Assignment is below at the bottom

Video 13.1 https://www.youtube.com/watch?v=kIGHE7Cfe1s

Video 13.2 https://www.youtube.com/watch?v=Rm9bJcDd1KU

Video 13.3 https://youtu.be/6HjZk-3LsjE

In [11]:
```
import tensorflow as tf
tf.compat.v1.logging.set_verbosity(tf.compat.v1.logging.ERROR)

from keras.callbacks import TensorBoard
from keras.layers import Input, Dense
from keras.models import Model
from keras.datasets import mnist
import numpy as np

(xtrain, ytrain), (xtest, ytest) = mnist.load_data()

xtrain = xtrain.astype('float32') / 255.
xtest = xtest.astype('float32') / 255.
xtrain = xtrain.reshape((len(xtrain), np.prod(xtrain.shape[1:])))
xtest = xtest.reshape((len(xtest), np.prod(xtest.shape[1:])))
xtrain.shape, xtest.shape
```

Out[11]:
```
((60000, 784), (10000, 784))
```

In [12]:
```
# this is the size of our encoded representations
encoding_dim = 4  # 32 floats -> compression of factor 24.5, assuming the input is 784 f

# this is our input placeholder
x = input_img = Input(shape=(784,))
# "encoded" is the encoded representation of the input
x = Dense(256, activation='relu')(x)
x = Dense(128, activation='relu')(x)
encoded = Dense(encoding_dim, activation='relu')(x)


# "decoded" is the lossy reconstruction of the input
x = Dense(128, activation='relu')(encoded)
x = Dense(256, activation='relu')(x)
decoded = Dense(784, activation='sigmoid')(x)

# this model maps an input to its reconstruction
autoencoder = Model(input_img, decoded)

encoder = Model(input_img, encoded)

# create a placeholder for an encoded (32-dimensional) input
encoded_input = Input(shape=(encoding_dim,))
# retrieve the last layer of the autoencoder model
dcd1 = autoencoder.layers[-1]
dcd2 = autoencoder.layers[-2]
dcd3 = autoencoder.layers[-3]

# create the decoder model
decoder = Model(encoded_input, dcd1(dcd2(dcd3(encoded_input))))
```

In [13]:
```
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

In [14]:
```
autoencoder.fit(xtrain, xtrain,
                epochs=50,
                batch_size=256,
                shuffle=True,
                validation_data=(xtest, xtest),
                callbacks=[TensorBoard(log_dir='/tmp/auto')])
```

```
Epoch 1/50
  1/235 [..............................] - ETA: 1:12 - loss: 0.6930
2022-11-19 18:15:27.757422: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2526
2022-11-19 18:15:29.959634: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 10ms/step - loss: 0.2526 - val_loss: 0.201
2
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1941 - val_loss: 0.1884
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1854 - val_loss: 0.1813
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1793 - val_loss: 0.1763
Epoch 5/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1750 - val_loss: 0.1727
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1719 - val_loss: 0.1703
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1696 - val_loss: 0.1690
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1678 - val_loss: 0.1670
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1662 - val_loss: 0.1660
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1650 - val_loss: 0.1649
Epoch 11/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1637 - val_loss: 0.1639
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1627 - val_loss: 0.1632
Epoch 13/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1619 - val_loss: 0.1623
Epoch 14/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1610 - val_loss: 0.1621
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1603 - val_loss: 0.1618
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1596 - val_loss: 0.1611
Epoch 17/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1589 - val_loss: 0.1603
Epoch 18/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1584 - val_loss: 0.1601
Epoch 19/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1578 - val_loss: 0.1598
Epoch 20/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1573 - val_loss: 0.1593
Epoch 21/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1568 - val_loss: 0.1590
Epoch 22/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1564 - val_loss: 0.1588
Epoch 23/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1559 - val_loss: 0.1585
Epoch 24/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1555 - val_loss: 0.1581
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1552 - val_loss: 0.1580
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1548 - val_loss: 0.1576
Epoch 27/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1544 - val_loss: 0.1576
Epoch 28/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1540 - val_loss: 0.1574
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1537 - val_loss: 0.1572
Epoch 30/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1535 - val_loss: 0.1569
Epoch 31/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1532 - val_loss: 0.1568
```

```
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1529 - val_loss: 0.1567
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1527 - val_loss: 0.1568
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1524 - val_loss: 0.1564
Epoch 35/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1522 - val_loss: 0.1565
Epoch 36/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1521 - val_loss: 0.1562
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1518 - val_loss: 0.1562
Epoch 38/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1516 - val_loss: 0.155
8
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1514 - val_loss: 0.1560
Epoch 40/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1512 - val_loss: 0.155
5
Epoch 41/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1510 - val_loss: 0.155
8
Epoch 42/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1508 - val_loss: 0.155
8
Epoch 43/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1507 - val_loss: 0.155
5
Epoch 44/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1506 - val_loss: 0.155
2
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1504 - val_loss: 0.1554
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1502 - val_loss: 0.1552
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1501 - val_loss: 0.1551
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1499 - val_loss: 0.1553
Epoch 49/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1499 - val_loss: 0.1550
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1497 - val_loss: 0.1550
```

Out[14]:
```
<keras.callbacks.History at 0x2e10d25e0>
```

In [22]:
```
encoded_imgs
```

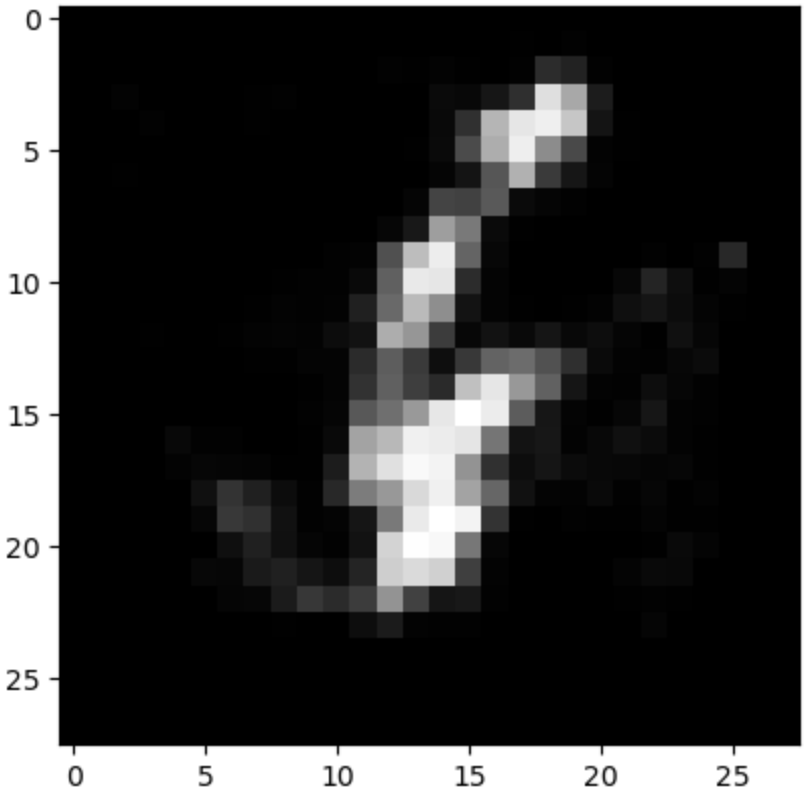
Out[22]:
```
array([[ 7.6594334 , 37.47538   ,  0.        ,  9.504147  ],
       [34.549664  , 13.835002  ,  0.        , 13.747142  ],
       [67.74897   , 48.452415  ,  0.        , 26.439318  ],
       ...,
       [11.790174  , 21.768717  ,  0.        ,  7.6855597 ],
       [12.447085  , 10.563789  ,  0.        ,  0.52747333],
       [21.274275  , 18.577665  ,  0.        , 33.929012  ]],
      dtype=float32)
```

In [28]:
```
noise = np.random.normal(20,4, (4,4))
noise_preds = decoder.predict(noise)
```

```
1/1 [==============================] - 0s 19ms/step
```

In [30]:
```
plt.imshow(noise_preds[2].reshape(28,28))
```

Out[30]:
```
<matplotlib.image.AxesImage at 0x2820edfd0>
```



In [23]:
```
np.max(encoded_imgs)
```

Out[23]:
```
106.08684
```

In [15]:
```
encoded_imgs = encoder.predict(xtest)
decoded_imgs = decoder.predict(encoded_imgs)
import matplotlib.pyplot as plt

n = 20  # how many digits we will display
plt.figure(figsize=(40, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(xtest[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

```
114/313 [=========>....................] - ETA: 0s
2022-11-19 18:17:12.053037: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
313/313 [==============================] - 1s 1ms/step
109/313 [=========>....................] - ETA: 0s
```

```
2022-11-19 18:17:12.623956: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
313/313 [==============================] - 0s 1ms/step
```

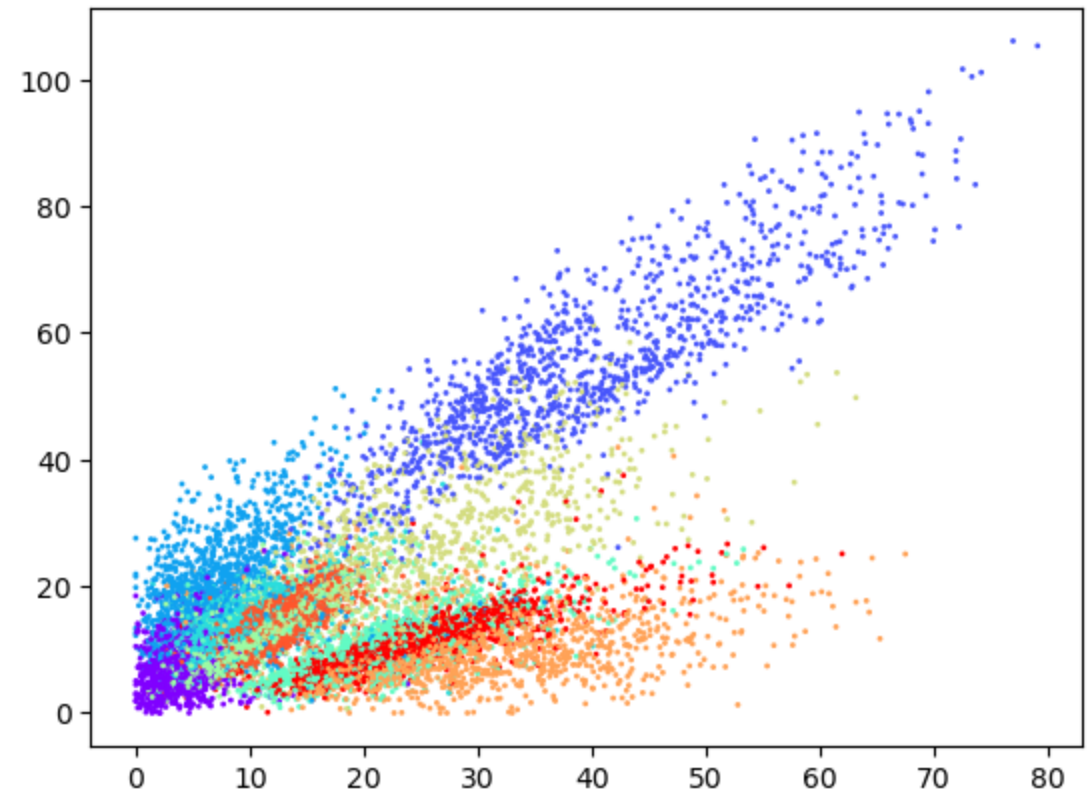
In [16]:
```
encoded_imgs
```

Out[16]:
```
array([[ 7.6594334 , 37.47538   ,  0.        ,  9.504147  ],
       [34.549664  , 13.835002  ,  0.        , 13.747142  ],
       [67.74897   , 48.452415  ,  0.        , 26.439318  ],
       ...,
       [11.790174  , 21.768717  ,  0.        ,  7.6855597 ],
       [12.447085  , 10.563789  ,  0.        ,  0.52747333],
       [21.274275  , 18.577665  ,  0.        , 33.929012  ]],
      dtype=float32)
```

In [17]:
```
%matplotlib inline
```

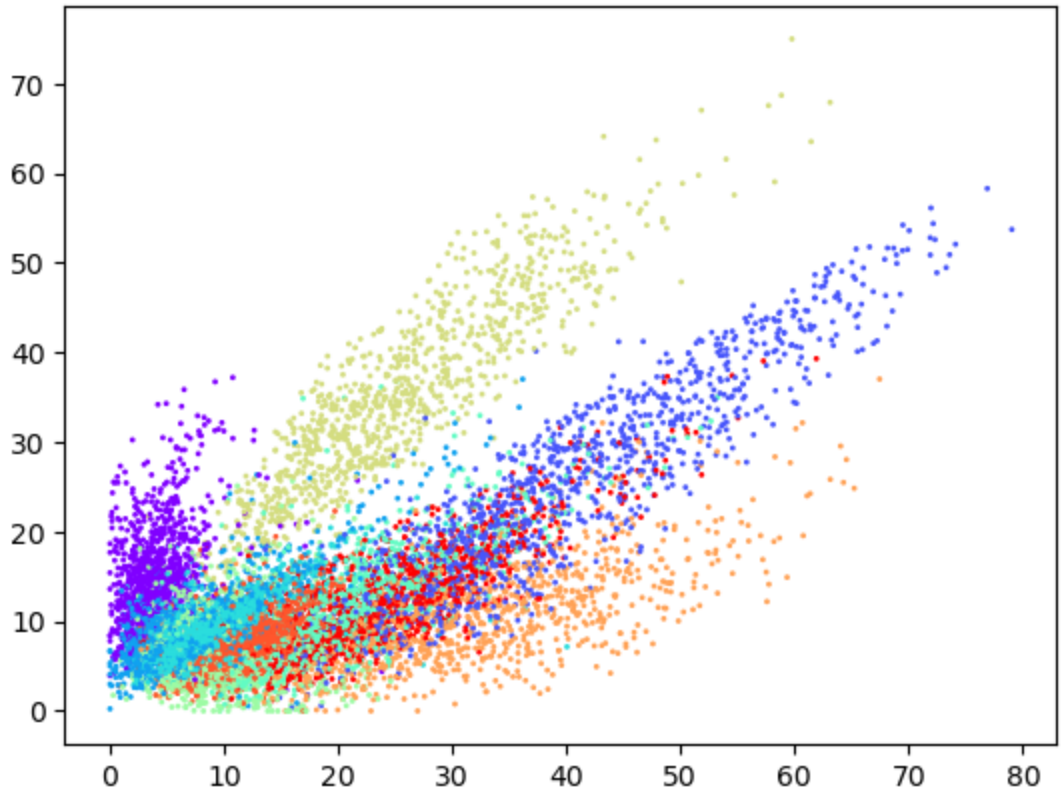
In [31]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,0], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[31]:
```
<matplotlib.collections.PathCollection at 0x2807b22b0>
```



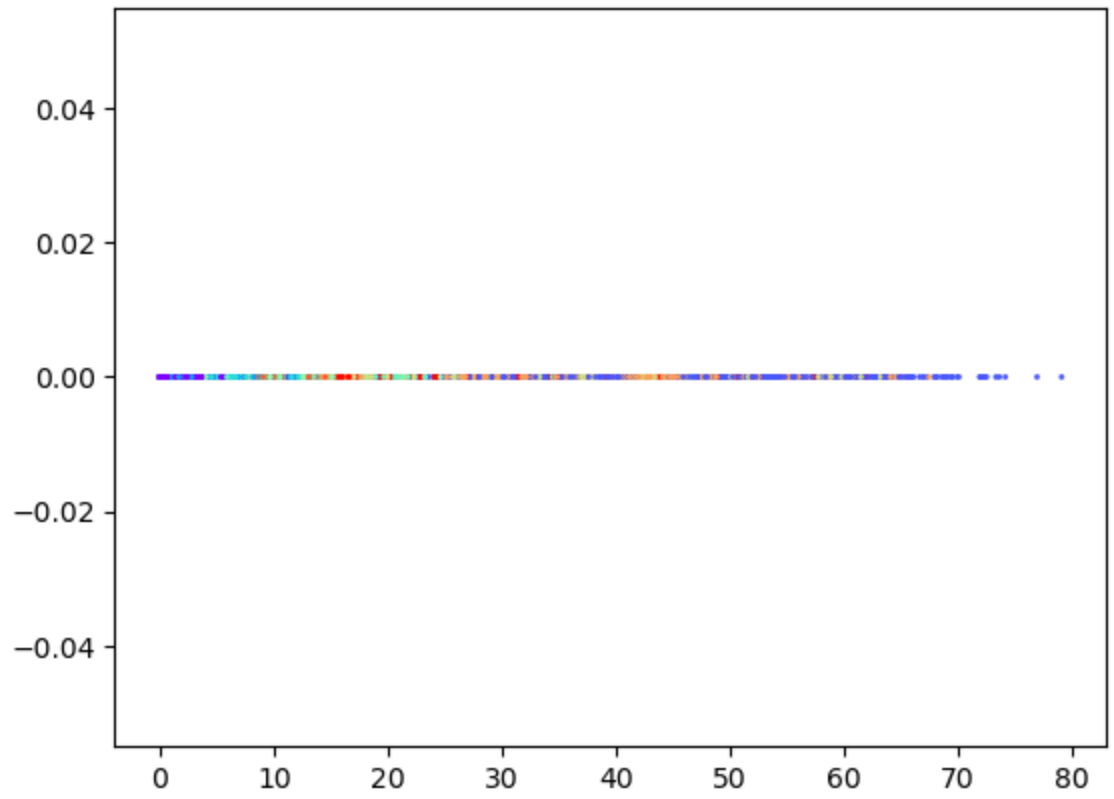
In [32]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,3], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[32]:
```
<matplotlib.collections.PathCollection at 0x2807b2370>
```



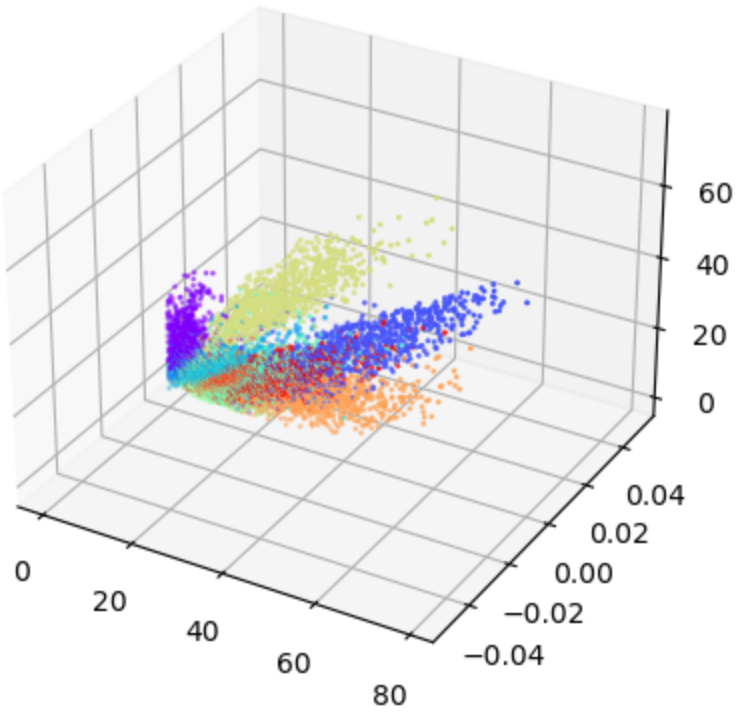
In [33]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,2], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[33]: <matplotlib.collections.PathCollection at 0x2806e7100>



In [34]:
```
from mpl_toolkits.mplot3d import Axes3D
fig = plt.figure()
ax = fig.add_subplot(111, projection='3d')
ax.scatter(encoded_imgs[:,1], encoded_imgs[:,2], encoded_imgs[:,3], c=ytest, cmap='rainb
```

Out[34]: <mpl_toolkits.mplot3d.art3d.Path3DCollection at 0x2806f2dc0>



Assignment

1. change the `encoding_dim` through various values (`range(2,18,2)` and store or keep track of the best loss you can get. Plot the 8 pairs of dimensions vs loss on a scatter plot

In [35]:
```
(xtrain, ytrain), (xtest, ytest) = mnist.load_data()

xtrain = xtrain.astype('float32') / 255.
xtest = xtest.astype('float32') / 255.
xtrain = xtrain.reshape((len(xtrain), np.prod(xtrain.shape[1:])))
xtest = xtest.reshape((len(xtest), np.prod(xtest.shape[1:])))
xtrain.shape, xtest.shape
```

Out[35]:
```
((60000, 784), (10000, 784))
```

In [38]:
```
dimensions = range(2,18,2)
```

In [46]:
```
losses = []
for encoding_dim in dimensions:

    encoding_dim = encoding_dim

    x = input_img = Input(shape=(784,))
    x = Dense(256, activation='relu')(x)
    x = Dense(128, activation='relu')(x)
    encoded = Dense(encoding_dim, activation='relu')(x)

    x = Dense(128, activation='relu')(encoded)
    x = Dense(256, activation='relu')(x)
    decoded = Dense(784, activation='sigmoid')(x)

    autoencoder = Model(input_img, decoded)
```

```
    encoder = Model(input_img, encoded)

    encoded_input = Input(shape=(encoding_dim,))

    dcd1 = autoencoder.layers[-1]
    dcd2 = autoencoder.layers[-2]
    dcd3 = autoencoder.layers[-3]

    decoder = Model(encoded_input, dcd1(dcd2(dcd3(encoded_input))))

    autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

    autoencoder.fit(xtrain, xtrain,
                epochs=50,
                batch_size=256,
                shuffle=True,
                validation_data=(xtest, xtest),
                callbacks=[TensorBoard(log_dir='/tmp/hmwk2')])

    loss = autoencoder.evaluate(xtrain,xtrain,verbose=0)
    losses.append(loss)
```

```
Epoch 1/50
2022-11-19 18:37:49.628826: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2715
2022-11-19 18:37:52.202169: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 11ms/step - loss: 0.2715 - val_loss: 0.227
8
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2215 - val_loss: 0.2131
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2099 - val_loss: 0.2056
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2022 - val_loss: 0.1981
Epoch 5/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1959 - val_loss: 0.193
5
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1924 - val_loss: 0.1908
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1900 - val_loss: 0.1893
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1882 - val_loss: 0.1873
Epoch 9/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1865 - val_loss: 0.185
7
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1854 - val_loss: 0.1851
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1844 - val_loss: 0.1843
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1836 - val_loss: 0.1833
Epoch 13/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1826 - val_loss: 0.182
3
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1818 - val_loss: 0.1818
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1811 - val_loss: 0.1814
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1805 - val_loss: 0.1812
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1800 - val_loss: 0.1804
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1796 - val_loss: 0.180
1
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1789 - val_loss: 0.179
6
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1784 - val_loss: 0.1793
Epoch 21/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1780 - val_loss: 0.178
7
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1774 - val_loss: 0.1781
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1769 - val_loss: 0.1786
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1766 - val_loss: 0.1779
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1760 - val_loss: 0.1776
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1756 - val_loss: 0.1772
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1754 - val_loss: 0.1768
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1752 - val_loss: 0.1768
```

```
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1747 - val_loss: 0.1768
Epoch 30/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1743 - val_loss: 0.1760
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1741 - val_loss: 0.1758
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1738 - val_loss: 0.1756
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1736 - val_loss: 0.1759
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1731 - val_loss: 0.1753
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1727 - val_loss: 0.1752
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1730 - val_loss: 0.1754
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1727 - val_loss: 0.1749
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1723 - val_loss: 0.1749
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1722 - val_loss: 0.1742
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1716 - val_loss: 0.1743
Epoch 41/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1714 - val_loss: 0.174
2
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1713 - val_loss: 0.1740
Epoch 43/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1711 - val_loss: 0.1739
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1707 - val_loss: 0.1741
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1706 - val_loss: 0.1739
Epoch 46/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1704 - val_loss: 0.173
5
Epoch 47/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1701 - val_loss: 0.173
3
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1698 - val_loss: 0.1731
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1697 - val_loss: 0.1731
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1695 - val_loss: 0.1735
Epoch 1/50
2022-11-19 18:39:44.180305: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2883
2022-11-19 18:39:46.682962: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 11ms/step - loss: 0.2883 - val_loss: 0.250
2
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2460 - val_loss: 0.2397
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2106 - val_loss: 0.1912
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1856 - val_loss: 0.1820
Epoch 5/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1799 - val_loss: 0.1782
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1765 - val_loss: 0.1755
Epoch 7/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1740 - val_loss: 0.173
2
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1719 - val_loss: 0.1717
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1703 - val_loss: 0.1705
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1690 - val_loss: 0.1693
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1678 - val_loss: 0.1683
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1668 - val_loss: 0.1674
Epoch 13/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1657 - val_loss: 0.1663
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1648 - val_loss: 0.1655
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1640 - val_loss: 0.1652
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1632 - val_loss: 0.1644
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1626 - val_loss: 0.1639
Epoch 18/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1620 - val_loss: 0.1635
Epoch 19/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1614 - val_loss: 0.1631
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1609 - val_loss: 0.1628
Epoch 21/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1604 - val_loss: 0.1625
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1599 - val_loss: 0.1620
Epoch 23/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1594 - val_loss: 0.162
2
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1591 - val_loss: 0.1618
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1586 - val_loss: 0.1611
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1582 - val_loss: 0.1609
Epoch 27/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1579 - val_loss: 0.160
8
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1576 - val_loss: 0.1607
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1572 - val_loss: 0.1602
Epoch 30/50
```

```
235/235 [==============================] - 2s 9ms/step - loss: 0.1569 - val_loss: 0.1601
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1566 - val_loss: 0.1600
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1563 - val_loss: 0.1601
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1561 - val_loss: 0.1596
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1557 - val_loss: 0.1593
Epoch 35/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1555 - val_loss: 0.158
9
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1553 - val_loss: 0.1593
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1550 - val_loss: 0.1590
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1548 - val_loss: 0.1589
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1545 - val_loss: 0.1587
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1543 - val_loss: 0.1589
Epoch 41/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1542 - val_loss: 0.1584
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1539 - val_loss: 0.1581
Epoch 43/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1537 - val_loss: 0.158
1
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1535 - val_loss: 0.1580
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1533 - val_loss: 0.1583
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1532 - val_loss: 0.1577
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1529 - val_loss: 0.1577
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1530 - val_loss: 0.1576
Epoch 49/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1527 - val_loss: 0.158
1
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1526 - val_loss: 0.1574
Epoch 1/50
2022-11-19 18:41:37.224172: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2440
2022-11-19 18:41:39.743493: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 11ms/step - loss: 0.2440 - val_loss: 0.177
9
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1691 - val_loss: 0.1622
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1590 - val_loss: 0.1556
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1537 - val_loss: 0.1518
Epoch 5/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1506 - val_loss: 0.1492
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1483 - val_loss: 0.1476
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1465 - val_loss: 0.1456
Epoch 8/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1449 - val_loss: 0.1447
Epoch 9/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1437 - val_loss: 0.1431
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1426 - val_loss: 0.1424
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1416 - val_loss: 0.1415
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1408 - val_loss: 0.1415
Epoch 13/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1400 - val_loss: 0.1405
Epoch 14/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1393 - val_loss: 0.1397
Epoch 15/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1387 - val_loss: 0.1390
Epoch 16/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1380 - val_loss: 0.1386
Epoch 17/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1375 - val_loss: 0.1385
Epoch 18/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1370 - val_loss: 0.1377
Epoch 19/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1365 - val_loss: 0.1379
Epoch 20/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1361 - val_loss: 0.1371
Epoch 21/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1356 - val_loss: 0.1370
Epoch 22/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1352 - val_loss: 0.1368
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1348 - val_loss: 0.1361
Epoch 24/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1344 - val_loss: 0.1361
Epoch 25/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1341 - val_loss: 0.1359
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1337 - val_loss: 0.1359
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1335 - val_loss: 0.1352
Epoch 28/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1331 - val_loss: 0.134
9
Epoch 29/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1328 - val_loss: 0.135
0
Epoch 30/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1325 - val_loss: 0.1347
```

```
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1322 - val_loss: 0.1345
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1319 - val_loss: 0.1343
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1317 - val_loss: 0.1341
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1314 - val_loss: 0.1341
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1312 - val_loss: 0.1337
Epoch 36/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1310 - val_loss: 0.133
8
Epoch 37/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1307 - val_loss: 0.133
4
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1306 - val_loss: 0.1334
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1304 - val_loss: 0.1333
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1302 - val_loss: 0.1331
Epoch 41/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1299 - val_loss: 0.1330
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1298 - val_loss: 0.1329
Epoch 43/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1296 - val_loss: 0.1329
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1295 - val_loss: 0.1331
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1293 - val_loss: 0.1329
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1291 - val_loss: 0.1326
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1290 - val_loss: 0.1325
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1289 - val_loss: 0.1328
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1287 - val_loss: 0.1323
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1285 - val_loss: 0.1324
Epoch 1/50
2022-11-19 18:43:27.577297: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2327
2022-11-19 18:43:30.076206: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 11ms/step - loss: 0.2327 - val_loss: 0.165
4
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1523 - val_loss: 0.1424
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1391 - val_loss: 0.1343
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1335 - val_loss: 0.1309
Epoch 5/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1300 - val_loss: 0.1278
Epoch 6/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1275 - val_loss: 0.125
5
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1254 - val_loss: 0.1243
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1237 - val_loss: 0.1230
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1223 - val_loss: 0.1213
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1211 - val_loss: 0.1201
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1201 - val_loss: 0.1191
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1192 - val_loss: 0.1186
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1184 - val_loss: 0.1177
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1177 - val_loss: 0.1176
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1171 - val_loss: 0.1174
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1165 - val_loss: 0.1164
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1160 - val_loss: 0.1160
Epoch 18/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1155 - val_loss: 0.1155
Epoch 19/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1151 - val_loss: 0.1152
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1147 - val_loss: 0.1146
Epoch 21/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1143 - val_loss: 0.1146
Epoch 22/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1139 - val_loss: 0.114
2
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1136 - val_loss: 0.1142
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1133 - val_loss: 0.1137
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1130 - val_loss: 0.1137
Epoch 26/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1127 - val_loss: 0.113
4
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1124 - val_loss: 0.1134
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1122 - val_loss: 0.1130
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1120 - val_loss: 0.1129
Epoch 30/50
```

```
235/235 [==============================] - 2s 9ms/step - loss: 0.1117 - val_loss: 0.1124
Epoch 31/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1115 - val_loss: 0.1124
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1114 - val_loss: 0.1126
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1111 - val_loss: 0.1122
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1109 - val_loss: 0.1120
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1107 - val_loss: 0.1119
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1106 - val_loss: 0.1120
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1105 - val_loss: 0.1116
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1103 - val_loss: 0.1116
Epoch 39/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1101 - val_loss: 0.1114
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1099 - val_loss: 0.1114
Epoch 41/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1098 - val_loss: 0.111
5
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1097 - val_loss: 0.1114
Epoch 43/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1096 - val_loss: 0.1112
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1095 - val_loss: 0.1114
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1093 - val_loss: 0.1110
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1092 - val_loss: 0.1113
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1090 - val_loss: 0.1108
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1089 - val_loss: 0.1110
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1088 - val_loss: 0.1110
Epoch 50/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1087 - val_loss: 0.1109
Epoch 1/50
2022-11-19 18:45:19.787173: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2374
2022-11-19 18:45:22.416920: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 12ms/step - loss: 0.2374 - val_loss: 0.161
0
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1508 - val_loss: 0.1423
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1399 - val_loss: 0.1354
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1346 - val_loss: 0.1315
Epoch 5/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1312 - val_loss: 0.1287
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1284 - val_loss: 0.1266
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1263 - val_loss: 0.1247
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1247 - val_loss: 0.1232
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1233 - val_loss: 0.1220
Epoch 10/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1221 - val_loss: 0.1208
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1210 - val_loss: 0.1201
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1201 - val_loss: 0.119
3
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1193 - val_loss: 0.1185
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1185 - val_loss: 0.1182
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1179 - val_loss: 0.1178
Epoch 16/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1173 - val_loss: 0.1170
Epoch 17/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1168 - val_loss: 0.116
6
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1163 - val_loss: 0.116
2
Epoch 19/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1158 - val_loss: 0.1157
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1154 - val_loss: 0.1152
Epoch 21/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1149 - val_loss: 0.1154
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1146 - val_loss: 0.1148
Epoch 23/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1142 - val_loss: 0.1146
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1139 - val_loss: 0.1141
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1136 - val_loss: 0.1140
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1134 - val_loss: 0.1139
Epoch 27/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1130 - val_loss: 0.1137
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1128 - val_loss: 0.1135
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1125 - val_loss: 0.1135
Epoch 30/50
```

```
235/235 [==============================] - 2s 9ms/step - loss: 0.1123 - val_loss: 0.1130
Epoch 31/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1121 - val_loss: 0.112
8
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1119 - val_loss: 0.1127
Epoch 33/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1116 - val_loss: 0.1125
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1115 - val_loss: 0.1126
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1112 - val_loss: 0.1125
Epoch 36/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1111 - val_loss: 0.1121
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1109 - val_loss: 0.1123
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1107 - val_loss: 0.1121
Epoch 39/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1106 - val_loss: 0.1120
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1104 - val_loss: 0.1118
Epoch 41/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1102 - val_loss: 0.1118
Epoch 42/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1102 - val_loss: 0.1115
Epoch 43/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1100 - val_loss: 0.1114
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1098 - val_loss: 0.1114
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1097 - val_loss: 0.1114
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1096 - val_loss: 0.1113
Epoch 47/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1095 - val_loss: 0.111
3
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1093 - val_loss: 0.1111
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1092 - val_loss: 0.1110
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1091 - val_loss: 0.1107
Epoch 1/50
2022-11-19 18:47:12.881691: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2380
2022-11-19 18:47:15.391630: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 11ms/step - loss: 0.2380 - val_loss: 0.163
5
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1506 - val_loss: 0.1405
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1372 - val_loss: 0.1315
Epoch 4/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1283 - val_loss: 0.1266
Epoch 5/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1237 - val_loss: 0.1209
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1207 - val_loss: 0.1185
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1186 - val_loss: 0.1166
Epoch 8/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1168 - val_loss: 0.1150
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1153 - val_loss: 0.1139
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1141 - val_loss: 0.1128
Epoch 11/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1130 - val_loss: 0.112
0
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1122 - val_loss: 0.1114
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1113 - val_loss: 0.1107
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1106 - val_loss: 0.1099
Epoch 15/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1099 - val_loss: 0.1095
Epoch 16/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1093 - val_loss: 0.1089
Epoch 17/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1088 - val_loss: 0.1087
Epoch 18/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1083 - val_loss: 0.1080
Epoch 19/50
235/235 [==============================] - 2s 8ms/step - loss: 0.1078 - val_loss: 0.1078
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1074 - val_loss: 0.1075
Epoch 21/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1069 - val_loss: 0.1069
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1066 - val_loss: 0.1065
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1062 - val_loss: 0.1067
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1058 - val_loss: 0.1061
Epoch 25/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1055 - val_loss: 0.105
8
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1053 - val_loss: 0.1060
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1049 - val_loss: 0.1052
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1047 - val_loss: 0.1053
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1044 - val_loss: 0.1048
Epoch 30/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1041 - val_loss: 0.104
```

```
8
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1039 - val_loss: 0.1046
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1037 - val_loss: 0.1045
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1035 - val_loss: 0.1046
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1033 - val_loss: 0.1041
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1031 - val_loss: 0.1041
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1029 - val_loss: 0.1039
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1028 - val_loss: 0.1039
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1025 - val_loss: 0.1036
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1023 - val_loss: 0.1037
Epoch 40/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1022 - val_loss: 0.103
5
Epoch 41/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1021 - val_loss: 0.1034
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1019 - val_loss: 0.1031
Epoch 43/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1017 - val_loss: 0.1032
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1016 - val_loss: 0.1031
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1015 - val_loss: 0.1029
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1014 - val_loss: 0.1028
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1012 - val_loss: 0.1027
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1011 - val_loss: 0.1028
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1011 - val_loss: 0.1028
Epoch 50/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1009 - val_loss: 0.102
7
Epoch 1/50
2022-11-19 18:49:05.793149: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2245
2022-11-19 18:49:08.443643: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 12ms/step - loss: 0.2245 - val_loss: 0.150
5
Epoch 2/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1378 - val_loss: 0.126
8
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1243 - val_loss: 0.1198
Epoch 4/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1189 - val_loss: 0.115
4
Epoch 5/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1156 - val_loss: 0.113
0
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1132 - val_loss: 0.1113
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1112 - val_loss: 0.1095
Epoch 8/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1097 - val_loss: 0.107
9
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1083 - val_loss: 0.1068
Epoch 10/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1071 - val_loss: 0.106
0
Epoch 11/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1060 - val_loss: 0.105
0
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1051 - val_loss: 0.1039
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1043 - val_loss: 0.1033
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1036 - val_loss: 0.1029
Epoch 15/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1029 - val_loss: 0.102
2
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1024 - val_loss: 0.1017
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1017 - val_loss: 0.1015
Epoch 18/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1013 - val_loss: 0.1006
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1008 - val_loss: 0.100
5
Epoch 20/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1003 - val_loss: 0.100
0
Epoch 21/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0999 - val_loss: 0.099
7
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0995 - val_loss: 0.0993
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0992 - val_loss: 0.0992
Epoch 24/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0989 - val_loss: 0.099
0
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0985 - val_loss: 0.0987
Epoch 26/50
```

```
235/235 [==============================] - 2s 10ms/step - loss: 0.0983 - val_loss: 0.098
4
Epoch 27/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0979 - val_loss: 0.098
2
Epoch 28/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0977 - val_loss: 0.098
4
Epoch 29/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0975 - val_loss: 0.097
9
Epoch 30/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0972 - val_loss: 0.097
5
Epoch 31/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0970 - val_loss: 0.097
3
Epoch 32/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0968 - val_loss: 0.097
3
Epoch 33/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0966 - val_loss: 0.097
0
Epoch 34/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0964 - val_loss: 0.097
2
Epoch 35/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0963 - val_loss: 0.096
8
Epoch 36/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0961 - val_loss: 0.096
6
Epoch 37/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0959 - val_loss: 0.096
4
Epoch 38/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0957 - val_loss: 0.096
5
Epoch 39/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0956 - val_loss: 0.096
2
Epoch 40/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0954 - val_loss: 0.096
1
Epoch 41/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0953 - val_loss: 0.096
0
Epoch 42/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0951 - val_loss: 0.096
0
Epoch 43/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0950 - val_loss: 0.096
0
Epoch 44/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0949 - val_loss: 0.095
7
Epoch 45/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0947 - val_loss: 0.096
1
Epoch 46/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0946 - val_loss: 0.095
8
```

```
Epoch 47/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0945 - val_loss: 0.095
4
Epoch 48/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0944 - val_loss: 0.095
3
Epoch 49/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0942 - val_loss: 0.095
2
Epoch 50/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0941 - val_loss: 0.095
2
Epoch 1/50
2022-11-19 18:51:09.233953: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2310
2022-11-19 18:51:12.249998: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

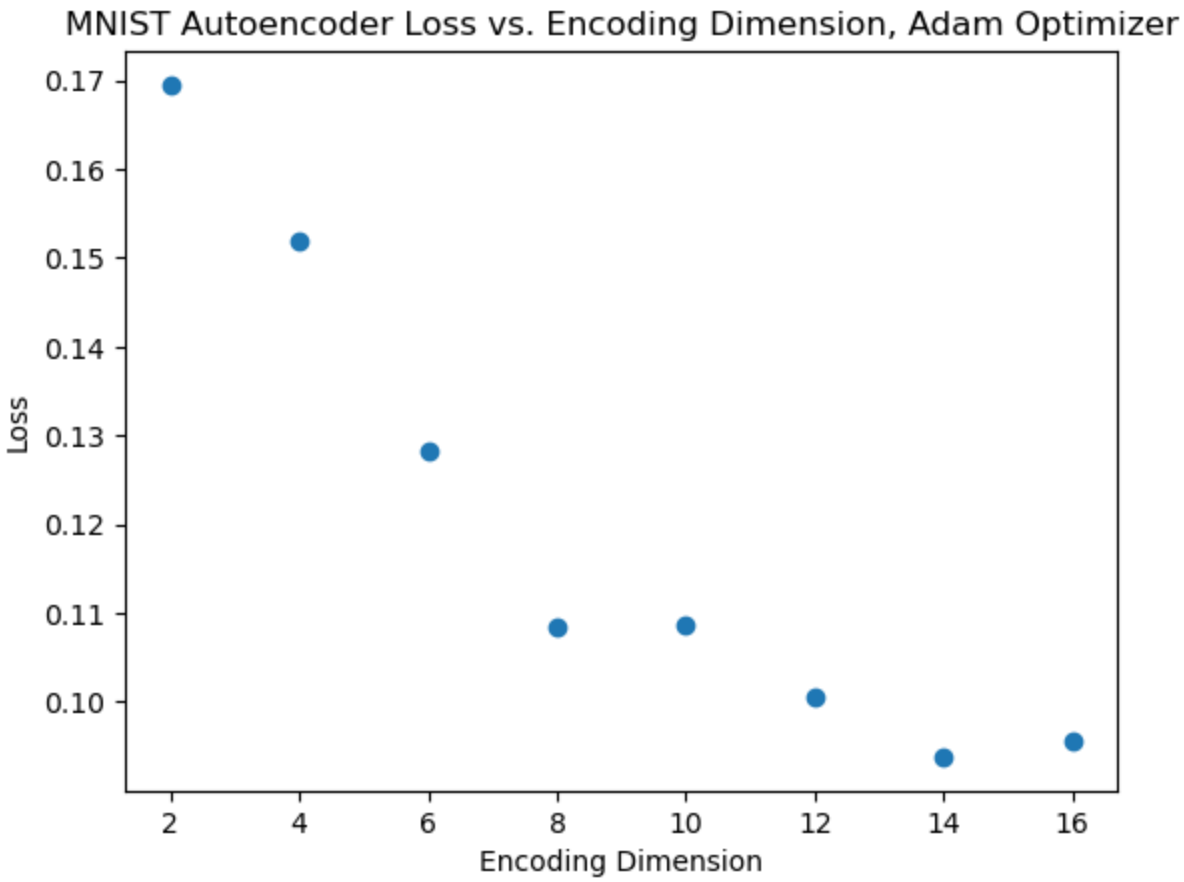
```
235/235 [==============================] - 4s 13ms/step - loss: 0.2310 - val_loss: 0.156
2
Epoch 2/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1424 - val_loss: 0.132
9
Epoch 3/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1298 - val_loss: 0.124
1
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1227 - val_loss: 0.119
2
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1187 - val_loss: 0.116
0
Epoch 6/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1159 - val_loss: 0.113
6
Epoch 7/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1138 - val_loss: 0.111
6
Epoch 8/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1121 - val_loss: 0.110
4
Epoch 9/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1106 - val_loss: 0.109
2
Epoch 10/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1093 - val_loss: 0.108
1
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1083 - val_loss: 0.1071
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1073 - val_loss: 0.106
4
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1065 - val_loss: 0.1060
Epoch 14/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1057 - val_loss: 0.105
0
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1050 - val_loss: 0.1041
Epoch 16/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1044 - val_loss: 0.103
9
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1038 - val_loss: 0.1034
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1033 - val_loss: 0.102
8
Epoch 19/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1027 - val_loss: 0.1024
Epoch 20/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1022 - val_loss: 0.1021
Epoch 21/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1019 - val_loss: 0.101
9
Epoch 22/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1015 - val_loss: 0.1015
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1011 - val_loss: 0.1012
Epoch 24/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1007 - val_loss: 0.100
```

```
9
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1004 - val_loss: 0.1005
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1001 - val_loss: 0.1004
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0999 - val_loss: 0.1001
Epoch 28/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0995 - val_loss: 0.0999
Epoch 29/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0992 - val_loss: 0.0996
Epoch 30/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0991 - val_loss: 0.0998
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0988 - val_loss: 0.0994
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0986 - val_loss: 0.0990
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0983 - val_loss: 0.0990
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0981 - val_loss: 0.0991
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0979 - val_loss: 0.0992
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0977 - val_loss: 0.0985
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0975 - val_loss: 0.0984
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0974 - val_loss: 0.0985
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0973 - val_loss: 0.0983
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0971 - val_loss: 0.0981
Epoch 41/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0970 - val_loss: 0.097
9
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0968 - val_loss: 0.0978
Epoch 43/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0966 - val_loss: 0.097
6
Epoch 44/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0965 - val_loss: 0.097
7
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0964 - val_loss: 0.0975
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0962 - val_loss: 0.0975
Epoch 47/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0961 - val_loss: 0.097
5
Epoch 48/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0960 - val_loss: 0.097
3
Epoch 49/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0958 - val_loss: 0.0973
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.0957 - val_loss: 0.0972
```

In [53]:

```
plt.scatter(dimensions,losses)
plt.ylabel('Loss')
plt.xlabel('Encoding Dimension')
```

```
plt.title('MNIST Autoencoder Loss vs. Encoding Dimension, Adam Optimizer')
plt.show()
```



2. ***After*** training an autoencoder with `encoding_dim=8`, apply noise (like the previous assignment) to *only* the input of the trained autoencoder (not the output). The output images should be without noise.

Print a few noisy images along with the output images to show they don't have noise.

In [48]:
```
encoding_dim = 8

x = input_img = Input(shape=(784,))
x = Dense(256, activation='relu')(x)
x = Dense(128, activation='relu')(x)
encoded = Dense(encoding_dim, activation='relu')(x)

x = Dense(128, activation='relu')(encoded)
x = Dense(256, activation='relu')(x)
decoded = Dense(784, activation='sigmoid')(x)

autoencoder = Model(input_img, decoded)

encoder = Model(input_img, encoded)

encoded_input = Input(shape=(encoding_dim,))

dcd1 = autoencoder.layers[-1]
dcd2 = autoencoder.layers[-2]
dcd3 = autoencoder.layers[-3]

decoder = Model(encoded_input, dcd1(dcd2(dcd3(encoded_input))))
```

```
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

autoencoder.fit(xtrain, xtrain,
            epochs=50,
            batch_size=256,
            shuffle=True,
            validation_data=(xtest, xtest),
            callbacks=[TensorBoard(log_dir='/tmp/hmwk2')])
```

```
Epoch 1/50
2022-11-19 19:03:49.925361: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
235/235 [==============================] - ETA: 0s - loss: 0.2349
2022-11-19 19:03:52.589516: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
235/235 [==============================] - 3s 12ms/step - loss: 0.2349 - val_loss: 0.163
5
Epoch 2/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1534 - val_loss: 0.146
1
Epoch 3/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1439 - val_loss: 0.1404
Epoch 4/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1394 - val_loss: 0.1368
Epoch 5/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1363 - val_loss: 0.134
2
Epoch 6/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1341 - val_loss: 0.1324
Epoch 7/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1323 - val_loss: 0.1311
Epoch 8/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1308 - val_loss: 0.129
5
Epoch 9/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1296 - val_loss: 0.1290
Epoch 10/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1285 - val_loss: 0.1281
Epoch 11/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1276 - val_loss: 0.1270
Epoch 12/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1267 - val_loss: 0.1262
Epoch 13/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1259 - val_loss: 0.1253
Epoch 14/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1252 - val_loss: 0.1253
Epoch 15/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1245 - val_loss: 0.1244
Epoch 16/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1240 - val_loss: 0.1238
Epoch 17/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1233 - val_loss: 0.1234
Epoch 18/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1228 - val_loss: 0.1229
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1222 - val_loss: 0.122
5
Epoch 20/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1218 - val_loss: 0.122
0
Epoch 21/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1213 - val_loss: 0.121
6
Epoch 22/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1210 - val_loss: 0.121
3
Epoch 23/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1205 - val_loss: 0.1210
Epoch 24/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1202 - val_loss: 0.1209
Epoch 25/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1199 - val_loss: 0.1206
Epoch 26/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1195 - val_loss: 0.1203
Epoch 27/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1192 - val_loss: 0.1201
Epoch 28/50
```

```
235/235 [==============================] - 2s 10ms/step - loss: 0.1189 - val_loss: 0.119
8
Epoch 29/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1186 - val_loss: 0.119
6
Epoch 30/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1183 - val_loss: 0.1195
Epoch 31/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1182 - val_loss: 0.1193
Epoch 32/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1178 - val_loss: 0.1190
Epoch 33/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1177 - val_loss: 0.1191
Epoch 34/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1174 - val_loss: 0.1189
Epoch 35/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1172 - val_loss: 0.1191
Epoch 36/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1170 - val_loss: 0.1185
Epoch 37/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1168 - val_loss: 0.1184
Epoch 38/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1165 - val_loss: 0.1185
Epoch 39/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1164 - val_loss: 0.1181
Epoch 40/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1163 - val_loss: 0.1183
Epoch 41/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1161 - val_loss: 0.1180
Epoch 42/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1159 - val_loss: 0.1179
Epoch 43/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1158 - val_loss: 0.118
3
Epoch 44/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1157 - val_loss: 0.1175
Epoch 45/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1155 - val_loss: 0.1177
Epoch 46/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1154 - val_loss: 0.1179
Epoch 47/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1153 - val_loss: 0.1177
Epoch 48/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1151 - val_loss: 0.1174
Epoch 49/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1150 - val_loss: 0.117
4
Epoch 50/50
235/235 [==============================] - 2s 9ms/step - loss: 0.1149 - val_loss: 0.1174
```

Out[48]:
```
<keras.callbacks.History at 0x17d2b6fd0>
```

In [49]:
```
noise = np.random.normal(xtest)
```

In [50]:
```
encoded_imgs = encoder.predict(noise)
decoded_imgs = decoder.predict(encoded_imgs)
```

```
 93/313 [=======>......................] - ETA: 0s
2022-11-19 19:08:01.107245: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
313/313 [==============================] - 1s 2ms/step
110/313 [=========>....................] - ETA: 0s
```

```
2022-11-19 19:08:01.707382: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
313/313 [==============================] - 0s 1ms/step
```

In [51]:

```
n = 20  # how many digits we will display
plt.figure(figsize=(40, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(noise[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```