```
!nvidia-smi

Sun Feb  2 09:02:26 2025
+-----------------------------------------------------------------------------
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| NVIDIA-SMI 550.54.15              Driver Version: 550.54.15
CUDA Version: 12.4     |
|-----------------------------------------+------------------------
+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A |
Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage |
GPU-Util  Compute M. |
|                                         |                        |
MIG M. |
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|   0  Tesla T4                       Off |   00000000:00:04.0 Off |
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| N/A   37C    P8             11W /   70W |       0MiB /  15360MiB |
0%      Default |
|                                         |                        |
N/A |
+-----------------------------------------+------------------------
+----------------------+


+-----------------------------------------------------------------------------
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| Processes:
|
|  GPU   GI   CI        PID   Type   Process name
GPU Memory |
|        ID   ID
Usage      |
|
=============================================================================
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|  No running processes found
|
+-----------------------------------------------------------------------------
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import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
from tensorflow.keras import layers
```

preparing dataset

```
(train_images, _), (_, _) = tf.keras.datasets.mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```

```
train_images = train_images.reshape(train_images.shape[0], 28, 28, 1).astype('float32')
train_images = (train_images - 127.5) / 127.5

BUFFER_SIZE = 60000
BATCH_SIZE = 128  # Reduced batch size
EPOCHS = 50
noise_dim = 100

train_dataset = tf.data.Dataset.from_tensor_slices(train_images)\
    .shuffle(BUFFER_SIZE)\
    .batch(BATCH_SIZE)\
    .prefetch(tf.data.AUTOTUNE)
```

creating the model

```
def make_generator_model():
    model = tf.keras.Sequential([
        # Input layer
        layers.Dense(7*7*256, use_bias=False, input_shape=(100,)),
        layers.BatchNormalization(),
        layers.LeakyReLU(),
        layers.Reshape((7, 7, 256)),

        # First upsampling block
        layers.Conv2DTranspose(128, (5, 5), strides=(1, 1), padding='same', use_bias=False),
        layers.BatchNormalization(),
        layers.LeakyReLU(),

        # Second upsampling block
        layers.Conv2DTranspose(64, (5, 5), strides=(2, 2), padding='same', use_bias=False),
        layers.BatchNormalization(),
        layers.LeakyReLU(),

        # Output layer
        layers.Conv2DTranspose(1, (5, 5), strides=(2, 2), padding='same', use_bias=False, activation='tanh')
    ])
    return model

def make_discriminator_model():
    model = tf.keras.Sequential([
```

```
        layers.Conv2D(64, (5, 5), strides=(2, 2), padding='same',
input_shape=[28, 28, 1]),
        layers.LeakyReLU(),
        layers.Dropout(0.3),

        layers.Conv2D(128, (5, 5), strides=(2, 2), padding='same'),
        layers.LeakyReLU(),
        layers.Dropout(0.3),

        layers.Flatten(),
        layers.Dense(1)
    ])
    return model

# Initialize models
generator = make_generator_model()
discriminator = make_discriminator_model()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/
dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim`
argument to a layer. When using Sequential models, prefer using an
`Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer,
**kwargs)
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional
/base_conv.py:107: UserWarning: Do not pass an
`input_shape`/`input_dim` argument to a layer. When using Sequential
models, prefer using an `Input(shape)` object as the first layer in
the model instead.
  super().__init__(activity_regularizer=activity_regularizer,
**kwargs)
```

loss and optimizer

```
# Loss functions
cross_entropy = tf.keras.losses.BinaryCrossentropy(from_logits=True)

def discriminator_loss(real_output, fake_output):
    real_loss = cross_entropy(tf.ones_like(real_output), real_output)
    fake_loss = cross_entropy(tf.zeros_like(fake_output), fake_output)
    return real_loss + fake_loss

def generator_loss(fake_output):
    return cross_entropy(tf.ones_like(fake_output), fake_output)

# Optimizers with adjusted learning rates
generator_optimizer = tf.keras.optimizers.Adam(2e-4, beta_1=0.5)
discriminator_optimizer = tf.keras.optimizers.Adam(2e-4, beta_1=0.5)
```

training loop

```python
# Training step with progress tracking
@tf.function
def train_step(images):
    noise = tf.random.normal([BATCH_SIZE, noise_dim])

    with tf.GradientTape() as gen_tape, tf.GradientTape() as
disc_tape:
        generated_images = generator(noise, training=True)

        real_output = discriminator(images, training=True)
        fake_output = discriminator(generated_images, training=True)

        gen_loss = generator_loss(fake_output)
        disc_loss = discriminator_loss(real_output, fake_output)

    gradients_of_generator = gen_tape.gradient(gen_loss,
generator.trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss,
discriminator.trainable_variables)

    generator_optimizer.apply_gradients(zip(gradients_of_generator,
generator.trainable_variables))

discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator
, discriminator.trainable_variables))

    return gen_loss, disc_loss

def train(dataset, epochs):
    gen_losses = []
    disc_losses = []

    # Progress bar
    for epoch in range(epochs):
        print(f"\nEpoch {epoch+1}/{epochs}")

        # Track batch progress
        batch_gen_losses = []
        batch_disc_losses = []
        num_batches = len(list(dataset))

        for batch_idx, image_batch in enumerate(dataset):
            gen_loss, disc_loss = train_step(image_batch)
            batch_gen_losses.append(gen_loss.numpy())
            batch_disc_losses.append(disc_loss.numpy())

            # Print progress every 50 batches
            if (batch_idx + 1) % 50 == 0:
                print(f"Batch {batch_idx + 1}/{num_batches} - "
                      f"Gen Loss: {np.mean(batch_gen_losses):.4f}, "
                      f"Disc Loss: {np.mean(batch_disc_losses):.4f}")
```

```
        # Store epoch losses
        gen_losses.append(np.mean(batch_gen_losses))
        disc_losses.append(np.mean(batch_disc_losses))

    return gen_losses, disc_losses

def generate_and_save_images(model, epoch, test_input):
    predictions = model(test_input, training=False)

    fig = plt.figure(figsize=(4, 4))
    for i in range(predictions.shape[0]):
        plt.subplot(4, 4, i+1)
        plt.imshow(predictions[i, :, :, 0] * 127.5 + 127.5,
cmap='gray')
        plt.axis('off')
    plt.show()

num_examples_to_generate = 16
seed = tf.random.normal([num_examples_to_generate, noise_dim])
```

training the model

```
# Train the model
gen_losses, disc_losses = train(train_dataset, EPOCHS)



Epoch 1/50
Batch 50/469 - Gen Loss: 0.5830, Disc Loss: 1.2179
Batch 100/469 - Gen Loss: 0.6153, Disc Loss: 1.2828
Batch 150/469 - Gen Loss: 0.6444, Disc Loss: 1.2915
Batch 200/469 - Gen Loss: 0.6612, Disc Loss: 1.2994
Batch 250/469 - Gen Loss: 0.6729, Disc Loss: 1.3061
Batch 300/469 - Gen Loss: 0.6827, Disc Loss: 1.3118
Batch 350/469 - Gen Loss: 0.6892, Disc Loss: 1.3175
Batch 400/469 - Gen Loss: 0.6944, Disc Loss: 1.3225
Batch 450/469 - Gen Loss: 0.6981, Disc Loss: 1.3252

Epoch 2/50
Batch 50/469 - Gen Loss: 0.7314, Disc Loss: 1.3534
Batch 100/469 - Gen Loss: 0.7294, Disc Loss: 1.3515
Batch 150/469 - Gen Loss: 0.7330, Disc Loss: 1.3511
Batch 200/469 - Gen Loss: 0.7339, Disc Loss: 1.3485
Batch 250/469 - Gen Loss: 0.7366, Disc Loss: 1.3510
Batch 300/469 - Gen Loss: 0.7377, Disc Loss: 1.3477
Batch 350/469 - Gen Loss: 0.7385, Disc Loss: 1.3472
Batch 400/469 - Gen Loss: 0.7409, Disc Loss: 1.3455
Batch 450/469 - Gen Loss: 0.7434, Disc Loss: 1.3434
```

```
Epoch 3/50
Batch 50/469 - Gen Loss: 0.7647, Disc Loss: 1.3089
Batch 100/469 - Gen Loss: 0.7748, Disc Loss: 1.3140
Batch 150/469 - Gen Loss: 0.7842, Disc Loss: 1.3057
Batch 200/469 - Gen Loss: 0.7891, Disc Loss: 1.3031
Batch 250/469 - Gen Loss: 0.7932, Disc Loss: 1.2982
Batch 300/469 - Gen Loss: 0.7935, Disc Loss: 1.2962
Batch 350/469 - Gen Loss: 0.7986, Disc Loss: 1.2880
Batch 400/469 - Gen Loss: 0.8052, Disc Loss: 1.2864
Batch 450/469 - Gen Loss: 0.8100, Disc Loss: 1.2820

Epoch 4/50
Batch 50/469 - Gen Loss: 0.8400, Disc Loss: 1.2461
Batch 100/469 - Gen Loss: 0.8517, Disc Loss: 1.2563
Batch 150/469 - Gen Loss: 0.8505, Disc Loss: 1.2486
Batch 200/469 - Gen Loss: 0.8552, Disc Loss: 1.2504
Batch 250/469 - Gen Loss: 0.8513, Disc Loss: 1.2501
Batch 300/469 - Gen Loss: 0.8490, Disc Loss: 1.2524
Batch 350/469 - Gen Loss: 0.8462, Disc Loss: 1.2555
Batch 400/469 - Gen Loss: 0.8456, Disc Loss: 1.2574
Batch 450/469 - Gen Loss: 0.8441, Disc Loss: 1.2613

Epoch 5/50
Batch 50/469 - Gen Loss: 0.8179, Disc Loss: 1.2838
Batch 100/469 - Gen Loss: 0.8097, Disc Loss: 1.2948
Batch 150/469 - Gen Loss: 0.8026, Disc Loss: 1.2999
Batch 200/469 - Gen Loss: 0.7991, Disc Loss: 1.3024
Batch 250/469 - Gen Loss: 0.7957, Disc Loss: 1.3075
Batch 300/469 - Gen Loss: 0.7939, Disc Loss: 1.3095
Batch 350/469 - Gen Loss: 0.7941, Disc Loss: 1.3102
Batch 400/469 - Gen Loss: 0.7967, Disc Loss: 1.3099
Batch 450/469 - Gen Loss: 0.7985, Disc Loss: 1.3089

Epoch 6/50
Batch 50/469 - Gen Loss: 0.7904, Disc Loss: 1.3106
Batch 100/469 - Gen Loss: 0.7831, Disc Loss: 1.3198
Batch 150/469 - Gen Loss: 0.7798, Disc Loss: 1.3199
Batch 200/469 - Gen Loss: 0.7797, Disc Loss: 1.3215
Batch 250/469 - Gen Loss: 0.7775, Disc Loss: 1.3233
Batch 300/469 - Gen Loss: 0.7787, Disc Loss: 1.3236
Batch 350/469 - Gen Loss: 0.7794, Disc Loss: 1.3235
Batch 400/469 - Gen Loss: 0.7833, Disc Loss: 1.3221
Batch 450/469 - Gen Loss: 0.7848, Disc Loss: 1.3211

Epoch 7/50
Batch 50/469 - Gen Loss: 0.7734, Disc Loss: 1.3226
Batch 100/469 - Gen Loss: 0.7709, Disc Loss: 1.3242
Batch 150/469 - Gen Loss: 0.7721, Disc Loss: 1.3229
Batch 200/469 - Gen Loss: 0.7714, Disc Loss: 1.3226
Batch 250/469 - Gen Loss: 0.7732, Disc Loss: 1.3220
```

```
Batch 300/469 - Gen Loss: 0.7784, Disc Loss: 1.3211
Batch 350/469 - Gen Loss: 0.7849, Disc Loss: 1.3182
Batch 400/469 - Gen Loss: 0.7867, Disc Loss: 1.3167
Batch 450/469 - Gen Loss: 0.7880, Disc Loss: 1.3157

Epoch 8/50
Batch 50/469 - Gen Loss: 0.7877, Disc Loss: 1.3153
Batch 100/469 - Gen Loss: 0.7845, Disc Loss: 1.3182
Batch 150/469 - Gen Loss: 0.7845, Disc Loss: 1.3180
Batch 200/469 - Gen Loss: 0.7853, Disc Loss: 1.3151
Batch 250/469 - Gen Loss: 0.7832, Disc Loss: 1.3160
Batch 300/469 - Gen Loss: 0.7822, Disc Loss: 1.3164
Batch 350/469 - Gen Loss: 0.7812, Disc Loss: 1.3172
Batch 400/469 - Gen Loss: 0.7854, Disc Loss: 1.3172
Batch 450/469 - Gen Loss: 0.7880, Disc Loss: 1.3158

Epoch 9/50
Batch 50/469 - Gen Loss: 0.7898, Disc Loss: 1.3135
Batch 100/469 - Gen Loss: 0.7857, Disc Loss: 1.3147
Batch 150/469 - Gen Loss: 0.7863, Disc Loss: 1.3133
Batch 200/469 - Gen Loss: 0.7870, Disc Loss: 1.3140
Batch 250/469 - Gen Loss: 0.7901, Disc Loss: 1.3125
Batch 300/469 - Gen Loss: 0.7943, Disc Loss: 1.3123
Batch 350/469 - Gen Loss: 0.7974, Disc Loss: 1.3105
Batch 400/469 - Gen Loss: 0.7981, Disc Loss: 1.3097
Batch 450/469 - Gen Loss: 0.7976, Disc Loss: 1.3096

Epoch 10/50
Batch 50/469 - Gen Loss: 0.7929, Disc Loss: 1.3105
Batch 100/469 - Gen Loss: 0.7903, Disc Loss: 1.3121
Batch 150/469 - Gen Loss: 0.7893, Disc Loss: 1.3127
Batch 200/469 - Gen Loss: 0.7921, Disc Loss: 1.3088
Batch 250/469 - Gen Loss: 0.7953, Disc Loss: 1.3086
Batch 300/469 - Gen Loss: 0.7957, Disc Loss: 1.3077
Batch 350/469 - Gen Loss: 0.7954, Disc Loss: 1.3083
Batch 400/469 - Gen Loss: 0.7952, Disc Loss: 1.3086
Batch 450/469 - Gen Loss: 0.7968, Disc Loss: 1.3075

Epoch 11/50
Batch 50/469 - Gen Loss: 0.8049, Disc Loss: 1.2981
Batch 100/469 - Gen Loss: 0.8041, Disc Loss: 1.3039
Batch 150/469 - Gen Loss: 0.7986, Disc Loss: 1.3063
Batch 200/469 - Gen Loss: 0.8031, Disc Loss: 1.3043
Batch 250/469 - Gen Loss: 0.8089, Disc Loss: 1.3032
Batch 300/469 - Gen Loss: 0.8116, Disc Loss: 1.3021
Batch 350/469 - Gen Loss: 0.8117, Disc Loss: 1.3017
Batch 400/469 - Gen Loss: 0.8106, Disc Loss: 1.3009
Batch 450/469 - Gen Loss: 0.8093, Disc Loss: 1.3008

Epoch 12/50
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```
Batch 50/469 - Gen Loss: 0.7931, Disc Loss: 1.3123
Batch 100/469 - Gen Loss: 0.7937, Disc Loss: 1.3112
Batch 150/469 - Gen Loss: 0.7936, Disc Loss: 1.3095
Batch 200/469 - Gen Loss: 0.7941, Disc Loss: 1.3098
Batch 250/469 - Gen Loss: 0.7959, Disc Loss: 1.3077
Batch 300/469 - Gen Loss: 0.7988, Disc Loss: 1.3072
Batch 350/469 - Gen Loss: 0.8051, Disc Loss: 1.3071
Batch 400/469 - Gen Loss: 0.8075, Disc Loss: 1.3052
Batch 450/469 - Gen Loss: 0.8093, Disc Loss: 1.3038

Epoch 13/50
Batch 50/469 - Gen Loss: 0.8059, Disc Loss: 1.3080
Batch 100/469 - Gen Loss: 0.8105, Disc Loss: 1.3024
Batch 150/469 - Gen Loss: 0.8130, Disc Loss: 1.2990
Batch 200/469 - Gen Loss: 0.8155, Disc Loss: 1.2975
Batch 250/469 - Gen Loss: 0.8149, Disc Loss: 1.2995
Batch 300/469 - Gen Loss: 0.8165, Disc Loss: 1.2999
Batch 350/469 - Gen Loss: 0.8172, Disc Loss: 1.2995
Batch 400/469 - Gen Loss: 0.8176, Disc Loss: 1.2984
Batch 450/469 - Gen Loss: 0.8173, Disc Loss: 1.2981

Epoch 14/50
Batch 50/469 - Gen Loss: 0.8135, Disc Loss: 1.2916
Batch 100/469 - Gen Loss: 0.8127, Disc Loss: 1.2953
Batch 150/469 - Gen Loss: 0.8126, Disc Loss: 1.2963
Batch 200/469 - Gen Loss: 0.8140, Disc Loss: 1.2978
Batch 250/469 - Gen Loss: 0.8173, Disc Loss: 1.2954
Batch 300/469 - Gen Loss: 0.8178, Disc Loss: 1.2957
Batch 350/469 - Gen Loss: 0.8175, Disc Loss: 1.2962
Batch 400/469 - Gen Loss: 0.8164, Disc Loss: 1.2974
Batch 450/469 - Gen Loss: 0.8151, Disc Loss: 1.2979

Epoch 15/50
Batch 50/469 - Gen Loss: 0.8043, Disc Loss: 1.2999
Batch 100/469 - Gen Loss: 0.8074, Disc Loss: 1.2982
Batch 150/469 - Gen Loss: 0.8082, Disc Loss: 1.3000
Batch 200/469 - Gen Loss: 0.8077, Disc Loss: 1.3010
Batch 250/469 - Gen Loss: 0.8063, Disc Loss: 1.3034
Batch 300/469 - Gen Loss: 0.8049, Disc Loss: 1.3047
Batch 350/469 - Gen Loss: 0.8047, Disc Loss: 1.3045
Batch 400/469 - Gen Loss: 0.8067, Disc Loss: 1.3033
Batch 450/469 - Gen Loss: 0.8142, Disc Loss: 1.3021

Epoch 16/50
Batch 50/469 - Gen Loss: 0.8466, Disc Loss: 1.2788
Batch 100/469 - Gen Loss: 0.8321, Disc Loss: 1.2894
Batch 150/469 - Gen Loss: 0.8292, Disc Loss: 1.2925
Batch 200/469 - Gen Loss: 0.8285, Disc Loss: 1.2929
Batch 250/469 - Gen Loss: 0.8297, Disc Loss: 1.2916
Batch 300/469 - Gen Loss: 0.8311, Disc Loss: 1.2925
```

```
Batch 350/469 - Gen Loss: 0.8287, Disc Loss: 1.2941
Batch 400/469 - Gen Loss: 0.8264, Disc Loss: 1.2947
Batch 450/469 - Gen Loss: 0.8234, Disc Loss: 1.2954

Epoch 17/50
Batch 50/469 - Gen Loss: 0.8051, Disc Loss: 1.3018
Batch 100/469 - Gen Loss: 0.8068, Disc Loss: 1.3014
Batch 150/469 - Gen Loss: 0.8071, Disc Loss: 1.2994
Batch 200/469 - Gen Loss: 0.8090, Disc Loss: 1.3009
Batch 250/469 - Gen Loss: 0.8134, Disc Loss: 1.2997
Batch 300/469 - Gen Loss: 0.8134, Disc Loss: 1.2992
Batch 350/469 - Gen Loss: 0.8165, Disc Loss: 1.2984
Batch 400/469 - Gen Loss: 0.8202, Disc Loss: 1.2982
Batch 450/469 - Gen Loss: 0.8223, Disc Loss: 1.2979

Epoch 18/50
Batch 50/469 - Gen Loss: 0.8314, Disc Loss: 1.2980
Batch 100/469 - Gen Loss: 0.8263, Disc Loss: 1.2981
Batch 150/469 - Gen Loss: 0.8279, Disc Loss: 1.2978
Batch 200/469 - Gen Loss: 0.8310, Disc Loss: 1.2962
Batch 250/469 - Gen Loss: 0.8301, Disc Loss: 1.2960
Batch 300/469 - Gen Loss: 0.8291, Disc Loss: 1.2950
Batch 350/469 - Gen Loss: 0.8270, Disc Loss: 1.2948
Batch 400/469 - Gen Loss: 0.8242, Disc Loss: 1.2962
Batch 450/469 - Gen Loss: 0.8224, Disc Loss: 1.2966

Epoch 19/50
Batch 50/469 - Gen Loss: 0.8106, Disc Loss: 1.3016
Batch 100/469 - Gen Loss: 0.8135, Disc Loss: 1.3007
Batch 150/469 - Gen Loss: 0.8181, Disc Loss: 1.3006
Batch 200/469 - Gen Loss: 0.8227, Disc Loss: 1.2988
Batch 250/469 - Gen Loss: 0.8257, Disc Loss: 1.2969
Batch 300/469 - Gen Loss: 0.8277, Disc Loss: 1.2967
Batch 350/469 - Gen Loss: 0.8264, Disc Loss: 1.2970
Batch 400/469 - Gen Loss: 0.8245, Disc Loss: 1.2977
Batch 450/469 - Gen Loss: 0.8239, Disc Loss: 1.2976

Epoch 20/50
Batch 50/469 - Gen Loss: 0.8220, Disc Loss: 1.3047
Batch 100/469 - Gen Loss: 0.8165, Disc Loss: 1.3072
Batch 150/469 - Gen Loss: 0.8157, Disc Loss: 1.3037
Batch 200/469 - Gen Loss: 0.8159, Disc Loss: 1.3037
Batch 250/469 - Gen Loss: 0.8171, Disc Loss: 1.3016
Batch 300/469 - Gen Loss: 0.8173, Disc Loss: 1.3004
Batch 350/469 - Gen Loss: 0.8173, Disc Loss: 1.3009
Batch 400/469 - Gen Loss: 0.8152, Disc Loss: 1.3026
Batch 450/469 - Gen Loss: 0.8145, Disc Loss: 1.3030

Epoch 21/50
Batch 50/469 - Gen Loss: 0.8086, Disc Loss: 1.3017
```

```
Batch 100/469 - Gen Loss: 0.8077, Disc Loss: 1.3036
Batch 150/469 - Gen Loss: 0.8105, Disc Loss: 1.3022
Batch 200/469 - Gen Loss: 0.8116, Disc Loss: 1.3036
Batch 250/469 - Gen Loss: 0.8120, Disc Loss: 1.3037
Batch 300/469 - Gen Loss: 0.8168, Disc Loss: 1.3033
Batch 350/469 - Gen Loss: 0.8200, Disc Loss: 1.3012
Batch 400/469 - Gen Loss: 0.8233, Disc Loss: 1.3000
Batch 450/469 - Gen Loss: 0.8253, Disc Loss: 1.2992

Epoch 22/50
Batch 50/469 - Gen Loss: 0.8285, Disc Loss: 1.2948
Batch 100/469 - Gen Loss: 0.8285, Disc Loss: 1.2931
Batch 150/469 - Gen Loss: 0.8293, Disc Loss: 1.2957
Batch 200/469 - Gen Loss: 0.8309, Disc Loss: 1.2940
Batch 250/469 - Gen Loss: 0.8314, Disc Loss: 1.2936
Batch 300/469 - Gen Loss: 0.8298, Disc Loss: 1.2936
Batch 350/469 - Gen Loss: 0.8278, Disc Loss: 1.2944
Batch 400/469 - Gen Loss: 0.8274, Disc Loss: 1.2948
Batch 450/469 - Gen Loss: 0.8273, Disc Loss: 1.2954

Epoch 23/50
Batch 50/469 - Gen Loss: 0.8219, Disc Loss: 1.3069
Batch 100/469 - Gen Loss: 0.8169, Disc Loss: 1.3025
Batch 150/469 - Gen Loss: 0.8206, Disc Loss: 1.3021
Batch 200/469 - Gen Loss: 0.8220, Disc Loss: 1.3000
Batch 250/469 - Gen Loss: 0.8225, Disc Loss: 1.2996
Batch 300/469 - Gen Loss: 0.8214, Disc Loss: 1.3010
Batch 350/469 - Gen Loss: 0.8225, Disc Loss: 1.3014
Batch 400/469 - Gen Loss: 0.8230, Disc Loss: 1.3011
Batch 450/469 - Gen Loss: 0.8241, Disc Loss: 1.3010

Epoch 24/50
Batch 50/469 - Gen Loss: 0.8181, Disc Loss: 1.3017
Batch 100/469 - Gen Loss: 0.8167, Disc Loss: 1.3018
Batch 150/469 - Gen Loss: 0.8159, Disc Loss: 1.3017
Batch 200/469 - Gen Loss: 0.8149, Disc Loss: 1.3018
Batch 250/469 - Gen Loss: 0.8147, Disc Loss: 1.3030
Batch 300/469 - Gen Loss: 0.8142, Disc Loss: 1.3030
Batch 350/469 - Gen Loss: 0.8135, Disc Loss: 1.3032
Batch 400/469 - Gen Loss: 0.8132, Disc Loss: 1.3036
Batch 450/469 - Gen Loss: 0.8130, Disc Loss: 1.3035

Epoch 25/50
Batch 50/469 - Gen Loss: 0.8159, Disc Loss: 1.3060
Batch 100/469 - Gen Loss: 0.8140, Disc Loss: 1.3037
Batch 150/469 - Gen Loss: 0.8135, Disc Loss: 1.3031
Batch 200/469 - Gen Loss: 0.8145, Disc Loss: 1.3030
Batch 250/469 - Gen Loss: 0.8192, Disc Loss: 1.3037
Batch 300/469 - Gen Loss: 0.8204, Disc Loss: 1.3044
Batch 350/469 - Gen Loss: 0.8215, Disc Loss: 1.3040
```

```
Batch 400/469 - Gen Loss: 0.8229, Disc Loss: 1.3029
Batch 450/469 - Gen Loss: 0.8228, Disc Loss: 1.3032

Epoch 26/50
Batch 50/469 - Gen Loss: 0.8276, Disc Loss: 1.2979
Batch 100/469 - Gen Loss: 0.8238, Disc Loss: 1.3015
Batch 150/469 - Gen Loss: 0.8168, Disc Loss: 1.3054
Batch 200/469 - Gen Loss: 0.8151, Disc Loss: 1.3050
Batch 250/469 - Gen Loss: 0.8166, Disc Loss: 1.3036
Batch 300/469 - Gen Loss: 0.8178, Disc Loss: 1.3027
Batch 350/469 - Gen Loss: 0.8169, Disc Loss: 1.3038
Batch 400/469 - Gen Loss: 0.8170, Disc Loss: 1.3032
Batch 450/469 - Gen Loss: 0.8169, Disc Loss: 1.3031

Epoch 27/50
Batch 50/469 - Gen Loss: 0.8130, Disc Loss: 1.2957
Batch 100/469 - Gen Loss: 0.8122, Disc Loss: 1.3001
Batch 150/469 - Gen Loss: 0.8156, Disc Loss: 1.3054
Batch 200/469 - Gen Loss: 0.8207, Disc Loss: 1.3038
Batch 250/469 - Gen Loss: 0.8249, Disc Loss: 1.3017
Batch 300/469 - Gen Loss: 0.8283, Disc Loss: 1.2997
Batch 350/469 - Gen Loss: 0.8288, Disc Loss: 1.3000
Batch 400/469 - Gen Loss: 0.8285, Disc Loss: 1.2990
Batch 450/469 - Gen Loss: 0.8280, Disc Loss: 1.2991

Epoch 28/50
Batch 50/469 - Gen Loss: 0.8285, Disc Loss: 1.2982
Batch 100/469 - Gen Loss: 0.8220, Disc Loss: 1.3031
Batch 150/469 - Gen Loss: 0.8172, Disc Loss: 1.3029
Batch 200/469 - Gen Loss: 0.8149, Disc Loss: 1.3038
Batch 250/469 - Gen Loss: 0.8132, Disc Loss: 1.3040
Batch 300/469 - Gen Loss: 0.8122, Disc Loss: 1.3046
Batch 350/469 - Gen Loss: 0.8114, Disc Loss: 1.3054
Batch 400/469 - Gen Loss: 0.8113, Disc Loss: 1.3052
Batch 450/469 - Gen Loss: 0.8120, Disc Loss: 1.3053

Epoch 29/50
Batch 50/469 - Gen Loss: 0.8047, Disc Loss: 1.3086
Batch 100/469 - Gen Loss: 0.8108, Disc Loss: 1.3046
Batch 150/469 - Gen Loss: 0.8083, Disc Loss: 1.3083
Batch 200/469 - Gen Loss: 0.8089, Disc Loss: 1.3071
Batch 250/469 - Gen Loss: 0.8100, Disc Loss: 1.3067
Batch 300/469 - Gen Loss: 0.8126, Disc Loss: 1.3062
Batch 350/469 - Gen Loss: 0.8176, Disc Loss: 1.3077
Batch 400/469 - Gen Loss: 0.8206, Disc Loss: 1.3068
Batch 450/469 - Gen Loss: 0.8220, Disc Loss: 1.3052

Epoch 30/50
Batch 50/469 - Gen Loss: 0.8360, Disc Loss: 1.2978
Batch 100/469 - Gen Loss: 0.8293, Disc Loss: 1.2981
```

```
Batch 150/469 - Gen Loss: 0.8239, Disc Loss: 1.2996
Batch 200/469 - Gen Loss: 0.8203, Disc Loss: 1.3011
Batch 250/469 - Gen Loss: 0.8205, Disc Loss: 1.3014
Batch 300/469 - Gen Loss: 0.8191, Disc Loss: 1.3012
Batch 350/469 - Gen Loss: 0.8178, Disc Loss: 1.3011
Batch 400/469 - Gen Loss: 0.8167, Disc Loss: 1.3018
Batch 450/469 - Gen Loss: 0.8165, Disc Loss: 1.3022

Epoch 31/50
Batch 50/469 - Gen Loss: 0.8060, Disc Loss: 1.3053
Batch 100/469 - Gen Loss: 0.8085, Disc Loss: 1.3083
Batch 150/469 - Gen Loss: 0.8092, Disc Loss: 1.3081
Batch 200/469 - Gen Loss: 0.8090, Disc Loss: 1.3077
Batch 250/469 - Gen Loss: 0.8102, Disc Loss: 1.3076
Batch 300/469 - Gen Loss: 0.8091, Disc Loss: 1.3090
Batch 350/469 - Gen Loss: 0.8100, Disc Loss: 1.3094
Batch 400/469 - Gen Loss: 0.8140, Disc Loss: 1.3077
Batch 450/469 - Gen Loss: 0.8147, Disc Loss: 1.3082

Epoch 32/50
Batch 50/469 - Gen Loss: 0.8164, Disc Loss: 1.3106
Batch 100/469 - Gen Loss: 0.8159, Disc Loss: 1.3094
Batch 150/469 - Gen Loss: 0.8165, Disc Loss: 1.3061
Batch 200/469 - Gen Loss: 0.8136, Disc Loss: 1.3061
Batch 250/469 - Gen Loss: 0.8131, Disc Loss: 1.3060
Batch 300/469 - Gen Loss: 0.8128, Disc Loss: 1.3056
Batch 350/469 - Gen Loss: 0.8127, Disc Loss: 1.3064
Batch 400/469 - Gen Loss: 0.8133, Disc Loss: 1.3060
Batch 450/469 - Gen Loss: 0.8136, Disc Loss: 1.3067

Epoch 33/50
Batch 50/469 - Gen Loss: 0.8122, Disc Loss: 1.3072
Batch 100/469 - Gen Loss: 0.8109, Disc Loss: 1.3056
Batch 150/469 - Gen Loss: 0.8103, Disc Loss: 1.3047
Batch 200/469 - Gen Loss: 0.8124, Disc Loss: 1.3046
Batch 250/469 - Gen Loss: 0.8157, Disc Loss: 1.3057
Batch 300/469 - Gen Loss: 0.8167, Disc Loss: 1.3047
Batch 350/469 - Gen Loss: 0.8161, Disc Loss: 1.3052
Batch 400/469 - Gen Loss: 0.8144, Disc Loss: 1.3064
Batch 450/469 - Gen Loss: 0.8141, Disc Loss: 1.3061

Epoch 34/50
Batch 50/469 - Gen Loss: 0.8314, Disc Loss: 1.3079
Batch 100/469 - Gen Loss: 0.8329, Disc Loss: 1.3046
Batch 150/469 - Gen Loss: 0.8329, Disc Loss: 1.3033
Batch 200/469 - Gen Loss: 0.8290, Disc Loss: 1.3041
Batch 250/469 - Gen Loss: 0.8246, Disc Loss: 1.3039
Batch 300/469 - Gen Loss: 0.8212, Disc Loss: 1.3059
Batch 350/469 - Gen Loss: 0.8188, Disc Loss: 1.3059
Batch 400/469 - Gen Loss: 0.8174, Disc Loss: 1.3063
```

```
Batch 450/469 - Gen Loss: 0.8174, Disc Loss: 1.3054

Epoch 35/50
Batch 50/469 - Gen Loss: 0.8070, Disc Loss: 1.3138
Batch 100/469 - Gen Loss: 0.8029, Disc Loss: 1.3141
Batch 150/469 - Gen Loss: 0.8049, Disc Loss: 1.3118
Batch 200/469 - Gen Loss: 0.8093, Disc Loss: 1.3118
Batch 250/469 - Gen Loss: 0.8097, Disc Loss: 1.3111
Batch 300/469 - Gen Loss: 0.8120, Disc Loss: 1.3095
Batch 350/469 - Gen Loss: 0.8128, Disc Loss: 1.3099
Batch 400/469 - Gen Loss: 0.8120, Disc Loss: 1.3095
Batch 450/469 - Gen Loss: 0.8110, Disc Loss: 1.3095

Epoch 36/50
Batch 50/469 - Gen Loss: 0.8074, Disc Loss: 1.3130
Batch 100/469 - Gen Loss: 0.8121, Disc Loss: 1.3116
Batch 150/469 - Gen Loss: 0.8133, Disc Loss: 1.3100
Batch 200/469 - Gen Loss: 0.8136, Disc Loss: 1.3076
Batch 250/469 - Gen Loss: 0.8148, Disc Loss: 1.3066
Batch 300/469 - Gen Loss: 0.8136, Disc Loss: 1.3063
Batch 350/469 - Gen Loss: 0.8128, Disc Loss: 1.3068
Batch 400/469 - Gen Loss: 0.8120, Disc Loss: 1.3077
Batch 450/469 - Gen Loss: 0.8115, Disc Loss: 1.3082

Epoch 37/50
Batch 50/469 - Gen Loss: 0.8068, Disc Loss: 1.3052
Batch 100/469 - Gen Loss: 0.8044, Disc Loss: 1.3100
Batch 150/469 - Gen Loss: 0.8028, Disc Loss: 1.3118
Batch 200/469 - Gen Loss: 0.8026, Disc Loss: 1.3122
Batch 250/469 - Gen Loss: 0.8028, Disc Loss: 1.3122
Batch 300/469 - Gen Loss: 0.8032, Disc Loss: 1.3127
Batch 350/469 - Gen Loss: 0.8041, Disc Loss: 1.3122
Batch 400/469 - Gen Loss: 0.8077, Disc Loss: 1.3129
Batch 450/469 - Gen Loss: 0.8098, Disc Loss: 1.3122

Epoch 38/50
Batch 50/469 - Gen Loss: 0.8315, Disc Loss: 1.3039
Batch 100/469 - Gen Loss: 0.8256, Disc Loss: 1.3042
Batch 150/469 - Gen Loss: 0.8253, Disc Loss: 1.3054
Batch 200/469 - Gen Loss: 0.8237, Disc Loss: 1.3067
Batch 250/469 - Gen Loss: 0.8219, Disc Loss: 1.3071
Batch 300/469 - Gen Loss: 0.8199, Disc Loss: 1.3073
Batch 350/469 - Gen Loss: 0.8181, Disc Loss: 1.3066
Batch 400/469 - Gen Loss: 0.8156, Disc Loss: 1.3073
Batch 450/469 - Gen Loss: 0.8143, Disc Loss: 1.3077

Epoch 39/50
Batch 50/469 - Gen Loss: 0.8127, Disc Loss: 1.3180
Batch 100/469 - Gen Loss: 0.8092, Disc Loss: 1.3127
Batch 150/469 - Gen Loss: 0.8084, Disc Loss: 1.3108
```

```
Batch 200/469 - Gen Loss: 0.8123, Disc Loss: 1.3112
Batch 250/469 - Gen Loss: 0.8161, Disc Loss: 1.3092
Batch 300/469 - Gen Loss: 0.8152, Disc Loss: 1.3096
Batch 350/469 - Gen Loss: 0.8141, Disc Loss: 1.3096
Batch 400/469 - Gen Loss: 0.8141, Disc Loss: 1.3091
Batch 450/469 - Gen Loss: 0.8130, Disc Loss: 1.3093

Epoch 40/50
Batch 50/469 - Gen Loss: 0.8053, Disc Loss: 1.3084
Batch 100/469 - Gen Loss: 0.8060, Disc Loss: 1.3108
Batch 150/469 - Gen Loss: 0.8062, Disc Loss: 1.3115
Batch 200/469 - Gen Loss: 0.8050, Disc Loss: 1.3135
Batch 250/469 - Gen Loss: 0.8044, Disc Loss: 1.3135
Batch 300/469 - Gen Loss: 0.8037, Disc Loss: 1.3149
Batch 350/469 - Gen Loss: 0.8033, Disc Loss: 1.3151
Batch 400/469 - Gen Loss: 0.8033, Disc Loss: 1.3147
Batch 450/469 - Gen Loss: 0.8031, Disc Loss: 1.3149

Epoch 41/50
Batch 50/469 - Gen Loss: 0.8115, Disc Loss: 1.3070
Batch 100/469 - Gen Loss: 0.8076, Disc Loss: 1.3113
Batch 150/469 - Gen Loss: 0.8088, Disc Loss: 1.3105
Batch 200/469 - Gen Loss: 0.8132, Disc Loss: 1.3099
Batch 250/469 - Gen Loss: 0.8111, Disc Loss: 1.3107
Batch 300/469 - Gen Loss: 0.8110, Disc Loss: 1.3106
Batch 350/469 - Gen Loss: 0.8108, Disc Loss: 1.3112
Batch 400/469 - Gen Loss: 0.8129, Disc Loss: 1.3104
Batch 450/469 - Gen Loss: 0.8122, Disc Loss: 1.3109

Epoch 42/50
Batch 50/469 - Gen Loss: 0.8185, Disc Loss: 1.3102
Batch 100/469 - Gen Loss: 0.8148, Disc Loss: 1.3135
Batch 150/469 - Gen Loss: 0.8115, Disc Loss: 1.3129
Batch 200/469 - Gen Loss: 0.8122, Disc Loss: 1.3128
Batch 250/469 - Gen Loss: 0.8095, Disc Loss: 1.3134
Batch 300/469 - Gen Loss: 0.8086, Disc Loss: 1.3133
Batch 350/469 - Gen Loss: 0.8095, Disc Loss: 1.3120
Batch 400/469 - Gen Loss: 0.8086, Disc Loss: 1.3124
Batch 450/469 - Gen Loss: 0.8085, Disc Loss: 1.3111

Epoch 43/50
Batch 50/469 - Gen Loss: 0.7998, Disc Loss: 1.3140
Batch 100/469 - Gen Loss: 0.8056, Disc Loss: 1.3124
Batch 150/469 - Gen Loss: 0.8070, Disc Loss: 1.3109
Batch 200/469 - Gen Loss: 0.8073, Disc Loss: 1.3103
Batch 250/469 - Gen Loss: 0.8059, Disc Loss: 1.3118
Batch 300/469 - Gen Loss: 0.8073, Disc Loss: 1.3131
Batch 350/469 - Gen Loss: 0.8072, Disc Loss: 1.3132
Batch 400/469 - Gen Loss: 0.8122, Disc Loss: 1.3132
Batch 450/469 - Gen Loss: 0.8163, Disc Loss: 1.3122
```

```
Epoch 44/50
Batch 50/469 - Gen Loss: 0.8367, Disc Loss: 1.3060
Batch 100/469 - Gen Loss: 0.8307, Disc Loss: 1.3028
Batch 150/469 - Gen Loss: 0.8242, Disc Loss: 1.3061
Batch 200/469 - Gen Loss: 0.8177, Disc Loss: 1.3084
Batch 250/469 - Gen Loss: 0.8135, Disc Loss: 1.3091
Batch 300/469 - Gen Loss: 0.8103, Disc Loss: 1.3100
Batch 350/469 - Gen Loss: 0.8094, Disc Loss: 1.3104
Batch 400/469 - Gen Loss: 0.8081, Disc Loss: 1.3109
Batch 450/469 - Gen Loss: 0.8081, Disc Loss: 1.3105

Epoch 45/50
Batch 50/469 - Gen Loss: 0.7977, Disc Loss: 1.3178
Batch 100/469 - Gen Loss: 0.8010, Disc Loss: 1.3122
Batch 150/469 - Gen Loss: 0.8022, Disc Loss: 1.3125
Batch 200/469 - Gen Loss: 0.8024, Disc Loss: 1.3139
Batch 250/469 - Gen Loss: 0.8020, Disc Loss: 1.3142
Batch 300/469 - Gen Loss: 0.8042, Disc Loss: 1.3140
Batch 350/469 - Gen Loss: 0.8041, Disc Loss: 1.3139
Batch 400/469 - Gen Loss: 0.8067, Disc Loss: 1.3127
Batch 450/469 - Gen Loss: 0.8060, Disc Loss: 1.3129

Epoch 46/50
Batch 50/469 - Gen Loss: 0.8095, Disc Loss: 1.3101
Batch 100/469 - Gen Loss: 0.8055, Disc Loss: 1.3104
Batch 150/469 - Gen Loss: 0.8070, Disc Loss: 1.3114
Batch 200/469 - Gen Loss: 0.8065, Disc Loss: 1.3123
Batch 250/469 - Gen Loss: 0.8069, Disc Loss: 1.3115
Batch 300/469 - Gen Loss: 0.8077, Disc Loss: 1.3126
Batch 350/469 - Gen Loss: 0.8066, Disc Loss: 1.3140
Batch 400/469 - Gen Loss: 0.8069, Disc Loss: 1.3146
Batch 450/469 - Gen Loss: 0.8070, Disc Loss: 1.3140

Epoch 47/50
Batch 50/469 - Gen Loss: 0.8017, Disc Loss: 1.3154
Batch 100/469 - Gen Loss: 0.8013, Disc Loss: 1.3176
Batch 150/469 - Gen Loss: 0.8020, Disc Loss: 1.3148
Batch 200/469 - Gen Loss: 0.8081, Disc Loss: 1.3147
Batch 250/469 - Gen Loss: 0.8111, Disc Loss: 1.3123
Batch 300/469 - Gen Loss: 0.8153, Disc Loss: 1.3126
Batch 350/469 - Gen Loss: 0.8177, Disc Loss: 1.3115
Batch 400/469 - Gen Loss: 0.8167, Disc Loss: 1.3110
Batch 450/469 - Gen Loss: 0.8158, Disc Loss: 1.3105

Epoch 48/50
Batch 50/469 - Gen Loss: 0.8076, Disc Loss: 1.3066
Batch 100/469 - Gen Loss: 0.8044, Disc Loss: 1.3112
Batch 150/469 - Gen Loss: 0.8054, Disc Loss: 1.3122
Batch 200/469 - Gen Loss: 0.8059, Disc Loss: 1.3132
```

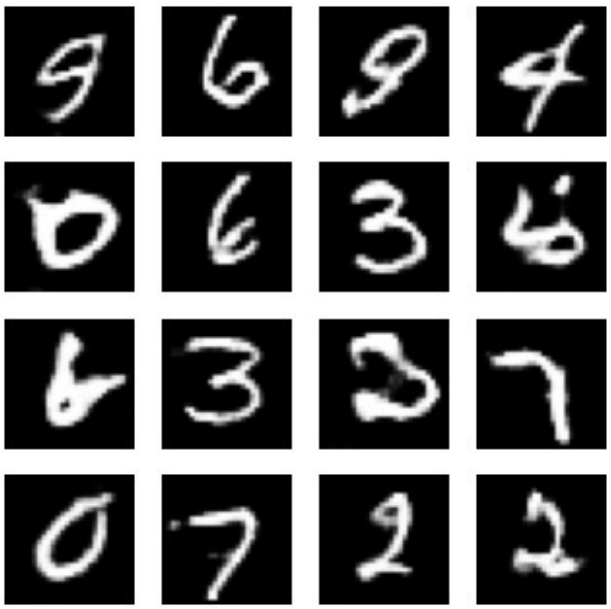
```
Batch 250/469 - Gen Loss: 0.8080, Disc Loss: 1.3124
Batch 300/469 - Gen Loss: 0.8086, Disc Loss: 1.3139
Batch 350/469 - Gen Loss: 0.8092, Disc Loss: 1.3134
Batch 400/469 - Gen Loss: 0.8097, Disc Loss: 1.3135
Batch 450/469 - Gen Loss: 0.8088, Disc Loss: 1.3137

Epoch 49/50
Batch 50/469 - Gen Loss: 0.8105, Disc Loss: 1.3077
Batch 100/469 - Gen Loss: 0.8110, Disc Loss: 1.3119
Batch 150/469 - Gen Loss: 0.8101, Disc Loss: 1.3123
Batch 200/469 - Gen Loss: 0.8071, Disc Loss: 1.3146
Batch 250/469 - Gen Loss: 0.8067, Disc Loss: 1.3145
Batch 300/469 - Gen Loss: 0.8067, Disc Loss: 1.3136
Batch 350/469 - Gen Loss: 0.8075, Disc Loss: 1.3134
Batch 400/469 - Gen Loss: 0.8066, Disc Loss: 1.3133
Batch 450/469 - Gen Loss: 0.8063, Disc Loss: 1.3132

Epoch 50/50
Batch 50/469 - Gen Loss: 0.8176, Disc Loss: 1.3038
Batch 100/469 - Gen Loss: 0.8130, Disc Loss: 1.3078
Batch 150/469 - Gen Loss: 0.8140, Disc Loss: 1.3091
Batch 200/469 - Gen Loss: 0.8147, Disc Loss: 1.3106
Batch 250/469 - Gen Loss: 0.8138, Disc Loss: 1.3110
Batch 300/469 - Gen Loss: 0.8166, Disc Loss: 1.3106
Batch 350/469 - Gen Loss: 0.8151, Disc Loss: 1.3116
Batch 400/469 - Gen Loss: 0.8156, Disc Loss: 1.3111
Batch 450/469 - Gen Loss: 0.8150, Disc Loss: 1.3113
```

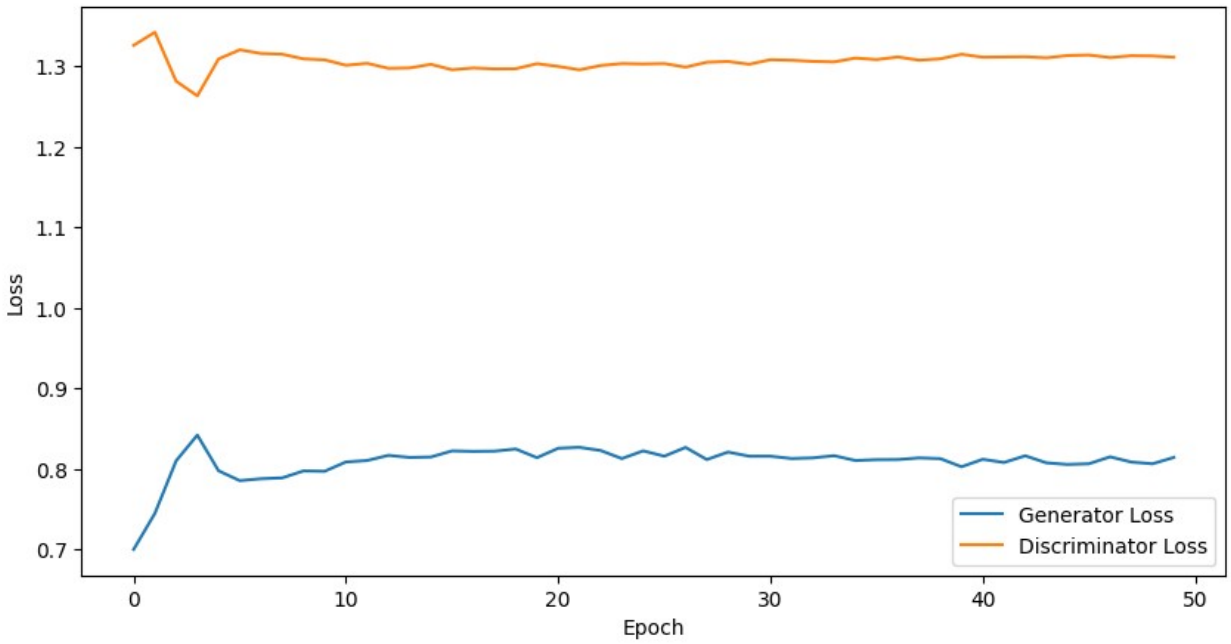
visualising images from generator

```
# Final generation and visualization
generate_and_save_images(generator, EPOCHS, seed)
```



plotting losses

```
# Plot losses
plt.figure(figsize=(10, 5))
plt.plot(gen_losses, label='Generator Loss')
plt.plot(disc_losses, label='Discriminator Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



minimum losses

```
print(f"minimum loss for generator is {min(gen_losses)}")
print(f"minimum loss for discriminator is {min(disc_losses)}")
```

```
minimum loss for generator is 0.7004441618919373
minimum loss for discriminator is 1.2633113861083984
```