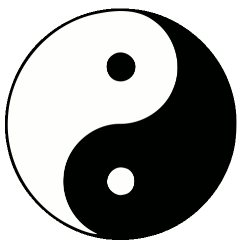
Complementarity

- ***Sometimes*** photons behave like ***waves***, and ***sometimes*** like ***particles***, but ***never both*** at the same time.
- According to Bohr, ***particle*** or ***wave*** are just classical concepts, used to describe the different behaviors of quanta under different circumstances.
- Neither concept by itself can completely describe the behavior of quantum systems.



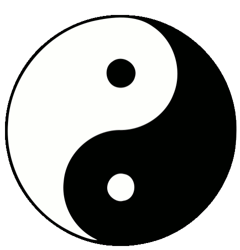
Contraria sunt Complementa

Latin for: opposites are complements

Complementarity

Depending on the context, complementarity can refer to:

- The mental picture we have of a physical system. (particle vs. wave)
- What an experiment can reveal. (which-path vs. interference)
- What quantum mechanics allows us to know. (position vs. momentum)



Contraria sunt Complementa

Latin for: opposites are complements

Complementarity

Complementarity applies to what are known as ***incompatible observables***. Some examples from class so far are:

- If we know the spin of an atom along one direction, its spin along other directions is indeterminate.
- If we know which path a photon takes, we can't observe its wave behavior.

Other Examples:
(from the readings, perhaps?)

Truth
vs.
Brevity

Classical Systems

For a classical system we can write down a list of all the characteristics of a physical system:

POSITION

LINEAR MOMENTUM

ANGULAR MOMENTUM

ENERGY

etc…

Knowing these quantities initially allows us to predict the quantities at later times.

In principle, all of these can be simultaneously measured with as much accuracy as we require.

Quantum Systems

For a quantum system we have to write down **TWO** lists:

A	B
PARTICLE WHICH-PATH POSITION	

- For every characteristic in **List A**, there is a corresponding characteristic in **List B**.
- Knowing a lot about one means we know only a little about the other.

Quantum Systems

These are also incompatible observables, but in a slightly different way than those in the previous list:*

A	B
L_Z	

L_Z = angular momentum about the z-axis (think magnetic moments)

If we know L_Z, then angular momentum about ***any*** other direction is indeterminate.

*This incompatibility is a consequence of the more familiar constraints placed on position and momentum about which we'll learn a lot more!

Quantum Systems

These are also incompatible observables, but in a slightly different way than those in the previous list:

A	B
ENERGY	TIME

Time is not a quality possessed by a physical system – it is a parameter in our equations. Here ***time*** refers to:

- The time required to measure the energy of a system.
- The lifetime of a state where there is uncertainty in the energy of that state (broadening of spectral lines).
- The time over which the average properties of a system change significantly.

Wave/Particle Duality

We have discussed wave/particle duality for photons:

- A single photon is detected at one point in space. [**PARTICLE**]
- When two paths are possible, each photon interferes with itself. [**WAVE**]

Is there something special about ***massless particles***?

Do ***massive particles*** exhibit the same kind of behavior?

A) Yes B) No C) Maybe(?)