March 2015


# Transit

The Newsletter of Cleveland And Darlington Astronomical Soiety

The Running Man & the Orion Nebula

Next Meeting:

**Friday 10th April**
**7:15pm**
At Wynyard Planetarium
**“One small step”**
**A celebration of Apollo**
Presented by
Neil Haggath

## Contents

## Editorial

Welcome to the March issue of Transit.

In this issue we have the 2nd part of Ray Browns piece on the small particles of nature, along with another interesting piece by Ray Worthy on clocks.

I have also included a small piece on the Constellation Orion in an attempt to include content for those members who are new to the world of astronomy. If there are other types of content you would like to see, or if you would like to contribute content, (be it articles, letters, comments, pictures, etc) please get in touch.

Regards
Jon Mathieson
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## Meeting Calendar (2014-2015)

All meetings are held at the Wynyard Planetarium (with the exception of the AGM).
Doors open at 19:15 for a 19:30 start

10th April 2015 — **One Small Step**
**(A Celebration of Apollo)**
Neil Haggath, FRAS, CaDAS

8th May 2015 — Title to be confirmed
Paul Money FRAS, FBIS

12th June 2015 — **CaDAS Annual General Meeting and Social Evening**
venue to be confirmed

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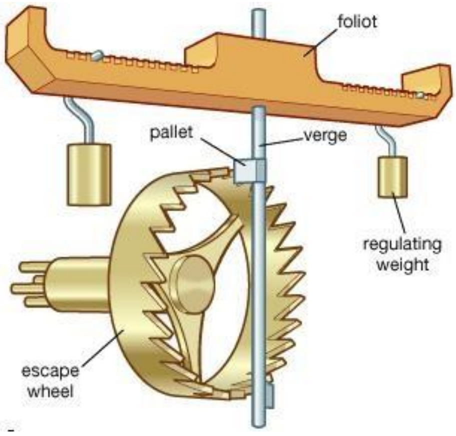
## "Tick Tock."

by Ray Worthy.

"Tick Tock, Tick Tock." What does that sound mean to you?

To me and all the "Old Fogies" like me, It means the old long case "Grandfather's clock" down the hall, with its slow measured pendulum swinging backwards and forwards, telling the world that time was slipping by. And yet, when that sound was heard for the first time in this land, there were no pendulums to be seen.

What was heard, of course, was he sound of the escapement claws slotting into the teeth of a geared wheel. The place where that sound was first heard was inside the clock tower of a church. I never realised however, that for more than a hundred years before the pendulum escapement was invented in the 1650 s, the clock's regulation was undertaken by what was called "The Verge escapement".




*The Verge Escapement*

Imagine a vertical shaft rotating on its bearings, and at the top was a heavy horizontal bar. The designer intended that the inertia of this heavy bar would impart steadiness to the rotation. (I wonder if one of these designers used a top bar with a slide to allow the length to be adjusted ? Just a thought.)

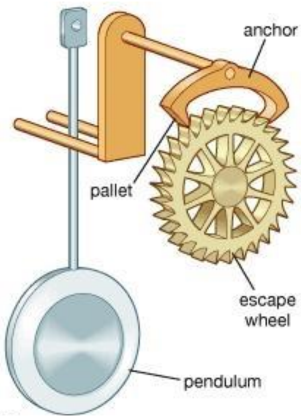
Centred upon the shaft was a horizontal wheel upon which were some blades which impinged upon the teeth of a vertically held crown wheel. The crown wheel was therefore allowed to rotate with measured speed. It was this mechanism which caused the "Tick Tock" sound.

Church records at the time of the first Queen Elizabeth, that is in the sixteenth century, show the financial burden of the installation and the constant bills for the clocks' upkeep.

Before that, folks had their sundials and hour glasses. Accuracy was not available and certainly not expected. What advancement occurred during the following hundred years is indicated by the fact that in the sixteen seventies , the astronomers, Cassini, Römer and Picard were accurately timing the transits and occultations of the moon Io as it circled around Jupiter. We know this in great detail, because it led to the establishment of the difference in longitudes between Paris and Copenhagen and, later to the first measurement of the finite speed of light by Ole Römer.

What had happened of course was the invention, by the Dutchman Christiaan Huygens of the pendulum clock. There was no better timekeeper until the twentieth century. Huygens, of course harnessed the discovery of the pendulum's accurate periodicity by Galileo.

It may have occurred to you astronomers who are wide awake, (and that, of course includes you), to wonder what was is it that these new fangled clocks were actually measuring? Astronomers and mathematicians had to establish a standard unit of time, and this was the second division by sixty parts of an hour. It was decided that the standard second was to be 1/86,400 parts of a mean solar day. This is easy to state, but, if you think a little about that statement it shows with what confidence those mathematical astronomers went about their business. Why they did not choose one sidereal day and be done with it I do not know.




*The Pendulum Escapement*

They had to measure that with some sort of transit apparatus anyway.

As time went on, better clocks and more accurate observations with transit telescopes led to the discovery that the rotation of the Earth was not as steady as had been supposed and other standards had to be adopted. I shall return to this matter later.

**The Quartz Revolution.**

In the 1970 s, there was a period when I was coaching a friend who owned a three masted schooner, berthed in Hartlepool. I was attempting to school him in stellar navigation. It was difficult, because rarely did we see a clear sky over the North Sea. However, and more to the point, my friend owned a chronometer, a proper one, revered by all who went to sea. It was very precious. We constantly checked its accuracy against the radio. It was the most accurate time piece I had ever used. We treasured it.

Then one day, I was at a filling station in Hartlepool where I saw an advert for a cheap battery powered kitchen clock. It was offered at less than five pounds if one bought a certain amount of petrol. To cut a long story short, I checked this clock against the radio timer and found this ridiculously cheap clock was as accurate as the expensive chronometer. I was absolutely astonished. A friend who worked in the Greenwich Maritime Museum and who was allowed to dismantle the Harrison chronometers explained that I had allowed the "Quartz Revolution" to pass me by unnoticed. He even told me that in the United States at that time you could find amazing time keepers given away in packets of breakfast cereals.

*Quartz Clock Movement*

This was my personal introduction to the age of the quartz crystal clock. Once I began making my enquiries, I found that the "Quartz Revolution" had long been anticipated. The story started as long ago as 1880 with the work of two men, Pieerre and Jaques Curie in Paris. It was Pierre who later married a lady called Marie Sklodovska. (You do not recognise the name?) As Marie Curie, she became the first woman to be awarded a scientific Nobel Prize and is the most famous female scientist ever. (Altogether, the Curie family amassed five Nobel prizes between them.)

Before he met Marie, Pierre, together with his older brother Jaques discovered that when pressure was applied to certain crystals, they responded by generating an electric current. They also found that the reverse was true, insofar that when an electric charge was applied to the crystal it became distorted, enlarging by about one percent of its original size before reverting to normal. These were given the name of "Piezoelectric" crystals. Further experiments showed that this alternation of size always occurred at an exceedingly regular frequency. The reverse was also true, in so far as if the crystal was placed in an electric circuit, the frequency of the current was regulated.

*"The regular alteration in the size of the crystal was a source of ultrasonic pulses which could be harnessed."*

The focus of many scientists of the period was on the newly discovered marvels of radio. It was found that these crystals could be cut to size or even changed in shape to give required frequencies of electrical output. As late as the 1950 s, I was using crystal calibrated radio circuits whilst doing my National Service in the Army.

Unfortunately for the normal radio user, these quartz crystals were very expensive. The best quartz crystals came from Brazil and even as late as the Second World War they were an expensive and important cargo.. This was why the quartz crystal watch was a millionaire's plaything.

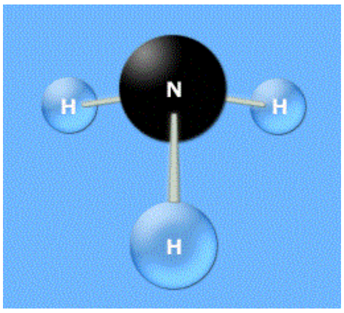
What changed and altered the face of the clock industry was the discovery of how to make artificial quartz crystals. These crystals became so cheap that the working parts of the clocks and watches could be stamped out in their millions. The pulses are so steady that a crystal can act as a tremendously reliable escape mechanism.

However, having written all the foregoing paragraphs extolling this new method of timekeeping, it has to be recorded that all might not be absolutely perfect with the quartz crystal watch or clock. There are one or two factors which can affect the accuracy of the crystal. No two quartz crystals are exactly the same size or shape. Of course we are talking about the loss of a hundredth of a second per day, or thereabouts. It has to be stated that , it is quite possible that certain cheap watches may be lucky in that they possess a crystal of great accuracy and it has been recorded that , in tests some bargain watches, even a fifteen dollar copy of a “Rolex” have been recorded as losing a thousandth of a second per day.

What is interesting is that the manufacturers of these clocks and watches often deliberately add the old “Tick Tock” sound, which is entirely unnecessary and plays no part in the time keeping.

**The Ammonium Clock and Beyond**

We move now into the realm of the molecule and, in particular, the ammonium molecule.



*Ammonium Molecule*

I want you to consider how the ammonium molecule is set up. It consists of four atoms, three hydrogens and one nitrogen, joined together by covalent bonds. The three hydrogens are arranged in the form of a triangle. The nitrogen atom is fastened to one side of the centre of the triangle. Now consider this arrangement and visualise it. The nitrogen might just as well be attached to the other side of the hydrogen triangle, because this arrangement fulfils all the necessary bond requirements. Well, in actuality, that nitrogen atom seems not to know just which side it should be and it flashes back and forth between its two positions. Furthermore, it performs this transition at a rate of 23,870 times each second. I am glad I was not the person who had to count them.

The ammonium gas is held in a tiny chamber and a MASER gun is used to excite the molecules. The plan is that the outgoing current issues forth at this carefully regulated frequency, which, in turn, drives the tiny motor.

At least that was the plan. In practice the time keeping result was, in the main, no better than that of the quartz clock. I think that the importance of this invention was that this method of finding a regulator in the world of the atom showed its practicality.

This line of research came of age in 2004 when much higher frequencies were used.

The next major step up was made possible when the LASER was used as an exciter and the regulating mechanism was found inside the atom of caesium 133. It all happens at a temperature as near as possible to absolute zero.

The electrons buzzing about the nucleus are to be found at particular and well defined energy levels. There are two of the lowest energy levels which are particularly close. You astronomers will already be aware that an electron at a low energy level can absorb energy in the form of a photon and be moved to a precisely defined higher level. The converse is true insofar as when an electron has jumped back to the lower energy level, it will release a photon of that particular frequency. In the caesium 133 atom, this transition back and forth takes place at a highly defined frequency of 9,192,631,770 Hz. and when this transition is used as a clock regulator, the accuracy of that clock is so high that it has been calculated that it loses one second in thirty million years.

Of course you do not wear this timepiece on your wrist or in your back pocket, but if you think that you would never need such accuracy in a time keeper you would be wrong. Your position finding GPS (Global Position System) relies on this level of accuracy. Not only that, but the calculations required to find your position have to take into their account the finest of adjustments dictated by Einstein's theory of relativity.

With these astonishing accuracy figures, you might have supposed that no advance could have possibly been made. Yet again, you would have been proved wrong.

Following the trend into yet higher frequencies, we now move to a device which uses frequencies which present us with visual light and further, into the ultra violet.

Experiments are continuing all over the developed world and many different elements are being looked at to supply steadier and yet steadier frequencies. I do realise that we have not yet come to a conclusion in this field, but let me tell you that a clock has been constructed using transitions in the atom of Ytterbium. The result is a clock which now either loses or gains a second once in fifteen billion years. That is the equivalent of the lifetime of the Universe.

Since 1919, scientists have been seeking ways to prove or disprove Einstein's theory in which he maintained that gravity influences time. Now we have such a perfect demonstration. Two of these Ytterbium clocks have been placed side by side, in which position they were calibrated. One of these clocks was raised by two feet and the difference in time was demonstrated.

**The Standard Second**

This topic has already been mentioned in the earliest part of this article, dealing with the period when astronomers and mathematicians needed to define a standard second. Naturally, they chose the one timekeeper that they could depend upon, namely the rotation of the Earth. However, once these atomic clocks came into play, it became evident that their timekeeping was steadier than that of our Earth.

Scientist could now measure by how much the tidal reaction slows down the rotation.  It is a mistake to think that “Tides” are only to do with the motion of the seas. When the tunnels were being dug out for CERN near Geneva, pin point surveying was being carried out with the aid of laser beams. These of course were sensitive to the phases of light waves.

A slow, rhythmical oscillation was observed in certain east west measurements and they could not be accounted for until one bright spark,( They were ALL bright sparks ) who kept a sailing boat near Bordeaux, realised that these changes coincided with the tide charts of the Bay of Biscay. It became apparent that the lunar tides affected all the rocks of the Earth as well as the seas.

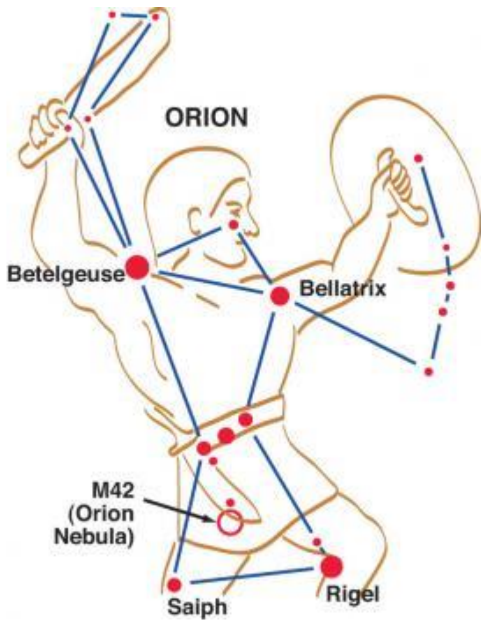
I mention the above because the tides have a slowing down effect on the Earth's rotation. They act as a braking system. This, of course remained just a theory until the advent of these modern atomic clocks. Now that these marvellous clocks can measure it, we know that the Earth's day is slower by 1.7 milliseconds than it was a hundred years ago.

There is yet more refinement, and this concerns the subduction of the oceanic plates as they slide beneath the continental plates.

It can be explained as follows. A figure skater, spinning on the ice can rotate faster by bringing the arms closer to the body. If we carry on with this analogy and look at the movement of the Earth's tectonic plates. There are many places where the rocks under the sea basins are pushing against the adjacent continent. The lighter rocks of the continental shelf are pushed up and the heavier rocks of the sea basin slide down further into the Earth. Of course,this does not happen smoothly and it is the sudden release of the strain which causes earthquakes. When this happens, many cubic kilometres of heavy rock suddenly move closer to the Earth's centre of gravity. It is this movement which can be recorded by these modern clocks and they record the Earth's rotation speeding up by one millionth of a second per day.

It is obvious now that the rotation of the Earth can no longer be used as a measure of the second. Whatever was used had to be more reliable. One absolute standard offered was the distance light could travel through a vacuum, but imagine if you were a scientist having to work with that standard. I'll bet that you would choose a measurement on a clock digital display.

## Beginners Bits - The Orion Constellation




The constellation of Orion is probably one of the easiest of the constellations to find in the night sky.

It is also known as the hunter (representing the mythical hunter Orion)

There are a number of myths, from several different cultures associated with Orion, so we will mention just a few of them here.

In Greek Mythology Orion was the son of the sea god Poseidon and Euryale (the daughter of king Minos of Crete).

In one myth Orion proclaimed himself to be the greatest hunter in the world, much to the dismay of Hera, the wife of Zeus. She killed him with a scorpion and Zeus placed him in the sky.

In another Orion was blinded for raping Merope, granddaughter of the god Dionysis, and now spends all his time travelling east to seek the suns rays to restore his sight.


In a third he fell in love with the daughters of Atlas and Pleione, the seven sisters (or the Pleiades). He started to pursue them, but Zeus scooped them up and placed them in the sky, where he chases them still.

Orions belt is made up of the stars Alnilam, Mintaka and Alnitak. His left shoulder is Betelgeuse (The 2nd brightest star in Orion) and his right shoulder is Bellatrix. His knees are marked by the stars Rigel (right knee) and Saiph (left knee) and his head is the star Meissa.

Just below Orions belt you will find what is probably one of the most studied objects in the night sky, the Orion Nebula (M42). It is easily seen through a pair of binoculars or small telescope and is certainly worth looking for. (See cover page for an image)

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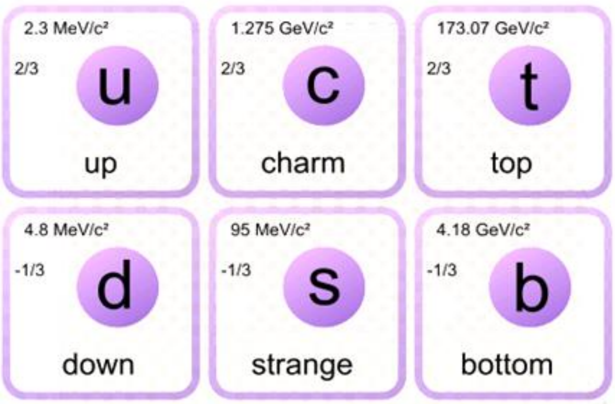
# The Small Particles of Nature (Part 2)

by Ray Brown

## Quarks and Hadrons

In 1964 Murray Gel-Mann and George Zweig proposed that mesons and *baryons* (the collective term for protons and neutrons as well as for the exotic delta, lambda, sigma, omega and xi baryons) together with their antiparticles are all composed of smaller units which they named *quarks*. Together mesons and baryons are known as *hadrons*. Quarks are a theoretical concept so individual quarks cannot exist but they are fundamental to the so-called "Standard Model" of particle physics which recognises 6 types (referred to as *flavours*) of quark. For each flavour of quark there is an anti-quark, making a total of twelve.

Baryons are made up from three quarks. Stable baryons consist of first generation quarks. For example a proton is composed of two up quarks and one down quark and so is described as uud. Its net charge is obtained by addition: ⅔ + ⅔ + (-⅓) = 1. A neutron has one up and two down quarks and is electrically neutral because ⅔ + (-⅓) + (-⅓) = 0. The second and third generations of quark crop up only in the highly unstable types of baryon.




*3 Generations (6 flavours) of quark showing respectively the values of their mass and electric charge*
*The corresponding anti-quarks have the opposite charges*

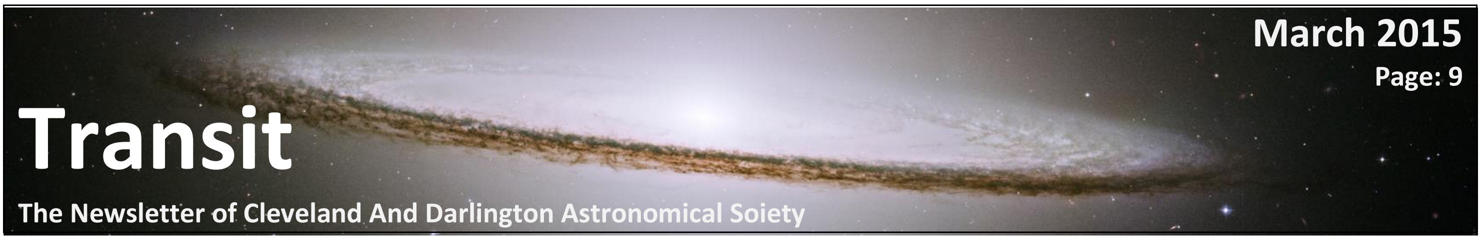
Every meson consists of one quark and one anti-quark and so is unstable. There are three pi-mesons $\pi^+$, $\pi^-$ and $\pi^0$ built from up and down flavours and there are three K-mesons: $K^+$, $K^-$ and $K^0$.which contain one strange flavour combined with either an up or a down flavour. The kaon ($K^-$), a meson consisting of a strange quark and an up anti-quark (sū), lives much longer than most mesons, which is why its quark (s) was called "strange". The phi, eta, chi, rho, omega ω, upsilon Υ, B- and D-particles are also mesons in which the heavier quarks and anti-quarks are components. http://en.wikipedia.org/wiki/List_of_particles .

> *Great fleas have little fleas upon their backs to bite 'em*
> *And little fleas have lesser fleas and so ad infinitum*
> From "A Budget of Paradoxes" by Augustus De Morgan

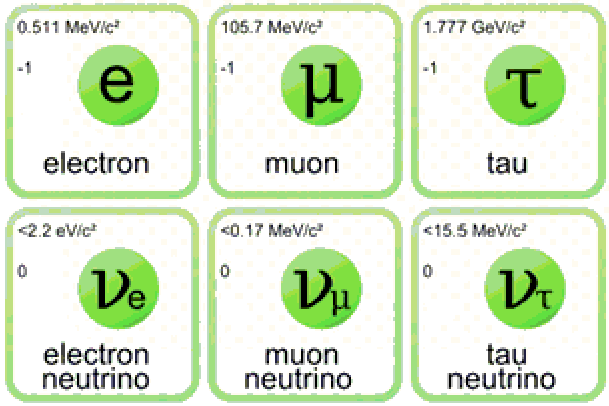
So the up and down quarks are regarded as primary units which make up the protons and neutrons which make up the nuclei of the atoms which make up the molecules which make up the substances with which we are all familiar. In the natural world the strange quark appears to feature only in the transitory kaon of cosmic rays. The charm, top and bottom quarks were initially concepts of the theoreticians and have provided evidence of their existence in particles briefly formed during experiments using particle accelerators.

## Leptons

Although hadrons are numerous they are only part of the *dramatis personae* of physics. Another main group of particles are the *leptons* which include the familiar electron, the muon which we met only briefly in cosmic rays and the tau particle which was discovered in collisions between high-energy electrons and positrons during the 1970s. The *tau* particle is unique amongst leptons in having sufficient mass to yield hadrons (actually pions) amongst its decay products; so a particle without quarks can actually form particles containing quarks!




Of the six leptons, only three have electrical charge. All are solitary particles i.e. do not form composites. They appear to be point-like particles without internal structure. The other leptons are the three types of *neutrino*($\nu$), one for each charged lepton. They have no electrical charge, very little mass, and they are almost impossible to find. Electrons and all three kinds of neutrino are stable and therefore are the four types of lepton which are around us. The muon and the tau are not found in ordinary matter at all. This is because when they are produced they very quickly decay, or transform, usually into lighter leptons.




*The family of 3 generations of leptons showing respectively the values of their mass and charge.*
*The corresponding anti-leptons have the opposite charges.*

Neutrinos have no charge so they almost never interact with any other particles. Most neutrinos pass right through the Earth without ever interacting with a single atom of it. They are produced in a variety of interactions, especially in particle decays. In fact, it was through a careful study of radioactive decays that physicists first hypothesized the neutrino's existence. In a radioactive nucleus, a neutron at rest (zero momentum) decays, releasing a proton and an electron. The law of conservation of momentum requires that the resulting products of the decay must have a net momentum of zero, but the observed proton and electron do not, so we need to infer the presence of another particle with appropriate momentum to balance the event. It was hypothesized that an antineutrino is released; further experiments have confirmed that this is indeed what happens. Because neutrinos are thought to have been produced in great abundance in the early universe and rarely interact with matter, there should be a lot of them still in the Universe. Their tiny masses but huge numbers might contribute to the total mass of the universe and affect its expansion.

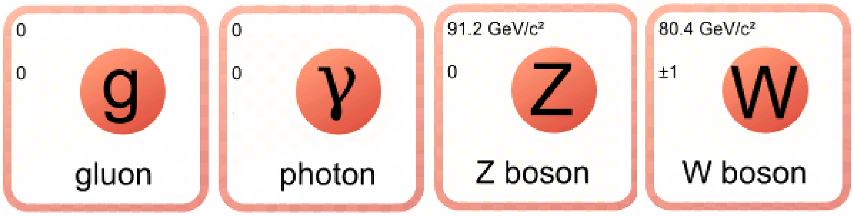
### Forces between particles

Inter-particle interactions include attractive and repulsive forces, decays and annihilations.

There are four fundamental interactions between particles, and all forces in the universe can be attributed to these four interactions: **gravity, electromagnetic, strong force** and **weak force**. Strictly speaking, a force is the effect on a particle due to the presence of other particles. The terms "force" and "interaction" are often used interchangeably, although "interaction" is more correct. For instance, we call the particles which carry the interactions “force carrier particles”. A force is something which is passed between two particles. A particular force carrier particle can only be absorbed or produced by a matter particle which is affected by that particular force. For instance, electrons and protons have electric charge, so they can produce and absorb the electromagnetic force carrier, the photon. Neutrinos, on the other hand, have no electric charge, so they cannot absorb or produce photons.

The **electromagnetic force** causes any two things carrying the same sign of charge to repel one another and any oppositely-charged things to attract. Many familiar forces, such as friction, and even magnetism, are caused by the electromagnetic, or E-M, force. For instance, the force that keeps you from falling through the floor is the electromagnetic force which causes the atoms making up the matter in your feet and in the floor to resist being displaced. The carrier particle of the electromagnetic force is the photon ($\gamma$). Photons of different energies span the electromagnetic spectrum of x-rays, visible light, radio waves, and so forth. Photons have zero rest mass, as far as is known, but they do have momentum and so participate in scattering phenomena. The electrostatic deflection of electrons by one another occurs through the exchange of virtual photons between them, causing recoil (quantum electrodynamics).

The force which holds together the quarks within a hadron is known as the **strong interaction**. It also has the effect (the **residual strong force**) which holds together the nucleons within a nucleus. This latter force needs to be strong to overcome the electromagnetic repulsion between protons which obeys the inverse square law. The residual force is powerfully attractive between hadrons at distances of about 1 x $10^{-15}$ metres (1fm) between their centres, but rapidly fades to insignificance beyond about 2.5 fm. At very short distances less than 0.7 fm, it becomes strongly repulsive, and so determines the physical size of nuclei, since the hadrons can bunch together no closer than the force permits. The force carrier for the strong force is the *gluon*. More detailed consideration of the strong force involves the concepts of "colour charge" and "colour force" and the associated rules of interactions between quarks (the subject of quantum chromodynamics) and would be likely completely to turn off anyone who has persevered thus far with this article!



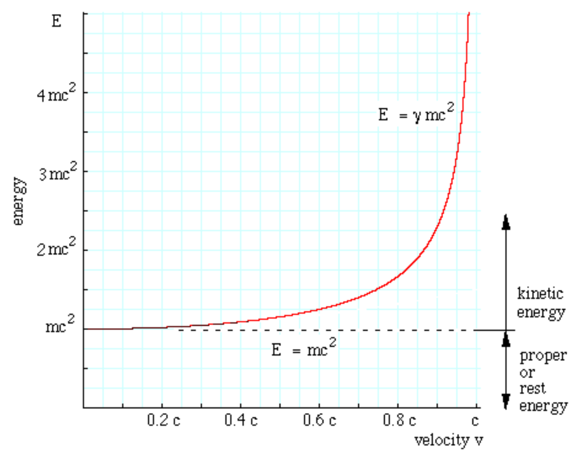
*The gauge bosons (force carrier particles) showing the values of their mass and charge.*

**Weak interactions** affect all fundamental particles and are the only processes in which a quark can change to a quark of different flavour, or a lepton to another lepton, so they cause the transmutation p → n and the change of a muon to an electron. When fundamental particles decay, we observe the particle vanishing and being replaced by two or more different particles. Although the total of mass and energy is conserved, some of the original particle's mass is converted into kinetic energy so the resulting particles always have less mass than the original particle. The carrier particles of the weak interactions are the $W^+$, $W^-$, and the Z *bosons*. The W bosons are electrically charged and the Z boson is neutral.

The Standard Model has united electromagnetic interactions and weak interactions into one unified interaction called **electroweak** which acts on both quarks and leptons. At very short distances (about $10^{-18}$ metres) the strength of the weak interaction is comparable to that of the electromagnetic. On the other hand, at thirty times that distance ($3x10^{-17}$ m) the strength of the weak interaction is merely $^1/_{10,000}$ that of the electromagnetic interaction. At separations typical for quarks in a proton or neutron ($10^{-15}$ m) the weak force is even less significant. The difference between their observed strengths is due to the considerable masses of W and Z particles contrasting with the photon, which has no rest mass as far as we know. Glashow, Salem and Weinberg predicted that the weak and electromagnetic forces can be described by a single set of equations from quantum electrodynamics (verified experimentally at CERN in 1983).

### High Energy Physics

The only stable sub-molecular particles of matter which can exist in isolation are atoms, ions (charged atoms), protons (and anti-protons), electrons (and positrons), photons and neutrinos. All other known particles are short-lived species formed in collisions between particles where at least one possesses extremely high energy. The high energy particles are either cosmic rays which interact with the atmosphere or are charged species such as electrons or ions which have been accelerated by electric fields to reach velocities comparable with the speed of light.



These conditions permit the creation of mass from energy: the opposite of the processes occurring in a nuclear bomb or power plant. In principle there is no limit to the amounts of energy (and therefore mass) involved. When a particle with rest mass $m$ is accelerated to a velocity $v$ then its relativistic mass is $m/\sqrt{(1 - v^2/c^2)}$ according to the Lorentz transformation

so its energy $E = mc^2/\sqrt{(1 - v^2/c^2)} = \gamma mc^2$

If this energy is converted into the mass of a particle at rest then its mass $M$ will be given by

$$M = m/\sqrt{(1 - v^2/c^2)} = \gamma m$$

As the value of $v$ approaches $c$ then $M$ tends to infinity.

However all collisions must obey the law of Conservation of Momentum so the question arises: in order to create the most massive new particles we need to minimise the speeds of the products of a high velocity collision. The solution is to arrange head-on collisions between particles of equal mass travelling at equal speeds in opposite directions. The Large Hadron Collider is the largest ring collider to have been built and so is able to accelerate ions to the highest energies so far achieved. The collisions take place between two protons or between a proton and an antiproton. An excellent account of all aspects of the Large Hadron Collider is available on line.

http://cds.cern.ch/record/1092437/files/CERN-Brochure-2008-001-Eng.pdf


In 2013 a Higgs Boson, one of the heaviest of the primary particles was detected in the LHC from collisions between protons moving within 0.0001% of $c$.

I am left wondering what particles more massive than the Higgs might yet be discovered.

> *And the great fleas themselves, in turn, have greater fleas to go on;*
> *While these again have greater still, and greater still, and so on.*
> From "A Budget of Paradoxes" by Augustus De Morgan

**Where Next?**

There are on-going searches for structure to leptons and quarks – can they be shown to have non-zero size? Also can fourth generations of quarks and leptons exist? Can the force-carrying particles have generations? Are there extra dimensions of space? Super-symmetry theory is a broadening of the Standard Model which hypothesises that each fermion has an undiscovered partner boson and *vice versa*. It also suggests that there are at least 5 different types of Higgs Boson.

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## The Quiz

This month all of the answer begin with the letters Y or Z.
As usual, they are in roughly increasing order of difficulty.

1. The observatory which houses the world's biggest refractor.

2. A faint conical glow, seen before sunrise and after sunset, due to sunlight scattered by dust in the Ecliptic plane.

3. The only astronaut who both landed on the Moon and commanded a space shuttle mission.

4. The maximum theoretical frequency of meteors of a shower, if observed in perfect conditions.

5. The pilot of the first manned spacecraft to be launched by a nation other than the USA and the USSR/Russia.

6. A Swiss astrophysicist, who spent most of his life in the USA, and who predicted the existence of both neutron stars and black holes.

7. The first unmanned space probe to fly around the Moon and return to Earth.

8. An observatory in Russia, which in 1976 overtook Palomar in having the world's biggest optical telescope.

9. The (not so) common name of Alpha Librae.

10. A phenomenon, concerned with the absorption and reradiation of heat by a rotating body, which gradually alters the orbits of small asteroids.

## Answers to Last Months Quiz

1. The Wild Duck Cluster.
2. Ed White, on Gemini 4 in 1965.
3. Thomas Wright – after whom our quiz trophy is named!
4. Fred Whipple (1906-2004).
5. Wolf-Rayet stars (spectral class W).
6. Rev. T. W. Webb (1806-8 ).
7. Williams Bay, Wisconsin.
8. Comet Wild 2. NASA's Stardust space probe, launched in 1999, flew through its coma in 2004, and collected material which stuck to its "aerogel" panels, which were returned to Earth in a re-entry capsule in 2006.
9. Wrinkle ridges.
10. Wolf 359.
11. Xylophone.