In [23]:
```
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
```

In [24]:
```
from tensorflow.keras.datasets import mnist
```

In [25]:
```
(x_train, y_train),(x_test,y_test) = mnist.load_data()
```

In [26]:
```
x_train.shape
```

Out[26]:
```
(60000, 28, 28)
```

In [27]:
```
single = x_train[0]
```

In [28]:
```
single
```

Out[28]:
```
array([[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   3,
         18,  18,  18, 126, 136, 175,  26, 166, 255, 247, 127,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,  30,  36,  94, 154, 170,
        253, 253, 253, 253, 253, 225, 172, 253, 242, 195,  64,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,  49, 238, 253, 253, 253, 253,
        253, 253, 253, 253, 251,  93,  82,  82,  56,  39,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,  18, 219, 253, 253, 253, 253,
        253, 198, 182, 247, 241,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,  80, 156, 107, 253, 253,
        205,  11,   0,  43, 154,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,  14,   1, 154, 253,
         90,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0, 139, 253,
        190,   2,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  11, 190,
        253,  70,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  35,
        241, 225, 160, 108,   1,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
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          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
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          0,   0],
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          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  39,
        148, 229, 253, 253, 253, 250, 182,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  24, 114, 221,
        253, 253, 253, 253, 201,  78,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,  23,  66, 213, 253, 253,
```

```
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   0,   0],
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   0,   0],
[  0,   0,   0,   0,  55, 172, 226, 253, 253, 253, 253, 244, 133,
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   0,   0],
[  0,   0,   0,   0, 136, 253, 253, 253, 212, 135, 132,  16,   0,
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   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
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   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0]], dtype=uint8)
```
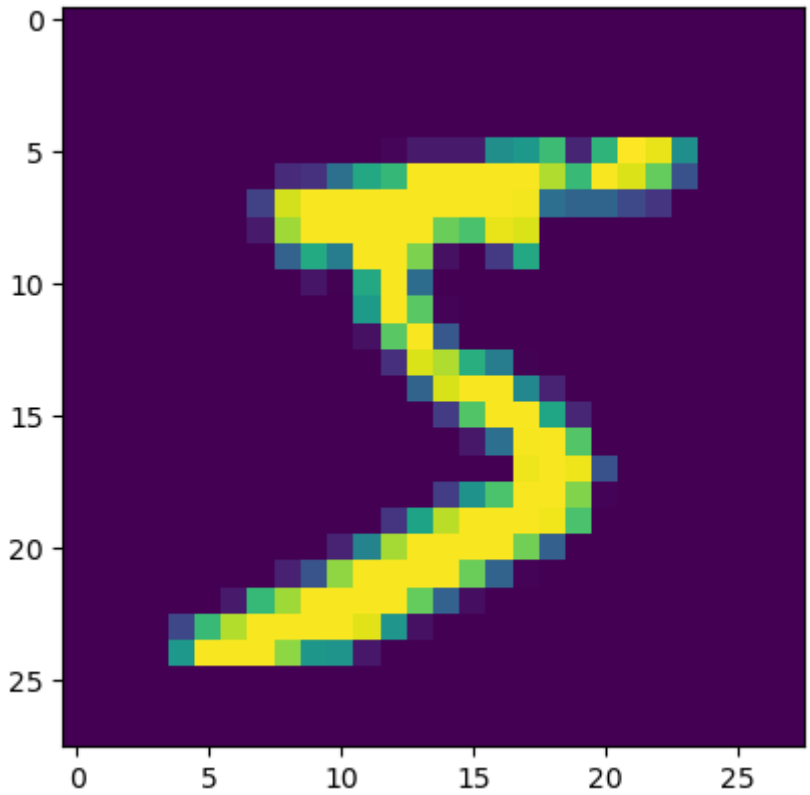

In [29]:
```
plt.imshow(single)
```

Out[29]:
```
<matplotlib.image.AxesImage at 0x1dd629d1340>
```



In [36]:
```
y_train
```

Out[36]:
```
array([5, 0, 4, ..., 5, 6, 8], dtype=uint8)
```

In [32]:
```
from tensorflow.keras.utils import to_categorical
```

In [33]:
```
y_example = to_categorical(y_train)
```

In [34]:
```
y_example.shape
```

Out[34]:
```
(60000, 10)
```

In [37]:
```
y_cat_test = to_categorical(y_test)
```

In [38]:
```
y_cat_train = to_categorical(y_train)
```

In [40]:
```
x_train = x_train/255
```

In [41]:
```
x_test = x_test/255
```

In [42]:
```
scaled_image = x_train[0]
```

In [43]:
```
scaled_image
```

Out[43]:
```
array([[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
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        0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
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        0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
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```

```
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```

```
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 0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
```

```
0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00,
0.00000000e+00, 0.00000000e+00, 0.00000000e+00, 0.00000000e+00]])
```

In [44]:
```
x_train = x_train.reshape(60000, 28, 28, 1)
```

In [45]:
```
x_test = x_test.reshape(10000, 28, 28, 1)
```

In [46]:
```
from tensorflow.keras.models import Sequential
```

In [47]:
```
from tensorflow.keras.layers import Dense, Conv2D, MaxPool2D, Flatten
```

In [49]:
```
model = Sequential()

model.add(Conv2D(filters=32, kernel_size= (4,4), input_shape=(28,28,1), activation=
model.add(MaxPool2D(pool_size=(2,2)))

model.add(Flatten())

model.add(Dense(128, activation='relu'))

model.add(Dense(10, activation='softmax'))

model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy
```

In [50]:
```
from tensorflow.keras.callbacks import EarlyStopping
```

In [52]:
```
early_stop = EarlyStopping(monitor='val_loss', patience=1)
```

In [75]:
```
model.fit(x_train, y_cat_train, epochs=10, validation_data=(x_test, y_cat_test), ca
```

```
Epoch 1/10
1875/1875 [==============================] - 14s 7ms/step - loss: 0.1043 - accurac
y: 0.9681 - val_loss: 24.0879 - val_accuracy: 0.9501
Epoch 2/10
1875/1875 [==============================] - 14s 7ms/step - loss: 0.0987 - accurac
y: 0.9699 - val_loss: 27.4901 - val_accuracy: 0.9463
```

Out[75]:
```
<keras.callbacks.History at 0x1dd160aff40>
```

In [76]:
```
historia = pd.DataFrame(model.history.history)
```

In [79]:
```
model.evaluate(x_test, y_cat_test, verbose=0)
```

Out[79]:
```
[27.490127563476562, 0.9463000297546387]
```

In [80]:
```
from sklearn.metrics import classification_report, confusion_matrix
```

In [81]:
```
predict = model.predict(x_test)
```

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

In [83]:
```
predictions = np.argmax(predict, axis=1)
```

In [84]:
```
print(classification_report(y_test, predictions))
```

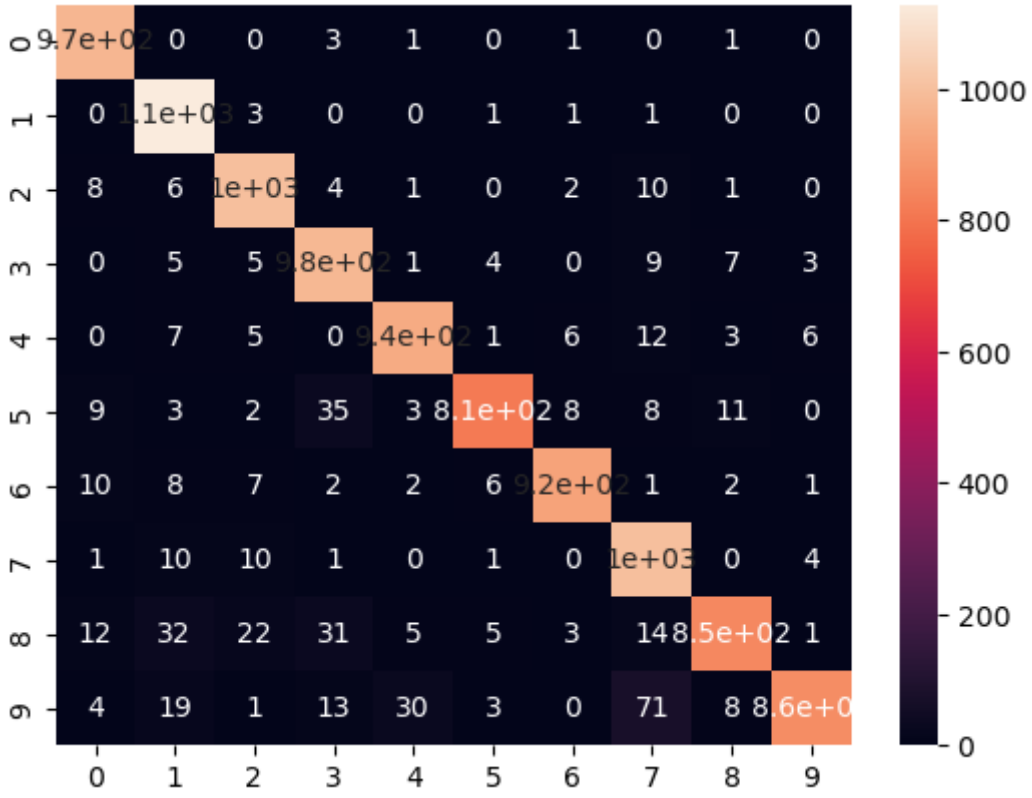
	precision	recall	f1-score	support
0	0.96	0.99	0.97	980
1	0.93	0.99	0.96	1135
2	0.95	0.97	0.96	1032
3	0.92	0.97	0.94	1010
4	0.96	0.96	0.96	982
5	0.97	0.91	0.94	892
6	0.98	0.96	0.97	958
7	0.89	0.97	0.93	1028
8	0.96	0.87	0.91	974
9	0.98	0.85	0.91	1009
accuracy			0.95	10000
macro avg	0.95	0.95	0.95	10000
weighted avg	0.95	0.95	0.95	10000

In [85]:
```
print(confusion_matrix(y_test, predictions))
```

```
[[ 974    0    0    3    1    0    1    0    1    0]
 [   0 1129    3    0    0    1    1    1    0    0]
 [   8    6 1000    4    1    0    2   10    1    0]
 [   0    5    5  976    1    4    0    9    7    3]
 [   0    7    5    0  942    1    6   12    3    6]
 [   9    3    2   35    3  813    8    8   11    0]
 [  10    8    7    2    2    6  919    1    2    1]
 [   1   10   10    1    0    1    0 1001    0    4]
 [  12   32   22   31    5    5    3   14  849    1]
 [   4   19    1   13   30    3    0   71    8  860]]
```

In [87]:
```
sns.heatmap(confusion_matrix(y_test, predictions), annot=True)
```

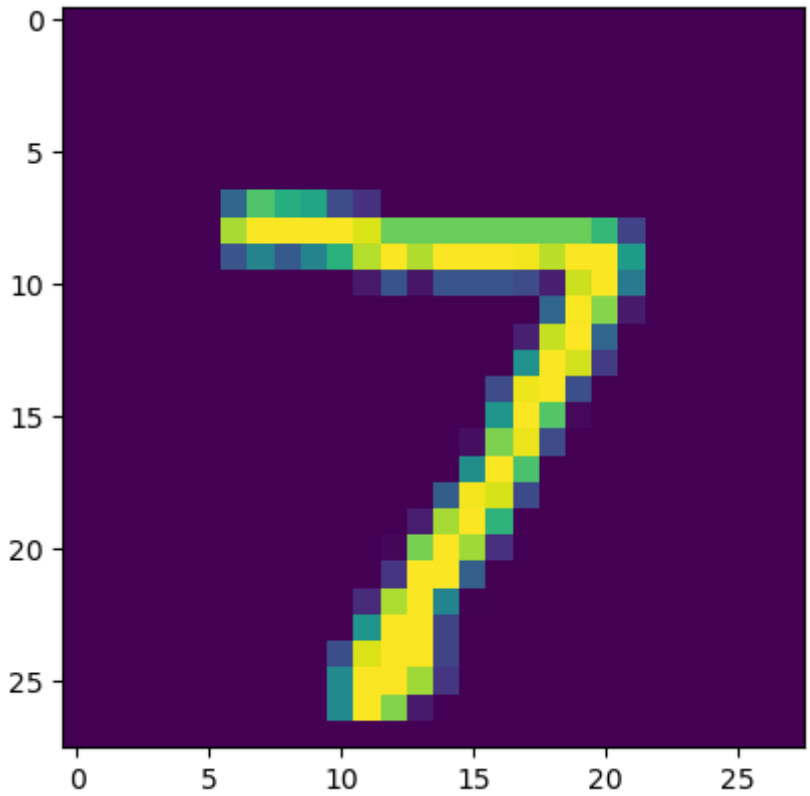
Out[87]: <AxesSubplot:>



In [88]:
```
my_number = x_test[0]
```

In [89]:
```
plt.imshow(my_number.reshape(28,28))
```

Out[89]:
```
<matplotlib.image.AxesImage at 0x1dd054bc760>
```



In [90]:
```
model.predict(my_number.reshape())
```

Out[90]:
```
1/1 [==============================] - 0s 14ms/step
array([[0., 0., 0., 0., 0., 0., 0., 1., 0., 0.]], dtype=float32)
```