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 [77]:
```
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[77]:
```
((60000, 784), (10000, 784))
```

In [78]:
```
# this is the size of our encoded representations
encoding_dim = 4  # 32 floats -> compression of factor 24.5, assuming the input is 784

# 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 [79]:
```
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

In [80]:
```
autoencoder.fit(xtrain, xtrain,
                epochs=100,
                batch_size=256,
                shuffle=True,
                validation_data=(xtest, xtest),
                callbacks=[TensorBoard(log_dir='/tmp/autoencoder')])
```

```
Epoch 1/100
235/235 [==============================] - 3s 9ms/step - loss: 0.2505 - val_loss: 0.1
888
Epoch 2/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1788 - val_loss: 0.1
708
Epoch 3/100
235/235 [==============================] - 2s 8ms/step - loss: 0.1677 - val_loss: 0.1
645
Epoch 4/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1628 - val_loss: 0.
1609
Epoch 5/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1596 - val_loss: 0.
1583
Epoch 6/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1573 - val_loss: 0.
1566
Epoch 7/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1556 - val_loss: 0.
1553
Epoch 8/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1541 - val_loss: 0.
1537
Epoch 9/100
235/235 [==============================] - 2s 10ms/step - loss: 0.1530 - val_loss: 0.
1527
Epoch 10/100
235/235 [==============================] - 2s 11ms/step - loss: 0.1518 - val_loss: 0.
1518
Epoch 11/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1509 - val_loss: 0.
1510
Epoch 12/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1499 - val_loss: 0.
1503
Epoch 13/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1491 - val_loss: 0.
1499
Epoch 14/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1483 - val_loss: 0.
1490
Epoch 15/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1476 - val_loss: 0.
1488
Epoch 16/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1470 - val_loss: 0.
1479
Epoch 17/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1463 - val_loss: 0.
1477
Epoch 18/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1458 - val_loss: 0.
1470
Epoch 19/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1452 - val_loss: 0.
1464
Epoch 20/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1447 - val_loss: 0.
1463
```

```
Epoch 21/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1442 - val_loss: 0.
1460
Epoch 22/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1438 - val_loss: 0.
1459
Epoch 23/100
235/235 [==============================] - 2s 11ms/step - loss: 0.1433 - val_loss: 0.
1454
Epoch 24/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1429 - val_loss: 0.
1450
Epoch 25/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1425 - val_loss: 0.
1447
Epoch 26/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1422 - val_loss: 0.
1448
Epoch 27/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1419 - val_loss: 0.
1443
Epoch 28/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1416 - val_loss: 0.
1444
Epoch 29/100
235/235 [==============================] - 2s 10ms/step - loss: 0.1412 - val_loss: 0.
1445
Epoch 30/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1409 - val_loss: 0.
1437
Epoch 31/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1406 - val_loss: 0.
1435
Epoch 32/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1404 - val_loss: 0.
1434
Epoch 33/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1401 - val_loss: 0.
1435
Epoch 34/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1398 - val_loss: 0.
1433
Epoch 35/100
235/235 [==============================] - 2s 10ms/step - loss: 0.1396 - val_loss: 0.
1431
Epoch 36/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1394 - val_loss: 0.
1431
Epoch 37/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1392 - val_loss: 0.
1427
Epoch 38/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1390 - val_loss: 0.
1427
Epoch 39/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1388 - val_loss: 0.
1425
Epoch 40/100
235/235 [==============================] - 2s 11ms/step - loss: 0.1386 - val_loss: 0.
1425
```

```
Epoch 41/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1384 - val_loss: 0.
1422
Epoch 42/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1382 - val_loss: 0.
1423
Epoch 43/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1381 - val_loss: 0.
1422
Epoch 44/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1379 - val_loss: 0.
1424
Epoch 45/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1377 - val_loss: 0.
1422
Epoch 46/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1376 - val_loss: 0.
1418
Epoch 47/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1374 - val_loss: 0.
1419
Epoch 48/100
235/235 [==============================] - 2s 10ms/step - loss: 0.1372 - val_loss: 0.
1418
Epoch 49/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1371 - val_loss: 0.
1418
Epoch 50/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1370 - val_loss: 0.
1420
Epoch 51/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1368 - val_loss: 0.
1416
Epoch 52/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1367 - val_loss: 0.
1416
Epoch 53/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1366 - val_loss: 0.
1416
Epoch 54/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1365 - val_loss: 0.
1417
Epoch 55/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1364 - val_loss: 0.
1413
Epoch 56/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1362 - val_loss: 0.
1412
Epoch 57/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1361 - val_loss: 0.
1414
Epoch 58/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1360 - val_loss: 0.
1414
Epoch 59/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1359 - val_loss: 0.
1417
Epoch 60/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1358 - val_loss: 0.
1413
```

```
Epoch 61/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1357 - val_loss: 0.
1414
Epoch 62/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1356 - val_loss: 0.
1413
Epoch 63/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1355 - val_loss: 0.
1414
Epoch 64/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1354 - val_loss: 0.
1413
Epoch 65/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1353 - val_loss: 0.
1414
Epoch 66/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1352 - val_loss: 0.
1412
Epoch 67/100
235/235 [==============================] - 3s 13ms/step - loss: 0.1352 - val_loss: 0.
1411
Epoch 68/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1351 - val_loss: 0.
1410
Epoch 69/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1350 - val_loss: 0.
1411
Epoch 70/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1349 - val_loss: 0.
1412
Epoch 71/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1348 - val_loss: 0.
1408
Epoch 72/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1347 - val_loss: 0.
1408
Epoch 73/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1346 - val_loss: 0.
1411
Epoch 74/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1346 - val_loss: 0.
1409
Epoch 75/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1345 - val_loss: 0.
1409
Epoch 76/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1345 - val_loss: 0.
1409
Epoch 77/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1344 - val_loss: 0.
1409
Epoch 78/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1343 - val_loss: 0.
1412
Epoch 79/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1342 - val_loss: 0.
1410
Epoch 80/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1342 - val_loss: 0.
1408
```

```
Epoch 81/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1341 - val_loss: 0.
1410
Epoch 82/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1340 - val_loss: 0.
1409
Epoch 83/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1340 - val_loss: 0.
1409
Epoch 84/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1339 - val_loss: 0.
1408
Epoch 85/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1339 - val_loss: 0.
1407
Epoch 86/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1338 - val_loss: 0.
1406
Epoch 87/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1338 - val_loss: 0.
1410
Epoch 88/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1337 - val_loss: 0.
1408
Epoch 89/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1336 - val_loss: 0.
1408
Epoch 90/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1336 - val_loss: 0.
1411
Epoch 91/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1335 - val_loss: 0.
1406
Epoch 92/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1335 - val_loss: 0.
1409
Epoch 93/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1334 - val_loss: 0.
1409
Epoch 94/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1333 - val_loss: 0.
1407
Epoch 95/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1333 - val_loss: 0.
1408
Epoch 96/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1332 - val_loss: 0.
1408
Epoch 97/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1332 - val_loss: 0.
1407
Epoch 98/100
235/235 [==============================] - 3s 13ms/step - loss: 0.1331 - val_loss: 0.
1408
Epoch 99/100
235/235 [==============================] - 3s 12ms/step - loss: 0.1331 - val_loss: 0.
1406
Epoch 100/100
235/235 [==============================] - 3s 11ms/step - loss: 0.1330 - val_loss: 0.
1410
```

Out[80]:
```
<keras.src.callbacks.History at 0x2202830f040>
```

In [11]:
```
encoded_imgs
```

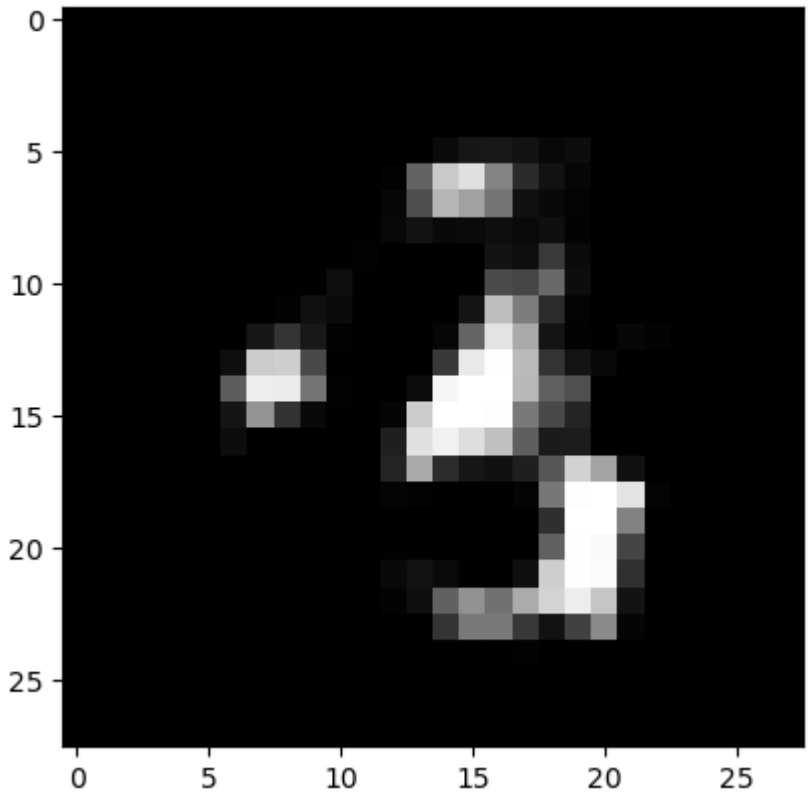
Out[11]:
```
array([[38.304043 ,  0.       ,  9.823541 , 22.699774 ],
       [ 4.0672283,  0.       ,  6.457829 ,  2.599104 ],
       [94.89234  ,  0.       , 48.237885 , 22.512798 ],
       ...,
       [20.050169 ,  0.       ,  8.473201 ,  8.569888 ],
       [19.308092 ,  0.       , 15.271025 ,  8.056674 ],
       [ 3.769403 ,  0.       ,  2.7675493,  3.3705957]], dtype=float32)
```

In [12]:
```
noise = np.random.normal(20,4, (4,4))
noise_preds = decoder.predict(noise)
```

```
1/1 [==============================] - 0s 18ms/step
```

In [81]:
```
plt.imshow(noise_preds[1].reshape(28,28))
```

Out[81]:
```
<matplotlib.image.AxesImage at 0x22028529e40>
```



In [14]:
```
np.max(encoded_imgs)
```

Out[14]:
```
98.423355
```

In [82]:
```
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()
```

```
313/313 [==============================] - 1s 2ms/step
313/313 [==============================] - 0s 1ms/step
```

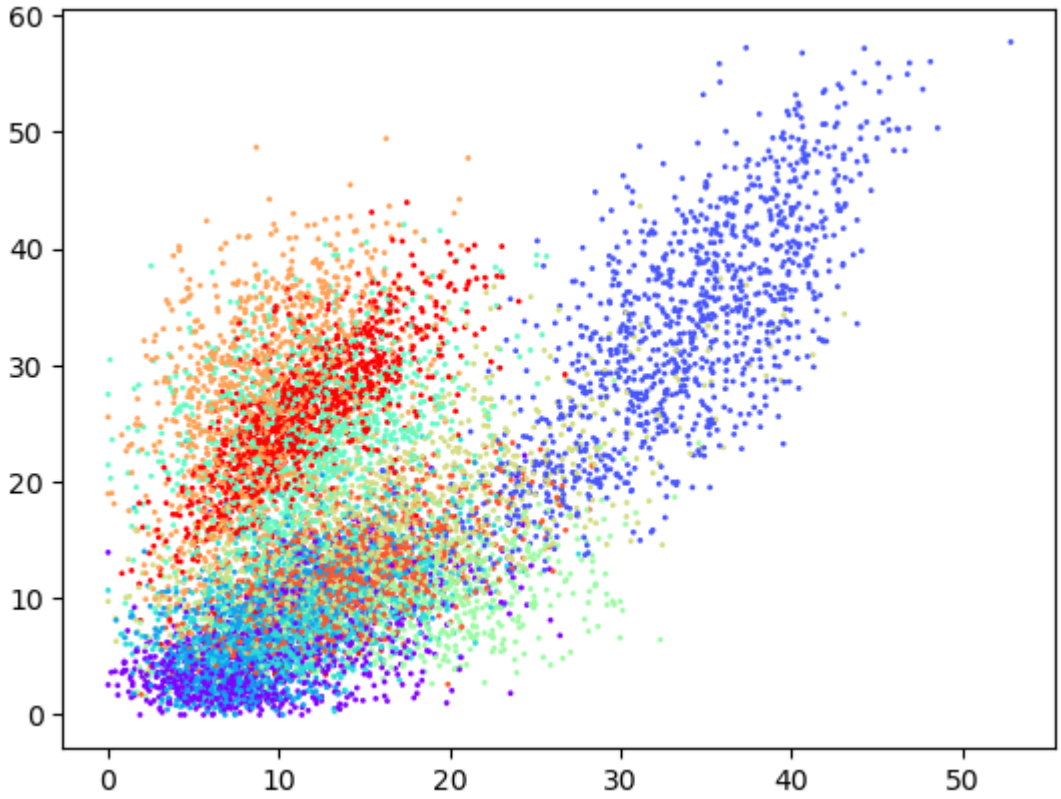
In [15]:
```
encoded_imgs
```

Out[15]:
```
array([[38.304043 ,  0.       ,  9.823541 , 22.699774 ],
       [ 4.0672283,  0.       ,  6.457829 ,  2.599104 ],
       [94.89234  ,  0.       , 48.237885 , 22.512798 ],
       ...,
       [20.050169 ,  0.       ,  8.473201 ,  8.569888 ],
       [19.308092 ,  0.       , 15.271025 ,  8.056674 ],
       [ 3.769403 ,  0.       ,  2.7675493,  3.3705957]], dtype=float32)
```

In [16]:
```
%matplotlib inline
```

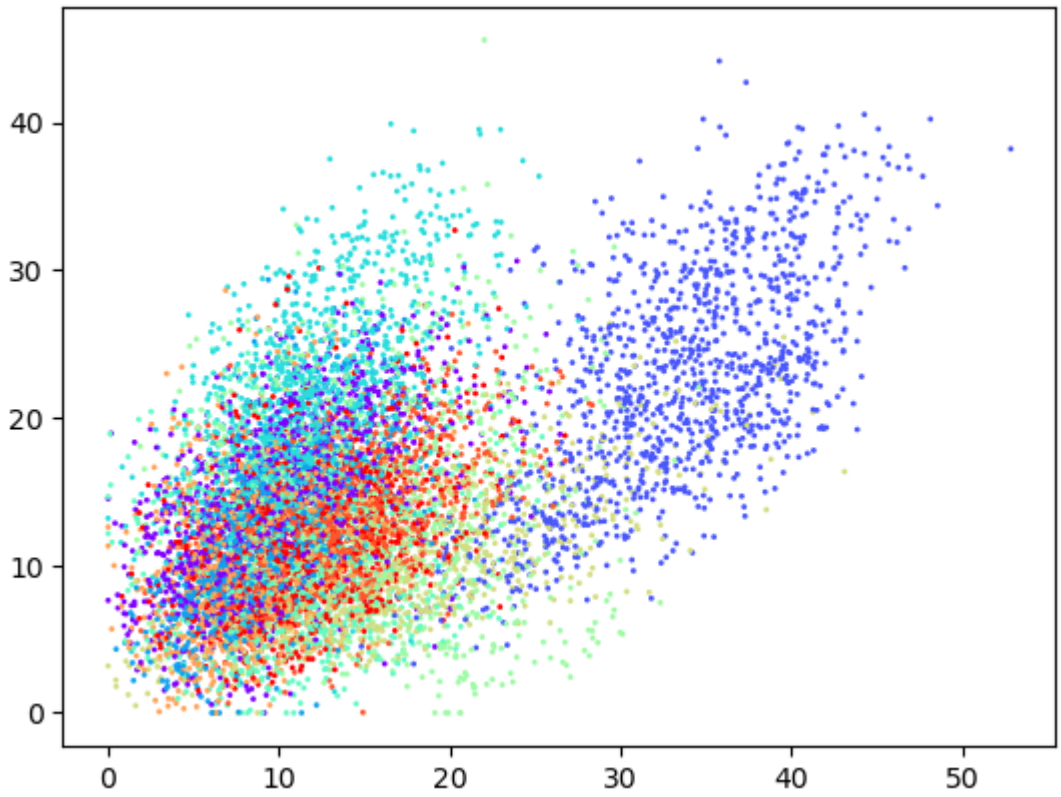
In [83]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,0], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[83]:
```
<matplotlib.collections.PathCollection at 0x22028502ce0>
```



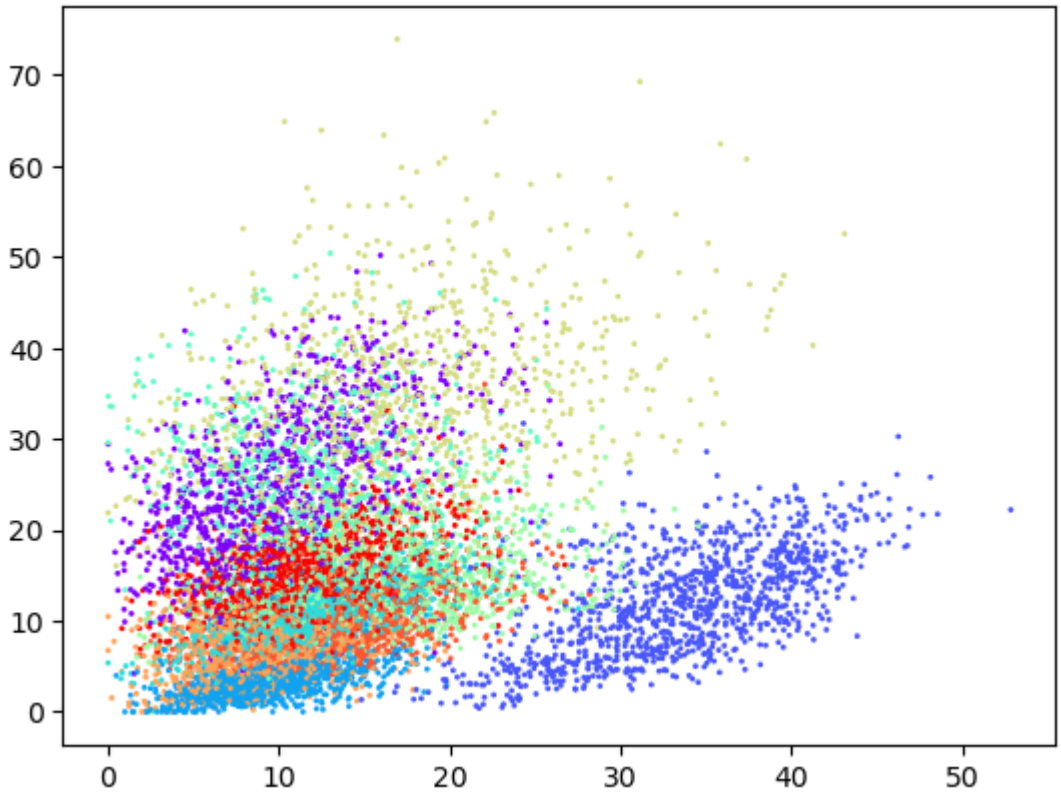
In [84]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,3], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[84]:
```
<matplotlib.collections.PathCollection at 0x220281d6710>
```



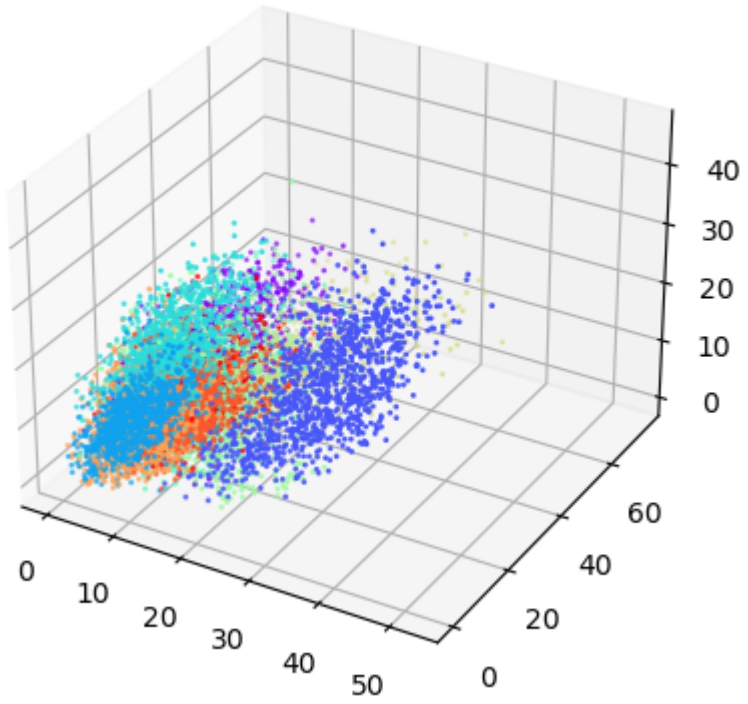
In [85]:
```
plt.scatter(encoded_imgs[:,1], encoded_imgs[:,2], s=1, c=ytest, cmap='rainbow')
# plt.show()
```

Out[85]: <matplotlib.collections.PathCollection at 0x22028109ff0>



In [86]:
```
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='rai
```

Out[86]: <mpl_toolkits.mplot3d.art3d.Path3DCollection at 0x2202802b9a0>



In [ ]:

Assignment

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

In [21]:
```
(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[21]:
```
((60000, 784), (10000, 784))
```

In [23]:
```
losses = []
dimensions = [2, 4, 6, 8, 10, 12, 14, 16]
for encoding_dim in dimensions:

    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/autoencoder')])

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

```
Epoch 1/50
235/235 [==============================] - 3s 9ms/step - loss: 0.2770 - val_loss: 0.2
498
Epoch 2/50
235/235 [==============================] - 2s 9ms/step - loss: 0.2323 - val_loss: 0.2
139
Epoch 3/50
235/235 [==============================] - 3s 11ms/step - loss: 0.2085 - val_loss: 0.
2040
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.2010 - val_loss: 0.
1981
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1956 - val_loss: 0.
1931
Epoch 6/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1916 - val_loss: 0.
1899
Epoch 7/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1886 - val_loss: 0.
1873
Epoch 8/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1863 - val_loss: 0.
1860
Epoch 9/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1845 - val_loss: 0.
1843
Epoch 10/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1832 - val_loss: 0.
1832
Epoch 11/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1819 - val_loss: 0.
1824
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1809 - val_loss: 0.
1819
Epoch 13/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1799 - val_loss: 0.
1811
Epoch 14/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1792 - val_loss: 0.
1801
Epoch 15/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1783 - val_loss: 0.
1796
Epoch 16/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1776 - val_loss: 0.
1793
Epoch 17/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1768 - val_loss: 0.
1786
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1762 - val_loss: 0.
1784
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1756 - val_loss: 0.
1781
Epoch 20/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1750 - val_loss: 0.
1774
```

```
Epoch 21/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1745 - val_loss: 0.
1771
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1741 - val_loss: 0.
1766
Epoch 23/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1737 - val_loss: 0.
1765
Epoch 24/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1733 - val_loss: 0.
1763
Epoch 25/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1729 - val_loss: 0.
1767
Epoch 26/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1727 - val_loss: 0.
1755
Epoch 27/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1722 - val_loss: 0.
1756
Epoch 28/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1720 - val_loss: 0.
1755
Epoch 29/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1717 - val_loss: 0.
1753
Epoch 30/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1713 - val_loss: 0.
1751
Epoch 31/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1711 - val_loss: 0.
1749
Epoch 32/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1707 - val_loss: 0.
1748
Epoch 33/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1706 - val_loss: 0.
1746
Epoch 34/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1703 - val_loss: 0.
1749
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1701 - val_loss: 0.
1743
Epoch 36/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1698 - val_loss: 0.
1741
Epoch 37/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1697 - val_loss: 0.
1741
Epoch 38/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1694 - val_loss: 0.
1739
Epoch 39/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1693 - val_loss: 0.
1742
Epoch 40/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1691 - val_loss: 0.
1735
```

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Epoch 41/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1689 - val_loss: 0.
1737
Epoch 42/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1686 - val_loss: 0.
1735
Epoch 43/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1685 - val_loss: 0.
1737
Epoch 44/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1684 - val_loss: 0.
1733
Epoch 45/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1681 - val_loss: 0.
1731
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1679 - val_loss: 0.
1731
Epoch 47/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1678 - val_loss: 0.
1730
Epoch 48/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1676 - val_loss: 0.
1730
Epoch 49/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1675 - val_loss: 0.
1728
Epoch 50/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1672 - val_loss: 0.
1727
Epoch 1/50
235/235 [==============================] - 4s 12ms/step - loss: 0.2675 - val_loss: 0.
2240
Epoch 2/50
235/235 [==============================] - 3s 12ms/step - loss: 0.2169 - val_loss: 0.
2093
Epoch 3/50
235/235 [==============================] - 3s 12ms/step - loss: 0.2056 - val_loss: 0.
2010
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1986 - val_loss: 0.
1955
Epoch 5/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1940 - val_loss: 0.
1933
Epoch 6/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1912 - val_loss: 0.
1902
Epoch 7/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1888 - val_loss: 0.
1879
Epoch 8/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1869 - val_loss: 0.
1864
Epoch 9/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1855 - val_loss: 0.
1851
Epoch 10/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1841 - val_loss: 0.
1839
```

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Epoch 11/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1830 - val_loss: 0.
1827
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1818 - val_loss: 0.
1823
Epoch 13/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1809 - val_loss: 0.
1818
Epoch 14/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1802 - val_loss: 0.
1802
Epoch 15/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1792 - val_loss: 0.
1804
Epoch 16/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1785 - val_loss: 0.
1793
Epoch 17/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1778 - val_loss: 0.
1787
Epoch 18/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1771 - val_loss: 0.
1784
Epoch 19/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1766 - val_loss: 0.
1779
Epoch 20/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1760 - val_loss: 0.
1772
Epoch 21/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1756 - val_loss: 0.
1769
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1751 - val_loss: 0.
1766
Epoch 23/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1747 - val_loss: 0.
1765
Epoch 24/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1744 - val_loss: 0.
1757
Epoch 25/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1738 - val_loss: 0.
1759
Epoch 26/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1733 - val_loss: 0.
1756
Epoch 27/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1732 - val_loss: 0.
1756
Epoch 28/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1729 - val_loss: 0.
1749
Epoch 29/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1722 - val_loss: 0.
1749
Epoch 30/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1721 - val_loss: 0.
1747
```

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Epoch 31/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1718 - val_loss: 0.
1746
Epoch 32/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1714 - val_loss: 0.
1742
Epoch 33/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1713 - val_loss: 0.
1741
Epoch 34/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1711 - val_loss: 0.
1743
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1708 - val_loss: 0.
1739
Epoch 36/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1705 - val_loss: 0.
1738
Epoch 37/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1703 - val_loss: 0.
1739
Epoch 38/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1702 - val_loss: 0.
1733
Epoch 39/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1701 - val_loss: 0.
1733
Epoch 40/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1697 - val_loss: 0.
1732
Epoch 41/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1693 - val_loss: 0.
1731
Epoch 42/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1691 - val_loss: 0.
1731
Epoch 43/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1690 - val_loss: 0.
1731
Epoch 44/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1689 - val_loss: 0.
1730
Epoch 45/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1685 - val_loss: 0.
1733
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1685 - val_loss: 0.
1725
Epoch 47/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1682 - val_loss: 0.
1726
Epoch 48/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1681 - val_loss: 0.
1727
Epoch 49/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1682 - val_loss: 0.
1730
Epoch 50/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1679 - val_loss: 0.
1731
```

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Epoch 1/50
235/235 [==============================] - 4s 12ms/step - loss: 0.2425 - val_loss: 0.
1823
Epoch 2/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1708 - val_loss: 0.
1577
Epoch 3/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1531 - val_loss: 0.
1480
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1469 - val_loss: 0.
1439
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1434 - val_loss: 0.
1412
Epoch 6/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1409 - val_loss: 0.
1395
Epoch 7/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1389 - val_loss: 0.
1375
Epoch 8/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1373 - val_loss: 0.
1360
Epoch 9/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1360 - val_loss: 0.
1350
Epoch 10/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1349 - val_loss: 0.
1341
Epoch 11/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1339 - val_loss: 0.
1331
Epoch 12/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1330 - val_loss: 0.
1324
Epoch 13/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1322 - val_loss: 0.
1318
Epoch 14/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1315 - val_loss: 0.
1311
Epoch 15/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1309 - val_loss: 0.
1305
Epoch 16/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1302 - val_loss: 0.
1303
Epoch 17/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1297 - val_loss: 0.
1297
Epoch 18/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1291 - val_loss: 0.
1291
Epoch 19/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1286 - val_loss: 0.
1285
Epoch 20/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1281 - val_loss: 0.
1282
```

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Epoch 21/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1276 - val_loss: 0.
1279
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1272 - val_loss: 0.
1278
Epoch 23/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1268 - val_loss: 0.
1276
Epoch 24/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1265 - val_loss: 0.
1275
Epoch 25/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1261 - val_loss: 0.
1266
Epoch 26/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1257 - val_loss: 0.
1263
Epoch 27/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1254 - val_loss: 0.
1262
Epoch 28/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1251 - val_loss: 0.
1261
Epoch 29/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1247 - val_loss: 0.
1258
Epoch 30/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1245 - val_loss: 0.
1258
Epoch 31/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1242 - val_loss: 0.
1252
Epoch 32/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1240 - val_loss: 0.
1252
Epoch 33/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1237 - val_loss: 0.
1252
Epoch 34/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1235 - val_loss: 0.
1247
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1233 - val_loss: 0.
1247
Epoch 36/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1230 - val_loss: 0.
1246
Epoch 37/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1228 - val_loss: 0.
1246
Epoch 38/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1226 - val_loss: 0.
1243
Epoch 39/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1225 - val_loss: 0.
1243
Epoch 40/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1223 - val_loss: 0.
1242
```

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Epoch 41/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1221 - val_loss: 0.
1241
Epoch 42/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1219 - val_loss: 0.
1241
Epoch 43/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1217 - val_loss: 0.
1239
Epoch 44/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1215 - val_loss: 0.
1239
Epoch 45/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1214 - val_loss: 0.
1233
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1212 - val_loss: 0.
1235
Epoch 47/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1211 - val_loss: 0.
1232
Epoch 48/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1210 - val_loss: 0.
1234
Epoch 49/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1208 - val_loss: 0.
1231
Epoch 50/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1207 - val_loss: 0.
1231
Epoch 1/50
235/235 [==============================] - 4s 11ms/step - loss: 0.2478 - val_loss: 0.
1857
Epoch 2/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1737 - val_loss: 0.
1572
Epoch 3/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1517 - val_loss: 0.
1469
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1455 - val_loss: 0.
1430
Epoch 5/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1423 - val_loss: 0.
1407
Epoch 6/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1400 - val_loss: 0.
1388
Epoch 7/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1384 - val_loss: 0.
1372
Epoch 8/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1370 - val_loss: 0.
1363
Epoch 9/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1358 - val_loss: 0.
1348
Epoch 10/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1347 - val_loss: 0.
1340
```

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Epoch 11/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1338 - val_loss: 0.
1331
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1329 - val_loss: 0.
1324
Epoch 13/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1321 - val_loss: 0.
1316
Epoch 14/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1314 - val_loss: 0.
1313
Epoch 15/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1307 - val_loss: 0.
1305
Epoch 16/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1300 - val_loss: 0.
1300
Epoch 17/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1295 - val_loss: 0.
1295
Epoch 18/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1289 - val_loss: 0.
1289
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1283 - val_loss: 0.
1287
Epoch 20/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1278 - val_loss: 0.
1283
Epoch 21/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1274 - val_loss: 0.
1283
Epoch 22/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1269 - val_loss: 0.
1273
Epoch 23/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1265 - val_loss: 0.
1270
Epoch 24/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1261 - val_loss: 0.
1267
Epoch 25/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1257 - val_loss: 0.
1268
Epoch 26/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1254 - val_loss: 0.
1261
Epoch 27/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1250 - val_loss: 0.
1264
Epoch 28/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1247 - val_loss: 0.
1261
Epoch 29/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1245 - val_loss: 0.
1258
Epoch 30/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1242 - val_loss: 0.
1250
```

```
Epoch 31/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1239 - val_loss: 0.
1253
Epoch 32/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1236 - val_loss: 0.
1253
Epoch 33/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1233 - val_loss: 0.
1250
Epoch 34/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1231 - val_loss: 0.
1248
Epoch 35/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1229 - val_loss: 0.
1247
Epoch 36/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1226 - val_loss: 0.
1244
Epoch 37/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1224 - val_loss: 0.
1240
Epoch 38/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1222 - val_loss: 0.
1239
Epoch 39/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1220 - val_loss: 0.
1240
Epoch 40/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1218 - val_loss: 0.
1237
Epoch 41/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1216 - val_loss: 0.
1236
Epoch 42/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1215 - val_loss: 0.
1238
Epoch 43/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1213 - val_loss: 0.
1236
Epoch 44/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1211 - val_loss: 0.
1233
Epoch 45/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1210 - val_loss: 0.
1233
Epoch 46/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1208 - val_loss: 0.
1230
Epoch 47/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1207 - val_loss: 0.
1234
Epoch 48/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1206 - val_loss: 0.
1230
Epoch 49/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1204 - val_loss: 0.
1229
Epoch 50/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1203 - val_loss: 0.
1229
```

```
Epoch 1/50
235/235 [==============================] - 4s 13ms/step - loss: 0.2353 - val_loss: 0.
1637
Epoch 2/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1501 - val_loss: 0.
1398
Epoch 3/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1376 - val_loss: 0.
1335
Epoch 4/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1327 - val_loss: 0.
1300
Epoch 5/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1295 - val_loss: 0.
1275
Epoch 6/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1272 - val_loss: 0.
1255
Epoch 7/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1253 - val_loss: 0.
1242
Epoch 8/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1237 - val_loss: 0.
1225
Epoch 9/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1223 - val_loss: 0.
1212
Epoch 10/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1211 - val_loss: 0.
1204
Epoch 11/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1201 - val_loss: 0.
1197
Epoch 12/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1193 - val_loss: 0.
1188
Epoch 13/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1185 - val_loss: 0.
1179
Epoch 14/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1177 - val_loss: 0.
1173
Epoch 15/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1171 - val_loss: 0.
1166
Epoch 16/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1165 - val_loss: 0.
1164
Epoch 17/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1160 - val_loss: 0.
1158
Epoch 18/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1155 - val_loss: 0.
1155
Epoch 19/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1150 - val_loss: 0.
1149
Epoch 20/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1146 - val_loss: 0.
1148
```

```
Epoch 21/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1142 - val_loss: 0.
1146
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1138 - val_loss: 0.
1141
Epoch 23/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1135 - val_loss: 0.
1138
Epoch 24/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1131 - val_loss: 0.
1136
Epoch 25/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1128 - val_loss: 0.
1133
Epoch 26/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1125 - val_loss: 0.
1134
Epoch 27/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1122 - val_loss: 0.
1129
Epoch 28/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1120 - val_loss: 0.
1127
Epoch 29/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1117 - val_loss: 0.
1128
Epoch 30/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1115 - val_loss: 0.
1125
Epoch 31/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1112 - val_loss: 0.
1123
Epoch 32/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1110 - val_loss: 0.
1121
Epoch 33/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1108 - val_loss: 0.
1120
Epoch 34/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1106 - val_loss: 0.
1120
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1104 - val_loss: 0.
1118
Epoch 36/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1102 - val_loss: 0.
1117
Epoch 37/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1100 - val_loss: 0.
1116
Epoch 38/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1098 - val_loss: 0.
1112
Epoch 39/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1096 - val_loss: 0.
1114
Epoch 40/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1095 - val_loss: 0.
1113
```

```
Epoch 41/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1093 - val_loss: 0.
1110
Epoch 42/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1092 - val_loss: 0.
1113
Epoch 43/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1090 - val_loss: 0.
1111
Epoch 44/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1088 - val_loss: 0.
1109
Epoch 45/50
235/235 [==============================] - 3s 13ms/step - loss: 0.1087 - val_loss: 0.
1106
Epoch 46/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1086 - val_loss: 0.
1105
Epoch 47/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1085 - val_loss: 0.
1104
Epoch 48/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1083 - val_loss: 0.
1103
Epoch 49/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1082 - val_loss: 0.
1103
Epoch 50/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1081 - val_loss: 0.
1103
Epoch 1/50
235/235 [==============================] - 4s 11ms/step - loss: 0.2319 - val_loss: 0.
1632
Epoch 2/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1479 - val_loss: 0.
1360
Epoch 3/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1331 - val_loss: 0.
1282
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1273 - val_loss: 0.
1237
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1236 - val_loss: 0.
1210
Epoch 6/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1210 - val_loss: 0.
1189
Epoch 7/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1189 - val_loss: 0.
1177
Epoch 8/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1172 - val_loss: 0.
1154
Epoch 9/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1157 - val_loss: 0.
1145
Epoch 10/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1145 - val_loss: 0.
1132
```

```
Epoch 11/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1134 - val_loss: 0.
1125
Epoch 12/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1125 - val_loss: 0.
1117
Epoch 13/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1117 - val_loss: 0.
1113
Epoch 14/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1109 - val_loss: 0.
1104
Epoch 15/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1102 - val_loss: 0.
1098
Epoch 16/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1095 - val_loss: 0.
1093
Epoch 17/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1090 - val_loss: 0.
1092
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1085 - val_loss: 0.
1083
Epoch 19/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1080 - val_loss: 0.
1078
Epoch 20/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1076 - val_loss: 0.
1076
Epoch 21/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1072 - val_loss: 0.
1074
Epoch 22/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1068 - val_loss: 0.
1071
Epoch 23/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1064 - val_loss: 0.
1069
Epoch 24/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1061 - val_loss: 0.
1064
Epoch 25/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1058 - val_loss: 0.
1062
Epoch 26/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1055 - val_loss: 0.
1061
Epoch 27/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1052 - val_loss: 0.
1057
Epoch 28/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1050 - val_loss: 0.
1057
Epoch 29/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1047 - val_loss: 0.
1055
Epoch 30/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1045 - val_loss: 0.
1052
```

```
Epoch 31/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1043 - val_loss: 0.
1053
Epoch 32/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1040 - val_loss: 0.
1048
Epoch 33/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1038 - val_loss: 0.
1049
Epoch 34/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1037 - val_loss: 0.
1046
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1034 - val_loss: 0.
1047
Epoch 36/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1033 - val_loss: 0.
1043
Epoch 37/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1031 - val_loss: 0.
1041
Epoch 38/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1029 - val_loss: 0.
1041
Epoch 39/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1027 - val_loss: 0.
1041
Epoch 40/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1026 - val_loss: 0.
1039
Epoch 41/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1024 - val_loss: 0.
1040
Epoch 42/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1023 - val_loss: 0.
1037
Epoch 43/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1022 - val_loss: 0.
1034
Epoch 44/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1020 - val_loss: 0.
1035
Epoch 45/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1018 - val_loss: 0.
1032
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1018 - val_loss: 0.
1033
Epoch 47/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1016 - val_loss: 0.
1034
Epoch 48/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1015 - val_loss: 0.
1031
Epoch 49/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1014 - val_loss: 0.
1030
Epoch 50/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1012 - val_loss: 0.
1029
```

```
Epoch 1/50
235/235 [==============================] - 4s 10ms/step - loss: 0.2262 - val_loss: 0.
1515
Epoch 2/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1390 - val_loss: 0.
1286
Epoch 3/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1258 - val_loss: 0.
1209
Epoch 4/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1193 - val_loss: 0.
1156
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1152 - val_loss: 0.
1124
Epoch 6/50
235/235 [==============================] - 2s 11ms/step - loss: 0.1122 - val_loss: 0.
1104
Epoch 7/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1101 - val_loss: 0.
1085
Epoch 8/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1084 - val_loss: 0.
1066
Epoch 9/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1069 - val_loss: 0.
1057
Epoch 10/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1058 - val_loss: 0.
1052
Epoch 11/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1048 - val_loss: 0.
1042
Epoch 12/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1039 - val_loss: 0.
1033
Epoch 13/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1031 - val_loss: 0.
1026
Epoch 14/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1023 - val_loss: 0.
1021
Epoch 15/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1017 - val_loss: 0.
1009
Epoch 16/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1011 - val_loss: 0.
1010
Epoch 17/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1006 - val_loss: 0.
1001
Epoch 18/50
235/235 [==============================] - 2s 10ms/step - loss: 0.1001 - val_loss: 0.
1001
Epoch 19/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0996 - val_loss: 0.
0995
Epoch 20/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0991 - val_loss: 0.
0997
```

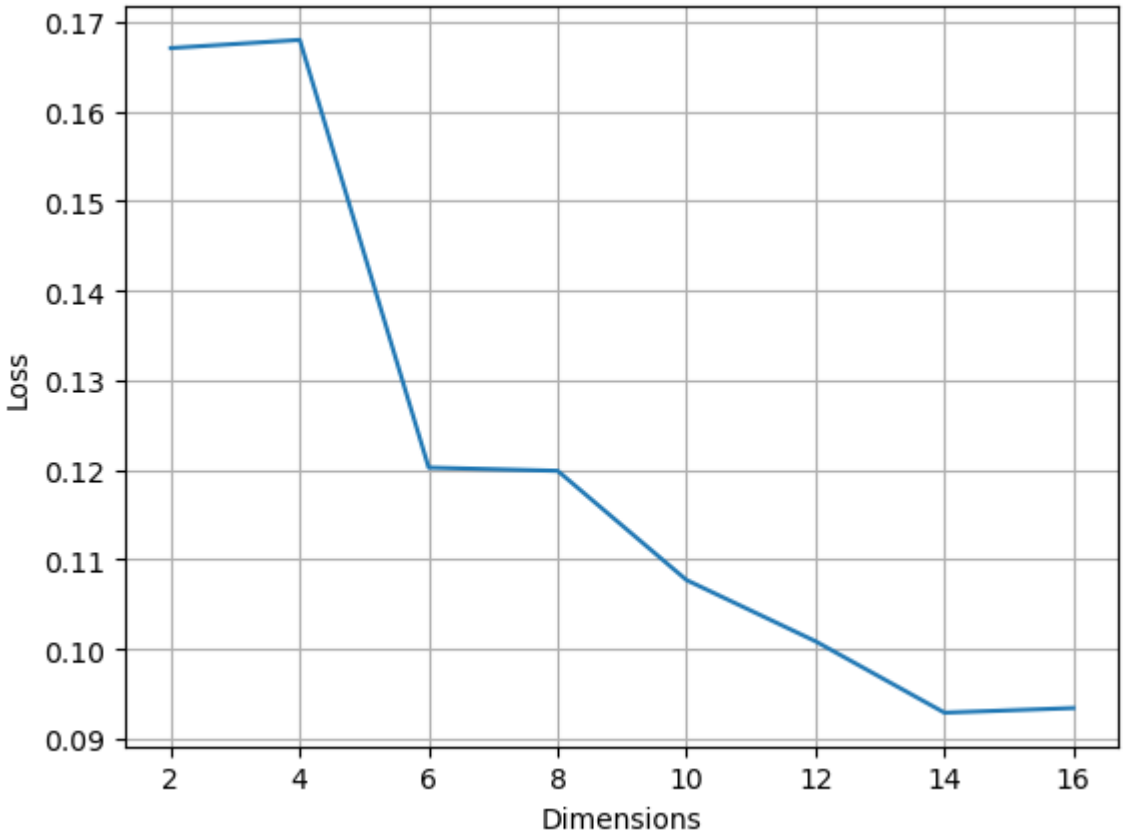
```
Epoch 21/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0988 - val_loss: 0.
0988
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0984 - val_loss: 0.
0984
Epoch 23/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0980 - val_loss: 0.
0987
Epoch 24/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0978 - val_loss: 0.
0979
Epoch 25/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0974 - val_loss: 0.
0978
Epoch 26/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0972 - val_loss: 0.
0975
Epoch 27/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0969 - val_loss: 0.
0970
Epoch 28/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0966 - val_loss: 0.
0972
Epoch 29/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0964 - val_loss: 0.
0968
Epoch 30/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0962 - val_loss: 0.
0968
Epoch 31/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0959 - val_loss: 0.
0966
Epoch 32/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0957 - val_loss: 0.
0962
Epoch 33/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0955 - val_loss: 0.
0962
Epoch 34/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0954 - val_loss: 0.
0963
Epoch 35/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0952 - val_loss: 0.
0960
Epoch 36/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0950 - val_loss: 0.
0959
Epoch 37/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0948 - val_loss: 0.
0956
Epoch 38/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0947 - val_loss: 0.
0955
Epoch 39/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0946 - val_loss: 0.
0955
Epoch 40/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0943 - val_loss: 0.
0953
```

```
Epoch 41/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0943 - val_loss: 0.
0951
Epoch 42/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0941 - val_loss: 0.
0951
Epoch 43/50
235/235 [==============================] - 2s 11ms/step - loss: 0.0940 - val_loss: 0.
0949
Epoch 44/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0939 - val_loss: 0.
0952
Epoch 45/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0938 - val_loss: 0.
0948
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0936 - val_loss: 0.
0951
Epoch 47/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0935 - val_loss: 0.
0947
Epoch 48/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0934 - val_loss: 0.
0946
Epoch 49/50
235/235 [==============================] - 2s 10ms/step - loss: 0.0933 - val_loss: 0.
0947
Epoch 50/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0932 - val_loss: 0.
0945
Epoch 1/50
235/235 [==============================] - 4s 12ms/step - loss: 0.2299 - val_loss: 0.
1554
Epoch 2/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1402 - val_loss: 0.
1294
Epoch 3/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1259 - val_loss: 0.
1197
Epoch 4/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1187 - val_loss: 0.
1149
Epoch 5/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1149 - val_loss: 0.
1120
Epoch 6/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1122 - val_loss: 0.
1100
Epoch 7/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1102 - val_loss: 0.
1084
Epoch 8/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1086 - val_loss: 0.
1067
Epoch 9/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1072 - val_loss: 0.
1058
Epoch 10/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1060 - val_loss: 0.
1047
```

```
Epoch 11/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1051 - val_loss: 0.
1038
Epoch 12/50
235/235 [==============================] - 3s 12ms/step - loss: 0.1041 - val_loss: 0.
1030
Epoch 13/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1033 - val_loss: 0.
1026
Epoch 14/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1026 - val_loss: 0.
1019
Epoch 15/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1020 - val_loss: 0.
1018
Epoch 16/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1015 - val_loss: 0.
1011
Epoch 17/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1009 - val_loss: 0.
1007
Epoch 18/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1004 - val_loss: 0.
1001
Epoch 19/50
235/235 [==============================] - 3s 11ms/step - loss: 0.1000 - val_loss: 0.
0998
Epoch 20/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0996 - val_loss: 0.
0994
Epoch 21/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0992 - val_loss: 0.
0992
Epoch 22/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0989 - val_loss: 0.
0987
Epoch 23/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0985 - val_loss: 0.
0984
Epoch 24/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0982 - val_loss: 0.
0980
Epoch 25/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0979 - val_loss: 0.
0981
Epoch 26/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0976 - val_loss: 0.
0984
Epoch 27/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0974 - val_loss: 0.
0974
Epoch 28/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0971 - val_loss: 0.
0974
Epoch 29/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0969 - val_loss: 0.
0968
Epoch 30/50
235/235 [==============================] - 3s 13ms/step - loss: 0.0966 - val_loss: 0.
0969
```

```
Epoch 31/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0964 - val_loss: 0.
0968
Epoch 32/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0962 - val_loss: 0.
0966
Epoch 33/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0960 - val_loss: 0.
0965
Epoch 34/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0958 - val_loss: 0.
0963
Epoch 35/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0956 - val_loss: 0.
0960
Epoch 36/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0955 - val_loss: 0.
0962
Epoch 37/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0953 - val_loss: 0.
0962
Epoch 38/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0951 - val_loss: 0.
0957
Epoch 39/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0950 - val_loss: 0.
0958
Epoch 40/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0948 - val_loss: 0.
0956
Epoch 41/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0947 - val_loss: 0.
0958
Epoch 42/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0946 - val_loss: 0.
0955
Epoch 43/50
235/235 [==============================] - 3s 12ms/step - loss: 0.0944 - val_loss: 0.
0954
Epoch 44/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0943 - val_loss: 0.
0951
Epoch 45/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0941 - val_loss: 0.
0952
Epoch 46/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0941 - val_loss: 0.
0953
Epoch 47/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0940 - val_loss: 0.
0949
Epoch 48/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0939 - val_loss: 0.
0949
Epoch 49/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0937 - val_loss: 0.
0948
Epoch 50/50
235/235 [==============================] - 3s 11ms/step - loss: 0.0937 - val_loss: 0.
0948
```

In [24]:
```
plt.figure()
plt.plot(dimensions, losses)
plt.xlabel('Dimensions')
plt.ylabel('Loss')
plt.grid(True)
plt.show()
```



1. ***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 [60]:
```
(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[60]:
```
((60000, 784), (10000, 784))
```

In [61]:
```
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))))
```

In [62]:
```
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

In [58]:
```
noise = np.random.normal(20, 4, (60000,784))
noisy_train = noise + xtrain
```

In [63]:
```
autoencoder.fit(noisy_train, xtrain,
                epochs=100,
                batch_size=256,
                shuffle=True,
                validation_data=(xtest, xtest),
                callbacks=[TensorBoard(log_dir='/tmp/autoencoder')])
```

```
Epoch 1/100
235/235 [==============================] - 3s 9ms/step - loss: 0.2771 - val_loss: 0.6
685
Epoch 2/100
235/235 [==============================] - 2s 8ms/step - loss: 0.2636 - val_loss: 0.6
652
Epoch 3/100
235/235 [==============================] - 2s 9ms/step - loss: 0.2633 - val_loss: 0.6
572
Epoch 4/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2628 - val_loss: 0.
6444
Epoch 5/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2620 - val_loss: 0.
6206
Epoch 6/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2611 - val_loss: 0.
6024
Epoch 7/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2602 - val_loss: 0.
5792
Epoch 8/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2590 - val_loss: 0.
5618
Epoch 9/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2583 - val_loss: 0.
5504
Epoch 10/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2580 - val_loss: 0.
5438
Epoch 11/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2577 - val_loss: 0.
5287
Epoch 12/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2576 - val_loss: 0.
5190
Epoch 13/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2577 - val_loss: 0.
5072
Epoch 14/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2570 - val_loss: 0.
4985
Epoch 15/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2576 - val_loss: 0.
4877
Epoch 16/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2573 - val_loss: 0.
4738
Epoch 17/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2571 - val_loss: 0.
4656
Epoch 18/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2572 - val_loss: 0.
4576
Epoch 19/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2571 - val_loss: 0.
4485
Epoch 20/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2567 - val_loss: 0.
4390
```

```
Epoch 21/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2567 - val_loss: 0.
4275
Epoch 22/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2569 - val_loss: 0.
4232
Epoch 23/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2571 - val_loss: 0.
4100
Epoch 24/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2569 - val_loss: 0.
3994
Epoch 25/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2566 - val_loss: 0.
3897
Epoch 26/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2566 - val_loss: 0.
3812
Epoch 27/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2567 - val_loss: 0.
3706
Epoch 28/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2567 - val_loss: 0.
3594
Epoch 29/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2566 - val_loss: 0.
3488
Epoch 30/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2565 - val_loss: 0.
3372
Epoch 31/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2562 - val_loss: 0.
3288
Epoch 32/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2563 - val_loss: 0.
3166
Epoch 33/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2562 - val_loss: 0.
3107
Epoch 34/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2561 - val_loss: 0.
3000
Epoch 35/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2559 - val_loss: 0.
2982
Epoch 36/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2559 - val_loss: 0.
2935
Epoch 37/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2557 - val_loss: 0.
2897
Epoch 38/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2555 - val_loss: 0.
2902
Epoch 39/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2559 - val_loss: 0.
2859
Epoch 40/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2556 - val_loss: 0.
2856
```

```
Epoch 41/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2556 - val_loss: 0.
2873
Epoch 42/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2554 - val_loss: 0.
2839
Epoch 43/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2553 - val_loss: 0.
2840
Epoch 44/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2554 - val_loss: 0.
2807
Epoch 45/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2554 - val_loss: 0.
2827
Epoch 46/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2553 - val_loss: 0.
2798
Epoch 47/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2551 - val_loss: 0.
2804
Epoch 48/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2553 - val_loss: 0.
2792
Epoch 49/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2549 - val_loss: 0.
2790
Epoch 50/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2548 - val_loss: 0.
2819
Epoch 51/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2549 - val_loss: 0.
2799
Epoch 52/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2548 - val_loss: 0.
2769
Epoch 53/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2547 - val_loss: 0.
2792
Epoch 54/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2548 - val_loss: 0.
2803
Epoch 55/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2550 - val_loss: 0.
2763
Epoch 56/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2548 - val_loss: 0.
2788
Epoch 57/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2547 - val_loss: 0.
2783
Epoch 58/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2546 - val_loss: 0.
2755
Epoch 59/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2546 - val_loss: 0.
2769
Epoch 60/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2545 - val_loss: 0.
2754
```

```
Epoch 61/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2543 - val_loss: 0.
2751
Epoch 62/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2544 - val_loss: 0.
2731
Epoch 63/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2542 - val_loss: 0.
2733
Epoch 64/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2541 - val_loss: 0.
2720
Epoch 65/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2544 - val_loss: 0.
2718
Epoch 66/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2540 - val_loss: 0.
2725
Epoch 67/100
235/235 [==============================] - 2s 10ms/step - loss: 0.2541 - val_loss: 0.
2710
Epoch 68/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2544 - val_loss: 0.
2720
Epoch 69/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2542 - val_loss: 0.
2729
Epoch 70/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2542 - val_loss: 0.
2698
Epoch 71/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2540 - val_loss: 0.
2690
Epoch 72/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2539 - val_loss: 0.
2754
Epoch 73/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2540 - val_loss: 0.
2731
Epoch 74/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2541 - val_loss: 0.
2685
Epoch 75/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2541 - val_loss: 0.
2701
Epoch 76/100
235/235 [==============================] - 3s 13ms/step - loss: 0.2538 - val_loss: 0.
2691
Epoch 77/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2540 - val_loss: 0.
2735
Epoch 78/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2537 - val_loss: 0.
2713
Epoch 79/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2536 - val_loss: 0.
2703
Epoch 80/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2536 - val_loss: 0.
2696
```

```
Epoch 81/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2538 - val_loss: 0.
2728
Epoch 82/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2538 - val_loss: 0.
2701
Epoch 83/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2539 - val_loss: 0.
2714
Epoch 84/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2536 - val_loss: 0.
2714
Epoch 85/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2534 - val_loss: 0.
2717
Epoch 86/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2536 - val_loss: 0.
2711
Epoch 87/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2535 - val_loss: 0.
2706
Epoch 88/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2536 - val_loss: 0.
2701
Epoch 89/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2535 - val_loss: 0.
2706
Epoch 90/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2535 - val_loss: 0.
2687
Epoch 91/100
235/235 [==============================] - 2s 11ms/step - loss: 0.2535 - val_loss: 0.
2691
Epoch 92/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2533 - val_loss: 0.
2733
Epoch 93/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2533 - val_loss: 0.
2680
Epoch 94/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2533 - val_loss: 0.
2709
Epoch 95/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2535 - val_loss: 0.
2685
Epoch 96/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2533 - val_loss: 0.
2710
Epoch 97/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2532 - val_loss: 0.
2678
Epoch 98/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2535 - val_loss: 0.
2682
Epoch 99/100
235/235 [==============================] - 3s 12ms/step - loss: 0.2536 - val_loss: 0.
2698
Epoch 100/100
235/235 [==============================] - 3s 11ms/step - loss: 0.2534 - val_loss: 0.
2686
```

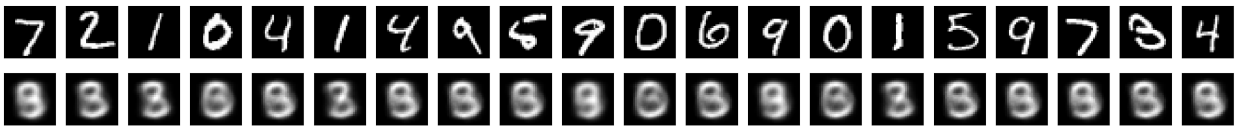
Out[63]:
```
<keras.src.callbacks.History at 0x2204524ed10>
```

In [73]:
```
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)

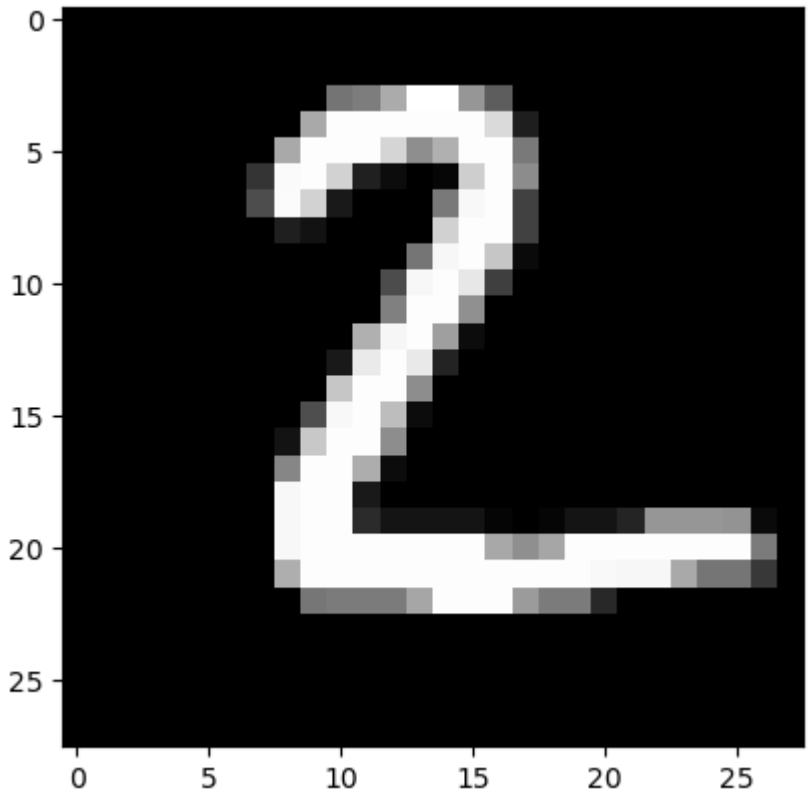
    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

```
313/313 [==============================] - 0s 1ms/step
313/313 [==============================] - 0s 1ms/step
```



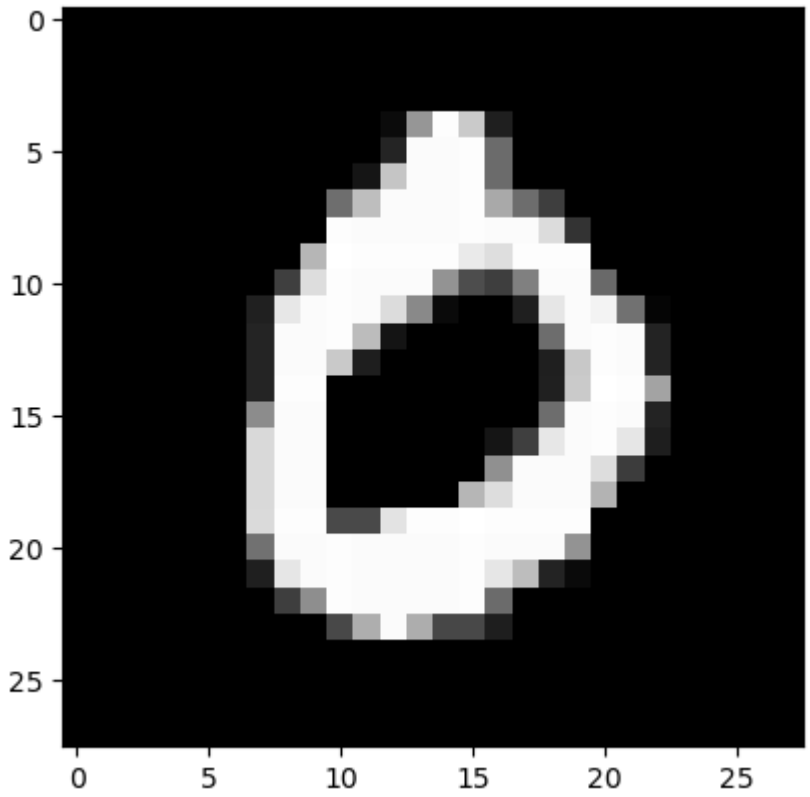
In [71]:
```
plt.imshow(xtest[1].reshape(28,28))
```

Out[71]:
```
<matplotlib.image.AxesImage at 0x220270c0760>
```



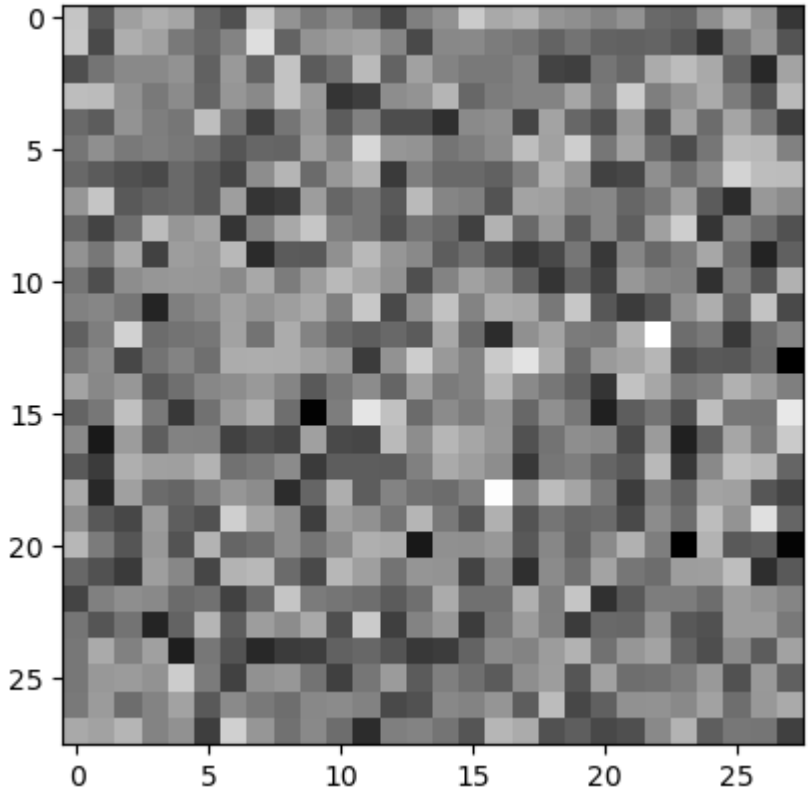
In [75]:
```
plt.imshow(xtest[3].reshape(28,28))
```

Out[75]:
```
<matplotlib.image.AxesImage at 0x220281f3520>
```



In [76]:
```
plt.imshow(noisy_train[3].reshape(28,28))
```

Out[76]:
```
<matplotlib.image.AxesImage at 0x2202826a620>
```



In [ ]: