The Forces Of Nature

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Introduction

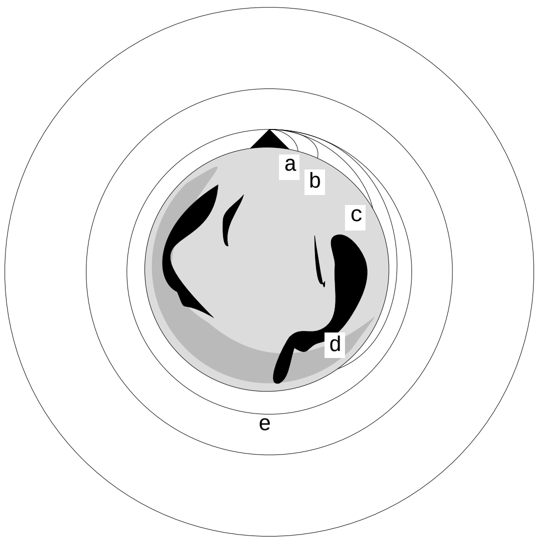
Imagine the dawn of a cold winters day, with the landscape covered in a crisp white blanket from the first snowfalls of winter. A robin darts from tree to tree, looking for breakfast. A spider hangs in mid air, about to begin weaving it's web. Wherever you look, the fruits of Nature's handiwork are on display, but how did Nature build this scene? What are the tools which have formed our world over the years, and are still at work now? Well, in our winter scene, an unseen hand is at work, pulling on each bird and each flake of snow. While the robin can resist this pull, by beating it's wings and pushing itself skywards, the snow is helpless against it, drawn slowly to the ground. Of course, it's the force of gravity pulling the snowflakes to the ground (not to mention keeping us on the surface and making sure our atmosphere doesn't float away!), but some other forces are at work here too, allowing gravity to be beaten, allowing the robin to fly. These forces are the tools of Nature, pushing and pulling the things around us into shape or into place. Over the centuries, science has examined the world around us and has attempted to identify the forces and discovered the laws that these forces obey (or at least reached some conclusions about them). Our current understanding is that there are four different forces which explain the natural phenomenon around us, and in this essay I intend to give some insight into each of them. I have already mentioned one of these fundamental forces, the force of gravity, and this is where I'll begin.

Of Apples And Planets

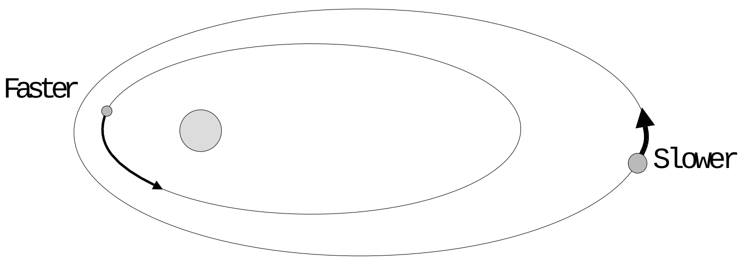
The laws of gravity are good example of the way in which one set of laws can unify many physical phenomenon. They are responsible for effects as diverse as falling apples and orbiting planets. The currently accepted laws are much the same as they were when published by Isaac Newton in his *Principia* in 1687 (with the exception of a more recent correction made by Einstein).

In the Newtonian system, the main idea is that any two pieces of matter (whether stars like our sun, planets like Earth or apples like Granny Smiths, ie any two physical bodies), attract each other. That is, they exert a force on each other, pulling them together, without any physical connection. This idea of action at a distance, where objects affect each other without touching, may seem a little strange, but it is a characteristic that all the fundamental forces share. Straight away this attraction explains why apples fall, the Earth exerts a force on the apple, and that force pulls it to the ground. The downward pull an apple feels is what we call the weight when we hold an apple (ie we stop it falling to the ground). This idea of attraction of matter is also the reason why the Earth orbits the sun. Newton came up with an excellent explanation of how this comes about, which I'll reproduce here.

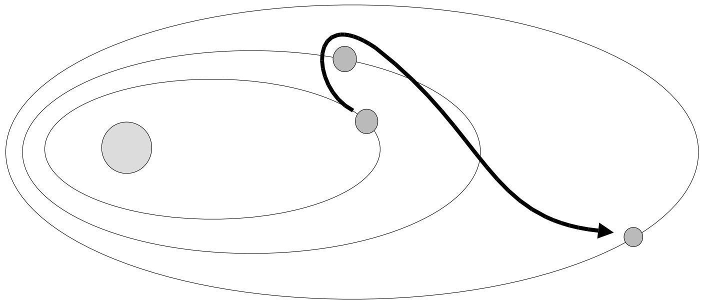
In Newton's thought experiment, artillery shells are fired horizontally from a high mountain. Ignoring air resistance, the shell will land farther and farther out as the speed with which the shell is fired increases (points a and b). Eventually, the curvature of the Earth becomes significant, and the surface begins to fall away from beneath the shell (points c and d). At last, for a high enough speed, the Earth's surface falls away from the the shell as the shell curves over the Earth, and this is a circular orbit.



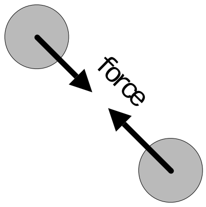
If the shell is fired in any direction other than horizontally, or falls into orbit from outer space, an elliptical orbit can be produced, like those which the planets in our solar system orbit the sun. In these orbits, the central body (like our sun) is not in the centre of the ellipse, but to one side. Re-balancing this lopsidedness, the orbiting body moves at different speeds depending on how close it is to the central body. On the near side, the body moves faster than on the far side (see figure). The movement of most heavenly bodies works in the same way, producing predictable elliptical orbits.



This predictability has become very important to space exploration. For example, when attempting to explore the outer reaches of our solar system, there are vast distances to cover in between the interesting bits (like the planets and their moons). Any space vehicle designed to cross these distances would have to be capable of moving very fast, otherwise it could take decades to reach it's destination. The process of getting up to speed using on board propulsion (like rocket engines) would require large and impractical amounts of fuel to be kept on board. A different way of building up this speed was required and this came in the form of the gravitational slingshot. In this technique the vehicle flies close to a nearby planet, allowing itself to be pulled in by the planets gravity. As the vehicle falls towards the planet, it picks up speed, and this speed is just enough to allow it to avoid hitting the planet and slingshot past it. The speed it gains during this carries it to it's destination (see figure).



Obviously, in such an endeavour the timing it critical. A small error in calculations could easily cause the vehicle to fly wide of it's destination. This requires any laws of gravity to be both accurate and flexible. To achieve this the laws have been built to explain the simplest possible case, so that any more complex situation is just so many of these simple cases put together. This elementary case considers two objects alone in space, and gives the size of the gravitational force attempting to pull them together (see figure).

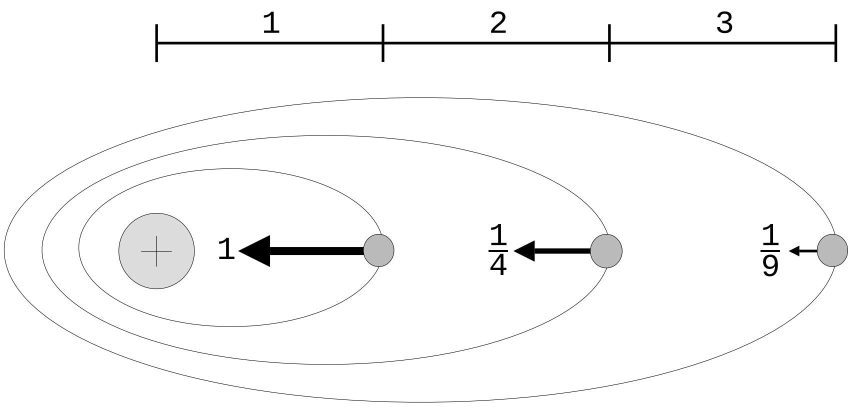


Note that a force is exerted on both bodies. This means that in the case of the falling apple, as the Earth pulls on it, the apple exerts an equal force on the Earth. However, Earth is so heavy that a much larger force is needed to get it moving noticeably, whereas the apple is so light it moves quickly under a relatively small force. Taking account of both forces becomes very important when analysing and predicting the behaviour of something like the solar system.

So far we have said that any two pieces of matter attract each other, but this statement is too simple to be of any use because the actual amount of matter present must at least partly define how strongly the objects are attracted. We know this because if not, an apple would feel the same pull due to the Earth's gravity as a brick, but we know a brick weighs more than an apple, and the pull due to the Earth's gravity *is* the weight. Mathematically speaking, the attractive force is proportional to the amount of matter present. This just means that twice the amount of matter feels twice the force, ie that two apples weigh twice as much as one apple.

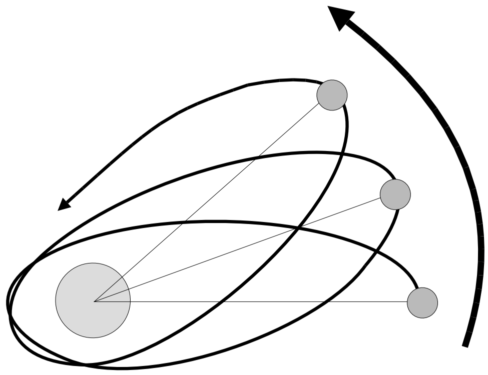
So far so good, but the amount of matter involved cannot be the only factor. One of the properties of action at a distance phenomenon such as gravity is that the force weakens as the distance between the objects is increased. For example, the outer planets of our solar system feel a much weaker attraction due to the sun's gravity than the closer ones. This means that the outer planets tend to take a lot longer to orbit the sun than the inner ones, as they are pulled along their orbit by a much weaker force, and so a year on Pluto is so much longer than a year on Earth.

Although this tells us there is a relationship between distance and the strength of gravity, it doesn't tell us precisely what that relationship is. It cannot be a proportional relationship, as that would mean the attraction increased as the distance increased, whereas the opposite is true. In fact the connection between the force and the distance is an inverse-square relationship. This means that instead of the force being multiplied (as in the case of the amount of matter, where two apples weigh two times as much as one), the force is divided by the square of the distance (the square being the number multiplied by itself, eg 3 squared is 3 multiplied by 3, which is 9). For example, in the figure below, the first planet feels one unit of force due to gravity from the star it orbits. The second planet is twice as far away from the star as the first, and so feels one quarter the force as the first planet did (a force of 1 divided by 2×2). The third planet is three times as far away as the first and so feels one ninth of the gravitational pull (a force of 1 divided by 3×3).



Newton's picture of gravity is, for most circumstances, a very accurate tool for predicting the behaviour of bodies under a gravitational force. In fact, when irregularities were discovered in the movement of Uranus, people looked for explanations other than Newton being wrong. Two scientists in particular, Adams and Leverrier, predicted the existence of another planet beyond Uranus that was causing the discrepancies. They told astronomers where this predicted planet should be, and this was how Neptune was discovered. This greatly boosted confidence in Newton's laws of gravity.

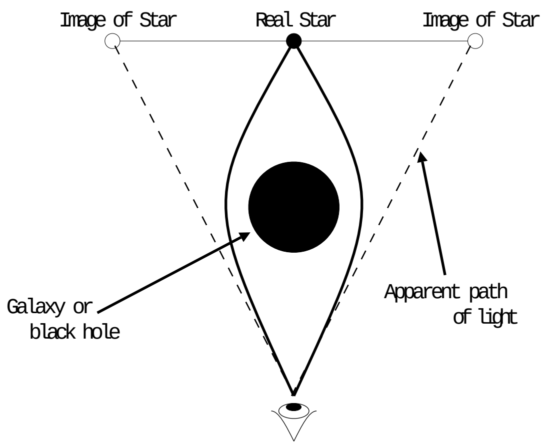
However, some things still could not be explained. In particular, the behaviour of the planet nearest to the sun, Mercury. Instead of following a steady ellipse, the planets orbit slowly progresses in a circle around the sun (see figure). Although this progression is very slight (it takes 3 million years to progress all the way around the sun), it was still enough to confound Newton's laws, and no extra planet would solve the problem.



It took until the early part of this century for someone to come up with a solution for this anomaly, and the solution changed scientific thinking forever. Einstein's theory of general relativity is too complex to discuss here in full, but some insight can be given into it's ideas. One of the concepts that arose from the theory is that the 'speed' of time changes due to the presence of a gravitational force or, more specifically, that time passes more slowly the nearer you are to a large gravitational force producing body, such as a star like our sun. The notion that a clock ticks slower on earths surface than when in orbit around the earth completely destroys the common sense notion that any particular instant occurs at the same moment in time anywhere. This helps explain the progression of Mercury's orbit, the planet "slowing" near the sun, curving in closer than expected and being pulled into an orbit to one side of it's original path.

Another product of Einstein's ideas concerned the interactions of light and gravity. Previously, light beams were thought to be immune to gravity, moving in dead straight lines untouched by the gravitational attractions of matter. Einstein proposed that light too felt the pull of gravity, and this led to some interesting discoveries. For example, if a large gravitational body, like a galaxy or a black hole moves between us and a bright distant star, a strange gravitational lensing effect can occur (see figure).

Under these circumstances, the large body bends the light from the star around it, so that we see the light coming at us from the wrong angle. This creates the illusion of a bright halo with a dark blob in the middle, where there should normally be a single bright star. Events such as this have been seen in the sky (of which this example is a simple case), and can now be explained using general relativity.



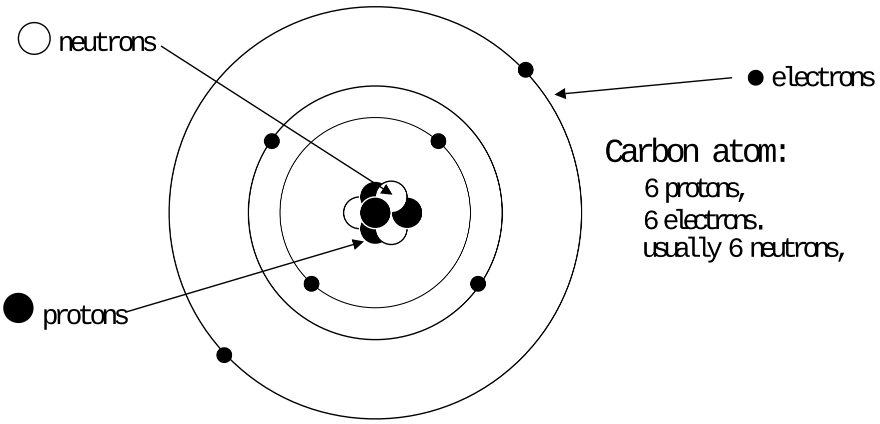
It should be noted that, under normal circumstances, general relativity breaks down to Newton's original laws of gravity and that for most problems concerning gravity, Newton's theory is plenty accurate enough.

Now gravity has been explained, how much of the shape of the world around us can be put down to the work of gravity. In our winter scene, while the fall of the snow and the earthward pull on the robin are consequences of gravity, it gives us nothing to explain their actual form. What forces give the snowflakes their symmetrical shape, and how does the robin resist the pull of gravity. Perhaps the most striking example is that of the spider hanging in it's web. Below it, the 6 million million billion tonnes of the Earth are doing their best to pull the spider to the ground by gravity, yet a few incredibly thin strands of silk are easily enough to hold the spider wherever it desires. The chemical forces that made the strands are plenty strong enough to withstand a little gravity, and the interactions behind the chemical forces are our next port of call.

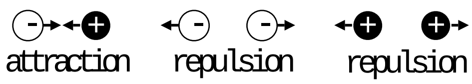
<u>Atoms, Structure and Chemistry</u>

To begin to work out what's happening on the chemical and structural level of matter, it is necessary to look at the building block of matter, the atom.

The general structure of the atom can be likened to the solar system. The central body, called the nucleus, is made up of two different particles, protons and neutrons. Orbiting the nucleus at various levels are electrons, another kind of particle which is much lighter (and therefore quicker) than protons or neutrons (see figure). The diagram is not to scale, as in fact the distance between the nucleus and the electrons is many times larger than the size of the nucleus. To get an idea of the scale, if the nucleus is likened to an egg in the middle of Wembley stadium, the crowd are about where the electrons would be.



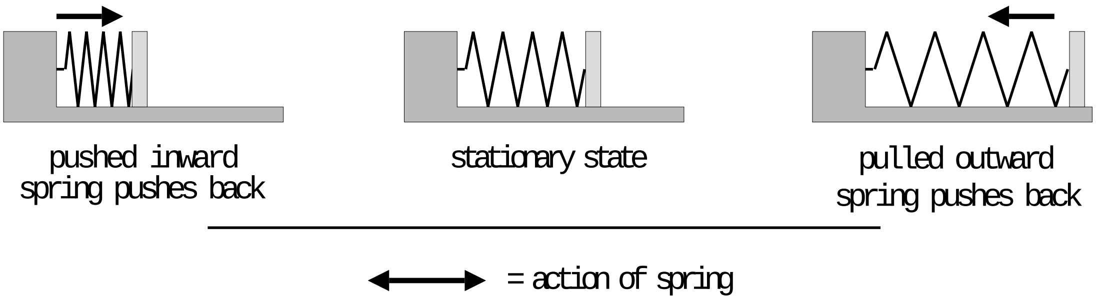
Just as the planets need the force of gravity to keep them in their orbits, the electrons have a force acting on them to keep them in orbit. This force, which has to be much stronger than gravity, is the electromagnetic force. In the case of gravity, the amount of matter was the factor that defined the strength of the force, but in this case the electrical charge of the particle defines the force. The term 'electromagnetic' arose from the fact that this one force explains all electrical and magnetic phenomenon (eg an electrically charged object creates a magnetic field when it's moving, the effects are closely interlinked). Charge differs from mass in another important respect. In the case of mass, there is only ever attraction, but with charge, there is both attraction and repulsion. Charge occurs in two kinds, positive and negative, and like charges repel while opposite charges attract (see figure).



In the atom, the proton has a charge of +1, the electron has a charge of -1 and the neutron has zero charge (neutral).

The interactions of the orbiting electrons mean that for any particular atom, there are certain numbers of electrons that make the atom more stable than others. This means that atoms will give, take or share electrons in order to make themselves more stable. This is the underlying process in any chemical reaction. When atoms give, take or share electrons, a strong bond is formed between them, for example, carbon can form long chains of atoms, the secret to forming DNA. Any collection of atoms linked in this way are molecules, although the long chain are called polymers. Also, when give and take is involved, the particles concerned become either positively or negatively charged ions.

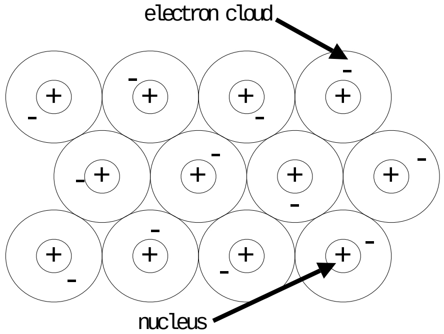
In electromagnetic interactions, and in common with gravitational forces, the distance holds an inverse-square relation to the force. So, the closer two opposite charges get together, the greater the attraction grows. However, with like charges, the *repulsion* grows as separation decreases, making it more difficult to move them together. In the case of atoms, the number of electrons is usually equal to the number of protons, this means that the are as many negative charges as there are positive ones, so from a distance, atoms appear to have no charge. However, when two atoms interact, the way the charges are distributed inside them comes into play. As they approach each other, each atoms (negative) cloud of orbiting electrons feels attracted to the other atoms (positive) nucleus. This means that the atoms attract each other, and as they get closer together the attraction builds. However, when they get very close, the (negative) clouds of electrons start to interact and so push the atoms apart. Therefore, although two atoms cannot touch, there is a mid-point where the mutual attraction balances the mutual repulsion. When two atoms can sit happily next to each other like this, either being pushed together or being pulled apart requires a bit of work to overcome the strength of the electromagnetic forces present. The atoms are bonded together.   To illustrate the nature of such a bond, we can think of a spring (see figure). The spring will happily sit still at a certain length, in a stationary state. However, if the spring is pushed inward or outwards the spring acts against the change and pushes back towards the stationary state. In the same way, two atoms will resist being being pushed or pulled apart. The strength of the spring depends on the type of atoms involved. Molecules are also capable of interacting like this, but it usually gets more complicated.



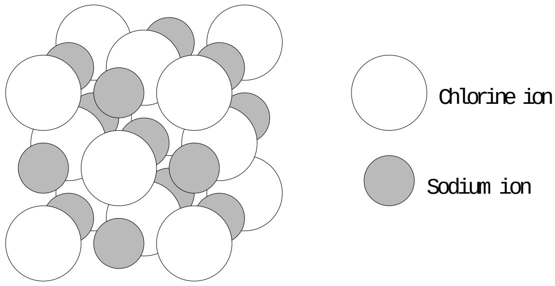
This is the principle that makes solid objects solid, millions of particles (meaning atoms or molecules in this case) interlinked and refusing to budge. Crystals are a special case of this behaviour. Whereas metals will interlink in any direction, forming a densely packed structure, crystalline particles will only join up at certain angles. This gives crystals their angular structure (eg salt, quartz etcetera). Diamonds works in a similar way, but the links are chemical bonds between carbon atoms.

(figure overleaf)

The struture of a metal



The structure of Sodium Chloride (common salt)

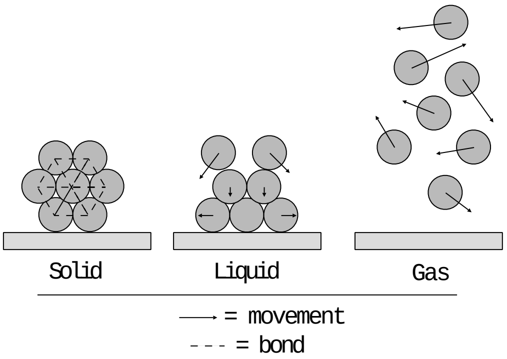


All well and good, but can electromagnetic interactions explain the other states of matter, the liquid and the gaseous? Yes, they can, but the agent used to change states needs explanation. We need to look at the nature of heat.

Although there are ways in which particles can transfer heat between each other, we need to look at how things get hot in the first place. When we receive heat from the sun, for example, it comes in the form of infra-red light rays. Infra-red, ultra-violet and the visible colours red, green and blue make up just a small slice of a larger spectrum, the electromagnetic spectrum. It's called that because it's members, called photons, are an important factor in the electromagnetic interactions. Photons are a strange kind of particle that sometimes behaves like a proper point-like particle, and sometimes like waves, as in water waves, this duality is an essays worth in itself. The electromagnetic spectrum includes radio-waves, micro-waves and gamma rays as well as the colours mentioned above, the wavelength (or frequency, as in radio wave frequency) of the photon defines it's position in the spectrum. The science that covers the interactions of photons and electrons, QED (short for Quantum ElectroDynamics), is a well understood science that covers all sorts of effects, from mirrors and lenses to the creation of positrons (positively charged electrons, lighter than protons). This science is far too large to cover here, but an excellent explanation of it's working can be found in 'QED, The strange theory of light and matter' by Richard P. Feynman.

When an infra-red heat photon hits an particle and makes it hotter, what it actually did is make it move faster. How fast a particle moves defines how hot it feels. For example, if you have box full of gas and heat it up, the pressure on the sides of the box increases as a consequence. This is because the particle of gas are moving quicker, and so are hitting the sides of the box harder and more often. So in the case of the spring link bonds in solids, the heat make the atom jiggle around on the spring, back and forth. There is a point when the spring is being made to jiggle so much that it is on the verge of giving way. This is better known as the liquid state (see figure overleaf). When the particles are like this the slightest applied force will ease the springs grip and the molecules will flow over each other, (eg spilt milk is flowing under the force of gravity). When the particles have stopped flowing, they will settle down again and be pulled back slightly into bonds with other particles. As a side point, a fracture is when enough force is applied to even break the spring bonds that are barely jiggling in a solid.

The gas state is an extension of this phenomenon. This time the particles are jiggling so much that any bonds will be broken and the particles stand virtually no chance of forming any bonds for any length of time. The spacing out of the particles is the reason why gases can be compressed while, by and large, liquids and solids cannot, although of course liquids will move as long as there's somewhere to go.



Once a collection of particles has been heated up, they can transfer the heat to other atoms by bumping into them. If a fast and a slow particle collide, you tend to end up with two pretty fast particles. This is what allows heat to spread, for example, along an iron bar heated at one end, that is the iron bar conducts the heat. Heat can also be moved around by convection, this occurs when you have a gas or a liquid which is hotter in some parts than in others. The hotter gas/liquid is less dense than the surrounding gas/liquid, and so the hot part rises and the cold part is pushed out the way and sinks.

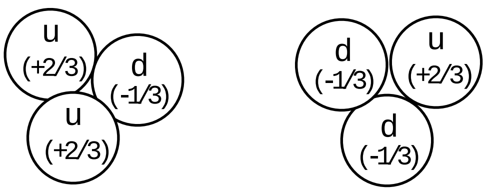
Returning to our winter scene, it seems like all the natural phenomenon are explained. Apart from what gravity covers, all chemical, structural and physical phenomenon seem accounted for. The crystalline structure of the snow is just a more complex version of the salt structure, giving it's constant hexagonal symmetry whilst allowing almost infinite variation of the details of the structure. The close electromagnetic repulsion effect is the agent of all physical interaction and collisions. For example, when we held the apple, the repulsion between the molecules of the surface of our hand and the apple stopped it from passing straight through, and the chemical and electromagnetic bonds give the hand it's form. The robin's wings are held together by the same bonds, and allow the wings to beat the air, colliding with the invisible cloud of particles which is our atmosphere and wrenching the bird into the air. And of course the spider, held up by an incredibly strong set of chains of molecules, all bonded together by the electromagnetic force.

Unfortunately, there is a fundamental problem, concerning the structure of the atom, or more precisely, of it's nucleus. We have said that protons and neutrons sit close together in the nucleus, but we have also said that, when close together, like charges repel each other very strongly. In fact, going by the two forces we have covered so far, every atom should be exploding, with the power of a nuclear bomb. It's reasonably obvious that this is not happening! There is another way of looking at this fallacy, in that the laws of QED do not work out right when applied to protons and neutrons. Either way, there is something amiss. The solution came in the form of a third force, a force able to hold these violent nuclei together, a force far stronger than any other. At least there was no trouble naming it...

The Strong Force

For many years, it was thought that protons, neutrons, electrons and photons were all fundamental particles, ie that they could not be broken down any further. The problem of the unstable nucleus, and what was going on in there to keep things together, blew this idea away. In order to investigate this, large machines were build to smash protons into nuclei, in the hope that the debris from these collisions would tell us something about the internal workings of the nuclei. These machines, called particle accelerators, work by using magnets to speed up particles. It has already been mentioned that a moving electrical charge creates a magnetic field, and the trick is that it works the other way around. If you put a charged particle into a magnetic field, it makes it move. Put them through enough magnets of enough strength, and the particles will move quick enough to smash the target nuclei to bits.

At first, they expected only protons and neutrons to come out, they were quite wrong. The existence of over 400 particles had to be accounted for by whatever theory would be used to explain them. It took many years, and possibly a few nervous breakdowns before anybody reached the current theory. The scientists involved noticed that when they plotted graphs of the characteristics of these particles, shapes formed in the arrays of information. The data formed triangular and hexagonal patterns, with enough regularity to allow limited prediction of the existence of new particles. Eventually (in the early 1970's), the scientists came up with the theory of strong interactions, QCD (Quantum ChromoDynamics). This theory suggested that all these varied particles were made from a combination of a few basic particles, called quarks. These quarks either collect in three's (called "baryons"), or in two's (called "measons"). For example, protons and neutrons are two different kinds of baryon, both made from combinations of two quarks, the up quark and the down quark. The up quark (*u*) has a charge of $+^{2}/_{3}$, and the down quark (*d*) has a charge of $-^{1}/_{3}$, and are organised as in the figure to form the proton with a +1 charge and the neutral (zero charge) neutron.

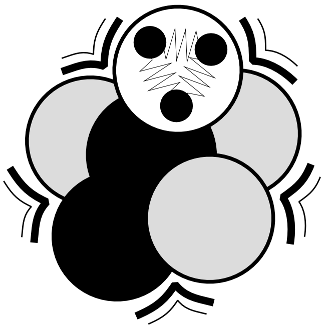


proton (+1)   neutron (0)

It should be noted that the electron and the photon are separate to the baryons and measons, in other words, that they are not constructed of quarks. They are also considered to be fundamental particles, that cannot be broken down into simpler components.

Our third force, the strong interaction, is what holds these baryons and measons together. Again like a spring, the strong force holds the quarks in place. The strong force differs from the others in that it does not follow an inverse square law. It acts like an unbreakable spring, no matter how hard you pull at the quarks, they will not separate. A consequence of this is that no matter how hard you try, you can never isolate a quark, which means that when we try and look for them in the particle accelerator debris, we have to look for signs that they exist, not for the actual particles themselves.

Well, fair enough, but we have yet to explain how nuclei hold together. The answer is that this incredibly strong force is so active in each proton and neutron, that it can't help leaking out, and it starts pulling the quarks in neighbouring baryons (see figure). The upshot of this being that the force that holds the quarks inside the protons and neutrons also hold the protons and neutrons together in the nucleus.



The particle accelerators have brought some curious facts to light. Although, by using the up and down quark, you can theoretically construct nearly every naturally occuring baryon and meason, it appears that nature has decided to create more quarks. They are exact copies of the up and down quarks, only heavier. Currently, there are the "strange" and "charm" (*s* and *c*) quarks, and then the "top" and "bottom" (*t* and *b*) quarks, and as each pair is heavier, it takes more and more powerful particle accelerators to find them. Nobody appears to know why these weighty carbon copies exist, and no-one knows if these six are the end of the story, or if there are more copies waiting to be found as the available accelerating power increases. Incidentally, the *d*-ness, *u*-ness of a quark is known as it's flavour. The others kinds (*s/c* and *b/t*) are also called flavours.

Surely now, with these three forces, we have covered all of physics. After the gravitational, electromagnetic and strong forces, what can be left? Well, there is a phenomenon occuring around us all the time, but it isn't a consequence of any of these forces. According to the laws of the strong force, a quark cannot change it's flavour: once a *d* quark, always a *d* quark, once a *u* quark, always a *u* quark. However, there is a kind of radioactivity that breaks this law, and so needs a fourth force to explain it.

Natural Radioactivity

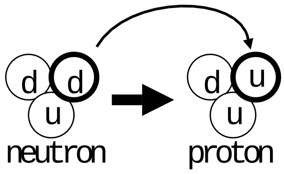
Despite it's dangerous potential, there are naturally occuring examples of radioactivity, perhaps the most notable example of this being carbon. There is a constant cycle of carbon on the earth, from being in the form of carbon dioxide on the air, being absorbed by plants, to be eaten by animals, to then becoming carbon dioxide again as the animals breathe it out. Whilst in the carbon dioxide form, some floats in the upper atmosphere where cosmic rays (actually particles containing "strange" quarks) can hit it. These rays turn the carbon in the carbon dioxide into a radioactive form called carbon 14. Because the cycle keeps replenishing the level of carbon 14, there is a constant amount of radioactivity present due to carbon. When any living thing dies, it stops taking in carbon 14, and so the amount of radioactivity in it starts to fall from the normal level. Radio carbon dating works by measuring the level of radioactivity in a dead organism, which will be less than the normal automatically replenished level, and because we can work out how long it takes for the radioactivity to fall that far, we can work out how long ago the organism died.

We have already said that the nucleus consists of protons and neutrons, but have said little about the neutrons role in the nucleus. They strong force is not enough to keep a nucleus consisting only of protons together, the neutrons give more strong interactions to calm the nucleus, without adding to the problem of like charges repelling each other. The upshot of this is that if, either by the joining or splitting (fusion or fission) of an atoms nucleus, the ratio of protons to neutrons becomes different, the nuclei can become unstable. The nucleus needs some way to gain some stability, and there are two main ways in which the nucleus can achieve it, through alpha and beta radiation.

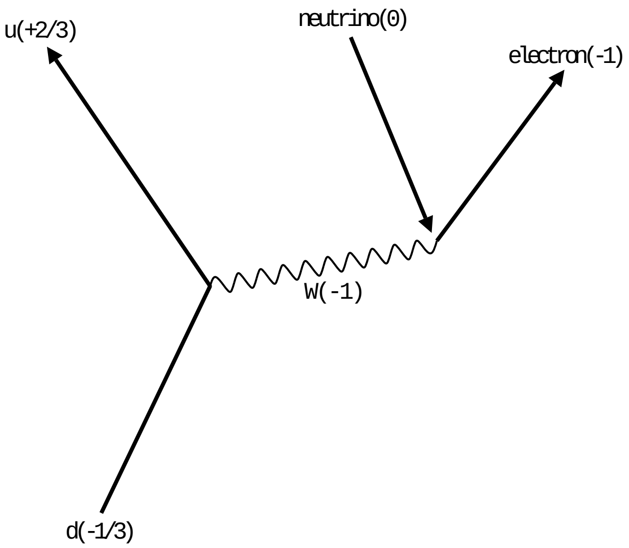
Alpha radiation occurs when the nucleus contains too many protons. To try and settle things down, the atom spits out two protons and two neutrons together (a stable helium nucleus). For example, an unstable plutonium nucleus (containing 94 protons) can release a helium nucleus, losing two neutrons and two protons. Since the number of protons defines what kind of chemical the nucleus is, the plutonium atom has become a uranium atom (it has 92 protons). This rather alchemistic idea of turning one substance into another is commonplace in nuclear reactions.

Beta radiation occurs when the nucleus contains too many neutrons. In this case the atom appears to spit out an electron, whilst one of it's neutrons turns into a proton, thus turning the nucleus into that of a different chemical. For example, an unstable protactinium nucleus (91 protons) can decay by beta radiation to become a uranium atom (92 protons). During both alpha and beta decay, gamma rays (a kind of photons) are given off as a side effect of the processes involved.

The problem is that while alpha decay can be explained using the laws of the strong interaction, beta decay occurs too slowly to be a consequence of the same laws. This slow radioactivity (which is the kind people worry about leaking out of nuclear reactors) is so sluggish because the process involves not just electrons, but (amongst other things) very heavy and sluggish particles, called W's. As I've already hinted, behind beta decay is the idea of a quark changing flavour, allowing a neutron to become a proton by changing a *d* quark into a *u* quark (see figure).



The actual mechanism behind this begins by a down quark emitting a W, which makes it change into an up quark. This new W particle is like a photon, except it is very heavy and has a charge of -1. This particle goes on to absorb another new particle called a neutrino (an electron with no charge that weighs nothing), whereupon the W becomes an electron (see figure).



As mentioned before, the force responsible for this transformation takes far too long to execute it to be the strong force. Hence a much slower and weaker force is deemed to be responsible. Because of it's weakness in relation to the strong interaction, this new interaction is called the weak force.

Conclusion

So, for all the complication of our winter scene, it all boils down to 4 fundamental forces. This would seem enough to ask, yet in recent years a theory has been put forward that, by taking advantage of the similarity between photons and the W particles, combines the electromagnetic force and the weak force into a single underlying force. This electroweak theory is by no means perfect (to quote Richard Feynman, "you can still see the seams"), but perhaps things *will* boil down to just three forces, or perhaps into even fewer forces than that. Although it should be born in mind that when Newton's gravity was closely inspected, it's flaws brought about the revelation of Einstein's theory of general relativity. So perhaps, just like examining a snowflake, closer and closer inspection of these four forces will simply reveal finer and finer detail.