In [45]:

```
import torch
# Device configuration
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
device
```

Out[45]:

```
device(type='cpu')
```

In [46]:

```
from torchvision import datasets, transforms
from torchvision.transforms import ToTensor
from torch import nn
import torch.nn.functional as F
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
```

In [57]:

```
learning_rate = 0.001
batch_size    = 100
N_epochs      = 10
N_iter_train  = 250
N_iter_test   = 40
N_iter_check  = 20
input_size    = 2

hidden_size   = 10
L = 10
loss_flag = 0
```

In [58]:

```
def binary_sequence_generator(L,batch_size = batch_size):

    x = np.zeros((batch_size, L+1 ,2)) #we zero pad as output sequence might have dimen
sion L+1
    y = np.zeros((batch_size,L+1)) #output

    for i in range(batch_size):
        a = np.random.randint(0,2**(L)) #number 1
        b = np.random.randint(0,2**L) #number 2
        c = a+b #sum


        bin_a = bin(a)[2:]
        bin_a = list(str('0')*(L+1 - len(bin_a)) + bin_a) #sign extension
        bin_a = np.asarray(bin_a[::-1],dtype = int) #converting to numpy array and reve
rsing the string

        bin_b = bin(b)[2:]
        bin_b = list(str('0')*(L+1 - len(bin_b)) + bin_b) #sign extension
        bin_b = np.asarray(bin_b[::-1],dtype = int) #converting to numpy array and reve
rsing the string


        bin_c = bin(c)[2:]
        bin_c = list(str('0')*(L+1 - len(bin_c)) + bin_c) #sign extension
        bin_c = np.asarray(bin_c[::-1],dtype = int) #converting to numpy array and reve
rsing the string



        x[i,:,0] = bin_a
        x[i,:,1] = bin_b
        y[i]     = bin_c

    x = torch.tensor(x, dtype=torch.int)
    y = torch.tensor(y, dtype=torch.int)

    return x.float(),y #returning float as that is what is used in forward pass
```

In [59]:

```
def cross_entropy(pred, target): #custom cross entropy loss function as normal Pytorch
 doesn't support
    return (1/2)*(torch.mean(-torch.sum(target * torch.log(pred))) + torch.mean(-torch.
sum((1-target) * torch.log(1-pred))))
```

In [60]:

```
class Binary_LSTM(nn.Module):
    def __init__(self, input_dim=2, hidden_dim=5, num_layers=1):
        super(Binary_LSTM, self).__init__()
        self.hidden_dim = hidden_dim
        self.num_layers = num_layers
        self.lstm = nn.LSTM(input_dim, hidden_dim, num_layers, batch_first=True,bidirec
tional=False)
        self.fc = nn.Linear(hidden_dim,1) #as size of the output is 1
        self.sigmoid = nn.Sigmoid()

    def forward(self,x):
        h0 = torch.zeros(self.num_layers, x.size(0), self.hidden_dim).requires_grad_().
to(device)
        c0 = torch.zeros(self.num_layers, x.size(0), self.hidden_dim).requires_grad_().
to(device)
        out, (hn, cn) = self.lstm(x, (h0.detach(), c0.detach()))
        pred   = self.sigmoid(self.fc(out)) #output at every time step
        return pred
```

In [61]:

```
from torch import optim
loss_func = nn.CrossEntropyLoss()
model = Binary_LSTM().to(device)
optimizer = optim.Adam(model.parameters(), lr = 0.001)
```

In [62]:

```
def Train_sum(model,L,optimizer,loss_func,loss_flag,N_iter_train = N_iter_train): #loss
_flag = 1 for MSE and 0 for CE

    model.train() #setting the model in training mode
    #initializing the total training loss and total correct training predictions to 0
    train_loss    = 0
    train_correct = 0 #correct predictions made

    train_length = batch_size*N_iter_train

    for i in range(N_iter_train):

        x,y = binary_sequence_generator(L)
        x = x.to(device)
        y = y.to(device)

        pred = model(x) #prediction using the input data (explicitly make it float)

        if(loss_flag == 0): #CE Loss

            loss = cross_entropy(pred,y.view(pred.size()))

        elif(loss_flag == 1): #MSE Loss

            loss = loss_func(pred,y.view(pred.size()).float()) #converting to float for
MSE loss

        optimizer.zero_grad() #zeroing out the gradients before backprop
        loss.backward()       #backprop from the loss
        optimizer.step()      #updating the weights


        #prediction made by LSTM
        threshold = torch.Tensor([0.5])
        pred_y = (pred > threshold).float() * 1

        #convert to base 10 equivalent
        pred_y = pred_y.numpy()[:,:,0]
        pred_y = pred_y.dot(2**np.arange(pred_y.shape[1]))

        y_10 = y.numpy()
        y_10 = y_10.dot(2**np.arange(y_10.shape[1]))

        #Adding this loss to  training loss and computing correct predictions
        train_loss    += loss
        train_correct += np.sum(pred_y == y_10) #as subtraction will result in 0 for co
rrect pred, bitwise accuracy

    #Computing training accuracy
    train_loss = train_loss/train_length
    train_correct /= train_length #training accuracy

    return train_loss.detach().cpu().numpy(), train_correct #returning loss and accurac
y
```

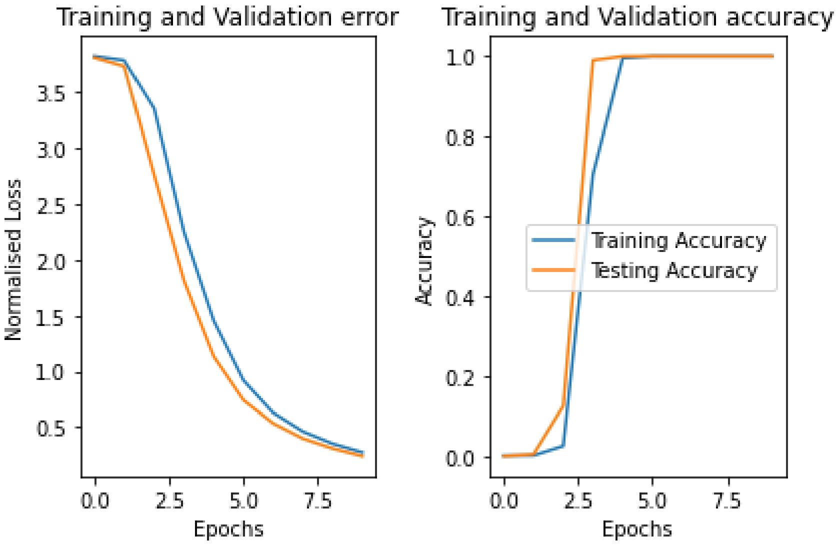
In [63]:

```
def Test_sum(model,L,loss_func,loss_flag,N_iter_test = N_iter_test): #as we're supposed
to test on 100 samples

    model.eval()  #setting the model in eval/test mode

    #initializing the total test loss and total correct test predictions to 0
    test_loss    = 0
    test_correct = 0 #correct predictions made
    test_length = batch_size*N_iter_test

    #switching off the gradient for eval
    with torch.no_grad():

        for i in range(N_iter_test):

            x,y = binary_sequence_generator(L)
            x = x.to(device)
            y = y.to(device)

            pred = model(x.float()) #prediction using the input data

            if(loss_flag == 0): #CE Loss

                loss = cross_entropy(pred,y.view(pred.size()))

            elif(loss_flag == 1): #MSE Loss

                loss = loss_func(pred,y.view(pred.size()).float()) #converting to float
for MSE loss


            #prediction made by LSTM
            threshold = torch.Tensor([0.5])
            pred_y = (pred > threshold).float() * 1

            #convert to base 10 equivalent
            pred_y = pred_y.numpy()[:,:,0]
            pred_y = pred_y.dot(2**np.arange(pred_y.shape[1]))

            y_10 = y.numpy()
            y_10 = y_10.dot(2**np.arange(y_10.shape[1]))

            #Adding this loss to  testing loss and computing correct predictions
            test_loss    += loss
            test_correct += np.sum(pred_y==y_10) #as subtraction will result in 0 for c
orrect pred

    #Computing prediction accuracy
    test_loss = test_loss/test_length
    test_correct /= test_length #prediction accuracy

    return test_loss.detach().cpu().numpy(), test_correct #returning loss and accuracy
```

In [64]:

```
#initialising the lists
train_losses   = []
test_losses    = []
train_accuracy = []
test_accuracy  = []
loss_flag = 0

for epoch in range(1, N_epochs+1):
       print(epoch, '/', N_epochs)

       #train the model
       loss,accuracy = Train_sum(model,L,optimizer,loss_func,loss_flag,N_iter_train = N
_iter_train)
       train_losses.append(loss)
       train_accuracy.append(accuracy)
       print('Train loss for Epoch ',epoch,': ',loss,' | ', 'Train accuracy for Epoch '
,epoch, ': ',accuracy)

       #test the model
       loss,accuracy = Test_sum(model,L,loss_func,loss_flag,N_iter_test = N_iter_test)
       test_losses.append(loss)
       test_accuracy.append(accuracy)
       print('Test loss for Epoch ',epoch,': ',loss, ' | ', 'Test accuracy for Epoch ',
epoch, ': ',accuracy)

#Plotting the Loss and the accuracy curves
fig, (ax1, ax2) = plt.subplots(1, 2)
ax1.plot(np.asfarray(train_losses),label = 'Train Loss') #converting to float array
ax1.plot(np.asfarray(test_losses),label = 'Validation Loss')
ax1.set(xlabel='Epochs', ylabel='Normalised Loss')
ax1.set_title('Training and Validation error')

ax2.plot(np.asfarray(train_accuracy),label = 'Training Accuracy')
ax2.plot(np.asfarray(test_accuracy),label = 'Testing Accuracy')
ax2.set(xlabel='Epochs', ylabel='Accuracy')
ax2.set_title('Training and Validation accuracy')
ax2.legend()
fig.tight_layout()
```

```
1 / 10
Train loss for Epoch  1 :  3.820615  |  Train accuracy for Epoch  1 :  0.0
0172
Test loss for Epoch  1 :  3.8069296  |  Test accuracy for Epoch  1 :  0.00
025
2 / 10
Train loss for Epoch  2 :  3.7838008  |  Train accuracy for Epoch  2 :  0.
0018
Test loss for Epoch  2 :  3.7308614  |  Test accuracy for Epoch  2 :  0.00
475
3 / 10
Train loss for Epoch  3 :  3.3522274  |  Train accuracy for Epoch  3 :  0.
02548
Test loss for Epoch  3 :  2.7577474  |  Test accuracy for Epoch  3 :  0.12
575
4 / 10
Train loss for Epoch  4 :  2.2501662  |  Train accuracy for Epoch  4 :  0.
70484
Test loss for Epoch  4 :  1.8127952  |  Test accuracy for Epoch  4 :  0.99
5 / 10
Train loss for Epoch  5 :  1.4532806  |  Train accuracy for Epoch  5 :  0.
9954
Test loss for Epoch  5 :  1.1328025  |  Test accuracy for Epoch  5 :  0.99
975
6 / 10
Train loss for Epoch  6 :  0.9191309  |  Train accuracy for Epoch  6 :  0.
99996
Test loss for Epoch  6 :  0.74274343  |  Test accuracy for Epoch  6 :  1.0
7 / 10
Train loss for Epoch  7 :  0.6284493  |  Train accuracy for Epoch  7 :  1.
0
Test loss for Epoch  7 :  0.53324753  |  Test accuracy for Epoch  7 :  1.0
8 / 10
Train loss for Epoch  8 :  0.46047288  |  Train accuracy for Epoch  8 :
1.0
Test loss for Epoch  8 :  0.39775005  |  Test accuracy for Epoch  8 :  1.0
9 / 10
Train loss for Epoch  9 :  0.3521427  |  Train accuracy for Epoch  9 :  1.
0
Test loss for Epoch  9 :  0.30962032  |  Test accuracy for Epoch  9 :  1.0
10 / 10
Train loss for Epoch  10 :  0.27509204  |  Train accuracy for Epoch  10 :
1.0
Test loss for Epoch  10 :  0.24194752  |  Test accuracy for Epoch  10 :
1.0
```


Training and Validation error
Normalised Loss
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.5
5.0
7.5
Epochs
Training and Validation accuracy
Accuracy
1.0
0.8
0.6
0.4
0.2
0.0
Training Accuracy
Testing Accuracy
0.0
2.5
5.0
7.5
Epochs

In [65]:

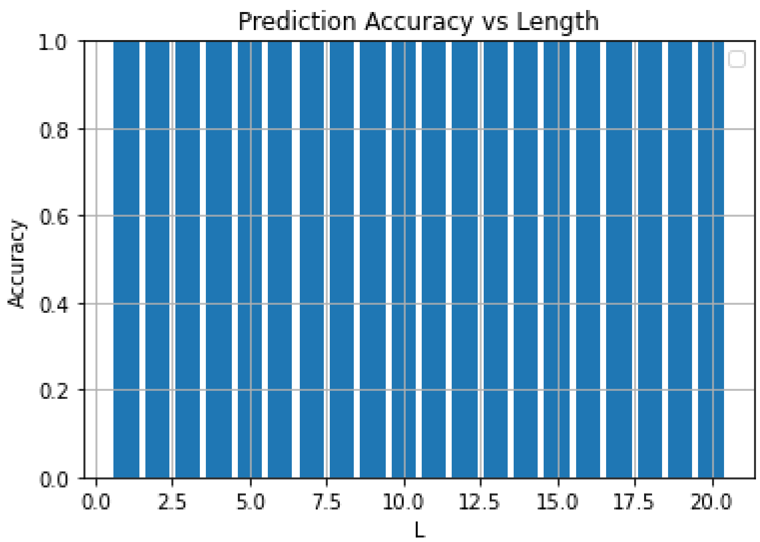
```
def Check_binary_sequence(model,loss_flag,lossfn,N_iter_check):

    model.eval()

    test_accuracies = []

    for L in range(1,21): #iterating through L in the required range

        #initializing the total test loss and total correct test predictions to 0
        test_loss    = 0
        test_correct = 0 #correct predictions made
        test_length = N_iter_check

        #switching off the gradient for eval
        with torch.no_grad():


            x,y = binary_sequence_generator(L,batch_size = N_iter_check)
            x = x.to(device)
            y = y.to(device)

            pred = model(x.float()) #prediction using the input data

            if(loss_flag == 0): #CE Loss

                loss = cross_entropy(pred,y.view(pred.size()))

            elif(loss_flag == 1): #MSE Loss

                loss = lossfn(pred,y.view(pred.size()).float()) #converting to float fo
r MSE loss

            #prediction made by LSTM
            threshold = torch.Tensor([0.5])
            pred_y = (pred > threshold).float() * 1

            #convert to base 10 equivalent
            pred_y = pred_y.numpy()[:,:,0]
            pred_y = pred_y.dot(2**np.arange(pred_y.shape[1]))

            y_10 = y.numpy()
            y_10 = y_10.dot(2**np.arange(y_10.shape[1]))

            #Adding this loss to  testing loss and computing correct predictions
            test_loss    += loss
            test_correct += np.sum(pred_y==y_10) #as subtraction will result in 0 for c
orrect pred

            #Computing prediction accuracy

            test_correct /= test_length #prediction accuracy

            test_accuracies.append(test_correct)


    #plotting test accuracies vs L

    plt.bar(np.arange(1,21),test_accuracies)
    plt.xlabel('L')
```

```
    plt.ylabel('Accuracy')
    plt.ylim(0,1) #as accuracy is between 0 and 1
    plt.grid()
    plt.legend()
    plt.title('Prediction Accuracy vs Length')
    plt.show()

    print(f'Prediction Accuracies : {test_accuracies}')
```

In [66]:

```
Check_binary_sequence(model,loss_flag,loss_func,N_iter_check)
```

```
WARNING:matplotlib.legend:No handles with labels found to put in legend.
```




```
Prediction Accuracies : [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0,
1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]
```