

Physics 100 - February 28, 2007

Exam 1 is graded

Solutions and grade distribution
are on the web

Mean was 71 → Great job!

Will return papers to you at end of class

Project groups

You need to meet and think about
what you want to do w/ your topic

... Then make a "group" Appt w/ Me.

QM treatment of H atom wave mechanics

Spherical Symmetry

Shapes of allowed electron states

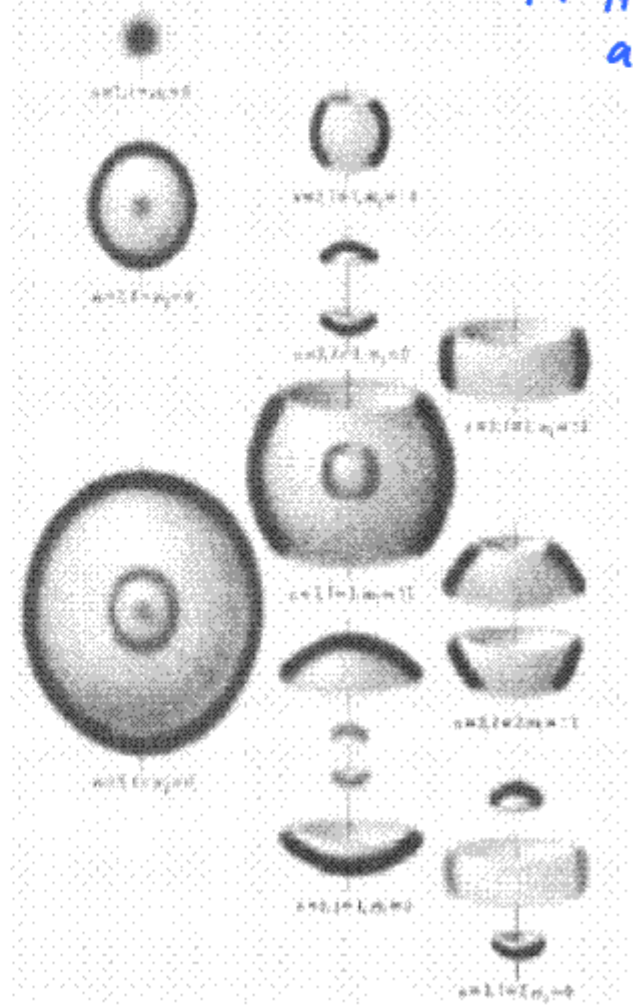
in hydrogen atom



Energy or principal quantum number
 $n = 1, 2, 3 \dots$

Orbital quantum number
 $l = 0, 1, \dots, n-1$

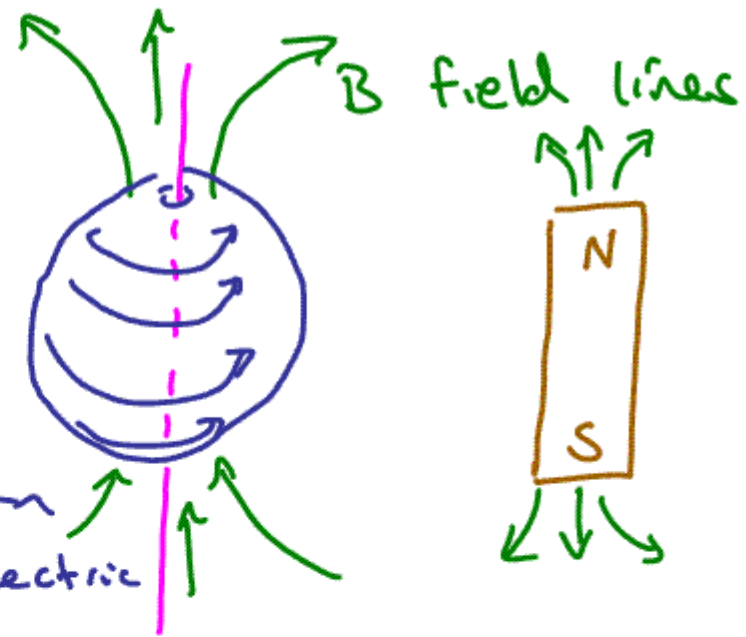
Magnetic quantum number
 $-l, -|l-1|, \dots, 0, 1, \dots, |l-1|, l$



Similar to Bohr - discrete states
But orbits are not circular

* Look at Falstad's Applet on [Lecture links page](#)

Spin



Imagine that the electron is a uniform ball of electric charge that "spins"

It would be like a little current loop

current loops create magnetic fields that look like magnetic fields coming from a bar magnet

Particles w/ spin have "magnetic moments" and look like tiny little bar magnets

This was discovered in 1922 by Stern + Gerlach

Spin is quantized

$0, \frac{1}{2}, 1, \frac{3}{2}, 2, \dots$

Integer Spin $0, 1, 2, \dots \Rightarrow$ Boson

$\frac{1}{2}$ -integer Spin $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \dots \Rightarrow$ Fermion

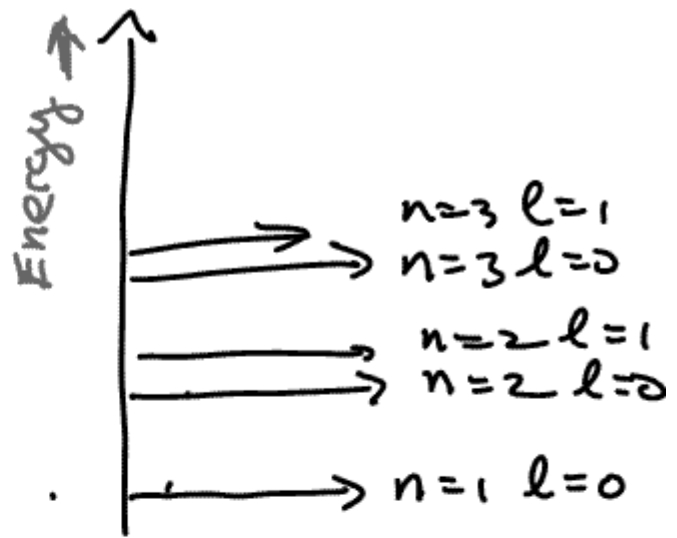
It's like you can only have bar magnets with certain discrete strengths

2 identical Fermions \rightarrow cannot occupy the same quantum state

2 identical Bosons \rightarrow can occupy the same quantum state

Schrödinger's eqn
gives allowed energy
states for e^- in
atom

They vary in energy like so \rightarrow



n = energy quantum number
 l = orbital angular momentum
quantum number

These characterize the
state... determine
the orbital

Z	ATOM	1	2	2	3	$\leftarrow n$
\downarrow	\downarrow	0	0	1	0	$\leftarrow l$
1	H	1	—	—	—	—
2	He	1↓	—	—	—	—
3	Li	1↓	1	—	—	—
4	Be	1↓	1↓	—	—	—
5	B	1↓	1↓	1	—	—
...						
11	Na	1↓	1↓	1↓	1↓	1

Electrons fill levels
lowest energy to highest

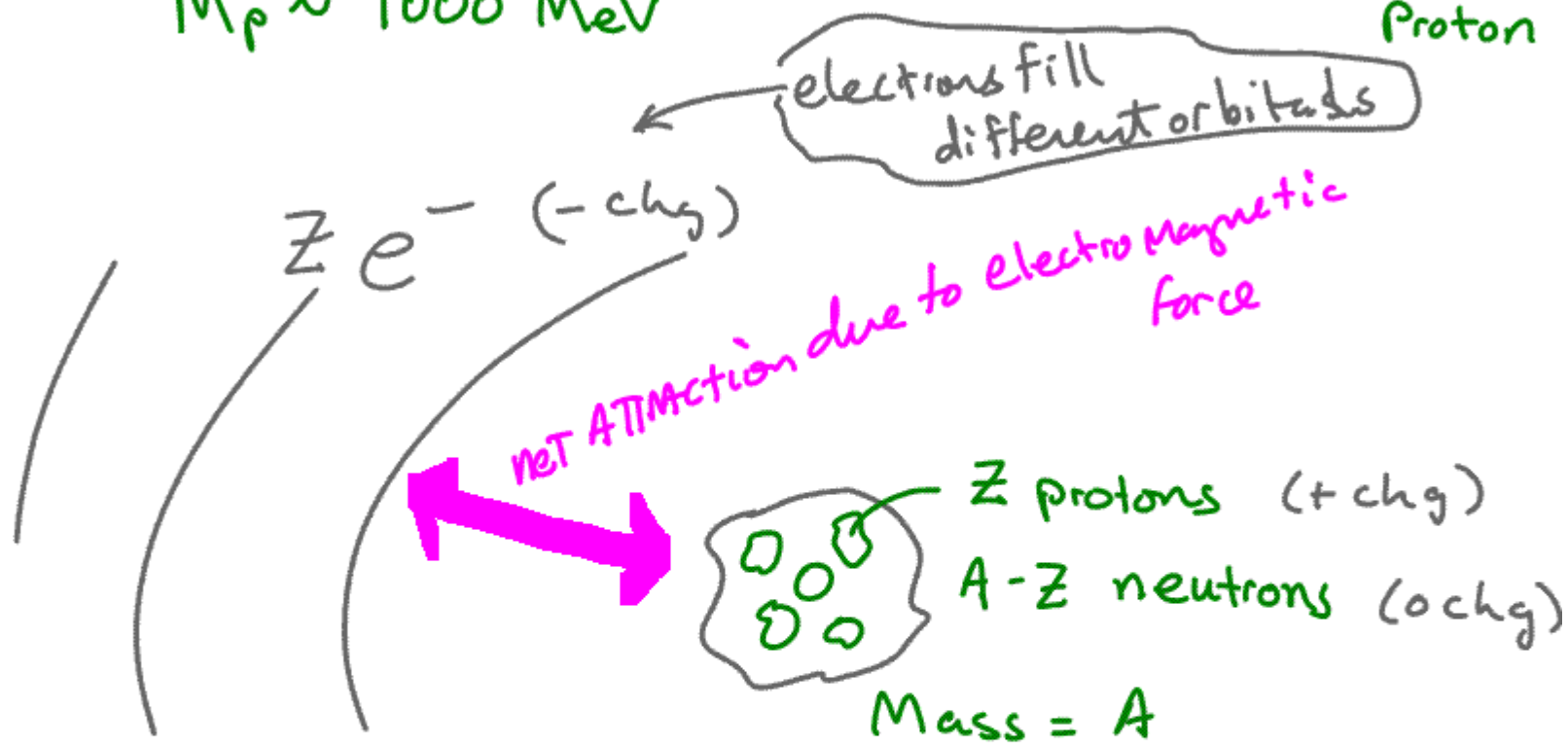
They do NOT all crowd
into lowest level
because they are

Fermions

$$M_e = .5 \text{ MeV}/c^2$$

$$M_p \sim 1000 \text{ MeV}$$

Mass of 1 A = Mass of Proton



The Atom

The way in which the orbitals are filled means there is periodicity in ATOMIC characteristics as Z increases

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

Very reactive in this column

Very inert in this column

1A 1 H Hydrogen 1.008																	8A 2 He Helium 4.003						
3 Li Lithium 6.941	2A 4 Be Beryllium 9.012																	3A 5 B Boron 10.81	4A 6 C Carbon 12.01	5A 7 N Nitrogen 14.01	6A 8 O Oxygen 16.00	7A 9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31																	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.58	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80						
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3						
55 Cs Cesium 132.9	56 Ba Barium 137.3	57 La* Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 208.9	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)						
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac~ Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (271)	111 Uuu Ununundium (272)	112 Uub Ununbium (277)	114 Uuq Ununquadium (286)		116 Uuh Ununhexium (288)		118 Uuo Ununoctium (289)							

Lanthanide Series~

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (147)	62 Sm Samarium (150.4)	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
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Actinide Series~

90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium (238)	93 Np Neptunium (237)	94 Pu Plutonium (242)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (249)	99 Es Einsteinium (254)	100 Fm Fermium (253)	101 Md Mendelevium (256)	102 No Nobelium (254)	103 Lr Lawrencium (257)
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Very reactive in this column



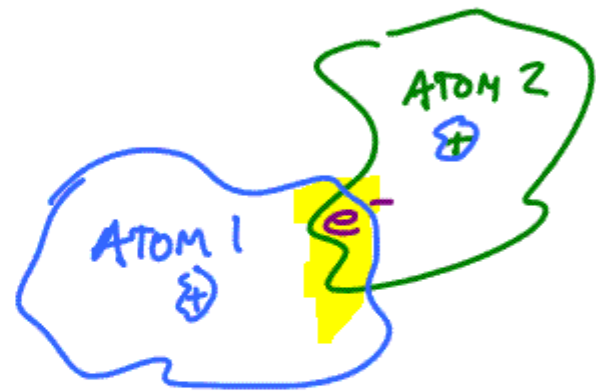
element names in blue are liquids at room temperature
 element names in red are gases at room temperature
 element names in black are solids at room temperature

Chemical Bonds

Due to way electrons are distributed in the available quantum levels — Sometimes energetically favorable for one atom to give another an electron ... or share electrons



Chemical "bond" from electric Attraction
→ ionic Bond



Atoms share an electron
Creates higher density of negative charge between the two positive nuclei

→ Covalent
Chemical
Bond

Quantum Mechanics and Uncertainty

$$-\frac{\hbar^2}{2m} \frac{d^2 \psi(x)}{dx^2} + V\psi(x) = E\psi(x) \quad \text{Schrödinger's EQUATION}$$

1927 Copenhagen Interpretation

BORN
Heisenberg
Bohr

$\psi(x)$ is not real \rightarrow Tool for calc.

$\psi^2(x)$ is well-defined \rightarrow probability

description is probabilistic

complementarity \rightarrow Expt can show
particle characteristic

BUT NOT Both $\left\langle \begin{array}{l} \text{-or-} \\ \text{Wave characteristics} \end{array} \right.$

Max Born German (1882-1970)



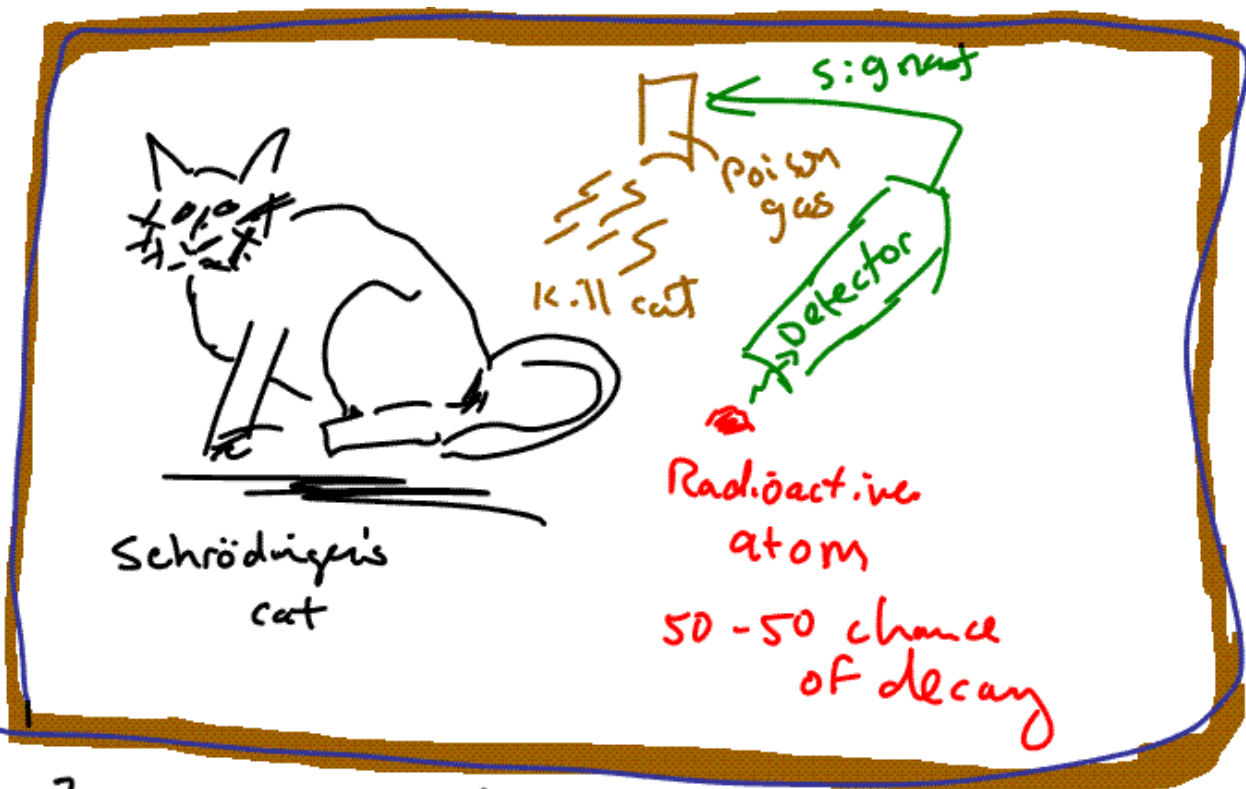
1954 Nobel Prize in physics

"For his fundamental research
in quantum mechanics,
especially for his statistical
interpretation of the
wavefunction"

$\psi(x)$ wave function

$\psi^2(x) \sim$ probability of finding particle
in region of space

Box



observer

Is cat Dead or Alive?

cop. Interpretation says

$$\text{cat} = \frac{1}{2} (|\text{Dead}\rangle + |\text{alive}\rangle)$$

Many worlds view of quantum Mechanics

relative STATE formalism

cat in box



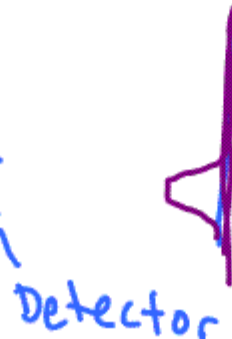
Hugh Everett

1957

one where cat is dead
" " " " alive

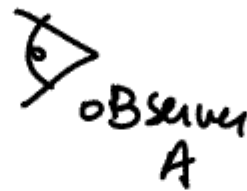
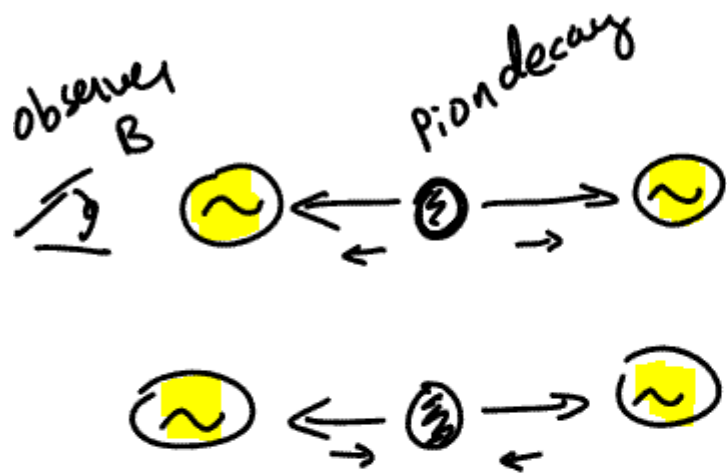


observation
of
electron
causes
collapse
of
wavefunction
and interference
pattern
disappears

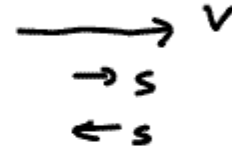


EPR Paradox — Einstein, Podolsky, Rosen 1935

"Spooky Action at a distance"



photon spin = 1



Two photons are produced at once — They are correlated.

If one has spin one way the other has spin the other way.

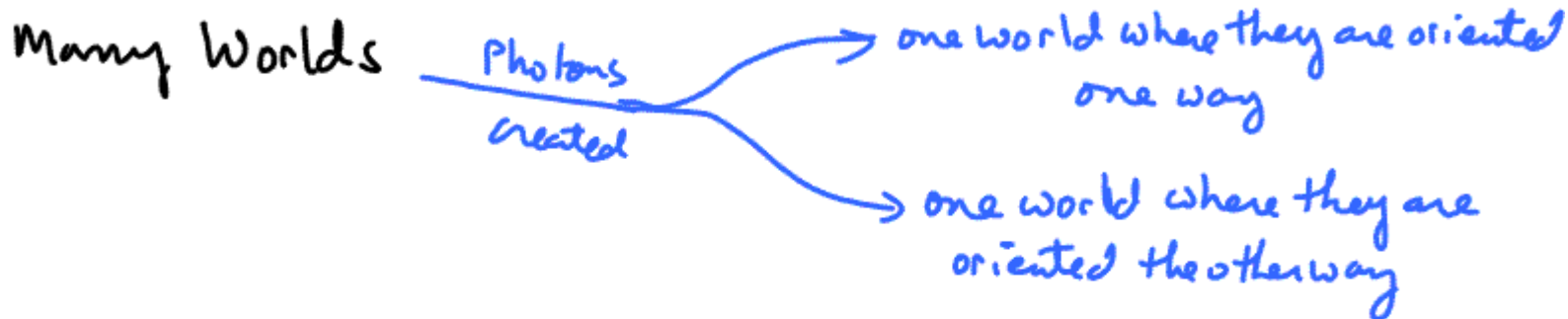
They are in an entangled quantum STATE

When observer A observes the spin of photon — The wavefunction collapses and the spin of the photon observer B will observe is determined.

But collapse instantaneous and observers A + B far apart

Does this mean information conveys faster than speed of light?

Copenhagen Interpretation $\rightarrow \psi(x)$ Not real
Things sort of only become when observation made



QUANTUM
cryptography

Entangled photons
QUANTUM STATE

Len Mandel (1928-2001) university of Rochester
Physicist

observed "entangled" photons

Hersenberg's Uncertainty principle

$$\Delta x \Delta p \leq \frac{h}{2\pi} \sim 10^{-34}$$

uncertainty in position

uncertainty in momentum (mv)

CANNOT know both the position and momentum with arbitrarily good precision

A different form of Heis. unc. princ.

$$\Delta E \Delta t \leq \frac{h}{2\pi}$$

unc. in energy

time over which it exists

CAN Break Conservation of energy - so long as you do it over a short enough time.

It's a Harry Potter universe

Tremendous implications