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ENGINEERING PHYSICS

R Vasudevan Iyer, Ph.D.

Department of Science and Humanities

ENGINEERING PHYSICS

Two state systems

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Class #14

- ***Quantum system can be***

➢ ***Electrons and other subatomic particles***

➢ ***Atoms***

➢ ***Molecules***

and so on.

Two state system

- A quantum system has many states.
- For example the atom has many states described by a quantum number n
- Each state of a quantum system is described by a wave function ψ
- If we choose two unique states then we have a two state system or if the quantum system has only two states then it qualifies as a two state system
- For example the energy levels of an atom are unique. If we take H – atom then the energy levels have values: -13.6eV, -3.4eV, -1.51eV and so on. Any pair of successive levels can be chosen to represent two unique states
- Another example is the spin of an electron which can be either up spin or down spin. They can become a two state system

Two state system

- Why is the two state system so important?

The answer is they become a perfect choice for what we know as a quantum bit or QUBIT.

- A bit in classical computing is the 0 and 1. Computers process information using the 0 and 1.
- A transistor in the on state is referred to as 1 and in off state referred to as 0
- A QUBIT is the unit for quantum computing and is 0 or 1 or a combination of 0 and 1
- One of the state of the quantum system can be referred to as 0 and the other as 1 or we could use the wavefunction to refer to the quantum state as follows:

Two state system

- One state can be ψ_1 and the other can be ψ_2.
- A QUBIT then in general is represented mathematically as $\psi = a\psi_1 + b\psi_2$ where a and b can be complex numbers or as $\psi = a(0) + b(1)$
- Quantum states are in general treated as vectors that live in a space called as vector space (technically called the Hilbert space)
- Thus ψ_1 and ψ_2 are vectors in that vector space (this will be treated in detail in the next class)

Qubit in Dirac notation

- Paul Dirac introduced a notation to represent the vectors of a quantum state
- This is referred to as KET and the and KET ψ is written as $|\psi\rangle$. What this means is that the vector which is ψ can be written $|\psi\rangle$
- Thus the qubit can be written as $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$
- This is a convenient notation and makes expressions in quantum mechanics very concise

Idea of superposition

- The qubit written as $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ is referred to as the superposition of the $|0\rangle$ and $|1\rangle$ states
- If α is 1 then $|\psi\rangle$ is the $|0\rangle$ state and if $\beta = 1$ then $|\psi\rangle$ is the $|1\rangle$ state. In general we can have contribution from both states
- The probability of $|\psi\rangle$ to be in the $|0\rangle$ state is given by $|\alpha|^2$ and the probability of it being the $|1\rangle$ state is $|\beta|^2$
- Since the total probability is always 1 we have $|\alpha|^2 + |\beta|^2 = 1$

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Class #14 …….. Quiz….

A quantum state is defined by $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ where $\alpha = \frac{1}{\sqrt{3}}$

In general the value of β can be

- $\sqrt{\frac{2}{3}}$
- $\frac{2}{\sqrt{3}}$
- $\sqrt{\frac{2}{3}}\, e^{i\theta}$
- $\frac{2}{\sqrt{3}}\, e^{i\theta}$

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THANK YOU

R Vasudevan Iyer, Ph.D.

Professor, Department of Science and Humanities

rviyer@pes.edu