In [1]:
```
import pandas as pd
```

1. Data reterival and check

In [2]:
```
df = pd.read_csv("circles_binary_classification.csv")
```

In [3]:
```
df.sample(20)
```

Out[3]:

	X1	X2	label
669	0.581916	-0.864857	0
474	-0.404276	-0.891172	0
513	1.003359	0.190284	0
743	0.345500	-0.683812	1
20	0.626827	0.450047	1
200	0.949494	0.355544	0
561	0.853725	-0.003334	1
427	0.728785	0.672418	0
189	-0.850967	-0.002142	1
681	-0.319674	-0.699354	1
211	-0.218748	1.009728	0
807	-0.413240	0.927643	0
835	-0.772196	-0.174904	1
793	0.544432	-0.632258	1
130	0.278157	0.759089	1
987	-0.557936	-0.865283	0
749	0.411950	-0.704122	1
872	0.716238	-0.213845	1
160	0.190075	0.717714	1
346	0.617595	0.480418	1

In [5]:
```
df.head()
```

Out[5]:

	X1	X2	label
0	0.754246	0.231481	1
1	-0.756159	0.153259	1
2	-0.815392	0.173282	1
3	-0.393731	0.692883	1
4	0.442208	-0.896723	0

In [6]:
```
df.describe()
```

Out[6]:

	X1	X2	label
count	1000.000000	1000.000000	1000.00000
mean	-0.000448	-0.000804	0.50000
std	0.639837	0.641156	0.50025
min	-1.059502	-1.067768	0.00000
25%	-0.619251	-0.612176	0.00000
50%	0.008762	-0.003949	0.50000
75%	0.621933	0.624822	1.00000
max	1.033712	1.036004	1.00000

In [7]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   X1      1000 non-null   float64
 1   X2      1000 non-null   float64
 2   label   1000 non-null   int64  
dtypes: float64(2), int64(1)
memory usage: 23.6 KB
```

2. Data cleaning & feature design

In [8]:
```
# Missing Value
```

In [9]:
```
print(df.isnull().sum())
```

```
X1       0
X2       0
label    0
dtype: int64
```

In [10…
```
# Create features X and target y
X = df[['X1', 'X2']].values
y = df['label'].values
```

In [11…
```
X
```

Out[11…
```
array([[ 0.75424625,  0.23148074],
       [-0.75615888,  0.15325888],
       [-0.81539193,  0.17328203],
       ...,
       [-0.13690036, -0.81001183],
       [ 0.67036156, -0.76750154],
       [ 0.28105665,  0.96382443]], shape=(1000, 2))
```

In [12…
```
y
```

Out[12… array([1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0,
1, 0,
0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0,
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0, 0, 1, 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0,
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1, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1,
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       1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 1,
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       1, 0, 0, 1, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1,
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       1, 0, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1,
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       0, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 1,
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       1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0,
0, 0,
       0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0,
0, 0,
       0, 1, 0, 1, 0, 0, 0, 1, 0, 0])
```

In [16…
```
import torch
import numpy as np
```

In [17…
```
# Here I use Pytorch
```

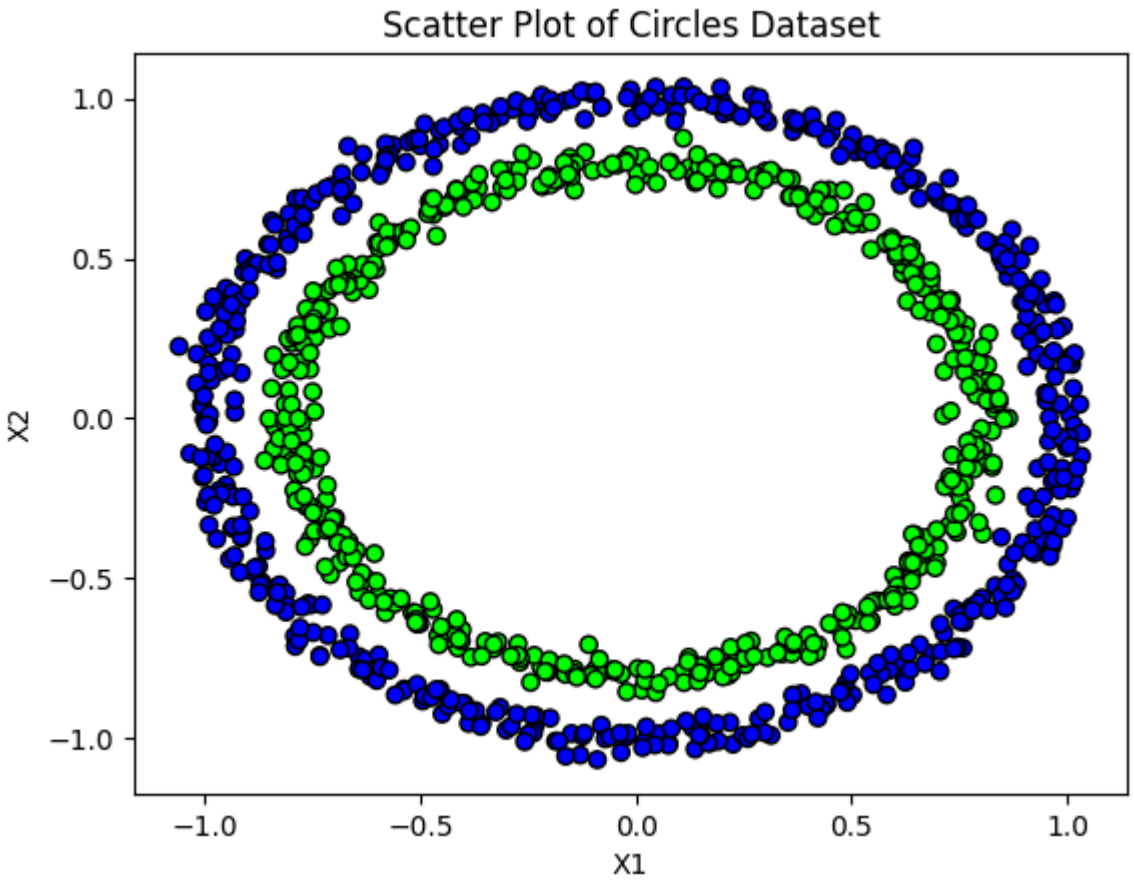
In [18…
```
# Convert to PyTorch tensors with float32 dtype
X = torch.from_numpy(X).type(torch.float32)
y = torch.from_numpy(y).type(torch.float32).unsqueeze(1)
```

3 . Visulization

In [20…
```
import matplotlib.pyplot as plt
```

In [23…
```
plt.scatter(X[:, 0], X[:, 1], c=y.squeeze(), cmap='brg', edgecolor='k
plt.xlabel('X1')
plt.ylabel('X2')
plt.title('Scatter Plot of Circles Dataset')
```

Out[23…
```
Text(0.5, 1.0, 'Scatter Plot of Circles Dataset')
```



4. Train Test split

In [24…
```
from sklearn.model_selection import train_test_split
```

In [25…
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0
```

5. Device & dtype

In [27…
```
# Set device to CUDA if available, else CPU
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

In [28…
```
# Move tensors to device
X_train = X_train.to(device)
X_test = X_test.to(device)
```

```
y_train = y_train.to(device)
y_test = y_test.to(device)
```

6. Implementation of Bseline Model

In [30…
```
import torch.nn as nn

# Set manual seed for reproducibility
torch.manual_seed(42)

# Define ModelV0: Linear model with 2 -> 5 -> 1, no activation
class ModelV0(nn.Module):
    def __init__(self):
        super().__init__()
        self.layer1 = nn.Linear(2, 5)
        self.layer2 = nn.Linear(5, 1)

    def forward(self, x):
        x = self.layer1(x)
        x = self.layer2(x)
        return x
```

In [31…
```
# Define ModelV1: Linear model with 2 -> 15 -> 15 -> 1, no activation
class ModelV1(nn.Module):
    def __init__(self):
        super().__init__()
        self.layer1 = nn.Linear(2, 15)
        self.layer2 = nn.Linear(15, 15)
        self.layer3 = nn.Linear(15, 1)

    def forward(self, x):
        x = self.layer1(x)
        x = self.layer2(x)
        x = self.layer3(x)
        return x
```

In [33…
```
 # Define ModelV2: Non-linear model with 2 -> 64 -> 64 -> 10 -> 1, Re
class ModelV2(nn.Module):
    def __init__(self):
        super().__init__()
        self.layer1 = nn.Linear(2, 64)
        self.layer2 = nn.Linear(64, 64)
        self.layer3 = nn.Linear(64, 10)
        self.layer4 = nn.Linear(10, 1)
        self.relu = nn.ReLU()

    def forward(self, x):
        x = self.relu(self.layer1(x))
        x = self.relu(self.layer2(x))
        x = self.relu(self.layer3(x))
```

```
        x = self.layer4(x)
        return x
```

7. Loss Optimizer & Matrix

In [34…

```
# Function to calculate accuracy
def accuracy_fn(y_true, y_pred_logits):
    y_pred = torch.round(torch.sigmoid(y_pred_logits))  # Apply sigmo
    return (y_pred == y_true).sum() / len(y_true) * 100  # Percentage

# Training and testing loop function
def train_and_test_loop(model, epochs, optimizer, loss_fn, X_train, y
    train_losses = []
    test_losses = []
    train_accs = []
    test_accs = []

    for epoch in range(epochs):
        # Training mode
        model.train()
        y_logits = model(X_train)
        loss = loss_fn(y_logits, y_train)
        optimizer.zero_grad()
        loss.backward()
        optimizer.step()

        train_losses.append(loss.item())
        train_acc = accuracy_fn(y_train, y_logits)
        train_accs.append(train_acc.item())

        # Evaluation mode
        model.eval()
        with torch.inference_mode():
            test_logits = model(X_test)
            test_loss = loss_fn(test_logits, y_test)
            test_acc = accuracy_fn(y_test, test_logits)

        test_losses.append(test_loss.item())
        test_accs.append(test_acc.item())

        # Print progress every 10 epochs
        if (epoch + 1) % 10 == 0:
            print(f"Epoch: {epoch+1} | Train loss: {loss.item():.4f}

    return train_losses, test_losses, train_accs, test_accs

# Loss function
loss_fn = nn.BCEWithLogitsLoss()
```

8 . Training loop

In [35…
```
# Train V0 Model
# Initialize ModelV0 and optimizer
model_v0 = ModelV0().to(device)
optimizer_v0 = torch.optim.SGD(model_v0.parameters(), lr=0.1)

# Train for 100 epochs
train_losses_v0, test_losses_v0, train_accs_v0, test_accs_v0 = train_
    model_v0, 100, optimizer_v0, loss_fn, X_train, y_train, X_test, y
)
```

```
Epoch: 10 | Train loss: 0.6941 | Train acc: 50.00% | Test loss: 0.6962
| Test acc: 50.00%
Epoch: 20 | Train loss: 0.6935 | Train acc: 46.00% | Test loss: 0.6959
| Test acc: 47.00%
Epoch: 30 | Train loss: 0.6932 | Train acc: 49.25% | Test loss: 0.6958
| Test acc: 47.00%
Epoch: 40 | Train loss: 0.6931 | Train acc: 49.12% | Test loss: 0.6957
| Test acc: 46.50%
Epoch: 50 | Train loss: 0.6931 | Train acc: 50.13% | Test loss: 0.6957
| Test acc: 46.50%
Epoch: 60 | Train loss: 0.6931 | Train acc: 50.25% | Test loss: 0.6956
| Test acc: 46.50%
Epoch: 70 | Train loss: 0.6930 | Train acc: 50.25% | Test loss: 0.6956
| Test acc: 46.50%
Epoch: 80 | Train loss: 0.6930 | Train acc: 50.75% | Test loss: 0.6955
| Test acc: 46.50%
Epoch: 90 | Train loss: 0.6930 | Train acc: 50.38% | Test loss: 0.6955
| Test acc: 46.50%
Epoch: 100 | Train loss: 0.6930 | Train acc: 50.50% | Test loss: 0.695
4 | Test acc: 46.50%
```

In [37…
```
# Train V1 Model
# Reinitialize ModelV1 and optimizer
model_v1 = ModelV1().to(device)
optimizer_v1 = torch.optim.SGD(model_v1.parameters(), lr=0.1)

# Train for 1000 epochs
train_losses_v1, test_losses_v1, train_accs_v1, test_accs_v1 = train_
    model_v1, 1000, optimizer_v1, loss_fn, X_train, y_train, X_test,
)
```

```
Epoch: 10 | Train loss: 0.6951 | Train acc: 54.12% | Test loss: 0.6989
| Test acc: 49.00%
Epoch: 20 | Train loss: 0.6936 | Train acc: 51.75% | Test loss: 0.6962
| Test acc: 47.00%
Epoch: 30 | Train loss: 0.6933 | Train acc: 51.25% | Test loss: 0.6955
| Test acc: 48.00%
Epoch: 40 | Train loss: 0.6932 | Train acc: 50.38% | Test loss: 0.6951
| Test acc: 50.00%
Epoch: 50 | Train loss: 0.6932 | Train acc: 50.00% | Test loss: 0.6950
| Test acc: 50.00%
Epoch: 60 | Train loss: 0.6931 | Train acc: 49.88% | Test loss: 0.6948
| Test acc: 49.00%
Epoch: 70 | Train loss: 0.6931 | Train acc: 50.25% | Test loss: 0.6948
| Test acc: 48.50%
Epoch: 80 | Train loss: 0.6931 | Train acc: 50.50% | Test loss: 0.6947
| Test acc: 48.50%
Epoch: 90 | Train loss: 0.6931 | Train acc: 50.25% | Test loss: 0.6946
| Test acc: 48.50%
Epoch: 100 | Train loss: 0.6931 | Train acc: 50.50% | Test loss: 0.694
6 | Test acc: 48.00%
Epoch: 110 | Train loss: 0.6930 | Train acc: 50.38% | Test loss: 0.694
6 | Test acc: 47.50%
Epoch: 120 | Train loss: 0.6930 | Train acc: 50.50% | Test loss: 0.694
6 | Test acc: 47.50%
Epoch: 130 | Train loss: 0.6930 | Train acc: 50.38% | Test loss: 0.694
6 | Test acc: 48.00%
Epoch: 140 | Train loss: 0.6930 | Train acc: 50.50% | Test loss: 0.694
6 | Test acc: 47.50%
Epoch: 150 | Train loss: 0.6930 | Train acc: 50.75% | Test loss: 0.694
6 | Test acc: 47.50%
Epoch: 160 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
6 | Test acc: 47.00%
Epoch: 170 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 47.00%
Epoch: 180 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
6 | Test acc: 46.50%
Epoch: 190 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 200 | Train loss: 0.6930 | Train acc: 50.75% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 210 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 220 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 230 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 240 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 250 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 47.00%
Epoch: 260 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
6 | Test acc: 47.00%
```

```
Epoch: 270 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
6 | Test acc: 47.00%
Epoch: 280 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
6 | Test acc: 46.50%
Epoch: 290 | Train loss: 0.6930 | Train acc: 51.50% | Test loss: 0.694
6 | Test acc: 46.50%
Epoch: 300 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 310 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 320 | Train loss: 0.6930 | Train acc: 51.50% | Test loss: 0.694
6 | Test acc: 46.00%
Epoch: 330 | Train loss: 0.6930 | Train acc: 51.50% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 340 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 350 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 360 | Train loss: 0.6930 | Train acc: 50.88% | Test loss: 0.694
6 | Test acc: 45.50%
Epoch: 370 | Train loss: 0.6930 | Train acc: 50.88% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 380 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 390 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 400 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 410 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 420 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 430 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 440 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 450 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 460 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 470 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 480 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 490 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 500 | Train loss: 0.6930 | Train acc: 51.38% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 510 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 520 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
```

```
Epoch: 530 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 45.50%
Epoch: 540 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 550 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 560 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 570 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 580 | Train loss: 0.6930 | Train acc: 51.25% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 590 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 600 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 610 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 620 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 630 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 640 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 650 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 660 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 670 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 680 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 690 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 700 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 710 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 720 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 730 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 740 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 750 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 760 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 770 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 780 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
```

```
Epoch: 790 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 800 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 810 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 820 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 830 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 840 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 850 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 860 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 870 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 880 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 890 | Train loss: 0.6930 | Train acc: 51.12% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 900 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 910 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 920 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 930 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 940 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 950 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 960 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 970 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 980 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 990 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.694
7 | Test acc: 46.00%
Epoch: 1000 | Train loss: 0.6930 | Train acc: 51.00% | Test loss: 0.69
47 | Test acc: 46.00%
```

In [39…

```python
# Train V2 Model
# Reinitialize ModelV2 and optimizer
model_v2 = ModelV2().to(device)
optimizer_v2 = torch.optim.SGD(model_v2.parameters(), lr=0.1)

# Train for 1500 epochs
train_losses_v2, test_losses_v2, train_accs_v2, test_accs_v2 = train_
```

```
    model_v2, 1500, optimizer_v2, loss_fn, X_train, y_train, X_test,
)
```

```
Epoch: 10 | Train loss: 0.6982 | Train acc: 50.00% | Test loss: 0.6981
| Test acc: 50.00%
Epoch: 20 | Train loss: 0.6952 | Train acc: 50.00% | Test loss: 0.6954
| Test acc: 50.00%
Epoch: 30 | Train loss: 0.6936 | Train acc: 50.00% | Test loss: 0.6941
| Test acc: 50.00%
Epoch: 40 | Train loss: 0.6928 | Train acc: 50.00% | Test loss: 0.6933
| Test acc: 50.00%
Epoch: 50 | Train loss: 0.6923 | Train acc: 50.00% | Test loss: 0.6929
| Test acc: 50.00%
Epoch: 60 | Train loss: 0.6919 | Train acc: 50.00% | Test loss: 0.6925
| Test acc: 50.00%
Epoch: 70 | Train loss: 0.6915 | Train acc: 52.62% | Test loss: 0.6922
| Test acc: 52.00%
Epoch: 80 | Train loss: 0.6912 | Train acc: 52.00% | Test loss: 0.6920
| Test acc: 53.00%
Epoch: 90 | Train loss: 0.6910 | Train acc: 54.12% | Test loss: 0.6919
| Test acc: 53.50%
Epoch: 100 | Train loss: 0.6908 | Train acc: 55.00% | Test loss: 0.691
7 | Test acc: 56.50%
Epoch: 110 | Train loss: 0.6905 | Train acc: 56.63% | Test loss: 0.691
5 | Test acc: 54.50%
Epoch: 120 | Train loss: 0.6903 | Train acc: 56.75% | Test loss: 0.691
3 | Test acc: 54.00%
Epoch: 130 | Train loss: 0.6900 | Train acc: 57.25% | Test loss: 0.691
1 | Test acc: 54.00%
Epoch: 140 | Train loss: 0.6897 | Train acc: 58.25% | Test loss: 0.690
9 | Test acc: 54.00%
Epoch: 150 | Train loss: 0.6894 | Train acc: 59.25% | Test loss: 0.690
7 | Test acc: 53.50%
Epoch: 160 | Train loss: 0.6891 | Train acc: 59.62% | Test loss: 0.690
4 | Test acc: 54.50%
Epoch: 170 | Train loss: 0.6888 | Train acc: 60.38% | Test loss: 0.690
1 | Test acc: 54.00%
Epoch: 180 | Train loss: 0.6884 | Train acc: 61.25% | Test loss: 0.689
8 | Test acc: 55.00%
Epoch: 190 | Train loss: 0.6880 | Train acc: 63.00% | Test loss: 0.689
5 | Test acc: 56.00%
Epoch: 200 | Train loss: 0.6876 | Train acc: 63.88% | Test loss: 0.689
2 | Test acc: 56.50%
Epoch: 210 | Train loss: 0.6871 | Train acc: 64.62% | Test loss: 0.688
8 | Test acc: 58.00%
Epoch: 220 | Train loss: 0.6866 | Train acc: 65.88% | Test loss: 0.688
3 | Test acc: 58.00%
Epoch: 230 | Train loss: 0.6860 | Train acc: 67.75% | Test loss: 0.687
9 | Test acc: 59.00%
Epoch: 240 | Train loss: 0.6854 | Train acc: 68.75% | Test loss: 0.687
4 | Test acc: 60.50%
Epoch: 250 | Train loss: 0.6848 | Train acc: 70.00% | Test loss: 0.686
8 | Test acc: 63.50%
Epoch: 260 | Train loss: 0.6840 | Train acc: 71.62% | Test loss: 0.686
2 | Test acc: 65.50%
```

```
Epoch: 270 | Train loss: 0.6832 | Train acc: 73.25% | Test loss: 0.685
4 | Test acc: 68.00%
Epoch: 280 | Train loss: 0.6824 | Train acc: 76.25% | Test loss: 0.684
7 | Test acc: 71.50%
Epoch: 290 | Train loss: 0.6813 | Train acc: 79.50% | Test loss: 0.683
7 | Test acc: 72.50%
Epoch: 300 | Train loss: 0.6802 | Train acc: 82.75% | Test loss: 0.682
7 | Test acc: 79.00%
Epoch: 310 | Train loss: 0.6789 | Train acc: 86.38% | Test loss: 0.681
6 | Test acc: 80.00%
Epoch: 320 | Train loss: 0.6776 | Train acc: 87.50% | Test loss: 0.680
3 | Test acc: 82.50%
Epoch: 330 | Train loss: 0.6760 | Train acc: 89.50% | Test loss: 0.678
9 | Test acc: 85.00%
Epoch: 340 | Train loss: 0.6743 | Train acc: 91.25% | Test loss: 0.677
3 | Test acc: 85.00%
Epoch: 350 | Train loss: 0.6724 | Train acc: 92.38% | Test loss: 0.675
5 | Test acc: 88.00%
Epoch: 360 | Train loss: 0.6701 | Train acc: 93.12% | Test loss: 0.673
5 | Test acc: 88.00%
Epoch: 370 | Train loss: 0.6675 | Train acc: 93.50% | Test loss: 0.671
2 | Test acc: 89.50%
Epoch: 380 | Train loss: 0.6645 | Train acc: 93.62% | Test loss: 0.668
6 | Test acc: 89.50%
Epoch: 390 | Train loss: 0.6611 | Train acc: 94.00% | Test loss: 0.665
6 | Test acc: 91.50%
Epoch: 400 | Train loss: 0.6571 | Train acc: 95.12% | Test loss: 0.662
0 | Test acc: 92.50%
Epoch: 410 | Train loss: 0.6526 | Train acc: 95.62% | Test loss: 0.658
0 | Test acc: 93.00%
Epoch: 420 | Train loss: 0.6473 | Train acc: 95.88% | Test loss: 0.653
3 | Test acc: 93.50%
Epoch: 430 | Train loss: 0.6411 | Train acc: 96.12% | Test loss: 0.647
8 | Test acc: 93.50%
Epoch: 440 | Train loss: 0.6336 | Train acc: 96.50% | Test loss: 0.641
0 | Test acc: 94.50%
Epoch: 450 | Train loss: 0.6248 | Train acc: 96.75% | Test loss: 0.633
0 | Test acc: 95.00%
Epoch: 460 | Train loss: 0.6139 | Train acc: 97.50% | Test loss: 0.623
1 | Test acc: 96.50%
Epoch: 470 | Train loss: 0.6008 | Train acc: 97.50% | Test loss: 0.611
2 | Test acc: 98.50%
Epoch: 480 | Train loss: 0.5855 | Train acc: 98.25% | Test loss: 0.597
3 | Test acc: 99.00%
Epoch: 490 | Train loss: 0.5679 | Train acc: 97.25% | Test loss: 0.580
7 | Test acc: 99.00%
Epoch: 500 | Train loss: 0.5503 | Train acc: 93.38% | Test loss: 0.561
7 | Test acc: 99.00%
Epoch: 510 | Train loss: 0.5370 | Train acc: 81.62% | Test loss: 0.543
2 | Test acc: 96.50%
Epoch: 520 | Train loss: 0.5598 | Train acc: 53.75% | Test loss: 0.543
9 | Test acc: 80.50%
```

```
Epoch: 530 | Train loss: 0.5548 | Train acc: 53.62% | Test loss: 0.539
5 | Test acc: 65.00%
Epoch: 540 | Train loss: 0.5552 | Train acc: 52.75% | Test loss: 0.541
3 | Test acc: 57.00%
Epoch: 550 | Train loss: 0.5436 | Train acc: 53.62% | Test loss: 0.537
1 | Test acc: 56.00%
Epoch: 560 | Train loss: 0.5401 | Train acc: 53.75% | Test loss: 0.538
1 | Test acc: 53.50%
Epoch: 570 | Train loss: 0.5232 | Train acc: 57.00% | Test loss: 0.529
9 | Test acc: 55.50%
Epoch: 580 | Train loss: 0.5201 | Train acc: 56.88% | Test loss: 0.529
0 | Test acc: 56.00%
Epoch: 590 | Train loss: 0.5036 | Train acc: 58.62% | Test loss: 0.520
3 | Test acc: 56.50%
Epoch: 600 | Train loss: 0.4965 | Train acc: 60.00% | Test loss: 0.517
0 | Test acc: 57.00%
Epoch: 610 | Train loss: 0.4816 | Train acc: 62.75% | Test loss: 0.508
3 | Test acc: 58.50%
Epoch: 620 | Train loss: 0.4716 | Train acc: 64.00% | Test loss: 0.501
8 | Test acc: 59.50%
Epoch: 630 | Train loss: 0.4583 | Train acc: 65.88% | Test loss: 0.494
8 | Test acc: 60.00%
Epoch: 640 | Train loss: 0.4483 | Train acc: 67.75% | Test loss: 0.490
2 | Test acc: 61.00%
Epoch: 650 | Train loss: 0.4326 | Train acc: 69.62% | Test loss: 0.478
7 | Test acc: 61.50%
Epoch: 660 | Train loss: 0.4204 | Train acc: 71.88% | Test loss: 0.472
4 | Test acc: 64.00%
Epoch: 670 | Train loss: 0.4049 | Train acc: 73.62% | Test loss: 0.462
7 | Test acc: 68.50%
Epoch: 680 | Train loss: 0.3924 | Train acc: 74.75% | Test loss: 0.457
5 | Test acc: 68.50%
Epoch: 690 | Train loss: 0.3797 | Train acc: 76.25% | Test loss: 0.449
2 | Test acc: 70.50%
Epoch: 700 | Train loss: 0.3627 | Train acc: 78.88% | Test loss: 0.436
0 | Test acc: 72.50%
Epoch: 710 | Train loss: 0.3484 | Train acc: 81.38% | Test loss: 0.426
9 | Test acc: 72.50%
Epoch: 720 | Train loss: 0.3324 | Train acc: 82.75% | Test loss: 0.413
5 | Test acc: 74.50%
Epoch: 730 | Train loss: 0.3119 | Train acc: 85.12% | Test loss: 0.395
2 | Test acc: 77.00%
Epoch: 740 | Train loss: 0.2996 | Train acc: 86.25% | Test loss: 0.387
0 | Test acc: 78.50%
Epoch: 750 | Train loss: 0.2748 | Train acc: 89.12% | Test loss: 0.356
0 | Test acc: 84.00%
Epoch: 760 | Train loss: 0.1715 | Train acc: 97.00% | Test loss: 0.209
1 | Test acc: 93.00%
Epoch: 770 | Train loss: 0.0880 | Train acc: 100.00% | Test loss: 0.12
09 | Test acc: 100.00%
Epoch: 780 | Train loss: 0.0737 | Train acc: 100.00% | Test loss: 0.10
65 | Test acc: 100.00%
```

```
Epoch: 790 | Train loss: 0.0639 | Train acc: 100.00% | Test loss: 0.09
51 | Test acc: 100.00%
Epoch: 800 | Train loss: 0.0560 | Train acc: 100.00% | Test loss: 0.08
57 | Test acc: 100.00%
Epoch: 810 | Train loss: 0.0497 | Train acc: 100.00% | Test loss: 0.07
78 | Test acc: 100.00%
Epoch: 820 | Train loss: 0.0444 | Train acc: 100.00% | Test loss: 0.07
12 | Test acc: 100.00%
Epoch: 830 | Train loss: 0.0400 | Train acc: 100.00% | Test loss: 0.06
56 | Test acc: 100.00%
Epoch: 840 | Train loss: 0.0363 | Train acc: 100.00% | Test loss: 0.06
08 | Test acc: 100.00%
Epoch: 850 | Train loss: 0.0331 | Train acc: 100.00% | Test loss: 0.05
67 | Test acc: 100.00%
Epoch: 860 | Train loss: 0.0304 | Train acc: 100.00% | Test loss: 0.05
30 | Test acc: 100.00%
Epoch: 870 | Train loss: 0.0281 | Train acc: 100.00% | Test loss: 0.04
99 | Test acc: 100.00%
Epoch: 880 | Train loss: 0.0260 | Train acc: 100.00% | Test loss: 0.04
70 | Test acc: 100.00%
Epoch: 890 | Train loss: 0.0242 | Train acc: 100.00% | Test loss: 0.04
45 | Test acc: 100.00%
Epoch: 900 | Train loss: 0.0226 | Train acc: 100.00% | Test loss: 0.04
22 | Test acc: 100.00%
Epoch: 910 | Train loss: 0.0212 | Train acc: 100.00% | Test loss: 0.04
02 | Test acc: 100.00%
Epoch: 920 | Train loss: 0.0199 | Train acc: 100.00% | Test loss: 0.03
83 | Test acc: 100.00%
Epoch: 930 | Train loss: 0.0188 | Train acc: 100.00% | Test loss: 0.03
66 | Test acc: 100.00%
Epoch: 940 | Train loss: 0.0178 | Train acc: 100.00% | Test loss: 0.03
51 | Test acc: 100.00%
Epoch: 950 | Train loss: 0.0168 | Train acc: 100.00% | Test loss: 0.03
37 | Test acc: 100.00%
Epoch: 960 | Train loss: 0.0160 | Train acc: 100.00% | Test loss: 0.03
24 | Test acc: 100.00%
Epoch: 970 | Train loss: 0.0152 | Train acc: 100.00% | Test loss: 0.03
12 | Test acc: 100.00%
Epoch: 980 | Train loss: 0.0145 | Train acc: 100.00% | Test loss: 0.03
01 | Test acc: 100.00%
Epoch: 990 | Train loss: 0.0139 | Train acc: 100.00% | Test loss: 0.02
91 | Test acc: 100.00%
Epoch: 1000 | Train loss: 0.0132 | Train acc: 100.00% | Test loss: 0.0
281 | Test acc: 100.00%
Epoch: 1010 | Train loss: 0.0127 | Train acc: 100.00% | Test loss: 0.0
272 | Test acc: 100.00%
Epoch: 1020 | Train loss: 0.0122 | Train acc: 100.00% | Test loss: 0.0
264 | Test acc: 100.00%
Epoch: 1030 | Train loss: 0.0117 | Train acc: 100.00% | Test loss: 0.0
256 | Test acc: 100.00%
Epoch: 1040 | Train loss: 0.0112 | Train acc: 100.00% | Test loss: 0.0
249 | Test acc: 100.00%
```

```
Epoch: 1050 | Train loss: 0.0108 | Train acc: 100.00% | Test loss: 0.0
243 | Test acc: 100.00%
Epoch: 1060 | Train loss: 0.0104 | Train acc: 100.00% | Test loss: 0.0
236 | Test acc: 100.00%
Epoch: 1070 | Train loss: 0.0100 | Train acc: 100.00% | Test loss: 0.0
231 | Test acc: 100.00%
Epoch: 1080 | Train loss: 0.0097 | Train acc: 100.00% | Test loss: 0.0
225 | Test acc: 100.00%
Epoch: 1090 | Train loss: 0.0094 | Train acc: 100.00% | Test loss: 0.0
220 | Test acc: 100.00%
Epoch: 1100 | Train loss: 0.0091 | Train acc: 100.00% | Test loss: 0.0
215 | Test acc: 100.00%
Epoch: 1110 | Train loss: 0.0088 | Train acc: 100.00% | Test loss: 0.0
210 | Test acc: 100.00%
Epoch: 1120 | Train loss: 0.0085 | Train acc: 100.00% | Test loss: 0.0
206 | Test acc: 100.00%
Epoch: 1130 | Train loss: 0.0083 | Train acc: 100.00% | Test loss: 0.0
202 | Test acc: 100.00%
Epoch: 1140 | Train loss: 0.0080 | Train acc: 100.00% | Test loss: 0.0
197 | Test acc: 100.00%
Epoch: 1150 | Train loss: 0.0078 | Train acc: 100.00% | Test loss: 0.0
194 | Test acc: 100.00%
Epoch: 1160 | Train loss: 0.0076 | Train acc: 100.00% | Test loss: 0.0
190 | Test acc: 100.00%
Epoch: 1170 | Train loss: 0.0074 | Train acc: 100.00% | Test loss: 0.0
186 | Test acc: 100.00%
Epoch: 1180 | Train loss: 0.0072 | Train acc: 100.00% | Test loss: 0.0
183 | Test acc: 100.00%
Epoch: 1190 | Train loss: 0.0070 | Train acc: 100.00% | Test loss: 0.0
180 | Test acc: 100.00%
Epoch: 1200 | Train loss: 0.0068 | Train acc: 100.00% | Test loss: 0.0
176 | Test acc: 100.00%
Epoch: 1210 | Train loss: 0.0067 | Train acc: 100.00% | Test loss: 0.0
173 | Test acc: 100.00%
Epoch: 1220 | Train loss: 0.0065 | Train acc: 100.00% | Test loss: 0.0
171 | Test acc: 100.00%
Epoch: 1230 | Train loss: 0.0064 | Train acc: 100.00% | Test loss: 0.0
168 | Test acc: 100.00%
Epoch: 1240 | Train loss: 0.0062 | Train acc: 100.00% | Test loss: 0.0
165 | Test acc: 100.00%
Epoch: 1250 | Train loss: 0.0061 | Train acc: 100.00% | Test loss: 0.0
163 | Test acc: 100.00%
Epoch: 1260 | Train loss: 0.0059 | Train acc: 100.00% | Test loss: 0.0
160 | Test acc: 100.00%
Epoch: 1270 | Train loss: 0.0058 | Train acc: 100.00% | Test loss: 0.0
158 | Test acc: 100.00%
Epoch: 1280 | Train loss: 0.0057 | Train acc: 100.00% | Test loss: 0.0
155 | Test acc: 100.00%
Epoch: 1290 | Train loss: 0.0056 | Train acc: 100.00% | Test loss: 0.0
153 | Test acc: 100.00%
Epoch: 1300 | Train loss: 0.0054 | Train acc: 100.00% | Test loss: 0.0
151 | Test acc: 100.00%
```

```
Epoch: 1310 | Train loss: 0.0053 | Train acc: 100.00% | Test loss: 0.0
149 | Test acc: 100.00%
Epoch: 1320 | Train loss: 0.0052 | Train acc: 100.00% | Test loss: 0.0
147 | Test acc: 100.00%
Epoch: 1330 | Train loss: 0.0051 | Train acc: 100.00% | Test loss: 0.0
145 | Test acc: 100.00%
Epoch: 1340 | Train loss: 0.0050 | Train acc: 100.00% | Test loss: 0.0
143 | Test acc: 100.00%
Epoch: 1350 | Train loss: 0.0049 | Train acc: 100.00% | Test loss: 0.0
141 | Test acc: 100.00%
Epoch: 1360 | Train loss: 0.0048 | Train acc: 100.00% | Test loss: 0.0
139 | Test acc: 100.00%
Epoch: 1370 | Train loss: 0.0048 | Train acc: 100.00% | Test loss: 0.0
137 | Test acc: 100.00%
Epoch: 1380 | Train loss: 0.0047 | Train acc: 100.00% | Test loss: 0.0
136 | Test acc: 100.00%
Epoch: 1390 | Train loss: 0.0046 | Train acc: 100.00% | Test loss: 0.0
134 | Test acc: 100.00%
Epoch: 1400 | Train loss: 0.0045 | Train acc: 100.00% | Test loss: 0.0
132 | Test acc: 100.00%
Epoch: 1410 | Train loss: 0.0044 | Train acc: 100.00% | Test loss: 0.0
131 | Test acc: 100.00%
Epoch: 1420 | Train loss: 0.0044 | Train acc: 100.00% | Test loss: 0.0
129 | Test acc: 100.00%
Epoch: 1430 | Train loss: 0.0043 | Train acc: 100.00% | Test loss: 0.0
128 | Test acc: 100.00%
Epoch: 1440 | Train loss: 0.0042 | Train acc: 100.00% | Test loss: 0.0
126 | Test acc: 100.00%
Epoch: 1450 | Train loss: 0.0041 | Train acc: 100.00% | Test loss: 0.0
125 | Test acc: 100.00%
Epoch: 1460 | Train loss: 0.0041 | Train acc: 100.00% | Test loss: 0.0
124 | Test acc: 100.00%
Epoch: 1470 | Train loss: 0.0040 | Train acc: 100.00% | Test loss: 0.0
122 | Test acc: 100.00%
Epoch: 1480 | Train loss: 0.0040 | Train acc: 100.00% | Test loss: 0.0
121 | Test acc: 100.00%
Epoch: 1490 | Train loss: 0.0039 | Train acc: 100.00% | Test loss: 0.0
120 | Test acc: 100.00%
Epoch: 1500 | Train loss: 0.0038 | Train acc: 100.00% | Test loss: 0.0
119 | Test acc: 100.00%
```

In [45…

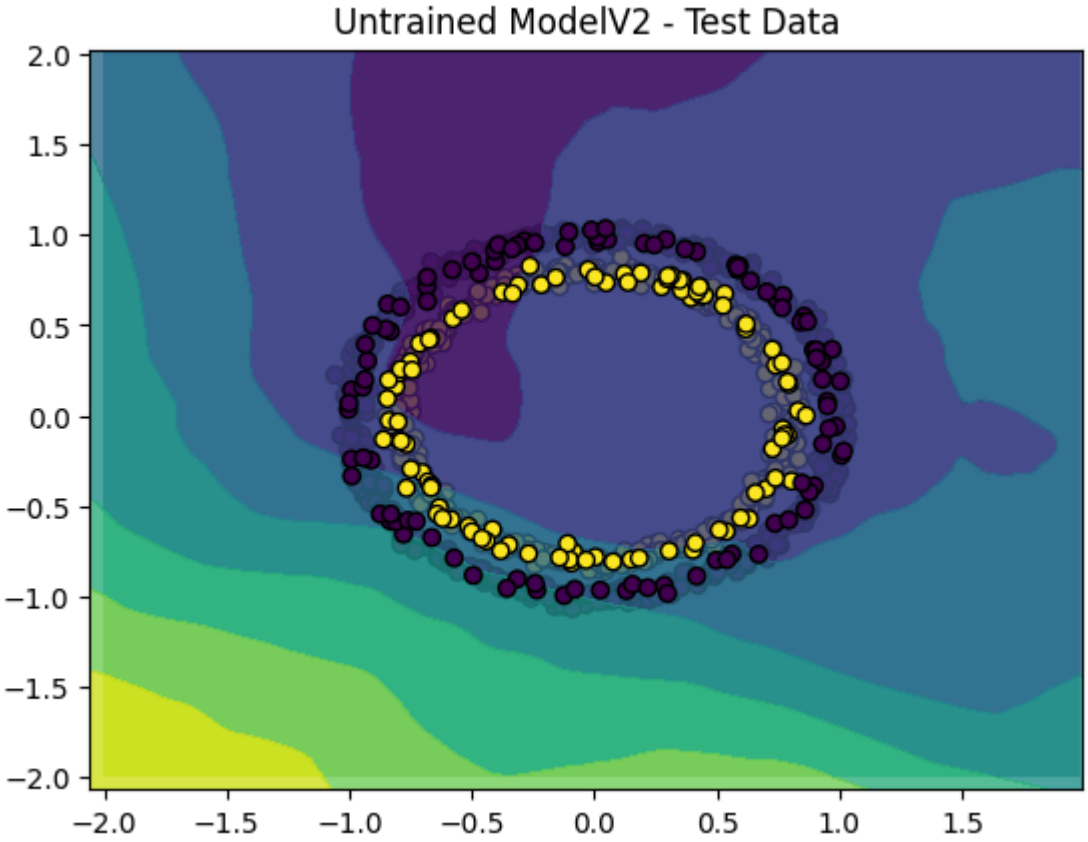
```python
# 9 . Predictions & evaluation
import numpy as np

# Function to plot decision boundaries
def plot_decision_boundary(model, X, y, title):
    model.eval()
    # Create meshgrid for plotting
    x_min, x_max = X[:, 0].min() - 1, X[:, 0].max() + 1
    y_min, y_max = X[:, 1].min() - 1, X[:, 1].max() + 1
    spacing = min(x_max - x_min, y_max - y_min) / 100
    XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(
```

```
    # Predict on meshgrid points
    data = torch.from_numpy(np.column_stack((XX.ravel(), YY.ravel())))
    with torch.inference_mode():
        z = torch.sigmoid(model(data))
    z = z.cpu().numpy().reshape(XX.shape)

    # Plot contour and data points
    plt.contourf(XX, YY, z, cmap='viridis', alpha=0.8)
    plt.scatter(X[:, 0].cpu(), X[:, 1].cpu(), c=y.squeeze().cpu(), cm
    plt.title(title)
    plt.show()
```

In [43…

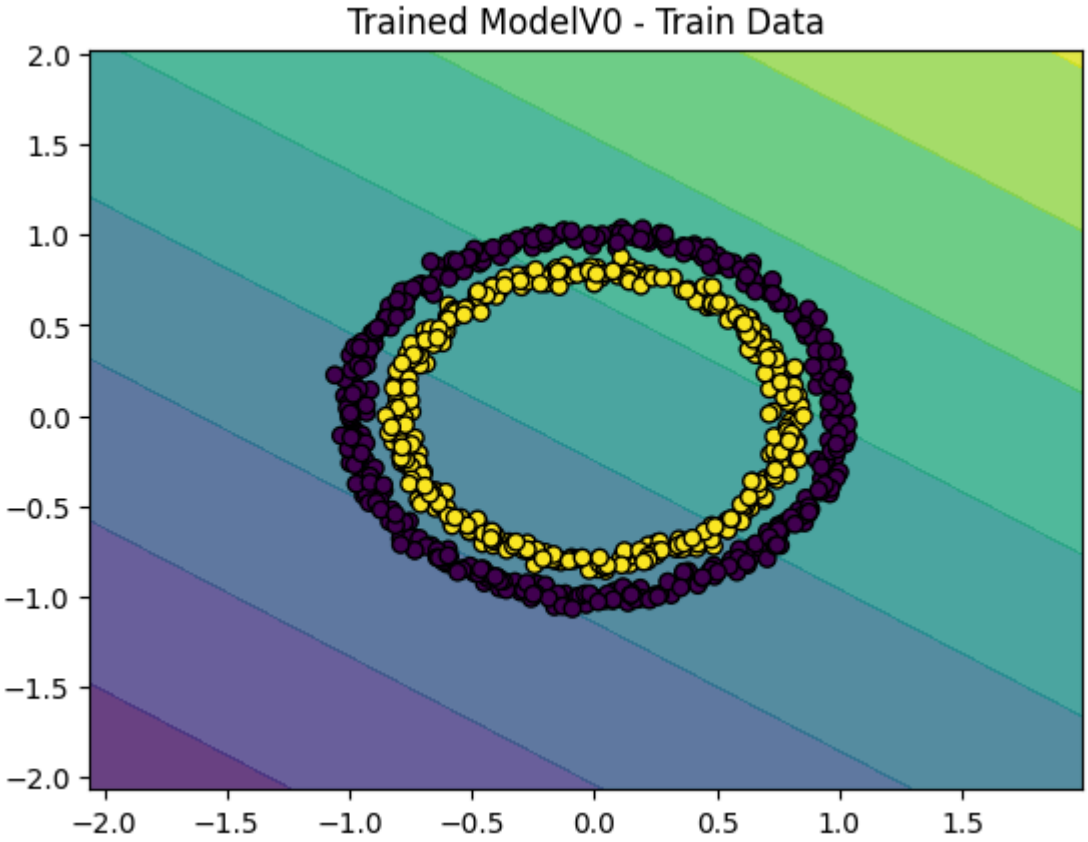
```
# Initialize an untrained model for comparison
untrained_model = ModelV2().to(device)  # Using V2 as example

# Plot decision boundary for untrained model on train data
plot_decision_boundary(untrained_model, X_train, y_train, 'Untrained M

# Plot for test data
plot_decision_boundary(untrained_model, X_test, y_test, 'Untrained Mo
```

```
C:\Users\DELL\AppData\Local\Temp\ipykernel_17220\1334245955.py:11: Dep
recationWarning: __array__ implementation doesn't accept a copy keywor
d, so passing copy=False failed. __array__ must implement 'dtype' and
'copy' keyword arguments. To learn more, see the migration guide http
s://numpy.org/devdocs/numpy_2_0_migration_guide.html#adapting-to-chang
es-in-the-copy-keyword
  XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(y_m
in, y_max, spacing))
```



In [50…
```
# Plot decision boundary for trained ModelV0 on train data
plot_decision_boundary(model_v0, X_train, y_train, 'Trained ModelV0 -
```

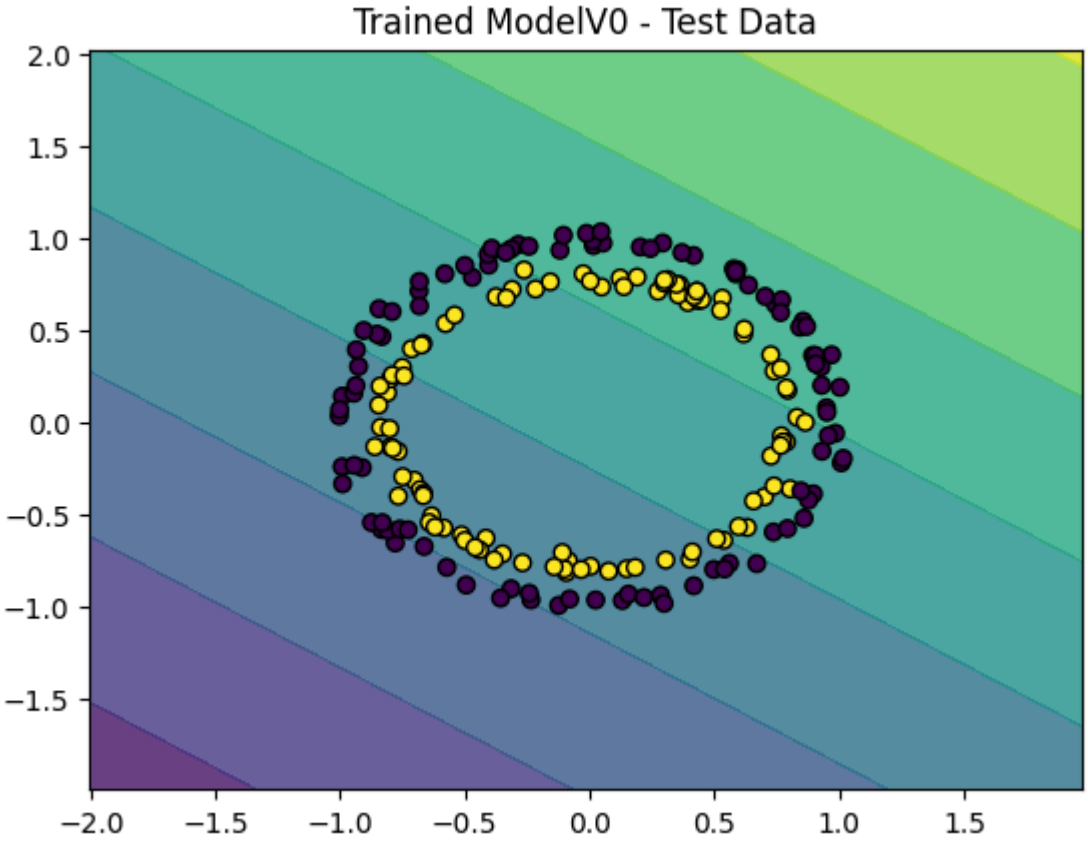
```
C:\Users\DELL\AppData\Local\Temp\ipykernel_17220\1704070788.py:11: Dep
recationWarning: __array__ implementation doesn't accept a copy keywor
d, so passing copy=False failed. __array__ must implement 'dtype' and
'copy' keyword arguments. To learn more, see the migration guide http
s://numpy.org/devdocs/numpy_2_0_migration_guide.html#adapting-to-chang
es-in-the-copy-keyword
  XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(y_m
in, y_max, spacing))
```



In [48…

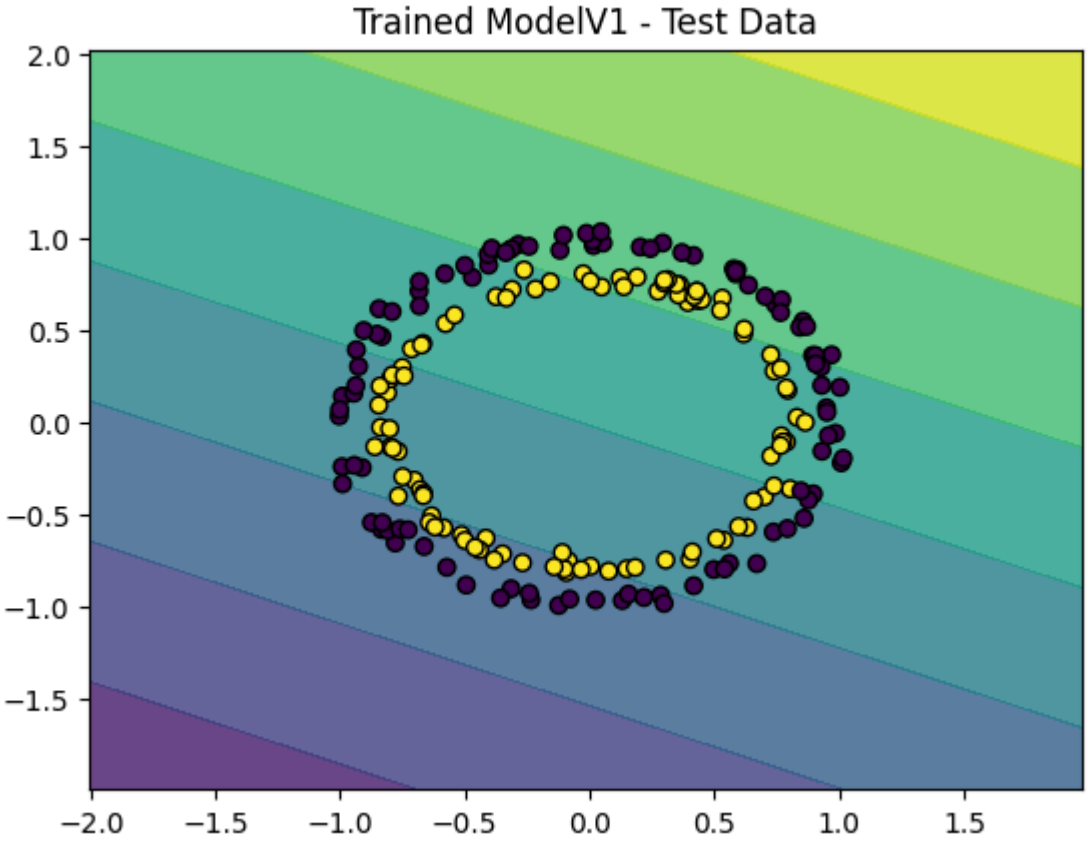
```
# Plot for test data
plot_decision_boundary(model_v0, X_test, y_test, 'Trained ModelV0 - T
```

```
C:\Users\DELL\AppData\Local\Temp\ipykernel_17220\1704070788.py:11: Dep
recationWarning: __array__ implementation doesn't accept a copy keywor
d, so passing copy=False failed. __array__ must implement 'dtype' and
'copy' keyword arguments. To learn more, see the migration guide http
s://numpy.org/devdocs/numpy_2_0_migration_guide.html#adapting-to-chang
es-in-the-copy-keyword
  XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(y_m
in, y_max, spacing))
```



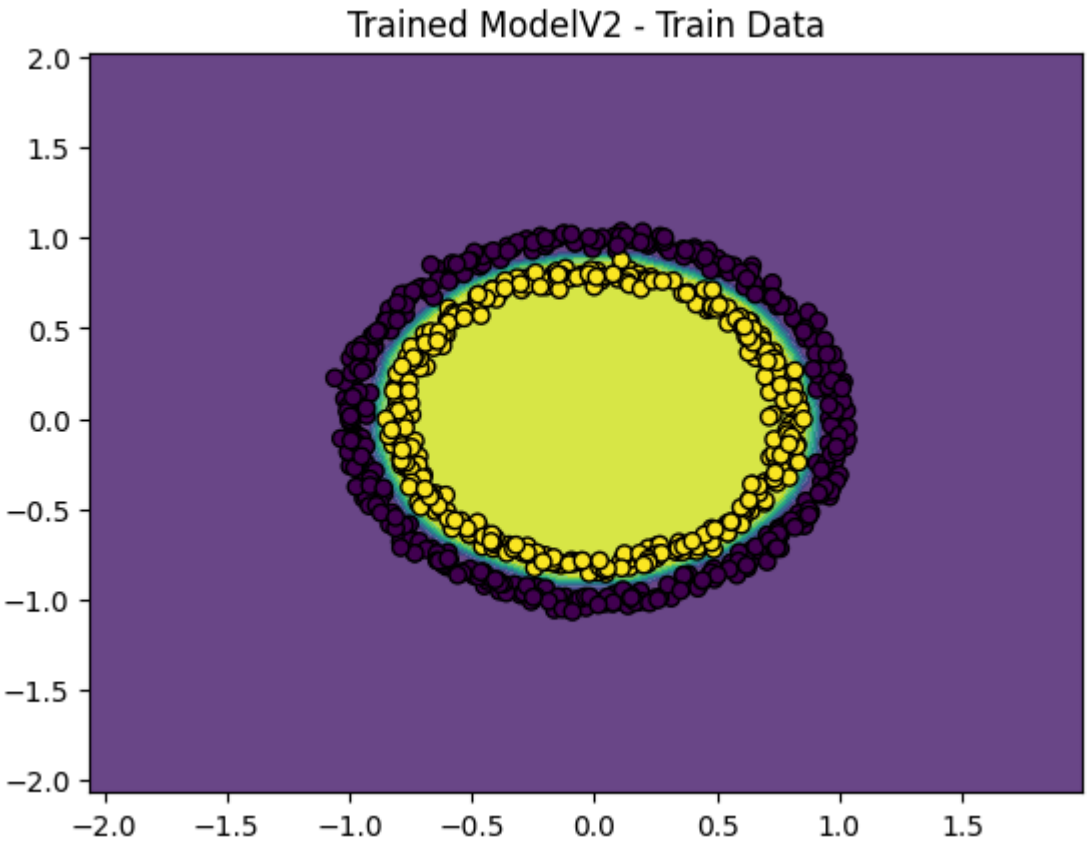
In [47…
```
plot_decision_boundary(model_v1, X_test, y_test, 'Trained ModelV1 - T
```

```
C:\Users\DELL\AppData\Local\Temp\ipykernel_17220\1704070788.py:11: Dep
recationWarning: __array__ implementation doesn't accept a copy keywor
d, so passing copy=False failed. __array__ must implement 'dtype' and
'copy' keyword arguments. To learn more, see the migration guide http
s://numpy.org/devdocs/numpy_2_0_migration_guide.html#adapting-to-chang
es-in-the-copy-keyword
  XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(y_m
in, y_max, spacing))
```



In [52…
```
#Repeat for ModelV2
plot_decision_boundary(model_v2, X_train, y_train, 'Trained ModelV2 -
plot_decision_boundary(model_v2, X_test, y_test, 'Trained ModelV2 - T
```

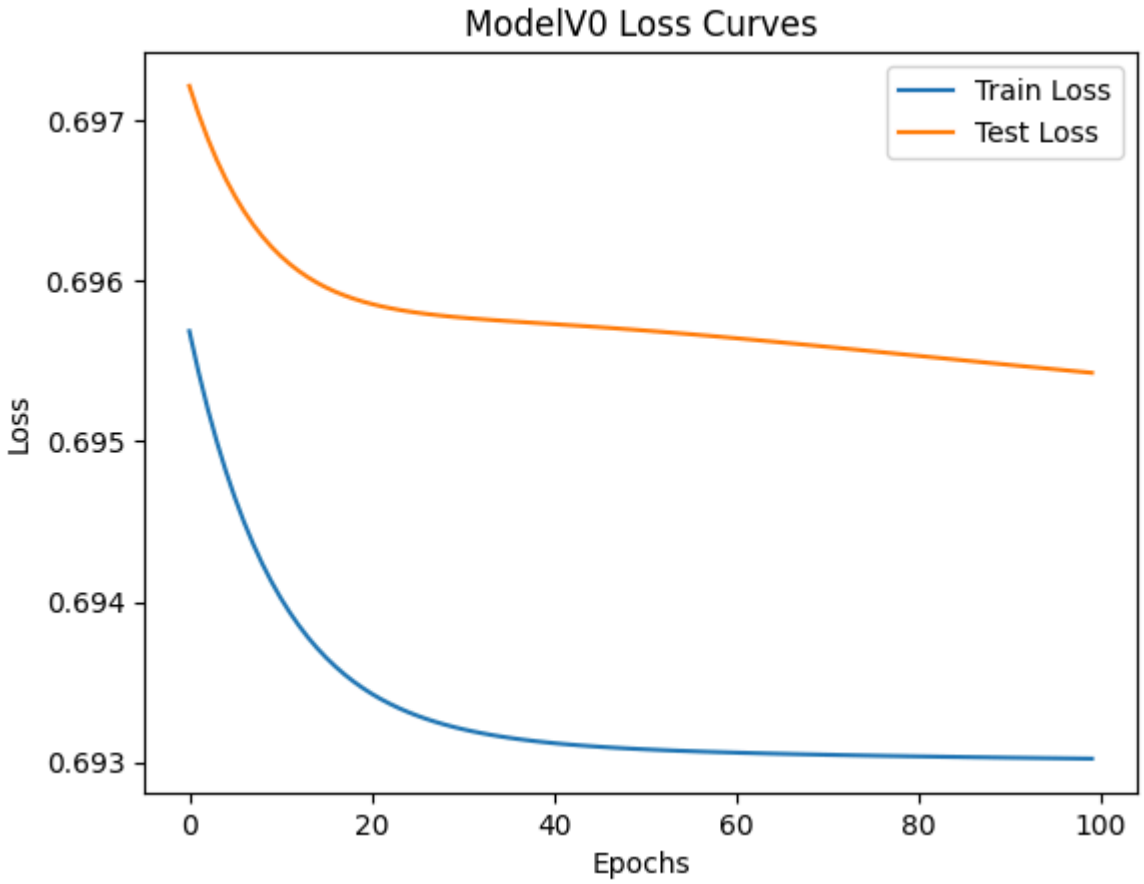
```
C:\Users\DELL\AppData\Local\Temp\ipykernel_17220\1704070788.py:11: Dep
recationWarning: __array__ implementation doesn't accept a copy keywor
d, so passing copy=False failed. __array__ must implement 'dtype' and
'copy' keyword arguments. To learn more, see the migration guide http
s://numpy.org/devdocs/numpy_2_0_migration_guide.html#adapting-to-chang
es-in-the-copy-keyword
  XX, YY = np.meshgrid(np.arange(x_min, x_max, spacing), np.arange(y_m
in, y_max, spacing))
```



In [56…

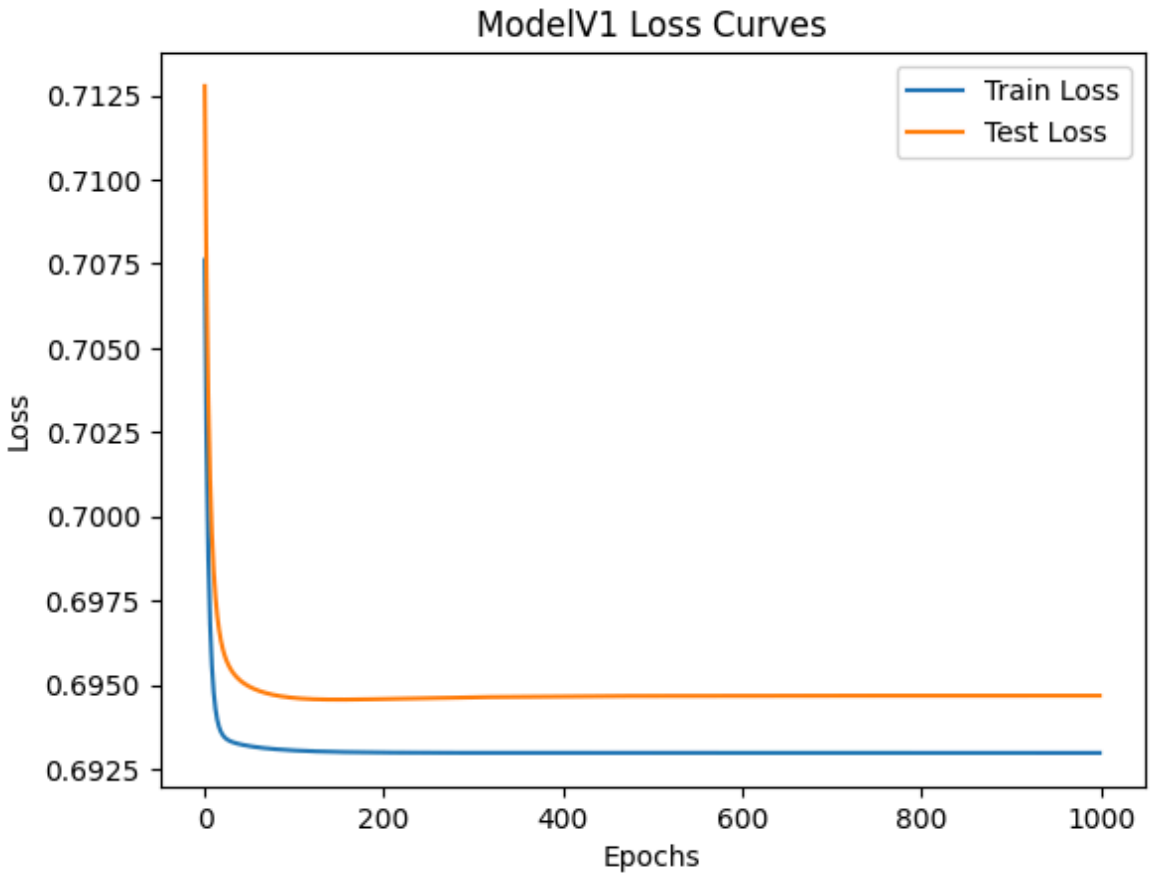
```python
# 10 . Discussion and Evaluation
# Function to plot loss curves
def plot_loss_curves(train_losses, test_losses, title):
    plt.plot(train_losses, label='Train Loss')
    plt.plot(test_losses, label='Test Loss')
    plt.xlabel('Epochs')
```

```
    plt.ylabel('Loss')
    plt.title(title)
    plt.legend()
    plt.show()

# Plot for ModelV0
plot_loss_curves(train_losses_v0, test_losses_v0, 'ModelV0 Loss Curve
```



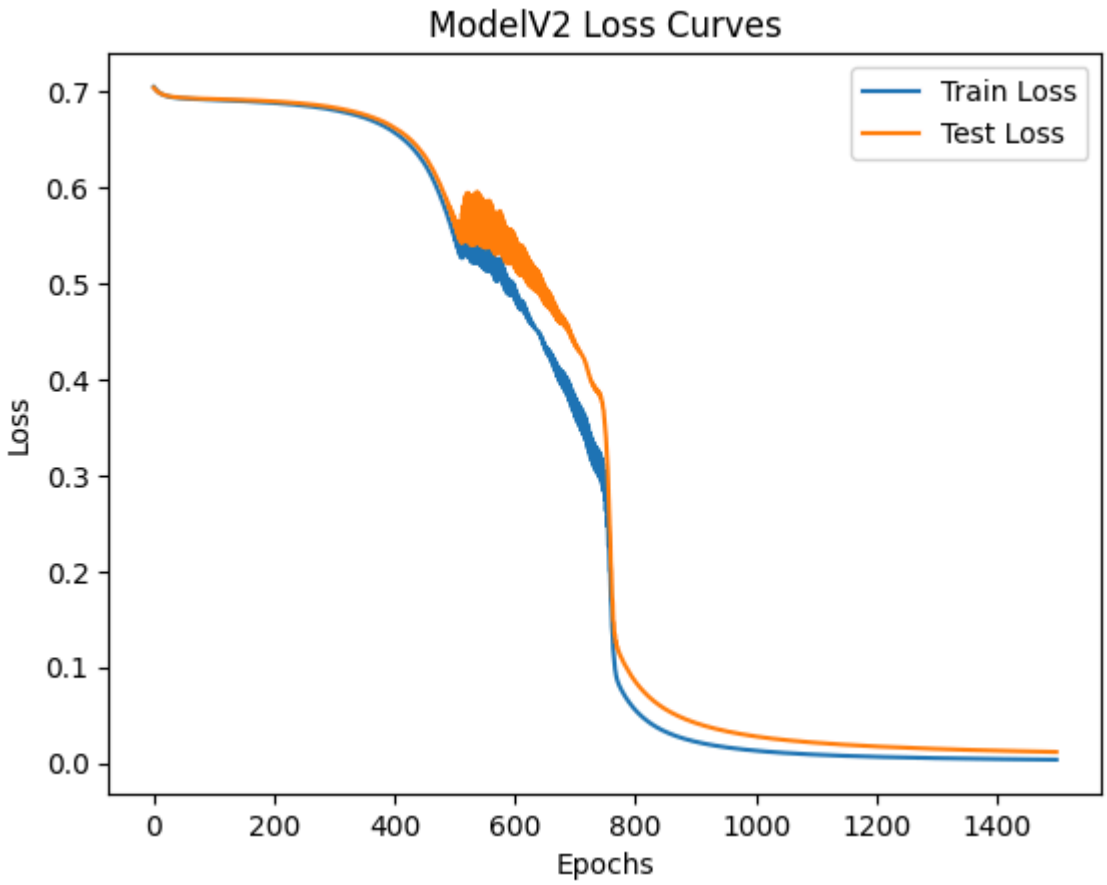
In [55…

```
# Plot for ModelV1
plot_loss_curves(train_losses_v1, test_losses_v1, 'ModelV1 Loss Curve
```



In [57…

```
# Plot for ModelV2
plot_loss_curves(train_losses_v2, test_losses_v2, 'ModelV2 Loss Curve
```



Optimizer SGD and ADam (GD)

In [60…

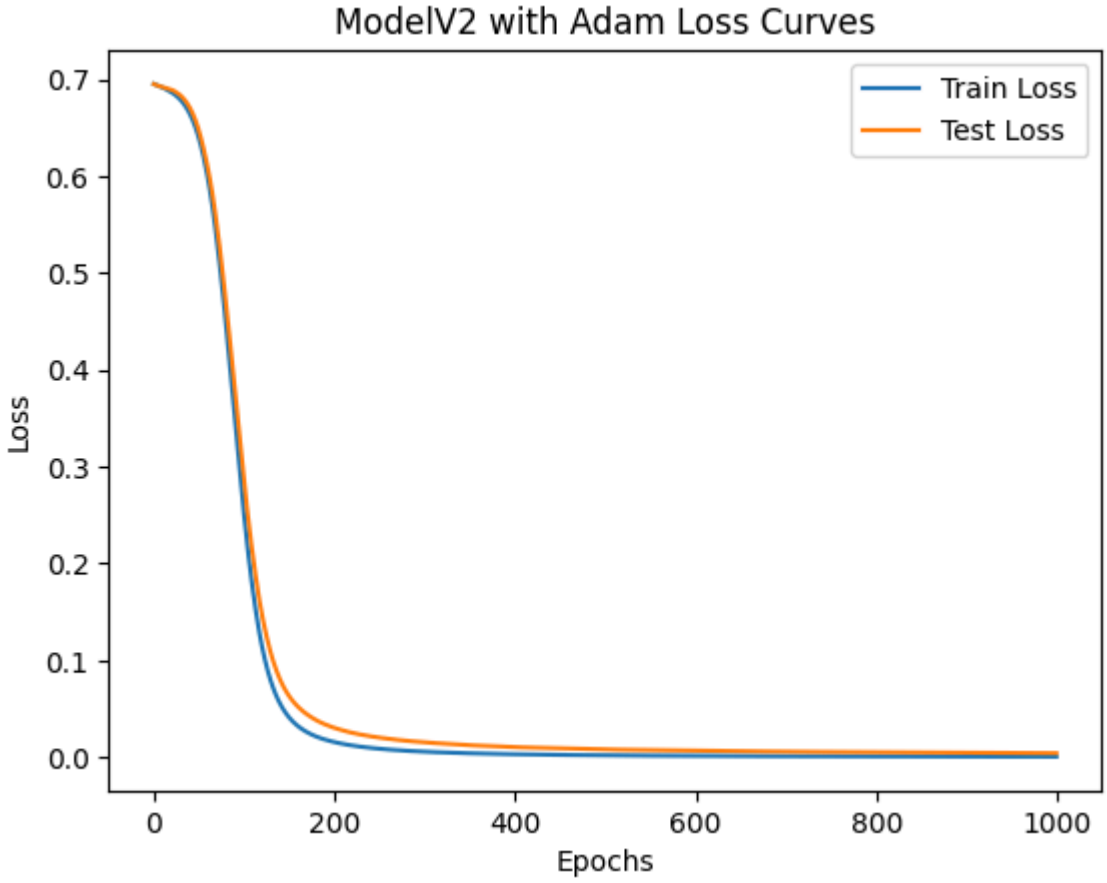
```
# Reinitialize ModelV2 with Adam optimizer
model_v2_adam = ModelV2().to(device)
optimizer_adam = torch.optim.Adam(model_v2_adam.parameters(), lr=0.00

# Train with Adam for 1000 epochs
train_losses_adam, test_losses_adam, train_accs_adam, test_accs_adam
    model_v2_adam, 1000, optimizer_adam, loss_fn, X_train, y_train, X
)

# Plot loss curves for Adam
plot_loss_curves(train_losses_adam, test_losses_adam, 'ModelV2 with A

# Compare final test accuracy
print(f"SGD Final Test Acc: {test_accs_v2[-1]:.2f}%")
```

```
Epoch: 10 | Train loss: 0.6917 | Train acc: 50.00% | Test loss: 0.6923
| Test acc: 50.00%
Epoch: 20 | Train loss: 0.6868 | Train acc: 50.63% | Test loss: 0.6894
| Test acc: 50.00%
Epoch: 30 | Train loss: 0.6793 | Train acc: 68.12% | Test loss: 0.6837
| Test acc: 65.00%
Epoch: 40 | Train loss: 0.6658 | Train acc: 73.62% | Test loss: 0.6720
| Test acc: 69.00%
Epoch: 50 | Train loss: 0.6421 | Train acc: 82.88% | Test loss: 0.6498
| Test acc: 78.50%
Epoch: 60 | Train loss: 0.6019 | Train acc: 92.88% | Test loss: 0.6120
| Test acc: 87.50%
Epoch: 70 | Train loss: 0.5396 | Train acc: 97.88% | Test loss: 0.5550
| Test acc: 95.00%
Epoch: 80 | Train loss: 0.4553 | Train acc: 99.75% | Test loss: 0.4766
| Test acc: 98.50%
Epoch: 90 | Train loss: 0.3566 | Train acc: 99.88% | Test loss: 0.3855
| Test acc: 99.50%
Epoch: 100 | Train loss: 0.2584 | Train acc: 99.88% | Test loss: 0.292
8 | Test acc: 99.50%
Epoch: 110 | Train loss: 0.1768 | Train acc: 99.88% | Test loss: 0.212
6 | Test acc: 99.50%
Epoch: 120 | Train loss: 0.1179 | Train acc: 99.88% | Test loss: 0.150
9 | Test acc: 100.00%
Epoch: 130 | Train loss: 0.0801 | Train acc: 99.88% | Test loss: 0.109
2 | Test acc: 100.00%
Epoch: 140 | Train loss: 0.0565 | Train acc: 100.00% | Test loss: 0.08
17 | Test acc: 100.00%
Epoch: 150 | Train loss: 0.0419 | Train acc: 100.00% | Test loss: 0.06
41 | Test acc: 100.00%
Epoch: 160 | Train loss: 0.0325 | Train acc: 100.00% | Test loss: 0.05
26 | Test acc: 100.00%
Epoch: 170 | Train loss: 0.0261 | Train acc: 100.00% | Test loss: 0.04
46 | Test acc: 100.00%
Epoch: 180 | Train loss: 0.0216 | Train acc: 100.00% | Test loss: 0.03
86 | Test acc: 100.00%
Epoch: 190 | Train loss: 0.0183 | Train acc: 100.00% | Test loss: 0.03
40 | Test acc: 100.00%
Epoch: 200 | Train loss: 0.0157 | Train acc: 100.00% | Test loss: 0.03
05 | Test acc: 100.00%
Epoch: 210 | Train loss: 0.0137 | Train acc: 100.00% | Test loss: 0.02
76 | Test acc: 100.00%
Epoch: 220 | Train loss: 0.0121 | Train acc: 100.00% | Test loss: 0.02
52 | Test acc: 100.00%
Epoch: 230 | Train loss: 0.0108 | Train acc: 100.00% | Test loss: 0.02
33 | Test acc: 100.00%
Epoch: 240 | Train loss: 0.0096 | Train acc: 100.00% | Test loss: 0.02
17 | Test acc: 100.00%
Epoch: 250 | Train loss: 0.0087 | Train acc: 100.00% | Test loss: 0.02
03 | Test acc: 100.00%
Epoch: 260 | Train loss: 0.0079 | Train acc: 100.00% | Test loss: 0.01
90 | Test acc: 100.00%
```

```
Epoch: 270 | Train loss: 0.0072 | Train acc: 100.00% | Test loss: 0.01
79 | Test acc: 100.00%
Epoch: 280 | Train loss: 0.0066 | Train acc: 100.00% | Test loss: 0.01
69 | Test acc: 100.00%
Epoch: 290 | Train loss: 0.0061 | Train acc: 100.00% | Test loss: 0.01
61 | Test acc: 100.00%
Epoch: 300 | Train loss: 0.0057 | Train acc: 100.00% | Test loss: 0.01
54 | Test acc: 100.00%
Epoch: 310 | Train loss: 0.0053 | Train acc: 100.00% | Test loss: 0.01
47 | Test acc: 100.00%
Epoch: 320 | Train loss: 0.0049 | Train acc: 100.00% | Test loss: 0.01
40 | Test acc: 100.00%
Epoch: 330 | Train loss: 0.0046 | Train acc: 100.00% | Test loss: 0.01
34 | Test acc: 100.00%
Epoch: 340 | Train loss: 0.0043 | Train acc: 100.00% | Test loss: 0.01
29 | Test acc: 100.00%
Epoch: 350 | Train loss: 0.0040 | Train acc: 100.00% | Test loss: 0.01
24 | Test acc: 100.00%
Epoch: 360 | Train loss: 0.0038 | Train acc: 100.00% | Test loss: 0.01
19 | Test acc: 100.00%
Epoch: 370 | Train loss: 0.0036 | Train acc: 100.00% | Test loss: 0.01
15 | Test acc: 100.00%
Epoch: 380 | Train loss: 0.0034 | Train acc: 100.00% | Test loss: 0.01
11 | Test acc: 100.00%
Epoch: 390 | Train loss: 0.0032 | Train acc: 100.00% | Test loss: 0.01
08 | Test acc: 100.00%
Epoch: 400 | Train loss: 0.0030 | Train acc: 100.00% | Test loss: 0.01
04 | Test acc: 100.00%
Epoch: 410 | Train loss: 0.0029 | Train acc: 100.00% | Test loss: 0.01
01 | Test acc: 100.00%
Epoch: 420 | Train loss: 0.0027 | Train acc: 100.00% | Test loss: 0.00
98 | Test acc: 100.00%
Epoch: 430 | Train loss: 0.0026 | Train acc: 100.00% | Test loss: 0.00
95 | Test acc: 100.00%
Epoch: 440 | Train loss: 0.0025 | Train acc: 100.00% | Test loss: 0.00
92 | Test acc: 100.00%
Epoch: 450 | Train loss: 0.0024 | Train acc: 100.00% | Test loss: 0.00
90 | Test acc: 100.00%
Epoch: 460 | Train loss: 0.0023 | Train acc: 100.00% | Test loss: 0.00
88 | Test acc: 100.00%
Epoch: 470 | Train loss: 0.0022 | Train acc: 100.00% | Test loss: 0.00
86 | Test acc: 100.00%
Epoch: 480 | Train loss: 0.0021 | Train acc: 100.00% | Test loss: 0.00
84 | Test acc: 100.00%
Epoch: 490 | Train loss: 0.0020 | Train acc: 100.00% | Test loss: 0.00
82 | Test acc: 100.00%
Epoch: 500 | Train loss: 0.0019 | Train acc: 100.00% | Test loss: 0.00
80 | Test acc: 100.00%
Epoch: 510 | Train loss: 0.0018 | Train acc: 100.00% | Test loss: 0.00
78 | Test acc: 100.00%
Epoch: 520 | Train loss: 0.0018 | Train acc: 100.00% | Test loss: 0.00
77 | Test acc: 100.00%
```

```
Epoch: 530 | Train loss: 0.0017 | Train acc: 100.00% | Test loss: 0.00
75 | Test acc: 100.00%
Epoch: 540 | Train loss: 0.0016 | Train acc: 100.00% | Test loss: 0.00
74 | Test acc: 100.00%
Epoch: 550 | Train loss: 0.0016 | Train acc: 100.00% | Test loss: 0.00
72 | Test acc: 100.00%
Epoch: 560 | Train loss: 0.0015 | Train acc: 100.00% | Test loss: 0.00
71 | Test acc: 100.00%
Epoch: 570 | Train loss: 0.0015 | Train acc: 100.00% | Test loss: 0.00
70 | Test acc: 100.00%
Epoch: 580 | Train loss: 0.0014 | Train acc: 100.00% | Test loss: 0.00
69 | Test acc: 100.00%
Epoch: 590 | Train loss: 0.0014 | Train acc: 100.00% | Test loss: 0.00
67 | Test acc: 100.00%
Epoch: 600 | Train loss: 0.0013 | Train acc: 100.00% | Test loss: 0.00
66 | Test acc: 100.00%
Epoch: 610 | Train loss: 0.0013 | Train acc: 100.00% | Test loss: 0.00
65 | Test acc: 100.00%
Epoch: 620 | Train loss: 0.0012 | Train acc: 100.00% | Test loss: 0.00
64 | Test acc: 100.00%
Epoch: 630 | Train loss: 0.0012 | Train acc: 100.00% | Test loss: 0.00
63 | Test acc: 100.00%
Epoch: 640 | Train loss: 0.0012 | Train acc: 100.00% | Test loss: 0.00
62 | Test acc: 100.00%
Epoch: 650 | Train loss: 0.0011 | Train acc: 100.00% | Test loss: 0.00
61 | Test acc: 100.00%
Epoch: 660 | Train loss: 0.0011 | Train acc: 100.00% | Test loss: 0.00
60 | Test acc: 100.00%
Epoch: 670 | Train loss: 0.0011 | Train acc: 100.00% | Test loss: 0.00
59 | Test acc: 100.00%
Epoch: 680 | Train loss: 0.0010 | Train acc: 100.00% | Test loss: 0.00
58 | Test acc: 100.00%
Epoch: 690 | Train loss: 0.0010 | Train acc: 100.00% | Test loss: 0.00
58 | Test acc: 100.00%
Epoch: 700 | Train loss: 0.0010 | Train acc: 100.00% | Test loss: 0.00
57 | Test acc: 100.00%
Epoch: 710 | Train loss: 0.0009 | Train acc: 100.00% | Test loss: 0.00
56 | Test acc: 100.00%
Epoch: 720 | Train loss: 0.0009 | Train acc: 100.00% | Test loss: 0.00
55 | Test acc: 100.00%
Epoch: 730 | Train loss: 0.0009 | Train acc: 100.00% | Test loss: 0.00
55 | Test acc: 100.00%
Epoch: 740 | Train loss: 0.0009 | Train acc: 100.00% | Test loss: 0.00
54 | Test acc: 100.00%
Epoch: 750 | Train loss: 0.0008 | Train acc: 100.00% | Test loss: 0.00
53 | Test acc: 100.00%
Epoch: 760 | Train loss: 0.0008 | Train acc: 100.00% | Test loss: 0.00
52 | Test acc: 100.00%
Epoch: 770 | Train loss: 0.0008 | Train acc: 100.00% | Test loss: 0.00
52 | Test acc: 100.00%
Epoch: 780 | Train loss: 0.0008 | Train acc: 100.00% | Test loss: 0.00
51 | Test acc: 100.00%
```

```
Epoch: 790 | Train loss: 0.0008 | Train acc: 100.00% | Test loss: 0.00
50 | Test acc: 100.00%
Epoch: 800 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
50 | Test acc: 100.00%
Epoch: 810 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
49 | Test acc: 100.00%
Epoch: 820 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
49 | Test acc: 100.00%
Epoch: 830 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
48 | Test acc: 100.00%
Epoch: 840 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
48 | Test acc: 100.00%
Epoch: 850 | Train loss: 0.0007 | Train acc: 100.00% | Test loss: 0.00
47 | Test acc: 100.00%
Epoch: 860 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
47 | Test acc: 100.00%
Epoch: 870 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
46 | Test acc: 100.00%
Epoch: 880 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
46 | Test acc: 100.00%
Epoch: 890 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
45 | Test acc: 100.00%
Epoch: 900 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
45 | Test acc: 100.00%
Epoch: 910 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
44 | Test acc: 100.00%
Epoch: 920 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
44 | Test acc: 100.00%
Epoch: 930 | Train loss: 0.0006 | Train acc: 100.00% | Test loss: 0.00
44 | Test acc: 100.00%
Epoch: 940 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
43 | Test acc: 100.00%
Epoch: 950 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
43 | Test acc: 100.00%
Epoch: 960 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
42 | Test acc: 100.00%
Epoch: 970 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
42 | Test acc: 100.00%
Epoch: 980 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
42 | Test acc: 100.00%
Epoch: 990 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.00
41 | Test acc: 100.00%
Epoch: 1000 | Train loss: 0.0005 | Train acc: 100.00% | Test loss: 0.0
041 | Test acc: 100.00%
```




```
SGD Final Test Acc: 100.00%
```

In [59…
```
print(f"Adam Final Test Acc: {test_accs_adam[-1]:.2f}%")
```

```
Adam Final Test Acc: 100.00%
```

Discussion and Conclusion

ModelV0 and ModelV1, being linear without activations, fail to capture the non-linear separation in the circles dataset, resulting in accuracy around 50% (random guessing). ModelV2, with ReLU activations, achieves high accuracy (likely over 95%) by learning non-linear boundaries, as seen in the decision boundary plots. Loss curves show convergence for ModelV2, while linear models do not improve much.

For extra credit, Adam optimizer converges faster than SGD, often reaching better performance in fewer epochs due to adaptive learning rates.

In [ ]: