In [6]:
```
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
import numpy as np
```

1. Load the Dataset

In [8]:
```
#Load dataset
(x_train,y_train), (x_test,y_test) = keras.datasets.mnist.load_data()
```

2. Analyze and explore the dataset

In [10]:
```
#Analyze the data
x_train.shape
```

Out[10]: (60000, 28, 28)

In [11]:
```
y_train.shape
```

Out[11]: (60000,)

In [12]:
```
x_test.shape
```

Out[12]: (10000, 28, 28)

In [83]:
```
x_train[10]
```

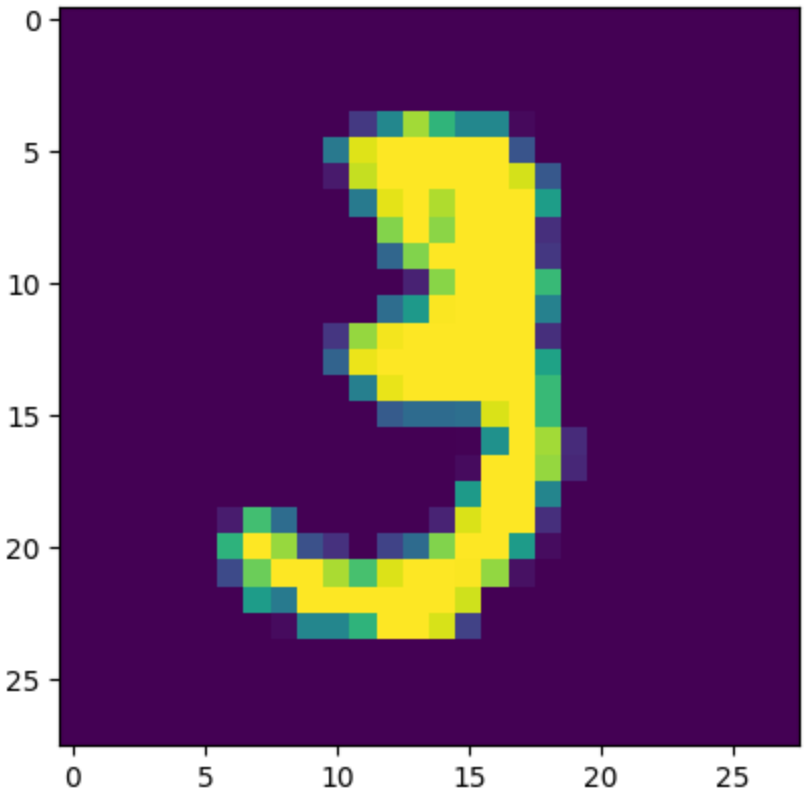
```
Out[83]: array([[0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 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.        , 0.16470588, 0.4627451 , 0.85882353, 0.65098039,
         0.4627451 , 0.4627451 , 0.02352941, 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.40392157, 0.94901961, 0.99607843, 0.99607843, 0.99607843,
         0.99607843, 0.99607843, 0.25882353, 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.07058824, 0.90980392, 0.99607843, 0.99607843, 0.99607843,
         0.99607843, 0.99607843, 0.93333333, 0.2745098 , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.40784314, 0.95686275, 0.99607843, 0.87843137,
         0.99607843, 0.99607843, 0.99607843, 0.55294118, 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.81176471, 0.99607843, 0.82352941,
         0.99607843, 0.99607843, 0.99607843, 0.13333333, 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
 0.        , 0.        , 0.32941176, 0.80784314, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.16078431, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.09411765, 0.81960784,
 0.99607843, 0.99607843, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.35686275, 0.5372549 , 0.99215686,
 0.99607843, 0.99607843, 0.99607843, 0.43921569, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.15686275, 0.83921569, 0.98039216, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.13333333, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.31764706, 0.96862745, 0.99607843, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.57254902, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.43137255, 0.96470588, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.28627451, 0.34901961, 0.34901961,
 0.36470588, 0.94117647, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.00392157, 0.50196078, 0.99607843, 0.85882353, 0.12156863,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.02745098, 0.99607843, 0.99607843, 0.83921569, 0.10980392,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.54117647, 0.99607843, 0.99607843, 0.45490196, 0.        ,
```

```
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.0745098 , 0.69411765, 0.35294118, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.09803922,
 0.94117647, 0.99607843, 0.99607843, 0.13333333, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.64313725, 0.99607843, 0.84313725, 0.24705882,
 0.14117647, 0.        , 0.2       , 0.34901961, 0.80784314,
 0.99607843, 0.99607843, 0.54509804, 0.03137255, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.22352941, 0.77254902, 0.99607843, 0.99607843,
 0.87058824, 0.70588235, 0.94509804, 0.99607843, 0.99607843,
 0.99215686, 0.83529412, 0.04313725, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.54901961, 0.41176471, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.99607843, 0.99607843,
 0.9254902 , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.02745098, 0.45882353,
 0.45882353, 0.64705882, 0.99607843, 0.99607843, 0.9372549 ,
 0.19607843, 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.        ]])
```

2.1 plot sample data to get a better visual representation

In [15]:
```
#plot sample data to get a better visual representation
plt.imshow(x_train[10])
plt.show()
```



2.2 Check the respective image label

In [17]:
```
# Check the respective image label
y_train[10]
```

Out[17]: 3

In [18]:
```
x_train.shape
```

Out[18]: (60000, 28, 28)

In [19]:
```
len(x_train)
```

Out[19]: 60000

3. Normalize the pixel data

In [31]:
```
#Normalized pixel data
x_train = x_train/255
x_test = x_test/255
```

In [85]:
```
x_train[10]
```

```
Out[85]: 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.        , 0.16470588, 0.4627451 , 0.85882353, 0.65098039,
          0.4627451 , 0.4627451 , 0.02352941, 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.40392157, 0.94901961, 0.99607843, 0.99607843, 0.99607843,
          0.99607843, 0.99607843, 0.25882353, 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.07058824, 0.90980392, 0.99607843, 0.99607843, 0.99607843,
          0.99607843, 0.99607843, 0.93333333, 0.2745098 , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.40784314, 0.95686275, 0.99607843, 0.87843137,
          0.99607843, 0.99607843, 0.99607843, 0.55294118, 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.81176471, 0.99607843, 0.82352941,
          0.99607843, 0.99607843, 0.99607843, 0.13333333, 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        ],
         [0.        , 0.        , 0.        , 0.        , 0.        ,
          0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
 0.        , 0.        , 0.32941176, 0.80784314, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.16078431, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.09411765, 0.81960784,
 0.99607843, 0.99607843, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.35686275, 0.5372549 , 0.99215686,
 0.99607843, 0.99607843, 0.99607843, 0.43921569, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.15686275, 0.83921569, 0.98039216, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.13333333, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.31764706, 0.96862745, 0.99607843, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.57254902, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.43137255, 0.96470588, 0.99607843, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.28627451, 0.34901961, 0.34901961,
 0.36470588, 0.94117647, 0.99607843, 0.67058824, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.00392157, 0.50196078, 0.99607843, 0.85882353, 0.12156863,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.02745098, 0.99607843, 0.99607843, 0.83921569, 0.10980392,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.54117647, 0.99607843, 0.99607843, 0.45490196, 0.        ,
```

```
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.0745098 , 0.69411765, 0.35294118, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.09803922,
 0.94117647, 0.99607843, 0.99607843, 0.13333333, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.64313725, 0.99607843, 0.84313725, 0.24705882,
 0.14117647, 0.        , 0.2       , 0.34901961, 0.80784314,
 0.99607843, 0.99607843, 0.54509804, 0.03137255, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.22352941, 0.77254902, 0.99607843, 0.99607843,
 0.87058824, 0.70588235, 0.94509804, 0.99607843, 0.99607843,
 0.99215686, 0.83529412, 0.04313725, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.54901961, 0.41176471, 0.99607843,
 0.99607843, 0.99607843, 0.99607843, 0.99607843, 0.99607843,
 0.9254902 , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.02745098, 0.45882353,
 0.45882353, 0.64705882, 0.99607843, 0.99607843, 0.9372549 ,
 0.19607843, 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.        ]])
```

4. Flattening the images

In [36]:
```
x_train_flattened = x_train.reshape(len(x_train),28*28)
x_train_flattened.shape
```

Out[36]: (60000, 784)

In [38]:
```
x_test_flattened = x_test.reshape(len(x_test),28*28)
x_test_flattened.shape
```

Out[38]: (10000, 784)

5.1 Building the first Model with a single Dense Layer

In [41]:
```
model = keras.Sequential(
    [
        keras.layers.Dense(10, input_shape= (784,) ,activation='sigmoid')
    ]
)

model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy', #we have categories of output
             metrics=['accuracy']
             )
model.fit(x_train_flattened,y_train,epochs=5)
```

```
C:\Anaconda3\Lib\site-packages\keras\src\layers\core\dense.py:93: UserWarning: Do no
t pass an `input_shape`/`input_dim` argument to a layer. When using Sequential model
s, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
Epoch 1/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 771us/step - accuracy: 0.8183 - loss: 0.7104
Epoch 2/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 1s 756us/step - accuracy: 0.9149 - loss: 0.3097
Epoch 3/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 1s 748us/step - accuracy: 0.9207 - loss: 0.2862
Epoch 4/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 1s 780us/step - accuracy: 0.9246 - loss: 0.2667
Epoch 5/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 1s 773us/step - accuracy: 0.9260 - loss: 0.2671
```

Out[41]: <keras.src.callbacks.history.History at 0x17968cc54c0>

5.2 Evaluating the model

In [44]:
```
#Evaluating the model
model.evaluate(x_test_flattened,y_test)
```

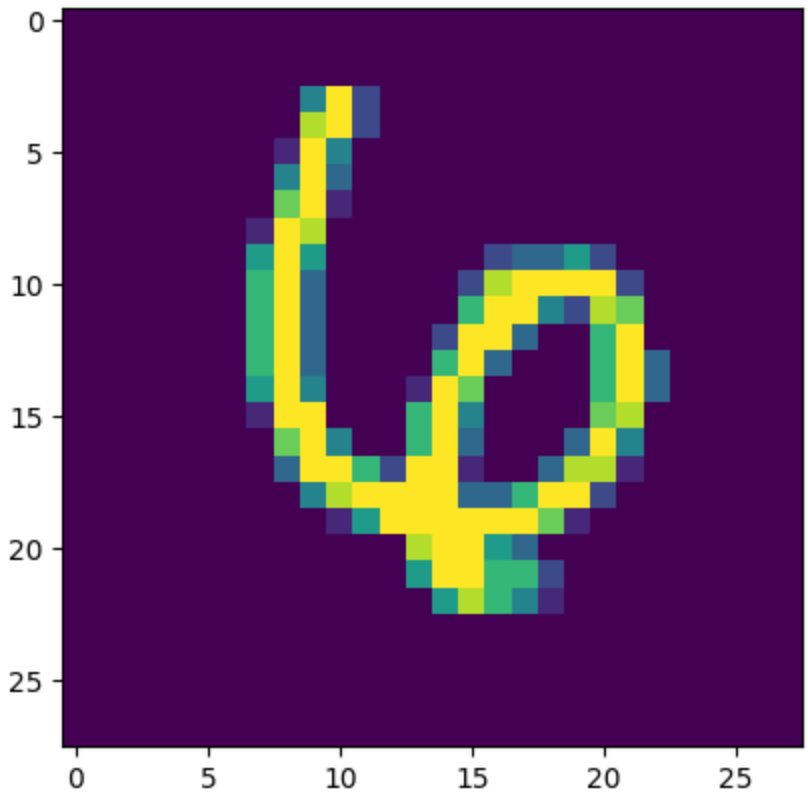
```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 827us/step - accuracy: 0.9161 - loss: 0.3025
```

Out[44]: [0.26626142859458923, 0.9265999794006348]

5.3 Testing the model with a sample prediction

In [47]:
```
plt.imshow(x_test[22])
```

Out[47]: <matplotlib.image.AxesImage at 0x17968b663c0>



In [49]:
```
k = model.predict(x_test[22].reshape(1,784))
np.argmax(k)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 47ms/step
```

Out[49]: 6

In [51]:
```
y_peddicted_Labels = [np.argmax(i) for i in model.predict(x_test_flattened)]
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 465us/step
```

5.4 Building a confusion metrix to evaluate he performance

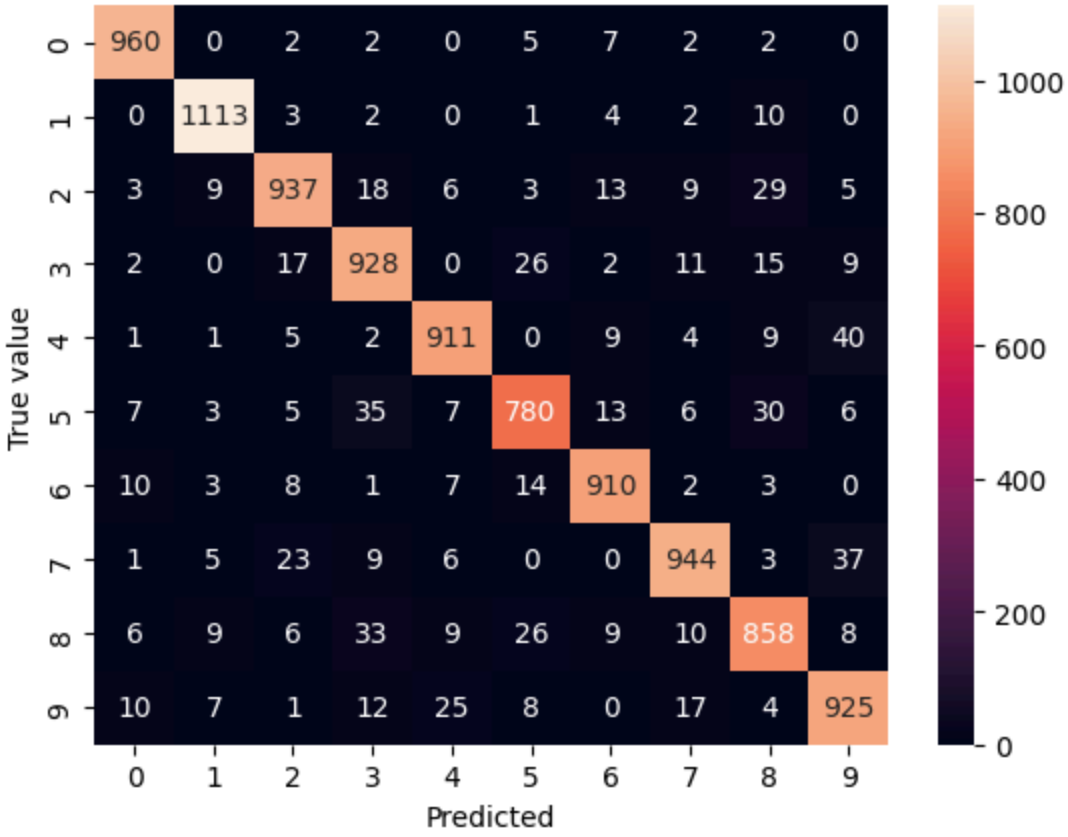
In [54]:
```
# Building a confusion metrix to evaluate he performance
cm = tf.math.confusion_matrix(labels=y_test,predictions=y_peddicted_Labels)
```

```
cm
```

Out[54]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 960,    0,    2,    2,    0,    5,    7,    2,    2,    0],
       [   0, 1113,    3,    2,    0,    1,    4,    2,   10,    0],
       [   3,    9,  937,   18,    6,    3,   13,    9,   29,    5],
       [   2,    0,   17,  928,    0,   26,    2,   11,   15,    9],
       [   1,    1,    5,    2,  911,    0,    9,    4,    9,   40],
       [   7,    3,    5,   35,    7,  780,   13,    6,   30,    6],
       [  10,    3,    8,    1,    7,   14,  910,    2,    3,    0],
       [   1,    5,   23,    9,    6,    0,    0,  944,    3,   37],
       [   6,    9,    6,   33,    9,   26,    9,   10,  858,    8],
       [  10,    7,    1,   12,   25,    8,    0,   17,    4,  925]])>
```

In [56]:
```
import seaborn as sns
```

In [58]:
```
#Plotting the confusion matix using seaborn library for a better visual representat
sns.heatmap(cm, annot=True, fmt='d')
plt.xlabel("Predicted")
plt.ylabel("True value")
plt.show()
```



6.1 Building the second Model with a hidden layer (with 100 neurones)

In [61]:
```
#building another model with hidden layer
model2 = keras.Sequential(
```

```
    [
        #without keras flatten layer, because we are manually flattening the image
        #100 is hidden layer neurones and activation function is relu
        keras.layers.Dense(100, input_shape= (784,) ,activation='relu'),
        keras.layers.Dense(10 ,activation='sigmoid')
    ]
)

model2.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy', #we have categories of output
             metrics=['accuracy']
             )
model2.fit(x_train_flattened,y_train,epochs=5)
```

```
Epoch 1/5
C:\Anaconda3\Lib\site-packages\keras\src\layers\core\dense.py:93: UserWarning: Do no
t pass an `input_shape`/`input_dim` argument to a layer. When using Sequential model
s, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.8780 - loss: 0.4451
Epoch 2/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9593 - loss: 0.1363
Epoch 3/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9736 - loss: 0.0908
Epoch 4/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9803 - loss: 0.0683
Epoch 5/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9829 - loss: 0.0547
```

Out[61]: <keras.src.callbacks.history.History at 0x17970bc7530>

6.2 Evaluating the model

In [64]:
```
# evaluate model for training data
model2.evaluate(x_train_flattened, y_train)
```

```
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 776us/step - accuracy: 0.9860 - loss: 0.0443
```

Out[64]: [0.04461903125047684, 0.9861500263214111]

In [66]:
```
# evaluate model for testing data
model2.evaluate(x_test_flattened, y_test)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 823us/step - accuracy: 0.9682 - loss: 0.1031
```

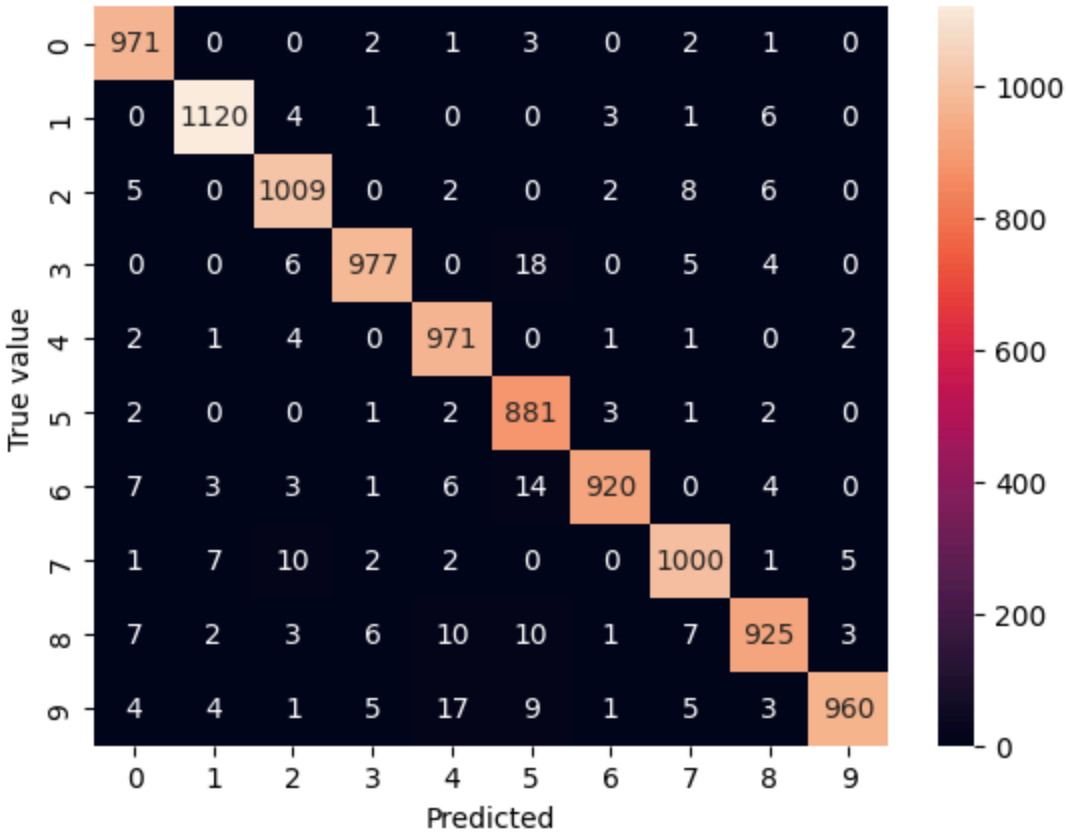
Out[66]: [0.08758094906806946, 0.9733999967575073]

In [68]:
```
# Building a confusion metrice to evaluate he performance
y_peddicted_Labels = [np.argmax(i) for i in model2.predict(x_test_flattened)]
cm1 = tf.math.confusion_matrix(labels=y_test,predictions=y_peddicted_Labels)
cm1
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 611us/step
```

Out[68]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 971,    0,    0,    2,    1,    3,    0,    2,    1,    0],
       [   0, 1120,    4,    1,    0,    0,    3,    1,    6,    0],
       [   5,    0, 1009,    0,    2,    0,    2,    8,    6,    0],
       [   0,    0,    6,  977,    0,   18,    0,    5,    4,    0],
       [   2,    1,    4,    0,  971,    0,    1,    1,    0,    2],
       [   2,    0,    0,    1,    2,  881,    3,    1,    2,    0],
       [   7,    3,    3,    1,    6,   14,  920,    0,    4,    0],
       [   1,    7,   10,    2,    2,    0,    0, 1000,    1,    5],
       [   7,    2,    3,    6,   10,   10,    1,    7,  925,    3],
       [   4,    4,    1,    5,   17,    9,    1,    5,    3,  960]])>
```

In [70]:
```
#Plotting the confusion matix using seaborn library for a better visual representat
sns.heatmap(cm1, annot=True, fmt='d')
plt.xlabel("Predicted")
plt.ylabel("True value")
plt.show()
```



7.1 Building the third Model using Flatten and a hidden layer

In [73]:
```
#building another model with hidden layer
model3 = keras.Sequential(
    [
        #Flatten layer
        keras.layers.Flatten(input_shape=(28,28)),
```

```
        keras.layers.Dense(100 ,activation='relu'),
        keras.layers.Dense(10 ,activation='sigmoid')
    ]
)

model3.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy', #we have categories of output
             metrics=['accuracy']
             )
model3.fit(x_train,y_train,epochs=5)
```

```
Epoch 1/5
C:\Anaconda3\Lib\site-packages\keras\src\layers\reshaping\flatten.py:37: UserWarnin
g: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequenti
al models, prefer using an `Input(shape)` object as the first layer in the model ins
tead.
  super().__init__(**kwargs)
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.8753 - loss: 0.4452
Epoch 2/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9610 - loss: 0.1342
Epoch 3/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9723 - loss: 0.0919
Epoch 4/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9796 - loss: 0.0665
Epoch 5/5
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 2s 1ms/step - accuracy: 0.9850 - loss: 0.0512
```

Out[73]: <keras.src.callbacks.history.History at 0x179722307a0>

7.2 Evaluating the model

In [76]:
```
# Evaluate the model for training data
# using x_train derectly without flattening
model3.evaluate(x_train, y_train)
```

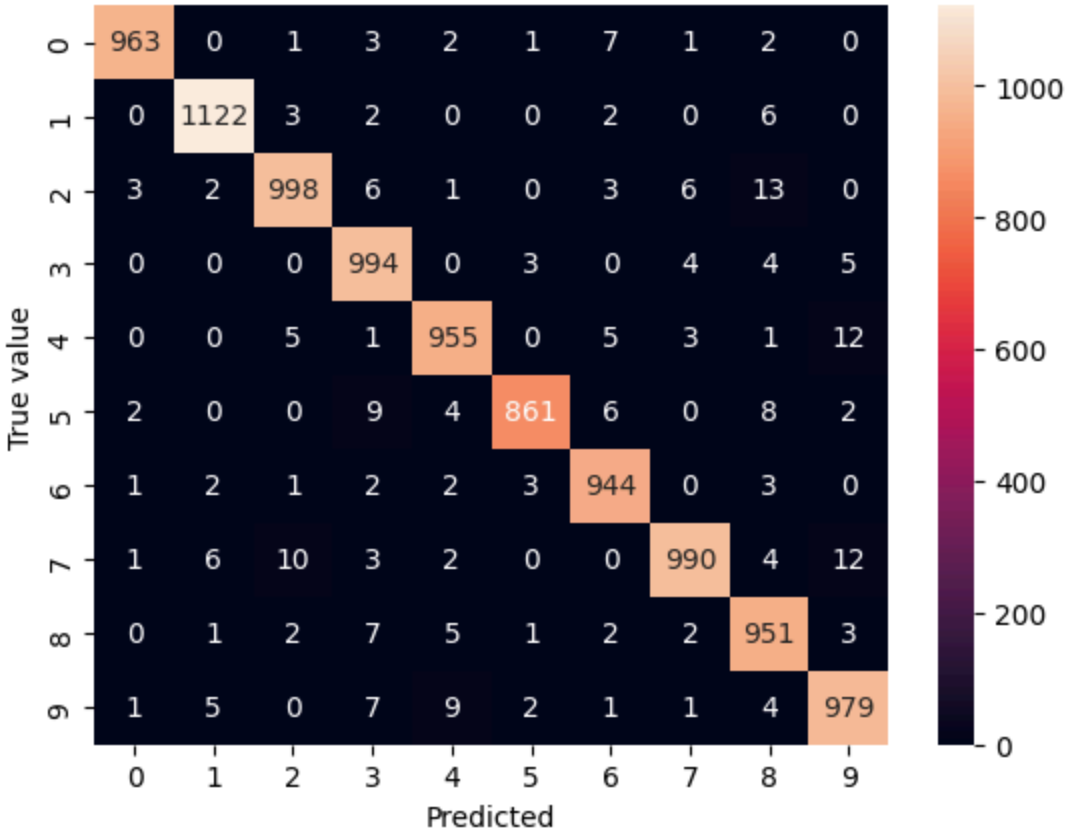
```
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 1s 752us/step - accuracy: 0.9894 - loss: 0.0381
```

Out[76]: [0.03898240998387337, 0.9888833165168762]

In [78]:
```
y_peddicted_Labels = [np.argmax(i) for i in model3.predict(x_test)]
cm3 = tf.math.confusion_matrix(labels=y_test,predictions=y_peddicted_Labels)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 632us/step
```

In [80]:
```
#Plotting the confusion matix using seaborn library for a better visual representat
sns.heatmap(cm3, annot=True, fmt='d')
plt.xlabel("Predicted")
plt.ylabel("True value")
plt.show()
```


True value
Predicted
0 963 0 1 3 2 1 7 1 2 0
1 0 1122 3 2 0 0 2 0 6 0
2 3 2 998 6 1 0 3 6 13 0
3 0 0 0 994 0 3 0 4 4 5
4 0 0 5 1 955 0 5 3 1 12
5 2 0 0 9 4 861 6 0 8 2
6 1 2 1 2 2 3 944 0 3 0
7 1 6 10 3 2 0 0 990 4 12
8 0 1 2 7 5 1 2 2 951 3
9 1 5 0 7 9 2 1 1 4 979
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0