In [1]:

```
import os
import torch
from torch import nn
import torch.nn as nn
import torch.nn.functional as F
import numpy as np
import matplotlib.pyplot as plt
import torchvision
from torch.utils.data import DataLoader
from torchvision import transforms, datasets
from torch.utils.data.sampler import SubsetRandomSampler
```

In [2]:

```
transform = transforms.Compose(
    [transforms.ToTensor(),
     transforms.Normalize((0.5), (0.5))])

batch_size = 4
trainSet = datasets.FashionMNIST('~/.pytorch/F_MNIST_data',download=True, train=True, trans
trainLoader = torch.utils.data.DataLoader(trainSet, batch_size=batch_size, shuffle=True, nu

testSet = datasets.FashionMNIST('~/.pytorch/F_MNIST_data',download=True, train=False, trans
testLoader = torch.utils.data.DataLoader(testSet, batch_size=batch_size, shuffle=False, num

classes = ('T-shirt/top', 'Trouser', 'Pullover', 'Dress',
           'Coat', 'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot')
```

```
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train
-images-idx3-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/train-images-idx3-ubyte.gz)
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train
-images-idx3-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/train-images-idx3-ubyte.gz) to /root/.pytorch/F_MNIST_data/FashionMNIS
T/raw/train-images-idx3-ubyte.gz

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Extracting /root/.pytorch/F_MNIST_data/FashionMNIST/raw/train-images-idx3-ub
yte.gz to /root/.pytorch/F_MNIST_data/FashionMNIST/raw

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-labels-idx1-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/train-labels-idx1-ubyte.gz)
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-labels-idx1-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/train-labels-idx1-ubyte.gz) to /root/.pytorch/F_MNIST_data/FashionMNIS
T/raw/train-labels-idx1-ubyte.gz

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yte.gz to /root/.pytorch/F_MNIST_data/FashionMNIST/raw

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images-idx3-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/t10k-images-idx3-ubyte.gz) to /root/.pytorch/F_MNIST_data/FashionMNIS
T/raw/t10k-images-idx3-ubyte.gz

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te.gz to /root/.pytorch/F_MNIST_data/FashionMNIST/raw

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labels-idx1-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/t10k-labels-idx1-ubyte.gz)
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/t10k-
labels-idx1-ubyte.gz (http://fashion-mnist.s3-website.eu-central-1.amazonaw
s.com/t10k-labels-idx1-ubyte.gz) to /root/.pytorch/F_MNIST_data/FashionMNIS
T/raw/t10k-labels-idx1-ubyte.gz
```
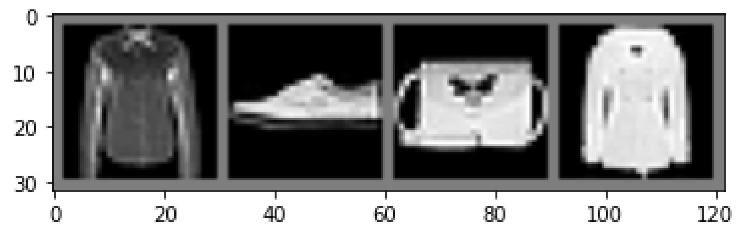

```
  0%|          | 0/5148 [00:00<?, ?it/s]

Extracting /root/.pytorch/F_MNIST_data/FashionMNIST/raw/t10k-labels-idx1-uby
te.gz to /root/.pytorch/F_MNIST_data/FashionMNIST/raw
```

In [3]:

```
def imshow(img):
    img = img / 2 + 0.5     # unnormalize
    npimg = img.numpy()
    plt.imshow(np.transpose(npimg, (1, 2, 0)))
    plt.show()


# get some random training images
dataiter = iter(trainLoader)
images, labels = next(dataiter)

# show images
imshow(torchvision.utils.make_grid(images))
# print labels
print(' '.join(f'{classes[labels[j]]:5s}' for j in range(batch_size)))
```



```
Shirt Sneaker Bag   Coat
```

In [4]:

```
class Net(nn.Module):
    def __init__(self):
        super().__init__()
        #filter = 12, kernal = 3*3
        self.conv1 = nn.Conv2d(1, 12, 3, padding=2)
        self.pool = nn.MaxPool2d(2, 2)
        #filter = 12, kernal = 6*6
        self.conv2 = nn.Conv2d(12, 12, 6, stride = 2, padding=2)
        #filter = 32, kernal = 6*6
        self.conv3 = nn.Conv2d(12, 32, 6, stride = 2, padding=2)

        self.droput = nn.Dropout(0.2)

        self.fc1 = nn.Linear(32, 120)
        self.fc2 = nn.Linear(120, 60)
        self.fc3 = nn.Linear(60, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.droput(x)
        x = self.pool(F.relu(self.conv2(x)))
        x = self.droput(x)
        x = F.relu(self.conv3(x))
        x = torch.flatten(x, 1) # flatten all dimensions except batch
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = F.softmax(self.fc3(x))
        return x


net = Net()
```

In [5]:

```
criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.SGD(net.parameters(), lr=0.001, momentum=0.9)
```

In [6]:

```
#Train Function
Loss = []
for epoch in range(20):  # loop over the dataset multiple times

    running_loss = 0.0
    for i, data in enumerate(trainLoader, 0):
        # get the inputs; data is a list of [inputs, labels]
        inputs, labels = data

        # zero the parameter gradients
        optimizer.zero_grad()

        # forward + backward + optimize
        outputs = net(inputs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        # print statistics
        running_loss += loss.item()
        Loss.append(running_loss)
        if i % 2000 == 1999:    # print every 2000 mini-batches
            print(f'[{epoch + 1}, {i + 1:5d}] loss: {running_loss / 2000:.3f}')
            running_loss = 0.0

print('Finished Training')
```

```
[11,  8000] loss: 1.663
[11, 10000] loss: 1.653
[11, 12000] loss: 1.653
[11, 14000] loss: 1.657
[12,  2000] loss: 1.652
[12,  4000] loss: 1.655
[12,  6000] loss: 1.655
[12,  8000] loss: 1.656
[12, 10000] loss: 1.653
[12, 12000] loss: 1.660
[12, 14000] loss: 1.657
[13,  2000] loss: 1.648
[13,  4000] loss: 1.657
[13,  6000] loss: 1.657
[13,  8000] loss: 1.651
[13, 10000] loss: 1.659
[13, 12000] loss: 1.651
[13, 14000] loss: 1.657
[14,  2000] loss: 1.653
```

In [7]:

```
#number of trainable parameters for this network
print(sum(p.numel() for p in net.parameters() if p.requires_grad))
```

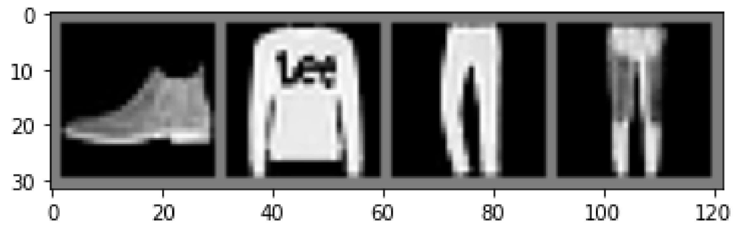
```
31002
```

In [8]:

```
PATH = './fashion_MNIST_net.pth'
torch.save(net.state_dict(), PATH)
```

In [9]:

```
dataiter = iter(testLoader)
images, labels = next(dataiter)

# print images
imshow(torchvision.utils.make_grid(images))
print('GroundTruth: ', ' '.join(f'{classes[labels[j]]:5s}' for j in range(4)))
```



```
GroundTruth:  Ankle boot Pullover Trouser Trouser
```

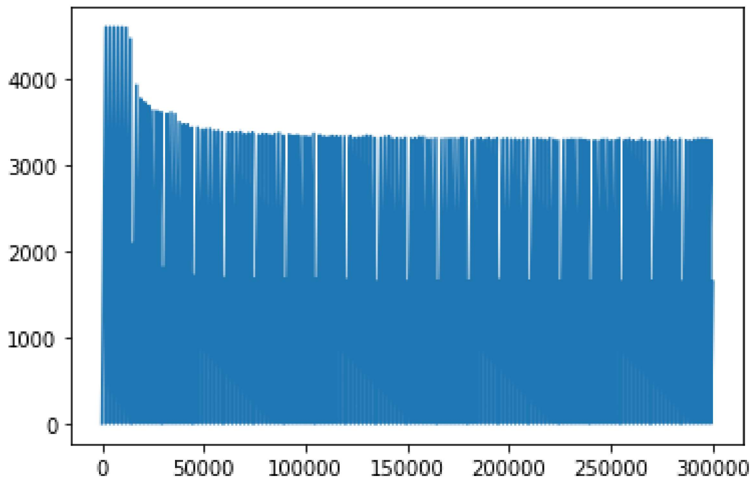
In [10]:

```
correct = 0
total = 0
accuracy = []
# since we're not training, we don't need to calculate the gradients for our outputs
with torch.no_grad():
    for data in testLoader:
        images, labels = data
        # calculate outputs by running images through the network
        outputs = net(images)
        # the class with the highest energy is what we choose as prediction
        _, predicted = torch.max(outputs.data, 1)
        total += labels.size(0)
        correct += (predicted == labels).sum().item()
        accuracy.append(100 * correct // total)
print(f'Accuracy of the network on the 10000 test images: {100 * correct // total} %')
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:27: UserWarnin
g: Implicit dimension choice for softmax has been deprecated. Change the cal
l to include dim=X as an argument.

Accuracy of the network on the 10000 test images: 79 %
```

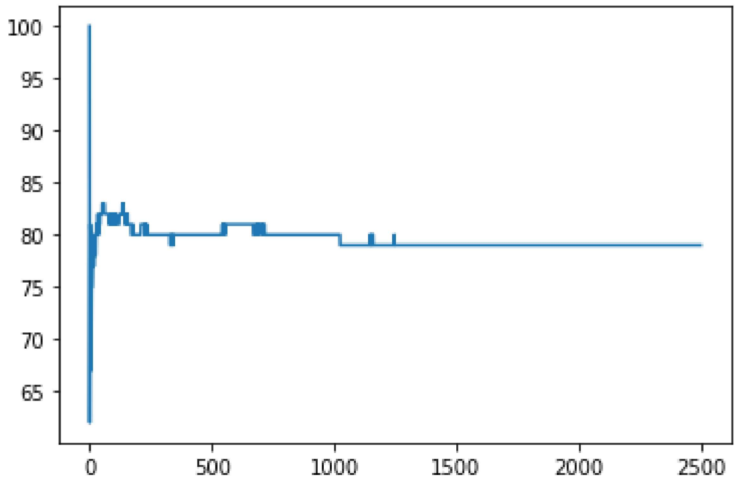
In [11]:

```
plt.plot(Loss,label = 'Loss')

plt.show()
```



In [12]:

```
plt.plot(accuracy, label = 'Accuracy')
plt.show()
```



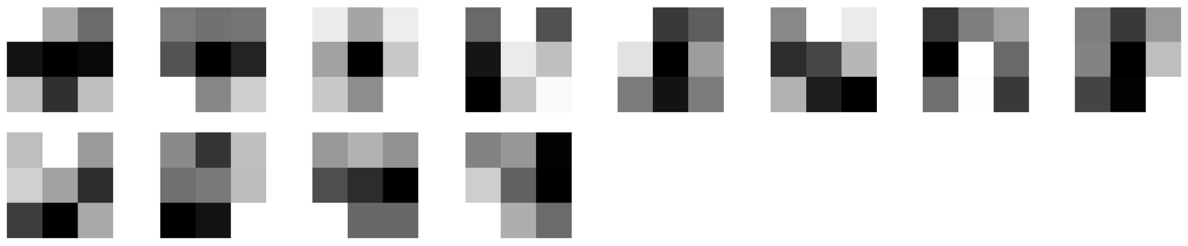
In [19]:

```
# load the model
model = net
print(model)
model_weights = [] # we will save the conv layer weights in this list
conv_layers = [] # we will save the 49 conv layers in this list
# get all the model children as list
model_children = list(model.children())
```

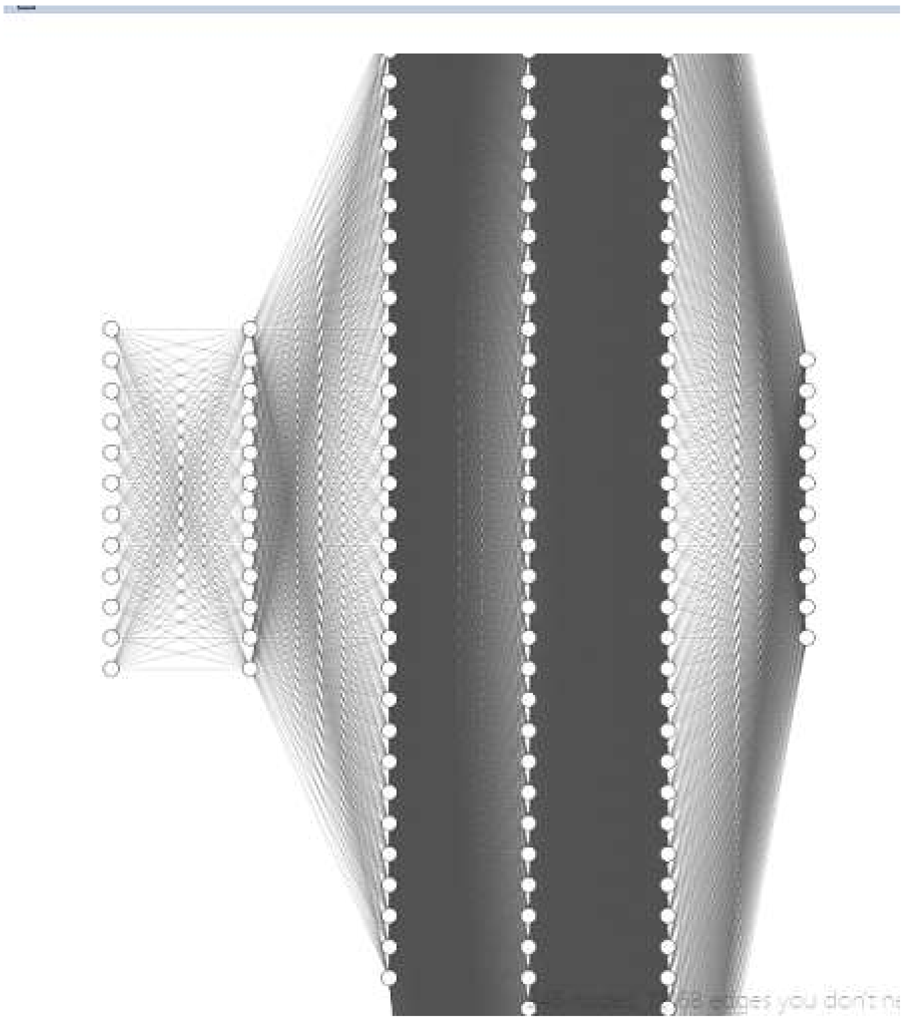
```
Net(
  (conv1): Conv2d(1, 12, kernel_size=(3, 3), stride=(1, 1), padding=(2, 2))
  (pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mod
e=False)
  (conv2): Conv2d(12, 12, kernel_size=(6, 6), stride=(2, 2), padding=(2, 2))
  (conv3): Conv2d(12, 32, kernel_size=(6, 6), stride=(2, 2), padding=(2, 2))
  (dropout): Dropout(p=0.2, inplace=False)
  (fc1): Linear(in_features=32, out_features=120, bias=True)
  (fc2): Linear(in_features=120, out_features=60, bias=True)
  (fc3): Linear(in_features=60, out_features=10, bias=True)
)
```

In [27]:

```
# visualize the first conv layer filters
plt.figure(figsize=(20, 17))
for i, filter in enumerate(model_weights[0]):
    plt.subplot(8, 8, i+1) # (8, 8) because in conv0 we have 7x7 filters and total of 64 (s
    plt.imshow(filter[0, :, :].detach(), cmap='gray')
    plt.axis('off')
plt.show()
```

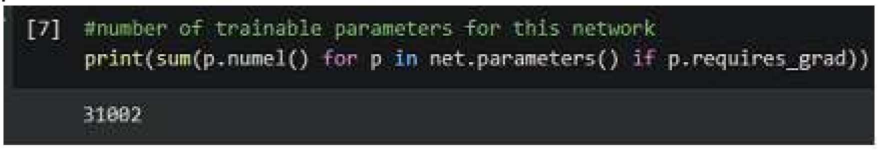


A. Show the network diagram.



B. Note the number of trainable parameters for this network.

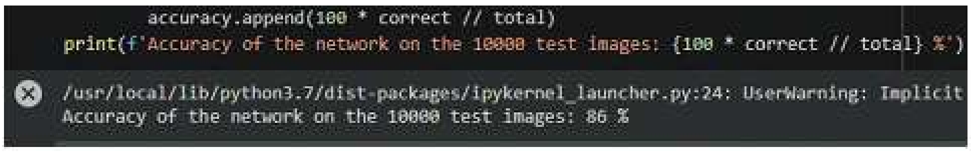
Number of trainable parameters are: 31002



```
[7]  #number of trainable parameters for this network
     print(sum(p.numel() for p in net.parameters() if p.requires_grad))

     31002
```

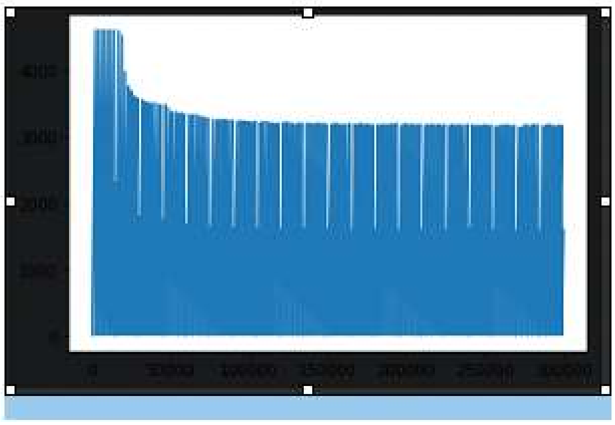
C. Describe the accuracy you obtain and show the loss/ accuracy curves.

Accuracy is 86%.

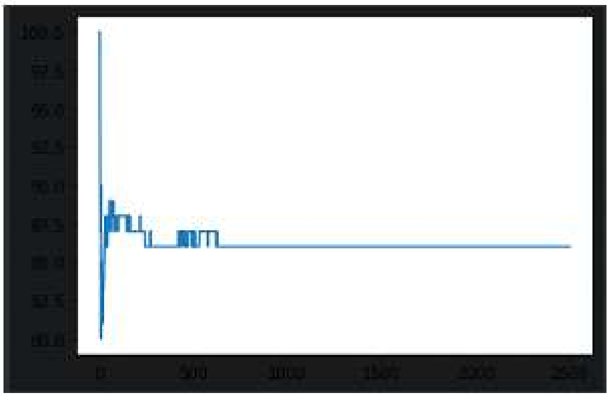


```
        accuracy.append(100 * correct // total)
    print(f'Accuracy of the network on the 10000 test images: {100 * correct // total} %')

    /usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:24: UserWarning: Implicit
    Accuracy of the network on the 10000 test images: 86 %
```

Loss curve:



Accuracy Curve:

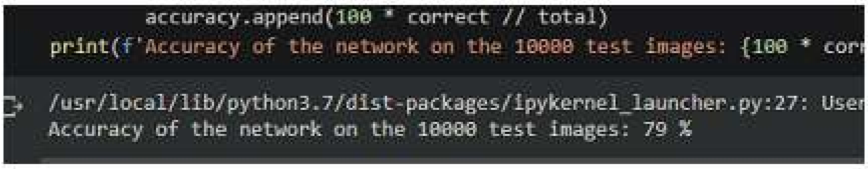


D. Do you observe any overfitting? Apply Dropout with CNN to see the effect of regularization? Report your results.

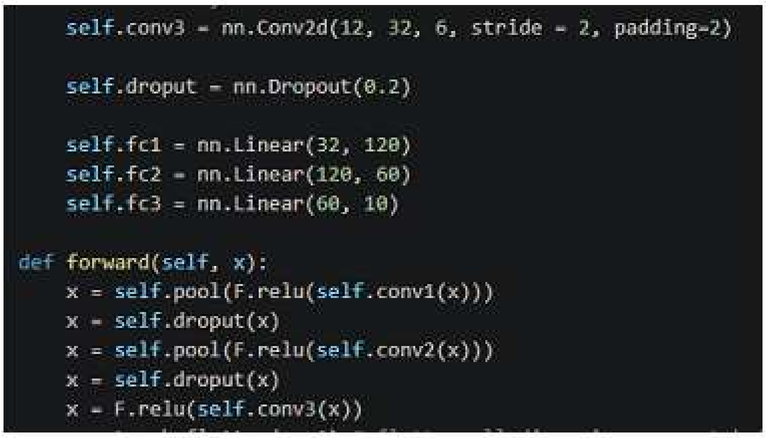
No I don't observe any overfitting because it gave accuracy on test data of about 86% and seems it hasn't remembered the images and more over it can make decision on random and unseen data, after validating it over few inputs it gave almost 100% correct result.

Apply Dropout:

After applying the dropout with CNN it can be seen that the accuracy of the model is dropped from 86% to 79%, but the data which I used to check the accuracy, this model gave 100% correct results.

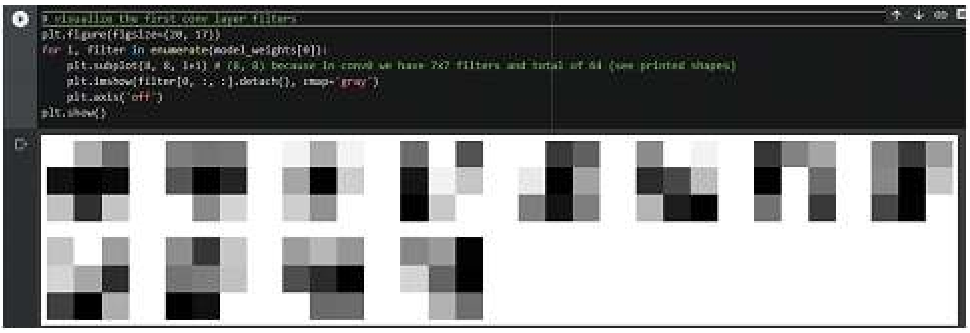


```
        accuracy.append(100 * correct // total)
print(f'Accuracy of the network on the 10000 test images: {100 * corr

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:27: User
Accuracy of the network on the 10000 test images: 79 %
```



```
        self.conv3 = nn.Conv2d(12, 32, 6, stride = 2, padding=2)

        self.droput = nn.Dropout(0.2)

        self.fc1 = nn.Linear(32, 120)
        self.fc2 = nn.Linear(120, 60)
        self.fc3 = nn.Linear(60, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.droput(x)
        x = self.pool(F.relu(self.conv2(x)))
        x = self.droput(x)
        x = F.relu(self.conv3(x))
```

E. Try to visualize the filter outputs of the first layer of your CNN model and reflect on your findings?



```
# visualize the first conv layer filters
plt.figure(figsize=(20, 17))
for i, filter in enumerate(model_weights[0]):
    plt.subplot(8, 8, i+1) # (8, 8) because in conv0 we have 7x7 filters and total of 64 (see printed shapes)
    plt.imshow(filter[0, :, :].detach(), cmap='gray')
    plt.axis('off')
plt.show()
```

The first convolution layer converts all the pixels in its receptive field into a single value.