In [72]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.metrics import accuracy_score
```

In [73]:
```
_train_data = pd.read_csv("optdigits.tra", header=None)
_test_data = pd.read_csv("optdigits.tes", header=None)

train_data = _train_data.drop(columns=_train_data.columns[-1], axis=1)
train_labels = _train_data[_train_data.columns[-1:]]

test_data = _test_data.drop(columns=_test_data.columns[-1], axis=1)
test_labels = _test_data[_test_data.columns[-1:]]

train_features = train_data.to_numpy()
train_labels = train_labels.to_numpy()
train_features = np.concatenate((np.ones((train_data.shape[0], 1)), train_fe
labels = np.unique(train_labels)

test_features = test_data.to_numpy()
test_labels = test_labels.to_numpy()
test_features = np.concatenate((np.ones((test_data.shape[0], 1)), test_featu
```

In [74]:
```
def one_vs_all(decision, labels):
    decisions = []
    for label in labels:
        label_class = np.where(decision == label, 1, 0)
        decisions.append(label_class)
    return decisions


_train = one_vs_all(train_labels, labels)
_test = one_vs_all(test_labels, labels)
```

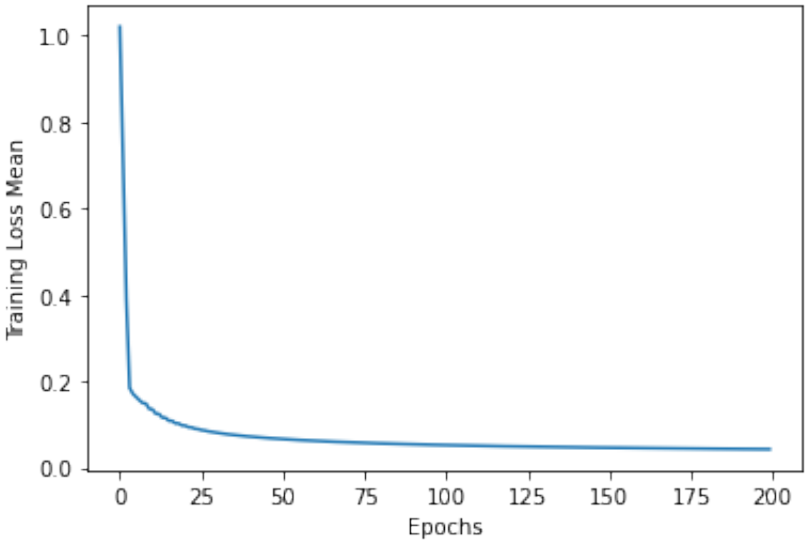
In [75]:
```
weights = []

def sigmoid(z):
        return 1 / (1 + np.exp(-z))


def loss(y, y_pred):
    losses = (y * np.log(y_pred)) + ((1 - y) * np.log(1 - y_pred))
    return -np.mean(losses)


def train(train_features, train_labels, test_features, test_labels, lam, alp
    weights = np.zeros((1, train_features.shape[1]))
    train_errors = []
    test_errors = []
    for epoch in range(max_epochs):
```

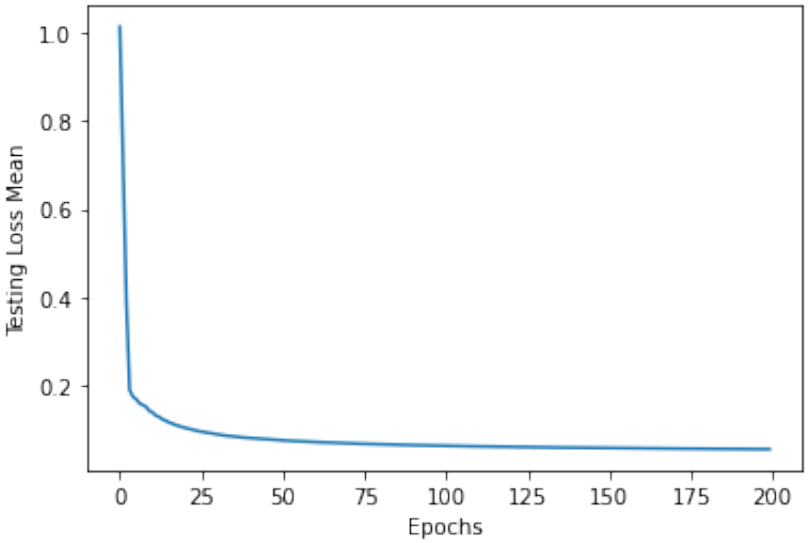
```
        wx = np.dot(train_features, weights.T)
        y_pred_train = sigmoid(wx)

        wx = np.dot(test_features, weights.T)
        y_pred_test = sigmoid(wx)

        dw = np.dot((y_pred_train - train_labels).T, train_features) * (1 /

        delta = dw + (lam * weights)

        weights = weights - (alpha * delta)

        wx = np.dot(train_features, weights.T)
        y_pred_train = sigmoid(wx)

        wx = np.dot(test_features, weights.T)
        y_pred_test = sigmoid(wx)

        train_loss = loss(train_labels, y_pred_train)
        test_loss = loss(test_labels, y_pred_test)
        train_errors.append(train_loss)
        test_errors.append(test_loss)
    return weights, train_errors, test_errors


epochs = 200
_training_losses = np.empty((10, epochs))
_test_losses = np.empty((10, epochs))
for i in labels:
    weight, train_loss, test_loss = train(train_features, _train[i],
                                          test_features, _test[i], 0, 0.01,
                                          epochs)
    _training_losses[i, :] = train_loss
    _test_losses[i, :] = test_loss
    weights.append(weight)

training_losses = np.mean(_training_losses, axis=0)
testing_losses = np.mean(_test_losses, axis=0)
```

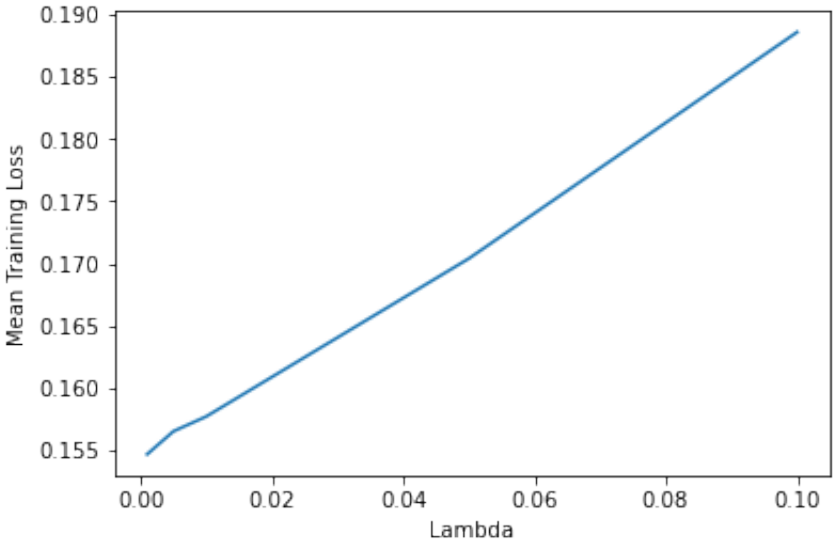
In [76]:

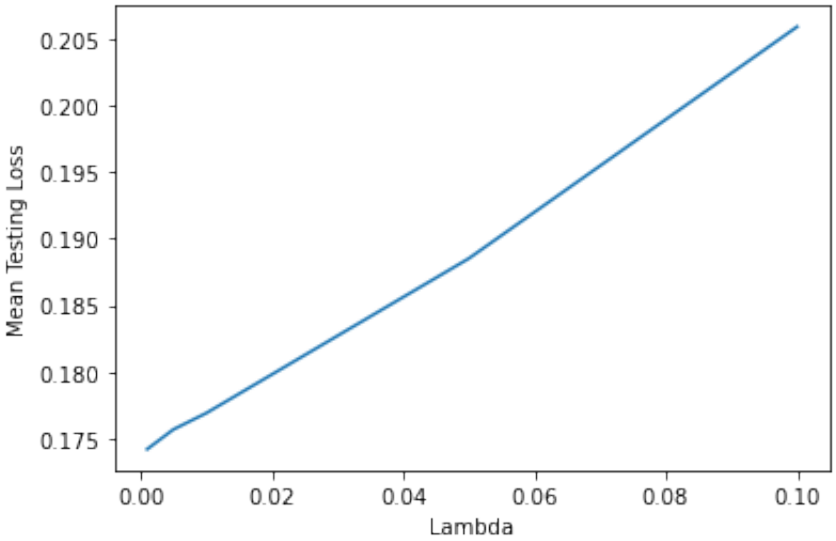
```
def predict(features_array_train, features_array_test, decision_train, decis
            one_vs_all_class_weights):

    def _predict(features, weight):
        wx = np.dot(features, weight.T)
        y_pred = sigmoid(wx)
        return y_pred

    train_prediction_list = []
    for i in labels:
        prediction_i = _predict(features_array_train, one_vs_all_class_weigh
        train_prediction_list.append(prediction_i)

    train_prediction_array = np.asarray(train_prediction_list)
```

```
    train_preds = np.argmax(train_prediction_array, axis=0)
    # training_accuracy = accuracy_score(decision_train, train_preds)

    test_prediction_list = []
    for i in labels:
        prediction_i = _predict(features_array_test, one_vs_all_class_weight
        test_prediction_list.append(prediction_i)

    test_prediction_array = np.asarray(test_prediction_list)
    test_preds = np.argmax(test_prediction_array, axis=0)
    # test_accuracy = accuracy_score(decision_test, test_preds)


plt.plot(range(epochs), training_losses)
plt.xlabel('Epochs')
plt.ylabel('Training Loss Mean')
plt.show()

plt.plot(range(epochs), testing_losses)
plt.xlabel('Epochs')
plt.ylabel('Testing Loss Mean')
plt.show()

predict(train_features, test_features, train_labels, test_labels,
        weights)

lambdas = [0.001, 0.005, 0.01, 0.05, 0.1]

training_loss = []
test_loss = []

for lam in lambdas:
    _training_loss = []
    _testing_loss = []
    for i in labels:
        weight, train_loss, _test_loss = train(train_features, _train[i],
                                               test_features, _test[i], lam,
                                               epochs)
        _training_loss.append(train_loss)
        _testing_loss.append(_test_loss)
    training_loss.append(np.mean(_training_loss))
    test_loss.append(np.mean(_testing_loss))

plt.plot(lambdas, training_loss)
plt.xlabel('Lambda')
plt.ylabel('Mean Training Loss')
plt.show()

plt.plot(lambdas, test_loss)
plt.xlabel('Lambda')
plt.ylabel('Mean Testing Loss')
plt.show()
```


Training Loss Mean
1.0
0.8
0.6
0.4
0.2
0.0
0
25
50
75
100
125
150
175
200
Epochs


Testing Loss Mean
1.0
0.8
0.6
0.4
0.2
0
25
50
75
100
125
150
175
200
Epochs


Mean Training Loss
0.190
0.185
0.180
0.175
0.170
0.165
0.160
0.155
0.00
0.02
0.04
0.06
0.08
0.10
Lambda


0.205
0.200
0.195
0.190
0.185
0.180
0.175
Mean Testing Loss
0.00
0.02
0.04
0.06
0.08
0.10
Lambda

In [76]: