Nanophysics - unit 1

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22PH324A PHYSICS OF NANOMATERIALS AND APPLICATIONS

Length Scale in Physics

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Length Scale

The concept of length scale is an important phenomena of different dimension of object. It gives idea of size of matter.

Ex: How big an atomic nuclei? the size of cell?, planet? and a Galaxy?

If you are concentrating on low dimensional structure, there are four important units of length or distance

1. Bohr radius of Hydrogen atom
2. The Compton wavelength of e^-
3. Classical electron wavelength
4. Planck length.

1. Hydrogen atom:

Hydrogen atom consists of a proton around which electron orbits at a radius of r under the influence of the attractive force The Coulomb's force prevail in this two particle system attracted by the electric field, governs uncertainty principle. As the charged particle whizzing around, the radius depend

on the electron charge e, and m, mass of e^-.

Further, as the electron is in a fuzzed out orbit because of Quantum

P=1836 of e^- effect, it involve planck's constant $\hbar$. Bohr radius does not depend on the proton mass, as 1836 times heavier than the e^- mass.

this is the relativistic calculation, so we don't use, c – velocity of light.

$r = \hbar^2 / me^2$

length scale is proportional to an inverse mass scale!

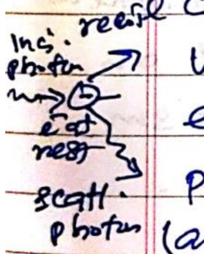
Hydrogen atom gets bigger when ħ is bigger, or gets smaller when ē charge is smaller (more attractive force).

$$a_0 = r = \frac{\varepsilon_0 h^2}{\pi m e^2} = 0.53\ A^\circ$$

half a angstroong.

2. Compton wavelength

Compton effect is the scattering of photon by electrons. Compton wavelength of a particle is ~~the~~ equal to the wavelength of a photon whose energy is the same as the mass of the particle.



$$= \frac{h}{m_0 c}(1-\cos\theta)$$

$$\lambda = \frac{\hbar}{mc} = 4\times10^{-13} \text{ meters.}$$

(Pl. check!)

Again, mass scale sets the length scale.

$\theta = ?$ $\theta = 180^\circ$

$h = 6.63\times10^{-34}$

$m_0 = 9.11\times10^{-31}$

$c = 3\times10^{8}$ m

$\lambda = 0.02078\ A^\circ$

$= 6.1244\ A^\circ$

or $E = 1.02$ MeV

3. The classical electron radius

The electromagnetic field produced by an electron, classically, has energy and thus should be counted as part of the mass of the electron! The length scale at which these effects becomes really important is called classical electron radius. It is not influenced by quantum field because only depend on the classical electromagnetism, which does not involve $\hbar$.

$$r_e = e^2/mc^2$$

$$= 3\times10^{-15}\ m.$$

The classical e^- radius is $\frac{1}{137}$ as big as Compton wavelength of e^-.

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4. planck length

The planck length is the smallest length at which space can be defined. At this scale the quantum gravity become important. The structure of spacetime becomes quite different from four dim. manifold

Spacetime is like a bucket of foam or dust or bubbling ~~of~~ sea of virtual black holes, In short, it is weired, but beyond that nobody really knows.

planck length at which Q.m. gravity and relativity will intesact very stronsly → Newton gravitational const.

$$L_{planck} = \left(\hbar G/c^3\right)^{1/2}$$

$$= 1.6 \times 10^{-35} \text{ m}$$

Comparison of different length scale:

1 metre	10^{0} m	Person..
mm	10^{-3} m	
μm	10^{-6} m	blood cell
nm	10^{-9} m	
pm	10^{-12} m	atom
fm	10^{-15} m	nucleus
(am) attometre	10^{-18} m	
zm – zeptometre	10^{-21} m	
ym – Yoctometer	10^{-24} m	
	10^{-27} m	
	10^{-30} m	
	10^{-33} m	⇐ planck scale
	10^{-36} m	