```
!pip install pennylane
```

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Collecting pennylane
  Downloading PennyLane-0.40.0-py3-none-any.whl.metadata (10 kB)
Requirement already satisfied: numpy<2.1 in /usr/local/lib/python3.11/dist-packages (from pennylane) (2.0.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages (from pennylane) (1.14.1)
Requirement already satisfied: networkx in /usr/local/lib/python3.11/dist-packages (from pennylane) (3.4.2)
Collecting rustworkx>=0.14.0 (from pennylane)
  Downloading rustworkx-0.16.0-cp39-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (10 kB)
Requirement already satisfied: autograd in /usr/local/lib/python3.11/dist-packages (from pennylane) (1.7.0)
Collecting tomlkit (from pennylane)
  Downloading tomlkit-0.13.2-py3-none-any.whl.metadata (2.7 kB)
Collecting appdirs (from pennylane)
  Downloading appdirs-1.4.4-py2.py3-none-any.whl.metadata (9.0 kB)
Collecting autoray>=0.6.11 (from pennylane)
  Downloading autoray-0.7.1-py3-none-any.whl.metadata (5.8 kB)
Requirement already satisfied: cachetools in /usr/local/lib/python3.11/dist-packages (from pennylane) (5.5.2)
Collecting pennylane-lightning>=0.40 (from pennylane)
  Downloading PennyLane_Lightning-0.40.0-cp311-cp311-manylinux_2_28_x86_64.whl.metadata (27 kB)
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-packages (from pennylane) (2.32.3)
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.11/dist-packages (from pennylane) (4.13.0)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-packages (from pennylane) (24.2)
Collecting diastatic-malt (from pennylane)
  Downloading diastatic_malt-2.15.2-py3-none-any.whl.metadata (2.6 kB)
Collecting scipy-openblas32>=0.3.26 (from pennylane-lightning>=0.40->pennylane)
  Downloading scipy_openblas32-0.3.29.0.0-py3-none-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (56 kB)
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Requirement already satisfied: astunparse in /usr/local/lib/python3.11/dist-packages (from diastatic-malt->pennylane) (1.6.3)
Requirement already satisfied: gast in /usr/local/lib/python3.11/dist-packages (from diastatic-malt->pennylane) (0.6.0)
Requirement already satisfied: termcolor in /usr/local/lib/python3.11/dist-packages (from diastatic-malt->pennylane) (2.5.0)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/dist-packages (from requests->pennylane)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-packages (from requests->pennylane) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/dist-packages (from requests->pennylane) (2.3.0)
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Requirement already satisfied: wheel<1.0,>=0.23.0 in /usr/local/lib/python3.11/dist-packages (from astunparse->diastatic-malt-
Requirement already satisfied: six<2.0,>=1.6.1 in /usr/local/lib/python3.11/dist-packages (from astunparse->diastatic-malt->pen
Downloading PennyLane-0.40.0-py3-none-any.whl (2.0 MB)
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Downloading rustworkx-0.16.0-cp39-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (2.1 MB)
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Downloading appdirs-1.4.4-py2.py3-none-any.whl (9.6 kB)
Downloading diastatic_malt-2.15.2-py3-none-any.whl (167 kB)
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Downloading tomlkit-0.13.2-py3-none-any.whl (37 kB)
Downloading scipy_openblas32-0.3.29.0.0-py3-none-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (8.6 MB)
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Installing collected packages: appdirs, tomlkit, scipy-openblas32, rustworkx, autoray, diastatic-malt, pennylane-lightning, pen
Successfully installed appdirs-1.4.4 autoray-0.7.1 diastatic-malt-2.15.2 pennylane-0.40.0 pennylane-lightning-0.40.0 rustworkx-
```

```
import numpy as np
import torch
from torch.utils.data import DataLoader
from torchvision import datasets, transforms
import pennylane as qml
from pennylane import numpy as qnp



transform = transforms.Compose([transforms.ToTensor(), transforms.Lambda(lambda x: x.view(-1))])

train_data = datasets.MNIST(root='./data', train=True, download=True, transform=transform)
test_data = datasets.MNIST(root='./data', train=False, download=True, transform=transform)

train_loader = DataLoader(train_data, batch_size=64, shuffle=True)
test_loader = DataLoader(test_data, batch_size=64, shuffle=False)
```

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100%|██████████| 9.91M/9.91M [00:00<00:00, 229MB/s]
100%|██████████| 28.9k/28.9k [00:00<00:00, 17.4MB/s]
100%|██████████| 1.65M/1.65M [00:00<00:00, 34.8MB/s]
100%|██████████| 4.54k/4.54k [00:00<00:00, 3.16MB/s]
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```
num_qubits = 8
dev = qml.device("default.qubit", wires=num_qubits)

def prepare_quantum_state(image, weights):
    image = qnp.array(image, dtype=np.float32)
    weights = qnp.array(weights, dtype=np.float32)
    for i in range(num_qubits):
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            angle = image[i] % (2 * np.pi)
            qml.RY(angle, wires=i)

        for i in range(0, len(weights), 2):
            qml.RZ(weights[i], wires=i % num_qubits)

    @qml.qnode(dev)
    def swap_test(image1, image2, weights):
        prepare_quantum_state(image1, weights)
        prepare_quantum_state(image2, weights)

        qml.Hadamard(wires=0)
        qml.CSWAP(wires=[0, 1, 2])
        return qml.expval(qml.PauliZ(0))



    def contrastive_loss(fidelity, label1, label2, margin=0.5):
        if label1 == label2:
            return (1 - fidelity)**2
        else:
            return qnp.array(max(0, fidelity)**2, dtype=float)


    def train_qnn_with_negative_pairs(model, train_loader, num_epochs=10, learning_rate=0.01):
        opt = qml.AdamOptimizer(learning_rate)
        weights = qnp.random.uniform(-np.pi, np.pi, num_qubits, requires_grad=True)  # Use qml.numpy for weights

        for epoch in range(num_epochs):
            total_loss = 0
            for batch_idx, (data, target) in enumerate(train_loader):
                idx1 = np.random.randint(0, data.size(0))
                idx2 = np.random.randint(0, data.size(0))

                image1 = data[idx1].squeeze(0).numpy()
                image2 = data[idx2].squeeze(0).numpy()

                label1 = target[idx1].item()
                label2 = target[idx2].item()

                image1 = np.array(image1, dtype=np.float32)
                image2 = np.array(image2, dtype=np.float32)

                # loss function
                def loss_fn(weights):
                    fidelity = swap_test(image1, image2, weights)
                    loss = contrastive_loss(fidelity, label1, label2)
                    return loss

                weights = opt.step(loss_fn, weights)
                total_loss += loss_fn(weights)

            print(f"Epoch {epoch+1}, Loss: {total_loss/len(train_loader)}")
        return weights



    def evaluate_qnn(model, test_loader, weights):
        correct = 0
        total = 0
        for data, target in test_loader:
            image1 = data[0].squeeze(0).numpy()
            image2 = data[1].squeeze(0).numpy()

            label1 = target[0].item()
            label2 = target[1].item()

            image1 = np.array(image1, dtype=np.float32)
            image2 = np.array(image2, dtype=np.float32)

            fidelity = swap_test(image1, image2, weights)

            prediction = 1 if fidelity > 0.5 else 0
            if prediction == (label1 == label2):
                correct += 1
            total += 1

        accuracy = correct / total
        print(f"Accuracy on the test set: {accuracy * 100:.2f}%")
```

```
weights = train_qnn_with_negative_pairs(swap_test, train_loader, num_epochs=10, learning_rate=0.01)

# Evaluate
evaluate_qnn(swap_test, test_loader, weights)
```

```
/usr/local/lib/python3.11/dist-packages/autograd/tracer.py:14: UserWarning: Output seems independent of input.
  warnings.warn("Output seems independent of input.")
Epoch 1, Loss: 0.10980810234541578
Epoch 2, Loss: 0.10767590618336886
Epoch 3, Loss: 0.1162046908315565
Epoch 4, Loss: 0.11940298507462686
Epoch 5, Loss: 0.11300639658848614
Epoch 6, Loss: 0.1140724946695096
Epoch 7, Loss: 0.09914712153518124
Epoch 8, Loss: 0.11833688699360341
Epoch 9, Loss: 0.11940298507462686
Epoch 10, Loss: 0.1257995735607676
Accuracy on the test set: 92.36%
```