S. KIMMEL

Things you should be able to do for exam: (up to PS 4 / no cloning)

- Analyze and describe situations using bra/ket & vector notation

including qudit
  - States
  - Measurements
  - Unitaries
  - Cryptographic protocols
  - Bomb protocol
  - No cloning proof

  - know common abbreviations:
    - $|0\rangle, |+\rangle, |\rightarrow\rangle$ etc.
    - I, X, Y, Z etc.

- Analyze 2-qubit scenarios
  - Use tensor product appropriately
  - Identify entangled / product systems
  - Determine outcomes & probabilities of local measurements + nonlocal measurements
  - Apply 2-qubit unitaries
  - Analyze non-local games
  - Analyze cloning strategies for Eve.
- Bloch Sphere: Identify correspondence between
  - states + vectors on B.S.
  - unitaries + rotations on B.S.
- Manipulate complex numbers

Resources: • Reserves e-book: Quantum Computing Explained

- Quiz + HW solns on canvas

S. KIMMEL

2 qubits

2 qubit state: $|\psi\rangle = \begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix}$, where $\langle\psi|\psi\rangle = 1$

2 qubit measurement: $\{|\phi_1\rangle, |\phi_2\rangle, |\phi_3\rangle, |\phi_4\rangle\}$, where

$$\langle\phi_i|\phi_j\rangle = \delta_{ij}$$

Outcome of measurement on $|\psi\rangle$:

→ Get $|\phi_i\rangle$ w/ probability $|\langle\phi_i|\psi\rangle|^2$, and $|\psi\rangle \to |\phi_i\rangle$

Product + "Local"

- Qubit A: $|\psi\rangle$
  Qubit B: $|\phi\rangle$
  ⇓
  Combine to $|\psi\rangle$

$|\psi\rangle_{AB} = |\psi\rangle_A |\phi\rangle_B$
$|\psi\rangle_{BA} = |\phi\rangle_B |\psi\rangle_A$
} Both OK, just be consistent

S. KIMMEL

- Alice + Bob each have qubit, may or may not be entangled.

  Alice measures $\{|\chi_1\rangle, |\chi_2\rangle\}$
  Bob measures $\{|\eta_1\rangle, |\eta_2\rangle\}$

  Effective 2-qubit measurement: $\{|\chi_1\rangle|\eta_1\rangle, |\chi_1\rangle|\eta_2\rangle, |\chi_2\rangle|\eta_1\rangle, |\chi_2\rangle|\eta_2\rangle\}$

  Orthonormal bases for $\mathbb{C}^4$ (4×1 vector space)