What Satellites See: Eyes Above the Skies

Introduction and Background

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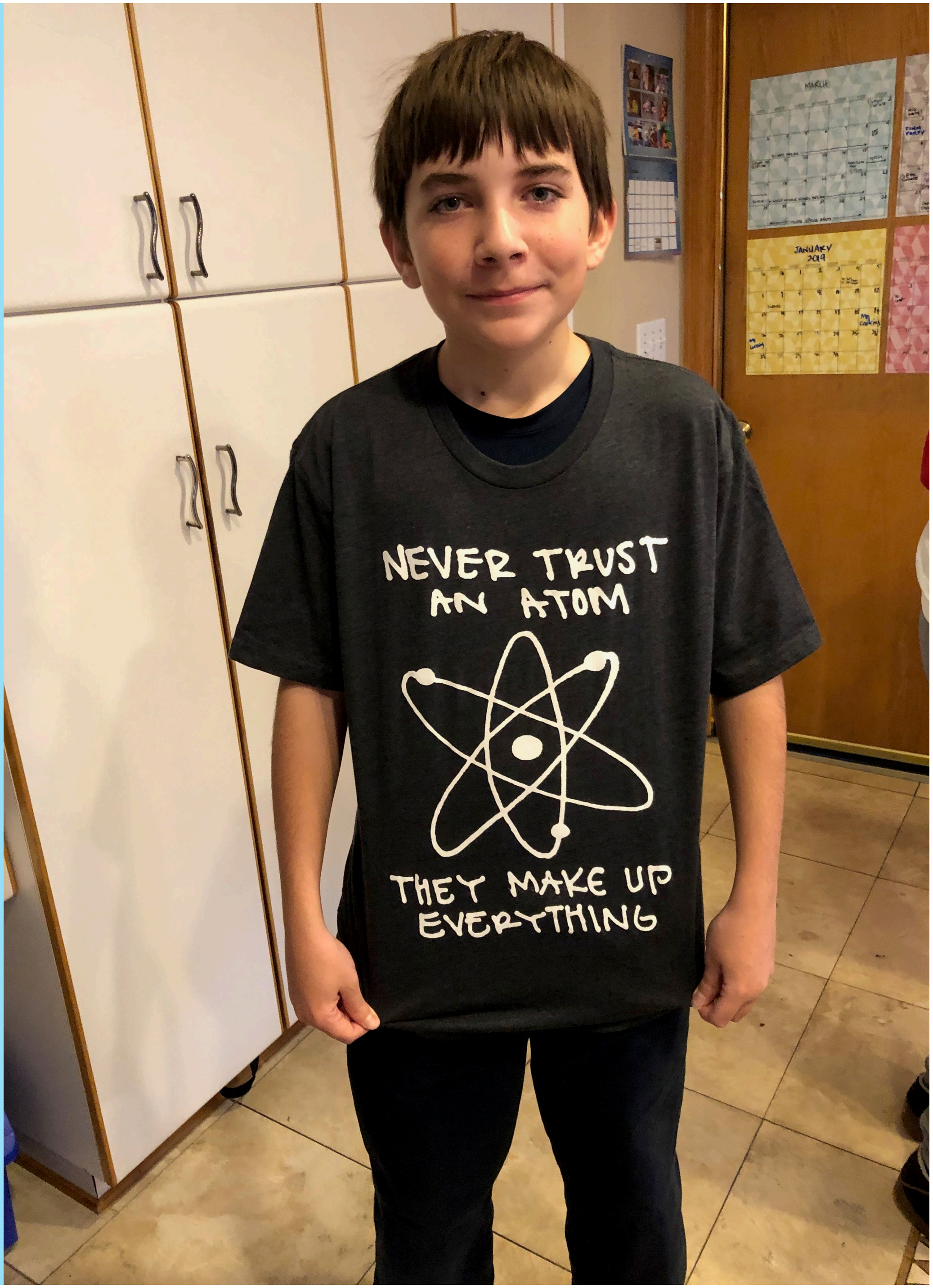
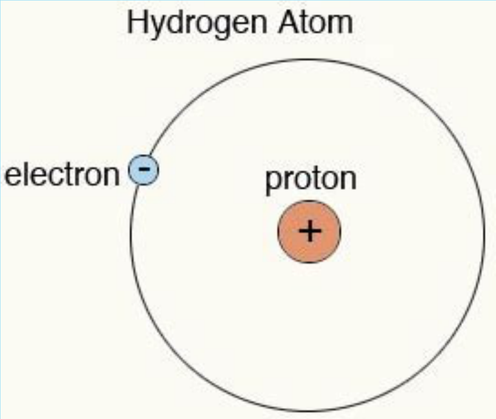
Wind Crest Learners
Academy for Lifelong Learning

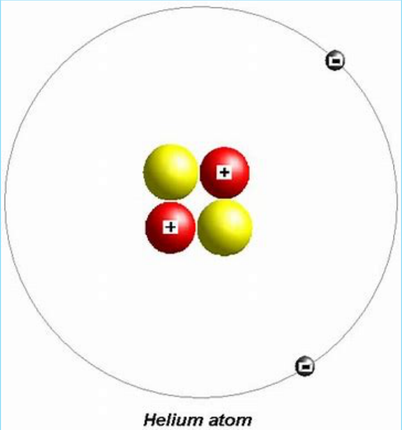
My 13 yr old grandson Ethan modeling his new T-shirt.

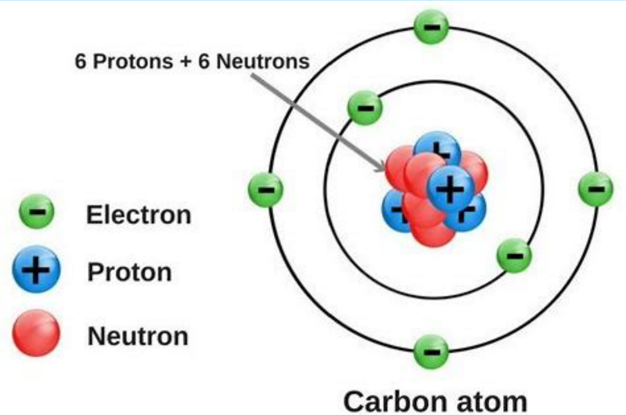
2/28/19



Size of atoms:
0.1 nanometer = 0.1 nm = 0.1 x 10^{-9} m







1.1 x 10^{-10} m

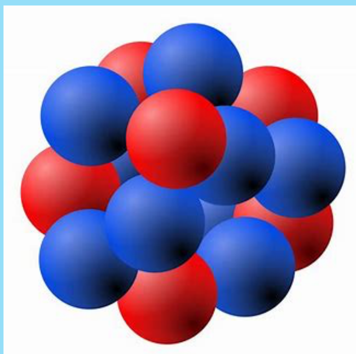
1.0 x 10^{-10} m

1.4 x 10^{-10} m

Size of nuclei ~10^{-15} m or femto meters

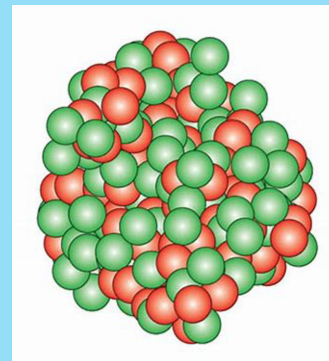
Size of nuclei: femtometer (10^{-15} m)

size of proton 0.84×10^{-15} m



Z=6, A = 12

Carbon nucleus, 6 neutrons
5.4×10^{-15} m



Z=92, A=238

Uranium nucleus
(146 neutrons)

15×10^{-15} m

size of electron 0.2×10^{-15} m
Four times smaller than a proton

What is a nanometer? -10^{-9} m

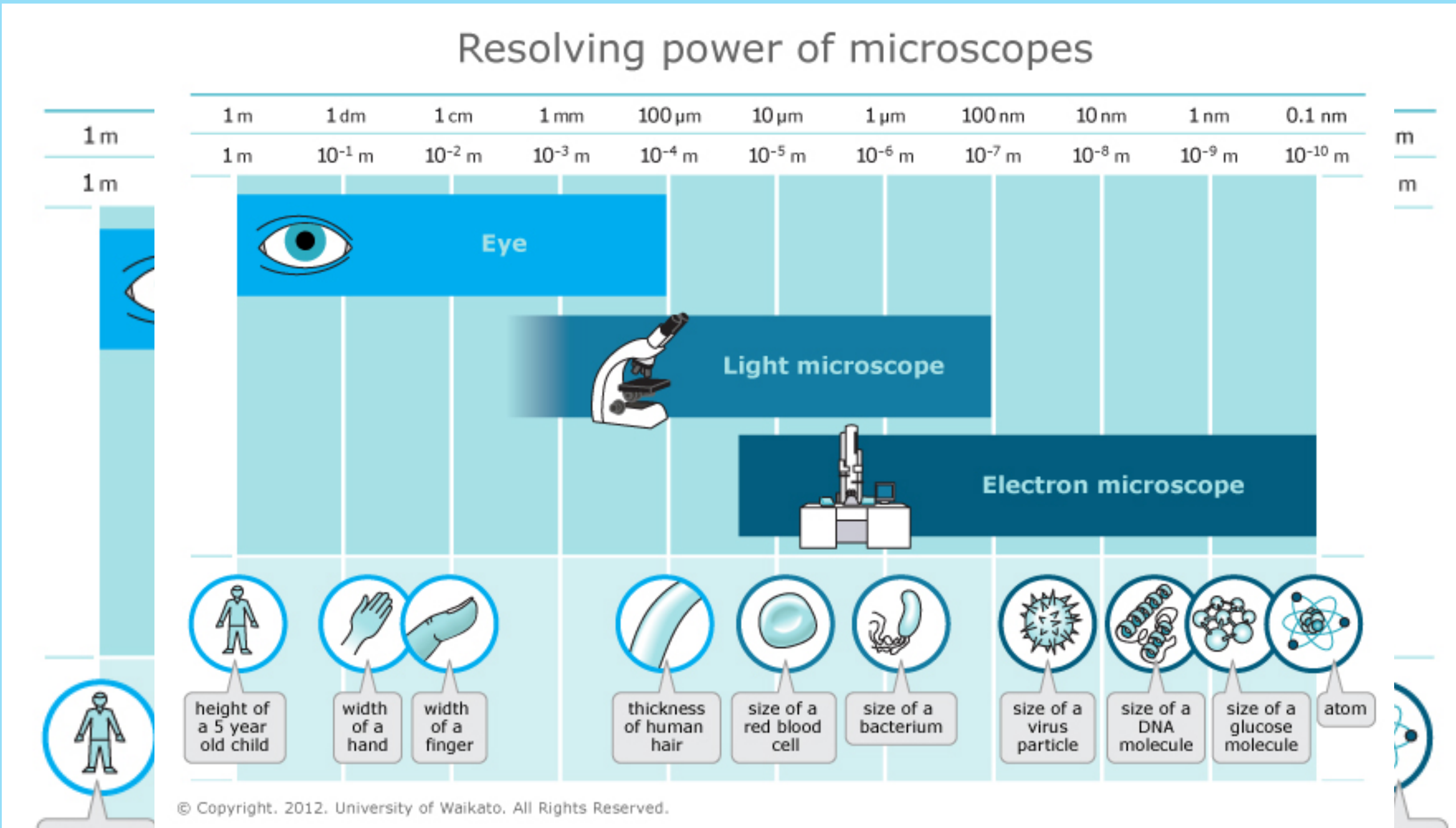
It is the size of a large molecule like glucose

It is 5 orders of magnitude (100,000 x) smaller than can be resolved by the human eye.

The de Broglie wavelength of an electron is 1.23×10^{-9} m. This applies to the ability to locate a free electron.

The electron in an atom is “in a box”, confined to a much smaller box. Since we know where it is, we can’t tell how fast it is going. Heisenberg’s Uncertainty principle.

How small a thing can an electron microscope see?



Electron focusing is limited by relativistic effects.

Electrons are going at 70% the speed of light at 0.1 nm.

What is a nanosecond? -10^{-9} s

Nano second= 10^{-9} seconds

A nanometer is the distance light can travel in
3×10^{-18} seconds.

The velocity of light: $c = 3 \times 10^{8}$ m/s = 1 ft/10^{-9} s= 1 ft/ns

$c = 1$ ft/ns

Earth to geosynchronous satellite – 0.11 s
Earth to moon – 1.3 s
Sun to Earth – 500 s = 8.3 min
Sun to 120 AU (Yoyager) – 16 hr
Sun to Alpha Centauri – 4.4 years

Neutrons

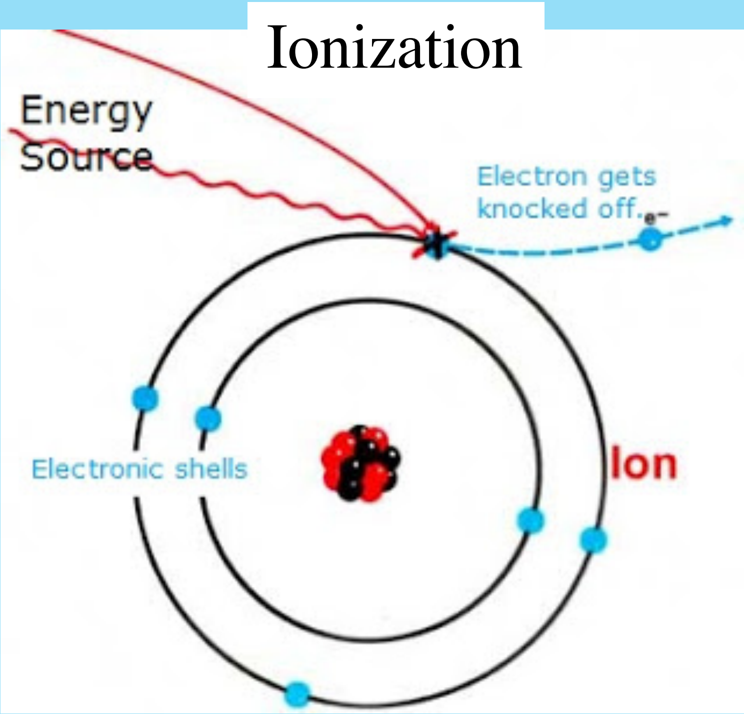
Neutrons are very much like protons, but they have no charge. They have essentially the same mass, and they both behave the same way in nuclei. (The same nuclear force.)

Groaners

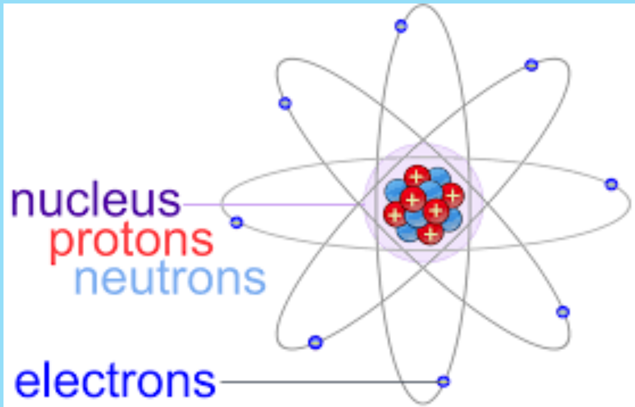
A neutron walked into a bar and asked, "How much for a gin and tonic?" The bartender smiled wryly and replied, "For you, no charge."

Two atoms were walking across a road when one of them said, "I think I lost an electron!" "Really!" the other replied, "Are you sure?" "Yes, I 'm absolutely positive."

Throw energy at an atom you kick off an electron and create an ion.

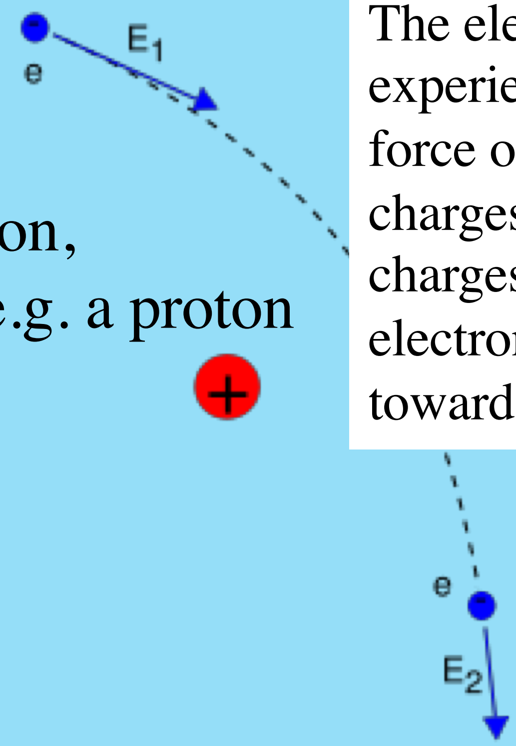


Protons and electrons: atoms and ions



You are familiar with this symbol of an atom, a nucleus surrounded by a cloud of electrons. Most of the mass is in the nucleus. The electrons are "bound" to the nucleus by the electric force.

For ions, the electrons have more energy and are not under the control of the nucleus. We call these ions and electrons (free).



ion,
e.g. a proton

The electron does experience the electric force of the ion. Like charges repel, unlike charges attract, so the electron is bent towards the ion.

Ions: atoms with one or more electrons removed.

For hydrogen it has mass A=1, charge Z=1 and we call it a proton, p.

For helium, if both electrons are removed, it has A=4, Z=2 and we call it an alpha particle. Alpha particles are emitted in radioactive decay of very heavy elements.

If a carbon has all 6 electrons removed, we still call it carbon (A=12, Z=6).

When ions get lots of energy in space we call them cosmic rays. We will see that they can be moving at essentially the speed of light.

What are the characteristics?

Electron

A = 1/1836; m_e = 0.511 MeV = 9.1×10^{-31} kg

Charge (Z) = -1

Size = 1.23×10^{-9} m de Broglie wavelength of free electron

Size = 1.23 nm

Size = 0.2×10^{-15} m Electron "in a box" localized by the electric force of the atom

Size = 0.2 fm

Proton (or a neutron)

A = 1; M_p = 938 MeV = 1.67×10^{-27} kg

Charge (Z) = +1

Size 0.84×10^{-15} m

Size = 0.84 fm Diameter

What is a nanometer? -10^{-9} m

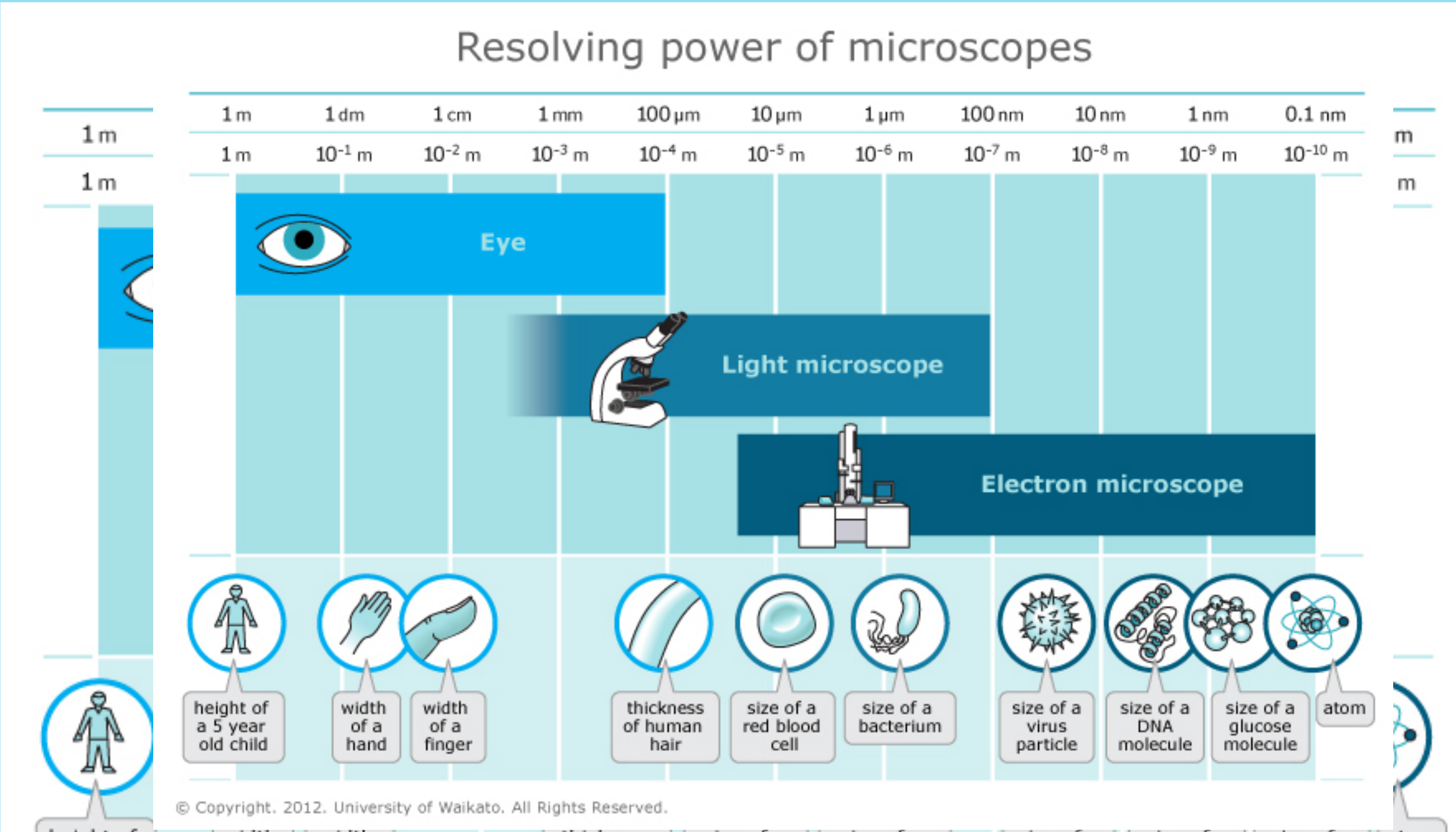
It is the size of a large molecule like glucose

It is the distance light can travel in a second

It is 5 orders of magnitude smaller than can be resolved by the human eye.

The de Broglie wavelength of an electron is $1.23\ 10^{-9}$ m

How small a thing can an electron microscope see?



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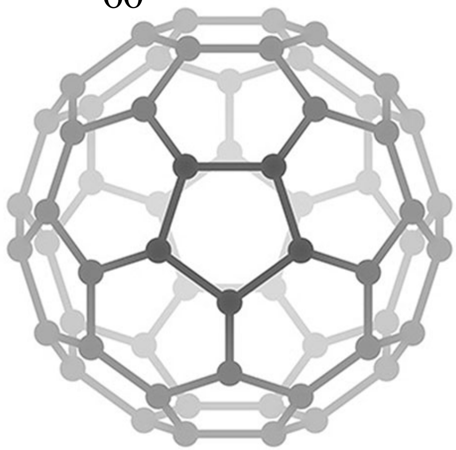
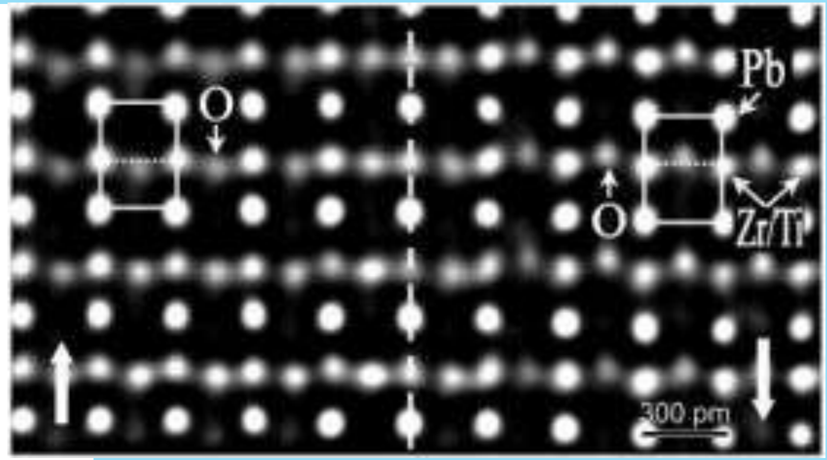
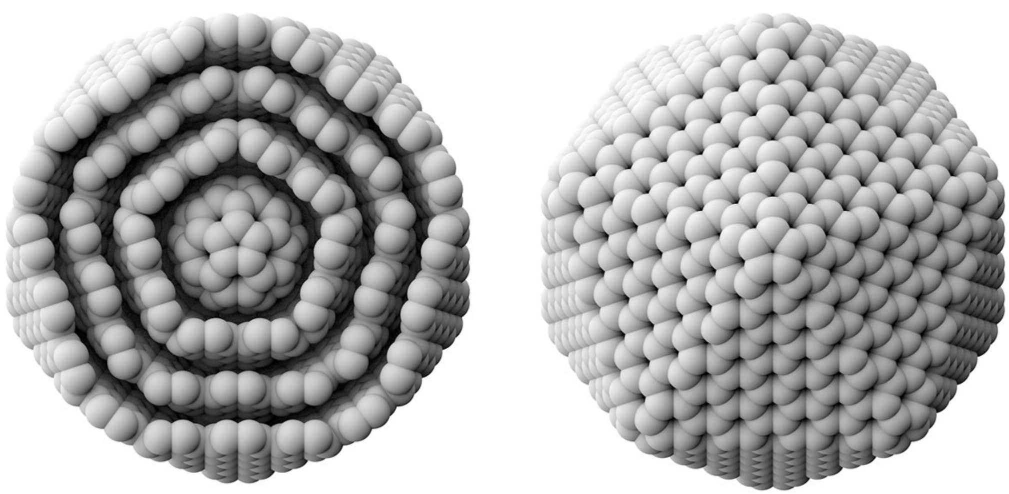
Carbon nanostructures

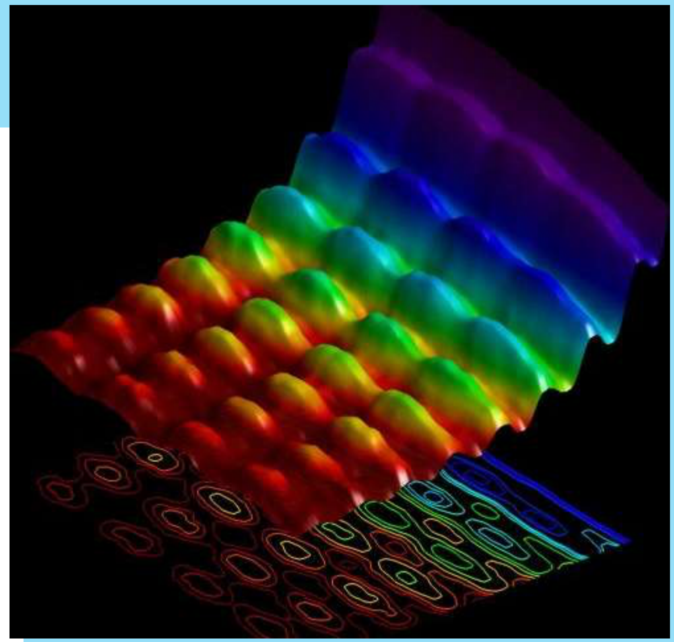
Fullerine C_{60}





carbon onion





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Size = 0.84 fm Diameter

momentum

A measure of how hard it is to stop something from moving

Momentum is important in collisions

Momentum has a direction associated with it

Momentum is a vector

Vectors are symbolized by boldface type

Momentum is given by mass times velocity ($\mathbf{p} = m\mathbf{v}$)

Velocity v has a direction associated, so **v** is a vector.

Momentum is conserved

Recoil of a rifle

Billiard ball collisions

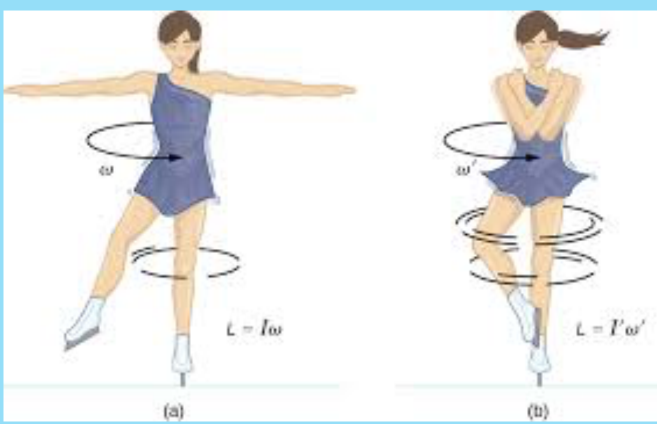
No change in momentum unless an outside force is applied.

Angular Momentum

A measure of how hard it is to stop something from moving

Angular momentum is the momentum associated with the rotation of an object. In this case the distribution of mass is important, because the linear speed is higher the further the matter is from the axis of rotation.

Skater with arms extended rotates faster as the arms are pulled in.



Angular momentum conserved
Change mass distribution,
Angular velocity changes.

Photons have momentum

A measure of how hard it is to stop something

Momentum is important in collisions

Momentum is given by mass times velocity

but photons have no mass

need to use relativistic equations

Photons can collide and transfer momentum

$p = h/\lambda$; since $\lambda\nu = c$, $p = h\nu/c$

The direction is the direction of the photon

The energy of a photon is given by $h\nu$.

So the momentum and energy

of a photon are closely related.

We will explore this in more depth later.