In [2]:

```
from __future__ import absolute_import, division, print_function

import tensorflow as tf
from tensorflow.keras import Model, layers
import numpy as np
```

In [3]:

```
# MNIST dataset parameters.
num_classes = 10 # total classes (0-9 digits).

# Training parameters.
learning_rate = 0.001
training_steps = 200
batch_size = 128
display_step = 10

# Network parameters.
conv1_filters = 32 # number of filters for 1st conv layer.
conv2_filters = 64 # number of filters for 2nd conv layer.
fc1_units = 1024 # number of neurons for 1st fully-connected layer.
```

In [4]:

```
# Prepare MNIST data.
from tensorflow.keras.datasets import mnist
(x_train, y_train), (x_test, y_test) = mnist.load_data()
# Convert to float32.
x_train, x_test = np.array(x_train, np.float32), np.array(x_test, np.float
32)
# Normalize images value from [0, 255] to [0, 1].
x_train, x_test = x_train / 255., x_test / 255.
```

In [5]:

```
# Use tf.data API to shuffle and batch data.
train_data = tf.data.Dataset.from_tensor_slices((x_train, y_train))
train_data = train_data.repeat().shuffle(5000).batch(batch_size).prefetch(
1)
```

In [6]:

```
# Create TF Model.
class ConvNet(Model):
    # Set layers.
    def __init__(self):
        super(ConvNet, self).__init__()
        # Convolution Layer with 32 filters and a kernel size of 5.
        self.conv1 = layers.Conv2D(32, kernel_size=5, activation=tf.nn.rel
u)
        # Max Pooling (down-sampling) with kernel size of 2 and strides of
2.
        self.maxpool1 = layers.MaxPool2D(2, strides=2)
```

```
        # Convolution Layer with 64 filters and a kernel size of 3.
        self.conv2 = layers.Conv2D(64, kernel_size=3, activation=tf.nn.rel
u)
        # Max Pooling (down-sampling) with kernel size of 2 and strides of
2.
        self.maxpool2 = layers.MaxPool2D(2, strides=2)

        # Flatten the data to a 1-D vector for the fully connected layer.
        self.flatten = layers.Flatten()

        # Fully connected layer.
        self.fc1 = layers.Dense(1024)
        # Apply Dropout (if is_training is False, dropout is not applied).
        self.dropout = layers.Dropout(rate=0.5)

        # Output layer, class prediction.
        self.out = layers.Dense(num_classes)

    # Set forward pass.
    def call(self, x, is_training=False):
        x = tf.reshape(x, [-1, 28, 28, 1])
        x = self.conv1(x)
        x = self.maxpool1(x)
        x = self.conv2(x)
        x = self.maxpool2(x)
        x = self.flatten(x)
        x = self.fc1(x)
        x = self.dropout(x, training=is_training)
        x = self.out(x)
        if not is_training:
            # tf cross entropy expect logits without softmax, so only
            # apply softmax when not training.
            x = tf.nn.softmax(x)
        return x

# Build neural network model.
conv_net = ConvNet()
```

In [7]:

```
# Cross-Entropy Loss.
# Note that this will apply 'softmax' to the logits.
def cross_entropy_loss(x, y):
    # Convert labels to int 64 for tf cross-entropy function.
    y = tf.cast(y, tf.int64)
    # Apply softmax to logits and compute cross-entropy.
    loss = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=y, logits
=x)
    # Average loss across the batch.
    return tf.reduce_mean(loss)

# Accuracy metric.
def accuracy(y_pred, y_true):
    # Predicted class is the index of highest score in prediction vector
 (i.e. argmax).
    correct_prediction = tf.equal(tf.argmax(y_pred, 1), tf.cast(y_true, tf
.int64))
    return tf.reduce_mean(tf.cast(correct_prediction, tf.float32), axis=-1
)
```

```
# Stochastic gradient descent optimizer.
optimizer = tf.optimizers.Adam(learning_rate)
```

In [8]:

```
# Optimization process.
def run_optimization(x, y):
    # Wrap computation inside a GradientTape for automatic differentiatio
n.
    with tf.GradientTape() as g:
        # Forward pass.
        pred = conv_net(x, is_training=True)
        # Compute loss.
        loss = cross_entropy_loss(pred, y)

    # Variables to update, i.e. trainable variables.
    trainable_variables = conv_net.trainable_variables

    # Compute gradients.
    gradients = g.gradient(loss, trainable_variables)

    # Update W and b following gradients.
    optimizer.apply_gradients(zip(gradients, trainable_variables))
```

In [9]:

```
# Run training for the given number of steps.
for step, (batch_x, batch_y) in enumerate(train_data.take(training_steps),
1):
    # Run the optimization to update W and b values.
    run_optimization(batch_x, batch_y)

    if step % display_step == 0:
        pred = conv_net(batch_x)
        loss = cross_entropy_loss(pred, batch_y)
        acc = accuracy(pred, batch_y)
        print("step: %i, loss: %f, accuracy: %f" % (step, loss, acc))
```

```
step: 10, loss: 1.836220, accuracy: 0.781250
step: 20, loss: 1.587380, accuracy: 0.890625
step: 30, loss: 1.548710, accuracy: 0.953125
step: 40, loss: 1.534813, accuracy: 0.960938
step: 50, loss: 1.559870, accuracy: 0.937500
step: 60, loss: 1.548814, accuracy: 0.937500
step: 70, loss: 1.511837, accuracy: 0.960938
step: 80, loss: 1.527663, accuracy: 0.960938
step: 90, loss: 1.516925, accuracy: 0.976562
step: 100, loss: 1.531665, accuracy: 0.960938
step: 110, loss: 1.509515, accuracy: 0.968750
step: 120, loss: 1.498860, accuracy: 0.992188
step: 130, loss: 1.529221, accuracy: 0.968750
step: 140, loss: 1.504202, accuracy: 0.984375
step: 150, loss: 1.509837, accuracy: 0.968750
step: 160, loss: 1.500904, accuracy: 0.976562
step: 170, loss: 1.496318, accuracy: 0.976562
step: 180, loss: 1.500421, accuracy: 0.968750
step: 190, loss: 1.506527, accuracy: 0.976562
step: 200, loss: 1.485476, accuracy: 0.992188
```

In [10]:

```
# Test model on validation set.
pred = conv_net(x_test)
print("Test Accuracy: %f" % accuracy(pred, y_test))
```

```
Test Accuracy: 0.978500
```

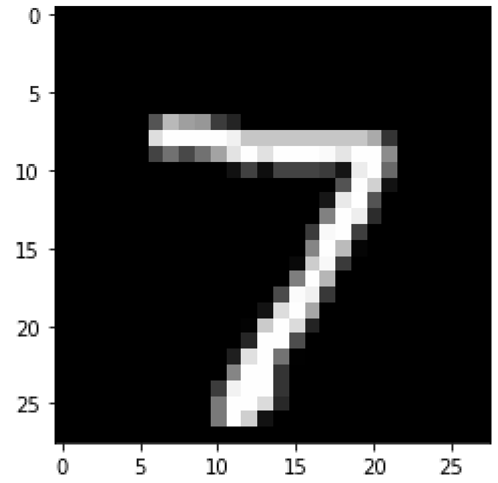
In [11]:

```
# Visualize predictions.
import matplotlib.pyplot as plt
```

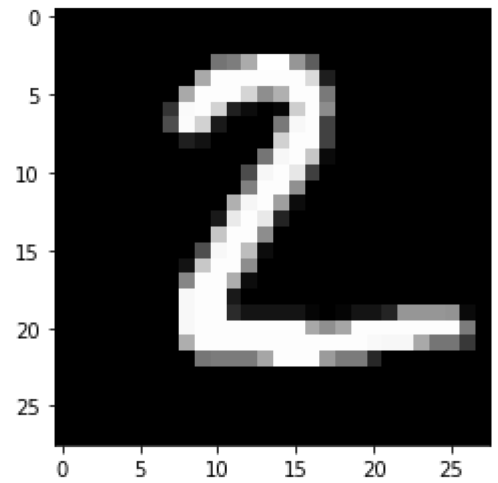
In [12]:

```
# Predict 5 images from validation set.
n_images = 5
test_images = x_test[:n_images]
predictions = conv_net(test_images)

# Display image and model prediction.
for i in range(n_images):
    plt.imshow(np.reshape(test_images[i], [28, 28]), cmap='gray')
    plt.show()
    print("Model prediction: %i" % np.argmax(predictions.numpy()[i]))
```

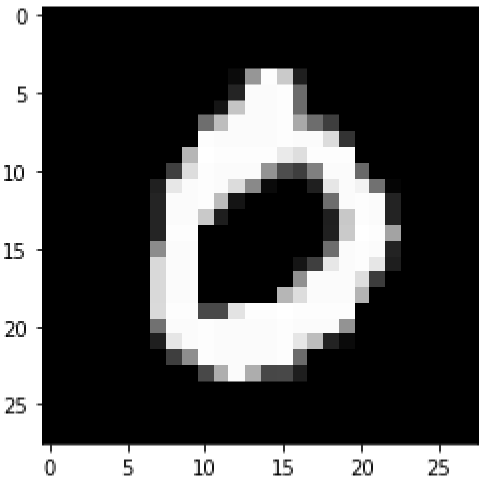



```
Model prediction: 7
```

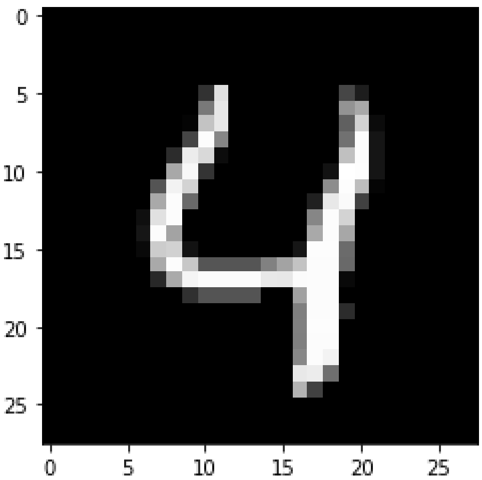



```
Model prediction: 2
```

Model prediction: 1



Model prediction: 0



Model prediction: 4

In [ ]: