IMPORTANT: Please read the following instructions carefully!

- Please answer all questions **to the best of your ability** (please don't consult other students). We don't expect you to get everything correct! Some of these questions are intentionally designed to be challenging.
- These questions are designed to assess *conceptual* aspects of quantum information and quantum computing, not rote mathematical skills. **If you find yourself having to do complicated computations, please let us know** -- this is not the intent of this instrument, and we might be overlooking something.
- Beneath each question, we will have a **box for feedback**. Filling this out is totally optional (though encouraged). If you feel a question is unfair, confusing, or unnecessarily easy or difficult, please say something! Each course is different in terms of content coverage, language, and notation, and we want to make sure the questions are understandable for everyone.
- Some questions ask you to fill in blanks using ASCII characters. This just means use the **standard characters on your keyboard** (i.e. no LaTeX or fancy symbols)

On all questions, **you may assume the following:**

- All measurements are in the standard (Z) basis*
- All quantum states are pure states; we are not considering mixed states* here

(*If you don't know what these terms mean, don't worry! These are more nuanced concepts taught in some but not all courses. If you haven't seen these terms before, then you've already been making these assumptions implicitly throughout your course and you don't need to do anything different.)

Q7

Question 1 (of 16)

I wish to write the state $|\psi\rangle = |01011\rangle$ as a column vector.

i. How many *total* components will this vector have?

ii. How many *nonzero* components will this vector have?

(Optional) Comments or feedback on this question for the survey development team?

- Unfamiliar/confusing terminology or notation?
- Issues with the Qualtrics interface?
- Suggestions for improving this question?

Q21

Question 2 (of 16)

Consider the mathematical object $X \otimes Z$.

Recall that X and Z are the usual Pauli gates, given by, respectively:

$$X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \text{ and } Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

i. What sort of mathematical object does $X \otimes Z$ represent?

- a. A scalar
- b. A vector of dimension 2
- c. A vector of dimension 4
- d. A vector of dimension 8
- e. A vector of dimension 16
- f. A matrix of dimension 2x2 (rows x columns)
- g. A matrix of dimension 2x4 (rows x columns)
- h. A matrix of dimension 4x2 (rows x columns)
- i. A matrix of dimension 4x4 (rows x columns)
- j. Something else

(Continued) Consider the mathematical object $X \otimes Z$.

Recall that X and Z are the usual Pauli gates, given by, respectively:

$$X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \text{ and } Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

ii. What sort of *physical* object does X ⊗ Z represent?

- ○ a. A quantum state
- ○ b. A measurement outcome
- ○ c. A 1-qubit gate composed of applying the X gate followed by the Z gate
- ○ d. A 1-qubit gate composed of applying the Z gate followed by the X gate
- ○ e. A 2-qubit gate composed of applying the X gate to the 1st qubit and the Z gate to the 2nd qubit
- ○ f. A 2-qubit gate composed of applying the Z gate to the 1st qubit and the X gate to the 2nd qubit
- ○ g. Something else
- ○ h. This expression is not physically meaningful

(Optional) Comments or feedback on this question for the survey development team?

- Unfamiliar/confusing terminology or notation?
- Issues with the Qualtrics interface?
- Suggestions for improving this question?

Q1

Question 3 (of 16)

For each of the expressions below, which of the following best describes the result of the expression? (Assume $|\varphi\rangle$ and $|\psi\rangle$ are well-defined states of a single qubit, and Z is the usual 1-qubit quantum gate.)

	A ket (of any dimension)	A bra (of any dimension)	A scalar	An operator	Undefined or meaningless
i. $(\langle\psi\| + \langle\varphi\|)(\|\psi\rangle - \|\varphi\rangle)$	○	○	○	○	○
ii. $\|\varphi\rangle + \langle\psi\|$	○	○	○	○	○
iii. $\langle\varphi\| \otimes \langle\psi\|$	○	○	○	○	○
iv. $\langle\varphi\| \otimes \|\psi\rangle$	○	○	○	○	○
v. $(\|\psi\rangle \otimes \|\psi\rangle) + \|\varphi\rangle$	○	○	○	○	○
vi. $Z \otimes \|\psi\rangle$	○	○	○	○	○

(Optional) Comments or feedback on this question for the survey development team?

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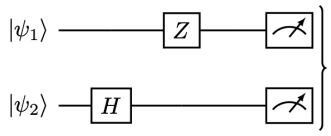
- Suggestions for improving this question?

Q2

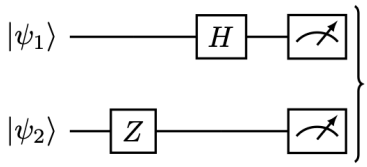
Question 4 (of 16)

Which of the following circuit diagrams is equivalent to (⋆) below? Select all that apply. (Assume $|\psi_1\rangle$ and $|\psi_2\rangle$ are arbitrary single-qubit states.)

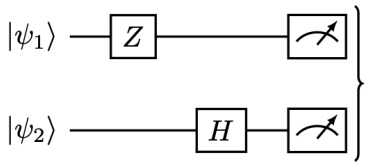
(⋆)



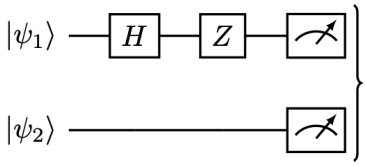
☐ a.



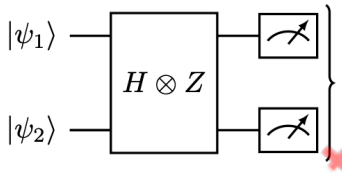
☐ b.



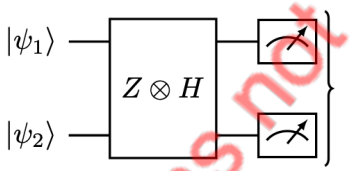
☐ c.



☐ d.



☐ e.



☐ f. None of these

(Optional) Comments or feedback on this question for the survey development team?

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- Issues with the Qualtrics interface?
- Suggestions for improving this question?