appeared in Aug 2005

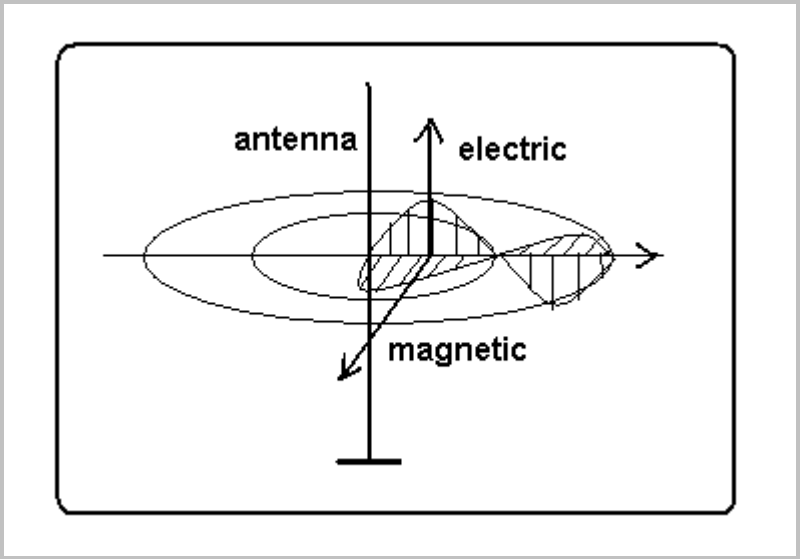
Atomic rhythms

Is the new physics the same old thing with just the assumptions changed? asks S.Ananthanarayanan.

The laws of physics have it that a charged particle that is accelerated will radiate electromagnetic waves. This is what happens in a radio antenna, for instance.

Radio antenna

The antenna is long metal wire that carries a rapidly alternating current. As the current grows from zero to maximum in the antenna wire, a magnetic field around the wire grows from zero to maximum. This growing magnetic field, in turn, induces a growing electric field, at right angles to itself and around the wire.



The growing electric field, somewhat like the current in the antenna, induces a magnetic field, which induces an electric field, and so on, in an expanding circle around the antenna.

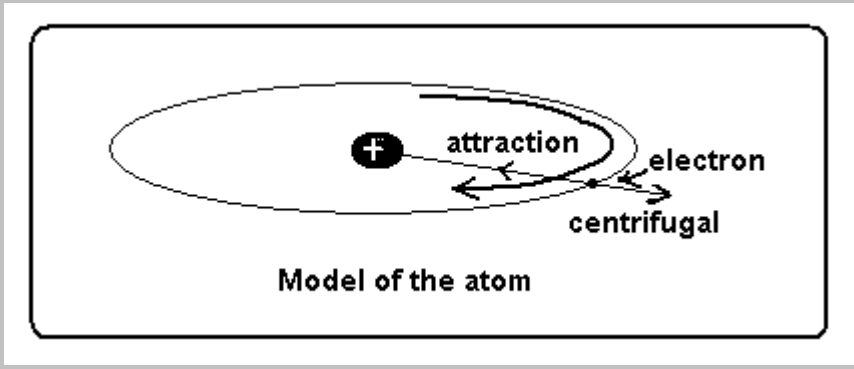
As the current in the antenna is rapidly alternating, the magnetic and electric fields also alternate, in the form of a radiating *wave*.

This wave carries energy, which can cause tiny currents in a conducting loop at a distance – and from this follow all the applications of wireless communications. But at the bottom is the principle that accelerating charges radiate and hence lose energy.

Atomic structure

Around a century ago, science had shown that atoms consisted of a heavy, positively charged nucleus, surrounded by tiny, negatively charged particles. To explain how these

negative charges remained in a cloud around the nucleus, without crashing in, it was proposed that they were in orbits, like the planets around the sun.



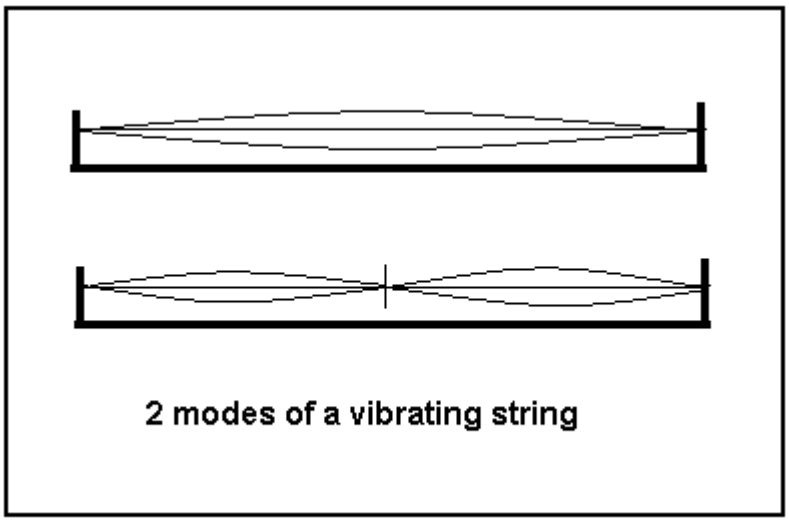
Model of the atom

The electrons then feel the centrifugal force, like what we feel pushing us outwards when the vehicle we are in takes a turn. This force then balances the attraction that the electrons fell towards the centre.

The trouble with this model of the atom was that electrons moving in a circle are continuously changing their direction of motion and should radiate energy, just like an antenna. The electron should then slow down and finally crash into the centre. A ready way out was to say that in special orbits, which had energies that explained the spectrum of light emitted by atoms, the electron is exempt from the need to radiate. The explanation saved the model, but was not really satisfactory.

The quantum theory

The Quantum Theory, a new way of looking at the atomic scale, is able to explain the atom without a seemingly artificial condition. In this view of nature, the electron is not seen as a point particle circular motion, like a planet, but as a wave, which is present at once all around the nucleus. It is something like a stretched wire vibrating.


2 modes of a vibrating string

.
A vibrating string describes a wave, in a loop that is not at any one point on the string, but is all along its length. And when the string is plucked harder, it could vibrate in 2 loops, again not at any one point, but in two loops, at twice the frequency.

In the same way, the electron is seen as a wave distributed around the nucleus. As the energy of the electron increases, it falls into successive waveforms that are in 2,3, 4, etc loops. Such a picture by itself introduces a need for the electron to exist only in fixed and discrete energy levels, which correspond to these steps in the waveform. And at these steps, the charged particle is not in fact in motion in a circle, like a planet, but is more like a charged disk that is rotating, with its charge distributed all over. In such a case, which is symmetrical, even classical physics does not require that the charge should radiate.

Emission from atoms

But when, for some reason, an electron in a higher energy level needs to come down to a lower level, then, for an instant, the first waveform is breaking and the second is forming. At this instant, the frequency of the lower energy level interferes with the higher level and the 2 frequencies interfere, like waves at the seaside. The effect is that the 2 waves ‘add up’ when they are ‘in step’ and ‘cancel’ when they are ‘out of step’. This leads to a non-uniform charge distribution looping around and this acts like an antenna. Energy then gets emitted at the frequency difference of the 2 energy levels, while the electron drops to the lower level.