#QML-HEP GSoC 2023 Task Solutions

##Installing Required Package

```
!pip install cirq
!pip install qiskit
!pip install pylatexenc
!pip install pennylane
!pip install -U tensorflow-addons
# # !pip install -q tensorflow==2.3.1
# !pip install -q tensorflow-quantum
```

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Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting cirq
  Downloading cirq-1.1.0-py3-none-any.whl (7.7 kB)
Collecting cirq-aqt==1.1.0
  Downloading cirq_aqt-1.1.0-py3-none-any.whl (27 kB)
Collecting cirq-rigetti==1.1.0
  Downloading cirq_rigetti-1.1.0-py3-none-any.whl (66 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 66.4/66.4 KB 3.9 MB/s eta
0:00:00
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 577.4/577.4 KB 17.7 MB/s eta
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ent already satisfied: requests~=2.18 in
/usr/local/lib/python3.9/dist-packages (from cirq-aqt==1.1.0->cirq)
(2.27.1)
Requirement already satisfied: numpy<1.24,>=1.16 in
/usr/local/lib/python3.9/dist-packages (from cirq-core==1.1.0->cirq)
(1.22.4)
Requirement already satisfied: sortedcontainers~=2.0 in
/usr/local/lib/python3.9/dist-packages (from cirq-core==1.1.0->cirq)
(2.4.0)
Requirement already satisfied: matplotlib~=3.0 in
/usr/local/lib/python3.9/dist-packages (from cirq-core==1.1.0->cirq)
(3.7.1)
Requirement already satisfied: tqdm in /usr/local/lib/python3.9/dist-
packages (from cirq-core==1.1.0->cirq) (4.65.0)
Collecting duet~=0.2.7
  Downloading duet-0.2.7-py3-none-any.whl (28 kB)
Requirement already satisfied: pandas in
/usr/local/lib/python3.9/dist-packages (from cirq-core==1.1.0->cirq)
(1.4.4)
Requirement already satisfied: sympy in /usr/local/lib/python3.9/dist-
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packages (from cirq-core==1.1.0->cirq) (1.11.1)
Collecting networkx~=2.4
  Downloading networkx-2.8.8-py3-none-any.whl (2.0 MB)
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ent already satisfied: typing-extensions in
/usr/local/lib/python3.9/dist-packages (from cirq-core==1.1.0->cirq)
(4.5.0)
Requirement already satisfied: scipy in /usr/local/lib/python3.9/dist-
packages (from cirq-core==1.1.0->cirq) (1.10.1)
Requirement already satisfied: protobuf<4,>=3.15.0 in
/usr/local/lib/python3.9/dist-packages (from cirq-google==1.1.0->cirq)
(3.20.3)
Collecting google-api-core[grpc]<2.0.0dev,>=1.14.0
  Downloading google_api_core-1.34.0-py3-none-any.whl (120 kB)
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0:00:00
ent already satisfied: proto-plus>=1.20.0 in
/usr/local/lib/python3.9/dist-packages (from cirq-google==1.1.0->cirq)
(1.22.2)
Collecting pyquil>=3.2.0
  Downloading pyquil-3.3.4-py3-none-any.whl (221 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 221.6/221.6 KB 28.3 MB/s eta
0:00:00
ent already satisfied: googleapis-common-protos<2.0dev,>=1.56.2 in
/usr/local/lib/python3.9/dist-packages (from google-api-
core[grpc]<2.0.0dev,>=1.14.0->cirq-google==1.1.0->cirq) (1.59.0)
Requirement already satisfied: google-auth<3.0dev,>=1.25.0 in
/usr/local/lib/python3.9/dist-packages (from google-api-
core[grpc]<2.0.0dev,>=1.14.0->cirq-google==1.1.0->cirq) (2.17.0)
Requirement already satisfied: grpcio-status<2.0dev,>=1.33.2 in
/usr/local/lib/python3.9/dist-packages (from google-api-
core[grpc]<2.0.0dev,>=1.14.0->cirq-google==1.1.0->cirq) (1.48.2)
Requirement already satisfied: grpcio<2.0dev,>=1.33.2 in
/usr/local/lib/python3.9/dist-packages (from google-api-
core[grpc]<2.0.0dev,>=1.14.0->cirq-google==1.1.0->cirq) (1.53.0)
Requirement already satisfied: pillow>=6.2.0 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (8.4.0)
Requirement already satisfied: importlib-resources>=3.2.0 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (5.12.0)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (2.8.2)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (23.0)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
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core==1.1.0->cirq) (1.0.7)
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (3.0.9)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (4.39.3)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (1.4.4)
Requirement already satisfied: cycler>=0.10 in
/usr/local/lib/python3.9/dist-packages (from matplotlib~=3.0->cirq-
core==1.1.0->cirq) (0.11.0)
Collecting lark<0.12.0,>=0.11.1
  Downloading lark-0.11.3.tar.gz (229 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 229.9/229.9 KB 26.0 MB/s eta
0:00:00
etadata (setup.py) ... ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━
147.4/147.4 KB 13.3 MB/s eta 0:00:00
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0:00:00
etadata (setup.py) ... ent already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.9/dist-packages (from requests~=2.18->cirq-
aqt==1.1.0->cirq) (3.4)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in
/usr/local/lib/python3.9/dist-packages (from requests~=2.18->cirq-
aqt==1.1.0->cirq) (1.26.15)
Requirement already satisfied: charset-normalizer~=2.0.0 in
/usr/local/lib/python3.9/dist-packages (from requests~=2.18->cirq-
aqt==1.1.0->cirq) (2.0.12)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.9/dist-packages (from requests~=2.18->cirq-
aqt==1.1.0->cirq) (2022.12.7)
Requirement already satisfied: pytz>=2020.1 in
/usr/local/lib/python3.9/dist-packages (from pandas->cirq-core==1.1.0-
>cirq) (2022.7.1)
Requirement already satisfied: mpmath>=0.19 in
/usr/local/lib/python3.9/dist-packages (from sympy->cirq-core==1.1.0-
>cirq) (1.3.0)
Requirement already satisfied: six>=1.9.0 in
/usr/local/lib/python3.9/dist-packages (from google-
auth<3.0dev,>=1.25.0->google-api-core[grpc]<2.0.0dev,>=1.14.0->cirq-
google==1.1.0->cirq) (1.16.0)
Requirement already satisfied: rsa<5,>=3.1.4 in
/usr/local/lib/python3.9/dist-packages (from google-
auth<3.0dev,>=1.25.0->google-api-core[grpc]<2.0.0dev,>=1.14.0->cirq-
google==1.1.0->cirq) (4.9)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in
/usr/local/lib/python3.9/dist-packages (from google-
auth<3.0dev,>=1.25.0->google-api-core[grpc]<2.0.0dev,>=1.14.0->cirq-
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google==1.1.0->cirq) (5.3.0)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/usr/local/lib/python3.9/dist-packages (from google-
auth<3.0dev,>=1.25.0->google-api-core[grpc]<2.0.0dev,>=1.14.0->cirq-
google==1.1.0->cirq) (0.2.8)
Requirement already satisfied: zipp>=3.1.0 in
/usr/local/lib/python3.9/dist-packages (from importlib-
resources>=3.2.0->matplotlib~=3.0->cirq-core==1.1.0->cirq) (3.15.0)
Requirement already satisfied: toml<0.11.0,>=0.10.2 in
/usr/local/lib/python3.9/dist-packages (from qcs-api-
client<0.22.0,>=0.21.0->pyquil>=3.2.0->cirq-rigetti==1.1.0->cirq)
(0.10.2)
Collecting PyJWT<3.0.0,>=2.4.0
  Downloading PyJWT-2.6.0-py3-none-any.whl (20 kB)
Collecting attrs<22.0.0,>=21.3.0
  Downloading attrs-21.4.0-py2.py3-none-any.whl (60 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 60.6/60.6 KB 8.2 MB/s eta
0:00:00
ent already satisfied: pydantic<2.0.0,>=1.7.2 in
/usr/local/lib/python3.9/dist-packages (from qcs-api-
client<0.22.0,>=0.21.0->pyquil>=3.2.0->cirq-rigetti==1.1.0->cirq)
(1.10.7)
Collecting rfc3339<7.0,>=6.2
  Downloading rfc3339-6.2-py3-none-any.whl (5.5 kB)
Collecting httpx<0.24.0,>=0.23.0
  Downloading httpx-0.23.3-py3-none-any.whl (71 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 71.5/71.5 KB 10.7 MB/s eta
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 98.7/98.7 KB 11.0 MB/s eta
0:00:00
ent already satisfied: decorator>=3.4.2 in
/usr/local/lib/python3.9/dist-packages (from retry<0.10.0,>=0.9.2-
>pyquil>=3.2.0->cirq-rigetti==1.1.0->cirq) (4.4.2)
Requirement already satisfied: msgpack<2.0,>=0.6 in
/usr/local/lib/python3.9/dist-packages (from rpcq<4.0.0,>=3.10.0-
>pyquil>=3.2.0->cirq-rigetti==1.1.0->cirq) (1.0.5)
Collecting python-rapidjson
  Downloading python_rapidjson-1.10-cp39-cp39-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.7 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.7/1.7 MB 68.0 MB/s eta
0:00:00
ent already satisfied: pyzmq>=17 in /usr/local/lib/python3.9/dist-
packages (from rpcq<4.0.0,>=3.10.0->pyquil>=3.2.0->cirq-
rigetti==1.1.0->cirq) (23.2.1)
Collecting ruamel.yaml
  Downloading ruamel.yaml-0.17.21-py3-none-any.whl (109 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 109.5/109.5 KB 11.3 MB/s eta
0:00:00
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 69.6/69.6 KB 8.8 MB/s eta
0:00:00
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ent already satisfied: pyasn1<0.5.0,>=0.4.6 in
/usr/local/lib/python3.9/dist-packages (from pyasn1-modules>=0.2.1-
>google-auth<3.0dev,>=1.25.0->google-api-core[grpc]<2.0.0dev,>=1.14.0-
>cirq-google==1.1.0->cirq) (0.4.8)
Collecting ruamel.yaml.clib>=0.2.6
  Downloading ruamel.yaml.clib-0.2.7-cp39-cp39-
manylinux_2_17_x86_64.manylinux2014_x86_64.manylinux_2_24_x86_64.whl
(519 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 519.4/519.4 KB 38.8 MB/s eta
0:00:00
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 58.3/58.3 KB 5.4 MB/s eta
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0:00:00
e=lark-0.11.3-py2.py3-none-any.whl size=99646
sha256=3fbdf5a3c50fb279ede331680bb10c13be520ad53fc8a3f5d4fa94c64566a4c
3
  Stored in directory:
/root/.cache/pip/wheels/ec/6a/24/f8eeaf52fee56bfe54309621b59c41bb7f1df
56f4bfbcdb0ce
  Building wheel for rpcq (setup.py) ... e=rpcq-3.11.0-py3-none-
any.whl size=45985
sha256=809c584a2b129cd3ca635d99b95ecbbfe80158d7c9f044bfb38492ef836c513
4
  Stored in directory:
/root/.cache/pip/wheels/a6/c4/42/34581dfe489802146924ad802b13aa7fe3820
f9e8c15f67afc
Successfully built lark rpcq
Installing collected packages: types-retry, types-python-dateutil,
rfc3986, rfc3339, lark, sniffio, ruamel.yaml.clib, retrying, python-
rapidjson, PyJWT, py, networkx, iso8601, h11, duet, attrs,
ruamel.yaml, retry, anyio, rpcq, httpcore, google-api-core, cirq-core,
httpx, cirq-web, cirq-pasqal, cirq-ionq, cirq-aqt, qcs-api-client,
cirq-google, pyquil, cirq-rigetti, cirq
  Attempting uninstall: networkx
    Found existing installation: networkx 3.0
    Uninstalling networkx-3.0:
      Successfully uninstalled networkx-3.0
  Attempting uninstall: attrs
    Found existing installation: attrs 22.2.0
    Uninstalling attrs-22.2.0:
      Successfully uninstalled attrs-22.2.0
  Attempting uninstall: google-api-core
    Found existing installation: google-api-core 2.11.0
    Uninstalling google-api-core-2.11.0:
      Successfully uninstalled google-api-core-2.11.0
Successfully installed PyJWT-2.6.0 anyio-3.6.2 attrs-21.4.0 cirq-1.1.0
cirq-aqt-1.1.0 cirq-core-1.1.0 cirq-google-1.1.0 cirq-ionq-1.1.0 cirq-
pasqal-1.1.0 cirq-rigetti-1.1.0 cirq-web-1.1.0 duet-0.2.7 google-api-
core-1.34.0 h11-0.14.0 httpcore-0.16.3 httpx-0.23.3 iso8601-1.1.0
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lark-0.11.3 networkx-2.8.8 py-1.11.0 pyquil-3.3.4 python-rapidjson-
1.10 qcs-api-client-0.21.3 retry-0.9.2 retrying-1.3.4 rfc3339-6.2
rfc3986-1.5.0 rpcq-3.11.0 ruamel.yaml-0.17.21 ruamel.yaml.clib-0.2.7
sniffio-1.3.0 types-python-dateutil-2.8.19.11 types-retry-0.9.9.3
```

{"pip_warning":{"packages":["google"]}}

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Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting qiskit
  Downloading qiskit-0.42.1.tar.gz (14 kB)
  Preparing metadata (setup.py) ...
anylinux_2_17_x86_64.manylinux2014_x86_64.whl (5.1 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 5.1/5.1 MB 33.8 MB/s eta
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anylinux_2_17_x86_64.manylinux2014_x86_64.whl (12.8 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 12.8/12.8 MB 46.0 MB/s eta
0:00:00
q-provider==0.20.2
  Downloading qiskit_ibmq_provider-0.20.2-py3-none-any.whl (241 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 241.5/241.5 KB 23.2 MB/s eta
0:00:00
ent already satisfied: scipy>=1.0 in /usr/local/lib/python3.9/dist-
packages (from qiskit-aer==0.12.0->qiskit) (1.10.1)
Requirement already satisfied: numpy>=1.16.3 in
/usr/local/lib/python3.9/dist-packages (from qiskit-aer==0.12.0-
>qiskit) (1.22.4)
Requirement already satisfied: python-dateutil>=2.8.0 in
/usr/local/lib/python3.9/dist-packages (from qiskit-ibmq-
provider==0.20.2->qiskit) (2.8.2)
Requirement already satisfied: requests>=2.19 in
/usr/local/lib/python3.9/dist-packages (from qiskit-ibmq-
provider==0.20.2->qiskit) (2.27.1)
Collecting websockets>=10.0
  Downloading websockets-11.0-cp39-cp39-
manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux
2014_x86_64.whl (129 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 129.5/129.5 KB 6.6 MB/s eta
0:00:00
ent already satisfied: urllib3>=1.21.1 in
/usr/local/lib/python3.9/dist-packages (from qiskit-ibmq-
provider==0.20.2->qiskit) (1.26.15)
Collecting websocket-client>=1.5.1
  Downloading websocket_client-1.5.1-py3-none-any.whl (55 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 55.9/55.9 KB 6.4 MB/s eta
0:00:00
<=1.1.0
  Downloading requests_ntlm-1.1.0-py2.py3-none-any.whl (5.7 kB)
Collecting symengine>=0.9
  Downloading symengine-0.10.0-cp39-cp39-
manylinux_2_12_x86_64.manylinux2010_x86_64.whl (37.5 MB)
```

```
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anylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.9 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.9/1.9 MB 13.7 MB/s eta
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ent already satisfied: sympy>=1.3 in /usr/local/lib/python3.9/dist-
packages (from qiskit-terra==0.23.3->qiskit) (1.11.1)
Collecting dill>=0.3
  Downloading dill-0.3.6-py3-none-any.whl (110 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 110.5/110.5 KB 7.7 MB/s eta
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ent already satisfied: psutil>=5 in /usr/local/lib/python3.9/dist-
packages (from qiskit-terra==0.23.3->qiskit) (5.9.4)
Collecting ply>=3.10
  Downloading ply-3.11-py2.py3-none-any.whl (49 kB)
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ent already satisfied: six>=1.5 in /usr/local/lib/python3.9/dist-
packages (from python-dateutil>=2.8.0->qiskit-ibmq-provider==0.20.2-
>qiskit) (1.16.0)
Requirement already satisfied: charset-normalizer~=2.0.0 in
/usr/local/lib/python3.9/dist-packages (from requests>=2.19->qiskit-
ibmq-provider==0.20.2->qiskit) (2.0.12)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.9/dist-packages (from requests>=2.19->qiskit-
ibmq-provider==0.20.2->qiskit) (3.4)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.9/dist-packages (from requests>=2.19->qiskit-
ibmq-provider==0.20.2->qiskit) (2022.12.7)
Requirement already satisfied: cryptography>=1.3 in
/usr/local/lib/python3.9/dist-packages (from requests-ntlm<=1.1.0-
>qiskit-ibmq-provider==0.20.2->qiskit) (40.0.1)
Collecting ntlm-auth>=1.0.2
  Downloading ntlm_auth-1.5.0-py2.py3-none-any.whl (29 kB)
Collecting pbr!=2.1.0,>=2.0.0
  Downloading pbr-5.11.1-py2.py3-none-any.whl (112 kB)
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ent already satisfied: mpmath>=0.19 in /usr/local/lib/python3.9/dist-
packages (from sympy>=1.3->qiskit-terra==0.23.3->qiskit) (1.3.0)
Requirement already satisfied: cffi>=1.12 in
/usr/local/lib/python3.9/dist-packages (from cryptography>=1.3-
>requests-ntlm<=1.1.0->qiskit-ibmq-provider==0.20.2->qiskit) (1.15.1)
Requirement already satisfied: pycparser in
/usr/local/lib/python3.9/dist-packages (from cffi>=1.12-
>cryptography>=1.3->requests-ntlm<=1.1.0->qiskit-ibmq-
provider==0.20.2->qiskit) (2.21)
Building wheels for collected packages: qiskit
```

```
  Building wheel for qiskit (setup.py) ... e=qiskit-0.42.1-py3-none-
any.whl size=12938
sha256=727022bb6132caec7f0462c7106119f07cf8d8628e4794f8476eae0d7ada4b2
0
  Stored in directory:
/root/.cache/pip/wheels/40/64/74/29c046bda04fd60f3f6b2e244fa85b70f219e
363fc3373f541
Successfully built qiskit
Installing collected packages: ply, websockets, websocket-client,
symengine, rustworkx, pbr, ntlm-auth, dill, stevedore, requests-ntlm,
qiskit-terra, qiskit-ibmq-provider, qiskit-aer, qiskit
Successfully installed dill-0.3.6 ntlm-auth-1.5.0 pbr-5.11.1 ply-3.11
qiskit-0.42.1 qiskit-aer-0.12.0 qiskit-ibmq-provider-0.20.2 qiskit-
terra-0.23.3 requests-ntlm-1.1.0 rustworkx-0.12.1 stevedore-5.0.0
symengine-0.10.0 websocket-client-1.5.1 websockets-11.0
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting pylatexenc
  Downloading pylatexenc-2.10.tar.gz (162 kB)
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etadata (setup.py) ... e=pylatexenc-2.10-py3-none-any.whl size=136831
sha256=00a6990882fd4dfb2054e571f5bf5d8203f74229e3a0b4068c07f6a2893a8a7
c
  Stored in directory:
/root/.cache/pip/wheels/a3/68/66/2f15abd0673d83c02f354115feedeb89c3dae
d2ac319b11090
Successfully built pylatexenc
Installing collected packages: pylatexenc
Successfully installed pylatexenc-2.10
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting pennylane
  Downloading PennyLane-0.29.1-py3-none-any.whl (1.3 MB)
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ent already satisfied: networkx in /usr/local/lib/python3.9/dist-
packages (from pennylane) (2.8.8)
Collecting semantic-version>=2.7
  Downloading semantic_version-2.10.0-py2.py3-none-any.whl (15 kB)
Requirement already satisfied: appdirs in
/usr/local/lib/python3.9/dist-packages (from pennylane) (1.4.4)
Requirement already satisfied: toml in /usr/local/lib/python3.9/dist-
packages (from pennylane) (0.10.2)
Collecting autoray>=0.3.1
  Downloading autoray-0.6.3-py3-none-any.whl (48 kB)
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anylinux_2_17_x86_64.manylinux2014_x86_64.whl (16.5 MB)
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```

```
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ent already satisfied: autograd in /usr/local/lib/python3.9/dist-
packages (from pennylane) (1.5)
Requirement already satisfied: cachetools in
/usr/local/lib/python3.9/dist-packages (from pennylane) (5.3.0)
Requirement already satisfied: scipy in /usr/local/lib/python3.9/dist-
packages (from pennylane) (1.10.1)
Requirement already satisfied: numpy<1.24 in
/usr/local/lib/python3.9/dist-packages (from pennylane) (1.22.4)
Requirement already satisfied: requests in
/usr/local/lib/python3.9/dist-packages (from pennylane) (2.27.1)
Requirement already satisfied: future>=0.15.2 in
/usr/local/lib/python3.9/dist-packages (from autograd->pennylane)
(0.18.3)
Requirement already satisfied: charset-normalizer~=2.0.0 in
/usr/local/lib/python3.9/dist-packages (from requests->pennylane)
(2.0.12)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in
/usr/local/lib/python3.9/dist-packages (from requests->pennylane)
(1.26.15)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.9/dist-packages (from requests->pennylane)
(3.4)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.9/dist-packages (from requests->pennylane)
(2022.12.7)
Requirement already satisfied: rustworkx==0.12.1 in
/usr/local/lib/python3.9/dist-packages (from retworkx->pennylane)
(0.12.1)
Installing collected packages: semantic-version, autoray, retworkx,
pennylane-lightning, pennylane
Successfully installed autoray-0.6.3 pennylane-0.29.1 pennylane-
lightning-0.29.0 retworkx-0.12.1 semantic-version-2.10.0
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Collecting tensorflow-addons
  Downloading tensorflow_addons-0.19.0-cp39-cp39-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.1 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.1/1.1 MB 14.8 MB/s eta
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ent already satisfied: packaging in /usr/local/lib/python3.9/dist-
packages (from tensorflow-addons) (23.0)
Requirement already satisfied: typing-extensions>=4.4.0 in
/usr/local/lib/python3.9/dist-packages (from typeguard>=2.7-
>tensorflow-addons) (4.5.0)
Requirement already satisfied: importlib-metadata>=3.6 in
/usr/local/lib/python3.9/dist-packages (from typeguard>=2.7-
>tensorflow-addons) (6.1.0)
Requirement already satisfied: zipp>=0.5 in
/usr/local/lib/python3.9/dist-packages (from importlib-metadata>=3.6-
```

```
>typeguard>=2.7->tensorflow-addons) (3.15.0)
Installing collected packages: typeguard, tensorflow-addons
Successfully installed tensorflow-addons-0.19.0 typeguard-3.0.2
```

##TASK VI

In this task you should implement a simple representation learning scheme based on a contrastive loss:

1. Load the MNIST dataset
2. Write a function which takes an image and prepares a quantum state. This function should have trainable parameters which we want to learn in order to have good quantum representations
3. Create a circuit with which takes two images and embeds both as quantum states with the function you wrote before. Afterwards the circuit should perform a SWAP test between the two states. In the end the measurement should give the fidelity of the quantum states.
4. Train the circuit parameters with a contrastive loss: For two MNIST images in the same class the fidelity should be maximized, while for images of different classes the fidelity should be minimized.

```
import tensorflow as tf
import pennylane as qml
import numpy as np
from tensorflow.keras.datasets import mnist
```

###Defining the hyperparameters

```
n_epochs = 30
n_layers = 1
n_train = 50
n_test = 30
n_wires = 4

PREPROCESS = True
np.random.seed(42)
tf.random.set_seed(42)
```

###Spliting the data into train and test

```
(x_train,y_train),(x_test,y_test) = mnist.load_data()

# Normalize pixel values within 0 and 1
x_train = x_train / 255
x_test = x_test / 255
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/mnist.npz
11490434/11490434 [==============================] - 1s 0us/step
```

```
# Define quantum circuit functions
def quantum_circuit(params, x):
    """
    A quantum circuit that performs angle embedding and strongly
entangling layers
    on the input tensor x with the given parameters.

    Args:
        params (array-like): An array of parameters for the circuit.
        x (array-like): The input tensor to the circuit.

    Returns:
        A list of expectation values for each wire in the circuit.
    """
    qml.templates.AngleEmbedding(x, wires=range(num_qubits))
    qml.templates.StronglyEntanglingLayers(params,
wires=range(num_qubits))
    return [qml.expval(qml.PauliZ(i)) for i in range(num_qubits)]

def contrastive_loss(y_true, y_pred, margin=1):
    """
    Compute the contrastive loss for a pair of predictions.

    Args:
        y_true (tensor): The true labels for the pair of predictions.
        y_pred (tensor): The predicted labels for the pair of
predictions.
        margin (float): The margin value for the contrastive loss.

    Returns:
        tensor: The contrastive loss value for the pair of
predictions.
    """
    loss = y_true * tf.square(tf.maximum(0., margin - y_pred)) + (1 -
y_true) * tf.square(y_pred)
    return tf.reduce_mean(loss)

def swap_test_circuit(params, x1, x2):
    """
    A quantum circuit that performs a SWAP test on the two input
tensors
    x1 and x2 with the given parameters.

    Args:
        params (array-like): An array of parameters for the circuit.
        x1 (array-like): The first input tensor to the circuit.
        x2 (array-like): The second input tensor to the circuit.

    Returns:
        The expectation value for the first wire in the circuit.
```

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

device = qml.device("default.qubit", wires=4)

@qml.qnode(device, interface="tf")
def quantum_model(inputs, params):
    """
    A quantum circuit model with Angle Embedding and Strongly
Entangling Layers.

    Args:
        inputs (tf.Tensor): Input tensor.
        params (np.ndarray): Parameters for the quantum circuit.

    Returns:
        list: A list of expectation values of Pauli Z operators for
each wire.
    """
    return quantum_circuit(params, inputs)

@qml.qnode(device, interface="tf")
def swap_test(inputs_1, inputs_2, params):
    """
    A quantum circuit model for swap test.

    Args:
        inputs_1 (tf.Tensor): First input tensor.
        inputs_2 (tf.Tensor): Second input tensor.
        params (np.ndarray): Parameters for the quantum circuit.

    Returns:
        float: An expectation value of Pauli Z operator for wire 0.
    """
    return swap_test_circuit(params, inputs_1, inputs_2)

params = np.random.randn(10)

def classical_model():
    """
    A classical model with two dense layers and softmax activation.

    Returns:
        tf.keras.Model: A keras model.
```

```
    """
    model = tf.keras.models.Sequential([
        tf.keras.layers.Input(shape=(28, 28)),
        tf.keras.layers.Flatten(),
        tf.keras.layers.Dense(128, activation='relu'),
        tf.keras.layers.Dense(10, activation='softmax')])
    model.compile(
        optimizer='adam',
        loss="sparse_categorical_crossentropy",
        metrics=["accuracy"],
    )
    return model

model = classical_model()
opt = tf.keras.optimizers.Adam(learning_rate=0.01)
model.compile(optimizer=opt, loss=lambda y_true, y_pred:
contrastive_loss(y_true, y_pred, margin=1))

params = np.random.normal(loc=0, scale=0.1, size=(n_layers, n_wires))

c_model = classical_model()

c_history = c_model.fit(
    x_train,
    y_train,
    validation_data=(x_test, y_test),
    batch_size=4,
    epochs=10,
    verbose=2,
)

Epoch 1/10
15000/15000 - 51s - loss: 0.2011 - accuracy: 0.9401 - val_loss: 0.1157
- val_accuracy: 0.9666 - 51s/epoch - 3ms/step
Epoch 2/10
15000/15000 - 55s - loss: 0.0953 - accuracy: 0.9709 - val_loss: 0.1242
- val_accuracy: 0.9618 - 55s/epoch - 4ms/step
Epoch 3/10
15000/15000 - 44s - loss: 0.0708 - accuracy: 0.9779 - val_loss: 0.0750
- val_accuracy: 0.9798 - 44s/epoch - 3ms/step
Epoch 4/10
15000/15000 - 65s - loss: 0.0550 - accuracy: 0.9833 - val_loss: 0.0871
- val_accuracy: 0.9765 - 65s/epoch - 4ms/step
Epoch 5/10
15000/15000 - 81s - loss: 0.0466 - accuracy: 0.9853 - val_loss: 0.1206
- val_accuracy: 0.9701 - 81s/epoch - 5ms/step
Epoch 6/10
15000/15000 - 72s - loss: 0.0392 - accuracy: 0.9883 - val_loss: 0.0893
- val_accuracy: 0.9793 - 72s/epoch - 5ms/step
Epoch 7/10
15000/15000 - 54s - loss: 0.0327 - accuracy: 0.9895 - val_loss: 0.1002
```

```
- val_accuracy: 0.9768 - 54s/epoch - 4ms/step
Epoch 8/10
15000/15000 - 54s - loss: 0.0294 - accuracy: 0.9906 - val_loss: 0.1111
- val_accuracy: 0.9763 - 54s/epoch - 4ms/step
Epoch 9/10
15000/15000 - 50s - loss: 0.0261 - accuracy: 0.9915 - val_loss: 0.1213
- val_accuracy: 0.9787 - 50s/epoch - 3ms/step
Epoch 10/10
15000/15000 - 72s - loss: 0.0236 - accuracy: 0.9927 - val_loss: 0.1279
- val_accuracy: 0.9770 - 72s/epoch - 5ms/step
```

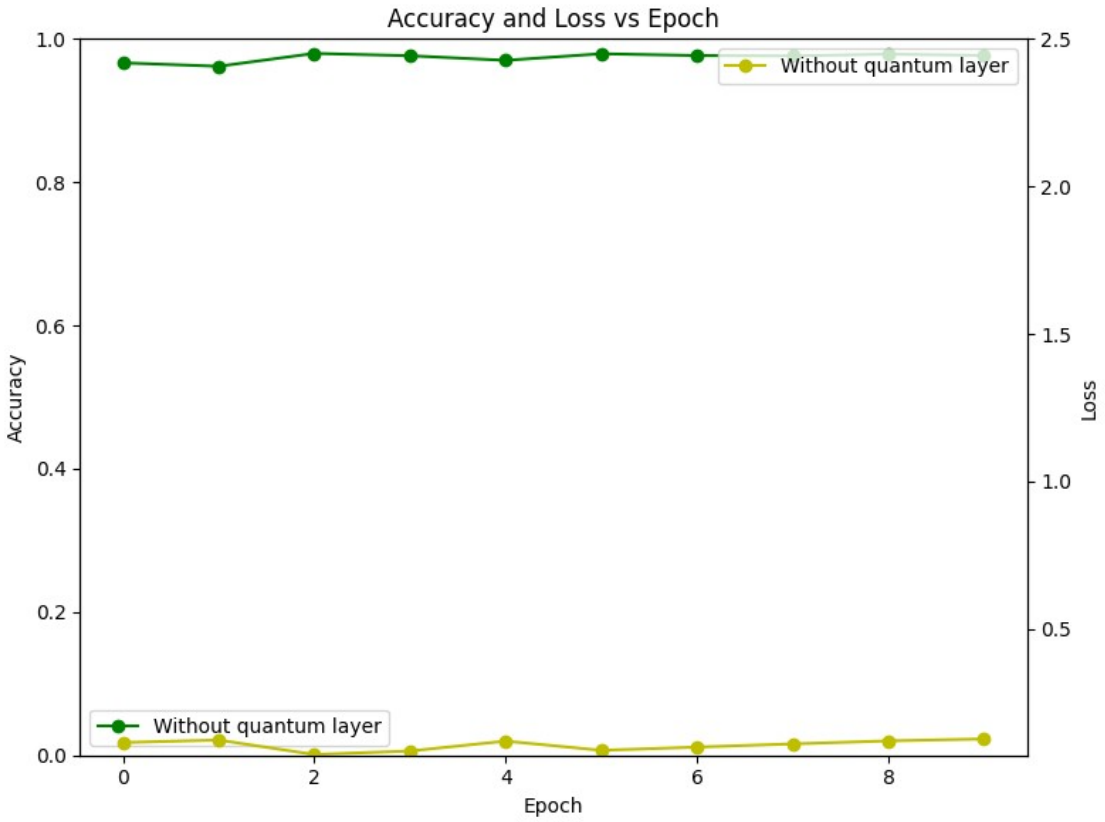
```python
import matplotlib.pyplot as plt

fig, ax1 = plt.subplots(figsize=(8,6))
ax2 = ax1.twinx()

ax1.plot(c_history.history["val_accuracy"], "-og", label="Without
quantum layer")
ax1.set_ylabel("Accuracy")
ax1.set_ylim([0, 1])
ax1.set_xlabel("Epoch")
ax1.legend()

ax2.plot(c_history.history["val_loss"], "-oy", label="Without quantum
layer")
ax2.set_ylabel("Loss")
ax2.set_ylim(top=2.5)
ax2.legend()

plt.title('Accuracy and Loss vs Epoch')
plt.tight_layout()
plt.show()
```




```
weight_shapes = {"weights": (2, 2), "bias": (2,)}


def Quantun_Model():
    model = tf.keras.models.Sequential([
        tf.keras.layers.Input(shape=(28, 28)),
        tf.keras.layers.Flatten(),
        tf.keras.layers.Lambda(lambda x: np.array([x]*n_wires)),  # 
Replicate input for multiple wires
        tf.keras.layers.Permute((2, 1)),  # Transpose to match wire 
order
        qml.qnn.KerasLayer(quantum_model, 
output_dim=n_wires,weight_shapes=weight_shapes),  # Quantum layer
        tf.keras.layers.Dense(10, activation='softmax')  # Final dense 
layer
    ])
    model.compile(
        optimizer='adam',
        loss="sparse_categorical_crossentropy",
        metrics=["accuracy"],
    )
    return model

model = Quantun_Model()
opt = tf.keras.optimizers.Adam(learning_rate=0.01)
```

```
model.compile(optimizer=opt, loss=lambda y_true, y_pred:
contrastive_loss(y_true, y_pred, margin=1))

q_model = Quantun_Model()

q_history = q_model.fit(
    x_train,
    y_train,
    validation_data=(x_test, y_test),
    batch_size=4,
    epochs=10,
    verbose=2,
)

Epoch 1/10
15000/15000 - 54s - loss: 0.1986 - accuracy: 0.9400 - val_loss: 0.1272
- val_accuracy: 0.9621 - 54s/epoch - 4ms/step
Epoch 2/10
15000/15000 - 72s - loss: 0.0960 - accuracy: 0.9707 - val_loss: 0.1124
- val_accuracy: 0.9659 - 72s/epoch - 5ms/step
Epoch 3/10
15000/15000 - 58s - loss: 0.0706 - accuracy: 0.9781 - val_loss: 0.0774
- val_accuracy: 0.9772 - 58s/epoch - 4ms/step
Epoch 4/10
15000/15000 - 54s - loss: 0.0563 - accuracy: 0.9829 - val_loss: 0.0943
- val_accuracy: 0.9751 - 54s/epoch - 4ms/step
Epoch 5/10
15000/15000 - 56s - loss: 0.0461 - accuracy: 0.9858 - val_loss: 0.1117
- val_accuracy: 0.9726 - 56s/epoch - 4ms/step
Epoch 6/10
15000/15000 - 40s - loss: 0.0394 - accuracy: 0.9883 - val_loss: 0.1134
- val_accuracy: 0.9749 - 40s/epoch - 3ms/step
Epoch 7/10
15000/15000 - 57s - loss: 0.0338 - accuracy: 0.9893 - val_loss: 0.1109
- val_accuracy: 0.9771 - 57s/epoch - 4ms/step
Epoch 8/10
15000/15000 - 38s - loss: 0.0307 - accuracy: 0.9905 - val_loss: 0.1183
- val_accuracy: 0.9767 - 38s/epoch - 3ms/step
Epoch 9/10
15000/15000 - 57s - loss: 0.0291 - accuracy: 0.9913 - val_loss: 0.1392
- val_accuracy: 0.9771 - 57s/epoch - 4ms/step
Epoch 10/10
15000/15000 - 42s - loss: 0.0255 - accuracy: 0.9920 - val_loss: 0.1359
- val_accuracy: 0.9763 - 42s/epoch - 3ms/step

import matplotlib.pyplot as plt

fig, ax1 = plt.subplots(figsize=(8,6))
ax2 = ax1.twinx()
```

```
ax1.plot(q_history.history["val_accuracy"], "-og", label="With quantum
layer")
ax1.set_ylabel("Accuracy")
ax1.set_ylim([0, 1])
ax1.set_xlabel("Epoch")
ax1.legend()

ax2.plot(q_history.history["val_loss"], "-or", label="With quantum
layer")
ax2.set_ylabel("Loss")
ax2.set_ylim(top=2.5)
ax2.legend()

plt.title('Accuracy and Loss vs Epoch')
plt.tight_layout()
plt.show()
```