In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
from scipy.io import loadmat
dataset = loadmat('face_emotion_data.mat')

X, y = dataset['X'], dataset['y']
n, p = np.shape(X)

y[y==-1] = 0  # use 0/1 for labels instead of -1/+1
X = np.hstack((np.ones((n,1)), X))  # append a column of ones

print(X.round(2))
print(X.shape)
print(y.shape)
```

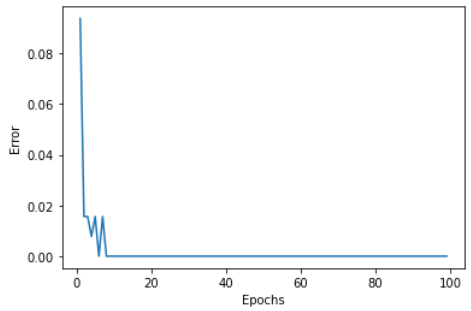
```
[[ 1.   -0.16  0.99 ...  2.01  1.8   2.94]
 [ 1.    1.51  2.43 ...  0.91  1.84  1.68]
 [ 1.   -0.08  0.95 ...  2.4   1.66  2.54]
 ...
 [ 1.    0.05 -0.11 ...  0.21 -1.17 -0.82]
 [ 1.    1.39  0.99 ...  1.73  0.92  0.73]
 [ 1.    1.61  0.36 ...  0.6   0.53 -0.15]]
(128, 10)
(128, 1)
```

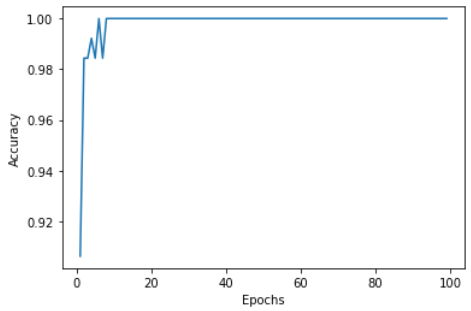
1a)

In [2]:
```
def logsig(_x):
    return 1/(1+np.exp(-_x))

def train(Xb, yb, L):
    n, p = np.shape(Xb)

    V = np.random.randn(M+1, 1)
    W = np.random.randn(p, M)

    for epoch in range(L):
        ind = np.random.permutation(n)
        for i in ind:
            H = logsig(np.hstack((np.ones((1,1)), Xb[[i],:]@W)))
            Yhat = logsig(H@V)
            delta = (Yhat-yb[[i], :])*Yhat*(1-Yhat)
            Vnew = V-alpha*H.T@delta
            gamma = delta@V[1:,:].T*H[:,1:]*(1-H[:,1:])
            Wnew = W - alpha*Xb[[i], :].T@gamma
            V = Vnew
            W =Wnew

    return W, V

def test(Xb, yb, W, V):
    H =logsig(np.hstack((np.ones((np.shape(Xb)[0],1)), Xb@W)))
    Yhat = logsig(H@V)
    # ERROR CALC
    error = np.mean(abs(np.round(Yhat[:,0]-yb[:,0])))
    return error
```

1b)

In [3]:
```
q = np.shape(y)[1]
M = 32 # Number of nodes

alpha = 0.5
L_arr = list(range(1,100))
err_arr = []
accuracy_arr = []

for L in L_arr:
    Wcurr, Vcurr = train(X, y, L)
    error = test(X, y, Wcurr, Vcurr)
    err_arr.append(error)
    accuracy_arr.append(1-error)

plt.figure()
plt.plot(L_arr, err_arr)
plt.xlabel("Epochs")
plt.ylabel("Error")
plt.show()

plt.figure()
plt.plot(L_arr, accuracy_arr)
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.show()
```





Yes after about 20 epochs the error drops to 0. Or accuracy goes to near perfect. This however varies from run to run, but on average is around the 20th mark (based on several runs).

1c)

In [4]:
```
L = 100
err_total = []

for iteration in range(L):
    err_somerun = []
    for i in range(8):
        start = i*16
        end = (i+1)*16

        X_train = np.vstack((X[0:start, :], X[end:-1, :]))
        y_train = np.vstack((y[0:start, :], y[end:-1, :]))

        X_test = X[start:end, :]
        y_test = y[start:end, :]

        V = np.random.randn(M+1, 1)
        W = np.random.randn(p, M)

        W, V = train(X_train, y_train, L)
        err = test(X_test, y_test, W, V)

        err_somerun.append(err)
    print(" run ", iteration, "error rate: ", np.mean(err_somerun), " and accuracy rate: ", 1-np.mean(err_somerun))
    err_total.append(err_somerun)
```

```
run  0 error rate:  0.0390625  and accuracy rate:  0.9609375
run  1 error rate:  0.03125  and accuracy rate:  0.96875
run  2 error rate:  0.0390625  and accuracy rate:  0.9609375
run  3 error rate:  0.0390625  and accuracy rate:  0.9609375
run  4 error rate:  0.03125  and accuracy rate:  0.96875
run  5 error rate:  0.03125  and accuracy rate:  0.96875
run  6 error rate:  0.0390625  and accuracy rate:  0.9609375
run  7 error rate:  0.0390625  and accuracy rate:  0.9609375
run  8 error rate:  0.0234375  and accuracy rate:  0.9765625
run  9 error rate:  0.046875  and accuracy rate:  0.953125
run  10 error rate:  0.03125  and accuracy rate:  0.96875
run  11 error rate:  0.0390625  and accuracy rate:  0.9609375
run  12 error rate:  0.03125  and accuracy rate:  0.96875
run  13 error rate:  0.03125  and accuracy rate:  0.96875
run  14 error rate:  0.0234375  and accuracy rate:  0.9765625
run  15 error rate:  0.0390625  and accuracy rate:  0.9609375
run  16 error rate:  0.0390625  and accuracy rate:  0.9609375
run  17 error rate:  0.0390625  and accuracy rate:  0.9609375
run  18 error rate:  0.03125  and accuracy rate:  0.96875
run  19 error rate:  0.0390625  and accuracy rate:  0.9609375
run  20 error rate:  0.03125  and accuracy rate:  0.96875
run  21 error rate:  0.046875  and accuracy rate:  0.953125
run  22 error rate:  0.0390625  and accuracy rate:  0.9609375
run  23 error rate:  0.03125  and accuracy rate:  0.96875
run  24 error rate:  0.0234375  and accuracy rate:  0.9765625
run  25 error rate:  0.03125  and accuracy rate:  0.96875
run  26 error rate:  0.03125  and accuracy rate:  0.96875
run  27 error rate:  0.015625  and accuracy rate:  0.984375
run  28 error rate:  0.0390625  and accuracy rate:  0.9609375
run  29 error rate:  0.03125  and accuracy rate:  0.96875
run  30 error rate:  0.0390625  and accuracy rate:  0.9609375
run  31 error rate:  0.046875  and accuracy rate:  0.953125
run  32 error rate:  0.0390625  and accuracy rate:  0.9609375
run  33 error rate:  0.0390625  and accuracy rate:  0.9609375
run  34 error rate:  0.0390625  and accuracy rate:  0.9609375
run  35 error rate:  0.046875  and accuracy rate:  0.953125
run  36 error rate:  0.0390625  and accuracy rate:  0.9609375
run  37 error rate:  0.0390625  and accuracy rate:  0.9609375
run  38 error rate:  0.0390625  and accuracy rate:  0.9609375
run  39 error rate:  0.03125  and accuracy rate:  0.96875
run  40 error rate:  0.0390625  and accuracy rate:  0.9609375
run  41 error rate:  0.0390625  and accuracy rate:  0.9609375
run  42 error rate:  0.0390625  and accuracy rate:  0.9609375
run  43 error rate:  0.03125  and accuracy rate:  0.96875
run  44 error rate:  0.046875  and accuracy rate:  0.953125
run  45 error rate:  0.0390625  and accuracy rate:  0.9609375
run  46 error rate:  0.046875  and accuracy rate:  0.953125
run  47 error rate:  0.0390625  and accuracy rate:  0.9609375
run  48 error rate:  0.046875  and accuracy rate:  0.953125
run  49 error rate:  0.046875  and accuracy rate:  0.953125
run  50 error rate:  0.03125  and accuracy rate:  0.96875
run  51 error rate:  0.03125  and accuracy rate:  0.96875
run  52 error rate:  0.0390625  and accuracy rate:  0.9609375
run  53 error rate:  0.03125  and accuracy rate:  0.96875
run  54 error rate:  0.046875  and accuracy rate:  0.953125
run  55 error rate:  0.0390625  and accuracy rate:  0.9609375
run  56 error rate:  0.0390625  and accuracy rate:  0.9609375
run  57 error rate:  0.0390625  and accuracy rate:  0.9609375
run  58 error rate:  0.0390625  and accuracy rate:  0.9609375
run  59 error rate:  0.03125  and accuracy rate:  0.96875
run  60 error rate:  0.0390625  and accuracy rate:  0.9609375
run  61 error rate:  0.046875  and accuracy rate:  0.953125
run  62 error rate:  0.0390625  and accuracy rate:  0.9609375
run  63 error rate:  0.0390625  and accuracy rate:  0.9609375
run  64 error rate:  0.0390625  and accuracy rate:  0.9609375
run  65 error rate:  0.0390625  and accuracy rate:  0.9609375
run  66 error rate:  0.046875  and accuracy rate:  0.953125
run  67 error rate:  0.0390625  and accuracy rate:  0.9609375
run  68 error rate:  0.046875  and accuracy rate:  0.953125
run  69 error rate:  0.03125  and accuracy rate:  0.96875
run  70 error rate:  0.0546875  and accuracy rate:  0.9453125
run  71 error rate:  0.0390625  and accuracy rate:  0.9609375
run  72 error rate:  0.03125  and accuracy rate:  0.96875
run  73 error rate:  0.0390625  and accuracy rate:  0.9609375
run  74 error rate:  0.0390625  and accuracy rate:  0.9609375
run  75 error rate:  0.03125  and accuracy rate:  0.96875
run  76 error rate:  0.0390625  and accuracy rate:  0.9609375
```

```
run  77 error rate:  0.0390625  and accuracy rate:  0.9609375
run  78 error rate:  0.046875  and accuracy rate:  0.953125
run  79 error rate:  0.0390625  and accuracy rate:  0.9609375
run  80 error rate:  0.0390625  and accuracy rate:  0.9609375
run  81 error rate:  0.0390625  and accuracy rate:  0.9609375
run  82 error rate:  0.046875  and accuracy rate:  0.953125
run  83 error rate:  0.0234375  and accuracy rate:  0.9765625
run  84 error rate:  0.0390625  and accuracy rate:  0.9609375
run  85 error rate:  0.0390625  and accuracy rate:  0.9609375
run  86 error rate:  0.0390625  and accuracy rate:  0.9609375
run  87 error rate:  0.0390625  and accuracy rate:  0.9609375
run  88 error rate:  0.03125  and accuracy rate:  0.96875
run  89 error rate:  0.03125  and accuracy rate:  0.96875
run  90 error rate:  0.0390625  and accuracy rate:  0.9609375
run  91 error rate:  0.03125  and accuracy rate:  0.96875
run  92 error rate:  0.03125  and accuracy rate:  0.96875
run  93 error rate:  0.046875  and accuracy rate:  0.953125
run  94 error rate:  0.0546875  and accuracy rate:  0.9453125
run  95 error rate:  0.0390625  and accuracy rate:  0.9609375
run  96 error rate:  0.046875  and accuracy rate:  0.953125
run  97 error rate:  0.03125  and accuracy rate:  0.96875
run  98 error rate:  0.0234375  and accuracy rate:  0.9765625
run  99 error rate:  0.0390625  and accuracy rate:  0.9609375
```

No. Even over 100 trials, the error rate was not 0. Thus we infer that the error rate for cross validation does not go to 0. This makes sense intuitively as the hold out set of the data could have features that the test set does not, thus leading to errors.

In [5]:
```
print("mean error rate over 100 iterations", np.mean(err_total))
```

```
mean error rate over 100 iterations 0.037578125
```

Thus we cannot achieve perfect accuracy. There is always some error.

In [ ]: