総合研究大学院大学先端学術院
加速器科学コース・素粒子原子核コース
５年一貫制博士課程入学試験問題
英　語

令和５年８月２３日（水）１１時２０分～１２時００分

注意

☆ 答案用紙の所定の欄に，受験番号，氏名を記入すること.

☆ 試験問題（２問）ごとに，異なった答案用紙を使用すること.

☆ 各問題に対して，答案用紙は複数使用してよいが，第○○問□□枚目というように，所定の欄に，選択した問題の番号及び答案用紙の順番を記入すること.

解答できない場合も，受験番号，氏名，問題番号を記入し，提出すること.

☆ 答案用紙がさらに必要な場合は，挙手をして監督者に知らせること.

第 1 問

次の文章は，Michael A. Nielsen and Isaac L. Chuang, "Quantum Computation and Quantum Information", 10th Anniversary Edition, Cambridge University Press (2010) から，量子ビットについての導入部を抜粋したものである（一部省略）．文章を読み，下の問いに答えなさい．

The bit is the fundamental concept of classical computation and classical information. Quantum computation and quantum information are built upon an analogous concept, the quantum bit, or qubit for short. In this section we introduce the properties of single and multiple qubits, comparing and contrasting their properties to those of classical bits.

What is a qubit? We're going to describe qubits as mathematical objects with certain specific properties. 'But hang on', you say, 'I thought qubits were physical objects.' It's true that qubits, like bits, are realized as actual physical systems. However, for the most part we treat qubits as abstract mathematical objects. The beauty of treating qubits as (a) abstract entities is that (b) it gives us the freedom to construct a general theory of quantum computation and quantum information which does not depend upon a specific system for its realization.

What then is a qubit? Just as a classical bit has a state – either 0 or 1 – a qubit also has a state. Two possible states for a qubit are the states $|0\rangle$ and $|1\rangle$, which as you might guess correspond to the states 0 and 1 for a classical bit. Notation like '$|\ \rangle$' is called the Dirac notation, and we'll be seeing it often, as it's the standard notation for states in quantum mechanics. The difference between bits and qubits is that a qubit can be in a state other than $|0\rangle$ or $|1\rangle$. It is also possible to form linear combinations of states, often called superpositions:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle .$$

The numbers α and β are complex numbers. Put another way, the state of a qubit is a vector in a two-dimensional complex vector space. The special states $|0\rangle$ and $|1\rangle$ are known as computational basis states, and form an orthonormal basis for this vector space.

（次ページに続く）

We can examine a bit to determine whether it is in the state 0 or 1. For example, computers do this all the time when they retrieve the contents of their memory. Rather remarkably, we cannot examine a qubit to determine its quantum state, that is, the values of α and β. Instead, quantum mechanics tells us that we can only acquire much more restricted information about the quantum state. When we measure a qubit we get either the result 0, with probability $|\alpha|^2$, or the result 1, with probability $|\beta|^2$. Naturally, $|\alpha|^2 + |\beta|^2 = 1$, since the probabilities must sum to one. Geometrically, we can interpret this as the condition that the qubit's state be normalized to length 1. Thus, in general a qubit's state is a unit vector in a two-dimensional complex vector space.

注： orthonormal basis　正規直交基底

【問１】

(1) 下線部(a)を次のように言い換えるとき，[　　]に当てはまる一単語を本文から抜き出して答えよ.

abstract entities → [　　] objects

(2) 下線部(b)を日本語に訳せ．ただし，“it”が指す内容を具体的に含めること.

【問２】

本文では，量子ビットは数学的にはどのようなものだと言っているか．日本語で簡潔に記せ.

【問３】

次の選択肢のうち，本文中に述べられている事柄を２つ選べ.

A) Physical objects are as abstract as mathematical objects.

B) In the vector space of qubits, there are two special states which form an orthonormal basis.

C) Few physicists use the Dirac notation to represent quantum mechanical states these days.

D) By measuring a qubit using an advanced physical apparatus, we can determine its quantum state exactly.

E) The state of a qubit can be represented by a point on the unit three-dimensional sphere.

F) Both bits and qubits are realized as actual physical systems.

第 2 問

あなたは学生として所属している研究グループのリーダー(Catherine)からミーティング開催通知の電子メールを受け取った．これに対する返信として，参加を希望する旨の電子メールを英語で作成しなさい．なお，下に示す「含めるべき事項」を返信内容に含めること．

> Dear colleagues,
>
> We will have our next research meeting on 27 September at 10:00 am. The meeting place will be our usual room 211 in the North Building (video meeting is also available). Please let me know by the end of this week if you would like to give a presentation, and how long (10, 15, or 20 minutes).
> We will take about 30 minutes at the end to discuss how to use our remaining research money. If you have any ideas or requests, please suggest them.
> I look forward to seeing you all.
>
> Best regards,
> Catherine

含めるべき事項：

- あなたの名前は Ichiro 又は Hanako とする．（いずれかを選ぶ）
- 現地（on-site）参加して発表を希望するが，当日朝空港に到着予定であり，遅れる可能性があるので発表の順番は最後にしてほしい．
- マルセイユ(Marseille)で開催されるウィンタースクールに参加したいので，旅費補助(financial support)を希望する．
- その他，返信として必要な事項を含めること．