IDI058-01

Final Exam
19 December 2022

Your Name and Honor Code Signature

1. Write your name and UIN below:

   Name: _____

   UIN: _____

2. Please sign the honor code. Your exam will NOT be graded without your signature.

   "On my honor, as a KIT Engineering Student, I have neither given nor received unauthorized aid on this academic work."

   Signature: _____

Directions

This exam consists of 5 problems for a total of **100 /100** points. The number of total page is 7 pages. **Check your exam now to make sure you have all the problems.** Work as many problems as you can before the end of the exam.

You can use Qiskit and Python on this exam. **However, you must clearly show your work including source code, calculation and all formulas used in your solution**. Your work needs to be such that someone could reproduce your answer. **No credit will be given for a problem where this is not the case.**

Show all work in the spaces provided and make certain that you apply the notation we have been using. In order to receive full or partial credit **your work must be clear and neat.**

Grading Grid

Problem 1 _____ out of 10
Problem 2 _____ out of 20
Problem 3 _____ out of 10
Problem 4 _____ out of 30
Problem 5 _____ out of 30

Total _____ out of 100

[Problem 1] - (10 points)

Consider a Quantum Operator

$$\mathrm{A} = \begin{pmatrix} 0 & 0 & -i \\ 0 & 1 & 0 \\ -i & 0 & 0 \end{pmatrix}$$

Using “Spectrum Decomposition”, it can be represented with the below representation

$$\mathrm{A} = \sum_{\mathrm{i}=1}^{3} a_i \cdot |u_i\rangle\langle u_i|$$

Calculate each a_i and $|u_i\rangle$. You have to show exact calculations.

[Problem 2] - (20 points)

Let consider two Quantum states, below

$$|A\rangle = \frac{1}{\sqrt{2}}|0\rangle - \frac{i}{\sqrt{2}}|1\rangle$$
$$|B\rangle = \frac{\sqrt{2}}{\sqrt{3}}|0\rangle + \frac{1}{\sqrt{3}}|1\rangle$$

Calculate

$$(H \otimes H)|C\rangle$$

Where, $|C\rangle = |A\rangle \otimes |B\rangle$

Show the explicit calculation with the answer.

[Problem 3] - (10 points)

Using “Quskit”, design an operator meeting these conditions

- Operator’s role is “X ⊗ H”
- Start with two quantum circuits
- It is measured with “Aer” and is represented with “array_to_latex”

Give a final matrix with “Qiskit code”.

[Problem 4] - (30 points)

Consider “4-qubit HHL” problem.

$$\mathrm{A} = \begin{pmatrix} 1 & -1/3 \\ -1/3 & 1 \end{pmatrix} \text{ and } |b\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

Find P(|1⟩).
The calculation and Qiskit codes have to be provided, respectively.

“Hint : Check the URL - https://qiskit.org/textbook/ch-applications/hhl_tutorial.html”

[Problem 5] - (30 points)

Consider a journal article – "Training deep quantum neural networks" – URL : https://www.nature.com/articles/s41467-020-14454-2.

$$\rho^{\text{out}} = tr_{in,hid}(u\ (\rho^{in} \otimes |0 \cdots 0\rangle_{hid,out}\langle 0 \cdots 0|)u^{+})$$

Answer each question.

1) What is $|0 \cdots 0\rangle$? What is the difference with ρ^{in}?

2) Give an example with your explicit input data, quantum deep learning architecture, and output data. The data and operators should be numeric forms.