODO

5 The Training Objective

TODO

6 Sampling

TODO

7 Conditional Generation and Guidance

TODO

8 Connections to Score Matching

TODO

9 A Minimal Diffusion Model in PyTorch

TODO

10 Summary

TODO

11 Exercises

Problem numbers refer to Prince, Chapter 18.

1. TODO
 2. TODO
 3. Computational. TODO
-

12 Further Reading

- Prince, *Understanding Deep Learning*, Chapter 18.
- TODO