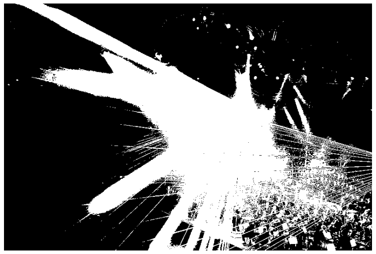
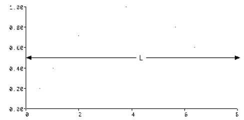
More Quantum Mechanics

Peter Watson



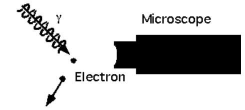
Heisenberg's Uncertainty Principle (1927)

- If an electron is a wave, how can we define its position?
- Suppose we try to measure position of electron by confining it to box, size L
- Uncertainty in position δx= L

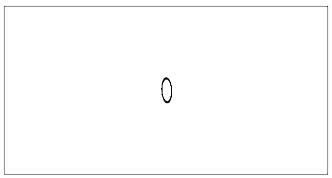


- but there is also an uncertainty in momentum : from de Broglie wavelength
- Can be “bouncing” in either direction so
- (uncertainty in position)× (uncertainty in momentum) > Planck’s constant
- if we squeeze walls together to measure position better, momentum becomes more uncertain.

- e.g. Suppose we try to measure position of electron with microscope
- if we could do it with one photon then the position uncertainty ~ wavelength:
- So decrease wavelength to get position better, but photon carries momentum p=h/λ and some of it gets transferred



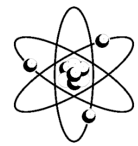
- e.g suppose we try to “confine” a photon by making it go through a small hole
- Its momentum becomes more uncertain, so it spreads out!



- This is a fundamental limitation on human knowledge: can always do worse but cannot do better
- There is another form of H's uncertainty principle, which is going to become important later
- This says that to measure the energy of anything perfectly, you need to take an infinite time.

Other atoms

- are complicated!
- many electrons, so many energy levels
- Nucleus (e.g. lithium) has Z (3) protons and Z (3) electrons so
- Deepest energy level has



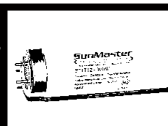
Razan Jaamour

1. - Why do the fluorescent lights take second or two to light up?

- When I changed my bathroom lights from incandescent light to fluorescent light, I have noticed that the fluorescent one take seconds to light up. It is bothering me.
- This is a hard question, but the prof. has the answer. I think it is related to an electronic physics and my prof. will talk about the light and the electrical power in the class. The scale is # 3

Text

Fluorescent lamps



1. Most use mercury vapour, which produces UV light.
2. Takes time to heat up cathode and start producing electrons

PW

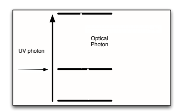
Kellie Grant

1. Question: Why do different gasses glow different colours when exposed to an electrical current? (such as neon signs)
2. Why was it a good question?: This is a good question it makes you explore the different aspects of many gasses and the reactions that can occur with them
3. Difficulty on a 5 point scale: 2/5 My prof. should know the answer and be able to tell me immediately

Text

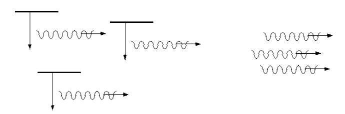
Fluorescence

- Usually multi stage process in gas
- UV photon (from mercury) excites electron
- makes 2-stage (or many stage) transitions back to ground state

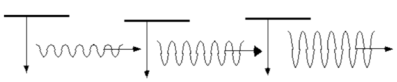


Lasers

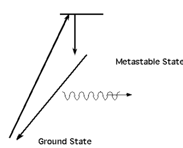
- Usually excited states decay producing photons.
- All photons have same energy but are produced at random by "spontaneous emission".
- Lifetime ~ 10^{-9}s
- Phase of photons is also random.



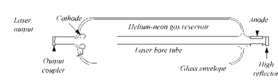
- However, if we have an atom in an excited state, a second photon will cause it to decay, and then the new photon will be added to the first.
- This is "stimulated emission", and amplifies original signal.
- Hence "Light Amplification by Stimulated Emission of Radiation" or Laser.
- In this case the outgoing photons are all in phase.



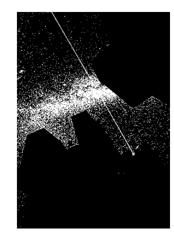
- Catch: How do we get the atoms in an excited state, when they want to drop back in a ns?
- Some states are much more long lived: "metastable".
- Find an atom with 3 levels, E_1,E_2,E_3, one of which is metastable.
- Get the atom into the highest state (by collision or excitation)
- drops into E_2 by spontaneous emission and then remains there until a second photon hits it

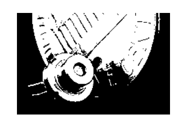


- e.g helium-neon laser
- electrons collide with He, excite it to higher level
- excited He collides with Ne, transfers energy
- Ne de-excites, emits 633 nm (red) photon
- reflectors at each end build up laser pulse



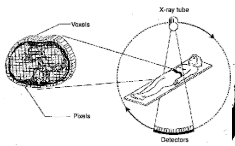
- Advantages: Can pump slowly, but de-excite rapidly. e.g. CO_2 lasers run at about 100W, but pulse can be 10^{-8} s, so instantaneous power ~ 10^{10}W.
- Beam is very tightly focussed (lenses give spread of about 1/2°, lasers can be 10^{-4}°)
- Beam is "coherent": i.e. all light is in phase
- Very small, very tough





Ionizing Radiation

- X-ray images intrinsically 2-D
- CAT scanner builds up 3-D picture from reconstruction of 2-D images



But

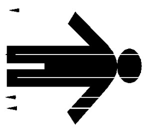
- X-rays are intrinsically dangerous
- Exposure has to be limited

Magnetic Resonance Imaging (MRI)

- Magnet in mag field has energy depending on orientation.
- Protons act as tiny magnets. Due to quantum mechanics, only two possible orientations of spin, up and down
- hence only two possible energy levels.

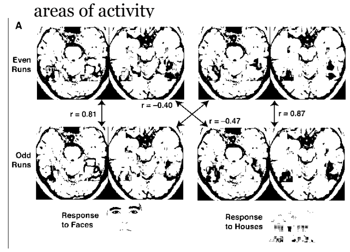
- Difference between these energy levels corresponds to a particular photon energy/ frequency.
- If field B = 1Tesla = 10000 Gauss
- f ≈42.6 MHz (microwave)
- Signal fed into matter will be strongly absorbed at one particular frequency if water is present.

- To turn this into a image, use a varying mag field so resonance frequency varies across object.
- Note bone appears as white (no water!).
- Picks out difference between fat, blood-vessels etc because of very slightly varying frequencies.



Functional MRI = FMRI

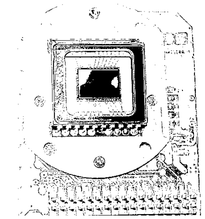
- Measures blood flow in brain to determine areas of activity



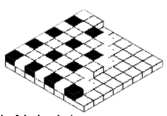
- Why do you own a lot of the 2009 Nobel prize?
- Charge-coupled devices
- Willard Boyle, George Smith at Bell labs

CCD devices

- Photon hits small metal plate, electron ejected
- Charge proportional to intensity of light.
- Charge from each pixel can then be read out and transferred to memory



- To turn it into colour picture, need filter on each pixel
- Used in
- Cameras
- Medicine
- Astronomy (this is the Crab Nebula)



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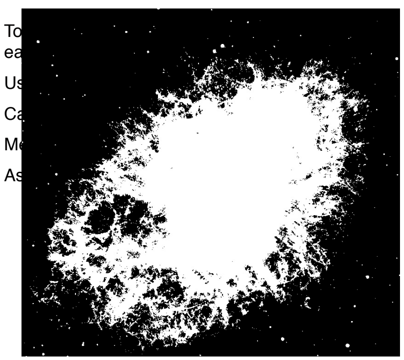

So they matter!

- How does the story get covered by the press? Guess where the headlines come from!
- 3 Americans share 2009 Nobel physics prize
- Nobel prize in physics goes to Briton who harnessed the power of light.Chinese-born Briton, Charles Kuen Kao, shares Nobel prize in physics with George Smith and Willard Boyle for developing optical fibres

- Canadian shares Nobel in physicsWillard S. Boyle, born in Amherst, N.S., takes the prize with two others for breakthroughs involving the transmission of light in fibre optics and inventing an imaging semiconductor circuit

Aharonov not awarded Nobel prize. The Royal Swedish Academy of Sciences on Tuesday did not award Tel Aviv University professor Yakir Aharonov with the Nobel Prize in the field of physics.