In [1]:
```
import torch
import numpy as np
import matplotlib.pyplot as plt
import torchvision
from torchvision import datasets
import torchvision.transforms as transforms
from torchvision.transforms import ToTensor
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch.autograd import Variable
from torchvision.utils import make_grid
from torch import flatten
import time
import sys
import os
import seaborn as sns
```

In [2]:
```
import seaborn as sns
import skimage.transform
from skimage import img_as_ubyte
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
```

In [3]:
```
### Fixing some values for the hyperparameters
batch_size=50
epochs=10
criterion=nn.MSELoss()
```

In [4]:
```
## If GPU is abailable, then the code will be pushed to it otherwise it wil
use_cuda=torch.cuda.is_available()
device = torch.device("cuda" if use_cuda else "cpu")
```

In [5]:
```
##Loading the data
transform=transforms.Compose([
        transforms.ToTensor(),
        transforms.Normalize((0.1307,), (0.3081,))
        ])
train_data = datasets.MNIST(root='../data', train=True,download=True, trans
test_data = datasets.MNIST(root='../data', train=False,download=True, trans

train_loader = torch.utils.data.DataLoader(train_data, batch_size=batch_siz
test_loader = torch.utils.data.DataLoader(test_data, batch_size=batch_size)
```

Question 1

PCA

In [6]:
```
### Scaling data
train_data_pca = np.asarray(train_data.data)/255
test_data_pca = np.asarray(test_data.data)/255

flatten_data=test_data_pca.reshape(-1,784)
```

In [7]:
```
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import mean_squared_error as mse
```

In [8]:
```
pca_vec = PCA(n_components = 30) #first 30 eigenvalues
pca_vec.fit(flatten_data)
train_pca = pca_vec.transform(flatten_data)
reconstructed_data = pca_vec.inverse_transform(train_pca)
PCA_error = mse(flatten_data,reconstructed_data)
print('Reconstruction error is : ',PCA_error)
```

```
Reconstruction error is :  0.01753543473942351
```

Vanilla Autoencoder

In [6]:
```
class autoencoder(nn.Module):

    def __init__(self):
        super(autoencoder,self).__init__()

        ## Encoder module

        self.encoder = nn.Sequential(nn.Linear(784,512),nn.ReLU(),
                                     nn.Linear(512,256),nn.ReLU(),
                                     nn.Linear(256,128),nn.ReLU(),
                                     nn.Linear(128,30),nn.ReLU())
        ## Decoder module

        self.decoder = nn.Sequential(nn.Linear(30,128),nn.ReLU(),
                                     nn.Linear(128,256),nn.ReLU(),
                                     nn.Linear(256,784),nn.ReLU())

    def forward(self,x):
        x = flatten(x,1)
        encoded_output = self.encoder(x.float())
        decoded_output = self.decoder(encoded_output)

        return decoded_output,encoded_output
```

In [7]:
```
def train(model,device,train_loader,optimizer,train_loss,train_acc):
    model.train()
    acc=0
    train_l=0
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        optimizer.zero_grad()
        output,_ = model(data)
        loss = criterion(output, flatten(data,1))
        loss.backward()
        optimizer.step()

        train_l+=loss.item()
        pred= output.argmax(dim=1, keepdim=True)
        acc+= pred.eq(target.view_as(pred)).sum().item()

    train_loss.append(train_l/len(train_loader.dataset))
    train_acc.append(100*acc/len(train_loader.dataset))
```

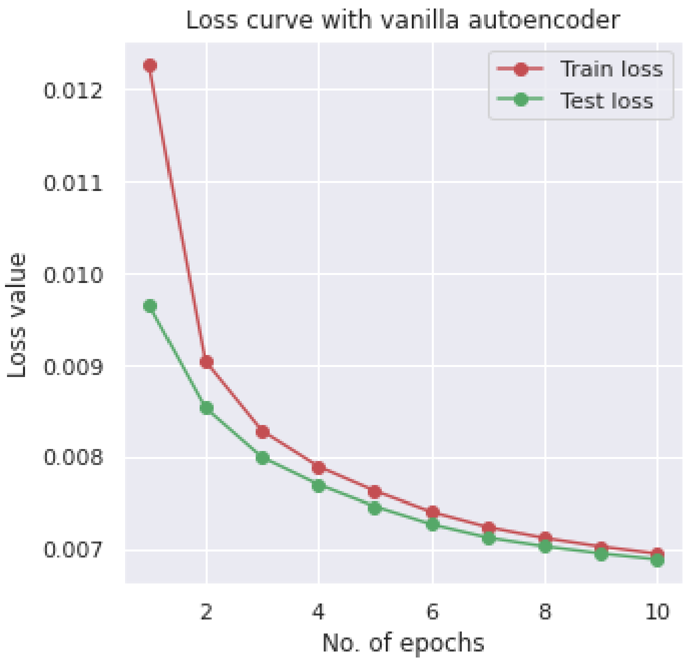
In [8]:
```
def test(model,device,test_loader,test_loss):
    model.eval()
    loss = 0
    acc = 0
    with torch.no_grad():
```

```
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            output,_ = model(data)
            loss +=criterion(output, flatten(data,1)).data.item()  # sum up


    loss /= len(test_loader.dataset)
    test_loss.append(loss)


    #print('\nTest set: Average loss: {:.4f}'.format(loss))
```

In [9]:
```
vanilla_ae=autoencoder()
model=vanilla_ae.to(device)
optimizer = optim.Adam(model.parameters(), lr=0.0001)
```

In [13]:
```
train_loss=[]
train_accuracy=[]
test_loss=[]
test_accuracy=[]
start=time.time()
for epoch in range(1,epochs+1):
    train(model,device,train_loader,optimizer,train_loss,train_accuracy)

    test(model, device, test_loader,test_loss)
end=time.time()
```

In [14]:
```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title("Loss curve with vanilla autoencoder")
plt.grid(True)
```

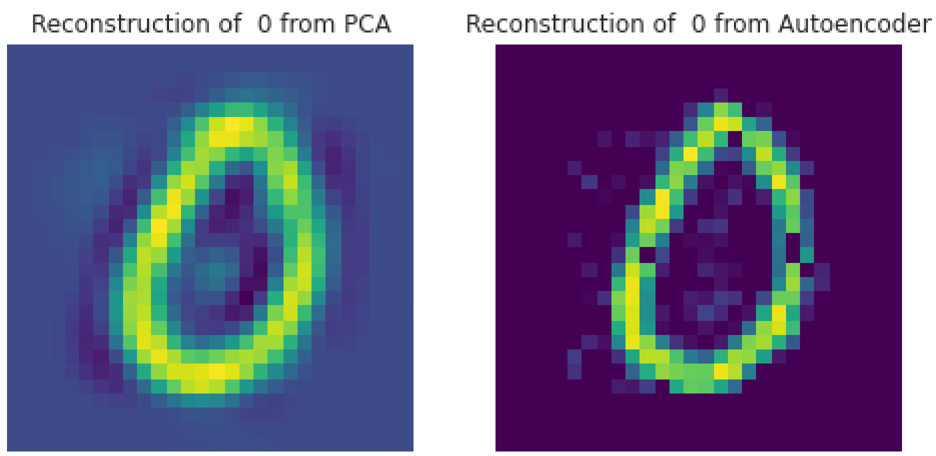


In [15]:
```
def random_plotting_of_test_images(network,test_loader):
    image_index= np.random.randint(low=0, high=9999) #test set has 10000 ima
```

```
    val=test_loader.dataset.targets
    test_image_id=int(val[image_index].detach().cpu().numpy())

    test_image = test_loader.dataset.data[image_index].clone()
    with torch.no_grad():#Using no_grad as it reduces memory consumption fo
        test_image = test_image.reshape(1,1,28,28).cuda().float()
        out,_ = network.forward(test_image)

    ##From PCA
    pca_image=reconstructed_data[image_index,:]

    f,axarr=plt.subplots(1,2,figsize=(8, 8))
    axarr[0].imshow(pca_image.reshape(28,28),cmap='viridis')
    axarr[0].axis('off')
    axarr[0].set_title(f"Reconstruction of  {test_image_id} from PCA")
    axarr[1].imshow(out.detach().cpu().numpy().reshape(28,28),cmap='viridis
    axarr[1].axis('off')
    axarr[1].set_title(f"Reconstruction of  {test_image_id} from Autoencode
```

In [126…

```
random_plotting_of_test_images(model,test_loader)
```



Question 2

In [97]:

```
class autoencoder_q2(nn.Module):

    def __init__(self,hidden_layer):
        super(autoencoder_q2,self).__init__()

        ## Encoder module

        self.encoder = nn.Sequential(nn.Linear(784,hidden_layer),nn.ReLU())

        ## Decoder module

        self.decoder = nn.Sequential(nn.Linear(hidden_layer,784),nn.ReLU())

    def forward(self,x):
        x = flatten(x,1)
        encoded_output = self.encoder(x.float())
        decoded_output = self.decoder(encoded_output)

        return decoded_output,encoded_output
```

In [11]:

```
x=[64,128,256]
i=0
```

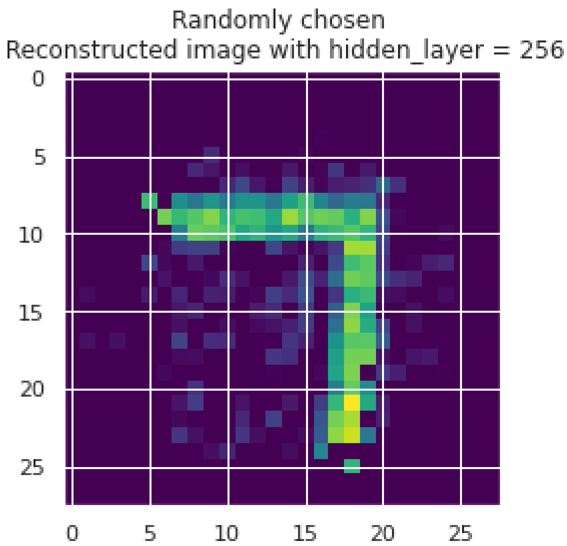
```
ae=autoencoder_q2(x[i])
model_q2=ae.to(device)
optimizer = optim.Adam(model_q2.parameters(), lr=0.0001)
```

In [35]:
```
train_loss=[]
train_accuracy=[]
test_loss=[]

for epoch in range(1,epochs+1):
    train(model_q2,device,train_loader,optimizer,train_loss,train_accuracy)

    test(model_q2, device, test_loader,test_loss)
```

In [78]:
```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title(f"Loss curve with autoencoder hidden_layer = {x[i]}")
plt.grid(True)
```

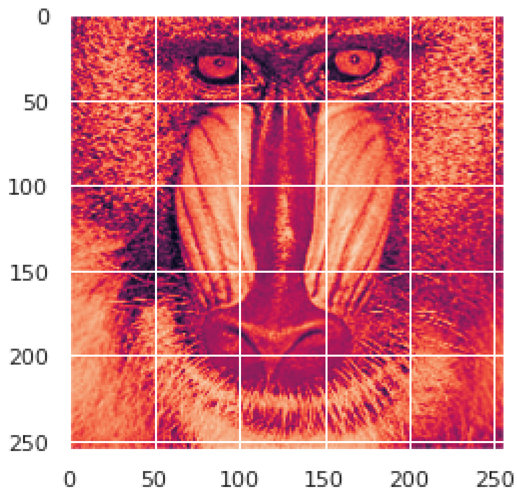
In [24]:
```
### Trying diffrent hidden layer on one image of test_set

image_index= np.random.randint(low=0, high=9999) #test set has 10000 images

val = test_loader.dataset.targets
test_image_id = int(val[image_index].detach().cpu().numpy())

test_image = test_loader.dataset.data[image_index].clone()

with torch.no_grad():#Using no_grad as it reduces memory consumption for co
        test_image = test_image.reshape(1,1,28,28).cuda().float()
        out,_ = model_q2.forward(test_image)

plt.imshow(out.detach().cpu().numpy().reshape(28,28),cmap='viridis')
plt.title(f"Randomly chosen \n Reconstructed image with hidden_layer = {x[i
```

Out[24]:
```
Text(0.5, 1.0, 'Randomly chosen \n Reconstructed image with hidden_layer =
256')
```



In [79]:
```
import cv2
img=cv2.imread("mandril.png")
img = cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)
plt.imshow(img)
```

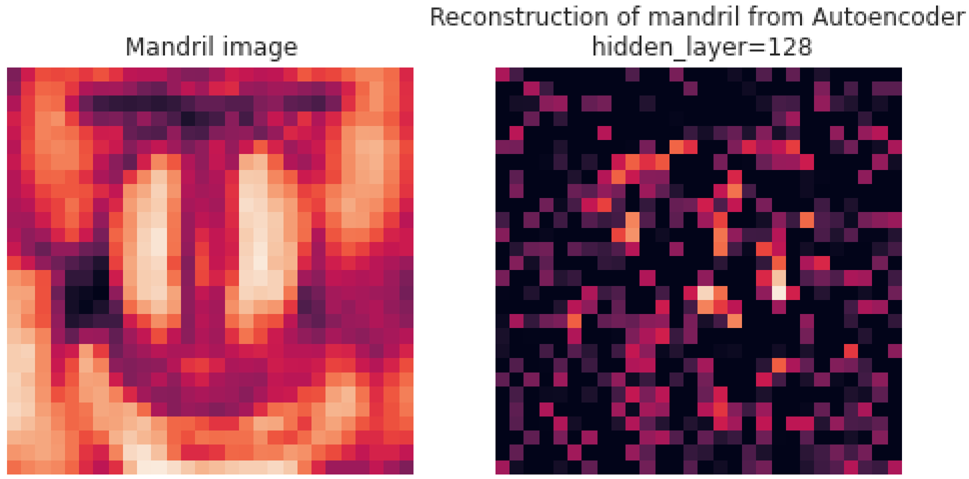
Out[79]: <matplotlib.image.AxesImage at 0x7f3ee2fb7610>



In [80]:
```
new_img = np.asarray(img)
rescaled_image= torch.from_numpy(img_as_ubyte(skimage.transform.resize(new_
noise_input=torch.from_numpy(np.random.normal(0, 1, size=(1,1,28,28))).cuda
with torch.no_grad():#Using no_grad as it reduces memory consumption for co
        rescaled_image = rescaled_image.reshape(1,1,28,28).cuda().float()
        out_mandril,_ = model_q2.forward(rescaled_image)
        out_noise,_= model_q2.forward(noise_input)
```

In [81]:
```
f,axarr=plt.subplots(1,2,figsize=(8, 8))
axarr[0].imshow(rescaled_image.detach().cpu().numpy().reshape(28,28))
axarr[0].axis('off')
axarr[0].set_title(f"Mandril image")
axarr[1].imshow(out_mandril.detach().cpu().numpy().reshape(28,28))
axarr[1].axis('off')
axarr[1].set_title(f"Reconstruction of mandril from Autoencoder\n hidden_la
```

Out[81]: Text(0.5, 1.0, 'Reconstruction of mandril from Autoencoder\n hidden_layer=1
28')

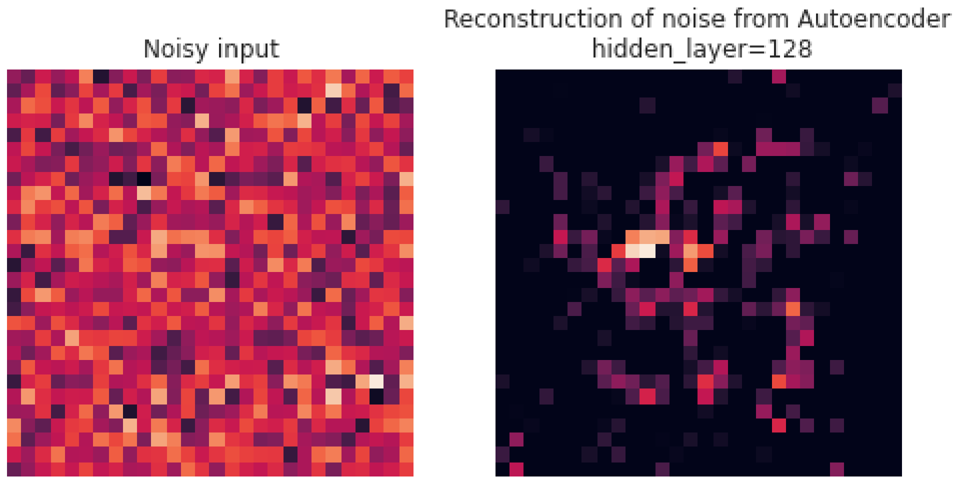


In [82]:

```
f,axarr=plt.subplots(1,2,figsize=(8, 8))
axarr[0].imshow(noise_input.detach().cpu().numpy().reshape(28,28))
axarr[0].axis('off')
axarr[0].set_title(f"Noisy input")
axarr[1].imshow(out_noise.detach().cpu().numpy().reshape(28,28))
axarr[1].axis('off')
axarr[1].set_title(f"Reconstruction of noise from Autoencoder\n hidden_laye
```

Out[82]:

```
Text(0.5, 1.0, 'Reconstruction of noise from Autoencoder\n hidden_layer=12
8')
```



Question 3

In [24]:

```
class autoencoder_q3(nn.Module):

    def __init__(self):
        super(autoencoder_q3,self).__init__()

        ## Encoder module

        self.encoder = nn.Sequential(nn.Linear(784,900),nn.ReLU())

        ## Decoder module

        self.decoder = nn.Sequential(nn.Linear(900,784),nn.ReLU())

    def forward(self,x):
        x = flatten(x,1)
        encoded_output = self.encoder(x.float())
        decoded_output = self.decoder(encoded_output)
```

```
        return decoded_output,encoded_output
```

In [25]:
```
def train_sparse(model,device,reg,train_loader,optimizer,train_loss,train_a
    model.train()
    acc=0
    train_l=0
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        optimizer.zero_grad()
        output,encoded = model(data)
        loss = criterion(output, flatten(data,1))
        loss += reg*torch.linalg.norm(encoded,1) #added L1 penalty term
        loss.backward()
        optimizer.step()

        train_l+=loss.item()
        pred= output.argmax(dim=1, keepdim=True)
        acc+= pred.eq(target.view_as(pred)).sum().item()

    train_loss.append(train_l/len(train_loader.dataset))
    train_acc.append(100*acc/len(train_loader.dataset))
```

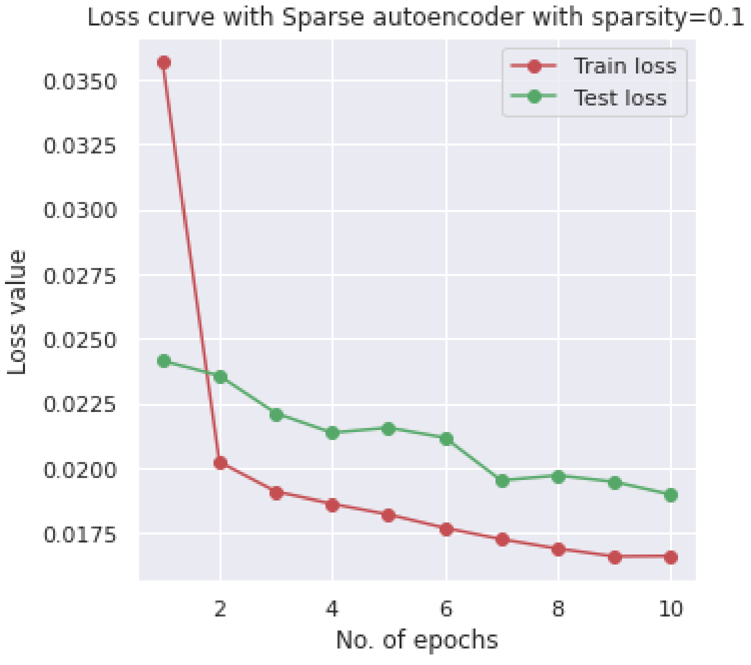
In [26]:
```
def test_sparse(model,device,reg,test_loader,test_loss):
    model.eval()
    tloss = 0
    acc = 0
    loss=0
    with torch.no_grad():
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            output,encoded = model(data)
            loss = criterion(output, flatten(data,1))
            loss += reg*torch.linalg.norm(encoded,1) #added L1 penalty term
            tloss +=loss.data.item()  # sum up batch loss


    tloss /= len(test_loader.dataset)
    test_loss.append(tloss)
```

In [27]:
```
ae_q3=autoencoder_q3()
model_q3=ae_q3.to(device)
optimizer = optim.Adam(model_q3.parameters(), lr=0.0001)
```

In [49]:
```
train_loss=[]
train_accuracy=[]
test_loss=[]
reg=0.001
for epoch in range(1,epochs+1):
    train_sparse(model_q3,device,reg,train_loader,optimizer,train_loss,trai

    test_sparse(model_q3, device,reg,test_loader,test_loss)
```

In [173…
```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
```

```
plt.title(f"Loss curve with Sparse autoencoder with sparsity={reg}")
plt.grid(True)
```



In [13]:
```
def average_activation_sparse(model,device,test_loader):
    model.eval()

    average_activation=0

    with torch.no_grad():


        for (data,label) in test_loader:

            data,label = data.to(device),label.to(device)

            reconstruction,encoded = model(data)

            average_activation += float(torch.mean(encoded))


    average_activation    /= len(test_loader.dataset)

    print('The average activation norm is ',average_activation)
```

In [174…
```
### Average activation for Sparse autoencoder, with sparsity 0.001,0.01,0.1
average_activation_sparse(model_q3,device,test_loader)
## For 0.001=0.005324395973980427, 0.01=0.0009793924264609813, 0.1=0.000131
```

```
The average activation norm is  0.00013127546962350608
```

In [21]:
```
average_activation_sparse(model_q2,device,test_loader)
```

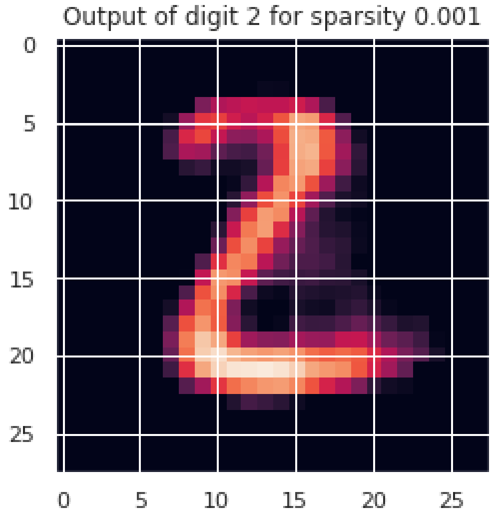
```
The average activation norm is  0.07290675175189971
```

In [22]:
```
### Average activation for standard autoencoder

## h=64, avg_acti= 0.13396140904426573

## h=128, avg_acti= 0.10157207226753234
```

```
## h=256, avg_acti= 0.07290675175189971
```

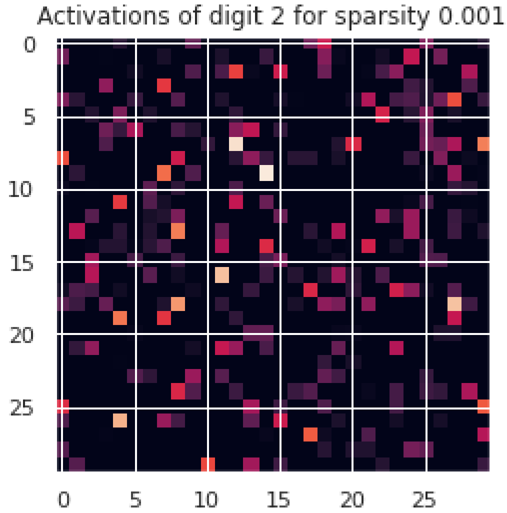
In [50]:
```
def visalize_output(model,test_loader):
    image_idx=[13,5,1,18,6,8,11,0,61,12]
    indices=1 ##digit 2

    test_image = test_loader.dataset.data[indices].clone()
    test_image = test_image.reshape(1,1,28,28).cuda().float()

    with torch.no_grad():
        reconstructed_image,encoded_img = model.forward(test_image)
        reconstructed_image = reconstructed_image.detach().cpu().numpy()
        plt.imshow(reconstructed_image.reshape(28,28))
        plt.title("Output of digit 2 for sparsity 0.001")
```

In [51]:
```
visalize_output(model_q3,test_loader)
```



In [52]:
```
def visalize_activations(model,test_loader):
    image_idx=[13,5,1,18,6,8,11,0,61,12]
    indices=1 ##digit 2

    test_image = test_loader.dataset.data[indices].clone()
    test_image = test_image.reshape(1,1,28,28).cuda().float()

    with torch.no_grad():
        reconstructed_image,encoded_img = model.forward(test_image)
        encoded_img = encoded_img.detach().cpu().numpy()
        plt.imshow(encoded_img.reshape(int(np.sqrt(900)),int(np.sqrt(900))))
        plt.title("Activations of digit 2 for sparsity 0.001")
```

In [53]:
```
visalize_activations(model_q3,test_loader)
```

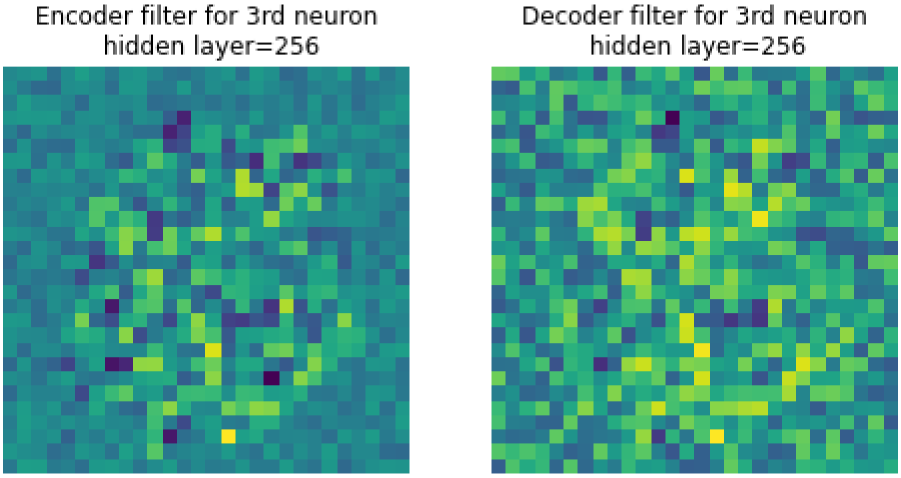


In [108…

```
def visualize_filter(model):
    with torch.no_grad():

        encoder_filters = model.encoder[0].weight.detach().cpu().numpy()
        decoder_filters = model.decoder[0].weight.detach().cpu().numpy()

        neuron_index=3## chosen in a whim

        f,axarr=plt.subplots(1,2,figsize=(8, 8))
        axarr[0].imshow(encoder_filters[neuron_index].reshape(28,28),cmap='
        axarr[0].axis('off')
        axarr[0].set_title(f"Encoder filter for {neuron_index}rd neuron\n n
        axarr[1].imshow(decoder_filters[:,neuron_index].reshape(28,28),cmap
        axarr[1].axis('off')
        axarr[1].set_title(f"Decoder filter for {neuron_index}rd neuron\n n
```

In [37]:

```
visualize_filter(model_q2)
```



Question 4

In [98]:

```
#### In denoisng autoencoder the hidden layer size is 256, and during train
ae_q4=autoencoder_q2(256)
model_q4=ae_q4.to(device)
optimizer = optim.Adam(model_q4.parameters(), lr=0.0001)
```

In [99]:

```
def adding_noise(data,noise_level):
```

```
    ## Adding gaussian noise
    noise=(torch.randn(data.size())*noise_level).to(device)
    noisy_data=noise+data
    return noisy_data
```

In [100…

```
def train_denoising(model,device,noise_level,train_loader,optimizer,train_l
    model.train()
    acc=0
    train_l=0
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        noisy_input=adding_noise(data,noise_level)
        optimizer.zero_grad()
        output,encoded = model(noisy_input)
        loss = criterion(output, flatten(data,1))
        loss.backward()
        optimizer.step()

        train_l+=loss.item()
        pred= output.argmax(dim=1, keepdim=True)
        acc+= pred.eq(target.view_as(pred)).sum().item()

    train_loss.append(train_l/len(train_loader.dataset))
    train_acc.append(100*acc/len(train_loader.dataset))
```

In [101…

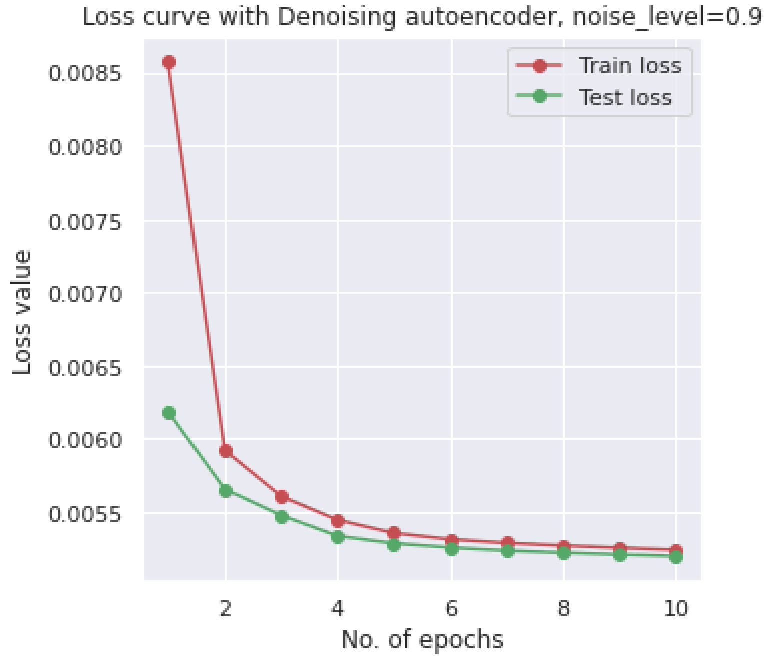
```
def test_denoising(model,device,noise_level,test_loader,test_loss):
    model.eval()
    loss = 0
    acc = 0
    with torch.no_grad():
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            noisy_input=adding_noise(data,noise_level)
            output,_ = model(noisy_input)
            loss +=criterion(output, flatten(data,1)).data.item()  # sum up


    loss /= len(test_loader.dataset)
    test_loss.append(loss)
```

In [105…

```
train_loss=[]
train_accuracy=[]
test_loss=[]
noise_level=0.5
for epoch in range(1,epochs+1):
    train_denoising(model_q4,device,noise_level,train_loader,optimizer,trai

    test_denoising(model_q4, device,noise_level, test_loader,test_loss)
```

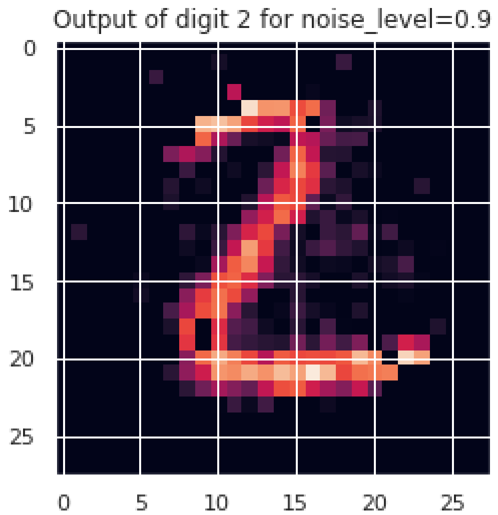
In [85]:

```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title(f"Loss curve with Denoising autoencoder, noise_level=0.9")
plt.grid(True)
```



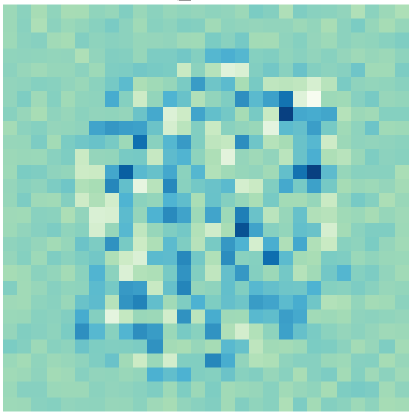
In [108…
```
def visalize_output(model,test_loader):
    image_idx=[13,5,1,18,6,8,11,0,61,12]
    indices=1 ##digit 2

    test_image = test_loader.dataset.data[indices].clone()
    test_image = test_image.reshape(1,1,28,28).cuda().float()

    with torch.no_grad():
        reconstructed_image,encoded_img = model.forward(test_image)
        reconstructed_image = reconstructed_image.detach().cpu().numpy()
        plt.imshow(reconstructed_image.reshape(28,28))
        plt.title("Output of digit 2 for noise_level=0.9")
```

In [109…
```
visalize_output(model_q4,test_loader)
```

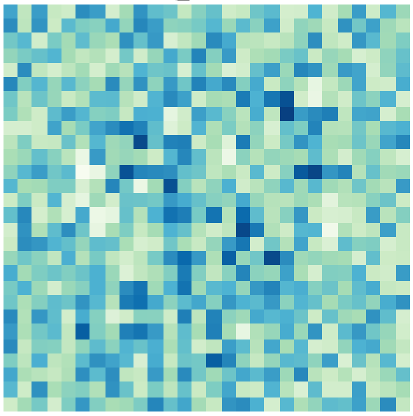


In [109…
```
visualize_filter(model_q4)
```

Encoder filter for 3rd neuron
noise_level=0.3



Decoder filter for 3rd neuron
noise_level=0.3



Question 5

In [6]:
```
class conv_AE_unpool(nn.Module): #define unpooling outside the decoder and 

    def __init__(self): #class constructor
        super(conv_AE_unpool,self).__init__() #calls the parent constructor

        #initializing the encoder module
        self.encoder_conv1 = nn.Sequential(nn.Conv2d(1,8, kernel_size = 3, 
        self.encoder_conv2 = nn.Sequential(nn.Conv2d(8,16, kernel_size = 3, 
        self.encoder_conv3 = nn.Sequential(nn.Conv2d(16,16, kernel_size = 3

        #initializing the decoder module
        self.decoder_conv1 = nn.Sequential(nn.Identity()) #7x7x16 to 7x7x16
        self.decoder_conv2 = nn.Sequential(nn.Conv2d(16,8, kernel_size = 3, 
        self.decoder_conv3 = nn.Sequential(nn.Conv2d(8,1, kernel_size = 3, 

        #defining the unpooling operation
        self.unpool = nn.MaxUnpool2d(kernel_size = (2,2))


    def forward(self,x): #defines the forward pass and also the structure o

        encoded_input,indices1  = self.encoder_conv1(x.float())  # 28x28x1 
        encoded_input,indices2  = self.encoder_conv2(encoded_input) #14x14x
        encoded_input,indices3  = self.encoder_conv3(encoded_input) #7x7x16


        reconstructed_input     = self.unpool(encoded_input,indices3,output_
        reconstructed_input     = self.decoder_conv1(reconstructed_input) #
        reconstructed_input     = self.unpool(reconstructed_input,indices2)
        reconstructed_input     = self.decoder_conv2(reconstructed_input)#1
        reconstructed_input     = self.unpool(reconstructed_input,indices1)
        reconstructed_input     = self.decoder_conv3(reconstructed_input)#2


        return reconstructed_input,encoded_input
```

In [7]:
```
class conv_AE_deconv(nn.Module):
    def __init__(self): #class constructor
        super(conv_AE_deconv,self).__init__() #calls the parent constructor

        #initializing the encoder module
        self.encoder_conv1 = nn.Sequential(nn.Conv2d(1,8, kernel_size = 3, 
        self.encoder_conv2 = nn.Sequential(nn.Conv2d(8,16, kernel_size = 3, 
```

```
        self.encoder_conv3 = nn.Sequential(nn.Conv2d(16,16, kernel_size = 3

        #initializing the decoder module
        self.decoder_conv1 = nn.Sequential(nn.ConvTranspose2d(16,16, kernel_
        self.decoder_conv2 = nn.Sequential(nn.ConvTranspose2d(16,8, kernel_
        self.decoder_conv3 = nn.Sequential(nn.ConvTranspose2d(8,1, kernel_s

    def forward(self,x): #defines the forward pass and also the structure o

        encoded_input  = self.encoder_conv1(x.float())
        encoded_input  = self.encoder_conv2(encoded_input)
        encoded_input  = self.encoder_conv3(encoded_input)

        reconstructed_input     = self.decoder_conv1(encoded_input)
        reconstructed_input     = self.decoder_conv2(reconstructed_input)
        reconstructed_input     = self.decoder_conv3(reconstructed_input)

        return reconstructed_input,encoded_input
```

In [8]:
```
class conv_AE_deconv_unpool(nn.Module):
    def __init__(self): #class constructor
        super(conv_AE_deconv_unpool,self).__init__() #calls the parent cons

         #initializing the encoder module
        self.encoder_conv1 = nn.Sequential(nn.Conv2d(1,8, kernel_size = 3,
        self.encoder_conv2 = nn.Sequential(nn.Conv2d(8,16, kernel_size = 3,
        self.encoder_conv3 = nn.Sequential(nn.Conv2d(16,16, kernel_size = 3

        #initializing the decoder module
        self.decoder_conv1 = nn.Sequential(nn.ConvTranspose2d(16,16, kernel_
        self.decoder_conv2 = nn.Sequential(nn.ConvTranspose2d(16,8, kernel_
        self.decoder_conv3 = nn.Sequential(nn.ConvTranspose2d(8,1, kernel_s

        #defining the unpooling operation
        self.unpool = nn.MaxUnpool2d(kernel_size = (2,2))

    def forward(self,x): #defines the forward pass and also the structure o

        encoded_input,indices1  = self.encoder_conv1(x.float())
        encoded_input,indices2  = self.encoder_conv2(encoded_input)
        encoded_input,indices3  = self.encoder_conv3(encoded_input)


        reconstructed_input     = self.unpool(encoded_input,indices3,output_
        reconstructed_input     = self.decoder_conv1(reconstructed_input)
        reconstructed_input     = self.unpool(reconstructed_input,indices2)
        reconstructed_input     = self.decoder_conv2(reconstructed_input)
        reconstructed_input     = self.unpool(reconstructed_input,indices1)
        reconstructed_input     = self.decoder_conv3(reconstructed_input)


        return reconstructed_input,encoded_input
```

In [9]:
```
def train_conv_AE(model,device,optimizer,train_loader,train_loss):
    model.train()
    acc=0
    train_l=0
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        optimizer.zero_grad()
        output,_ = model(data)
        loss = criterion(output, data)
        loss.backward()
```

```
        optimizer.step()

        train_l+=loss.item()
        #pred= output.argmax(dim=1, keepdim=True)
        #acc+= pred.eq(target.view_as(pred)).sum().item()

    train_loss.append(train_l/len(train_loader.dataset))
    #train_acc.append(100*acc/len(train_loader.dataset))
```

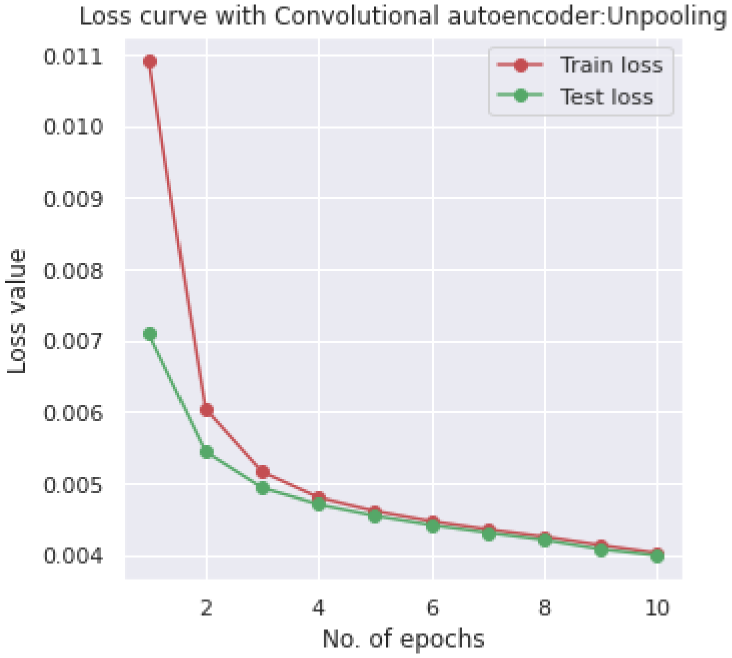
In [10]:
```
def test_conv_AE(model,device,optimizer,test_loader,test_loss):
    model.eval()
    loss = 0
    acc = 0
    with torch.no_grad():
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            output,_ = model(data)
            loss +=criterion(output, data).data.item()  # sum up batch loss


    loss /= len(test_loader.dataset)
    test_loss.append(loss)
```

In [11]:
```
ae_q5_unpool=conv_AE_unpool()
model_q5_unpool=ae_q5_unpool.to(device)
optimizer_unpool=optim.Adam(model_q5_unpool.parameters(), lr=0.0001)

ae_q5_deconv=conv_AE_deconv()
model_q5_deconv=ae_q5_deconv.to(device)
optimizer_deconv=optim.Adam(model_q5_deconv.parameters(), lr=0.0001)

ae_q5_deconv_unpool=conv_AE_deconv_unpool()
model_q5_deconv_unpool=ae_q5_deconv_unpool.to(device)
optimizer_deconv_unpool=optim.Adam(model_q5_deconv_unpool.parameters(), lr=
```

In [12]:
```
train_loss=[]
train_accuracy=[]
test_loss=[]
for i in range(1,epochs+1):
    train_conv_AE(model_q5_unpool,device,optimizer_unpool,train_loader,trai
    test_conv_AE(model_q5_unpool,device,optimizer_unpool,test_loader,test_l
```

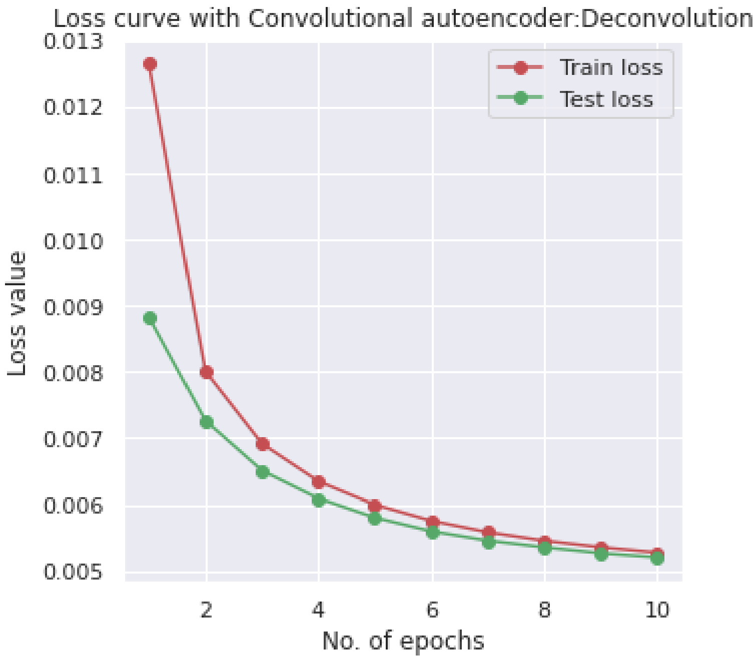
```
/home/htic/GE_APW/lib/python3.8/site-packages/torch/nn/functional.py:749: U
serWarning: Note that order of the arguments: ceil_mode and return_indices
will changeto match the args list in nn.MaxPool2d in a future release.
  warnings.warn("Note that order of the arguments: ceil_mode and return_ind
ices will change"
```

In [13]:
```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title(f"Loss curve with Convolutional autoencoder:Unpooling")
plt.grid(True)
```



In [14]:
```
train_loss=[]
train_accuracy=[]
test_loss=[]
for i in range(1,epochs+1):
    train_conv_AE(model_q5_deconv,device,optimizer_deconv,train_loader,trai
    test_conv_AE(model_q5_deconv,device,optimizer_deconv,test_loader,test_l
```

In [134…
```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title(f"Loss curve with Convolutional autoencoder:Deconvolution")
plt.grid(True)
```

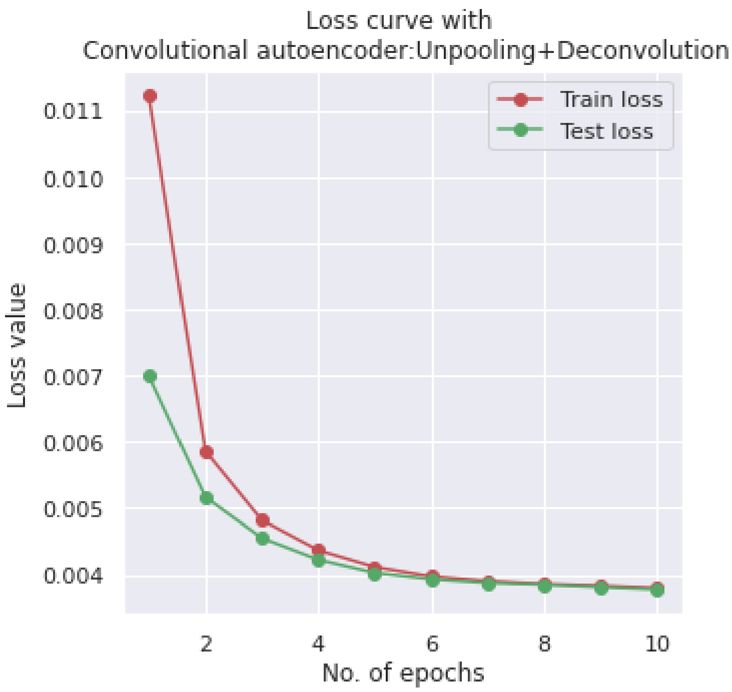


In [15]:
```
train_loss=[]
train_accuracy=[]
```

```
test_loss=[]
for i in range(1,epochs+1):
    train_conv_AE(model_q5_deconv_unpool,device,optimizer_deconv_unpool,tra
    test_conv_AE(model_q5_deconv_unpool,device,optimizer_deconv_unpool,test_
```

In [136…

```
sns.set_theme()
plt.figure(figsize=(5, 5))
xval=np.arange(1,epochs+1,1)
plt.plot(xval,train_loss,color='r',marker='o')
plt.plot(xval,test_loss,color='g',marker='o')
plt.xlabel("No. of epochs")
plt.ylabel("Loss value")
plt.legend(["Train loss","Test loss"])
plt.title(f"Loss curve with \n Convolutional autoencoder:Unpooling+Deconvol
plt.grid(True)
```

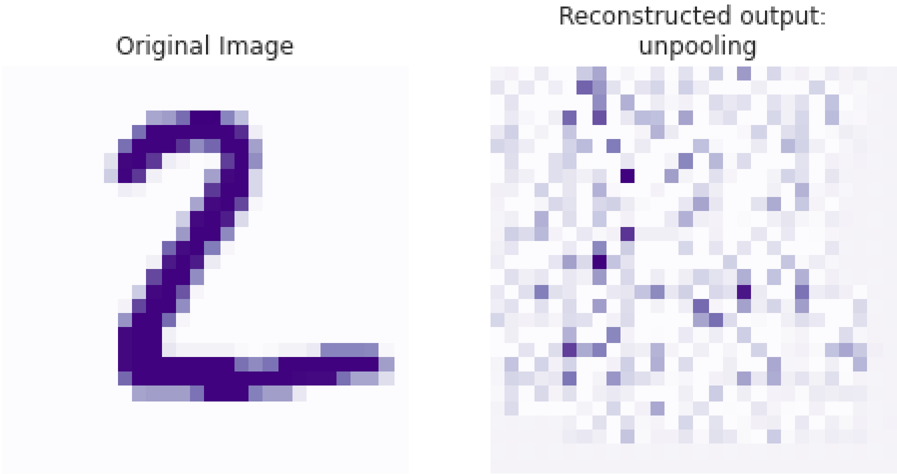


In [153…

```
def visalize_convoutput(model):
    image_idx=[13,5,1,18,6,8,11,0,61,12]
    indices=1 ##digit 2

    test_image = test_loader.dataset.data[indices].clone()
    test_image = test_image.reshape(1,1,28,28).cuda().float()

    with torch.no_grad():
        reconstructed_image,encoded_img = model.forward(test_image)
        reconstructed_image = reconstructed_image.detach().cpu().numpy()
        test_image=test_image.detach().cpu().numpy()

        f,axarr=plt.subplots(1,2,figsize=(8, 8))
        axarr[0].imshow(test_image.reshape(28,28),cmap='Purples')
        axarr[0].axis('off')
        axarr[0].set_title(f"Original Image")
        axarr[1].imshow(reconstructed_image.reshape(28,28),cmap='Purples')
        axarr[1].axis('off')
        axarr[1].set_title(f"Reconstructed output:\n unpooling")
```

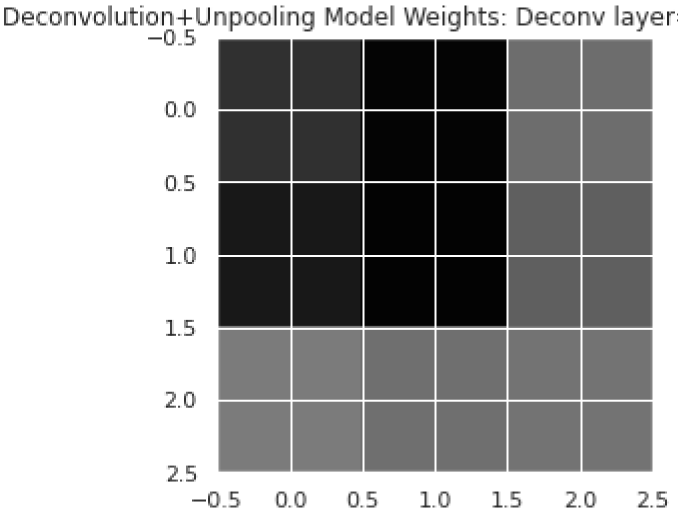
In [154…

```
visalize_convoutput(model_q5_unpool)
```

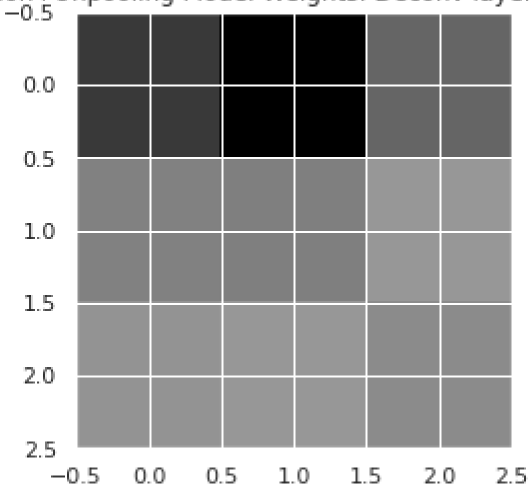


In [94]:
```
def visualize_deconv_filter(model,decoder_weights):

    decoder_weights=decoder_weights.cpu()
    decoder_weights -= decoder_weights.min()
    decoder_weights /= decoder_weights.max()

    (x,y,z,w) = decoder_weights.shape

    channel = np.random.randint(0 ,x ,3)

    for idx in channel:
        weight= make_grid(decoder_weights[idx].reshape(y,1,z,w))
        weight=weight.permute(1,2,0)
        plt.imshow(weight)
        plt.title(f"Deconvolution+Unpooling Model Weights: Deconv layer=3 o
        plt.show()
```

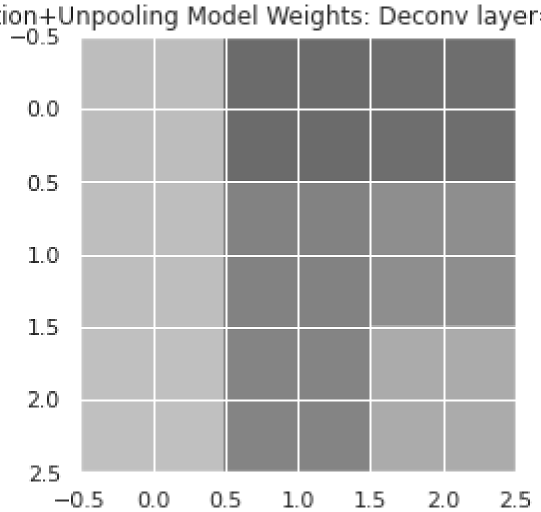
In [95]:
```
decoder_weights=model_q5_deconv_unpool.decoder_conv3[0].weight.detach().clo
visualize_deconv_filter(model_q5_deconv_unpool,decoder_weights)
```



Deconvolution+Unpooling Model Weights: Deconv layer=3 of channel 4



Deconvolution+Unpooling Model Weights: Deconv layer=3 of channel 1



In [ ]:

```

```