**Equivalence between maximizing log-likelihood of label and minimizing criterion function with negative log likelihood**

Aiming to minimize the log likelihood function given by:

$$J(w) = -\log(\prod_n \prod_{m=0}^{9} p(t_n = m|x_n; w))$$

for m ranging from digit 0 to 9

Let $p(t_m|x; w)$ be a categorical probability distribution :

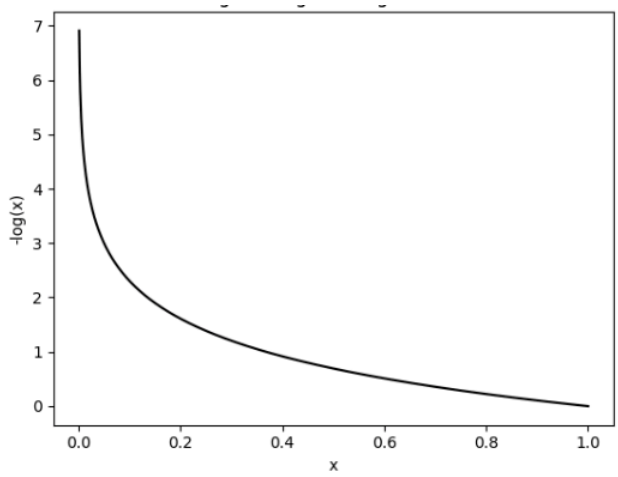
$$p(t_m|x; w) = y_m(x; w)^{t_m}$$

$$t_m \in \{0, 1\} and \sum_m t_m = 1$$

Let $y_m(x; w)$ be softmax probabilities from the output nodes i.e.

$$y_i(x; w) = \frac{\exp^{y_i(x;w)}}{\sum_{j=0}^{m} \exp^{y_j(x;w)}}$$

The curve for negative log-likelihood looks as follows:




which means for it to be minimum the value of the likelihood must be close to 1.

The negative log likelihood can be reduced to :

$$J(w) = -\sum_n \sum_{m=0}^{9} t_m^{(n)} \log(y_m^{(n)}(x^{(n)}; w))$$

$t_m$ is one-hot encoded vector thus for all wrong class labels the terms reduces to 0. If we denote the correct label to be 'c' for every feature sample we get:

$$J(w) = -\sum_n 1 * \log(y_c^{(n)}(x^{(n)}; w)) = -\log(\prod_n (y_c^{(n)}(x^{(n)}; w)))$$

To minimize the negative log-likelihood function, we need to maximize $(\prod_n (y_c^{(n)}(x^{(n)}; w)))$ to make it as close to 1 as possible.

Thus we can prove that a neural network to maximize the log likelihood of the correct label is one that has softmax output nodes and minimizes the criterion function of the negative log probability of training data set.

**Equivalence between maximizing posterior likelihood of training data and minimizing cost function with L2 regularization**

Let's say that the output $y$ is dependent on input feature $x$ using the following equation:

$y_i = wx_i + \epsilon$

where w is the set of weights and $\epsilon$ is Gaussian noise $\mathcal{N}(0, \sigma^2)$

$w$ also has the Gaussian prior $\mathcal{N}(0, \alpha^{-1})$

Using Bayes Rule:

$P(w|D) = \frac{P(D|w)P(w)}{P(D)}$

Ignoring P(D) we can write:

$P(w|D) \approx P(D|w)P(w)$

The posterior probability we aim to maximize over w is :

$P(w|D) = \prod_{i=1}^{N} \mathcal{N}(y_i; x_i, w, \sigma^2)\mathcal{N}(0, \alpha^{-1})$

Taking logarithm of the posterior and ignoring any constants:

$\log P(w|D) = \sum_{i=1}^{N} \log \mathcal{N}(y_i; x_i, w, \sigma^2) + \log \mathcal{N}(0, \alpha^{-1})$

$\log P(w|D) = -\frac{1}{\sigma^2} \sum_{i=1}^{N}(y_i - wx_i)^2 - \alpha w^2$

This proves that maximizing the posterior likelihood of observing the training data is the same as minimizing the cost function with L2 regularization with $\alpha$ being the regularization constant.

The more we maximize the log of posterior likelihood of training data $\log P(w|D)$, the more cost function with L2 regularization $\sum_{i=1}^{N}(y_i - wx_i)^2 + \alpha w^2$ is minimized.

**Importing the Library functions**

In [91]:
```
import numpy as np
import tensorflow as tf
from keras.datasets import mnist
from numpy import loadtxt
from keras.models import Sequential
from keras.layers import Dense
(X_train, y_train), (X_test, y_test) = mnist.load_data()
```

In [92]:
```
import matplotlib.pyplot as plt
```

In [93]:
```
X_train.shape
```

Out[93]:
```
(60000, 28, 28)
```

### Reshaping the data

In [94]:
```
X_train=X_train.reshape(60000,784)
X_test=X_test.reshape(10000,784)
y_train.shape
```

Out[94]:
```
(60000,)
```

### Function to extraxt 1000 training and testing data with each of the 10 classes having 100 samples of data

In [95]:
```
def get_data(x_data,y_data):
    data_list=[]
    label_list=[]
    count=[0,0,0,0,0,0,0,0,0,0]
    flag=[0,0,0,0,0,0,0,0,0,0]
    for i in range(len(x_data)):
        c=0
        if(count[y_data[i]]<100):
            count[y_data[i]]+=1
            data_list.append(x_data[i])
            label_list.append(y_data[i])
        else:
            continue
        for j in range(len(flag)):
            if(flag[j]==1):
                c+=1
        if(c==10):
            break
    return np.array(data_list),np.array(label_list)
```

In [96]:
```
X_train,y_train=get_data(X_train,y_train)
X_test, y_test=get_data(X_test, y_test)
```

In [97]:
```
X_train.shape
```

Out[97]:
```
(1000, 784)
```

In [98]:
```
y_train.shape
```

Out[98]:
```
(1000,)
```

### Performing One Hot encoding on the training and testing label data

In [99]:
```
y_z=np.zeros((1000,10))
for i in range(len(y_z)):
    y_z[i][y_train[i]]=1
y_train=y_z

y_z=np.zeros((1000,10))
for i in range(len(y_z)):
    y_z[i][y_test[i]]=1
y_test=y_z
```

In [100]:
```
y_train.shape
```

Out[100]:
```
(1000, 10)
```

### Normalising the data

In [101]:
```
#Normalizing the data
from sklearn.preprocessing import StandardScaler
sc = StandardScaler()
X_train = sc.fit_transform(X_train)
X_test=sc.fit_transform(X_test)
```

### Defining the Models with the given parameters in the question

### Model with One Layer

In [102]:
```
def model_nn(X,Y,L2):
    model = Sequential()
    if(L2==True):
        model.add(Dense(X, input_dim=784, activation='sigmoid',kern
el_regularizer=tf.keras.regularizers.l2(5)))
    else:
        model.add(Dense(X, input_dim=784, activation='sigmoid'))
    model.add(Dense(Y, activation='softmax'))
    model.summary()
    adam=tf.keras.optimizers.Adam(learning_rate=0.1)
    model.compile(loss='categorical_crossentropy', optimizer=adam,
metrics=['accuracy'])

    return model
```

### Model with Two Layers

In [14]:
```
def model_nn_2(X,Y,L2):
    model = Sequential()
    if(L2==True):
        model.add(Dense(X, input_dim=784, activation='sigmoid',kern
el_regularizer=tf.keras.regularizers.l2(5)))
        model.add(Dense(X, input_dim=30, activation='sigmoid',kerne
l_regularizer=tf.keras.regularizers.l2(5)))
    else:
        model.add(Dense(X, input_dim=784, activation='sigmoid'))
        model.add(Dense(X, input_dim=30, activation='sigmoid'))

    model.add(Dense(Y, activation='softmax'))
    model.summary()
    adam=tf.keras.optimizers.Adam(learning_rate=0.1)
    model.compile(loss='categorical_crossentropy', optimizer=adam,
metrics=['accuracy'])

    return model
```

### Model with Three Layers

In [15]:
```
def model_nn_3(X,Y,L2):
    model = Sequential()
    if(L2==True):
        model.add(Dense(X, input_dim=784, activation='sigmoid',kern
el_regularizer=tf.keras.regularizers.l2(5)))
        model.add(Dense(X, input_dim=30, activation='sigmoid',kerne
l_regularizer=tf.keras.regularizers.l2(5)))
        model.add(Dense(X, input_dim=30, activation='sigmoid',kerne
l_regularizer=tf.keras.regularizers.l2(5)))
    else:
        model.add(Dense(X, input_dim=784, activation='sigmoid'))
        model.add(Dense(X, input_dim=30, activation='sigmoid'))
        model.add(Dense(X, input_dim=30, activation='sigmoid'))

    model.add(Dense(Y, activation='softmax'))
    model.summary()
    adam=tf.keras.optimizers.Adam(learning_rate=0.1)
    model.compile(loss='categorical_crossentropy', optimizer=adam,
metrics=['accuracy'])

    return model
```

### Function for Model Accuracy

In [16]:
```
def model_accuracy():

    plt.plot(history.history['accuracy'])
    plt.plot(history.history['val_accuracy'])
    plt.title('Model accuracy')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()
```

### Function for Model Loss

In [17]:
```
def model_loss():
    import matplotlib.pyplot as plt
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('Model Loss')
    plt.ylabel('Loss')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()
```

### Function for Zero-one error

In [18]:
```
def error_model(model):

    X_train_err=[]
    X_train_acc=[]
    X_test_err=[]
    X_test_acc=[]

    for i in range(30):
        model.fit(X_train,y_train,epochs=1,batch_size=10)
        pred_train=model.predict_classes(X_train)
        pred_test=model.predict_classes(X_test)

        hits_train=0
        for i in range(1000):
            if(y_train[i][pred_train[i]]==1):
                hits_train+=1

        X_train_acc.append(hits_train/1000)
        X_train_err.append(1-(hits_train/1000))

        hits_test=0
        for i in range(1000):
            if(y_test[i][pred_test[i]]==1):
                hits_test+=1

        X_test_acc.append(hits_test/1000)
        X_test_err.append(1-(hits_test/1000))

    plt.plot(X_train_err)
    plt.plot(X_test_err)
    plt.title('Model Error')
    plt.ylabel('Error')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()

    plt.plot(X_train_acc)
    plt.plot(X_test_acc)
    plt.title('Model Accuracy')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Test'], loc='upper left')
    plt.show()
```

### Function for Learning Speed

In [19]:
```
def LearningRate(model,parameters):
    i=0
    W_diff_list=[]
    #model=model_nn(30,10)
    while(i<30):
        W_old=[]
        W_new=[]
        W_diff=[]

        old=model.get_weights()
        for j in range(len(old)):
            W_old.append(old[j])

        model.fit(X_train,y_train,validation_data=(X_test,y_test),e
pochs=1,batch_size=10)

        new=model.get_weights()
        for j in range(len(new)):
            W_new.append(new[j])

        for j in range(len(W_new)):
            W_diff.append(np.absolute((W_old[j]- W_new[j])/W_new[j]
))

        W_diff_avg=0
        for j in range(len(W_diff)):
            W_diff_avg+=(np.sum(W_diff[j]))
        W_diff_avg/=(parameters)
        W_diff_list.append(W_diff_avg)
        i+=1
    return W_diff_list
```

### Learning Speed Plot function

In [20]:
```
def LearningRate_plot(W_diff_list):
    plt.plot(W_diff_list)
    plt.title('Learning Rate of Hidden Layers')
    plt.ylabel('Learning rate')
    plt.xlabel('Epoch')
    plt.show()
```

### One Layer Model without regularization

In [112]:
```
model=model_nn(30,10,False)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
```

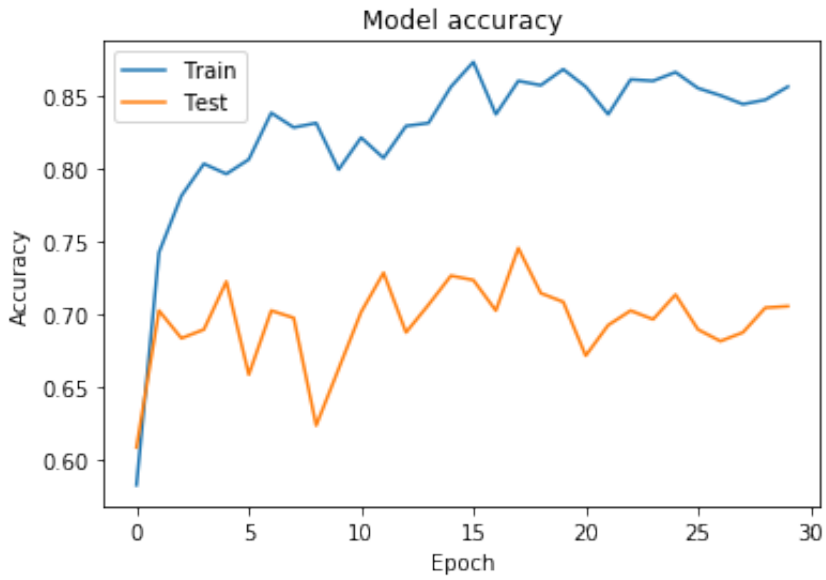
Model: "sequential_28"

```
Model: "sequential_26"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_75 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_76 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 0s 315us/step - loss:
1.3813 - accuracy: 0.5820 - val_loss: 1.1861 - val_accuracy: 0.608
0
Epoch 2/30
1000/1000 [==============================] - 0s 242us/step - loss:
0.8243 - accuracy: 0.7420 - val_loss: 1.0511 - val_accuracy: 0.702
0
Epoch 3/30
1000/1000 [==============================] - 0s 244us/step - loss:
0.7777 - accuracy: 0.7810 - val_loss: 1.0581 - val_accuracy: 0.683
0
Epoch 4/30
1000/1000 [==============================] - 0s 248us/step - loss:
0.6566 - accuracy: 0.8030 - val_loss: 1.1093 - val_accuracy: 0.689
0
Epoch 5/30
1000/1000 [==============================] - 0s 280us/step - loss:
0.7526 - accuracy: 0.7960 - val_loss: 1.0422 - val_accuracy: 0.722
0
Epoch 6/30
1000/1000 [==============================] - 0s 270us/step - loss:
0.6560 - accuracy: 0.8060 - val_loss: 1.2998 - val_accuracy: 0.658
0
Epoch 7/30
1000/1000 [==============================] - 0s 257us/step - loss:
0.5523 - accuracy: 0.8380 - val_loss: 1.3144 - val_accuracy: 0.702
0
Epoch 8/30
1000/1000 [==============================] - 0s 310us/step - loss:
0.5658 - accuracy: 0.8280 - val_loss: 1.1843 - val_accuracy: 0.697
0
Epoch 9/30
1000/1000 [==============================] - 0s 238us/step - loss:
0.5778 - accuracy: 0.8310 - val_loss: 1.6351 - val_accuracy: 0.623
0
Epoch 10/30
1000/1000 [==============================] - 0s 276us/step - loss:
0.6377 - accuracy: 0.7990 - val_loss: 1.5187 - val_accuracy: 0.662
0
Epoch 11/30
```

```
1000/1000 [==============================] - 0s 283us/step - loss:
0.6232 - accuracy: 0.8210 - val_loss: 1.2663 - val_accuracy: 0.701
0
Epoch 12/30
1000/1000 [==============================] - 0s 259us/step - loss:
0.7043 - accuracy: 0.8070 - val_loss: 1.2167 - val_accuracy: 0.728
0
Epoch 13/30
1000/1000 [==============================] - 0s 264us/step - loss:
0.6053 - accuracy: 0.8290 - val_loss: 1.4983 - val_accuracy: 0.687
0
Epoch 14/30
1000/1000 [==============================] - 0s 252us/step - loss:
0.5730 - accuracy: 0.8310 - val_loss: 1.4864 - val_accuracy: 0.706
0
Epoch 15/30
1000/1000 [==============================] - 0s 321us/step - loss:
0.5127 - accuracy: 0.8560 - val_loss: 1.3327 - val_accuracy: 0.726
0
Epoch 16/30
1000/1000 [==============================] - 0s 295us/step - loss:
0.5138 - accuracy: 0.8730 - val_loss: 1.3927 - val_accuracy: 0.723
0
Epoch 17/30
1000/1000 [==============================] - 0s 310us/step - loss:
0.5675 - accuracy: 0.8370 - val_loss: 1.5509 - val_accuracy: 0.702
0
Epoch 18/30
1000/1000 [==============================] - 0s 297us/step - loss:
0.5240 - accuracy: 0.8600 - val_loss: 1.2896 - val_accuracy: 0.745
0
Epoch 19/30
1000/1000 [==============================] - 0s 355us/step - loss:
0.5188 - accuracy: 0.8570 - val_loss: 1.4224 - val_accuracy: 0.714
0
Epoch 20/30
1000/1000 [==============================] - 0s 437us/step - loss:
0.4376 - accuracy: 0.8680 - val_loss: 1.4534 - val_accuracy: 0.708
0
Epoch 21/30
1000/1000 [==============================] - 0s 355us/step - loss:
0.5043 - accuracy: 0.8560 - val_loss: 1.8864 - val_accuracy: 0.671
0
Epoch 22/30
1000/1000 [==============================] - 0s 345us/step - loss:
0.5897 - accuracy: 0.8370 - val_loss: 1.6244 - val_accuracy: 0.692
0
Epoch 23/30
1000/1000 [==============================] - 0s 308us/step - loss:
0.5293 - accuracy: 0.8610 - val_loss: 1.6176 - val_accuracy: 0.702
0
Epoch 24/30
1000/1000 [==============================] - 0s 326us/step - loss:
```

```
0.5387 - accuracy: 0.8600 - val_loss: 1.7369 - val_accuracy: 0.696
0
Epoch 25/30
1000/1000 [==============================] - 0s 287us/step - loss:
0.5098 - accuracy: 0.8660 - val_loss: 1.5451 - val_accuracy: 0.713
0
Epoch 26/30
1000/1000 [==============================] - 0s 294us/step - loss:
0.5573 - accuracy: 0.8550 - val_loss: 1.7745 - val_accuracy: 0.689
0
Epoch 27/30
1000/1000 [==============================] - 0s 263us/step - loss:
0.5803 - accuracy: 0.8500 - val_loss: 1.8844 - val_accuracy: 0.681
0
Epoch 28/30
1000/1000 [==============================] - 0s 321us/step - loss:
0.6512 - accuracy: 0.8440 - val_loss: 1.7489 - val_accuracy: 0.687
0
Epoch 29/30
1000/1000 [==============================] - 0s 270us/step - loss:
0.5997 - accuracy: 0.8470 - val_loss: 1.6187 - val_accuracy: 0.704
0
Epoch 30/30
1000/1000 [==============================] - 0s 266us/step - loss:
0.5813 - accuracy: 0.8560 - val_loss: 1.7132 - val_accuracy: 0.705
0
```

In [113]:
```
model_accuracy()
```



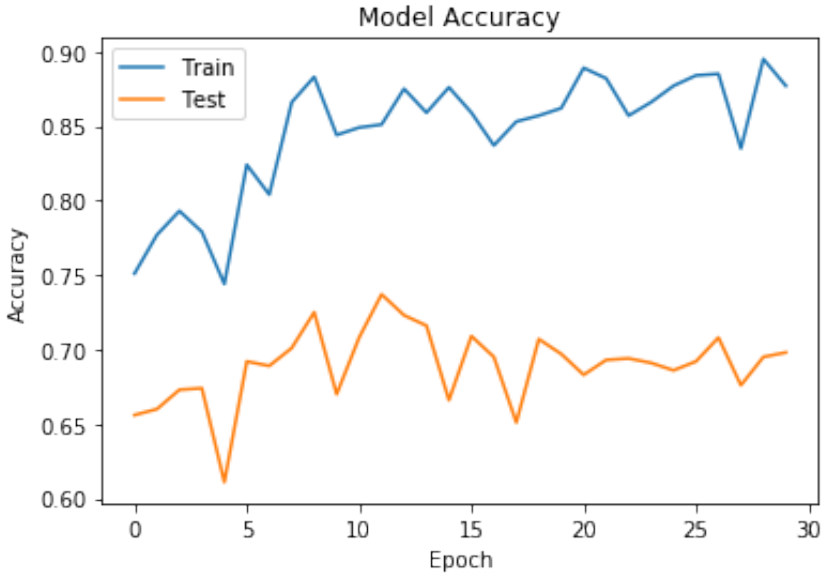
In [114]:
```
model_loss()
```


In [115]:
```
model=model_nn(30,10,False)
error_model(model)
```

```
Model: "sequential_29"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_77 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_78 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
1.2557 - accuracy: 0.5900
Epoch 1/1
1000/1000 [==============================] - 0s 228us/step - loss:
0.8311 - accuracy: 0.7400
Epoch 1/1
1000/1000 [==============================] - 0s 232us/step - loss:
0.8485 - accuracy: 0.7470
Epoch 1/1
1000/1000 [==============================] - 0s 184us/step - loss:
0.8604 - accuracy: 0.7410
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.8221 - accuracy: 0.7730
Epoch 1/1
1000/1000 [==============================] - 0s 149us/step - loss:
0.7245 - accuracy: 0.7930
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.6639 - accuracy: 0.8000
Epoch 1/1
1000/1000 [==============================] - 0s 181us/step - loss:
0.6385 - accuracy: 0.8310
Epoch 1/1
1000/1000 [==============================] - 0s 171us/step - loss:
0.6803 - accuracy: 0.8090
Epoch 1/1
1000/1000 [==============================] - 0s 181us/step - loss:
0.5553 - accuracy: 0.8350
Epoch 1/1
1000/1000 [==============================] - 0s 175us/step - loss:
0.5202 - accuracy: 0.8410
Epoch 1/1
1000/1000 [==============================] - 0s 177us/step - loss:
0.6903 - accuracy: 0.8150
Epoch 1/1
1000/1000 [==============================] - 0s 145us/step - loss:
0.5876 - accuracy: 0.8540
Epoch 1/1
1000/1000 [==============================] - 0s 146us/step - loss:
0.6494 - accuracy: 0.8300
Epoch 1/1
1000/1000 [==============================] - 0s 147us/step - loss:
0.5848 - accuracy: 0.8570
Epoch 1/1
1000/1000 [==============================] - 0s 147us/step - loss:
0.5124 - accuracy: 0.8560
Epoch 1/1
1000/1000 [==============================] - 0s 147us/step - loss:
0.5490 - accuracy: 0.8400
Epoch 1/1
1000/1000 [==============================] - 0s 147us/step - loss:
0.5866 - accuracy: 0.8290
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.6858 - accuracy: 0.8280
Epoch 1/1
1000/1000 [==============================] - 0s 166us/step - loss:
0.7074 - accuracy: 0.8320
Epoch 1/1
1000/1000 [==============================] - 0s 195us/step - loss:
0.6447 - accuracy: 0.8380
Epoch 1/1
1000/1000 [==============================] - 0s 196us/step - loss:
0.5707 - accuracy: 0.8480
Epoch 1/1
1000/1000 [==============================] - 0s 183us/step - loss:
0.4940 - accuracy: 0.8660
Epoch 1/1
1000/1000 [==============================] - 0s 174us/step - loss:
```

```
0.5199 - accuracy: 0.8690
Epoch 1/1
1000/1000 [==============================] - 0s 154us/step - loss:
0.5080 - accuracy: 0.8600
Epoch 1/1
1000/1000 [==============================] - 0s 148us/step - loss:
0.5122 - accuracy: 0.8660
Epoch 1/1
1000/1000 [==============================] - 0s 146us/step - loss:
0.5599 - accuracy: 0.8480
Epoch 1/1
1000/1000 [==============================] - 0s 153us/step - loss:
0.5447 - accuracy: 0.8690
Epoch 1/1
1000/1000 [==============================] - 0s 151us/step - loss:
0.5849 - accuracy: 0.8500
Epoch 1/1
1000/1000 [==============================] - 0s 147us/step - loss:
0.5972 - accuracy: 0.8410
```

In [116]:
```
model=model_nn(30,10,False)
W=LearningRate(model,(23550+310))
```

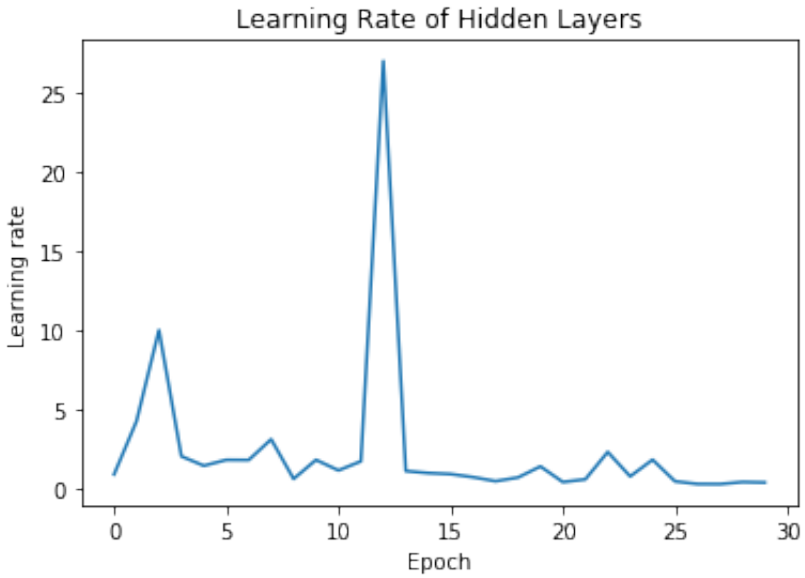
```
Model: "sequential_30"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_79 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_80 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 391us/step - loss:
1.3404 - accuracy: 0.5840 - val_loss: 1.1035 - val_accuracy: 0.651
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 366us/step - loss:
0.8214 - accuracy: 0.7520 - val_loss: 1.0649 - val_accuracy: 0.671
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 340us/step - loss:
0.8646 - accuracy: 0.7170 - val_loss: 1.5765 - val_accuracy: 0.611
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 323us/step - loss:
0.8428 - accuracy: 0.7640 - val_loss: 0.9702 - val_accuracy: 0.716
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 299us/step - loss:
0.7332 - accuracy: 0.7820 - val_loss: 1.0934 - val_accuracy: 0.717
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 254us/step - loss:
0.7188 - accuracy: 0.7840 - val_loss: 1.1495 - val_accuracy: 0.713
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 302us/step - loss:
0.7578 - accuracy: 0.7890 - val_loss: 1.2277 - val_accuracy: 0.707
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 241us/step - loss:
```

```
0.7382 - accuracy: 0.7950 - val_loss: 1.3397 - val_accuracy: 0.688
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 341us/step - loss:
0.6214 - accuracy: 0.8250 - val_loss: 1.2497 - val_accuracy: 0.708
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 292us/step - loss:
0.6024 - accuracy: 0.8160 - val_loss: 1.1809 - val_accuracy: 0.738
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 269us/step - loss:
0.5961 - accuracy: 0.8400 - val_loss: 1.3578 - val_accuracy: 0.692
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 232us/step - loss:
0.6621 - accuracy: 0.8120 - val_loss: 1.3480 - val_accuracy: 0.698
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 268us/step - loss:
0.5636 - accuracy: 0.8380 - val_loss: 1.2664 - val_accuracy: 0.718
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 323us/step - loss:
0.5421 - accuracy: 0.8490 - val_loss: 1.3030 - val_accuracy: 0.707
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 236us/step - loss:
0.4924 - accuracy: 0.8600 - val_loss: 1.3042 - val_accuracy: 0.728
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 256us/step - loss:
0.4973 - accuracy: 0.8540 - val_loss: 1.6256 - val_accuracy: 0.699
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 305us/step - loss:
0.5775 - accuracy: 0.8520 - val_loss: 1.3143 - val_accuracy: 0.750
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 291us/step - loss:
0.5433 - accuracy: 0.8460 - val_loss: 1.3032 - val_accuracy: 0.733
0
Train on 1000 samples, validate on 1000 samples
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 262us/step - loss:
0.5624 - accuracy: 0.8460 - val_loss: 1.4631 - val_accuracy: 0.705
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 335us/step - loss:
0.5327 - accuracy: 0.8400 - val_loss: 1.5068 - val_accuracy: 0.705
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 268us/step - loss:
0.5627 - accuracy: 0.8460 - val_loss: 1.4558 - val_accuracy: 0.726
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 253us/step - loss:
0.6012 - accuracy: 0.8470 - val_loss: 1.5806 - val_accuracy: 0.735
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 262us/step - loss:
0.5935 - accuracy: 0.8570 - val_loss: 1.6910 - val_accuracy: 0.704
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 248us/step - loss:
0.6661 - accuracy: 0.8270 - val_loss: 1.4802 - val_accuracy: 0.706
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 253us/step - loss:
0.6006 - accuracy: 0.8370 - val_loss: 1.4876 - val_accuracy: 0.721
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 254us/step - loss:
0.6010 - accuracy: 0.8570 - val_loss: 1.5184 - val_accuracy: 0.715
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 256us/step - loss:
0.5882 - accuracy: 0.8500 - val_loss: 1.6943 - val_accuracy: 0.682
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 313us/step - loss:
0.5309 - accuracy: 0.8700 - val_loss: 1.7444 - val_accuracy: 0.668
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 302us/step - loss:
0.5464 - accuracy: 0.8560 - val_loss: 1.8721 - val_accuracy: 0.671
```

```
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 283us/step - loss:
0.5182 - accuracy: 0.8620 - val_loss: 1.5086 - val_accuracy: 0.712
0
```

In [117]:
```
LearningRate_plot(W)
```




### One Layer Model with regularization

In [118]:
```
model=model_nn(30,10,True)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
```

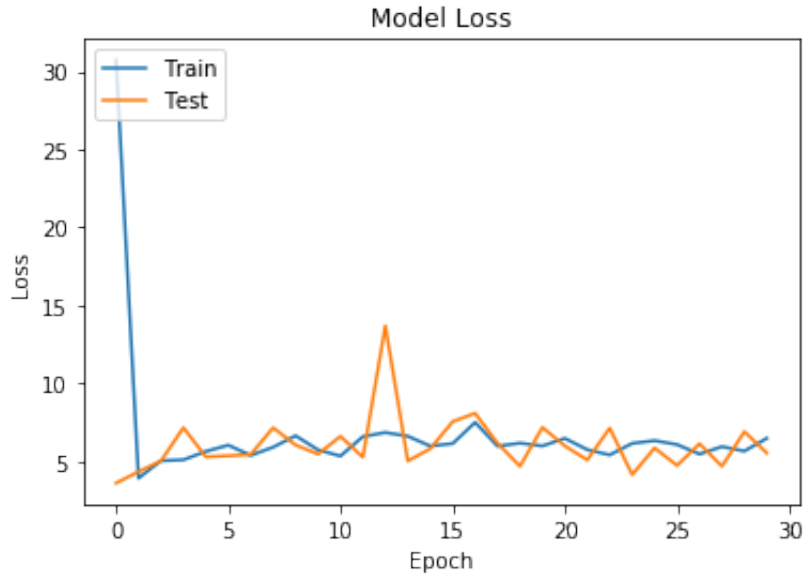
```
Model: "sequential_31"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_81 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_82 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 0s 332us/step - loss:
30.7283 - accuracy: 0.1450 - val_loss: 3.5953 - val_accuracy: 0.20
70
Epoch 2/30
1000/1000 [==============================] - 0s 255us/step - loss:
```

```
3.9097 - accuracy: 0.1840 - val_loss: 4.3267 - val_accuracy: 0.195
0
Epoch 3/30
1000/1000 [==============================] - 0s 254us/step - loss:
5.0275 - accuracy: 0.2040 - val_loss: 5.0154 - val_accuracy: 0.232
0
Epoch 4/30
1000/1000 [==============================] - 0s 258us/step - loss:
5.0857 - accuracy: 0.1940 - val_loss: 7.1511 - val_accuracy: 0.185
0
Epoch 5/30
1000/1000 [==============================] - 0s 254us/step - loss:
5.6280 - accuracy: 0.1910 - val_loss: 5.2823 - val_accuracy: 0.256
0
Epoch 6/30
1000/1000 [==============================] - 0s 263us/step - loss:
6.0281 - accuracy: 0.1990 - val_loss: 5.3458 - val_accuracy: 0.169
0
Epoch 7/30
1000/1000 [==============================] - 0s 262us/step - loss:
5.3717 - accuracy: 0.2030 - val_loss: 5.4259 - val_accuracy: 0.074
0
Epoch 8/30
1000/1000 [==============================] - 0s 259us/step - loss:
5.8973 - accuracy: 0.1970 - val_loss: 7.1485 - val_accuracy: 0.154
0
Epoch 9/30
1000/1000 [==============================] - 0s 257us/step - loss:
6.6315 - accuracy: 0.2300 - val_loss: 6.0361 - val_accuracy: 0.183
0
Epoch 10/30
1000/1000 [==============================] - 0s 277us/step - loss:
5.7259 - accuracy: 0.1740 - val_loss: 5.4541 - val_accuracy: 0.140
0
Epoch 11/30
1000/1000 [==============================] - 0s 281us/step - loss:
5.3292 - accuracy: 0.2280 - val_loss: 6.5923 - val_accuracy: 0.177
0
Epoch 12/30
1000/1000 [==============================] - 0s 304us/step - loss:
6.5765 - accuracy: 0.1970 - val_loss: 5.2524 - val_accuracy: 0.249
0
Epoch 13/30
1000/1000 [==============================] - 0s 325us/step - loss:
6.8387 - accuracy: 0.2150 - val_loss: 13.6791 - val_accuracy: 0.12
90
Epoch 14/30
1000/1000 [==============================] - 0s 325us/step - loss:
6.6008 - accuracy: 0.1790 - val_loss: 5.0134 - val_accuracy: 0.156
0
Epoch 15/30
1000/1000 [==============================] - 0s 299us/step - loss:
5.9707 - accuracy: 0.2070 - val_loss: 5.7958 - val_accuracy: 0.175
```

```
0
Epoch 16/30
1000/1000 [==============================] - 0s 255us/step - loss:
6.1286 - accuracy: 0.2010 - val_loss: 7.5381 - val_accuracy: 0.256
0
Epoch 17/30
1000/1000 [==============================] - 0s 269us/step - loss:
7.4863 - accuracy: 0.1940 - val_loss: 8.0740 - val_accuracy: 0.224
0
Epoch 18/30
1000/1000 [==============================] - 0s 268us/step - loss:
5.9644 - accuracy: 0.2040 - val_loss: 6.1484 - val_accuracy: 0.218
0
Epoch 19/30
1000/1000 [==============================] - 0s 257us/step - loss:
6.1578 - accuracy: 0.1820 - val_loss: 4.6749 - val_accuracy: 0.228
0
Epoch 20/30
1000/1000 [==============================] - 0s 256us/step - loss:
5.9762 - accuracy: 0.1990 - val_loss: 7.1665 - val_accuracy: 0.230
0
Epoch 21/30
1000/1000 [==============================] - 0s 262us/step - loss:
6.4633 - accuracy: 0.1810 - val_loss: 5.9801 - val_accuracy: 0.193
0
Epoch 22/30
1000/1000 [==============================] - 0s 260us/step - loss:
5.7364 - accuracy: 0.1880 - val_loss: 5.0777 - val_accuracy: 0.199
0
Epoch 23/30
1000/1000 [==============================] - 0s 260us/step - loss:
5.4011 - accuracy: 0.1930 - val_loss: 7.1246 - val_accuracy: 0.175
0
Epoch 24/30
1000/1000 [==============================] - 0s 256us/step - loss:
6.1415 - accuracy: 0.1670 - val_loss: 4.1313 - val_accuracy: 0.196
0
Epoch 25/30
1000/1000 [==============================] - 0s 260us/step - loss:
6.3176 - accuracy: 0.2180 - val_loss: 5.8490 - val_accuracy: 0.101
0
Epoch 26/30
1000/1000 [==============================] - 0s 260us/step - loss:
6.0663 - accuracy: 0.1990 - val_loss: 4.7250 - val_accuracy: 0.213
0
Epoch 27/30
1000/1000 [==============================] - 0s 263us/step - loss:
5.4542 - accuracy: 0.2270 - val_loss: 6.1186 - val_accuracy: 0.105
0
Epoch 28/30
1000/1000 [==============================] - 0s 357us/step - loss:
5.9321 - accuracy: 0.1610 - val_loss: 4.6736 - val_accuracy: 0.334
0
```

```
Epoch 29/30
1000/1000 [==============================] - 0s 295us/step - loss:
5.6481 - accuracy: 0.1960 - val_loss: 6.8911 - val_accuracy: 0.133
0
Epoch 30/30
1000/1000 [==============================] - 0s 311us/step - loss:
6.4662 - accuracy: 0.1880 - val_loss: 5.5241 - val_accuracy: 0.222
0
```

In [119]:
```
model_accuracy()
model_loss()
```

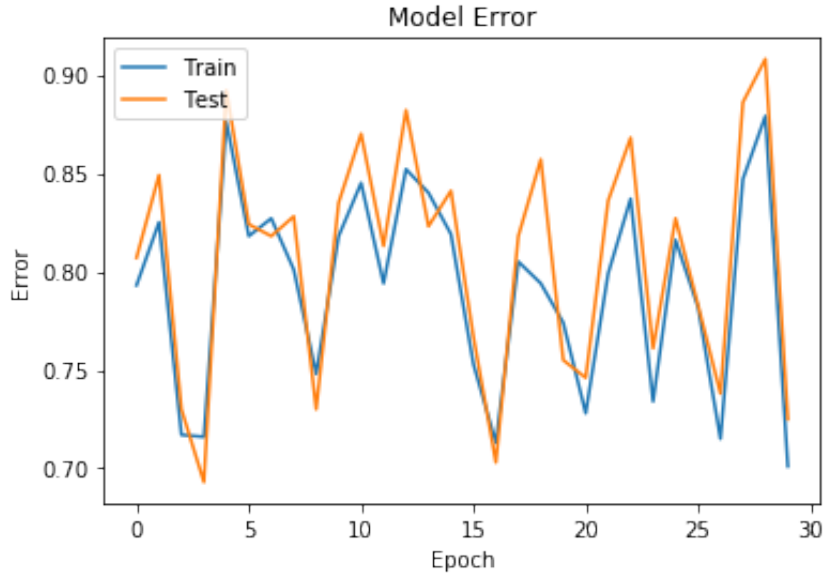



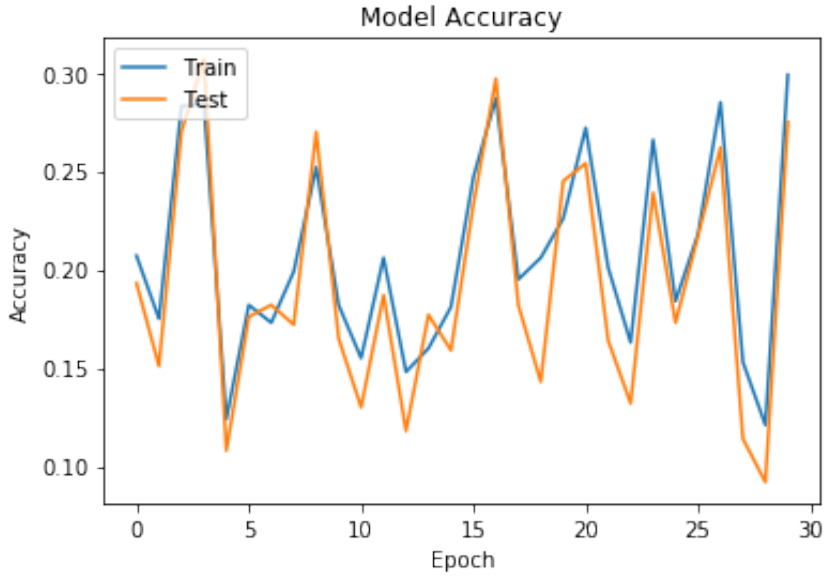

In [120]:
```
model=model_nn(30,10,True)
error_model(model)
```

```
Model: "sequential_32"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
dense_83 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_84 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 228us/step - loss:
30.6951 - accuracy: 0.1230
Epoch 1/1
1000/1000 [==============================] - 0s 254us/step - loss:
3.7179 - accuracy: 0.1740
Epoch 1/1
1000/1000 [==============================] - 0s 237us/step - loss:
4.6770 - accuracy: 0.1780
Epoch 1/1
1000/1000 [==============================] - 0s 204us/step - loss:
4.8421 - accuracy: 0.2070
Epoch 1/1
1000/1000 [==============================] - 0s 191us/step - loss:
5.0461 - accuracy: 0.1980
Epoch 1/1
1000/1000 [==============================] - 0s 165us/step - loss:
5.1083 - accuracy: 0.1840
Epoch 1/1
1000/1000 [==============================] - 0s 153us/step - loss:
5.7680 - accuracy: 0.2050
Epoch 1/1
1000/1000 [==============================] - 0s 153us/step - loss:
5.5682 - accuracy: 0.2080
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
5.9194 - accuracy: 0.2230
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
6.0916 - accuracy: 0.1960
Epoch 1/1
1000/1000 [==============================] - 0s 175us/step - loss:
5.4155 - accuracy: 0.2070
Epoch 1/1
1000/1000 [==============================] - 0s 211us/step - loss:
5.9289 - accuracy: 0.1810
Epoch 1/1
1000/1000 [==============================] - 0s 220us/step - loss:
5.4300 - accuracy: 0.1860
Epoch 1/1
1000/1000 [==============================] - 0s 203us/step - loss:
7.2165 - accuracy: 0.2050
Epoch 1/1
1000/1000 [==============================] - 0s 159us/step - loss:
5.4273 - accuracy: 0.1610
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 159us/step - loss:
5.7662 - accuracy: 0.2180
Epoch 1/1
1000/1000 [==============================] - 0s 170us/step - loss:
6.1361 - accuracy: 0.2080
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
6.8780 - accuracy: 0.1960
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
6.7338 - accuracy: 0.2210
Epoch 1/1
1000/1000 [==============================] - 0s 157us/step - loss:
6.1083 - accuracy: 0.2150
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
6.6663 - accuracy: 0.1930
Epoch 1/1
1000/1000 [==============================] - 0s 157us/step - loss:
6.0698 - accuracy: 0.1900
Epoch 1/1
1000/1000 [==============================] - 0s 169us/step - loss:
6.8879 - accuracy: 0.2230
Epoch 1/1
1000/1000 [==============================] - 0s 214us/step - loss:
5.9167 - accuracy: 0.1850
Epoch 1/1
1000/1000 [==============================] - 0s 205us/step - loss:
5.6246 - accuracy: 0.1920
Epoch 1/1
1000/1000 [==============================] - 0s 189us/step - loss:
4.8924 - accuracy: 0.1750
Epoch 1/1
1000/1000 [==============================] - 0s 162us/step - loss:
5.4305 - accuracy: 0.2020
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
5.8140 - accuracy: 0.1830
Epoch 1/1
1000/1000 [==============================] - 0s 168us/step - loss:
5.2853 - accuracy: 0.1620
Epoch 1/1
1000/1000 [==============================] - 0s 154us/step - loss:
4.9126 - accuracy: 0.1930
```




In [121]:
```
model=model_nn(30,10,True)
W=LearningRate(model,(23550+310))
```

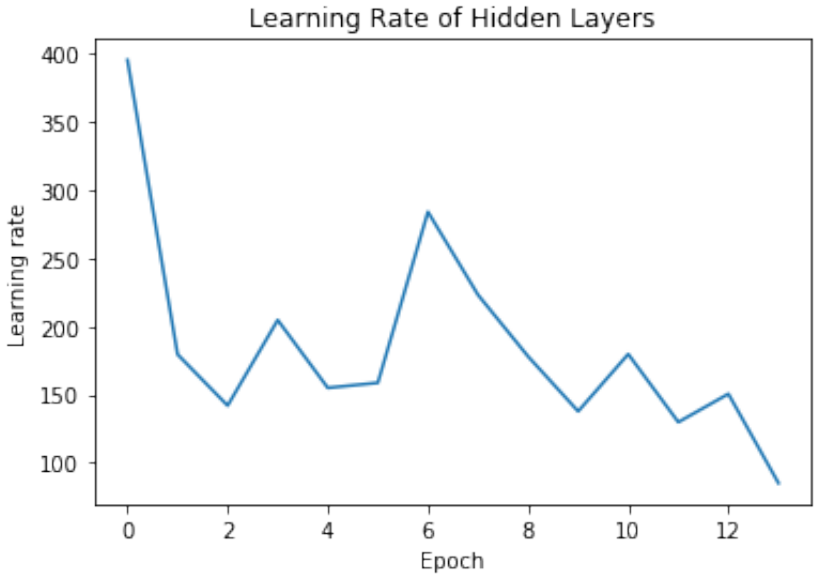
```
Model: "sequential_33"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_85 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_86 (Dense)             (None, 10)                310
=================================================================
Total params: 23,860
Trainable params: 23,860
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 373us/step - loss:
30.8374 - accuracy: 0.1340 - val_loss: 3.0594 - val_accuracy: 0.12
```

```
50
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 268us/step - loss:
3.9004 - accuracy: 0.1730 - val_loss: 4.5355 - val_accuracy: 0.175
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 365us/step - loss:
4.7082 - accuracy: 0.1800 - val_loss: 6.2007 - val_accuracy: 0.204
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 282us/step - loss:
5.2843 - accuracy: 0.2160 - val_loss: 5.0703 - val_accuracy: 0.267
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 283us/step - loss:
5.6730 - accuracy: 0.2260 - val_loss: 5.5772 - val_accuracy: 0.166
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 305us/step - loss:
5.7531 - accuracy: 0.2020 - val_loss: 6.2607 - val_accuracy: 0.248
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 398us/step - loss:
6.0863 - accuracy: 0.2320 - val_loss: 7.2565 - val_accuracy: 0.167
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 362us/step - loss:
5.4375 - accuracy: 0.2040 - val_loss: 5.1689 - val_accuracy: 0.184
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 261us/step - loss:
7.0406 - accuracy: 0.2190 - val_loss: 6.3355 - val_accuracy: 0.306
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 264us/step - loss:
6.1361 - accuracy: 0.2030 - val_loss: 5.4977 - val_accuracy: 0.269
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 282us/step - loss:
5.8373 - accuracy: 0.2080 - val_loss: 5.6226 - val_accuracy: 0.166
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
```

```
1000/1000 [==============================] - 0s 259us/step - loss:
6.1951 - accuracy: 0.2010 - val_loss: 4.2848 - val_accuracy: 0.168
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 328us/step - loss:
5.3097 - accuracy: 0.1770 - val_loss: 5.3263 - val_accuracy: 0.157
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 338us/step - loss:
6.0497 - accuracy: 0.1910 - val_loss: 6.0244 - val_accuracy: 0.286
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 298us/step - loss:
6.6310 - accuracy: 0.2090 - val_loss: 6.4096 - val_accuracy: 0.194
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 266us/step - loss:
6.2579 - accuracy: 0.2080 - val_loss: 6.5253 - val_accuracy: 0.156
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 274us/step - loss:
6.2270 - accuracy: 0.1940 - val_loss: 6.8317 - val_accuracy: 0.239
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 269us/step - loss:
6.9005 - accuracy: 0.2080 - val_loss: 6.7235 - val_accuracy: 0.272
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 261us/step - loss:
6.8350 - accuracy: 0.1780 - val_loss: 7.0064 - val_accuracy: 0.191
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 326us/step - loss:
6.3891 - accuracy: 0.1950 - val_loss: 5.7205 - val_accuracy: 0.146
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 345us/step - loss:
6.6304 - accuracy: 0.1880 - val_loss: 5.2031 - val_accuracy: 0.167
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 355us/step - loss:
5.5980 - accuracy: 0.1990 - val_loss: 4.8382 - val_accuracy: 0.143
0
```

```
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 262us/step - loss:
5.9083 - accuracy: 0.2100 - val_loss: 6.1855 - val_accuracy: 0.283
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 263us/step - loss:
6.4476 - accuracy: 0.2320 - val_loss: 9.4106 - val_accuracy: 0.153
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
6.3843 - accuracy: 0.2030 - val_loss: 7.6869 - val_accuracy: 0.186
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 252us/step - loss:
6.0698 - accuracy: 0.2010 - val_loss: 4.6945 - val_accuracy: 0.168
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 345us/step - loss:
6.2490 - accuracy: 0.2180 - val_loss: 7.9760 - val_accuracy: 0.258
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 346us/step - loss:
6.2856 - accuracy: 0.1960 - val_loss: 5.8173 - val_accuracy: 0.180
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 354us/step - loss:
6.7535 - accuracy: 0.1920 - val_loss: 7.1048 - val_accuracy: 0.165
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 267us/step - loss:
5.9238 - accuracy: 0.2110 - val_loss: 5.5343 - val_accuracy: 0.172
0
```

In [122]:
```
LearningRate_plot(W)
```




### Two Layer Model without regularization

In [27]:
```
model=model_nn_2(30,10,False)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
```

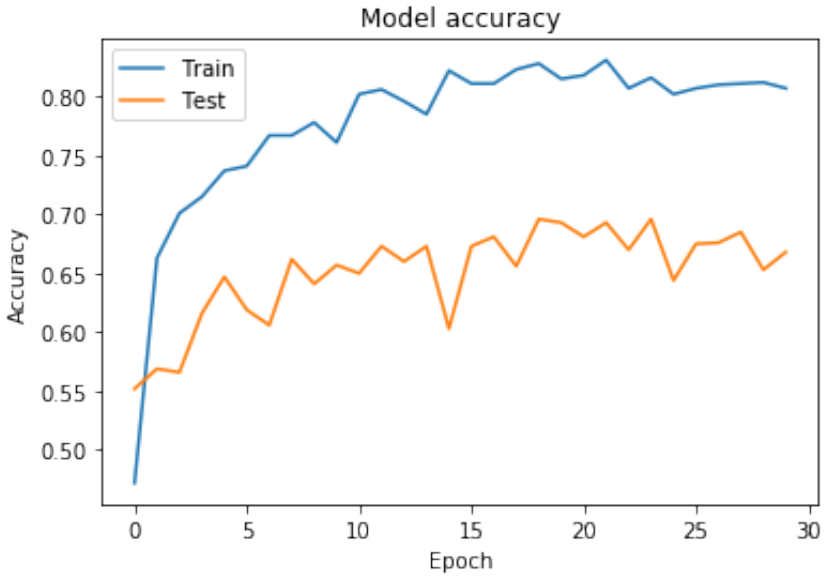
```
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_7 (Dense)              (None, 30)                23550
_________________________________________________________________
dense_8 (Dense)              (None, 30)                930
_________________________________________________________________
dense_9 (Dense)              (None, 10)                310
=================================================================
Total params: 24,790
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 0s 388us/step - loss:
1.5217 - accuracy: 0.4720 - val_loss: 1.3268 - val_accuracy: 0.552
0
Epoch 2/30
1000/1000 [==============================] - 0s 243us/step - loss:
1.0205 - accuracy: 0.6630 - val_loss: 1.2290 - val_accuracy: 0.569
0
Epoch 3/30
1000/1000 [==============================] - 0s 271us/step - loss:
0.9120 - accuracy: 0.7010 - val_loss: 1.3091 - val_accuracy: 0.566
```

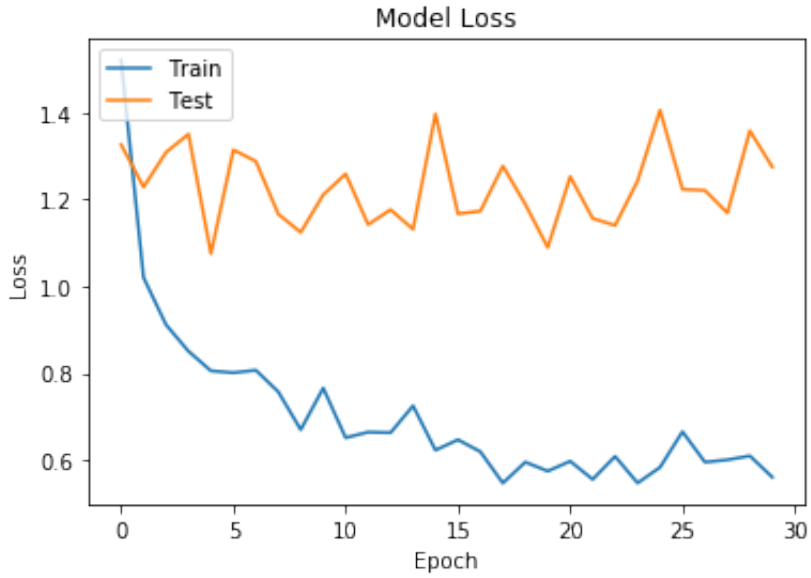
```
0
Epoch 4/30
1000/1000 [==============================] - 0s 242us/step - loss:
0.8509 - accuracy: 0.7150 - val_loss: 1.3510 - val_accuracy: 0.616
0
Epoch 5/30
1000/1000 [==============================] - 0s 319us/step - loss:
0.8057 - accuracy: 0.7370 - val_loss: 1.0755 - val_accuracy: 0.647
0
Epoch 6/30
1000/1000 [==============================] - 0s 320us/step - loss:
0.8014 - accuracy: 0.7410 - val_loss: 1.3148 - val_accuracy: 0.619
0
Epoch 7/30
1000/1000 [==============================] - 0s 324us/step - loss:
0.8071 - accuracy: 0.7670 - val_loss: 1.2884 - val_accuracy: 0.606
0
Epoch 8/30
1000/1000 [==============================] - 0s 260us/step - loss:
0.7575 - accuracy: 0.7670 - val_loss: 1.1667 - val_accuracy: 0.662
0
Epoch 9/30
1000/1000 [==============================] - 0s 310us/step - loss:
0.6700 - accuracy: 0.7780 - val_loss: 1.1247 - val_accuracy: 0.641
0
Epoch 10/30
1000/1000 [==============================] - 0s 265us/step - loss:
0.7660 - accuracy: 0.7610 - val_loss: 1.2113 - val_accuracy: 0.657
0
Epoch 11/30
1000/1000 [==============================] - 0s 258us/step - loss:
0.6516 - accuracy: 0.8020 - val_loss: 1.2593 - val_accuracy: 0.650
0
Epoch 12/30
1000/1000 [==============================] - 0s 365us/step - loss:
0.6646 - accuracy: 0.8060 - val_loss: 1.1427 - val_accuracy: 0.673
0
Epoch 13/30
1000/1000 [==============================] - 0s 244us/step - loss:
0.6633 - accuracy: 0.7960 - val_loss: 1.1770 - val_accuracy: 0.660
0
Epoch 14/30
1000/1000 [==============================] - 0s 250us/step - loss:
0.7252 - accuracy: 0.7850 - val_loss: 1.1318 - val_accuracy: 0.673
0
Epoch 15/30
1000/1000 [==============================] - 0s 305us/step - loss:
0.6230 - accuracy: 0.8220 - val_loss: 1.3976 - val_accuracy: 0.603
0
Epoch 16/30
1000/1000 [==============================] - 0s 260us/step - loss:
0.6471 - accuracy: 0.8110 - val_loss: 1.1675 - val_accuracy: 0.673
0
```

```
Epoch 17/30
1000/1000 [==============================] - 0s 252us/step - loss:
0.6195 - accuracy: 0.8110 - val_loss: 1.1737 - val_accuracy: 0.681
0
Epoch 18/30
1000/1000 [==============================] - 0s 256us/step - loss:
0.5472 - accuracy: 0.8230 - val_loss: 1.2776 - val_accuracy: 0.656
0
Epoch 19/30
1000/1000 [==============================] - 0s 233us/step - loss:
0.5955 - accuracy: 0.8280 - val_loss: 1.1894 - val_accuracy: 0.696
0
Epoch 20/30
1000/1000 [==============================] - 0s 237us/step - loss:
0.5747 - accuracy: 0.8150 - val_loss: 1.0899 - val_accuracy: 0.693
0
Epoch 21/30
1000/1000 [==============================] - 0s 250us/step - loss:
0.5975 - accuracy: 0.8180 - val_loss: 1.2533 - val_accuracy: 0.681
0
Epoch 22/30
1000/1000 [==============================] - 0s 277us/step - loss:
0.5558 - accuracy: 0.8310 - val_loss: 1.1568 - val_accuracy: 0.693
0
Epoch 23/30
1000/1000 [==============================] - 0s 239us/step - loss:
0.6087 - accuracy: 0.8070 - val_loss: 1.1407 - val_accuracy: 0.670
0
Epoch 24/30
1000/1000 [==============================] - 0s 236us/step - loss:
0.5474 - accuracy: 0.8160 - val_loss: 1.2430 - val_accuracy: 0.696
0
Epoch 25/30
1000/1000 [==============================] - 0s 251us/step - loss:
0.5834 - accuracy: 0.8020 - val_loss: 1.4061 - val_accuracy: 0.644
0
Epoch 26/30
1000/1000 [==============================] - 0s 244us/step - loss:
0.6656 - accuracy: 0.8070 - val_loss: 1.2240 - val_accuracy: 0.675
0
Epoch 27/30
1000/1000 [==============================] - 0s 305us/step - loss:
0.5954 - accuracy: 0.8100 - val_loss: 1.2214 - val_accuracy: 0.676
0
Epoch 28/30
1000/1000 [==============================] - 0s 283us/step - loss:
0.6008 - accuracy: 0.8110 - val_loss: 1.1694 - val_accuracy: 0.685
0
Epoch 29/30
1000/1000 [==============================] - 0s 302us/step - loss:
0.6098 - accuracy: 0.8120 - val_loss: 1.3587 - val_accuracy: 0.653
0
Epoch 30/30
```

```
1000/1000 [==============================] - 0s 294us/step - loss:
0.5608 - accuracy: 0.8070 - val_loss: 1.2754 - val_accuracy: 0.668
0
```

In [28]:
```
model_accuracy()
model_loss()
```



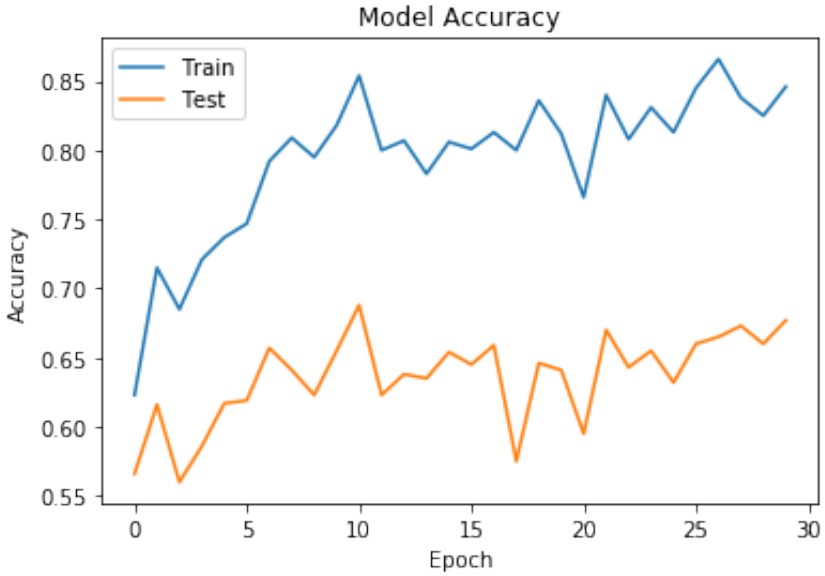




In [29]:
```
model=model_nn_2(30,10,False)
error_model(model)
```

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_10 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_11 (Dense)             (None, 30)                930
_________________________________________________________________
dense_12 (Dense)             (None, 10)                310
```

```
=================================================================
Total params: 24,790
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 243us/step - loss:
1.5514 - accuracy: 0.4320
Epoch 1/1
1000/1000 [==============================] - 0s 184us/step - loss:
1.0612 - accuracy: 0.6320
Epoch 1/1
1000/1000 [==============================] - 0s 150us/step - loss:
1.0390 - accuracy: 0.6740
Epoch 1/1
1000/1000 [==============================] - 0s 165us/step - loss:
1.0138 - accuracy: 0.6930
Epoch 1/1
1000/1000 [==============================] - 0s 159us/step - loss:
0.9350 - accuracy: 0.6990
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
0.8352 - accuracy: 0.7240
Epoch 1/1
1000/1000 [==============================] - 0s 170us/step - loss:
0.8036 - accuracy: 0.7480
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.7505 - accuracy: 0.7770
Epoch 1/1
1000/1000 [==============================] - 0s 150us/step - loss:
0.6336 - accuracy: 0.7950
Epoch 1/1
1000/1000 [==============================] - 0s 148us/step - loss:
0.6915 - accuracy: 0.7760
Epoch 1/1
1000/1000 [==============================] - 0s 149us/step - loss:
0.6812 - accuracy: 0.7790
Epoch 1/1
1000/1000 [==============================] - 0s 149us/step - loss:
0.6426 - accuracy: 0.7960
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.5851 - accuracy: 0.7970
Epoch 1/1
1000/1000 [==============================] - 0s 213us/step - loss:
0.6521 - accuracy: 0.7880
Epoch 1/1
1000/1000 [==============================] - 0s 189us/step - loss:
0.7033 - accuracy: 0.7740
Epoch 1/1
1000/1000 [==============================] - 0s 205us/step - loss:
0.6875 - accuracy: 0.7820
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 158us/step - loss:
0.7111 - accuracy: 0.7840
Epoch 1/1
1000/1000 [==============================] - 0s 148us/step - loss:
0.6399 - accuracy: 0.7840
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
0.6203 - accuracy: 0.8030
Epoch 1/1
1000/1000 [==============================] - 0s 155us/step - loss:
0.6716 - accuracy: 0.7930
Epoch 1/1
1000/1000 [==============================] - 0s 164us/step - loss:
0.6271 - accuracy: 0.7950
Epoch 1/1
1000/1000 [==============================] - 0s 149us/step - loss:
0.6147 - accuracy: 0.8120
Epoch 1/1
1000/1000 [==============================] - 0s 153us/step - loss:
0.6186 - accuracy: 0.8000
Epoch 1/1
1000/1000 [==============================] - 0s 177us/step - loss:
0.5723 - accuracy: 0.8250
Epoch 1/1
1000/1000 [==============================] - 0s 151us/step - loss:
0.5857 - accuracy: 0.8070
Epoch 1/1
1000/1000 [==============================] - 0s 154us/step - loss:
0.6289 - accuracy: 0.7900
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
0.5474 - accuracy: 0.8240
Epoch 1/1
1000/1000 [==============================] - 0s 151us/step - loss:
0.5329 - accuracy: 0.8390
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.5649 - accuracy: 0.8150
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
0.5775 - accuracy: 0.8120
```

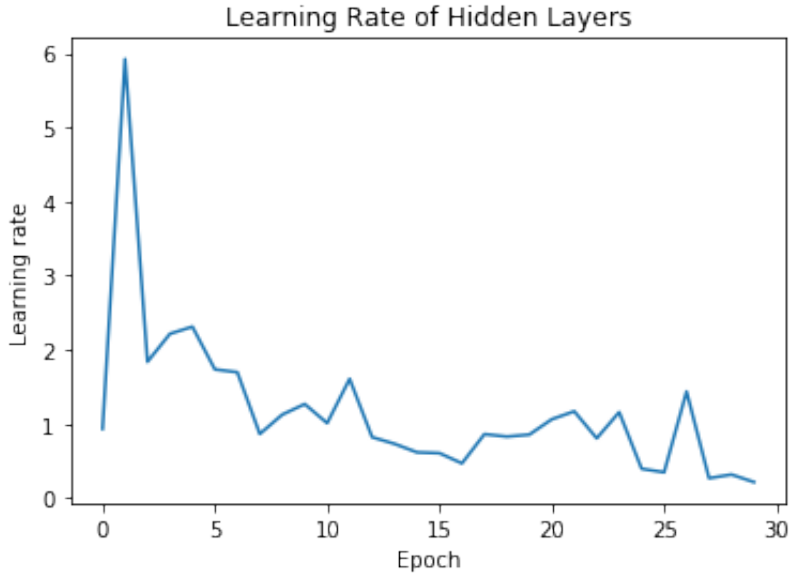

In [30]:
```
model=model_nn_2(30,10,False)
W=LearningRate(model,(24790))
LearningRate_plot(W)
```

```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_13 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_14 (Dense)             (None, 30)                930
_________________________________________________________________
dense_15 (Dense)             (None, 10)                310
=================================================================
Total params: 24,790
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 381us/step - loss:
1.6348 - accuracy: 0.4370 - val_loss: 1.1676 - val_accuracy: 0.625
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 327us/step - loss:
0.9744 - accuracy: 0.6670 - val_loss: 1.2375 - val_accuracy: 0.603
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 303us/step - loss:
0.8864 - accuracy: 0.7070 - val_loss: 1.2527 - val_accuracy: 0.624
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 289us/step - loss:
0.7607 - accuracy: 0.7580 - val_loss: 1.0989 - val_accuracy: 0.656
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
0.7365 - accuracy: 0.7710 - val_loss: 1.2092 - val_accuracy: 0.631
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 242us/step - loss:
0.6508 - accuracy: 0.7950 - val_loss: 1.2522 - val_accuracy: 0.635
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 241us/step - loss:
0.7625 - accuracy: 0.7400 - val_loss: 1.2239 - val_accuracy: 0.673
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 334us/step - loss:
0.6754 - accuracy: 0.7880 - val_loss: 1.3125 - val_accuracy: 0.619
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 284us/step - loss:
0.6287 - accuracy: 0.8060 - val_loss: 1.1229 - val_accuracy: 0.692
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 263us/step - loss:
0.6979 - accuracy: 0.7790 - val_loss: 1.2111 - val_accuracy: 0.647
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 337us/step - loss:
0.7371 - accuracy: 0.7760 - val_loss: 1.2419 - val_accuracy: 0.673
```

```
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 326us/step - loss:
0.7865 - accuracy: 0.7430 - val_loss: 1.1829 - val_accuracy: 0.650
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 305us/step - loss:
0.6862 - accuracy: 0.7780 - val_loss: 1.2147 - val_accuracy: 0.645
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 320us/step - loss:
0.6424 - accuracy: 0.7980 - val_loss: 1.1490 - val_accuracy: 0.656
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 320us/step - loss:
0.6348 - accuracy: 0.7910 - val_loss: 1.0250 - val_accuracy: 0.706
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 254us/step - loss:
0.5291 - accuracy: 0.8270 - val_loss: 1.0832 - val_accuracy: 0.651
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 253us/step - loss:
0.5403 - accuracy: 0.8090 - val_loss: 1.1473 - val_accuracy: 0.678
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 280us/step - loss:
0.5685 - accuracy: 0.8230 - val_loss: 1.3053 - val_accuracy: 0.644
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 252us/step - loss:
0.6827 - accuracy: 0.7700 - val_loss: 1.1737 - val_accuracy: 0.644
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 247us/step - loss:
0.7070 - accuracy: 0.7790 - val_loss: 1.2195 - val_accuracy: 0.649
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 324us/step - loss:
0.6382 - accuracy: 0.7750 - val_loss: 1.1927 - val_accuracy: 0.654
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
```

```
1000/1000 [==============================] - 0s 327us/step - loss:
0.6127 - accuracy: 0.8000 - val_loss: 1.1720 - val_accuracy: 0.640
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 329us/step - loss:
0.6526 - accuracy: 0.7930 - val_loss: 1.3098 - val_accuracy: 0.660
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 285us/step - loss:
0.6720 - accuracy: 0.7870 - val_loss: 1.1865 - val_accuracy: 0.653
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 253us/step - loss:
0.6819 - accuracy: 0.7890 - val_loss: 1.0842 - val_accuracy: 0.688
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 272us/step - loss:
0.5799 - accuracy: 0.8160 - val_loss: 1.4624 - val_accuracy: 0.646
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 265us/step - loss:
0.5994 - accuracy: 0.8110 - val_loss: 1.2177 - val_accuracy: 0.685
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 257us/step - loss:
0.5275 - accuracy: 0.8210 - val_loss: 1.2296 - val_accuracy: 0.660
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 267us/step - loss:
0.5231 - accuracy: 0.8310 - val_loss: 1.1760 - val_accuracy: 0.685
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 331us/step - loss:
0.5255 - accuracy: 0.8300 - val_loss: 1.1911 - val_accuracy: 0.675
0
```




### Two Layer Model with regularization

In [31]:
```
model=model_nn_2(30,10,True)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
```

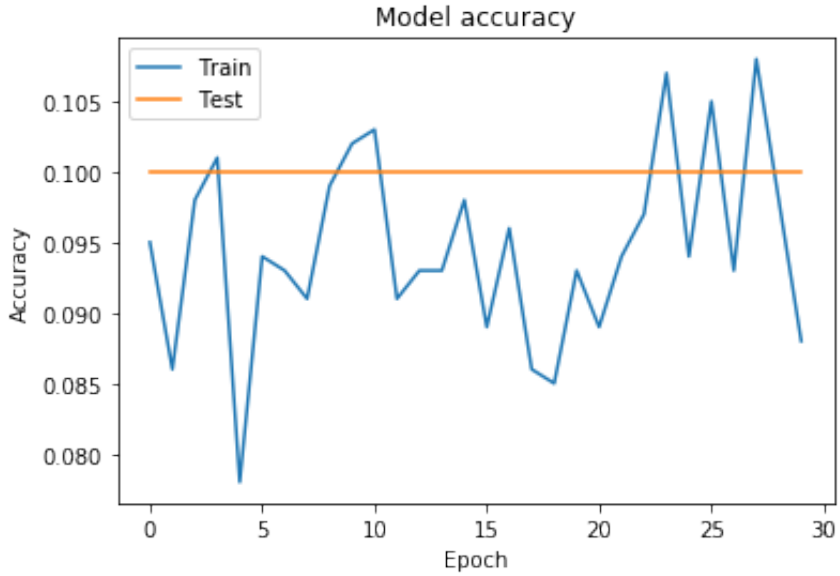
```
Model: "sequential_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_16 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_17 (Dense)             (None, 30)                930
_________________________________________________________________
dense_18 (Dense)             (None, 10)                310
=================================================================
Total params: 24,790
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 0s 411us/step - loss:
35.3744 - accuracy: 0.0950 - val_loss: 2.3468 - val_accuracy: 0.10
00
Epoch 2/30
1000/1000 [==============================] - 0s 299us/step - loss:
2.3355 - accuracy: 0.0860 - val_loss: 2.3122 - val_accuracy: 0.100
0
Epoch 3/30
1000/1000 [==============================] - 0s 269us/step - loss:
2.3358 - accuracy: 0.0980 - val_loss: 2.3313 - val_accuracy: 0.100
0
Epoch 4/30
```

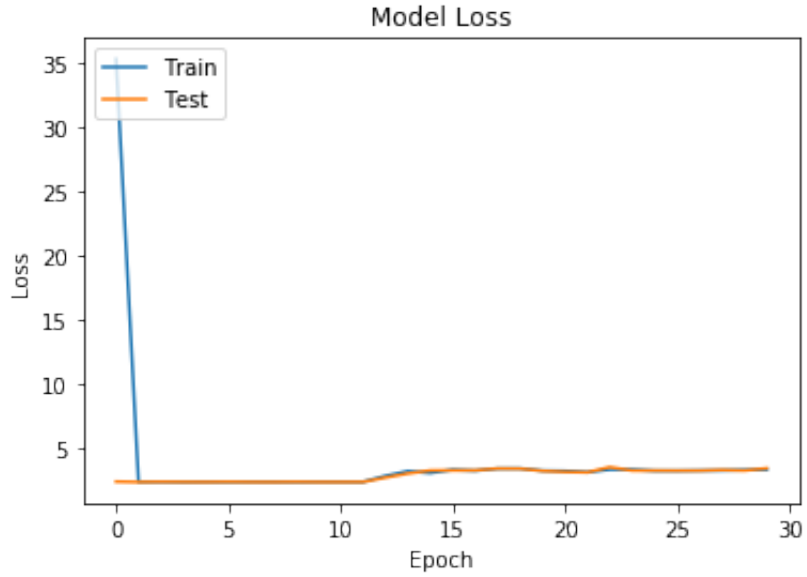
```
1000/1000 [==============================] - 0s 261us/step - loss:
2.3237 - accuracy: 0.1010 - val_loss: 2.3196 - val_accuracy: 0.100
0
Epoch 5/30
1000/1000 [==============================] - 0s 268us/step - loss:
2.3307 - accuracy: 0.0780 - val_loss: 2.3124 - val_accuracy: 0.100
0
Epoch 6/30
1000/1000 [==============================] - 0s 261us/step - loss:
2.3272 - accuracy: 0.0940 - val_loss: 2.3306 - val_accuracy: 0.100
0
Epoch 7/30
1000/1000 [==============================] - 0s 264us/step - loss:
2.3334 - accuracy: 0.0930 - val_loss: 2.3133 - val_accuracy: 0.100
0
Epoch 8/30
1000/1000 [==============================] - 0s 268us/step - loss:
2.3308 - accuracy: 0.0910 - val_loss: 2.3102 - val_accuracy: 0.100
0
Epoch 9/30
1000/1000 [==============================] - 0s 269us/step - loss:
2.3253 - accuracy: 0.0990 - val_loss: 2.3266 - val_accuracy: 0.100
0
Epoch 10/30
1000/1000 [==============================] - 0s 269us/step - loss:
2.3341 - accuracy: 0.1020 - val_loss: 2.3122 - val_accuracy: 0.100
0
Epoch 11/30
1000/1000 [==============================] - 0s 265us/step - loss:
2.3326 - accuracy: 0.1030 - val_loss: 2.3123 - val_accuracy: 0.100
0
Epoch 12/30
1000/1000 [==============================] - 0s 263us/step - loss:
2.3252 - accuracy: 0.0910 - val_loss: 2.3213 - val_accuracy: 0.100
0
Epoch 13/30
1000/1000 [==============================] - 0s 268us/step - loss:
2.7882 - accuracy: 0.0930 - val_loss: 2.6617 - val_accuracy: 0.100
0
Epoch 14/30
1000/1000 [==============================] - 0s 327us/step - loss:
3.1588 - accuracy: 0.0930 - val_loss: 2.9804 - val_accuracy: 0.100
0
Epoch 15/30
1000/1000 [==============================] - 0s 350us/step - loss:
3.0242 - accuracy: 0.0980 - val_loss: 3.2150 - val_accuracy: 0.100
0
Epoch 16/30
1000/1000 [==============================] - 0s 327us/step - loss:
3.2754 - accuracy: 0.0890 - val_loss: 3.2276 - val_accuracy: 0.100
0
Epoch 17/30
1000/1000 [==============================] - 0s 276us/step - loss:
```

```
3.2059 - accuracy: 0.0960 - val_loss: 3.2298 - val_accuracy: 0.100
0
Epoch 18/30
1000/1000 [==============================] - 0s 287us/step - loss:
3.3675 - accuracy: 0.0860 - val_loss: 3.3688 - val_accuracy: 0.100
0
Epoch 19/30
1000/1000 [==============================] - 0s 279us/step - loss:
3.3742 - accuracy: 0.0850 - val_loss: 3.3581 - val_accuracy: 0.100
0
Epoch 20/30
1000/1000 [==============================] - 0s 270us/step - loss:
3.2005 - accuracy: 0.0930 - val_loss: 3.1862 - val_accuracy: 0.100
0
Epoch 21/30
1000/1000 [==============================] - 0s 268us/step - loss:
3.1839 - accuracy: 0.0890 - val_loss: 3.1087 - val_accuracy: 0.100
0
Epoch 22/30
1000/1000 [==============================] - 0s 265us/step - loss:
3.0820 - accuracy: 0.0940 - val_loss: 3.0726 - val_accuracy: 0.100
0
Epoch 23/30
1000/1000 [==============================] - 0s 267us/step - loss:
3.2921 - accuracy: 0.0970 - val_loss: 3.4771 - val_accuracy: 0.100
0
Epoch 24/30
1000/1000 [==============================] - 0s 264us/step - loss:
3.2909 - accuracy: 0.1070 - val_loss: 3.2132 - val_accuracy: 0.100
0
Epoch 25/30
1000/1000 [==============================] - 0s 268us/step - loss:
3.2000 - accuracy: 0.0940 - val_loss: 3.2102 - val_accuracy: 0.100
0
Epoch 26/30
1000/1000 [==============================] - 0s 274us/step - loss:
3.1983 - accuracy: 0.1050 - val_loss: 3.2025 - val_accuracy: 0.100
0
Epoch 27/30
1000/1000 [==============================] - 0s 264us/step - loss:
3.2142 - accuracy: 0.0930 - val_loss: 3.2074 - val_accuracy: 0.100
0
Epoch 28/30
1000/1000 [==============================] - 0s 264us/step - loss:
3.2232 - accuracy: 0.1080 - val_loss: 3.2593 - val_accuracy: 0.100
0
Epoch 29/30
1000/1000 [==============================] - 0s 266us/step - loss:
3.2619 - accuracy: 0.0980 - val_loss: 3.2137 - val_accuracy: 0.100
0
Epoch 30/30
1000/1000 [==============================] - 0s 266us/step - loss:
3.2872 - accuracy: 0.0880 - val_loss: 3.3858 - val_accuracy: 0.100
```

0

In [32]:
```
model_accuracy()
model_loss()
```



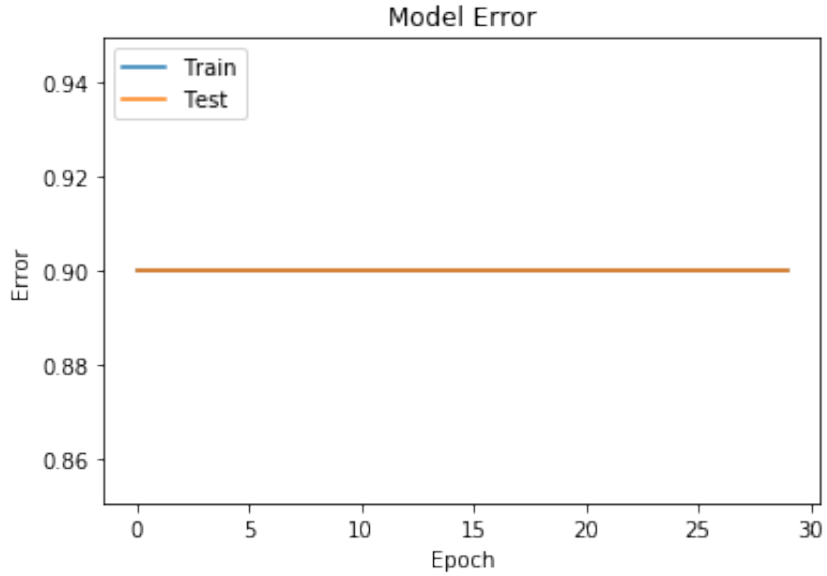



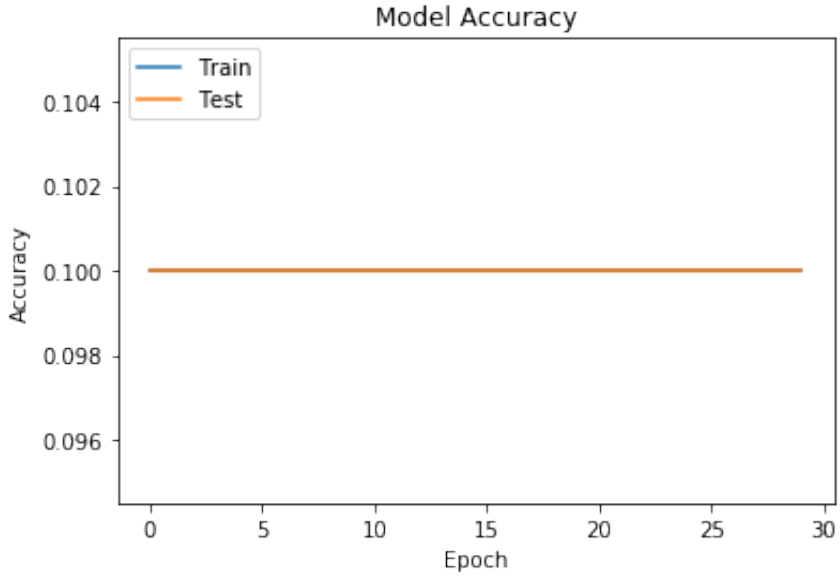

In [33]:
```
model=model_nn_2(30,10,True)
error_model(model)
```

```
Model: "sequential_8"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_19 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_20 (Dense)             (None, 30)                930
_________________________________________________________________
dense_21 (Dense)             (None, 10)                310
=================================================================
Total params: 24,790
```

```
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 248us/step - loss:
35.3365 - accuracy: 0.0980
Epoch 1/1
1000/1000 [==============================] - 0s 186us/step - loss:
2.3469 - accuracy: 0.1020
Epoch 1/1
1000/1000 [==============================] - 0s 232us/step - loss:
2.3366 - accuracy: 0.1010
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
2.3296 - accuracy: 0.0950
Epoch 1/1
1000/1000 [==============================] - 0s 152us/step - loss:
2.3343 - accuracy: 0.0840
Epoch 1/1
1000/1000 [==============================] - 0s 181us/step - loss:
2.3261 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 179us/step - loss:
2.3406 - accuracy: 0.0870
Epoch 1/1
1000/1000 [==============================] - 0s 198us/step - loss:
2.3287 - accuracy: 0.0860
Epoch 1/1
1000/1000 [==============================] - 0s 207us/step - loss:
2.3456 - accuracy: 0.0830
Epoch 1/1
1000/1000 [==============================] - 0s 189us/step - loss:
2.3290 - accuracy: 0.1050
Epoch 1/1
1000/1000 [==============================] - 0s 200us/step - loss:
2.3343 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 192us/step - loss:
2.3244 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 157us/step - loss:
2.7683 - accuracy: 0.0930
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
3.1566 - accuracy: 0.0960
Epoch 1/1
1000/1000 [==============================] - 0s 165us/step - loss:
3.0189 - accuracy: 0.0850
Epoch 1/1
1000/1000 [==============================] - 0s 165us/step - loss:
3.2681 - accuracy: 0.1070
Epoch 1/1
1000/1000 [==============================] - 0s 158us/step - loss:
```

```
3.1728 - accuracy: 0.1010
Epoch 1/1
1000/1000 [==============================] - 0s 157us/step - loss:
3.3784 - accuracy: 0.0960
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
3.3574 - accuracy: 0.0900
Epoch 1/1
1000/1000 [==============================] - 0s 157us/step - loss:
3.1954 - accuracy: 0.1080
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
3.2192 - accuracy: 0.0930
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
3.0684 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
3.2873 - accuracy: 0.1030
Epoch 1/1
1000/1000 [==============================] - 0s 164us/step - loss:
3.2926 - accuracy: 0.0880
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
3.1975 - accuracy: 0.0780
Epoch 1/1
1000/1000 [==============================] - 0s 162us/step - loss:
3.2314 - accuracy: 0.1020
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
3.1762 - accuracy: 0.0820
Epoch 1/1
1000/1000 [==============================] - 0s 159us/step - loss:
3.2260 - accuracy: 0.0810
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
3.2875 - accuracy: 0.0910
Epoch 1/1
1000/1000 [==============================] - 0s 160us/step - loss:
3.2493 - accuracy: 0.0870
```



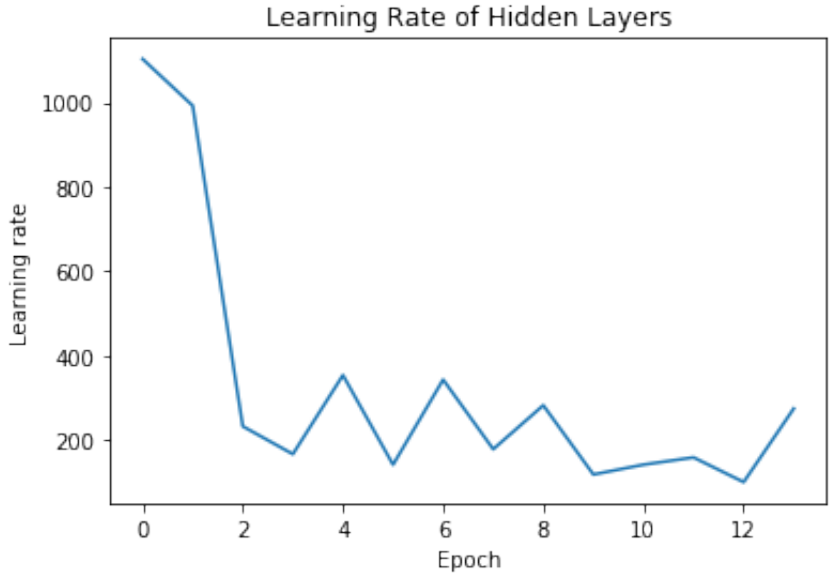

In [34]:
```
model=model_nn_2(30,10,True)
W=LearningRate(model,(24790))
LearningRate_plot(W)
```

```
Model: "sequential_9"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_22 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_23 (Dense)             (None, 30)                930
_________________________________________________________________
dense_24 (Dense)             (None, 10)                310
=================================================================
Total params: 24,790
Trainable params: 24,790
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
```

```
Epoch 1/1
1000/1000 [==============================] - 0s 393us/step - loss:
35.5635 - accuracy: 0.0870 - val_loss: 2.3364 - val_accuracy: 0.10
00
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
2.3427 - accuracy: 0.0890 - val_loss: 2.3202 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 272us/step - loss:
2.3239 - accuracy: 0.1080 - val_loss: 2.3292 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 350us/step - loss:
2.3285 - accuracy: 0.1080 - val_loss: 2.3199 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 325us/step - loss:
2.3268 - accuracy: 0.1000 - val_loss: 2.3165 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 353us/step - loss:
2.3264 - accuracy: 0.0870 - val_loss: 2.3430 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 332us/step - loss:
2.3328 - accuracy: 0.0960 - val_loss: 2.3126 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 399us/step - loss:
2.3246 - accuracy: 0.0850 - val_loss: 2.3177 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 292us/step - loss:
2.3294 - accuracy: 0.0900 - val_loss: 2.3187 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 276us/step - loss:
2.3297 - accuracy: 0.0970 - val_loss: 2.3310 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 289us/step - loss:
2.3320 - accuracy: 0.0970 - val_loss: 2.3204 - val_accuracy: 0.100
```

```
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 269us/step - loss:
2.3353 - accuracy: 0.0830 - val_loss: 2.3098 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 263us/step - loss:
2.7779 - accuracy: 0.0900 - val_loss: 2.6920 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 264us/step - loss:
3.1551 - accuracy: 0.0970 - val_loss: 3.0345 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 263us/step - loss:
3.0333 - accuracy: 0.0960 - val_loss: 3.3473 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 266us/step - loss:
3.2913 - accuracy: 0.0820 - val_loss: 3.1382 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
3.2017 - accuracy: 0.1020 - val_loss: 3.1455 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 258us/step - loss:
3.3607 - accuracy: 0.0950 - val_loss: 3.3978 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 267us/step - loss:
3.3583 - accuracy: 0.1110 - val_loss: 3.2230 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
3.1981 - accuracy: 0.0970 - val_loss: 3.2989 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
3.1952 - accuracy: 0.0860 - val_loss: 3.0777 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
```

```
1000/1000 [==============================] - 0s 270us/step - loss:
3.0801 - accuracy: 0.0890 - val_loss: 2.9939 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 275us/step - loss:
3.2927 - accuracy: 0.0920 - val_loss: 3.4838 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
3.2493 - accuracy: 0.0970 - val_loss: 3.2052 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 265us/step - loss:
3.2396 - accuracy: 0.0860 - val_loss: 3.2858 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 264us/step - loss:
3.2099 - accuracy: 0.0890 - val_loss: 3.1612 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 276us/step - loss:
3.1604 - accuracy: 0.0990 - val_loss: 3.1999 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 338us/step - loss:
3.2390 - accuracy: 0.1040 - val_loss: 3.2264 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 327us/step - loss:
3.2582 - accuracy: 0.1030 - val_loss: 3.1761 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 306us/step - loss:
3.2963 - accuracy: 0.0850 - val_loss: 3.5017 - val_accuracy: 0.100
0
```




### Three Layer Model without regularization

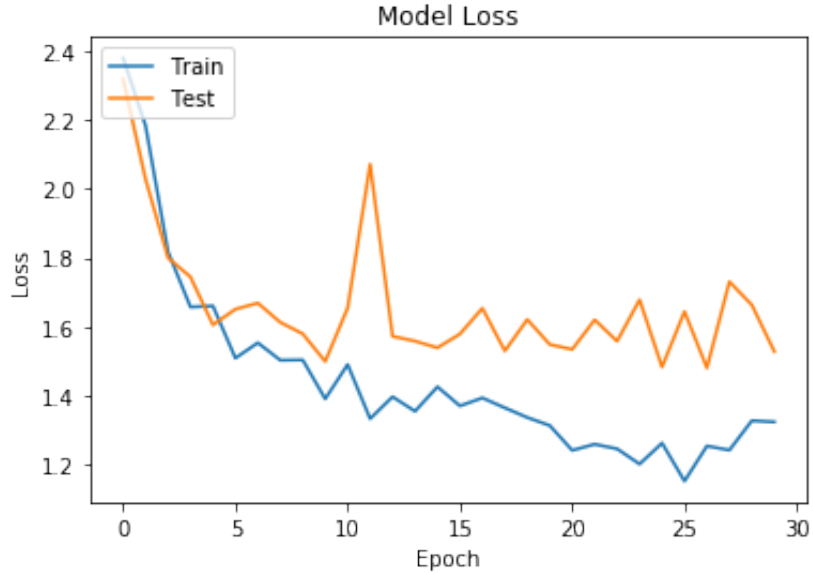
In [35]:
```
model=model_nn_3(30,10,False)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
model_accuracy()
model_loss()
```

```
Model: "sequential_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_25 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_26 (Dense)             (None, 30)                930
_________________________________________________________________
dense_27 (Dense)             (None, 30)                930
_________________________________________________________________
dense_28 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 0s 377us/step - loss:
2.3781 - accuracy: 0.0850 - val_loss: 2.3173 - val_accuracy: 0.100
0
Epoch 2/30
1000/1000 [==============================] - 0s 268us/step - loss:
2.1821 - accuracy: 0.1650 - val_loss: 2.0271 - val_accuracy: 0.258
0
Epoch 3/30
```

```
1000/1000 [==============================] - 0s 342us/step - loss:
1.8174 - accuracy: 0.3160 - val_loss: 1.8001 - val_accuracy: 0.381
0
Epoch 4/30
1000/1000 [==============================] - 0s 369us/step - loss:
1.6577 - accuracy: 0.3610 - val_loss: 1.7447 - val_accuracy: 0.376
0
Epoch 5/30
1000/1000 [==============================] - 0s 273us/step - loss:
1.6607 - accuracy: 0.3760 - val_loss: 1.6059 - val_accuracy: 0.423
0
Epoch 6/30
1000/1000 [==============================] - 0s 267us/step - loss:
1.5097 - accuracy: 0.4280 - val_loss: 1.6514 - val_accuracy: 0.390
0
Epoch 7/30
1000/1000 [==============================] - 0s 286us/step - loss:
1.5541 - accuracy: 0.4100 - val_loss: 1.6691 - val_accuracy: 0.382
0
Epoch 8/30
1000/1000 [==============================] - 0s 270us/step - loss:
1.5038 - accuracy: 0.4260 - val_loss: 1.6133 - val_accuracy: 0.389
0
Epoch 9/30
1000/1000 [==============================] - 0s 265us/step - loss:
1.5046 - accuracy: 0.3970 - val_loss: 1.5802 - val_accuracy: 0.446
0
Epoch 10/30
1000/1000 [==============================] - 0s 265us/step - loss:
1.3919 - accuracy: 0.4780 - val_loss: 1.5002 - val_accuracy: 0.461
0
Epoch 11/30
1000/1000 [==============================] - 0s 265us/step - loss:
1.4913 - accuracy: 0.4300 - val_loss: 1.6549 - val_accuracy: 0.418
0
Epoch 12/30
1000/1000 [==============================] - 0s 306us/step - loss:
1.3343 - accuracy: 0.4990 - val_loss: 2.0707 - val_accuracy: 0.406
0
Epoch 13/30
1000/1000 [==============================] - 0s 319us/step - loss:
1.3979 - accuracy: 0.5000 - val_loss: 1.5730 - val_accuracy: 0.460
0
Epoch 14/30
1000/1000 [==============================] - 0s 274us/step - loss:
1.3561 - accuracy: 0.5130 - val_loss: 1.5590 - val_accuracy: 0.489
0
Epoch 15/30
1000/1000 [==============================] - 0s 279us/step - loss:
1.4269 - accuracy: 0.4720 - val_loss: 1.5397 - val_accuracy: 0.499
0
Epoch 16/30
1000/1000 [==============================] - 0s 275us/step - loss:
```

```
1.3716 - accuracy: 0.5110 - val_loss: 1.5796 - val_accuracy: 0.487
0
Epoch 17/30
1000/1000 [==============================] - 0s 276us/step - loss:
1.3947 - accuracy: 0.4810 - val_loss: 1.6541 - val_accuracy: 0.407
0
Epoch 18/30
1000/1000 [==============================] - 0s 317us/step - loss:
1.3659 - accuracy: 0.4930 - val_loss: 1.5306 - val_accuracy: 0.508
0
Epoch 19/30
1000/1000 [==============================] - 0s 257us/step - loss:
1.3380 - accuracy: 0.5270 - val_loss: 1.6215 - val_accuracy: 0.447
0
Epoch 20/30
1000/1000 [==============================] - 0s 278us/step - loss:
1.3148 - accuracy: 0.4880 - val_loss: 1.5492 - val_accuracy: 0.484
0
Epoch 21/30
1000/1000 [==============================] - 0s 273us/step - loss:
1.2430 - accuracy: 0.5270 - val_loss: 1.5352 - val_accuracy: 0.469
0
Epoch 22/30
1000/1000 [==============================] - 0s 314us/step - loss:
1.2606 - accuracy: 0.5160 - val_loss: 1.6205 - val_accuracy: 0.477
0
Epoch 23/30
1000/1000 [==============================] - 0s 325us/step - loss:
1.2473 - accuracy: 0.5400 - val_loss: 1.5589 - val_accuracy: 0.463
0
Epoch 24/30
1000/1000 [==============================] - 0s 332us/step - loss:
1.2033 - accuracy: 0.5460 - val_loss: 1.6787 - val_accuracy: 0.453
0
Epoch 25/30
1000/1000 [==============================] - 0s 333us/step - loss:
1.2640 - accuracy: 0.5140 - val_loss: 1.4841 - val_accuracy: 0.513
0
Epoch 26/30
1000/1000 [==============================] - 0s 318us/step - loss:
1.1540 - accuracy: 0.5900 - val_loss: 1.6444 - val_accuracy: 0.486
0
Epoch 27/30
1000/1000 [==============================] - 0s 319us/step - loss:
1.2556 - accuracy: 0.5560 - val_loss: 1.4814 - val_accuracy: 0.520
0
Epoch 28/30
1000/1000 [==============================] - 0s 347us/step - loss:
1.2435 - accuracy: 0.5600 - val_loss: 1.7310 - val_accuracy: 0.422
0
Epoch 29/30
1000/1000 [==============================] - 0s 311us/step - loss:
1.3289 - accuracy: 0.5630 - val_loss: 1.6636 - val_accuracy: 0.487
```

```
0
Epoch 30/30
1000/1000 [==============================] - 0s 289us/step - loss:
1.3253 - accuracy: 0.5530 - val_loss: 1.5290 - val_accuracy: 0.493
0
```

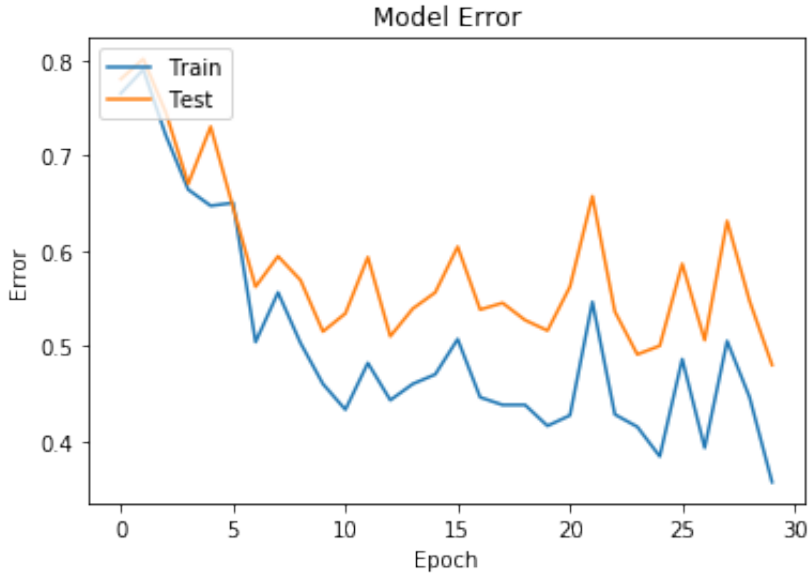



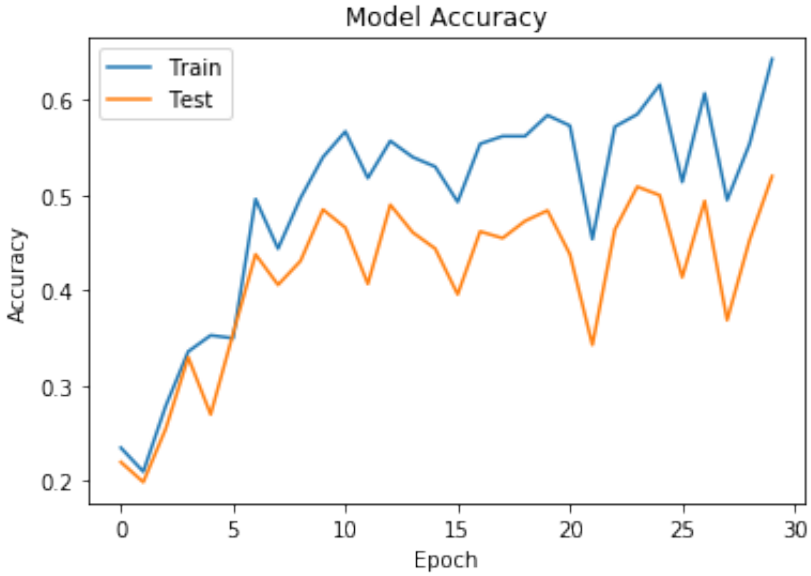

In [38]:
```
model=model_nn_3(30,10,False)
error_model(model)
```

```
Model: "sequential_13"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_37 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_38 (Dense)             (None, 30)                930
_________________________________________________________________
dense_39 (Dense)             (None, 30)                930
_________________________________________________________________
```

```
dense_40 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 260us/step - loss:
2.3267 - accuracy: 0.1190
Epoch 1/1
1000/1000 [==============================] - 0s 178us/step - loss:
2.0401 - accuracy: 0.2010
Epoch 1/1
1000/1000 [==============================] - 0s 202us/step - loss:
1.9195 - accuracy: 0.2560
Epoch 1/1
1000/1000 [==============================] - 0s 171us/step - loss:
1.7588 - accuracy: 0.3090
Epoch 1/1
1000/1000 [==============================] - 0s 165us/step - loss:
1.6189 - accuracy: 0.3660
Epoch 1/1
1000/1000 [==============================] - 0s 159us/step - loss:
1.6184 - accuracy: 0.4210
Epoch 1/1
1000/1000 [==============================] - 0s 164us/step - loss:
1.5744 - accuracy: 0.4580
Epoch 1/1
1000/1000 [==============================] - 0s 189us/step - loss:
1.4426 - accuracy: 0.4990
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
1.5098 - accuracy: 0.4870
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
1.3939 - accuracy: 0.5090
Epoch 1/1
1000/1000 [==============================] - 0s 174us/step - loss:
1.3892 - accuracy: 0.5220
Epoch 1/1
1000/1000 [==============================] - 0s 168us/step - loss:
1.3021 - accuracy: 0.5450
Epoch 1/1
1000/1000 [==============================] - 0s 162us/step - loss:
1.4805 - accuracy: 0.5030
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
1.3706 - accuracy: 0.5330
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
1.3775 - accuracy: 0.5100
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
```

```
1.3309 - accuracy: 0.5120
Epoch 1/1
1000/1000 [==============================] - 0s 199us/step - loss:
1.3773 - accuracy: 0.5220
Epoch 1/1
1000/1000 [==============================] - 0s 206us/step - loss:
1.4196 - accuracy: 0.4980
Epoch 1/1
1000/1000 [==============================] - 0s 193us/step - loss:
1.3176 - accuracy: 0.5350
Epoch 1/1
1000/1000 [==============================] - 0s 230us/step - loss:
1.3127 - accuracy: 0.5500
Epoch 1/1
1000/1000 [==============================] - 0s 177us/step - loss:
1.4921 - accuracy: 0.4940
Epoch 1/1
1000/1000 [==============================] - 0s 161us/step - loss:
1.3964 - accuracy: 0.5150
Epoch 1/1
1000/1000 [==============================] - 0s 175us/step - loss:
1.4125 - accuracy: 0.5380
Epoch 1/1
1000/1000 [==============================] - 0s 168us/step - loss:
1.3543 - accuracy: 0.5490
Epoch 1/1
1000/1000 [==============================] - 0s 166us/step - loss:
1.4085 - accuracy: 0.5190
Epoch 1/1
1000/1000 [==============================] - 0s 164us/step - loss:
1.2611 - accuracy: 0.5640
Epoch 1/1
1000/1000 [==============================] - 0s 163us/step - loss:
1.2508 - accuracy: 0.5810
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
1.3344 - accuracy: 0.5560
Epoch 1/1
1000/1000 [==============================] - 0s 226us/step - loss:
1.2962 - accuracy: 0.5710
Epoch 1/1
1000/1000 [==============================] - 0s 166us/step - loss:
1.2448 - accuracy: 0.6010
```



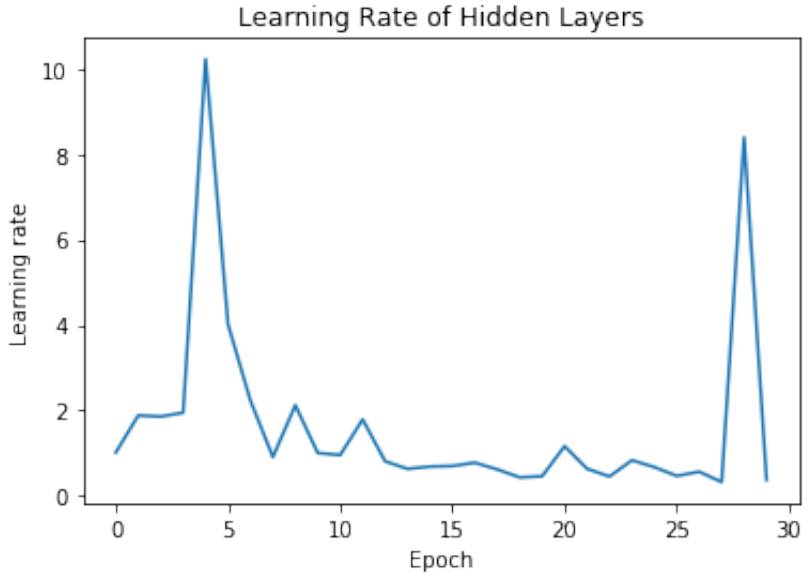

In [37]:
```
model=model_nn_3(30,10,False)
W=LearningRate(model,(24790))
LearningRate_plot(W)
```

```
Model: "sequential_12"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_33 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_34 (Dense)             (None, 30)                930
_________________________________________________________________
dense_35 (Dense)             (None, 30)                930
_________________________________________________________________
dense_36 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
```

```
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 396us/step - loss:
2.2507 - accuracy: 0.1540 - val_loss: 2.1032 - val_accuracy: 0.177
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 288us/step - loss:
1.8492 - accuracy: 0.2680 - val_loss: 1.8162 - val_accuracy: 0.256
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 287us/step - loss:
1.5780 - accuracy: 0.4040 - val_loss: 1.5697 - val_accuracy: 0.418
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 366us/step - loss:
1.4318 - accuracy: 0.4690 - val_loss: 1.5633 - val_accuracy: 0.364
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 347us/step - loss:
1.4519 - accuracy: 0.4600 - val_loss: 1.6301 - val_accuracy: 0.441
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 287us/step - loss:
1.3433 - accuracy: 0.5350 - val_loss: 1.6292 - val_accuracy: 0.460
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 265us/step - loss:
1.3035 - accuracy: 0.5390 - val_loss: 1.4576 - val_accuracy: 0.507
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 289us/step - loss:
1.3012 - accuracy: 0.5530 - val_loss: 1.4668 - val_accuracy: 0.510
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 323us/step - loss:
1.2242 - accuracy: 0.5740 - val_loss: 1.2963 - val_accuracy: 0.579
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 350us/step - loss:
1.2400 - accuracy: 0.5910 - val_loss: 1.5393 - val_accuracy: 0.463
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
```

```
1000/1000 [==============================] - 0s 349us/step - loss:
1.1613 - accuracy: 0.6240 - val_loss: 1.6911 - val_accuracy: 0.462
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 298us/step - loss:
1.2474 - accuracy: 0.6090 - val_loss: 1.5336 - val_accuracy: 0.509
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
1.1576 - accuracy: 0.6300 - val_loss: 1.3663 - val_accuracy: 0.580
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 302us/step - loss:
1.1351 - accuracy: 0.6610 - val_loss: 1.4352 - val_accuracy: 0.552
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 317us/step - loss:
1.1092 - accuracy: 0.6660 - val_loss: 1.4057 - val_accuracy: 0.573
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 340us/step - loss:
1.0824 - accuracy: 0.6660 - val_loss: 1.3471 - val_accuracy: 0.577
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 327us/step - loss:
1.1116 - accuracy: 0.6600 - val_loss: 1.3435 - val_accuracy: 0.571
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 268us/step - loss:
1.0706 - accuracy: 0.6620 - val_loss: 1.4118 - val_accuracy: 0.562
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 288us/step - loss:
1.0189 - accuracy: 0.6920 - val_loss: 1.2614 - val_accuracy: 0.586
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 270us/step - loss:
0.9120 - accuracy: 0.7350 - val_loss: 1.2826 - val_accuracy: 0.605
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 273us/step - loss:
0.9882 - accuracy: 0.7120 - val_loss: 1.3823 - val_accuracy: 0.608
0
```

```
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 294us/step - loss:
0.9810 - accuracy: 0.7150 - val_loss: 1.3732 - val_accuracy: 0.589
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 350us/step - loss:
0.9436 - accuracy: 0.7140 - val_loss: 1.3441 - val_accuracy: 0.604
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 353us/step - loss:
0.9516 - accuracy: 0.7220 - val_loss: 1.4234 - val_accuracy: 0.582
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 336us/step - loss:
0.9703 - accuracy: 0.6870 - val_loss: 1.3739 - val_accuracy: 0.565
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 284us/step - loss:
0.9880 - accuracy: 0.7140 - val_loss: 1.3223 - val_accuracy: 0.592
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 290us/step - loss:
0.9670 - accuracy: 0.6910 - val_loss: 1.3103 - val_accuracy: 0.604
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 356us/step - loss:
0.9717 - accuracy: 0.6910 - val_loss: 1.3959 - val_accuracy: 0.582
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 336us/step - loss:
1.0063 - accuracy: 0.6910 - val_loss: 1.4337 - val_accuracy: 0.556
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 339us/step - loss:
1.0367 - accuracy: 0.6600 - val_loss: 1.3723 - val_accuracy: 0.556
0
```




### Three Layer Model with regularization

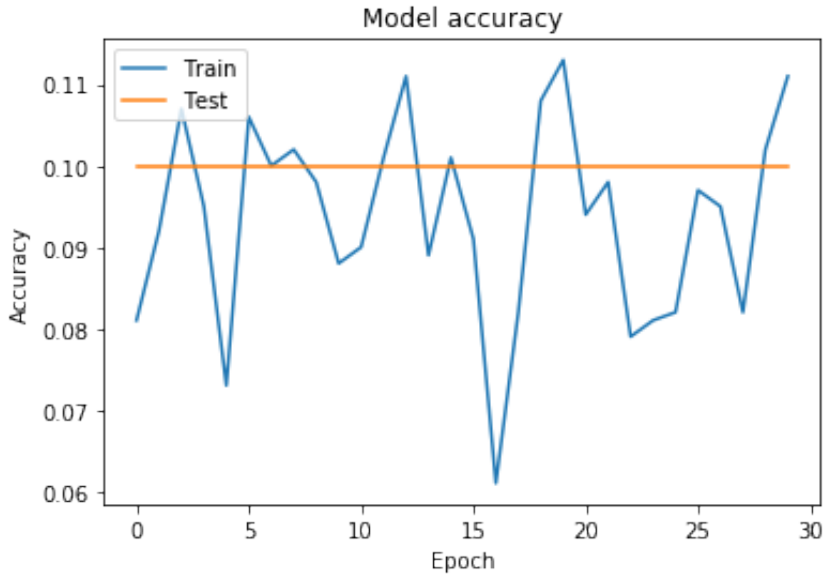
In [39]:
```
model=model_nn_3(30,10,True)
history = model.fit(X_train,y_train,validation_data=(X_test,y_test)
,epochs=30, batch_size=10)
model_accuracy()
model_loss()
```

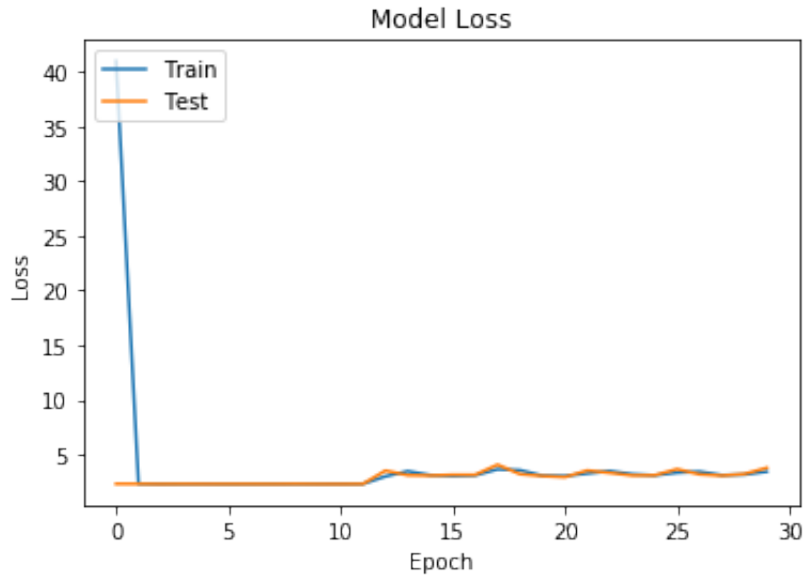
```
Model: "sequential_14"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_41 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_42 (Dense)             (None, 30)                930
_________________________________________________________________
dense_43 (Dense)             (None, 30)                930
_________________________________________________________________
dense_44 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
_________________________________________________________________
Train on 1000 samples, validate on 1000 samples
Epoch 1/30
1000/1000 [==============================] - 1s 518us/step - loss:
40.9483 - accuracy: 0.0810 - val_loss: 2.3330 - val_accuracy: 0.10
00
Epoch 2/30
1000/1000 [==============================] - 0s 314us/step - loss:
2.3452 - accuracy: 0.0920 - val_loss: 2.3288 - val_accuracy: 0.100
0
Epoch 3/30
```

```
1000/1000 [==============================] - 0s 258us/step - loss:
2.3267 - accuracy: 0.1070 - val_loss: 2.3122 - val_accuracy: 0.100
0
Epoch 4/30
1000/1000 [==============================] - 0s 264us/step - loss:
2.3298 - accuracy: 0.0950 - val_loss: 2.3229 - val_accuracy: 0.100
0
Epoch 5/30
1000/1000 [==============================] - 0s 261us/step - loss:
2.3334 - accuracy: 0.0730 - val_loss: 2.3163 - val_accuracy: 0.100
0
Epoch 6/30
1000/1000 [==============================] - 0s 265us/step - loss:
2.3234 - accuracy: 0.1060 - val_loss: 2.3178 - val_accuracy: 0.100
0
Epoch 7/30
1000/1000 [==============================] - 0s 263us/step - loss:
2.3276 - accuracy: 0.1000 - val_loss: 2.3195 - val_accuracy: 0.100
0
Epoch 8/30
1000/1000 [==============================] - 0s 268us/step - loss:
2.3293 - accuracy: 0.1020 - val_loss: 2.3136 - val_accuracy: 0.100
0
Epoch 9/30
1000/1000 [==============================] - 0s 265us/step - loss:
2.3299 - accuracy: 0.0980 - val_loss: 2.3266 - val_accuracy: 0.100
0
Epoch 10/30
1000/1000 [==============================] - 0s 264us/step - loss:
2.3303 - accuracy: 0.0880 - val_loss: 2.3116 - val_accuracy: 0.100
0
Epoch 11/30
1000/1000 [==============================] - 0s 270us/step - loss:
2.3318 - accuracy: 0.0900 - val_loss: 2.3106 - val_accuracy: 0.100
0
Epoch 12/30
1000/1000 [==============================] - 0s 266us/step - loss:
2.3285 - accuracy: 0.1010 - val_loss: 2.3227 - val_accuracy: 0.100
0
Epoch 13/30
1000/1000 [==============================] - 0s 271us/step - loss:
3.0105 - accuracy: 0.1110 - val_loss: 3.5358 - val_accuracy: 0.100
0
Epoch 14/30
1000/1000 [==============================] - 0s 267us/step - loss:
3.4854 - accuracy: 0.0890 - val_loss: 3.1242 - val_accuracy: 0.100
0
Epoch 15/30
1000/1000 [==============================] - 0s 280us/step - loss:
3.1300 - accuracy: 0.1010 - val_loss: 3.0899 - val_accuracy: 0.100
0
Epoch 16/30
1000/1000 [==============================] - 0s 259us/step - loss:
```

```
3.0634 - accuracy: 0.0910 - val_loss: 3.1579 - val_accuracy: 0.100
0
Epoch 17/30
1000/1000 [==============================] - 0s 258us/step - loss:
3.1053 - accuracy: 0.0610 - val_loss: 3.1554 - val_accuracy: 0.100
0
Epoch 18/30
1000/1000 [==============================] - 0s 262us/step - loss:
3.6642 - accuracy: 0.0820 - val_loss: 4.0776 - val_accuracy: 0.100
0
Epoch 19/30
1000/1000 [==============================] - 0s 267us/step - loss:
3.5802 - accuracy: 0.1080 - val_loss: 3.2243 - val_accuracy: 0.100
0
Epoch 20/30
1000/1000 [==============================] - 0s 261us/step - loss:
3.0764 - accuracy: 0.1130 - val_loss: 3.0521 - val_accuracy: 0.100
0
Epoch 21/30
1000/1000 [==============================] - 0s 273us/step - loss:
3.0462 - accuracy: 0.0940 - val_loss: 2.9504 - val_accuracy: 0.100
0
Epoch 22/30
1000/1000 [==============================] - 0s 265us/step - loss:
3.2782 - accuracy: 0.0980 - val_loss: 3.5513 - val_accuracy: 0.100
0
Epoch 23/30
1000/1000 [==============================] - 0s 268us/step - loss:
3.4983 - accuracy: 0.0790 - val_loss: 3.3394 - val_accuracy: 0.100
0
Epoch 24/30
1000/1000 [==============================] - 0s 265us/step - loss:
3.2159 - accuracy: 0.0810 - val_loss: 3.0996 - val_accuracy: 0.100
0
Epoch 25/30
1000/1000 [==============================] - 0s 263us/step - loss:
3.1089 - accuracy: 0.0820 - val_loss: 3.1162 - val_accuracy: 0.100
0
Epoch 26/30
1000/1000 [==============================] - 0s 265us/step - loss:
3.3532 - accuracy: 0.0970 - val_loss: 3.6727 - val_accuracy: 0.100
0
Epoch 27/30
1000/1000 [==============================] - 0s 264us/step - loss:
3.4477 - accuracy: 0.0950 - val_loss: 3.2031 - val_accuracy: 0.100
0
Epoch 28/30
1000/1000 [==============================] - 0s 268us/step - loss:
3.1250 - accuracy: 0.0820 - val_loss: 3.0840 - val_accuracy: 0.100
0
Epoch 29/30
1000/1000 [==============================] - 0s 266us/step - loss:
3.1779 - accuracy: 0.1020 - val_loss: 3.2363 - val_accuracy: 0.100
```

```
0
Epoch 30/30
1000/1000 [==============================] - 0s 262us/step - loss:
3.4499 - accuracy: 0.1110 - val_loss: 3.7903 - val_accuracy: 0.100
0
```



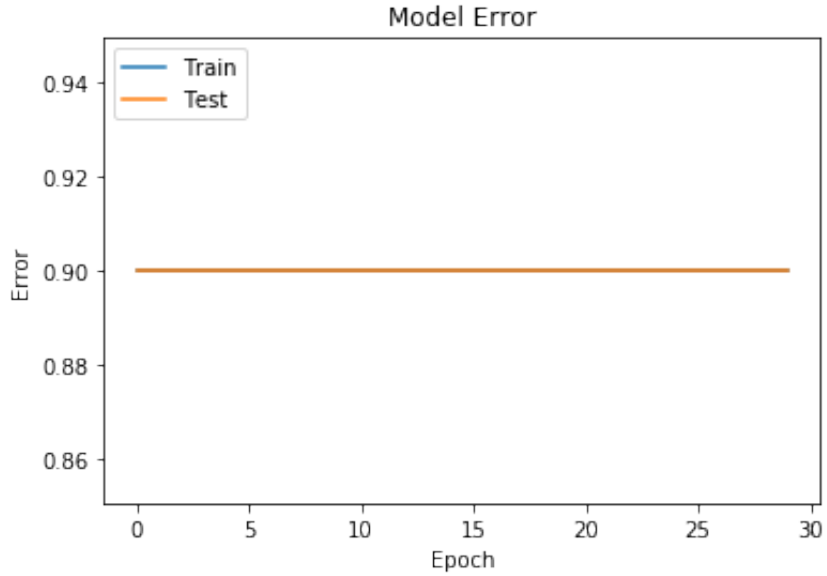



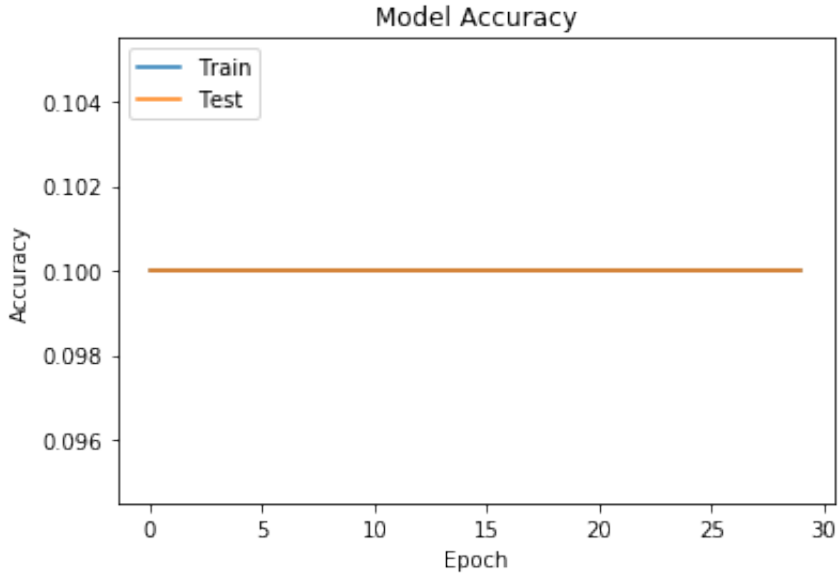

In [40]:
```
model=model_nn_3(30,10,True)
error_model(model)
```

```
Model: "sequential_15"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_45 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_46 (Dense)             (None, 30)                930
_________________________________________________________________
dense_47 (Dense)             (None, 30)                930
_________________________________________________________________
```

```
dense_48 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
_________________________________________________________________
Epoch 1/1
1000/1000 [==============================] - 0s 269us/step - loss:
40.8970 - accuracy: 0.1110
Epoch 1/1
1000/1000 [==============================] - 0s 188us/step - loss:
2.3433 - accuracy: 0.0940
Epoch 1/1
1000/1000 [==============================] - 0s 179us/step - loss:
2.3361 - accuracy: 0.0980
Epoch 1/1
1000/1000 [==============================] - 0s 195us/step - loss:
2.3323 - accuracy: 0.0940
Epoch 1/1
1000/1000 [==============================] - 0s 180us/step - loss:
2.3304 - accuracy: 0.0880
Epoch 1/1
1000/1000 [==============================] - 0s 236us/step - loss:
2.3315 - accuracy: 0.0860
Epoch 1/1
1000/1000 [==============================] - 0s 219us/step - loss:
2.3293 - accuracy: 0.0970
Epoch 1/1
1000/1000 [==============================] - 0s 221us/step - loss:
2.3380 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 174us/step - loss:
2.3266 - accuracy: 0.1140
Epoch 1/1
1000/1000 [==============================] - 0s 175us/step - loss:
2.3339 - accuracy: 0.0890
Epoch 1/1
1000/1000 [==============================] - 0s 187us/step - loss:
2.3286 - accuracy: 0.0880
Epoch 1/1
1000/1000 [==============================] - 0s 181us/step - loss:
2.3272 - accuracy: 0.0900
Epoch 1/1
1000/1000 [==============================] - 0s 173us/step - loss:
3.0129 - accuracy: 0.1030
Epoch 1/1
1000/1000 [==============================] - 0s 174us/step - loss:
3.5045 - accuracy: 0.0920
Epoch 1/1
1000/1000 [==============================] - 0s 173us/step - loss:
3.1295 - accuracy: 0.0890
Epoch 1/1
1000/1000 [==============================] - 0s 175us/step - loss:
```

```
3.0997 - accuracy: 0.0870
Epoch 1/1
1000/1000 [==============================] - 0s 176us/step - loss:
3.0516 - accuracy: 0.1090
Epoch 1/1
1000/1000 [==============================] - 0s 176us/step - loss:
3.6236 - accuracy: 0.1060
Epoch 1/1
1000/1000 [==============================] - 0s 180us/step - loss:
3.6269 - accuracy: 0.0950
Epoch 1/1
1000/1000 [==============================] - 0s 180us/step - loss:
3.1198 - accuracy: 0.0830
Epoch 1/1
1000/1000 [==============================] - 0s 169us/step - loss:
3.0338 - accuracy: 0.1030
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
3.1860 - accuracy: 0.1000
Epoch 1/1
1000/1000 [==============================] - 0s 173us/step - loss:
3.5229 - accuracy: 0.0850
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
3.2443 - accuracy: 0.0880
Epoch 1/1
1000/1000 [==============================] - 0s 177us/step - loss:
3.1260 - accuracy: 0.0910
Epoch 1/1
1000/1000 [==============================] - 0s 182us/step - loss:
3.2801 - accuracy: 0.0950
Epoch 1/1
1000/1000 [==============================] - 0s 173us/step - loss:
3.3932 - accuracy: 0.0940
Epoch 1/1
1000/1000 [==============================] - 0s 176us/step - loss:
3.2184 - accuracy: 0.0990
Epoch 1/1
1000/1000 [==============================] - 0s 172us/step - loss:
3.2048 - accuracy: 0.0890
Epoch 1/1
1000/1000 [==============================] - 0s 177us/step - loss:
3.3562 - accuracy: 0.0890
```



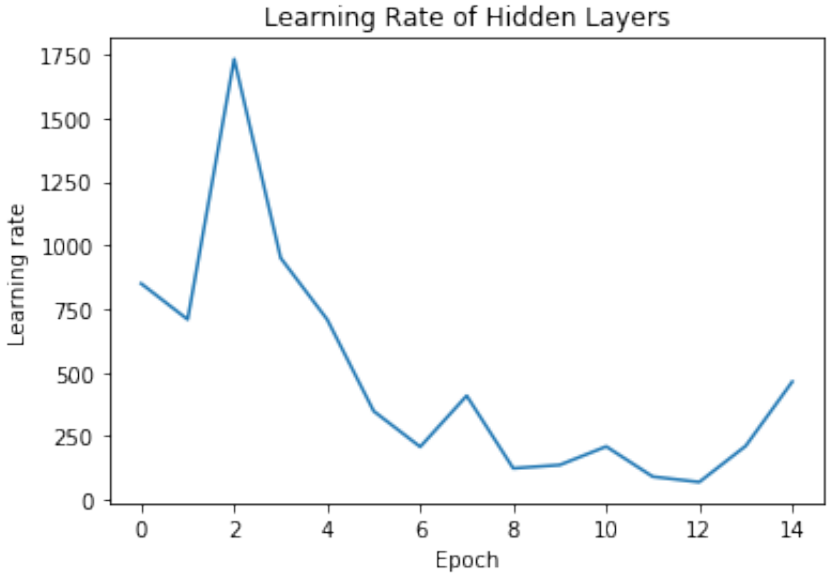

In [41]:
```
model=model_nn_3(30,10,True)
W=LearningRate(model,(24790))
LearningRate_plot(W)
```

```
Model: "sequential_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_49 (Dense)             (None, 30)                23550
_________________________________________________________________
dense_50 (Dense)             (None, 30)                930
_________________________________________________________________
dense_51 (Dense)             (None, 30)                930
_________________________________________________________________
dense_52 (Dense)             (None, 10)                310
=================================================================
Total params: 25,720
Trainable params: 25,720
Non-trainable params: 0
```

```
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 405us/step - loss:
40.6369 - accuracy: 0.1070 - val_loss: 2.3445 - val_accuracy: 0.10
00
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
2.3492 - accuracy: 0.0930 - val_loss: 2.3382 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 281us/step - loss:
2.3296 - accuracy: 0.1010 - val_loss: 2.3533 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 368us/step - loss:
2.3319 - accuracy: 0.1080 - val_loss: 2.3329 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 359us/step - loss:
2.3296 - accuracy: 0.0970 - val_loss: 2.3300 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 318us/step - loss:
2.3252 - accuracy: 0.0990 - val_loss: 2.3208 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 389us/step - loss:
2.3365 - accuracy: 0.0890 - val_loss: 2.3343 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 300us/step - loss:
2.3299 - accuracy: 0.0800 - val_loss: 2.3182 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 304us/step - loss:
2.3208 - accuracy: 0.1120 - val_loss: 2.3241 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 299us/step - loss:
2.3284 - accuracy: 0.0830 - val_loss: 2.3153 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
```

```
1000/1000 [==============================] - 0s 320us/step - loss:
2.3231 - accuracy: 0.1040 - val_loss: 2.3265 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 278us/step - loss:
2.3284 - accuracy: 0.0970 - val_loss: 2.3248 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 287us/step - loss:
3.0088 - accuracy: 0.0900 - val_loss: 3.4482 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 293us/step - loss:
3.4916 - accuracy: 0.0960 - val_loss: 3.2517 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
3.1169 - accuracy: 0.0880 - val_loss: 3.0378 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 275us/step - loss:
3.0654 - accuracy: 0.1100 - val_loss: 3.0522 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 279us/step - loss:
3.0898 - accuracy: 0.0820 - val_loss: 3.2365 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
3.6430 - accuracy: 0.0900 - val_loss: 4.1971 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 283us/step - loss:
3.5887 - accuracy: 0.0900 - val_loss: 3.2497 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 284us/step - loss:
3.1262 - accuracy: 0.0840 - val_loss: 3.1051 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 281us/step - loss:
3.0207 - accuracy: 0.1000 - val_loss: 3.0554 - val_accuracy: 0.100
0
```

```
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 280us/step - loss:
3.2636 - accuracy: 0.0740 - val_loss: 3.4238 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 284us/step - loss:
3.5086 - accuracy: 0.1060 - val_loss: 3.3532 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 273us/step - loss:
3.2125 - accuracy: 0.0890 - val_loss: 3.1706 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 274us/step - loss:
3.0988 - accuracy: 0.1130 - val_loss: 3.0557 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 279us/step - loss:
3.3321 - accuracy: 0.0960 - val_loss: 3.5043 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 277us/step - loss:
3.4340 - accuracy: 0.0850 - val_loss: 3.1911 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 271us/step - loss:
3.1545 - accuracy: 0.0810 - val_loss: 3.1151 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 288us/step - loss:
3.1840 - accuracy: 0.0920 - val_loss: 3.2157 - val_accuracy: 0.100
0
Train on 1000 samples, validate on 1000 samples
Epoch 1/1
1000/1000 [==============================] - 0s 284us/step - loss:
3.4083 - accuracy: 0.0930 - val_loss: 3.8243 - val_accuracy: 0.100
0
```




### Defining CNN Model

In [126]:
```
from keras.models import Sequential, Model
from keras.layers import Conv2D, MaxPooling2D, AveragePooling2D, La
mbda, Input, Dense, Dropout, Flatten
from keras.layers.advanced_activations import LeakyReLU,Thresholded
ReLU
from keras.layers.normalization import BatchNormalization
from keras.preprocessing.image import ImageDataGenerator
from keras.optimizers import SGD,Adam,Nadam,Adamax,TFOptimizer
```

In [127]:
```
def cnn():

    # Create Model
    model = Sequential()
    model.add(Conv2D(32,kernel_size=(3, 3),activation='linear',inpu
t_shape=(28,28,1),padding='same'))
    model.add(LeakyReLU(alpha=0.1))
    model.add(MaxPooling2D((2, 2),padding='same'))
    model.add(Dropout(0.2))
    model.add(Conv2D(64,(3, 3),activation='linear',padding='same'))
    model.add(LeakyReLU(alpha=0.1))
    model.add(MaxPooling2D(pool_size=(2, 2),padding='same'))
    model.add(Dropout(0.2))
    model.add(Conv2D(128,(3, 3),activation='linear',padding='same')
)
    model.add(LeakyReLU(alpha=0.1))
    model.add(Dropout(0.2))
    model.add(MaxPooling2D(pool_size=(2,2),padding='same'))
    model.add(Flatten())
    model.add(Dense(256,activation='linear'))
    model.add(LeakyReLU(alpha=0.1))
    model.add(Dense(10,activation='softmax'))
    model.compile(loss='categorical_crossentropy',optimizer=Adam(le
arning_rate=0.1),metrics=['accuracy'])
    model.summary()

    return model
```

In [128]:
```
model=cnn()
```

```
Model: "sequential_35"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_22 (Conv2D)           (None, 28, 28, 32)        320
_________________________________________________________________
leaky_re_lu_29 (LeakyReLU)   (None, 28, 28, 32)        0
_________________________________________________________________
max_pooling2d_22 (MaxPooling (None, 14, 14, 32)        0
_________________________________________________________________
dropout_22 (Dropout)         (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_23 (Conv2D)           (None, 14, 14, 64)        18496
_________________________________________________________________
leaky_re_lu_30 (LeakyReLU)   (None, 14, 14, 64)        0
_________________________________________________________________
max_pooling2d_23 (MaxPooling (None, 7, 7, 64)          0
_________________________________________________________________
dropout_23 (Dropout)         (None, 7, 7, 64)          0
_________________________________________________________________
conv2d_24 (Conv2D)           (None, 7, 7, 128)         73856
_________________________________________________________________
leaky_re_lu_31 (LeakyReLU)   (None, 7, 7, 128)         0
_________________________________________________________________
dropout_24 (Dropout)         (None, 7, 7, 128)         0
_________________________________________________________________
max_pooling2d_24 (MaxPooling (None, 4, 4, 128)         0
_________________________________________________________________
flatten_8 (Flatten)          (None, 2048)              0
_________________________________________________________________
dense_89 (Dense)             (None, 256)               524544
_________________________________________________________________
leaky_re_lu_32 (LeakyReLU)   (None, 256)               0
_________________________________________________________________
dense_90 (Dense)             (None, 10)                2570
=================================================================
Total params: 619,786
Trainable params: 619,786
Non-trainable params: 0
_________________________________________________________________
```

In [129]:
```
X_train.shape,X_test.shape
```

Out[129]:
```
((1000, 784), (1000, 784))
```

In [130]:
```
y_train.shape
```

Out[130]:
```
(1000, 10)
```

In [131]:
```
X_train=X_train.reshape(1000,28,28,1)
X_test=X_test.reshape(1000,28,28,1)
```

In [132]:
```
X_train.shape
```

Out[132]:
```
(1000, 28, 28, 1)
```

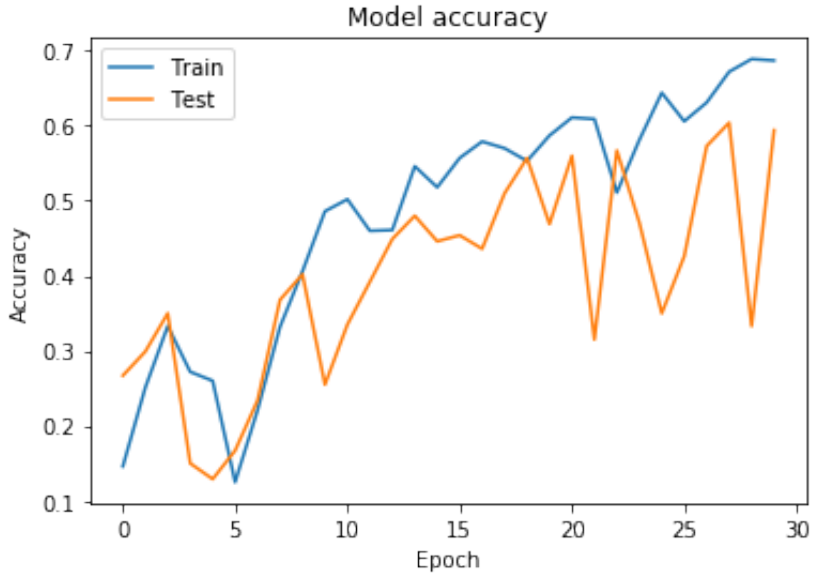
In [133]:
```
gen = ImageDataGenerator(width_shift_range=3,height_shift_range=3,r
otation_range=3)
batches = gen.flow(X_train, y_train, batch_size=10)
val_batches = gen.flow(X_test, y_test, batch_size=10)

history=model.fit_generator(batches, steps_per_epoch=1000//10, epoc
hs=30,validation_data=val_batches, validation_steps=1000//10)
```

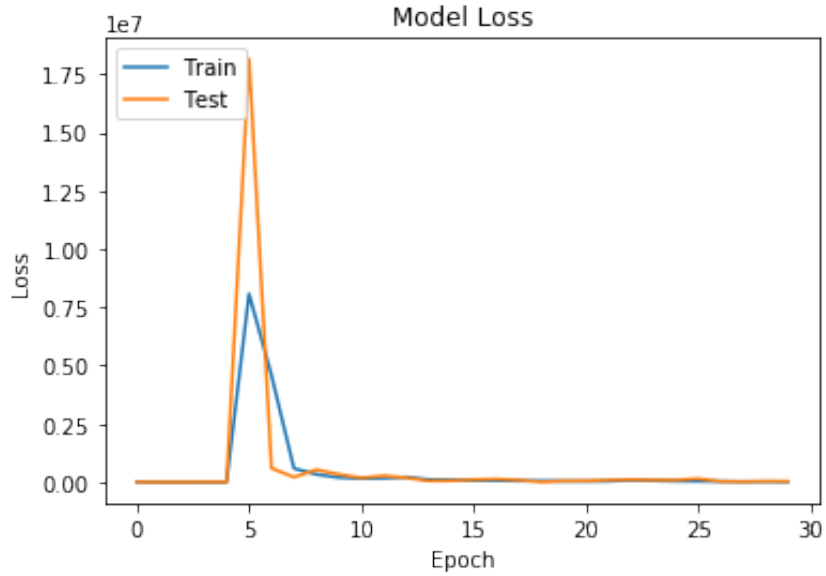
```
Epoch 1/30
100/100 [==============================] - 4s 39ms/step - loss: 16
014.3135 - accuracy: 0.1460 - val_loss: 1971.1371 - val_accuracy:
0.2670
Epoch 2/30
100/100 [==============================] - 3s 34ms/step - loss: 10
30.2441 - accuracy: 0.2510 - val_loss: 67.2700 - val_accuracy: 0.2
990
Epoch 3/30
100/100 [==============================] - 3s 35ms/step - loss: 15
3.7517 - accuracy: 0.3330 - val_loss: 191.4404 - val_accuracy: 0.3
500
Epoch 4/30
100/100 [==============================] - 4s 37ms/step - loss: 11
36.5329 - accuracy: 0.2720 - val_loss: 2472.2087 - val_accuracy: 0
.1500
Epoch 5/30
100/100 [==============================] - 4s 36ms/step - loss: 11
91.7899 - accuracy: 0.2600 - val_loss: 5188.4268 - val_accuracy: 0
.1290
Epoch 6/30
100/100 [==============================] - 3s 35ms/step - loss: 80
73340.3646 - accuracy: 0.1250 - val_loss: 18144960.0000 - val_accu
racy: 0.1670
Epoch 7/30
100/100 [==============================] - 3s 34ms/step - loss: 45
79967.4138 - accuracy: 0.2210 - val_loss: 593103.2500 - val_accura
cy: 0.2340
Epoch 8/30
100/100 [==============================] - 4s 37ms/step - loss: 58
5645.8569 - accuracy: 0.3320 - val_loss: 212050.1719 - val_accurac
y: 0.3680
Epoch 9/30
100/100 [==============================] - 4s 35ms/step - loss: 32
9384.7674 - accuracy: 0.4060 - val_loss: 529407.1250 - val_accurac
y: 0.4020
Epoch 10/30
100/100 [==============================] - 3s 35ms/step - loss: 19
6399.3884 - accuracy: 0.4860 - val_loss: 333899.0938 - val_accurac
y: 0.2550
Epoch 11/30
```

```
100/100 [==============================] - 3s 34ms/step - loss: 15
1382.6084 - accuracy: 0.5020 - val_loss: 178355.2500 - val_accurac
y: 0.3350
Epoch 12/30
100/100 [==============================] - 4s 35ms/step - loss: 16
7572.5747 - accuracy: 0.4600 - val_loss: 271296.0938 - val_accurac
y: 0.3920
Epoch 13/30
100/100 [==============================] - 4s 37ms/step - loss: 21
2337.0158 - accuracy: 0.4610 - val_loss: 183798.0000 - val_accurac
y: 0.4490
Epoch 14/30
100/100 [==============================] - 4s 37ms/step - loss: 10
6882.1790 - accuracy: 0.5460 - val_loss: 49503.0000 - val_accuracy
: 0.4800
Epoch 15/30
100/100 [==============================] - 4s 35ms/step - loss: 94
829.3142 - accuracy: 0.5180 - val_loss: 56790.2734 - val_accuracy:
0.4460
Epoch 16/30
100/100 [==============================] - 3s 35ms/step - loss: 69
711.0031 - accuracy: 0.5570 - val_loss: 105118.8281 - val_accuracy
: 0.4540
Epoch 17/30
100/100 [==============================] - 4s 37ms/step - loss: 64
046.1290 - accuracy: 0.5790 - val_loss: 129631.1250 - val_accuracy
: 0.4360
Epoch 18/30
100/100 [==============================] - 4s 35ms/step - loss: 52
272.6501 - accuracy: 0.5700 - val_loss: 87196.1406 - val_accuracy:
0.5100
Epoch 19/30
100/100 [==============================] - 4s 39ms/step - loss: 56
672.8345 - accuracy: 0.5530 - val_loss: 4202.5562 - val_accuracy:
0.5570
Epoch 20/30
100/100 [==============================] - 4s 36ms/step - loss: 42
749.8611 - accuracy: 0.5870 - val_loss: 48134.4492 - val_accuracy:
0.4690
Epoch 21/30
100/100 [==============================] - 4s 36ms/step - loss: 35
196.1669 - accuracy: 0.6110 - val_loss: 56403.7734 - val_accuracy:
0.5600
Epoch 22/30
100/100 [==============================] - 4s 40ms/step - loss: 40
193.2020 - accuracy: 0.6090 - val_loss: 83542.1875 - val_accuracy:
0.3150
Epoch 23/30
100/100 [==============================] - 4s 38ms/step - loss: 83
601.5778 - accuracy: 0.5110 - val_loss: 108153.8281 - val_accuracy
: 0.5670
Epoch 24/30
100/100 [==============================] - 3s 34ms/step - loss: 60
```

```
569.3805 - accuracy: 0.5810 - val_loss: 87683.2500 - val_accuracy:
0.4710
Epoch 25/30
100/100 [==============================] - 4s 35ms/step - loss: 40
339.9521 - accuracy: 0.6440 - val_loss: 85272.8750 - val_accuracy:
0.3500
Epoch 26/30
100/100 [==============================] - 3s 34ms/step - loss: 37
744.4988 - accuracy: 0.6060 - val_loss: 146556.0469 - val_accuracy
: 0.4260
Epoch 27/30
100/100 [==============================] - 4s 38ms/step - loss: 29
169.2627 - accuracy: 0.6310 - val_loss: 28230.4375 - val_accuracy:
0.5730
Epoch 28/30
100/100 [==============================] - 4s 36ms/step - loss: 22
701.6729 - accuracy: 0.6720 - val_loss: 16576.8320 - val_accuracy:
0.6040
Epoch 29/30
100/100 [==============================] - 4s 36ms/step - loss: 21
549.0789 - accuracy: 0.6890 - val_loss: 37421.1172 - val_accuracy:
0.3330
Epoch 30/30
100/100 [==============================] - 4s 35ms/step - loss: 17
167.5762 - accuracy: 0.6870 - val_loss: 28015.0312 - val_accuracy:
0.5940
```

In [134]:
```
model_accuracy()
model_loss()
```




**References:**

https://www.kaggle.com/imrandude/fashion-mnist-cnn-imagedatagenerator (https://www.kaggle.com/imrandude/fashion-mnist-cnn-imagedatagenerator)