THE NEW SCIENCE
THE FUNDAMENTAL PHYSICS
THE GIFT
OF
THE AUTHOR
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THE
FUNDAMENTAL PHYSICS

BY
W. W. STRONG, Ph. D.
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OF
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W. W. STRONG, B. S., PH. D.

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This work is dedicated to two whose love has been as true as nature, the inspiration of my life, the fondest treasure of my memories, and the foundation of the hope that these loves are the earnest of the great transformation to a love unbound by fate and a truth unfettered by ignorance.

The blessings of such unselfish love inspires this, my credo of life:

I believe in the intelligible ordering of all phenomena by a Good and Supreme Being in whose image we are privileged to understand and direct His creations.

I believe in the most perfect philosophy of the world and of life that we can devise as the guide for ourselves and our organizations so that the heritage of the Past and the works of the present will bring most directly the Great Democracy of Truth and Love to all men.

And I dedicate the full striving of my heart and mind to the gaining and giving of the Truth and Love of my Heavenly Father to men with the full Faith that we here prepare for that most glorious transformation to the perfect ordering of our perpetual Homeland with our Father and our brethren.
The author wishes to record that the formation of the Research Corporation by Dr. F. G. Cottrell appears as an important step toward the time when the ambitions and dreams of our youth will be for knowledge and truth and the employment of wealth will be for the realization of all those visions that experience intimates will be for the uplift of all.
PREFACE

There has been in the writer’s and there is probably among all of us an intense longing for the fundamentals in life. Busy as we may be with the common details and tragedies of existence, there are times when we contemplate a much more enduring scheme of living and thinking than that which now guides or rules us. The college student sometimes elects his subjects with reference to what he is lead to believe is of fundamental value in so far as he can judge. A very few people direct the energy and the enthusiasm of their lives along carefully planned channels in which they believe the most fundamental and valuable results will be obtained. For the great unthinking majority it is as in politics, every man always votes for the best candidate and so as regards the fundamentals of our philosophy of experience and of living most of us vote right.

The unsophisticated might be awed into believing that surely the pages of our select journals and books of science written by the inspired disciples direct from the research fields of nature, would contain in them part of the real philosopher’s stone; and this I sincerely believe is true. Those of us that have been in those fields of research also know that they are indeed stony—stony even unto becoming a wilderness of doubt; and that while sojourning there we must subsist upon the manna of our optimism, else the promised fundamentals beyond the Jordan become clouded by the fleshpots of our Egypt of selfish, “what’s the use” philosophy, and that we may still be in pursuit of the fundamentals when every citizen possesses a heart enriched by the experiences of Gethsemane, and whose mind has been trained by years of fruitful research in the fields of knowledge.

But were all goals to be achieved only Nirvana would remain, and our optimism is to be measured by the progress that is being made, rather than pessimism as regards the reaching of the absolute. Surely the recent discoveries and the visions given us by the new Science inspire a most unbounded optimism, that yet greater progress is to come.
There is arising among the sciences and in technology many new developments that foretell a new natural philosophy or outlook upon knowledge that promises to greatly clarify and simplify knowledge. We appear to be in the midst of a period of a revival of knowledge as well as of the humanities, steps of which have been marked by the new geometries and the principle of relativity.

Events appear to hold the promise that the concentrated efforts of peoples to win in a war will be replaced by a more unified aim to know life and nature and to apply this knowledge more fully to the service of man. The following essay is the writer’s bit in a movement which he hopes will eventually provide every man and every organization with the most advanced and well-ordered program for the direction of their efforts.

W. W. S.

500 S. York St., Mechanicsburg, Pa.

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4. THE GOAL OF THE NEW SCIENCE

The outline of the older natural philosophy is quite well exemplified by the contents of the ordinary textbooks of physics. In quite separate divisions there are treated mechanics and the properties of matter, kinematics, dynamics, gases, liquids and solids; heat, wave motion and sound, light, magnetism and electricity. In a similar fashion the different sciences and branches of engineering are separated from each other on account of the way that they have developed historically and it has only been quite recently that a new science has arisen from a critical examination of the groundwork of the sciences.

This new science is essentially a more complete application of laboratory methods to the basic units, measurements and laws of science. It aims to apply the empirical method and eventually the same method, units and apparatus to all phenomena. The new science is essentially a philosophy of the laboratory and aims for the universal extension of the experimental method. It states that no term or theory of the natural world possesses any meaning unless it is usable in the laboratory. Such terms as time, length, direction and mass must be definable in terms of experiences of the natural world and unless they can be so defined in a given region of experience they possess no meaning there, fundamental though these terms may appear to be.

Philosophically the view that the world consisted of the four elements, water, fire, earth and air would be quite convenient and comprehensive for the Greeks. In Plato’s time some could consistently believe that everything is explained by motion or that all is rest. For a large group of phenomena the phlogiston theory is ample and probably no theory appeared so complete to some minds as the vortex ether theory of the atoms. The past philosophies of phenomena have been quite fruitful and if we change their phraseology they bear a remarkable likeness to the theories of today. Call the four Greek elements solids, liquids, gases and energy: speak of the motion theory as the kinetic theory of gases and liquids: adopt the theory of a stagnant ether; change
phlogiston to energy: and view the atoms as consisting of rings of electrons rotating about the nucleus of the atom and we perceive a remarkable similarity of ideas.

The workers of the new science aim to develop as simple and as comprehensive a philosophy of phenomena as did the workers in the past. But they are devising a system and a laboratory method best suited for the study of phenomena as the first step in the problem and as the investigations continue the very fundamental elements of the experimental system employed are to be modified so as to further these investigations. As a concrete problem let us consider the motion of an alpha particle (which consists of a helium atom carrying a double positive unit of electrical charge) with a velocity of 120,000 miles a second. The collisions of this particle with other particles of matter is entirely different from those we are familiar with when lower velocities are concerned. This alpha particle will pass through all of an atom except a very minute portion called the nucleus and it will leave a path strewn with the wreckage of atoms, all broken to pieces, many of the broken parts being charged, while the medium is filled with the disturbances that we speak of as radiations. In order to describe these phenomena we may consider these changes from afar and under conditions of comparative rest and quiet or we may bravely try to establish our experimental outfit on the rapidly moving alpha particle itself. And the results of the two methods of observation will of course appear very different and perhaps for a long time we will be unable to correlate the two sets of observations.

The charge of the alpha particle will cause it to be surrounded by an electric field which will be comparatively weak if the field is uniform. If however our place of observation had been a beta particle moving with the same velocity the potential of the particle would be a million volts and we would have been forced to develop a laboratory and a system of science that would apply to these conditions of intense electric fields.

Let us now try to measure time on the alpha particle. In the first place we have never devised a clock except for conditions of comparative rest. Would any of our chronometers run regularly when possessing a speed of 120,000 miles per second? If the observer was 6 ft. from the clock and made observations by sight the clock would move a distance of 4 ft. while the light was passing from the clock to the observer, assuming that the velocity of
light is unaffected by the velocity of the observing system. Would not the measurement of time greatly depend as to whether the clock and the observer was in the line of motion of the alpha particle or not? How can the mass of a body be determined under these conditions? What kind of observers will be able to direct the measurements? Can we devise an automatic set of apparatus that could record the measurements that we wish to have made and place the apparatus on the alpha particle? These are some of the problems that confront the new science and considerable advances are being made outlining and answering some of the easier of these problems.

The science that is developed on the rapidly moving alpha particle may then be called the alpha particle science. As the beta particle is very much smaller and is surrounded by a very intense electric field we will have a beta particle at rest physics and a rapidly moving beta particle physics. Such phenomena as the propagation of light may then be very different according as we view them from our own standpoint, in regions like our own but with very intense electric fields, or from rapidly moving alpha and beta particles. The new science aims to unify all these sciences of the systems, no matter how differently they may appear, into one harmonious whole. It purposes to correlate the laboratory in the mind with the laboratory of the shop. Length, time, and the other “fundamental units” and the laws of science are defined and measured if possible under every condition that is known. There is to be one common science based on the same laboratory plan for the inside of the atoms, for molecular spaces, for conditions as they may exist in the center of the sun or for free space.

The origin of the new science is to be found in the new geometries developed from axioms differing from those assumed by Euclid. The discovery of the electron, radioactivity, and studies in radiation and the propagation of light with reference to the earth’s motion have furnished the beginnings and the outlook of the new fields to be covered. On account of the prominent rôle played by electrical phenomena it is necessary to restrict this treatment largely to a description of an ensemble of electrical charge, mass and energy, for so far as we know electrical charge always appears with a certain quantity of mass and energy, the latter being usually of the potential type. As all knowledge comes to us through the senses, it seems well
to consider very briefly the transformations in phenomena imposed upon us by the gateways of the senses and to indicate how it may be possible to introduce laboratory methods into mental phenomena. The various entity systems are viewed in regard to the problems introduced for the new science and an outline is given of a possible system of laboratory method that would be applicable to all of these entity systems.

All of our scientific advances by the laboratory method have shown that the magnitudes of quantities defined by the expressions “greater than” or “less than” are constituted of parts. These parts have been sorted into classes, the parts in each class being found to be alike in some or all of their properties. The smallest parts of a magnitude will be called the elements or atoms of that magnitude. The citizens of a nation constitute its elements or the atoms of ordinary masses of matter, its elements. The term element as thus used depends upon the point of view and is a relative term. The term ultimate element could be defined as the smallest magnitude that any quantity can be partitioned into. Thus as far as we know the electron is the ultimate element of electrical charge and it may be one of the ultimate elements of the universe in the absolute sense if the electron does not possess parts or as we may say a “structure.” In the vortex ether theory of matter there was only one ultimate element of the universe as regards ordinary matter and free space.

A natural system such as a star, an animal, a magnet or an electron will be spoken of as an entity or an entity system. A laboratory or an assumed grouping of elements, such as a cavity of radiations used in the definition of a black body will be called an ensemble. An aim of science is to discover the ultimate elements and to explore and derive laws for the simplest ensembles. As an example of this kind of problem we might consider space or the free ether as we will name it. In many theories the free ether is assumed to be isotropic and to be without structure. How can it be possible to apply the term extension to such an ether for there is no way of defining direction? How is there to be any relation to time for in any such ether it would be impossible to measure time. Terms such as time and direction are therefore meaningless for such an ether because there is no way to define them. There is then no time or direction qualities to an isotropic ether possessing no structure.
Consider an ensemble of the above ether and radiation elements. If this ensemble is without a structure how can we define a length because we must possess some marking elements for a unit of length or how can we speak of time in such an ensemble because we are unable to measure length? For the above ensemble the velocity of the radiation cannot be employed to measure time because there is no way of defining length. For this ensemble of ether and radiation the terms length, direction and local time can possess no local meaning but must be received from some other ensemble. For a medium as the ether to be intelligible, to possess directed qualities and to be described by equations, employing terms such as length and time, it is necessary that it possess a structure and certain other "fundamental" qualities.

The new science develops a consistent and a local philosophy for each ensemble and determines as fundamental a system of local definitions, units and laws as possible. The laws of the transformations of the local philosophies of the different ensembles is then determined. The philosophy that possesses the most universal application among the natural entities and whose convenience is greatest may then be adopted for general use.
5. THE DISAPPEARANCE AND CONSERVATION OF ENERGY, ELECTRICAL CHARGE AND MASS

It has long been assumed that energy disappears or changes its form and one can consider phenomena as largely if not altogether marked by energy changes. To us the conception of energy is most satisfying when we consider kinetic energy or one-half mv². Potential energy is in an intangible condition or form for how can we conceive of this energy as existing except in the medium or the ether. Since we apparently know so little of the ether we can almost speak of the energy as being lost. The classical illustration of the transformations of kinetic and potential energy is that of the vibrating pendulum. In the middle of its swing the energy is all kinetic while at the ends of the swing the energy is all potential. Our laboratory work consists of experiments with the energy in the kinetic form. To be studied energy must first be converted into the kinetic form adapted to the problem at hand. A piece of uranium or a piece of coal can be used as regards their radioactive or chemical energy content only when radioactive energy or when heat is developed.

The law of the conservation of energy is found to hold when we consider the existence of the two forms of energy and we feel entirely justified in treating potential energy as "existing" in the same way as kinetic energy because it can be converted into the kinetic form.

Our ordinary world as we see it every day is one in which kinetic energy is usually being converted back and forth into potential or "heat" energy. And it requires much of our engineering effort to maintain our kinetic condition. Friction is ever working against the moving elements. Most of us are kept busy to keep things going. Even in the astronomical world the philosophy of many is that the suns are becoming cold and dead and that the revolving planets and moons are slowing down in their motion. Yet this death of kinetic energy that is everywhere about us and which we will designate as a condition of our type of physical world is counteracted by more or less unknown elements so that conservation may always apply.
The energy world is then ruled by these conditions: energy is conserved: the energy changes of our every day life is marked by the natural tendency of kinetic energy to disappear: and the second law of thermodynamics which may be stated in a number of forms such as the ever increasing value of the entropy content of any isolated system, the impossibility of perpetual motion apparatus or the ever tendency of the universe to run down as regards many energy changes (in the same way as a clock, the potential energy of the spring being converted into the kinetic energy of the pendulum and this kinetic energy changed gradually into the kinetic energy of heat motions).

The continual flow of energy through so many transformations leads one to suppose that when it ultimately is found to consist of units, particles, quanta, entities, atoms or whatever term we may call them, these ultimate elements may be all alike because all quantities of energy, like electrical charges, depend upon the total amount of energy present and are independent of the nature of the elements of energy combined to form the whole.

The appearance of electrical charges bears some analogies to the appearance of energy. The commercial problems relating to electricity have to do with the generation, the transmission and the absorption of charges of electricity, the phenomena of magnetism being assumed as being due to the motion of electrical charges. The constitution of electrical charges is very simple in that all electrical charges appear to be built of elementary parts all having the magnitude of 4.7 \(10^{-10}\) e.s. units, all these units being identical except as they may be positive or negative in character.

Like kinetic energy electrical charges never appear except in connection with masses of matter thus making the trio of kinetic energy, mass and electrical charge an inseparable ensemble as far as experimental knowledge extends. As kinetic energy is characterized by its tendency to disappear so free electrical charges always disappear unless special precautions are taken to prevent this change. The electrical elements possess the unique property however of neutralizing themselves in that the approach of equal charges of positive and negative electrical discharges causes the more or less complete disappearance of the charges.

The smallest element of negative electricity, the electron, is associated with a mass of matter about the one-eighteen
hundredth part of that of the smallest element of matter, the hydrogen atom. Since the ratio of mass to charge is found to vary with the velocity of the electron it has been assumed that this mass is variable rather than the electrical charge. Experimentally the magnitude that is measured is the ratio of the charge to the mass so that for the rapidly moving electron we have a condition arising where electrical charge, mass and of course the kinetic energy appears as a variable ensemble for which no experiment has been devised that will permit of the determination of the varying elements.

As the philosophy that assumes that natural phenomena are extremely simple has led to many of the greatest discoveries, so the assumption that the magnitude of the electrical charge is constant rather than the mass of the electron, makes the treatment of the ensemble of energy, charge and mass more simple and apparently just as accurate as would any other assumption. The law of the conservation of electrical charge can thus be considered to be absolute. The second law and the general condition that applies to electrical charges is that all the natural changes in a closed electrical system are such as to make the magnitude of the free charge a minimum.

No positive electrical charge has been found except as being associated with atoms of matter and the view commonly held is that the positive charges are an essential part of the nuclei of the atoms. The generation of free charges of electricity always results in the disappearance of energy. The disappearance of free electrical charges always takes place in matter and the picture of the process assumes that the positive and negative charges neutralize each other inside the molecules and atoms. The energy that is lost in the generation of free charges is considered as the energy of the electrical field between the positive and negative charges and that on the localization of the electrical field inside of atoms or molecules some of its potential energy is changed into kinetic energy.

As in energy changes the disappearance of kinetic energy was considered as accompanied by the appearance of an equal amount of potential energy in the ether so the disappearance of negative charges into molecules and atoms could be associated with the appearance of certain characteristics of matter which we ordinarily associate with the neutral state. In other words the characteristic properties of matter may be those associated with what
we consider as matter after it has lost all of its electrons. Such matter we will speak of as "natural" or "free" matter. "Ordinary" matter will be called "neutral" matter. All electrical charges then become aggregates of electrons and all masses become aggregates of electrons and the "atoms" of "natural" matter.

The constitution of matter is found to be atomic, all matter being built out of some 92 elementary atoms with accumulating evidence that these atoms may themselves be composed of much simpler systems such as hydrogen or helium. The fundamental property of matter is usually believed to be its mass and the science of chemistry is based on the assumption that mass is conserved. We have seen that the mass of the electron is considered as a variable. Whether this kind of mass is acted upon by gravitational forces remains for future experiments to determine and whether the mass of the various atoms varies as does that of the electron at high speeds also remains for future investigations to tell. There may be an electrical and a material mass, or a kinetic and a potential mass corresponding to the energy terms. The law of conservation might be considered as applying to the two types of mass. "Natural" matter would always naturally disappear into ordinary or neutral matter and the law corresponding to the second law of thermodynamics would be that the complex atomic systems are running down or in other words the radioactivity of the elementary atoms always results in simpler atomic systems through the disintegration of the more complex atoms.

The law of conservation and the disappearance of kinetic energy, electric charge and natural matter appear to be the same. These elements naturally partition themselves between the ether and neutral matter. Neutral matter is then the vehicle of kinetic energy, electrical charge and natural matter. The disappearance of kinetic energy, of free electric charges or of natural matter is accompanied by potential energy changes for which the ether is the vehicle. The ether about an ensemble of energy, charge and natural matter may be considered to be in a state or to be approaching a state of equilibrium with the ensemble. Thus the ether about ordinary matter could be considered as "ordinary" ether and might be the same or different from the ether at a very great distance from any of these elements or from ensembles of one or more of these elements. Experimental work of the most
fundamental character remains to be done as to the relations between the free ether, energy, electric charge, and natural matter and the partitioning of these elements between ordinary ether and matter. The law of conservation applies by definition to electrical charges absolutely and to energy and mass only as elements in a closed ensemble of ether, energy, matter and charge.

The writer proposes the ether to be an analogue of matter possessing a much more fine grained structure. The elements of electrons and natural atoms of matter become the electroethons of the ether. The potential or hidden energy becomes the kinetic energy of the electroethons. The vibrations and sound waves of neutral matter are paralleled by the electromagnetic waves of the ether. As sound waves are pictured as the ordered collisions of particles of matter so the electromagnetic waves are the ordered collisions of electroethon particles. For purposes of illustration rather than as an exact analogue there can be pictured an atmosphere of mobile electroethons in a lattice work of immobile electroethons somewhat similar to the existence of an atmosphere of electrons in a framework of the natural atoms of matter in a metal. An electric field is a region of the ether where the neutral condition has been disturbed in much the same way that an electromotive force disturbs the condition of equilibrium of the electron atmosphere of a metal.

In treating the second law of thermodynamics Maxwell considered that there could be “demons” that could reverse the changes whose direction was given by the law. Our credo as optimists leads us to believe that there are “angels” that can direct the transformation of any natural phenomena. For example the direction of the radioactivity of matter is that of the disintegration of the more complex elements. We believe that experimental discoveries will be made that will indicate how “angels” (and perhaps ourselves) can build the more complex atoms from the simpler conserved elements. These “angels” might possibly work in the center of the sun, in very intense electric fields or by “breaking down” the ether under electrical stresses so that even electrical charges or natural atoms would result. And the Director of these “angels” we might define as the “Creator” or “Ruler” of the Universe, and this form of philosophy as “monotheism.”

As regards kinetic energy we know that its magnitude is relative depending on how \( \frac{1}{2}mv^2 \) is defined and measured.
Presumably potential energy and possibly mass and electrical charge may be viewed in the same way for the latter two quantities are measured by "forces" and accordingly if the system upon which measurements were being made was subjected to acceleration the measurements would be subject to modification. The condition of relativity thus appears amongst the conserved elements. An example of such relativity is that of electrical charge and mass. No electrical charge has ever been separated entirely from a mass, the electron possessing a certain charge and a certain mass defined with reference to the system with reference to which its motion is measured.

These problems as to the way the ether is modified by its energy content are very important and can be studied by the effect produced upon the velocity of the electromagnetic radiations (the writer is now engaged in experiments of this kind). Indeed apparently no more fundamental and isolated experiments can be performed because these are the simplest ensembles at present open to the new science.

The marked effects of electric charges and natural matter upon the ether (the electric and magnetic fields), the apparent absolute conservation of these elements and their disappearance by their "mutual neutralization" have few analogues in the coarser grained entity systems unless we consider phenomena like the formation of salts from acids and bases, the phenomena of permanent magnetism and some life phenomena.

Experiments have already indicated that the structure of electrical charge is more "fine grained" than that of ordinary neutral matter though the atoms of natural matter, the positive nuclei of the ordinary atoms, possess about the same size as the electron. The "fineness" of structure of natural matter is thus made to depend upon the magnitude of the nuclei of the atoms. The ultimate and individual elementary units of energy and of the ether have not been discovered experimentally and it is reasonable to assume that these elements are much finer grained than mass or electrical charge.

From the Zeeman, Stark and similar effects and the modification of the velocity of electromagnetic radiations by matter it seems certain that electrical charges remain as such in the neutral atomic and molecular systems. The disappearance of energy and mass in the ether without changing its properties to any great extent would lead us to believe that the ether may be such a
“dense” energy and mass medium that the increment due to these disappeared elements affects the “density” but little. The older elastic ether theory developed from these disappearance phenomena.

The possible conditions of relativity in any ensemble are so numerous that it is always highly important to reduce the number of elementary units in the ensemble to the minimum. The new science aims to obtain the ultimate units or atoms of all the entity systems of the universe and then consider if any of the properties of these elementary atoms can be defined as “absolute” in the sense of “nondisappearing.” Other elements will then be described relative to the “absolute” elements. If the elements that appear to be definable in an “absolute” manner do not determine a physics uniquely then the new science will develop all the consistent systems of physics that appear to equally simulate phenomena and employ the system that is simplest and most convenient.
6. IONIZATION PHENOMENA

According to the freedom of neutral atoms of matter we classify bodies into solids, liquids and gases. In solids the atoms may possess an orderly arrangement in planes (as is the case in crystals) or a more or less disordered arrangement (as in substances such as glass). The atoms are not free to move about. In liquids the molecules possess some freedom of movement but are not "free." In gases the molecules are comparatively "free" except during collisions. The kinetic energy content increases as one passes from solid to liquid to gas.

Electrical charges are "bound" in neutral matter. The "binding" is greatest in the insulators or nonconductors. It becomes very much less in electrolytes when a difference of potential of a few volts will "free" the charges. It is least in metals where an "electron atmosphere" or electron gas is quite "free" to be acted upon by very small electromotive forces.

Temperature can be employed as a measure of the kinetic energy of molecules when in the gaseous state. The absolute zero of temperature being a condition where the kinetic energy vanishes. Conductivity varies as the freedom of the electrical charges in matter and becomes practically perfect for metals for the absolute zero of temperature. Electrical currents will flow in metals at very low temperatures for hours after the applied e.m.f. has been discontinued.

High temperatures of all substances results in their intense ionization and increased conductivity. The upper limit of temperature results from the generation of free electrical charges or ions and the flow of kinetic energy into "potential energy" then restricts the attainment of any higher temperatures. The density of the potential energy may be assumed to measure the "temperature" of the electroethons.

The motion of atoms or molecules in solids and of ions in nonconductors is ordered and consists largely of oscillations about positions of equilibrium. The motion of molecules and ions in liquids is more disordered. The motion of molecules in gases, of electrons in metals and of ions in substances at high temperatures
is largely disordered, the values of the “free paths” and velocities of the particles following Maxwell’s law and being that of the variation in the distance of the bullet marks on a bull’s eye pattern used as a target in rifle practice.

Ordered motions are added to the natural motions when a direct electric current flows through a metal, a vacuum tube or any conducting substance, when heat flows, or when a mechanical pressure is transmitted. Alternating motions are added to the natural motions when alternating currents of electricity, heat, or mechanical pressure or sound waves are transmitted through a substance.

Thanks to the existence of electron atmospheres we are able to cover the earth with a network of cables, telegraph, telephone and electric power transmission lines. We can picture these as “electric lines of force” making a loose lattice work everywhere. The electric cars would be the “ions” following the “electric lines of force of the polarized electric field”—the cables overhead or beneath the electric car. The atoms and molecules could be represented by the trains on the railroads and the automobile trucks on the national highways. The locomotives are the “energized” atoms giving kinetic energy to the train molecules. The chunks of coal and the tanks of gasoline are the quanta, radions or elements of radiation that are being partitioned to the molecular elements. Coal and gasoline represent “potential,” stored or lost kinetic energy. The motion of the automobile trucks is disordered and is represented by gas motions while the motive electric cars in a city are more like the motions taking place in the lattice work of solids and liquids.

The analogy between our system of electrical current transmission by threads of electron atmospheres and the lattice line structure of an atmosphere of electroethons indicates that the supposed difficulty of the ether problems may not be as great as at first surmised. In the first place we at first feel that a system of matter could with difficulty pass through an ether lattice work. The diameter of an atom is about $10^{-8}$ cm. while the diameters of the atom nucleus and the electron are about $10^{-15}$ cm. The emptiness of the atom is then equivalent to the emptiness of the United States when filled with about 1000 buildings 30 ft. square. Even though a large part of our population enjoy the telephone and the electric current the “porosity” of these electron atmospheric threads through the country is “extremely tenuous.”
Each atom could be cut by an ether thread and yet the ether lattice structure could be much more tenuous than our lattice system of telephone threads. The nature of the ions and the ionic radiations will permit an outline the electron and "natural matter" world.

An ion consists of a certain amount of electrical charge with a certain quantity of matter. Experimental evidence indicates that every atom of matter contains one or more atoms of negative electricity or electrons. These electrons may be ejected from the atoms or molecules of matter under certain conditions, leaving the atoms or molecules positively charged. The atoms or molecules may gain or lose negative electrons and by this means an innumerable number of different kinds of negative and positive ions can be formed. All kinds of ions are combinations of atoms and molecules that have either lost or gained electrons.

Ions composed of a comparatively small number of atoms or molecules are called simple ions. Thus the ions produced in chemically pure gases at low pressures are simple ions. When the gases are not pure; when fog, dust and similar particles are present, the ions may be very complex. The ions resulting from many kinds of chemical reactions such as those to be found in the neighborhood of flames are complex. There is probably no sharp dividing line in the above classification, the division being one of convenience.

An ion is a charged particle that may be considered to be practically at rest or at least it does not possess any greater kinetic energy than does a gaseous molecule at the same temperature. It may be given kinetic energy of motion by the action of an electric field. The "particles" that constitute radiations such as $\alpha$, $\beta$ or cathode ray particles are moving rapidly and are not usually spoken of as ions.

Under no condition is the number of free ions in a given space of the same order of magnitude as the number of atoms. Ionizing agents in general produce equal numbers of positive and negative ions or at least this is usually assumed to be the case. It is possible that the ions formed may possess charges of different magnitude so that the number of positive ions need not necessarily be equal to the number of negative ions. It requires some time for an ionizing agent to act before the number of ions being formed is equal to the number of positive and negative ions recombining. It is in phenomena of this kind that the
term coefficient of recombination is used. This coefficient is probably not a constant but depends upon the process under which ionization takes place. In most cases the production of ions is approximately uniform throughout any given body and under these conditions the coefficient is practically a constant. The term coefficient of diffusion is defined in the same way as in the theory of gases. Its constancy also depends upon the uniformity of the ionization.

Any gas that is ionized when placed between electrodes maintained at a certain difference of electrical potential will permit an electrical or ionization current to flow. This current increases to a maximum value called the saturation current for an increase in the potential difference up to a certain value called the saturation potential difference. These current potential curves depend upon the nature, the pressure, the temperature, etc., of the ionized medium. They also depend upon the nature of the ionizing agent.

In ionization literature the terms ray and radiation are often used indiscriminately. x-“rays” and x-“radiations” are both used. The term “ray” applies to the emission from “x-ray” tubes and from the radioactive bodies. Thus we have α, β, γ, δ and x-rays, recoil rays, cathode and the various vacuum tube rays. When the nature of the emitted particle or wave is characteristic and possesses properties that can be accurately measured, the term radiation is used. Thus we have black body radiations, the radiations from definite radioactive products, characteristic x radiations, etc. The term secondary radiation is generally used because these radiations are often characteristic of the kind of matter emitting them. The terms “ray,” “beam of rays,” “pencil” of rays, etc., are used in much the same way as they are used in optics.

It may be considered convenient to classify radiations into the “bullet” or atomistic and the “medium” types. γ and x-rays are of the wave or pulse type. Experimental evidence indicates that the ionization produced by the x and γ rays is due to the secondary radiations excited by these rays: Indeed it may be possible that all ionizing rays consist of moving particles, these particles being invariably charged. According to this view the process of ionization would be a collision phenomena, the resultant ions being due to the action of an electric field upon molecules or atoms.
IONIZATION PHENOMENA

Primary Radiations

I. Electromagnetic radiations:
   1. Hertzian waves.
   2. Reststrahlen and radiant heat.
   3. Light.
   4. Ultraviolet light.
   5. X-rays.

II. Cathode rays.

III. Ionic radiations due to the action of the electric force:
   1. Anode or positive rays.
   2. Canal rays.
   3. Negative rays.
   4. Entladungstrahlen.
   5. Magnetic rays.
   6. Neutral rays. “Retrograde” rays are probably neutral during a large portion of their path.

IV. Thermionic radiations:
   1. Electron radiations.
   2. Rays of positive and negative ions and neutral matter.

Secondary Radiations

(a) Normal photo-electron radiations.
(b) Selective photo-electron radiations.
(c) Secondary cathode rays.
(d) Homogenous x-rays.
(e) Secondary scattered x-rays.
(f) δ rays.
(g) δ-rays or slowly moving electrons.
(h) Soft x-rays and possibly characteristic x-radiations of Sn and Pb.

(i) Homogenous x-rays characteristic of the anticathode.
(ii) Independent x-rays characteristic of the velocity of the primary rays.

(a) Secondary rays produced by neutral rays. These may consist of positive or negative ions or of neutral particles.
V. Radioactive radiations:

1. \( \alpha \) rays.
   Atoms of helium with a double positive charge.
   
2. \( \beta \) rays.
   Electrons.
   
3. \( \gamma \) rays.
   
4. Recoil rays.
   Atoms of radioactive products.
   
5. Penetrating radiation.

Of the above radiations, photo-electron radiations, primary and secondary cathode rays, primary and secondary \( \beta \) rays, high temperature negative thermionic radiations and \( \delta \) rays consist of streams of rapidly moving electrons. The only essential difference between these various types of electron radiation lies in the fact that the electrons possess different velocities. \( \delta \) rays consist of very slowly moving electrons. \( \beta \) rays derive their energy from atoms undergoing radioactive change and usually consist of very rapidly moving electrons. Cathode rays are due to electrons that have fallen through electric fields of a certain potential difference \( (V) \) and have acquired a kinetic energy \( \frac{1}{2}mv^2 = Ve \).

The other radiations either consist of “waves,” “pulses,” “entities” or moving particles composed of one or more atoms of matter. \( \alpha \) rays are rapidly moving helium ions carrying a double positive charge. \( \beta \) and \( \gamma \) rays derive their energy from atoms undergoing radioactive change. There are then three types of high speed radiations, the ether, electron and atomistic radiations. All these radiations are ionizing agents except the long wave length ether radiations.

Ionizing radiations are either spontaneous or subject to experimental control. The \( \alpha, \beta \) and \( \gamma \) rays are spontaneous in origin and their initial properties on emission cannot be altered in any way by changes in the surrounding physical and chemical environment. While many of the other radiations are emitted by atomic or molecular systems, these systems can be controlled in certain ways by the action of outside forces. Thermionic radiations depend upon the temperature, the nature
of the incandescent surface, etc. The nature of x-rays depends upon the velocity of the exciting cathode ray particles.

With the possible exception of the spontaneous radiation, all the "material" or electron radiations are due either to the existence of high temperatures or to electric fields.

Experimental evidence supports the view that only material or electron radiations produce ionization directly. X and γ rays and ultraviolet light seem to ionize bodies indirectly through the action of secondary electron radiations. It therefore follows that the ionization of neutral particles takes place during the moments of collision between these particles and the rapidly moving radiation particles. According to this view ionization is a collision phenomenon.

Though intimately related in the phenomena as they actually take place, the various ionizing radiations can be discussed and classified according to the changes which take place in the radiations when they pass through matter, the changes produced in the atoms from which they originate and the changes produced in the molecules and atoms of the absorbing matter.

(A) Effects on the ray particles and beams of radiation produced by the atoms and molecules of absorbing matter.

(a) The ray particles lose their velocity. This decrease of velocity obeys certain laws and depends upon the nature of the particles, the nature of the atoms with which they come into mutual action or collision and the dynamic conditions of each collision. (b) The rays or radiation beams lose energy due to decrease in velocity though not necessarily according to the ordinary mechanical relation. (c) The ray particles or entities may disappear. (d) The ray particles or entities may be transformed so that a different type of radiation results. (e) The direction of the rays may be changed. This changed part may be either of a reflected or a scattered type.

(B) The effects that take place during the formation of the radiation particles or entities.

(a) The velocity of α and β particles appears to be related to the period of disintegration of the parent atom. (b) β and γ rays are usually emitted by the same product probably simultaneously. (c) α particles may be emitted in pairs. (d) The emission of α particles often precedes the existence of short period disintegration products. (e) The parent atom may become a recoil ray particle. (f) The emission of primary rays by an
atom may be accompanied by the emission of secondary radia-
tion due to the passage of the primary ray particle through the
atom. (g) Various vibrations and changes in structure of
the parent atom may accompany the ejection of any radiation
particle or entity. (h) The energy changes due to the forma-
tion of the primary and secondary radiation particles may take
place according to the elementarquanta theory.

(C) Some effects produced in the molecules and atoms of
the matter absorbing the given radiation. These effects may be
temporary or they may possess any degree of permanency.

(a) The atoms or molecules may be dissociated into neutral
parts. (b) The atoms or molecules may be ionized. The ions
may be formed within the molecule or they may separate from
each other and exist as independent particles. Secondary
electrons radiations are of this latter type. (c) The atoms,
molecules or their ions may be caused to become recoil ray par-
ticles. (d) Atoms may be permanently broken down. This
constitutes a transmutation of the element and has not been
positively proven to take place. (e) The atom or molecule may
be caused to emit some of its intrinsic energy. This constitutes
a "trigger" effect and has not been proven to take place. (f)
The atom or molecule may absorb energy and store it in a ki-
netic or a potential form. (g) Parts of the atom or molecule may
be put into vibration. This may result in a transformation and
radiation of the energy absorbed. Phosphorescence and fluo-
rescence are examples of this kind. (h) The ionizing particles
may combine with an atom, molecule or ion and form a new sys-
tem. The resultant particle need not necessarily be a radiation
particle. The production of particles by dissociation, ioniza-
tion and possibly by transmutation is opening a new field in dy-
namical chemistry, and promises much from both the theoretical
and practical points of view.

From the point of view of generating the ionizing agents many
problems arise. Even in the visible part of the spectrum it is
very difficult to obtain monochromatic light. The ordinary
incandescent lamp does not possess an electric current to light
energy emission efficiency of more than a few (a) per cent. and
the efficiency of converting the original energy of the coal into
electric current is only some twenty (b) per cent. at best.

If then we wish to generate ultraviolet light of $\lambda$ 2500 to $\lambda$ 2550,
we might use a very hot incandescent filament and screen out by
absorption all of the spectrum except those wavelengths thus obtaining a certain very small (c) percentage of ultraviolet light out of the total radiation energy of the incandescent filament. We then employ this ultraviolet light to generate ozone and again obtain a certain percentage (d) of energy transformation which in no case would be large. The total efficiency of the various processes is almost infinitesimally small, abcd, and this condition is typical of the generation of all ionizing agents.

Not only is the efficiency of the process small but only a few of all the possible short wavelengths of the electromagnetic radiations and only a few of the thousands of possible atomistic radiations at comparatively low velocities are obtainable. We ought to be able to get beams of gold radiations (charged Au atoms) possessing any velocity we wished up to our assumed limit of $3 \times 10^4$ cm. per sec. We might wish to know whether the benzene rings would remain stable for all possible velocities. Would these radiations resemble the beams of helium ions known as $\alpha$ rays?

With the electron radiations we are more successful. In x-ray tubes we can generate these electrons with velocities approaching that of light. By using windows these electron radiations can be utilized outside the x-ray tube. But even here the efficiency of generation and the intensity of the electron beams are small.

The generation of the atomistic radiations has only been applicable to the lighter atoms in gases at low pressures. In vacuum tubes weak radiations of the gaseous atoms such as oxygen and nitrogen can be generated with varying velocities approaching say a tenth that of light. But these radiations are easily absorbed by any material that can be used as a window for a vacuum tube and hence only very weak atomistic radiations can be transmitted outside the tube.

Atomistic radiations homogenous in constitution, magnitude and direction of velocity are not generated in gases at ordinary pressures because the gases do not support an electric field of sufficient intensity. As soon as these radiations are generated they begin to transmit their energy to the gas molecules during collision and this prevents the acquirement of any considerable velocity at all.

The problem of generating atomistic radiations will be greatly aided by the use of very high voltages, very large vacuum tubes and rapid vacuum pumps. In this way it may be possible to
produce a great many new kinds of atomistic aggregates and ions and possibly to disintegrate matter, i.e., produce artificial radioactivity and even to build up new atoms. Only one kind of atomistic radiation possessing a high velocity, the $\alpha$ rays, is known and on account of its being ejected by a number of radioactive products it is assumed to be a component part possibly of all atoms. The question of the philosopher's stone, of learning the structure of the atoms, of analyzing and synthesizing them is to be answered when and only when the subject of atomistic radiations has been fully investigated.
7. THE GATEWAYS OF KNOWLEDGE AND OUR SCIENTIFIC DEVELOPMENT

Every one of us receive our knowledge through the sense organs and the nervous system so that all phenomena of the outside world are received by the mind after the intricate and not well understood transformations made by these mechanisms. One of the big problems of science consists in accurately describing these transformations.

It follows as a corollary that we do not now know of any “agent” in the outside world except in terms of the perceptions of the mind. Revolutionary as scientific discovery has been we have found no new “agent” in nature. At one time x-rays were thought to be such but now it is quite certain that they are electromagnetic radiations. If x-rays had been a new “agent” its nature would have remained unknown because only the properties “felt” by our senses could have been understood. It is for this reason that the terms electric, magnetic and gravitational fields of force mean so little to us beyond the mechanical effects which they produce. An illustration of this kind is given by Bragg’s theory of x-rays before they were shown to possess the same diffractive properties as light. The x-ray according to Bragg was an “entity” that received energy from an electron striking the anticathode. It was propagated “with the velocity of light” just as a “particle of matter.” In this “entity” stage absolutely nothing was known of the x-ray except as a carrier of energy. When x-rays were absorbed by ionizing a gas Bragg assumed that the “entity” again became an electron and the ionization was produced by the electron. In other words the “entity” stage was the x or unknown ray state acting as the vehicle of the electron’s energy.

It seems probable then that if we did not have eyes and a temperature sense we would know nothing of the electromagnetic
radiations in the way we do. It would indeed be very interesting to develop a philosophy of nature ignoring one or more of the “fundamental” sense elements such for instance as inertia or temperature.

Our evolution as a race and as individuals has contained determinative factors as to what our natural philosophy shall be. The flow of consciousness in ourselves is without beginning or end (for if it ends we of course cannot know it). It is a flow of “entity” elements carried into the main channel by the branch sources of the sense organs. It originates in its womb of darkness and hence the muscular sensations—or the mechanistic philosophy is the earliest to appear and remains more or less dominant through life. It therefore results that to us the universe appears as a mechanical structure—a world of forces. The Newtonian mechanics need not give us the laws of this force world necessarily but some system of mechanical forces seems directed by our origin and environment as the guide to our natural philosophy.

It is reasonable to assume that by opening new gateways of knowledge our philosophy would be entirely changed. We might imagine some “field of force” or radiation that could directly affect the molecular processes of the brain. Molecules of a certain type could be introduced into the brain. Experiments for example have been made where a person was placed in an intense magnetic field. The only effect seemed to be a light sensation on the retina. Some day there may however be opened to us a world of melody by some now unknown agent of the external world and many of us believe that a future life transforms us to a new universe of phenomena by opening many new gateways of knowledge and by freeing us from the incessant molecular changes of our present world.

It is very easy then for us to picture the elements of the mental world freed from the temporary gateways of the present molecular systems (nerves, etc.) and opening (through systems obeying the law of conservation of properties) into the ensembles of the “fundamental” elements. The “disappearance” of the mental elements does not indicate that they are not conserved for by analogy this is a frequent phenomenon in the outside world. As the ether appears as the reservoir of “lost” but conserved elements of the outside world so it may also serve for the mental elements.
To continue, the course of our training and the development of our civilization have controlled and determined the course of our philosophy just as environment and the past guides the evolution of the animals. Our words carry a meaning to us long before we know of forces in physics. Our arithmetic and grammar are accepted processes in any theory of electricity which we may develop and try as we may we cannot rebuild any parts of our natural philosophy without at least using some of the stones of the previous structures which had been erected. An illustration of the effect of grammar upon theoretical physics is sometimes given by the history of our views of the ether. We had discovered the wave properties of light and we could conceive of the phenomena only as the undulating motion of some medium. As a verb requires a noun so “to undulate” required a subject and influenced in part at least by our training in grammar we felt and many feel today that “the ether undulates.”

As a result one finds that the tactual and muscular sensations predominate. We imagine a world of things separated by distances; these things may be portions of matter that we can actually touch or they may be atoms or molecules. Whatever they are, most of us conceive them as belonging essentially to the realm of the tactual and muscular. Our world is largely one of matter in motion, a c.g.s. world. But why should the concepts of one sense seem more “fundamental” to us than those of another? Does not each sense organ possess its own peculiar sensation concepts and are not each of these concepts of the same theoretical value? Are not other quantities as important as those indicated by the senses? Indeed an almost infinitude of worlds are possible assuming some other trinity of units than the centimeter, gram and second as being the predominate ones.

It is thus possible to attribute the domination of some sense concepts by others as being due to the fact that some of these concepts have been much more important to us in our development, both as individuals and as a race. But this does not prove that they are the most valuable for the description of the external world and that they should therefore possess the greater scientific value.

One thus comes to recognize the narrowness of many of our views of the external world and the relation between the world outside the senses and the world inside. The meaning of space,
time, matter, energy, etc., are dependent upon the limited avenues connecting the inner and outer worlds. We can easily conceive of a means of communicating between these worlds directly without the aid of the senses. We might be endowed with an entropy sense; a sense corresponding to any thing or function of things and changes in the outside world. Then, too, could not systems in the mental world be "tuned" to the physical world? And may not this "tuning" be accomplished some time experimentally by the introduction of certain atomic or molecular systems into the brain as is done with the digestive tract previous to taking x-ray photographs.

The alphabet of the language we select to describe the outside world is the one most convenient to our type of mind. Another type of mind might use an entirely different alphabet and it sometimes seems reasonable to think the number of alphabets innumerable. Our ideas as to the convenience of any given system of symbols is only determined by the present state of our knowledge. But somehow we believe we are ultimately to reach what we picture is "reality."

We continually try to make our units absolute and to place the "center of our coordinate axes" at a place suitable to natural phenomena yet somewhere, someway and somehow our system is largely limited by our past experience from our birth, both as individuals and as races. Nietzsche may bring us a strange system but he has simply and but slightly changed either the origin or the bearings of philosophy. So we in our efforts to make a world picture of phenomena are constantly making use of our past experiences, for all terms must be interpreted in the language of experience. Some day when people become truly scientific the state will purposely train persons to obtain as varied an interpretation of nature and life as possible. Imagine a person whose only sense was hearing. What would he write as the encyclopædia of knowledge? Compare with that person one who saw the universe by means of any electromagnetic vibration, who possessed a sense attune to the electric field and the magnetic field, who could "feel" the various phases of each molecular impact and we get some appreciation of what a "broad view" of our world and the universe should be. Our advancement in science will become very rapid when a large number of the people will throw off the shackles of heredity and environment and develop new "philosophies" of Truth. Up to the present only some of the
powers of a very few individuals directing an infinitesimal portion of the wealth of society have endeavored to effectually map out the Republic of Truth.

By sufficiently correlating our sensation stimuli we are able to find a source for all the stimuli that our sense organs receive.

The source of sensation stimuli may be defined as matter. The means by which these stimuli reach our sense organs are "direct" (touch, taste, and muscular sensations) and "indirect" (sight, sound). The terms direct and indirect are sufficiently evident to all of us. But how are stimuli transmitted by the indirect method? Only two means are conceivable. Either the indirect method consists of particles, entities or what not, passing from the source of the stimulus (i.e., matter) to our sense organs, particles that we do not or cannot notice, or there is an intervening medium that carries the means that affects our sense organs. The former method may be designated as the "bullet" type of radiation and the latter as the "wave" or "pulse" type of radiation. All our experience is unanimously in support of the view that it is impossible for us to receive either separate or direct sensation stimuli from a single or any natural group of "bullets" or direct sensations from the "medium" itself so that it follows that matter must be the source of all radiations. Neither the "bullets" nor the "medium" can therefore consist of matter as above defined. All our concepts of the physical world except some of those that can be derived by the "direct" method of sensation must be correlated by the use of space, the element necessitated by the term motion. Our concepts of time, space, the "ether," the "electric," "magnetic" and "gravitational" forces, etc., are plans of the physical world for "explaining" or rather correlating and classifying our sensations.

Our present work is largely restricted to the application of the "atomic" theory to our view of the external world. Whenever we obtain sufficient knowledge concerning any concept of the external world so as to be able to apply the atomic theory to the phenomena representing that concept then that concept ceases to be merely a plan and becomes something finite and discontinuous. Terms that simply represent plans of the external world usually possess continuous and infinite values. Any quantitative application of such terms to the external world or
of anything is arbitrary. There can be no natural unit of time, of space, of the electrical field or of the ether until these quantities are shown to be atomic. Concepts that are merely plans of the world are used for convenience. When these terms cease to be useful they are discarded. Any term representing something in the world that possesses an atomic composition may be said to be "real," the atoms being natural units. It is one of the aims of the physicist to prove an "atomic" composition for as many physical concepts as he can.

At present some of our more important physical concepts are those of space, time, matter, the electric, magnetic and gravitational fields and possibly a chemical field of force. Energy is found to be related to matter or vice versa. The means by which energy is transmitted from one portion of matter to another portion is by three methods, the "bullet," the "medium" and the "direct contact" methods. All types of radiation that cannot be shown to consist of moving particles of matter must naturally be included in the "bullets" or the "medium" types of transmission. In the bullet type of transmission "entities" or elementarquanta" of unknown properties must carry the energy from the emitter to the absorber. In the medium type the intervening medium is made to carry the energy and this process necessitates the particles of the medium transferring the energy from one to the other.

Crudely drawing a rough analogy between the humanistics and the natural world we might correlate the terms money and energy and people and matter. The elements of money are cents, of energy, radions, of people, men and women, and of matter, electrons and the natural atoms. Money in the pocket is kinetic energy that makes "the mare go." Relations with other people result in the interchange of the circulating medium. Money in a bank is a field of force that draws men to or away from it according as their bank account is positive or negative. The marriage of a positive and a negative ion destroys a tremendous amount of kinetic energy of pocket change as those old neutral atoms of married men can verify. And most of the collision phenomena of individuals can be or at least is attributed by their enemies as being one of money relations or forced by future hopes of this variety. So it is that terms are used in "exact" and "fundamental" science and in the other affairs of men.
THE GATEWAYS OF KNOWLEDGE

TRANFORMATION PROCESSES OF PHENOMENA

<table>
<thead>
<tr>
<th>Mental World</th>
<th>Gateways of Communication</th>
<th>The Physical World</th>
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<tbody>
<tr>
<td>Continuous currents of entities in the stream of time.</td>
<td>A flow of entities back and forth between the two worlds</td>
<td>Continuous currents of entities in the stream of time and space.</td>
</tr>
<tr>
<td>By analogy many believe that certain elements in this world are conserved as in the physical world.</td>
<td></td>
<td>All &quot;laws&quot; indicate a conservation and nondisappearance of certain elements in this world which can therefore be defined as the &quot;fundamental&quot; elements.</td>
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<tr>
<td></td>
<td>By analogy many believe that certain elements in this world are conserved as in the physical world.</td>
<td>Eventually our convenient elements (e.g., atoms) will be made the &quot;fundamental&quot; elements.</td>
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</table>

Because the elements of one world can be transformed into elements of the other world and because there are "fundamental" elements in the physical world we believe that these remain conserved during their transformation and hence must exist as such in the mental world. A law similar to the second law of thermodynamics could intervene by making the flow of these fundamental elements such that they would eventually reach the reservoir of the physical world. But by analogy we can imagine "angels" that could control the transformation processes and even reverse their flow.

The above assumption that all the phenomena of the physical world are intelligible, i.e., can be transformed into elements of the mental world and vice versa and that all these elements can be derived and are constructed from a few fundamental elements that are conserved (i.e., are indestructible) may be assumed as a system of philosophy, the "source," "base" and "ending" of the system being the fundamental elements.

As the "elements" of the mental world are obtained from the transformation of "elements" of the conserved ensemble we will assume that the laws of this ensemble apply to both realms.

Law 1.—There is a conserved nondisappearing ensemble of mental elements in which an electrical element is "absolutely" conserved.

Law 2.—The equations of transformation between the "elements" possess a natural direction of flow.
Law 3.—The “medium” provides the only means for this flow of transformations.

To summarize we have transformations in the Newtonian world brought about during “collisions” or the “contact” of magnitudes of ordinary matter. Apparently the ether does not function in these transformations, at any rate the “contact” of two portions of matter is the necessary and sufficient condition and “free space” is a perfect screen in preventing the interchanges. The senses of touch, taste, smell, hearing and the muscular sense apparently operate by the contact process. Our individual and racial growth has founded our knowledge very largely upon a Newtonian philosophy.

The transformations which take place through the ether and whose emission and absorption are largely if not entirely “electrical” (such as light and heat) are observed through the eyes and the temperature sense. How the nerves transform these sensations before they reach the brain we do not know though they appear to be at least partly electrical. This condition affords the hope that the mind can be reached directly or indirectly by other electrical methods and that new channels of information to the mind may be discovered. This view is especially inviting if the mental processes themselves are electrical rather than Newtonian, the chemical changes being regarded as largely electrical.

The mental world then, is pictured as an ensemble of the fundamental elements of the natural world directed by angel elements of which we, as individuals, are entity systems. We may assume that angels may possess as fine grained a structure as the natural entities, and that the angel elements are as certainly conserved and nondisappearing, though as subject to transformation, as are the elements of the natural world. Should we care to do so the electrical attributes of the positive and negative could be assigned to the mental elements as they have been to ordinary matter and the ether thus making a complete parallelism in this triune ensemble.
8. SOME PROBLEMS IN PHYSICS

The new science started in geometry. It appeared as an analysis of the axioms assumed by Euclid. We may consider the three geometries to be based on the view that the angles of a triangle are equal to, greater than or less than two right angles and develop the three consistent systems of geometry for Euclidean, hyperbolic and elliptic space. The new science movement consists of a thorough criticism of the axioms or "fundamental" "elements" of any branch of knowledge, the development of as many consistent treatments or "systems" of knowledge as the fundamental elements permit and then comparing these systems to reality by the most exacting and comprehensive empirical methods available.

Applied to natural phenomena the new science applies the keenest analysis possible of the methods, apparatus and the units of measurement. From the "laws" of nature it develops as many consistent systems of science as are possible. That system (applied perhaps in many ways directly and indirectly) which agrees "at every angle" with "reality" when tested experimentally, is then accepted. In natural philosophy the branch of relativity exemplifies the nature of the new science, the problems which it faces and the methods which it employs to answer them.

That the development of the new science is extremely difficult, will be recognized as soon as we enter the laboratory. Let us assume that our physicist is to demonstrate the measurement of the unit of electric charge before a Pharaoh, who has set out to develop the new science of electricity. No metrical instruments are available so that convenient units must be selected. (1) A convenient length is chosen and used as a standard; (2) the Newtonian or some similar type of mechanics is carried sufficiently far to define and measure forces; (3) electric charges are generated and disposed so that they simulate point charges; (4) a method of measuring electrical charges is devised and a "definition" and a method of obtaining two "equal" electrical
charges is agreed upon; (5) Coulomb’s law that the force \( F \) of repulsion of two charges \( (e_1, e_2) \) when placed at a distance \( r \) from each other is \( F = \frac{e_1 e_2}{kr^2} \) is obtained experimentally.

(6) The law \( F = \frac{e_1 e_2}{kr^2} \) must be verified as being consistent with all phenomena as they may be known in the realm of Pharaoh. The law is then assumed to be “universal.” (7) The magnitude of the charges is independent of the kind of matter with which they may be associated; (8) the temperature; (9) the kind of matter along \( r \); (10) the presence of a magnetic field; (11) the earth’s gravity field; (12) the rotation of the earth or its motion in space; (13) \( k \) is assumed to be a constant; (14) the force \( F \) is assumed to be independent of the streams of energy flowing about the charges.

(15) After having subjected Coulomb’s law to a thorough investigation of which the above is but a very superficial analysis and having found it to be consistent with the ideas of Pharaoh, we employ it to define the unit of electric charge. Two “equal” “point” charges of electricity, each possesses unit magnitude when they repel each other with a force of one dyne when separated a distance of one centimeter in a medium whose dielectric constant is unity.

The difficulties of the new science can be the better appreciated when Pharaoh asks if these conditions apply to two electrons carried along by the front of a light wave; by two electrons existing in the center of the sun; by two electrons rotating in a uranium atom; or by two electrons in the brain of a person swept by the thought storms of “new” science.

Yet the difficulties of applying the philosophy of the new science to natural phenomena are not as appalling as we might at first expect, and this condition is due to the most marvelous simplicity of natural phenomena. If there is any reason for optimism and for faith it lies in our being able to successfully apply the new science to phenomena unreachable to our sense organs and to find that the fundamental elements of these phenomena are extremely simple and apparently form a single consistent system.

We have only to point to the complex phenomena of electricity. So far as our knowledge extends all electrical phenomena can be consistently explained by means of the electron
and natural atoms. The hidden shadow of this is the positive charge denoted as the positive electron. Like "potential" energy the positive electron is assumed to explain the disappearance of the negative electron.

The "single consistent system" is denoted as the natural philosophy of the new science. The new science asserts that there is an ensemble of fundamental elements in the universe and that all natural phenomena consist in the transformations of the fundamental elements according to laws which it is the problem of science to ascertain. With a knowledge of the fundamental elements, the laws of the system and a certain "locus" of conditions, the whole universe system can be mapped. It is the aim of the new science to so map all natural phenomena and then to test these results experimentally.

The modus operandi of this tremendous task is that of dividing the universe into entity assemblages. In any entity assemblage phenomena may be considered as forming a system where a common "atmosphere" prevails. As an example we may consider the ordinary earth phenomena to form an entity assemblage where Newton's laws of motion consistently apply. There is the atmosphere of Newtonian mechanics everywhere pervading the assemblage. It of course follows that the entity assemblage will be determined largely by the point of view. We shall view phenomena in terms of the apparatus, convenient units, methods of observing and laws of physics required to map them as the factors determining the entities.

The procedure will be that of developing a consistent and convenient system of physics for each entity assemblage. The ensemble of entity assemblages will then be considered with a view of adopting a single universal system of physics. When this work has been successfully completed the new science of physics will be the result.
9. THE DIRECTED ELEMENTS

Amongst the elements that are necessary in the development of a science employing geometrical processes are those that possess the quality of direction. In the Newtonian mechanics rigid bodies are well suited for defining directions as the parts can be marked and a set of coördinate axes established with comparative ease. But when the simpler ensembles of natural elements such as rapidly moving electrical charges and the ether are to be given a geometrical interpretation the problem of defining direction and of measuring elements that possess a directive quality is very different.

The natural direction most used in the past has been that of the axis of rotation of the earth. Knowing that this axis is subject to a certain amount of wobbling, the North Pole star has been used to define direction. But it is fully understood that this “north” direction is not constant or absolute when so defined. It is then natural to hunt through the entity systems of nature to see if in any sense direction can be absolutely defined or if it will always be necessary to speak of direction in a local sense and employ that local direction (such as that of the earth’s axis) that is most convenient for our purpose.

Of the “directed” quantities it appears that the ether states such as the electrical, magnetic and gravitational fields possess somewhat similar “directive” properties. The gravitational “direction” is unidirectional in that a mass always experiences the same directive effect whereas the electric and magnetic fields exert reversed directive effects according as a plus or negative and a north or south magnetic pole is placed in the field. Ordinarily the “direction” quality of the electric field is assumed fixed the same as it is for the gravitational field. We may go so far as to consider the physical world as possessing a certain number of direction “elements” and that these elements may possess an “atomic” structure.

The elements that appear with directive properties include electric charge, natural matter, time and length if defined by means of a rigid lattice structure such as possessed by crystals
and assumed for a "latticed" ether. If our lattice structure is not isotropic, this property serves to define direction also. Some of these directed qualities resemble the series of positive and negative numbers in that the sum of a "negative" and a "positive" unit results in a disappearance of both units. Directed qualities of this type may aid in defining an origin for an ensemble. Other magnitudes such as temperature, mass and entropy do not possess "negative" values.

There are certain systems that appear to possess "absolutely" directed quantities. We can imagine a system of science developed in the interior of a crystal (placed in a liquid) for which an "absolute" origin of space coordinates could be defined that would introduce a symmetry into phenomena that would otherwise not be possible. The lattice work of the crystal would provide a means of defining "direction" in an "absolute" manner especially if the crystal lattice work is not isotropic. The most symmetrical form of physics that could be developed would apparently be that in which the center of the crystal would be the origin of the coordinate axes. The "direction" of any atom from the origin in the lattice work could be defined as so many "lattice" spaces along each one of the crystalline axes. If the minimum length of measurement was the distance between two neighboring lattice elements, then the "atomic" angle of "direction" would be that subtended by a lattice element at the boundary of the crystal.

The number of independently "directed" elements of the physical universe may aid in indicating the number and nature of the "fundamental units" of science. The number of "directions" may give the degree of the manifold of phenomena. Thus we may agree that the ether fields of force give us the three "directions" of extension, the succession of events gives us the "direction" of time and the entropy and radioactive changes give us the "direction" or the "running" down of the universe. If these could be considered as fundamental and independent "direction" elements just as length, mass and electric charge have been considered as fundamental physical elements then the universe "space" would consist of five dimensions and physical transformations would take place in a 5-manifold. The degree of the manifold will determine the nature of the geometry to be adopted.

Let us assume that the physical space is to be defined by ul-
timate and directed elements that are conserved and never disappear. Let us assume a lattice type of an absolutely stagnant ether and that the magnitudes of the axial quantities are to possess positive and negative characteristics. An arbitrary origin and direction is marked on the lattice work. A stream of radiation is directed so that its energy flow is along that of the arbitrary axis. The electric and magnetic vectors of this radiation stream could be assumed to define two more axes; an electric charge and a time axis - could be added thus constituting a 5-manifold space. On account of the universal existence of the ether in all entity systems it seems most promising to expect any absolute definition of directed elements to be made with reference to the structure of the ether. Up to the present all definitions of this sort have been local and except for the ether there appears no other base for a universal science. It is for this reason that the transformation of the direction properties of any magnitude from one ensemble to another is very difficult.

We can picture the energy changes and atomize the direction qualities that enter into these changes by assuming radion elements for the elementarquanta. These radions contain the elements of directed energy. To give extension there is assumed six types of radions, a type for each quadrant, there being positive and negative radions whose oppositely directed energy neutralizes with the result that any element containing these two elements would be at rest. The radions could be considered as $\pm rx, \pm ry$ and $\pm rz$. The motion of any body could be described as being due to its containing a given number of these radion elements in the way that we describe motions and forces by considering the projected components on the axes. Collisions would be described by the interchange of radions. Fields of force would be regions where a certain type of radion predominated and matter, charge and the ether would be the vehicles of radions. We could assume the radions to be conserved and to be the ultimate energy elements. The assumed positive and negative characteristics of charge, natural matter and the electroethons could be attributed to the radions. A reason for not attributing these energy properties to the ether is that the ether is frequently assigned a stagnant quality when we wish to define direction absolutely. This objection is removed however, when we consider the energy direction of the radions to be conserved.
If, then, energy can all be considered to be kinetic and the trend of modern discovery supports this view, it is possible to believe that all directed quantities may consist of three elements. A quantity such as time may be the measure of energy changes and therefore a function of other quantities.

The theory of relativity indicates that we can only determine relative motion and that in the case of rotation, we can say, that if our universe was set rotating, the physical laws would be changed.
10. THE GENERAL ENTITY VIEW OF THE UNIVERSE

In taking a survey of phenomena we find that there are systems that are more or less complete in themselves and to a great degree isolated from each other. These systems are invariably composed of similar parts, individuals, groups, atoms or entities as we may wish to name them. This universal condition is described as the entity view of the universe. To be seen in a clear light the entity structure of any system must be observed from a finer grained system than the system under observation. From our everyday world water may be considered as a continuous fluid and its behavior can be accurately described by hydrodynamical equations assuming that water is a perfect fluid. Viewed from the electron world however, water consists mostly of space filled at rare intervals with whirling electrons and the positive nuclei of hydrogen and oxygen atoms.

The entity or atomic theory of phenomena has been found to be universal and applicable everywhere if a finer grained system could be employed in the laboratory than the one under observation. Experience would therefore lead us to consider all systems as constituted of entities. The second experimental law of the entity structure of systems is that the number of different entity elements becomes less as the system becomes finer grained. The complete entity view would then lead us to consider the finest grained system as consisting of a single entity element.

(a) The large star and nebulae systems that drift in groups through space probably give us our coarsest grained system with the stars as entity elements. The adaptation of the laboratory and the units to suit the system is very well illustrated by the use of the light year as the unit of length for this system.

A few relations appear among the stars and the nebulae. The redder and apparently “older” stars and a class of nebulae possess greater velocities than the hotter stars. An effect, such as a differential light pressure on a moving star, might result in a star system increasing its velocity as it grew older. The universal appearance of substances, such as hydrogen, sodium, calcium and iron in the star systems, indicates a common atomic constitution of the universe, and the view is that the universal existence of this form of matter is due to similar boundary conditions.
with the ether, rather than to any intercommunication of this matter between the stars. These forms of matter have been genetically formed in situ in the particular entity system from the ether and the elements that the ether can transmit, such as the electromagnetic vibrations. The origin of a star center may even be cyclonic, starting from a peculiarly unstable condition of the medium.

The sorting that takes place in an entity system, is illustrated by the appearance of spectra in the nebulae and nebulous stars that are unknown on the earth. Were it not for "low temperature" compounds, such as water and the radioactive elements, hydrogen and probably helium, would be unknown to us. Assuming the width of spectrum lines to vary as the square root of absolute temperature, Buisson and Fabry have found the "temperature" of the Orion nebula to be about 15,000°.

(b) Our solar system with entity elements of the planets, satellites, and comets is probably the best ordered entity system known and the most accurately described at the present time. Undoubtedly this system as a whole is one of the atoms in a star system. The almost perfect ordering of the system is due to its being in a steady gravitational state. Only collisions with minute particles in space occur. We have only to imagine collisions with similar systems to obtain a very disordered condition. The atomic elements of matter can be compared with much profit to our solar system, the "emptiness" of space inside of the atoms being even more pronounced than is the case of our solar system.

(c) The phenomena that take place on the planets and the sun such as sun spots, storms or the formation of water streams or islands are extremely disordered though there may appear similar entity elements. These elements are short lived. It may be stated that in general the ordering and simplicity of any entity system is proportional to the life period of the entity elements. In the planetary systems many of the phenomena are of the cyclone variety in that their origin is more or less sporadic and due to a play of forces that are infinitesimal compared to those developed at a later stage. Once started the cyclone type of phenomena possesses a track or life that is at least partly amenable to mathematical treatment and prediction but their birth cannot be very accurately predicted.

Cyclone phenomena differ from the trigger type in that the
latter possess a greater degree of uniformity and owe their origin to a source usually outside of the system.

(d) Animal and plant life illustrate atomic structure very well in that the individual plants and animals may be considered as the natural units with the cell to be the universal elemental unit in this whole kingdom of life. Like the atoms of matter the cell possesses a structure.

The world of life presents its individual units with certain polar characteristics of sex which may be pictured as the fading out of the very pronounced polar characteristics of electrical and magnetic entities and of the natural atoms of matter. Many chemists speak of valency as possessing polar characteristics and it is only natural to expect that if the life entities are the continuation of the series of the molecular systems then the polar characteristics not only of the physical life of the individuals but also of the mental and the moral atmospheres of these entities may be the glimmering traces flowing from those extremely fine grained entity systems where these properties are so pronounced.

The operation of ill-defined forces to produce entity systems is illustrated in the university. A man must be either a chemist or a psychologist or some other type of entitist or else he finds himself alone, ostracized and running little chance of securing a stable position in the satellite electrons that are drawn to the nucleus president and board of trustees by the financial forces. The brilliancy of illuminating knowledge to the surrounding spaces of ignorance and the reception of all the hard blows of collisions is the function of the satellite electron teachers while all the force of the system is held by the central nucleus. And if the system is subjected to outside criticism the divine rights of the central powers complacently permits of the ejection of one or more of the outer electrons. So we perceive the faint echoes of the elementary material systems resounding in the clash and din of the far removed entities in the realms of life, even in the sacred institutions of learning.

(e) The molecular systems form the natural units of our ordinary world. The molecules are the units of neutral or ordinary matter and they constitute the natural frontiers of the realm of Newtonian mechanics. The treatment and laws of solids, liquids and gases is essentially the science of molecules and comparatively small molecular systems. An exact and complete molecular science, a full understanding of life phenomena,
the discovery of the missing links between the life elements and the molecules and the practical acquirement of the powers of the angels to control molecular and life transformations remain as some of the fundamental problems for state and other social organizations to grapple with their full energies.

(f) The chemical world lies between the boundaries of the molecular and atomic worlds. Many claim that the transformations that take place here are essentially electrical while others postulate chemical "fields" of force of an elementary nature. The very nature of these claims emphasizes the tremendous field here inviting research work. The backward state of our knowledge of chemistry is due to our not being able to experiment with individual chemical reactions and for the reason that these reactions are extremely variable and are short "collision" phenomena rather than conditions of long steady states such as is exemplified by our solar system.

(g) The atomic world is described in a separate chapter and the ionization world has been briefly treated. The Newtonian philosophy no longer applies and another science arises. The world of the electrons and the natural atoms is essentially an electrical world. The world of ordinary "contacts" ends. The muscular senses are dumb. There is no tactual touch to these phenomena. This is the world of the eye and of radiations. This is the world of the "radions," electricity, magnetism, natural atoms and the ether. A new philosophy reigns. We may call this the electrical philosophy and it has to do with electrons and the "natural" atoms.

Almost a science has developed concerning the family groups of the periodic system of the natural atoms. The radioactivity of the heavier atoms has shed much light upon these family relations in a genetic sense and future experiments promise to show that the 92 natural atoms may possess as simple a constitution as electrical charges. The life history of the stars is closely associated with the birth and death of the natural atoms.

(h) The subatomic world is sketched under the structure of the atoms. This region remains almost entirely for future exploitation as does the (i) radiation entity systems and (j) the ether. We presume that the relative "grain" or fineness of structure of these entity systems is roughly as given: (a) Star clusters; (b) suns; (c) "cyclones" (temporary); (d) living beings (temporary?); (e) molecules; (f) neutral atoms; (g) electrons and natural atoms; (h) helium nuclei; (i) ether electroethons and
(j) radions. The i and j groups can be given their mathematical significance of imaginary quantities.

So much for the existence of entities in the natural world. As you read this page your eye crosses it in jerks; each jerk in a way being transformed into a thought entity. A thought entity, a phrase or a word may be considered as a molecule or an aggregate, this latter being constructed of words, the simple molecules and ultimately of letters, the atoms of our thought structures. Our number system is even simpler, all numbers ("molecules") being formed from nine elementary atoms. Our music is also based on a few notes covering only several octaves.

In a way each thought of the outside world is an entity corresponding to an assumed entity in the natural world. Our science has shown that the elementary entities (electrons and atoms) of the outside world are almost as simple as our atom letters. In addition as the entities become infinitesimal and of a lower order the units are found to become simpler. The means of communication of energy between the larger order of units (suns) seems to be the same as that between the smallest units (atoms, electrons, atom nuclei), thus leading us to believe that all intercommunication between entity systems must be by means of the ether electromagnetic processes.

The entity philosophy is indeed of a very wide and subtle application on account of our mental process. Any thought entity based upon knowledge of the outside world can be applied to that knowledge so that innumerable entities may be assumed. Any physical magnitude may thus be assumed to possess an atomic structure and the assumption made a natural hypothesis to be tested by experiment. And if the ultimate elements of the physical world are atomic in nature, presumably all physical magnitudes will at least ultimately be found to possess an atomic structure. Our fundamental units will however be those of nature. For example the ultimate unit of time would be the shortest periodic occurrence in nature that can be observed, the unit of length, the shortest physical entity that can be used as a measuring bar and the unit of mass, the smallest mass entity that can be separated from other masses.

The general entity theory of nature also asserts that every measurement of natural phenomena must yield a rational integral number when the natural entity elements are employed as units. All natural phenomena are granular and ratios of all natural quantities may be commensurable.
It was established by Dalton and his contemporaries that matter is constituted of an aggregate of discrete entities which are all alike for any homogeneous substance. The smallest portion of matter that can be manipulated by the chemist consists of a vast assemblage of molecules, and his knowledge always relates to the average behavior and relations of a crowd of molecules. Among the smallest quantities of unelectrified matter ever detected was that of neon, one of the inert gases of the atmosphere (there is about one part of neon to 100,000 parts of air). Prof. Strutt has shown that the neon in one-twentieth of a cubic centimeter of air at ordinary pressure could be detected. In this quantity of air there are about ten million million molecules of neon, or seven million times as many neon molecules as there are people in the world.

Dealing thus with such immense numbers of molecules, it is not surprising that nothing concerning any possible individuality of atoms and molecules has ever been detected. Indeed, little is known of the nature of neutral atoms and molecules, or of the forces that operate in interatomic spaces. All our laws are for masses of matter that are extremely large compared with atoms, and cannot be applied to them, without extrapolation. However, chemists have shown that all matter is made up of a number of elementary substances which they cannot decompose. The relative weight of the atoms of these elements are known, and it is becoming more and more probable that chemical combination consists of an arrangement of atoms alongside of each other under steady cohesive forces, the properties of each atom being somewhat, though not essentially, modified by the near presence of the others. It is not wonderful then, that although we are certain that molecules have a very definite structure, when we inquire into the details of their constitution we do not have much more than the distant analogy of familiar dynamical systems to aid us.
The last century gave us a good example of how assumptions and hypotheses that are not disproved by experiment seem to us like the truth itself. The analytical methods of chemistry succeeded in showing that all matter was composed of some ninety-two elements. As no division of matter smaller than the atom was known, and as no case was known of the loss or gain of weight, one of the most fundamental properties of matter, scientists in general began to consider the elementary atoms as the foundation stones of the material universe, which, amid all the changes of molecular structure, remained forever the same.

On the physical side, the mathematical development of the kinetic theory of gases has extended the utility of the atomic theory very greatly. In the kinetic theory the properties of gases are explained by assuming every gas to be composed of minute particles or molecules in continuous motion, colliding with each other at intervals that are short compared with the times between collisions. No definite conception of the molecules or of the forces acting between them is assumed. The molecules could either be considered to be elastic spheres or Boscovitch centers of force, and the gas would show the same general statistical properties.

The kinetic theory of gases affirms that matter is composed of definite units of mass or molecules, and that heat energy consists of the kinetic energy of the motion of these molecules. This kinetic energy may consist of energy of rotation as well as of translation.

In 1859 Maxwell announced the theorem of the partition of kinetic energy. In more recent years the mathematical demonstration has been perfected by Maxwell, Boltzmann, Jeans, and others, so that the evidence has become quite strong in favor of the hypothesis that energy is distributed equally among different types of molecules and also among the various degrees of freedom of each type of molecule considered independently. The molecules seem to be surrounded by fields of force, and it is probably these fields that we measure. Apparently, collisions take place when molecules approach each other sufficiently close for their fields of force to slightly overlap. The nature of these forces is such that molecules, on collision, behave like elastic spheres, practically none of the kinetic energy of heat being frittered away into energy having a comparatively high frequency.

The nature of molecular forces is a problem concerning which
a great number of assumptions have been made. As an example we may take a few hypotheses as applied to liquids. Mills was able to explain some latent heat phenomena by assuming a molecular attraction obeying the inverse square law. Kleeman has deduced the following law,

\[ \varphi \left( \frac{Z}{X_c} \frac{T}{T_c} \right) \left( \sum \sqrt{m_i} \right)^2 \frac{1}{Z^5} \]

where \( Z \) is the distance between the molecules, \( \sum \sqrt{m_i} \) is the sum of the square roots of the atomic weights of the atoms of the molecule, \( X_c \) is the distance between the molecules at the critical temperature, \( T_c \), and the function \( \varphi \) is unknown though it is constant at corresponding temperatures. In the equation of state of Van der Waals, it is assumed that the attraction between molecules varies as the inverse fourth power of the distance between them. Tyrer gives the law \( \frac{K^2}{Z^n} \) where \( K^2 \) is a constant for a given pair of molecules, and \( n \) is not less than 5 and may be greater than 7.

Fortunately many of the properties of gases can be treated without any assumptions being made as to the nature of the molecular forces, the molecules being considered as perfectly elastic bodies occupying a certain volume of space, and possessing a certain amount of heat energy.

The general theorem of equipartition of energy states that the energy of the body is distributed among the different degrees of freedom by which the state of the body as a dynamical system is described, and that an equal share is allotted to each degree of freedom. The mathematical development contains assumptions that can hardly be justified, yet experimental evidence corroborates the view in general.

It should be kept in mind, however, that the theorem of equipartition must be applied in a somewhat restricted form. The energy which corresponds to certain degrees of freedom often does pass away rapidly as energy of radiation, whereas the energy of other degrees of freedom passes away with extreme slowness and by indirect means. It is the latter energy that is indicated by the thermometer and is distributed equally among the degrees of freedom of this type. Jeans assumes that the degrees of freedom that permit their energy to be lost by radiation also possess a temperature which he calls subsidiary. The two types of degrees of freedom are called principal and vibra-
tory. When a gas is heated, practically all the energy is distributed among the principal degrees of freedom.

The distribution of energy in different degrees of freedom of the molecules of various gases has been treated in popular manner by Magie and others, and serves to indicate the nature of molecular structure. Let $C_v$ be the specific heat of a gas at constant volume; $C_p$ the specific heat at constant pressure; $E_0$ the increase in the energy of translation of the molecules of a gas when the temperature is raised from $0^\circ$ to $1^\circ$C. at constant volume; $K$ the energy corresponding to one degree of freedom which a gram molecule of the gas receives when its temperature is raised $1^\circ$C.; $m$ is the molecular weight; and $\gamma = C_p/C_v$. From the laws of thermodynamics it follows that

$$\gamma - 1 = \frac{2 \ E_0}{3 \ C_v}$$

Assume that each one of the $n$ degrees of freedom acquire the same amount of kinetic energy, say $K$. The energy of translation is then increased by $3K$, so that

$$\gamma - 1 = \frac{2K}{C_v}; \ C_v = Kn + P; \ \gamma = \frac{2K}{Kn + P} + 1.$$ 

Where $P$ is an unknown quantity of potential energy.

Assuming that $P = 0$, and that the molecules are points having nothing but translational energy, $n = 3$: $\gamma = 1.66$. This value of $\gamma$ is obtained experimentally for the monatomic gases. Following is given a table of values of $\gamma$ and $n$ calculated from the formula $\gamma = 1 + \frac{2}{n + 3}$.

<table>
<thead>
<tr>
<th>Gas</th>
<th>$\gamma$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>1.666</td>
<td>3.00</td>
</tr>
<tr>
<td>Krypton</td>
<td>1.666</td>
<td>3.00</td>
</tr>
<tr>
<td>Helium</td>
<td>1.652</td>
<td>3.07</td>
</tr>
<tr>
<td>Neon</td>
<td>1.642</td>
<td>3.12</td>
</tr>
<tr>
<td>Argon</td>
<td>1.63</td>
<td>3.20</td>
</tr>
<tr>
<td>Xenon</td>
<td>1.666</td>
<td>3.00</td>
</tr>
<tr>
<td>HCl</td>
<td>1.33</td>
<td>5.06</td>
</tr>
<tr>
<td>Ethylene</td>
<td>1.248</td>
<td>8.06</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1.402</td>
<td>4.98</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.405</td>
<td>4.94</td>
</tr>
<tr>
<td>CO</td>
<td>1.409</td>
<td>4.89</td>
</tr>
<tr>
<td>Air</td>
<td>1.405</td>
<td>4.95</td>
</tr>
<tr>
<td>Nitric oxide</td>
<td>1.394</td>
<td>5.08</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1.402</td>
<td>4.98</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>1.300</td>
<td>6.67</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>1.304</td>
<td>6.58</td>
</tr>
</tbody>
</table>
Assume that $P$ is due to the displacement of the atoms in the molecule. Assume that the motions of these atoms are simple harmonic; then the mean value of $P$ corresponding to each internal degree of freedom is equal to the mean kinetic energy. Let $a$ be the number of degrees of freedom of the atom taken as a whole, and $i$ the number of internal degrees of freedom. Then

$$n = a + i, \quad P = iK, \quad \gamma = \frac{2}{a + 2i} + 1 = \frac{\theta + 2}{\theta}$$

Each internal degree of freedom contains equal amounts of kinetic and potential energy, each amount of energy being equal to that in an external degree of freedom.

In the case of the monatomic gases, $i = 0$, $n = 3$, $\theta = 3$ $mC_p = 4.943$. The theoretical value of $\gamma$ is $1\frac{3}{4}$, and it is found experimentally that the value of $\gamma$ ranges between 1.64 and 1.66 for mercury vapor, krypton, helium, and argon and the vapors of many metals. The value of $\gamma$ therefore indicates that the whole energy of these gases is translational, and that the molecules of these gases are spherically symmetrical so far as their internal structure is concerned. If the structure of the molecules was not spherical, some translational energy would be changed into rotational energy at each collision, but the value of $\gamma$ indicates that there is no such equipartition, and the dissipation of this rotational energy must be very small, since the gas loses energy very slowly. It therefore follows that little if any energy goes into producing rotation.

In the case of diatomic molecules, the value of $n = 5$ gives a value of $\gamma$ that agrees very well with the experimental value as found for hydrogen, nitrogen, oxygen, nitrous oxide and hydrobromic acid. This value of $n$ corresponds to the number of external degrees of freedom if the distance between the atoms of these molecules remains constant. The values of $\gamma$ for chlorine, bromine and iodine, indicate that each of these gases has an internal degree of freedom to which energy is distributed.

The possibility of the variability of the distance between the atoms of some of the diatomic molecules, may be correlated with the fact that bromine, iodine and chlorine have such characteristic absorption spectra, and dissociate at comparatively low temperatures.
The elucidation of the conditions underlying the partition of energy among the degrees of freedom of bodies is a very interesting and important study and the few data here given serve more as an illustration of the subject than as an outline of our knowledge.
Some very remarkable relationships have been discovered in recent years as regards the nature of the system of matter atoms. Atoms have been compared as regards their atomic weights, their chemical properties, their electrical properties, their spectra and lastly and probably most fundamentally by means of their characteristic \( x \) radiations, as discovered by Moseley, and which states that the square root of an atom's \( x \) radiation frequency is proportional to the atomic number which represents the number of excess electrons outside the nuclei. This law gives 92 elements all but six of which have been discovered.

The disintegration of the atoms of uranium and thorium into a large number of resultant atoms in a genetic series has thrown much light upon the nature and the relationships of the high-number atoms and that these atoms all contain helium. The discovery that an atom of lead may have a variable atomic weight and yet manifest the same chemical properties and emit the same spectral lines has lead to the theory of isotropes, atoms that we ordinarily consider alike as regards their properties except as regards the exact nature of their nucleus and which have different disintegration histories.

The law governing the rate of disintegration of any simple radioactive element or product is an exponential one. If there are \( N_0 \) atoms of this product at a time \( t = 0 \) and \( N \) atoms at the time \( t \) then,

\[
N = N_0 e^{-\lambda t}
\]

\( e \) is the base of the natural system of logarithms and \( \lambda \) is a constant characteristic of the given radioactive substance. One has,

\[
\frac{dN}{dt} = -N \lambda e^{-\lambda t} = -\lambda N
\]

The number of atoms disintegrating per second is a fraction equal to the product of \( \lambda \) and the number of atoms existing at
the time. The same law applies to an irreversible monomolecular chemical reaction. The time \((T)\) required for half the active material to disintegrate is 

\[
\frac{N}{N_0} = \frac{1}{2} = e^{-\lambda T} \quad T = \frac{\log 2}{\lambda \log e}.
\]

The average life of any atom \(\theta\) is given as follows:

\[
\frac{1}{N_0} \sum t \lambda N dt = \frac{1}{N_0} \int_0^\infty \lambda N t dt = \frac{\lambda}{N_0} \int_0^\infty N_0 t e^{-\lambda t} = \frac{1}{\lambda} = \theta
\]

The disintegration of a mixture of radioactive substance can be obtained in the same way as given above, the computations becoming quite difficult however, for a large number of radioactive substances.

The above law for the disintegration of a simple radioactive substance is that given by chance. Let \(X dt\) be the probability that an atom is destroyed in the time \(dt\). If this probability is independent of the instant considered and of the number of atoms, then \(\lambda\) is a constant. If \(N\) is the number of atoms and \(-dN\) the number that disintegrate in the time \(dt\), one has,

\[
-\frac{dN}{N} = \lambda dt \quad \text{and} \quad N = N_0 e^{-\lambda t}
\]

This law only applies when \(N\) is very large. When \(N\) is small the value of \(-dN\) will show fluctuations with the time.

There appears to be a relation between the velocity of the emitted \(\alpha\) particle and the constant of disintegration \(\lambda\). A form of this relation sometimes given is \(\log \lambda = a + bV^n\), \(a\) and \(b\) being constants, \(V\) the initial velocity of the \(\alpha\) particle and \(n\) a number such as 1 or 2. The complexity of \(\beta\) rays and the possible diffraction effects produced by \(\gamma\) rays promises to give us many valuable glimpses into disintegration phenomena.

In the radioactive changes that take place with the emission of \(\beta\) rays, the \(\beta\) particles may be ejected from the atom through different "avenues." The emission of \(\gamma\) rays may therefore, depend upon the "avenue" through which the \(\beta\) particle escaped. According to Rutherford it seems that \(\gamma\) rays are the "characteristic" \(x\) radiation of the given element. Rutherford has also shown that the energy of the \(\beta\) particles emitted by a product such as radium \(C\) can be represented by a value \(pE_1 + qE_2\) where \(E_1\) and \(E_2\) are constants and \(p\) and \(q\) are positive.
integers (or zero) having a different value for each group of $\beta$ rays. A detailed energy study of the radiations will throw much light on radiation theory.

The nature of molecular collision phenomena indicates that the outer regions of the molecules and atoms are the seats of repulsive forces. Whether the atoms possess a structure or "shell" from which certain "avenues" of egress or absorption of electrons is possible is of course an open question. If as we believe there are reasons for assuming a structure for the ether in the nature of a lattice work it is natural to expect the atoms to possess a peculiar ether framework. In the ether vortex theory the atom contained closed vortex rings. We may picture the atoms as containing closed ether "threads" or "lines" of force such that an electron would rotate about one of these closed "lines" of force in the same way that it follows a "line" in the ether. The repulsion experienced during collisions would be due to the mutual reactions between these lines. While following a "line" the electron would be in a steady state but in passing to another line radiation might take place. Isotropes such as radium lead, thorium lead and ordinary lead might possess the same "line" structure and would be alike as regards radiation properties while the nuclei differ.

Experimental evidence has been obtained for the formation of a branch series in the study of radium $C$. Recoil methods indicate that radium $C$ is complex consisting of radium $C_1$ and radium $C_2$. A very small amount of radium $C_2$ is obtained by recoil from the active deposit and it appears that radium $C_1$ may disintegrate into either radium $D$ or radium $C_2$. Similarly in the breaking down of uranium it seems that two products, uranium $X$ and uranium $Y$ may be formed simultaneously, the relative amount of uranium $Y$ being very small. In the case of thorium some experimenters have concluded that thorium $C_1$, and the parent of thorium $C_2$ are simultaneous products of thorium $B$.

K. Fajans considers that the scheme of disintegration of $RaB$ may be as follows:

$$
\begin{align*}
\beta & \quad RaC_2 \xrightarrow{\alpha} \\
RaB \rightarrow RaC \xrightarrow{\beta} RaC' \xrightarrow{\alpha, \text{em.}} RaD \rightarrow RaE \rightarrow RaF
\end{align*}
$$
The period of \( RaC_1 \), is 19.5 min. and of \( RaC_2 \), 1.4 min. The ratio of the number of atoms disintegrating in the branches \( RaC_2 \) and \( RaD \) are as 3 to 10,000 about.

The short heavy arrows indicate a disintegration where a \( \beta \) particle has been emitted from the central nucleus. The atomic number is increased by one. A long arrow indicates the loss of an \( \alpha \) particle and a decrease of the atomic number by two. Elements with the same atomic number are isotopes and possess the same chemical and physical properties. Element 92 has 6 valency and 86 other "outer" electrons; 90 has 4 and 86; 88 has 2 and 86; 86 has 0 and 86; 84 has 6 and 78; 82 has 4 and 78.
The radioactive changes of the atoms are of tremendously great value in analyzing the system of elements. A careful comparison of the radiation, atomic weight, chemical and other properties of the atoms leads to many important relationships and it is not being too optimistic to say that in the immediate future we may discover the ultimate elements that go to make the nuclei of the atoms and to construct the family tree of the whole system of elements and to learn the laws involved in these changes. Perchance we may even be able to direct some of these changes.
Hypotheses concerning the structure of atoms are comparatively new since it has only been a few years that any clues have been obtained relating to inner atomic phenomena. Lord Kelvin and Helmholtz were inclined to view atoms as a type of vortex ring in the ether and by assuming that the ether was a frictionless fluid they could show that these rings would continue to rotate forever once they had been set into motion. The indestructibility of the ether atom agreed with the chemist's views at that time. Atomic models of this type were not found to be helpful in "explaining" the properties of atoms and hence they gradually ceased to interest investigators.

The discovery of the electron, the prediction of the effect of a magnetic field upon the vibrations of light centers by Lorentz and its experimental verification by Zeeman, the many electron phenomena of spectroscopy and radioactivity, the Stark effect of an electrostatic field upon the vibrations of light centers, the absorption of $\alpha$ and $\beta$ rays, Barkla's and Moseley's work on $x$ radiations, these and many other phenomena have recently contributed important data that aid greatly in an interpretation of the intra-atomic world and have actually made the subject of atomic structure a branch of experimental science. Investigators have therefore frequently endeavored to picture the atomic structure from their point of view as being spectroscopic, chemical and radioactive. It is for this reason that the same problem has been elaborated in such a way as to lead one to suppose that several atom models are equally capable of explaining known phenomenon. In the present chapters we will describe several types of models.

In attempting to explain atomic structure and the phenomena that take place within atoms or even in their near vicinity we must remember that we have truly entered into a mystic "country." Gravitation, the existence of point forces, our laws of mechanics, of magnetism and electrostatics, our methods of measurement, the use of Euclidean geometry, the nature of light and electromagnetic waves may be meaningless expressions
for these phenomena. How can we define a unit of length to an intra-atomic being? How can we define a unit of time? What is the nature of radiation under these conditions? Can it be expressed by equations in the same way that it is expressed for free space or are its properties all different? What happens when a beam of x-rays pass an atom? How does an atom absorb or radiate energy? What effect does a violent collision have upon an atom? What takes place when one radioactive atom changes over into an entirely different kind of atom?

Amongst the earliest types of the electron model of the atom is that elaborated by J. J. Thomson. This atom consisted of a uniformly distributed volume charge of positive electricity in a sphere of atomic size. In the outer region of this sphere were large numbers of negative electrons, the charge of the electrons being equal to that of the positive sphere, these charges practically neutralizing each other. The electrons were usually assumed to be rotating about the atom in much the same way as the particles in the rings of Saturn. For this reason Thomson’s atom model is often called the Saturnian atom. At one time it was thought that a large part of the mass of this atom was due to the electrons in it. This large number of electrons thus required was a view welcomed by the spectroscopists who aim to explain the complex spectra of the elements.

The Rutherford atom differs from the Thomson atom in that the positive charge is concentrated into a small volume at the center of the atom. Both types of atom assume much the same distribution of negative electrons. The Ritz atom model assumes the existence of magnetic poles and makes little if any use of positive and negative charges though of course magnetic poles could be obtained by the proper motion of one or more electrons. A free magnetic pole (magneton) has also been assumed, the magneton playing the same rôle in magnetic phenomena that the electron does in electricity. Various “dipoles” “neutrons,” positive electrons, etc., have been hypotheticated.

The English physicists have been very active in developing an atom model for the interpretation of physical phenomena and probably the two best known models are those of Thomson, and Rutherford and Bohr. The early work of Thomson and others of the Cambridge school proved the existence of electrons in the numerous types of vacuum tube discharge, in the emission of electricity by hot bodies, in the photoelectric effect
and directly or indirectly in nearly all phenomena of ionization and radioactivity. The Zeeman effect, dispersion and many other optical phenomena, metallic conduction and the various electrical and thermal properties of the metals indicated that the negative electron existed as a component part of practically every kind of atom. On the other hand no corresponding free "positive electron" has ever been isolated and although indirect (spectroscopic) evidence of its existence has been obtained yet this evidence is far from conclusive. Positive charges are always found to accompany masses of atomic size so that it is natural to assume that positive charges are due in every instance to the removal of negative electrons from the "atom." Positive atom ions therefore differ amongst themselves in the way that atoms differ. On the other hand negative electrons appear to be identical no matter from what kind of atom they are removed.

Thomson naturally assumed his atom model to consist of electrons and a positive charge sufficiently large to neutralize the charge of the electrons. The positive charge was considered to be uniformly distributed throughout the atom, the electrons moving about freely through this positive charge and being attracted toward the center by a force whose intensity is indirectly proportional to the square of the distance of the electron from the center. Some electrons may describe closed orbits within the atom or within the atom's neighborhood or they may vibrate about certain positions of equilibrium. Rings of electrons rotating about the center of the atom may exist. These rings may all be in one plane (Saturnian atom) or they may be located in different planes.

One of the most successful simulations of the Thomson atom to phenomena is its "explanation" of the various families of elements. The Mendelejeff classification of the elements is based largely on the "valency" properties of different atoms and Thomson showed how a model containing one or more rings of electrons could represent the different families and the different valencies. The analogy is indeed very striking but it remains a mere analogy. It is pretty generally conceded that valency in chemistry is an electron phenomena and many have gone so far as to consider the valency of an atom to be the number of electrons it is capable of gaining or losing. This view of valency gives this quantity a vector quality. This interpretation of
valency also offers a picture as to how atoms can combine with each other to form molecules of greater or less stability. Unfortunately we have few ways of verifying any conclusions of this kind and it may be said that our knowledge of interatomic structure is more certain than our knowledge of intramolecular structure. On the whole it seems quite certain that chemical phenomena and most of the physical properties of substances depend upon "some outer" or "valency" electron atmosphere of the atoms and that the remainder of the atom plays a very small part in these phenomena. The absorption of the bullet type of radiation ($\alpha$, $\beta$ and the ion radiations) is in marked contrast to the absorption of light and heat and is more or less entirely independent of the physical and chemical nature of the absorbing substance, depending only upon its density. According to this view the stability of atoms is to be attributed to the part other than the "electron" atmosphere while the wonderful variety of physical and chemical changes are due largely to the changes taking place among the various interlocking electrons. The universal distribution of electrons results in these changes being infinitely more simple than they would be were there as many types of electrons as there are atoms of matter. The impenetrability of solids under ordinary conditions, their small diminution of volume when cooled to very low temperatures and their small compressibility seem to indicate that the "electron atmosphere" of an atom or molecule possesses quite a definite volume which is not greatly affected by the heat motions of molecules.

Some interesting models of the Thomson atom have been made by floating magnets upon mercury or by suspending small charged spheres so as to be acted upon by a central force. Under these conditions the magnets and spheres arrange themselves in concentric circles depending upon their number and the intensity and direction of the forces. Probably the most elaborate work of this kind has been done by Crehore. By assuming definite models it is possible to calculate when two atoms can combine with one another or in other words occupy places where the interacting forces are in equilibrium. These positions of equilibrium depend upon the velocity as well as the number of electrons in the model. In the case of two atoms having two electrons each it is shown that there are two places where the forces of attraction and repulsion neutralize. In this way it may be possible to
explain the size of molecules, the spheres of action of molecules, the formation of aggregates, etc.

In order to account for the reflection and scattering of \( \alpha \) rays, Rutherford's theory assumes that the atom must be the seat of sufficiently intense electrical forces to reflect an \( \alpha \) particle in certain encounters. He assumes that an atom possesses a central nucleus of charge \( Ne \) sufficient to neutralize the surrounding charges. This charge is considered as a point charge and an \( \alpha \) particle passing near this nucleus will be caused to move in a hyperbolic orbit giving a deviation \( \phi \) to the \( \alpha \) particle, where \( Ne \) is the central charge; \( p \) the perpendicular distance from the nucleus to the original path of the \( \alpha \) particle, \( E \) the charge of the \( \alpha \) particle of mass \( m \) and velocity \( v \),

\[
\cot \frac{\phi}{2} = \frac{2p}{b} = \frac{2pmv^2}{NeE^2}.
\]

Let a beam of \( Q \) \( \alpha \) particles pass through a thin screen of thickness \( t \) containing \( n \) atoms per unit volume. The number of \( \alpha \) particles per unit area (to be counted by the scintillation method) on a screen at a distance \( r \) from the radiator is

\[
y = \frac{ntb^2 \cosec^4 \frac{\phi}{2}}{16r^2}.
\]

Geiger has found that \( y \) varies as \( t \) and as \( \cosec^4 \frac{\phi}{2} \) over quite a wide range of angle. The value of \( Ne \) is about 100e for gold, \( N \) varies as the atomic weight.

Darwin assumes a type of atom similar to that assumed by Rutherford. The penetration of atoms by \( \alpha \) and \( \beta \) particles is then reduced largely to the action of the outer electrons in receiving energy. Bohr assumes that the rate of decrease of velocity of the \( \alpha \) or \( \beta \) particle depends on the frequency of vibration of the electrons in the absorbing material. Bohr concludes that the hydrogen atom only contains one electron outside the nucleus while the helium atom contains two such electrons.

Nicholson has assumed that the whole mass of the atom is of electrodynamic form due to the presence of equivalent amounts of positive and negative electricity. The negative charge consists of electrons and is now generally admitted to constitute but a small part of the total mass of any atom. The unknown positive charges may therefore be regarded as consisting of units that
are very small compared with that of the electron and since the inertia is proportional to $\frac{e^2}{a}$, $e$ being the charge and $a$ the radius, the mass contributed by the positive charge may be made to represent nearly the whole atomic mass. These positive charges may be assumed to be distributed uniformly throughout the atom.

The single positive electron is not supposed to exist in a free state. Permanence may be assumed, according to Nicholson, to systems of two, three, four, five, etc., negative electrons in rings at equidistant intervals around a single concentrated positive charge. Four so-called protyles or primary atoms are constructed according to the first four models given above and the atoms of the various elements are supposed to consist of these protyles uniformly distributed throughout their volumes. These protyles are coronuim, hydrogen, nebulium and protofluorine respectively. These protyles may consist of multiples of the above electron construction. Their relative atomic weights are Cu 0.5131; H 1.008; Nu 1.6277 and Pf 2.3604. The extraordinary agreement between the calculated and the observed atomic weight is remarkable.

<table>
<thead>
<tr>
<th>Element</th>
<th>Constitution</th>
<th>Calculated atomic weight</th>
<th>International atomic weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td>NuPf</td>
<td>3.988</td>
<td>3.99</td>
</tr>
<tr>
<td>Lithium</td>
<td>H$_2$Nu$_2$</td>
<td>6.900</td>
<td>6.94</td>
</tr>
<tr>
<td>Glucinum</td>
<td>H$_3$Pf$_3$</td>
<td>9.097</td>
<td>9.10</td>
</tr>
<tr>
<td>Boron</td>
<td>H$_3$He$_3$</td>
<td>11.000</td>
<td>11.00</td>
</tr>
<tr>
<td>Carbon</td>
<td>H$_4$He$_2$</td>
<td>12.008</td>
<td>12.00</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>H$_6$He$_2$</td>
<td>14.020</td>
<td>14.01</td>
</tr>
<tr>
<td>Oxygen</td>
<td>H$_4$He$_3$</td>
<td>15.996</td>
<td>16.00</td>
</tr>
<tr>
<td>Fluorine</td>
<td>H$_7$He$_3$</td>
<td>19.020</td>
<td>19.00</td>
</tr>
<tr>
<td>Neon</td>
<td>H$_8$He$_3$</td>
<td>20.210</td>
<td>20.20</td>
</tr>
<tr>
<td>Sodium</td>
<td>H$_7$He$_4$</td>
<td>23.008</td>
<td>23.00</td>
</tr>
<tr>
<td>Gold</td>
<td>8(H$_2$Pf$_3$H$_3$)2(H$_2$Nu$_2$Pf$_3$H$_3$)Nu$_2$Pf$_3$H$_2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium</td>
<td>8(H$_2$Nu$_2$Pf$_3$H$_3$)2(H$_2$Pf$_3$H$_3$)He$_2$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If there is any protyle basis of the theory of elements, the disintegration products of uranium and thorium will serve as a test for the theory.

A few characteristics of atomic weights as considered by Harkins are:

(a) The atomic weights on the hydrogen basis approximate whole numbers and are usually lighter, rather than heavier
than the nearest whole number. Harkins puts forward the theory that the "packing" of hydrogen atoms in the nuclei reduces their mass.

(b) Since the alpha particle is emitted by the even number elements and the even numbered elements of low values show differences in their atomic weights by 4, there is evidence that these elements are helium compounds, nHe', according to Harkins.

(c) Most of the odd numbered elements of low atomic weight can be represented by nHe' + H', the primes indicating that the mass of He and H has been decreased by being packed into the nucleus.

(d) Some 98 per cent. of the meteorites consist of the even numbered elements. As far as abundance of the elements is concerned the system plays out at about 30. The conclusion is reached that helium forms the substructure of practically all matter.

The Bohr type of atom is quite successful in explaining the spectra of hydrogen and the K and L x radiations of the elements. The following items briefly indicate the nature of the model. It is designed for radiation purposes and is considered to obey the classic laws of electrodynamics during the steady state. It is during this steady state that the ordinary inverse square forces are assumed to hold.

(a) Assuming that the inverse square law holds for the forces (F) exerted by the atomic nucleus (E) upon negative electrons, then Moseley's law leads to the distance (a) of the innermost electron (e) orbit from the nucleus being inversely proportional to the atomic number.

\[ F = \frac{eE_1}{a^2} = (2\pi n)^2 ma \]

or for two different atoms, \( \frac{n_1^2}{n_2^2} = \frac{E_1a_2^3}{E_2a_1^3} \)

with Moseley's law \( \frac{E_1}{E_2} = \frac{\sqrt{n_1}}{\sqrt{n_2}} \) one has \( \frac{E_1}{E_2} = \frac{a_1}{a_2} \). Millikan considers that these conditions can be assumed because only circular orbits are to be considered stable and are indicated by the Zeeman and magnetic effects.

(b) The L x radiations obey Moseley's law in the same way as the K lines, the frequency being about one-eighth as great. The L lines indicate the second electronic orbit to be about five times as great as the first.
The data indicate that for hydrogen the \( K \) lines appear in the ultraviolet at about 90\( \mu \mu \) as has been obtained by Lyman. The \( L \) series appears to be the ordinary Balmer series in the visible spectrum. The \( M \) series is Paschen's infra-red spectrum.

(c) The frequencies of the Balmer series of hydrogen is given by \( \nu = N \left( \frac{1}{n_1^2} - \frac{n_2^2}{1} \right) \) where \( n_1 = 2 \) in the visible region and \( n_2 \) takes values 3, 4, 5, etc., for the different lines. Paschen's infra-red lines have \( n_1 = 3 \) and Lyman's bands \( n_1 = 1 \). Bohr assumed that hydrogen consisted of one electron rotating about the nucleus in a series of nonradiating orbits governed by conditions described in (a).

(d) Radiation takes place when an electron moves from one orbit \( \langle A_1 \rangle \) to another \( \langle A_2 \rangle \) in such a way that \( h\nu = A_1 - A_2 \) where \( h \) is Planck's constant and \( A_1 \) is the energy of orbit 1.

(e) The possible orbits of hydrogen are determined by the kinetic energy of rotation \( (T) \) being equal to \( \frac{1}{2} \tau \hbar n \) where \( \tau \) is a whole number and \( n \) is the orbital frequency. From (c), (d) and (e) \( N = \frac{2\pi^2 \alpha^2 E^2 m}{\hbar^3} \). The value of \( N \) observed spectroscopically agrees with that calculated for this Bohr atom, \( N = 3.294(10)^{15} \).

The radii \( \left( a = \frac{T^2 \hbar^2}{4\pi^2 \alpha^2} \right) \) for hydrogen are in the ratios 1, 4, 9, 16, 25. The diameter of the normal hydrogen atom comes to 1.1 \( (10)^{-8} \) cm. The Bohr atom explains why hydrogen does not absorb the spectra which it emits.

(f) Condition (e) implies the atomic nature of angular momentum.

(g) The smaller the number of electrons in the outer part of the atom the less should be their mutual actions and hence the less deviation from the Moseley law. This is found to be the case.

(h) The Bohr view of the atom in an unmodified form applies to hydrogen, to helium that has lost a charge and to the inner electron of the heavier atoms. The fact that it assumes the electron orbits to be in a single plane does not necessarily mean that in the complex atoms a disc structure is necessary.

Important work on the series of spectrum lines has been done by Kayser and Runge, Rydberg and Ritz. Ritz has developed a theory of the constitution of the atom that explains the series distribution of spectrum lines based on a magneton (Bauer).

The different formulae of spectral series may be said to be an extension of Balmer’s equation for the principle lines of hydrogen. This series is the secondary spectrum which is obtained in vacuum tube discharges. The formula is:

$$\lambda_m = N \frac{m^2}{m^2 - 4} \quad \text{or} \quad \frac{1}{\lambda} = N\left[\frac{1}{2^2} - \frac{1}{m^2}\right]$$

$N$ is a constant and $m$ is the number of the line under consideration of wave length $\lambda_m$. Pickering has observed a series of supposedly hydrogen lines in $\zeta$ Puppis that follows the law:

$$\frac{1}{\lambda_m} = N\left[\frac{1}{2^2} - \frac{1}{(m + \frac{1}{2})^2}\right]$$

The constant $N$ is the same as in Balmer’s formula; $m$ has the values 1, 2. The series has not been obtained in the laboratory. Kayser and Runge have represented series by equations of the form

$$\frac{1}{\lambda_m} = A + Bm^{-2} + Cm^{-4}.$$  

The series are primary or secondary according to the values of the constants $A$, $B$, $C$. Rydberg’s formula can be stated as follows:

$$\frac{1}{\lambda_m} = A + Bm^{-2} + Cm^{-3}.$$  

The formula of Ritz is, $N$ being a constant for all elements while $a$, $b$, $a'$ and $b'$ differ for the various elements.

$$\frac{1}{N\lambda} = \frac{1}{\left(n + a + \frac{b}{n^2}\right)^2} - \frac{1}{\left(M + a' + \frac{b'}{m^2}\right)^2}.$$  

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Most physicists have applied the same kind of differential equations to the source of light vibrations as would apply to elastic vibrations. These equations contain the frequencies as squares while the simple laws of series lines contain the frequencies as a first power. Ritz assumes that the frequency of the oscillations is proportional to the force that produces the oscillations, the force being due to a magnetic field. The intensity of magnetic field required is about \(10^8\) gauss. This is in agreement with the theories of magnetism of Langevin and Weiss and of the pressure shift of Humphreys and Mohler, these theories assuming a field of about \(10^7\) gauss.

The intense magnetic fields, to which is due the vibrations which give rise to series lines, consists of magnetic poles distributed within the atom according to simple geometrical laws. From the poles come fields \(H\) and \(H'\). The fields \(H_n\) and \(H'_n\), normal to the plane of vibration of each particle determine the frequency of its circular motion. Increasing the intensity of the field causes a proportionate increase in the frequency. Every solid of revolution rotating around its axis may, by a suitable distribution of electric charge, become equivalent to a linear magnet. When the magnetic poles approach the surface, the electric density increases indefinitely in their vicinity and the surfaces carrying the electricity become practically equivalent to point charges. These solids are alternately positive and negative, having rotations in opposite senses. Electrostatic attraction fixes them together as a linear chain.

Ritz supposes that the magnetic fields within atoms is due to elementary magnets of length \(a\) and having poles of intensity \(m\). According to this view, where \(A\) depends on the charge and mass of the corpuscle,

\[
\frac{1}{\lambda} = \frac{A}{a^2} \left( \frac{1}{n^2} - \frac{1}{m^2} \right)
\]

which is the same equation as Balmer's. To explain other series it is assumed that the orientation of the magnets with respect to the corpuscle, or the number of magnets is changed. If \(n_1\) is the distance of the electron \(P\) to one pole \(N\) and \(n_2\) the distance to the other pole, the frequency \(n\) of the resulting circular vibration is: \(n = HK = K\mu \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right)\). By letting the first magnet have a length \(\frac{a}{2}\), one obtains Balmer's formula. Other formulæ
can be obtained by giving different values to \( n \), and to the lengths of the magnet.

The theories of Ritz also explain many complicated cases of the Zeeman effect and Cotton has discussed the positive Zeeman effect in terms of Ritz’s views of the atom.

According to Ritz a vibration of frequency \( \nu = N \left( \frac{1}{4} - \frac{1}{m^2} \right) \) is produced by the magnetic field of \((m - 2)\) elementary magnets turned toward each other, which are all identical: in addition to this magnet series the electron is subject to rigid combinations. Higher numbers of the order correspond to higher magnet polymerizations, which constantly become less stable, so that the lines become broader with an increasing number of the order, and also become constantly weaker. The magnetic field in an atom Ritz considers as being produced by two poles of opposite sign, which separately may occupy different positions in the atom. In the case of hydrogen, these points lie at equal distances on a straight line. In any combination formula each of the terms represents the influence of one pole, and the possible positions of the separate poles permit the most varied combinations of the poles in pairs. As to a certain minimum prescribed in the number of the order \( m \)—which occurs in the case of no known processes of vibration—this mode of representation only affirms that the magnet poles are held by the structure of the atom at a certain minimum distance from the electron vibrating within an atom.

The theories of Ritz have been applied with greatest success to series spectra. Band spectra may be considered as due to closed rings or polygons of elementary magnets, these structures forming an important part of the atom. A series spectrum may result when these structures have been excited in some way by electrical or chemical processes.

The researches of P. Curie and others showed that the diamagnetic susceptibility of a substance is independent of the temperature whereas the paramagnetic susceptibility is inversely proportional to the absolute temperature. Accordingly there must be a fundamental difference between the two kinds of magnetism. Langevin’s theory makes diamagnetism a characteristic property of each molecule, the resultant magnetic moment of the revolving electrons in each atom being zero. An external magnetic field only affects the orbits. When the
revolving electrons possess a magnetic moment the substance is paramagnetic. For a diamagnetic substance the susceptibility

\[ K = \frac{1}{2m} N e^2 r^2, \]

\( m \) being the mass, \( e \) the charge and \( r \) the radius of the electron orbits, \( N \) being the number of electrons per unit volume.

<table>
<thead>
<tr>
<th>Substance</th>
<th>( K \times 10^6 )</th>
<th>Substance</th>
<th>( K \times 10^6 )</th>
<th>Substance</th>
<th>( K \times 10^6 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>-1.37</td>
<td>Cd</td>
<td>-1.16</td>
<td>Na</td>
<td>2.2</td>
</tr>
<tr>
<td>Au</td>
<td>-3.07</td>
<td>Tl</td>
<td>-4.6</td>
<td>Pd</td>
<td>5.15</td>
</tr>
<tr>
<td>C, diamond</td>
<td>-0.49</td>
<td>Cu</td>
<td>-0.82</td>
<td>Pt</td>
<td>29.0</td>
</tr>
<tr>
<td>C, amorphous</td>
<td>-2.02</td>
<td>Al</td>
<td>1.8</td>
<td>Si</td>
<td>0.2</td>
</tr>
<tr>
<td>Hg</td>
<td>-2.6</td>
<td>Be</td>
<td>0.29</td>
<td>N</td>
<td>0.0537</td>
</tr>
<tr>
<td>Ag</td>
<td>-1.4</td>
<td>B</td>
<td>4.32</td>
<td>Mo</td>
<td>2.2</td>
</tr>
<tr>
<td>Bi</td>
<td>-13.7</td>
<td>Mg</td>
<td>0.57</td>
<td>Os</td>
<td>0.62</td>
</tr>
</tbody>
</table>

The phenomena of magnetism are extremely complex and seem to be very closely related to the processes that take place during chemical reactions, in optical phenomena and in mechanical changes. These properties of matter appear to be due to electrons revolving in orbits in the outer parts of atoms.

According to Langevin molecules contain a large number of electrons moving in closed orbits, each of which has a certain magnetic moment. In an increasingly intense magnetic field, according to Lenz’s law, the motion of the electrons would be modified so as to oppose the increase of the intensity of the field and would thus show the phenomena of diamagnetism, as well as the Zeeman effect. Paramagnetism is then only the property of such molecules or aggregates whose resultant magnetic moment is not zero. The theory of Langevin fails to explain many of the magnetic properties of solids although it explains the magnetic properties of oxygen.

In order to explain the magnetic properties of solids, Weiss imagines a molecular magnetic field that is to be measured by the magnetic action of an aggregate of molecules upon any one of them. Such a field is considered as uniform and its intensity and direction are given by its effect on the hypothetical isolated molecule. If \( H_m \) is the strength of the molecular field, \( d \) the density of the magnetic material, \( m \) its molecular weight, \( A \) a constant and \( O_m \) the magnetic moment per gram-molecule of material,

\[ H_m = \frac{dA}{m} \sigma_m \]
According to the theory of Weiss, the magnetic moments of molecules are integral multiples of a common magnetic moment which he calls the magneton. This unit magnetic moment would be expected to be independent of the temperature, the latter affecting the size and arrangement of the molecular aggregates.

Weiss and Onnes have studied the magnetic properties of various ferromagnetic substances at low temperatures and the following gives the experimental value of the magnetic moment of a gram atom or of a \( \frac{1}{2} \) gram-molecule.

<table>
<thead>
<tr>
<th>Substance</th>
<th>( Z_m(10)^6 )</th>
<th>( \sigma_m )</th>
<th>( \frac{\sigma_m}{1,123.3} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel</td>
<td>3,381</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>9,650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>12,410</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetite</td>
<td>7,417</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values for iron and nickel are quite exact and are in the ratio of 11:3. After making certain temperature corrections Weiss calls \( \frac{12,360}{11} = \frac{3,370}{3} = 1123.5 \), the gram magneton. Dividing by the number of atoms in a gram-atom Weiss gets a number \( 16.4 (10)^{-22} \) which he considers to be the magnetic moment of the magneton or elementary magnet. A magnetic molecule is a quantity of matter whose magnetic axis possesses 2 degrees of rotational freedom.
The Parson "electron" or "magneton" (Smith, "Misc. Collections," Vol. 65, No. 11, 1915) is a thin ring of negative electricity (about 1.5 \(10^{-9}\) cm. in radius) revolving with a velocity approaching that of light and possesses electrostatic and magnetic properties.

The change of wave length of spectrum lines due to increase of pressure discovered by Humphreys and Mohler has been attributed by Humphreys as being due to the magnetic properties of surrounding atoms. This theory was advanced owing to a supposed connection with the Zeeman effect. Livens attributes the effect to an increase in the density of the vapor emitting or absorbing the given light.

Duane has proposed a magnetic moment \(M\) for the holding of positive nuclei \(E\) together against their electrostatic repulsion. He proposes to account for the ejection of an \(\alpha\) particle by assuming that it is disturbed sufficiently for it to get beyond the critical magnetic field. The critical distance \(\gamma_0\) is \(\frac{E^2}{r_0^2} = \frac{6M^2}{r_0^4}\) and if the disturbed displacement exceeds \(r_0\) the \(\alpha\) particle will escape.

Oxley finds that the change of magnetic susceptibility on the crystallization of some 40 diamagnetic substances indicates fields of \(10^7\) gauss. Merritt has intimated that the fluorescence of uranium compounds gives evidence of the presence of magnetic fields.

Some experimenters have resorted to the view that a gas may contain certain molecules, or neutrons, which are in a condition allowing of easy ionization. Neutrons may themselves be formed by the action of ionizing agents. One can easily imagine a diatomic molecule being split into the monatomic condition, and these atoms may be comparatively easy to ionize. According to Wellisch and Bronson \(\alpha\) rays may produce neutrons, relatively more neutrons being formed in the early part of the range of the \(\alpha\) particle. In this way an effort is made to explain the fact that the "saturated" portion of the ionization current curve is not parallel to the current axis. The radioactive rest-atoms are considered to be in the neutron condition.
15. THE CORPUSCLULAR THEORY OF LIGHT.

The nature of light and of radiant energy in general has been a subject of discussion ever since the introduction of the experimental method in science. Among the classic controversies on this subject was that between Newton, Hooke and others of the time. Hooke supported the wave theory while Newton upheld the view that light consisted of the propagation of some sort of corpuscular radiation. Hooke believed that space was permeated by an elastic medium, the ether, which was capable of propagating vibrations. This ether pervaded matter in which it possessed less density than in free space, and it did not necessarily consist of a single substance.

Newton considered that ether and the light “emanation” were capable of mutual interaction and that when light passes through strata of ether of different densities, it was deflected from its rectilinear course. The heat resulting from the absorption of light Newton thought might be due to vibrations set up in the ether. Color was associated with some property of the corpuscles acting in a way somewhat like Helmholtz resonators in setting up waves in the surrounding medium of different frequencies.

It may be of interest to note that it was customary for chemists to include light corpuscles among the chemical elements for a long time after Newton had died. When Lavoisier announced however, that the weight of substances was the same before chemical reactions as after they had taken place, the classification of the elements became much the same as that used today.

About this time radiant heat was also considered to consist of rays of light-corpuscles. When it was found that light and heat could be separated by selective absorption, it was necessary to accept the “heat corpuscle” as a separate element called caloric. Caloric was considered as filling the interstices between the particles of ponderable matter. This view gave a reasonable explanation of the expansion of bodies on being heated. Whether caloric possessed weight or not was left an open question.
16. HUYGHENS' SECONDARY WAVELET CENTERS

To explain the phenomena of color Newton assumed that "every ray of light, in its passage through any refracting surface, is put into a certain transient constitution of state, which, in the progress of the ray, returns at equal intervals, and disposes the ray, at every return, to be easily transmitted through the next refracting surface, and, between the returns, to be easily reflected by it." The "length of fit" was supposed to be proportional to what we now consider as the wavelength.

At about the same time, Huygens wrote his defense of the wave theory of light, and developed the principle that each surface element of a wave front or locus of disturbance, may be considered as the source of a secondary wave which will be propagated in the form of a spherical wave if the medium is isotropic. The wave front at any subsequent time is simply the envelope of the secondary waves from these various surface elements. By this means refraction and reflection were easily explained. Huyghens assumed that the solid particles of transparent bodies affected the elasticity of the ether, and thus altered the velocity of light in them. Metals were opaque because they contained the particles that damped the luminous motion.
17. THE FINITE STRUCTURE OF THE ELECTRIC FIELD

The conceptions of Faraday lead naturally to the view that the electric and magnetic fields may possess a structure. The electric lines of force may occupy only a small portion of the space which they traverse and a finite number of electric lines of force may radiate outward from a charge of given value. Indeed it has been suggested that one line of electric force might proceed from a unit charge of electricity or an electroethon. The cross section of this elementary line of force might remain constant or it might vary as one proceeded away from the electric charge at the end of the line. In other words the electric field might be considered as possessing an atomic structure.

The conception of lines of magnetic and electric force is very useful in discussing a large number of physical and engineering problems. For these purposes any arbitrary unit such as a Faraday tube of electric force or a gauss may be used.

Light may be pictured as a transverse motion along the fibers of the ether. The energy of a wave front would not be distributed uniformly over the surface but would be concentrated at the points of the surface cut by the lines of force.

A theory of this kind permits considerable latitude of variation in case the electric charge or magnetic pole is moving. Do the lines of force move with the charge or the pole? Do the lines of force consist of ether threads surrounded by vacuous space or do they consist of some peculiar state of the ether? If the latter is the case, then does all the ether move with the tubes, or part of the ether or only the disturbance?

When lines of electric force cross the boundary of two contiguous media possessing different dielectric constants, the necessary conditions imposed upon the differential equations representing the electromagnetic wave motion are that the tangential component of $E$ on either side of the boundary is continuous and the normal component of the electric displacement is continuous.
This involves a refraction of the line of force in crossing the boundary. If the dielectric constants \((K_1 \text{ and } K_2)\), the angles which the lines of force makes with the normal \((\theta_1 \text{ and } \theta_2)\), the refractive indices for light \((\mu_1 \text{ and } \mu_2)\) in the two media \((1 \text{ and } 2)\) are given, then:

\[
K_1 \cot \theta_1 = K_2 \cot \theta_2 \text{ and } \mu_1 \sin \theta_1 = \mu_2 \sin \theta_2.
\]

In any theory of the transmission or reflection of electromagnetic waves by two or more different media it is always necessary to make certain assumptions concerning the boundary conditions.
Between the time of Newton and of Faraday, various views were taken as to the nature of electricity and the medium in which electromagnetic and optical phenomena take place. During this time the one and two fluid theories of electricity were in vogue. After the establishment of the wave theory of light by Young and Fresnel, the luminiferous medium was treated for a long time as an elastic solid. No connection was known to hold between optical and electromagnetic phenomena.

It is to the genius of Faraday that we owe our present hypothetical working models as to the structure of electrical and magnetic fields and the correlation of electrical and magnetic phenomena. The curves produced by sprinkling iron filings on a paper placed over a magnet led him to the idea of magnetic lines of force, curves whose direction at any point corresponds to the direction of the magnetic intensity at the point. Faraday considered all space to be filled with these magnetic lines of force, every line being a closed curve. The density of the lines of force through a unit area is taken to be proportional to the magnetic intensity at a central point in the area, and its magnitude is arbitrarily defined. The fundamental principle of the induction of currents was discovered by Faraday and, stated in his own words, is: “Whether the wire moves directly or obliquely across the lines of force, in one direction or another, it sums up the amount of the forces represented by the lines it has crossed,” so that “the quantity of electricity thrown into a current is directly as the number of curves intersected.”

Faraday also suggested that the particles of an insulating dielectric under the action of an electric field become polarized, the particles acting like electrical doublets. Lorentz added to the theory by assuming ions to exist in the dielectric, these ions being subjected to certain elastic and viscous forces.
We may consider that the electromagnetic theory of light is due to Faraday, for it was he who suggested that if the existence of a luminiferous ether is to be admitted, it may also be taken as the seat of magnetic phenomena as well.

Maxwell succeeded in translating Faraday's conceptions into mathematical equations. The lines of magnetic or electric force represent the direction of a vector \( \mathbf{B} = \mu \mathbf{H} \) for the magnetic field or \( \mathbf{D} = \varepsilon \mathbf{E} \) for the electric field, and the magnitude of this vector is inversely proportional to the cross section of the tubes of force formed by the lines. This relation between magnitude and direction is a property of any circuital vector—such as a vector that represents the velocity of an incompressible fluid at any point. Hydrodynamical sources and sinks correspond to electrical charges or magnetic poles.

The energy of electrification resides in the medium, provided it is capable of transmitting electrical action.

The energy in any part of the medium is considered by Maxwell to exist as a state of constraint or strain called the electric polarization \( \mathbf{D} = \frac{k \mathbf{E}}{4\pi} \). In general the direction of the force \( \mathbf{E} \) and the displacement are the same.

The energy per unit volume of the dielectric arising from the polarization is \( \frac{1}{2} \mathbf{E} \mathbf{D} \cos \theta \), where \( \theta \) is the angle between \( \mathbf{E} \) and \( \mathbf{D} \).

In "fluid" dielectrics the electric polarization is accompanied by a tension in the direction of the lines of force equal to the pressure in all directions normal to the lines of force, the amount of the tension or pressure per unit area being numerically equal to the energy per unit volume at the same place.

From this view Maxwell derived his equations of the electromagnetic field.

\[
\begin{align*}
4\pi \mathbf{D} &= k \mathbf{E} \\
\mathbf{B} &= \mu \mathbf{H} \\
4\pi \mathbf{D} &= k \mathbf{E} = \text{curl} \mathbf{H}.
\end{align*}
\]

\[
- \mathbf{B} = - \mu \mathbf{H} = \text{curl} \mathbf{E}.
\]
The entire magnetic intensity round the boundary of any surface measures the quantity of electric current which passes through that surface.

The view introduced by the electromagnetic theory of light is that the energy of radiation is essentially of the same nature as the energy that is localized about a charged body either at rest or in motion. The ether is the medium of the energy of radiation and of electromagnetic energy, and its properties are so chosen as to satisfy the requirements of the equations of Maxwell. As far as optical phenomena are concerned the ether medium is considered homogenous as regards its power of containing energy. The velocity of radiation is rectilinear and is the same in every direction.

In his “Thoughts of Ray Vibrations” Faraday suggested that an atom may only be a field of force surrounding a point center—a view similar to that of Boscovich and Michell. Such an atom would have no definite size. It could be considered as completely penetrable and extending throughout all space. It was also suggested that light and radiant heat might consist of transverse vibrations propagated along the lines of force radiating from the atomic centers. In this way Faraday proposed to “dismiss the ether.”

H. A. Lorentz, in 1892, began a series of memoirs upon an electron theory—all electrodynamical phenomena being attributed to moving electric charges. In contrast to the older electron theories of Weber, Riemann and Clausius, the electrons were considered as acting upon the medium rather than between each other. Electrons do not (Clausius’ theory) act instantaneously at a distance but through a space subjected to Maxwell’s equations, the actions being propagated with the velocity of light.

One form of the equations of Lorentz is:

\[
\begin{align*}
\text{div } \vec{D} &= 4\pi\epsilon_0 \rho, \\
\text{div } \vec{H} &= 0, \\
\text{curl } \vec{D} &= -\vec{H} \\
\text{curl } \vec{H} &= \frac{1}{c^2} \vec{D} + 4\pi\rho \vec{V}
\end{align*}
\]

The “ponderomotive” force on an electron of charge \(e\) and velocity \(\vec{V}\) being \(e\vec{D} + e[\vec{V} \cdot \vec{H}]\).
The equations of Lorentz, based on the electron theory, assume an absolutely motionless ether to which neither density, elasticity nor any mechanical property is ascribed. To such an ether Thomson's lines of force, Lodge's idea of density and Bjerknes' and Korn's mechanical analogies would have to give additional properties.

The fact that radiant energy would exert a definite amount of pressure on material surfaces was first predicted by Maxwell on the view of dielectric stresses; by Bartoli from thermodynamic principles and by Planck from electrodynamical principles by assuming a perfect reflector to be a perfect electrical conductor. The electric vector of a light beam induces a finite charge on the surface of the reflector and a finite current within. The current in the field of the magnetic vector of the beam results in a mechanical force. The resultant of the two mechanical forces gives the radiation pressure.

If \( \vec{R} \) represents the time rate per unit of area at which electromagnetic energy is transferred at a point then Poynting's theorem gives \( \vec{R} = \vec{V} \vec{E} \vec{H} \sin \theta \) where \( \theta \) is the angle between \( \vec{E} \) and \( \vec{H} \). \( \vec{V} = \int E \vec{dr} \) along a line of electric intensity. By using Poynting's theorem the energy of the electric and magnetic fields is \( \frac{1}{8\pi} E^2 \) and \( \frac{1}{8\pi} H^2 \).

The electromagnetic theory of Maxwell based on a polarizable ether and the mechanics upon which it rests may be spoken of as the classical theory. It has had many brilliant successes and from it many of our laws of today such as the Rayleigh law for long wave length radiation and the Wien displacement law for radiation have been derived. The Rayleigh law assumes the equipartition of energy and Wien assumed that the length of a wave sent out by a molecule depends only upon the velocity of the molecule \( [V = f(\lambda)] \) and the intensity of the radiation between \( \lambda \) and \( \lambda + d\lambda \) is proportional to the number of molecules (as given by Maxwell's law) which send out waves between \( \lambda \) and \( \lambda + d\lambda \). From these assumptions the intensity of radiation \( \varphi(\lambda, \theta) \) of a black body at the temperature \( \theta \) produced by the waves \( \lambda \) to \( \lambda + d\lambda \) is

\[
\varphi(\lambda, \theta) = \frac{C e^{\lambda \theta}}{\theta^5} \quad \text{where} \quad C \quad \text{and} \quad c \quad \text{are constants.}
\]
The principle of the conservation of energy asserts that \( R + r = \text{a constant} \), where \( R \) is ordinary mechanical kinetic energy and \( r \) is the "hidden" or potential energy. If the system can be expressed in generalized coordinates \((x_1, x_2, \ldots)\) then \( r \) is a function of \( x, x_1^2 \) while \( R \) is a function of the coordinates and their first derivatives \((\dot{x}, \dot{x}_1, \dot{x}_2, \ldots)\) with respect to the time. Now \((R + r)\) in a time \( dt \) follows a certain path or sequence of changes in an interval of time \( dt \). There are many possible paths and Hamilton's principle asserts a path of "least action" and is: \( \delta \int (R - r) \, dt = 0 \), where \( R - r \) is the Lagrangian function \((L)\). Consider a field of force of components \( F_1, F_2, F_3 \) due to a density distribution of \( r^a \) derivable from a Lagrangian function and \( K_a = -(v_1 F_1 + v_2 F_2 + v_3 F_3) \) so that \( \Sigma (a) v_a K_a = 0 \).

Instead of subjecting the system to the possible motions determined by Hamilton's principle they are subjected to the motion defined by the equation

\[
\delta \int (R - r) \, dt + \int \sum_a K_a \delta x_a \, dt = 0.
\]

Now Einstein shows that if \( R - r = -m \frac{ds}{dt} \) then the point of mass \( m \) moves as it would in a gravitational field. (Einstein has \( R - r = -m \sqrt{\Sigma_{ab} g_{ab} v_a v_b} \).)

A large number of such material points free from each other passes into continuously distributed matter without internal forces and the laws of motion of such a system follow from those of a single point. Let \( dS \) be an element of volume in the extension, then \((x_1 = dx, x_2 = dy, x_3 = dz, x_4 = dt, K \text{ is the external force per unit volume})\)

\[
\delta \int (R - r) dS + \int \sum_{(a)} K_a \delta x_a \, dS = 0.
\]

This would represent the general principle for such a gravitation force field.

The theorem of equipartition of energy refers to the distribution of energy among the coordinates of a system. Consider a system to be described by a large number \( n \) of coordinates \((x_1, x_2, \ldots)\) and \( n \) momenta and that the energy is a homogenous quadratic function of the \( x' \), and the momenta. Separate from the energy all the squared terms involving coordinates and momenta (the \( R' \)), and take two sets of a large number of these
terms $xR$ and $yR$, then the law of equipartition states that the average of the $xR'$, is the same as the average of the $yR'$. This law has been applied to a large number of different systems as for instance the condition of an electron atmosphere in a metal, the surrounding gas and the radiation wavelengths of radiation without. It is questionable if this application is justifiable because the selection of the $xR'$ and $yR'$ should not be exclusive so that the $xR'$ are chosen from among the electrons in the metal and the $yR'$ from among the gas molecules. However it is remarkable that the law does give us accurate results such as the Rayleigh law for long wavelength radiations.

The general elementarquanta theory is of somewhat this type (Wilson). If $x_1, x_2, x_j$ are the positional coordinates of a material system and $z_1, z_2, z_j$ are the impulse coordinates, then the steady periodic motion of the system (or of an ensemble of elementary systems of this kind) is such that each plane is divided into regions of equal probability, the mean value of which for any state of the system is

\[
\frac{1}{j} \sum_{i=1}^{i=j} z_i dx_i = \hbar \text{ (a universal constant)}. \]

Each system is conservative except at very short intervals when it absorbs or emits energy. During the conserved periods the system follows the Hamiltonian dynamics. During the critical epochs

\[
\int z_1 dx_1 = \rho \hbar, \int z_2 dx_2 = \sigma \hbar, \int z_3 dx_3 = \tau \hbar, \rho, \sigma \text{ and } \tau \text{ are positive integers and the integrations cover the } x_i, z_i \text{ corresponding to the period } 1/\nu. \]

From classic electromagnetic theory Schott and Crehore develop an atom model consisting of electrons in a ring rotating about the nucleus. The electrons are then subjected to radial and tangential forces. For two electrons at the end of a diameter ($2a$) the radial force is

\[
e^2 \left( -\frac{7}{4a^2} + \frac{\beta^4}{2a^3} \right) + \frac{m_e V^2}{a}. \]

The radial force vanishes at $a_1 = 2(10)^{-10}$ and $a_2 = 1.8(10)^{-8}$ cms. All regions for a greater than $a_2$ or less than $a_1$ gives a repulsion and between these values an attraction. The velocity of the electron is independent of the value of $a$. By slightly changing classic theory Crehore derives the constant of gravitation. He considers the weight of an atom to be proportional to the kinetic energy of the electrons relative to the nucleus.
Some of the characteristics of the atomic structure of entity systems are: the definite character of the atom elements; the frequent simplicity of the first order laws such as those of gravitation and of gases; the universal occurrence of the finer grained elements everywhere and the wealth of lower ordered structure and phenomena that accompany what constitutes the individuality of each of the atom elements. One has only to view the earth’s surface and consider that from the point of view of an atom element in the solar system the earth itself consists only of a point possessing a given mass.

As regards first order effects the ether will be found no doubt to possess a very simple structure and the equations of electromagnetic theory indicate that some of the properties of the ether are of the polarization type so characteristic of electrical and magnetic phenomena. But at the same time it may not be wise to require too elementary a structure to be the medium of all that complex of radiation and force fields that the ether is considered to be.

We will assume that the ether in an ensemble of electroethons $ee$, possessing relatively mobile and immobile, negative and positive characteristics similar to the elements of neutral matter, the electrons $e$ and the atomic nuclei $h$. Energy transfer takes place through the interchange of energy elements $r$.

These energy elements or radions may be the mobile electroethons or they may be independent of these. We may picture them as constituting a gas whose particles possess the light velocity and which constitutes the only reservoir of energy at the absolute zero of thermal temperature. The ether, matter and electrical charge constitute the vehicles for carrying radions. Either the radions or the electroethons constitute that portion of the ether carried by matter according to the experiments of Fizeau.
The ether will be viewed as a porous lattice work that can be defined as stagnant and when free of force fields always propagates radiation with the velocity \( c \). The electroethons can be pictured as resembling the electron gas as it exists in the lattices of the conducting metals. The porosity of the ether is such as to offer no friction to the passage of matter through it. It can be imagined that even the \( e \) and \( h \) elements may be aggregates or ordered structures of the \( ee \) elements. The force fields are due to peculiar distributions of polarization of the ether lattice whereby the flow of the \( r \) elements between the \( ee \), \( e \) and \( h \) elements is modified. The tangible model of the vehicles of the \( r \) elements is to consider the "interior" of the \( ee \), \( e \) and \( h \) elements to contain the \( r \) elements as a gas.

The interchange of \( r \) elements among the masses of matter is considered as a flow of these elements between \( e \) and \( e \) elements; \( e \) and \( h \) elements, \( e \) and \( ee \) elements and \( h \) and \( ee \) elements. The outer "atmosphere" of the neutral atoms being electrons it follows that the surfaces of solids and liquids consist of an electron "film." Ordinary mechanics, gas, temperature and sound phenomena may represent the interflow of \( r \) elements between the \( e \) elements, as long as potential energy changes are not included. Potential energy is to be viewed as a relation between \( r \) and \( ee \) elements of the ether radiations and force fields. Ionization phenomena relate primarily to the interchange of \( r \) elements between the \( e \) and \( h \) elements.

The Great Unknown

1. Life and Mind \( \rightarrow \) Gateways of the Senses \( \rightarrow \) Physical World.

Neutral Matter (\( M \))

2. Natural Matter \( \rightarrow \) Ether Medium, Radiation \( \rightarrow \) Electrical World

\((E\,+)\) 92 Atomic Nuclei composed of \( h \) elements.
\((E\,-)\) Electrons and Magnetons. \( e \) elements.

"Free Space" (\( S \)), with a \( c \) Velocity Characteristic

3. Immobile Ether \( \rightarrow \) Energy Elements \( \rightarrow \) Mobile Ether.

Force fields due to a flux of mobile ether and \( r \) elements. \( ee \) and \( r \) elements.
Potential Energy (P) World


Radiation “Molecules” by Planck’s law are $e = h\nu = jh\nu r$ where $\nu$ is the frequency of the radiation and $j$ is an integer. Experiments remain to tell whether there is a “continuous” series of these molecules or a discontinuous series as is the case of matter molecules. The general atomic theory would answer that the latter condition holds.

The theory of radions would lead to the result that at the absolute zero of temperature there is a condition of equilibrium of radions between the atoms of neutral matter and the electrons such that the radions in each molecule and possibly in each atom neutralize each other.
20. SOME OF THE UNIVERSAL CONSTANTS OF NATURE

The chapter of the new science that has to deal with the determination of a more fundamental set of definitions and units has been greatly advanced by the discovery of the method of studying atoms of electrical charge and of the atoms of natural matter. These discoveries permit for the first time of the use of individual atoms of electricity and matter for the definition of the natural fundamental units of electric charge, and possibly of mass.

One of the previous methods of defining units was that of selecting a set of laws that appeared to be of universal application, carefully determining the constants of this law, and then defining the constants in terms of units of the Newtonian system of mechanics. It has been in this way that the conceptions of the Newtonian system has penetrated into our whole philosophy of nature though we may make an effort to view phenomena independently. An example of this was cited in the discussion of Coulomb's law and the definition of the unit of electric charge in the electrostatic system of units. In this definition which is used in all theory the charges are of unit magnitude when they are equal and act as point charges repelling each other with a force of one dyne while the dyne is defined in the phenomena of the acceleration of mass by Newtonian forces. An electric charge is thus defined by means of a mass and in later experiments when the ratio of electric charge to mass is found not to be constant it is assumed that the electric charge is constant while the mass varies. To be consistent a set of units should be defined throughout the whole range of conditions for which it is to be employed. Ultimately the units of the Newtonian mechanics must be defined for what we have designated as the electrical or energy worlds.

On account of Newton's universal application of gravitation and the wonderful success of the law in mathematical astronomy it has frequently been assumed to be one of the most fundamental laws of the universe.

\[ F = G \frac{mm'}{r^2} \]
$F$ is the force of attraction between masses $m$ and $m'$ a distance $r$ apart and $G$ is a "universal constant." Unfortunately this law is not a convenient one for laboratory study though it appears applicable with great precision to coarse grained (astronomical) systems. It has been suggested that this law represents the "left over effects" of the electrical laws of attraction and repulsion. At present we do not know whether the mass of the electron is subject to this law or whether the mass of the natural atoms of matter are of the gravitational type.

The corresponding inverse square laws for magnetic, electrical and gravitational attraction furnish a basis for the c.g.s. units and indicate a marvelous simplicity and a common origin. The relation between the pressure ($p$) volume ($v$) and absolute temperature ($T$) of a gas $pv = RT$ is of significance because of its interpretation by the kinetic theory in terms of the motions of the gas molecules and the electron atmospheres of metals in temperature equilibrium with the surrounding gas and the ether radiations of the black body type. $T$ is a unit in the c.g.s., thermodynamics. There are many empirical laws worked out under limited conditions that should be extended as widely as possible. For instance the time of electrical contact of impacting steel spheres in microseconds $T = 74.7 \frac{D}{V}$, where $d$ is the diameter and $V$ is the velocity of the spheres in c.g.s. units is suggestive of a large field of research work. The laws of collision are very important as these give epoch points of the laws of transformation of the variable elements of ensembles.

The principle of least action, Hamilton's principle, certain hydrodynamical differential equations, Maxwell's and the later electromagnetic equations, the laws of thermodynamics, the phase rule, Kirchhoff's radiation propositions, Huyghen's wavelet centers, Poynting's law, Provost's theory of exchanges, the radiation laws of Stefan, Boltzmann, Wien and Planck ($aSVe = h\nu$) are a few of the laws of nature, the groundwork of which has not been at all correlated. The "laboratory" black bodies and "cavities" for measuring fields of force should be carefully considered from an experimental point of view. The opportunity of employing $\alpha$ and $\beta$ particles opens a new region of "cavities" for experimental study. The following are the values of a few constants, the invariants of the transformations amongst the atomic assemblages of matter and ether. These
invariants may be pure numbers, magnitudes with dimensions and directed magnitudes with dimensions.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>$e = 4.774$</td>
<td>$(10)^{-10}$</td>
</tr>
<tr>
<td>Avagadro's constant</td>
<td>$N = 6.022$</td>
<td>$(10)^{23}$</td>
</tr>
<tr>
<td>Gas molecules per cm.$^3$ at 0°C. and 76 cm</td>
<td>$n = 2.705$</td>
<td>$(10)^{19}$</td>
</tr>
<tr>
<td>Kinetic energy of translation of a molecule at 0°C.</td>
<td>$E_0 = 5.621$</td>
<td>$(10)^{-14}$</td>
</tr>
<tr>
<td>Change of translational molecular energy per 1°C</td>
<td>$e = 2.058$</td>
<td>$(10)^{-16}$</td>
</tr>
<tr>
<td>Mass of hydrogen atom</td>
<td>$m = 1.66$</td>
<td>$(10)^{-24}$</td>
</tr>
<tr>
<td>Planck's element of action</td>
<td>$h = 6.55$</td>
<td>$(10)^{-27}$</td>
</tr>
<tr>
<td>Wien's constant of spectral radiation</td>
<td>$C_2 = 1.43$</td>
<td></td>
</tr>
<tr>
<td>Stefan-Boltzmann constant of total radiation</td>
<td>$\sigma = 5.72$</td>
<td>$(10)^{-13}$</td>
</tr>
<tr>
<td>Grating space in calcite</td>
<td>$d = 3.030 \text{ Å}$</td>
<td></td>
</tr>
</tbody>
</table>

The fundamental units may be chosen so that the gravitational constant ($G$), the velocity of light ($c$) in free space, the gas constant ($R$), Planck’s ($h$) constant, or the constant of electrical ($k$) and magnetic ($\mu$) attraction shall possess assigned values. If $G = c = R = h = 1$ we have Planck’s “absolute” system of units.

$$
G = [G] m^{-1} l^3 t^{-2}
$$
$$
c = [c] l t^{-1}
$$
$$
R = [R] m l^2 t^{-2} \theta^{-1}
$$
$$
h = [h] m l^2 t^{-1}
$$
$$
K = [K] l^{-2} m l^3 t^{-2}
$$

where $e$ refers to electric charge and $\theta$ to temperature. All the dimensional constants can then be expressed in terms of $c$, $R$, $h$ and $K$ of the above constants.

The laboratory has discovered a large number of “effects” for many of which a comprehensive theory has not been developed. The more complicated types of the Zeeman effect belong to this class while the electrostatic Stark effect on spectrum lines is barely touched by theory, so complex are the components of effected lines. Indeed the whole subject of line and band spectra furnishes many worlds for many Alexanders to conquer, much more worthy and requiring higher talent than disorganized Persias. The conditions in spectroscopy are indicated because every physicist has the instinctive feeling that here lies the answer to the questions involving the structure of the atoms. All provinces of science contain undeveloped fields and one of the pressing problems of the laboratory is that of the development of apparatus and methods of attack that will permit of quicker and more effective offensive movements into the regions that are unexplained and unexplored.
21. FUNDAMENTAL DEFINITIONS AND UNITS AND THE CEER THEORY

The treatment of natural quantities is made possible by means of assigning certain magnitudes and in some instances a sense or direction property. The atomic elements are the magnitudes that are smallest. We have seen that throughout nature entity magnitudes are composed of practically identical elements. The aim of the laboratory is to obtain the smallest number of elements for the description of phenomena and to select these elements so that they can be the most universally and conveniently used.

In the past, definitions and units of a local character have usually been selected for given natural systems. The foot length is convenient in the making of shoes. The meter is adapted to geodetic work. The definition of unit density in terms of water or the unit electric charge in terms of the repulsion of spheres are all examples of convenient local units. The great disadvantage of these local units is that they have been defined for different local systems and none of them have been based upon the natural atomic elements. Units defined in terms of the natural elements would have their magnitudes and perhaps their sense qualities frequently expressed in a one to one correspondence to the elements themselves. Suppose that the unit of electric charge is defined in terms of the charge of the electron. Every number representing an electric charge would then be a positive or negative integer.

A natural system of units would then always employ integers in the expression of the elements used for the definitions. If the finest grained elements are employed in the determination of the units then all magnitudes and senses or directions would be expressed in terms of integers. This is the general atomic theory of natural philosophy and this philosophy is being continually supported by experiment. In so far as it is supported by experiment it is a part of the new science.

The smallest number of natural elements required to explain phenomena constitute the ensemble of defining elements.
Whether there is a unique ensemble of this kind or whether a number of equally simple ensembles will be available remains for experiment to determine. At any rate we may aim to select our laboratory definitions and units from the most universally distributed and fine grained of the entity elements.

The transformations between the entity systems have been found to be of two types, contact transformations taking place during the collisions of matter (apparently described by the Newtonian mechanics when the velocities concerned are comparatively small and new electromagnetic laws when the velocities are high) and the ether transformations which take place between portions of matter that may be at great distances from each other. If we are to view the outer parts of atoms as being constituted of rotating electrons and an ether more or less modified by the presence of the atom (and this condition is supported by experiments as far as they go), then contact transformations possess an electrical and ether quality. Then if experiments indicate that the ether is electrical in character it may follow that all natural transformations possess an electrical quality. Assuming that both contact and ether transformations are electrical and that these transformations are universal for all the entity systems of the universe it follows that our definitions and units should be selected to make our scientific laws simulate these contact and ether transformations as closely as possible.

The conditions of energy interchange also suggests that if possible our definitions and units should describe these interchanges as simply as possible.

The elements appearing in all natural changes then appear to be the vehicles of electrons and the atoms of natural matter, the carrier or the ether and the elements that appear and disappear among the ensemble of ether, electrons and the natural atoms. Whether any of these elements are absolutely conserved will remain for experience to decide. Our present theories usually accept the view that the electron as regards its electrical charge, the natural atoms as regards their simple elements such as possibly the hydrogen and helium nuclei and the ether of free space are absolutely conserved, the unchanging elements of an eternal universe.

The elements that are variable and that appear and disappear such as kinetic energy, potential energy and the radiation quanta
are certain changes among the absolutely conserved elements that are to be measured by magnitudes such as mass, time, velocity, acceleration and temperature.

The following table defines certain physical magnitudes in terms of certain elementary units, \( e \), the electrical charge of the electron (or perhaps eventually \( ee \) of the ether); \( c \), the velocity of light and \( r \) the element of energy. \( e \) possesses a + and − sense while \( c \) and \( r \) are directed elements and may be employed to define the three elements of extension.

### Dimensions of Laboratory Units

<table>
<thead>
<tr>
<th>Laboratory assumed to be at rest</th>
<th>Laboratory with velocity ( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometrical:</td>
<td>Transverse</td>
</tr>
<tr>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
</tr>
<tr>
<td>Velocity</td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td></td>
</tr>
<tr>
<td>Kinematical:</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Mechanical:</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td></td>
</tr>
<tr>
<td>Momentum</td>
<td></td>
</tr>
<tr>
<td>Force</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
</tr>
<tr>
<td>Electrical:</td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
</tr>
<tr>
<td>Inductivity</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td></td>
</tr>
<tr>
<td>Electric field</td>
<td></td>
</tr>
<tr>
<td>Magnetic field</td>
<td></td>
</tr>
<tr>
<td>Magnetic pole</td>
<td></td>
</tr>
<tr>
<td>Permeability</td>
<td></td>
</tr>
</tbody>
</table>

The first column of dimensions gives the values as obtained in the electrostatic system by using Coulomb’s law and the fundamental units are taken as inductivity, length, mass and time. In the second column the fundamental units are electric charge, length, mass and time. For the medium where the inductivity remains constant this quantity can be omitted from consideration as is done in the last five columns.
There is in common use two systems of units, the electrostatic and the electromagnetic according as the inductivity or the permeability are used as dimensions. If \( m, l \) and \( t \) are given integral exponents then the inductivity appears as an elasticity and the permeability as a density or \textit{vice versa}. There is no alternative. Corresponding to this condition is that relating to the directions of the ether vibrations and the problem as to whether electrical energy is potential and the magnetic energy kinetic or \textit{vice versa}, using the vibrations of a mechanical system as the pendulum as an analogue. Either the electric or the magnetic fields can be represented by a mechanical analogue but the relations of the two fields cannot be so represented.

In the third column the fundamental units \( c \), the velocity of light in free space, \( d \), the diameter of the electron and, \( e \), the charge of the electron are considered as the natural units. In the fourth column the fundamental units are taken as \( c, e \) and \( r \) the energy of the radion. If \( e \) is ever found to be a multiple of a unit such as \( ee \) then \( ee \) would become the natural unit of charge. This system will be called the absolute system of natural units because it lays at the bottom of our laboratory experience that these natural elements are absolutely conserved and are constituted of identical atoms.

The laws upon which the above system of units are based are the laws of our own laboratories which we consider invariably at rest when making experiments. Our mechanics indicate that motion is relative and that by mechanical means we cannot observe the velocity of any laboratory by experiments made in that laboratory. Electrical experiments indicate that the assumption that electrical charge remains constant gives a consistent explanation of phenomena and if there is discovered an element of mass that is found to be conserved then that element can be employed as an absolute unit. Experiments also indicate that we cannot measure the motion of our system by measuring the velocity of light in different directions.

When we consider that the kinetic energy of a system is measured in terms of \( mc^2 \) and that the value of this energy is relative to the way the velocity of a system is measured it follows at once that \( l, m \) and \( t \) must necessarily be relative to each other and the velocity given to the laboratory if our assumed laws of \( r \) and \( c \) are to hold. A relative theory based on these conditions will be outlined shortly.
The application of such a relative theory for electromagnetic theory is complicated by our not knowing the dimensions of the permeability and the inductivity hence the relative theory as applying to the electrostatic system is developed.

An interesting application to ancient cosmogony may be noticed to relate to the definition of time in the cer units, there being the beginning of time when it was said, "Let there be light."

Consider two laboratories $L_1$ and $L_2$ moving with a relative velocity of $v$ cm. per sec. or with $\beta$ units velocity according to the $r$ dimensions in terms of $c = 1$, the observing angels $A_1$ and $A_2$ in $L_1$ and $L_2$, respectively, considering themselves to be at rest. The relative velocity $\beta$ must indicate that if this velocity is apportioned to the two laboratories, the laboratories must move along parallel paths (parallel paths being defined as the paths of two light beams from two stars whose distance from the laboratory telescope is too great to be measured by any means such as the parallax method and the stars are so close together that they can just be resolved. This may be taken as a definition of parallel lines). Only when three or more laboratories are concerned does relative motion other than along two parallel lines require to be considered. The relative method could then define the units of one laboratory as being absolute.

The parallel paths of $L_1$ and $L_2$ define a direction and mechanics such that $A_1$ and $A_2$ agree in their measurement of the distance between these lines.

Let $A_1$ and $A_2$ define a unit of time as the time required to traverse a distance equal to the diameter of an electron $d$.

\[ L_1 \quad \quad d_1 \quad \quad L_2 \quad \quad a \quad \quad \beta \quad \quad d_2 = d_1 \quad \quad d \]

$A_1$ assumes he is at rest and that the light track is $d_1$ perpendicular to the direction of their relative motion. $A_2$ considers his light track $d_2$, $A_1$ considers however that while the light traversed $d_2$ the laboratory moved to $b$ where $bd$ represents the velocity of the laboratory. The unit of his own time $A_1$ considers to be $\frac{d_1}{c} = t_1$.

$A_2$ "considers" his unit to be $\frac{d_2}{c} = t_2$ because he thinks he is at
rest but \( A_1 \) says that his unit is really \( \frac{ab}{c} = t_2 \) and is therefore too large, \( d_1 = d_2 \).

Hence (1) \( t_2 \sqrt{1 - \beta^2} = t_1 \) (to terms in \( \beta^4 \))

In any laboratory it is assumed that the time intervals are independent of the "direction" in which they are measured so that relation (1) can be applied to "longitudinal" time if we wish to think of such a unit.

\[
\frac{l_1}{l_1} = c_1 \text{ and } \frac{l_2}{l_2} = c_2, \text{ from (1) if } c_1 = c_2 \text{ we have } l_2 \sqrt{1 - \beta^2} = l_1 (2).
\]

Let \( A_1 \) send a radion of momentum \( M_1c \) to \( A_2 \) who determines its momentum in his laboratory to be \( M_2c, M_1 \frac{l_1}{l_1} = M_2 \frac{l_2}{l_2} \) whence \( M_1 = M_2 \sqrt{1 - \beta^2} \) (transverse masses) \( (3) \)

Consider \( A_1 \) and \( A_2 \) each having a radion with the velocity of \( c^2 \) in the same direction as \( \beta \). \( A_1 \) considers the energy of his to be \( M_1(c^2 = 1) \) and \( A_2 \) his to be \( M_2(c^2 = 1) \). But \( A_1 \) claims that \( A_2 \)'s radion must have \( M_2\beta^2 \) more energy than what his radion possesses and hence is too large. So \( M_1 \) varies as \( (1 - \beta^2)M_2 \) where the values of \( M_1 \) and \( M_2 \) are to be viewed as in (3), \( A_1 \) not only considering that \( A_2 \) has not correctly indicated the energy of his system but that his masses are to be considered by (3) so that \( M_1 = (1 - \beta^2)^{\frac{1}{2}}M_2 \) (longitudinal mass) \( (4) \)

The definition of time by means of the velocity of a light wave immediately indicates the difficulty of defining the simultaneity of events that occur in two different systems. Consider that \( (A. \quad C \quad B \rightarrow ) A_2 \) arranges in his laboratory vibrating atoms or other suitable time measuring apparatus. He regulates these from \( C \) where \( AC = CB = d \). \( A_2 \) defines the "atoms" at \( A \) and \( B \) as vibrating synchronously. \( A_1 \) considers \( AC = CB = d \sqrt{1 - \beta^2} \). \( A_1 \) also considers that in "setting" the atoms the velocity of the signal in going from \( C \) to \( A \) was \( 1 - \beta \) and from \( C \) to \( B \), \( 1 + \beta \). \( A_1 \) considers that the clock (or atom) at \( B \) is too slow and \( A \) is too fast, the difference in time being \( d \sqrt{1 - \beta^2} \left( \frac{1}{1 - \beta} - \frac{1}{1 + \beta} \right) = \frac{\beta d}{c \sqrt{1 - \beta^2}} \) \( (5) \)

Let \( A_1 \) establish coordinates on his system of \( x_1, y_1, z_1, t_1 \) and \( A_2, x_2, y_2, z_2, t_2 \) where \( x \) is in the direction of \( \beta \). As it has
been assumed that the distance between the laboratories is found to be the same by $A_1$ and $A_2$, $y_2 = y_1$ and $z_2 = z_1$. $A_1$ considers a point appearing to be at $x_1$ from the $y_2z_2$ plane at time $t_1 = 0$. When $t = t_1$ the point will appear to be at $x_1 - \beta t_1$ from the $y_2z_2$ plane. $A_2$ considers this distance to be $x_2$ because he considers himself to be at rest and from (2) $x_2\sqrt{1 - \beta^2} = x_1 - \beta t_1$. To $A_1$ considering the point $x_1$ from the $y_1z_1$ plane at $t = t_1$ the clock on $L_2$ at the same distance $x_1$ from $y_1z_1$ appears by (5) to be slow by the amount $\frac{\beta x_1}{c}$ and in the units of $L_1$ this clock would register $\left(t_1 - \frac{\beta x_1}{c}\right)$ time. From (1) $t_2\sqrt{1 - \beta^2} = t_1 - \frac{\beta x_1}{c}$. From these relations are obtained the equations of transformation of coördinates of two systems in relative motion.

\[
\begin{align*}
t_2 &= \frac{1}{\sqrt{1 - \beta^2}} \left(t_1 - \frac{\beta x_1}{c}\right) \\
x_2 &= \frac{1}{\sqrt{1 - \beta^2}} \left(x_1 - \beta t_1\right) \\
y_2 &= y_1 \\
z_2 &= z_1
\end{align*}
\]

These are sometimes written in the form where $\alpha = \frac{1}{\sqrt{1 - \beta^2}}$.

\[
t_2 = \alpha \left(t_1 - \frac{\beta x_1}{c}\right), \quad x_2 = \alpha(x_1 - \beta t_1), \quad y_2 = y_1, \quad \text{and} \quad z_2 = z_1.
\]

In electrodynamics the fundamental laws are left unaltered when the coördinates of $A_1$ are changed to those of $A_2$ and vice versa. For dynamical phenomena the equations are $x_2 = x_1 - ut_1$, $y_2 = y_1 - vt_1$, $z_2 = z_1 - \omega t_1$ and $t_2 = t_1$ (where $u$, $v$, $\omega$ are the components of the relative velocity) and transformations of these coördinates leave the equations defining the units unaltered.

It has been suggested that the fundamental units might be such that a miniature reality could be constructed that would faithfully simulate what we consider such to be. But this view is dispelled immediately when we select a natural set of units such as $e$, $c$ and $r$. The ultimate entity is so gross that individuals of them can be studied for minutes at a time. Any hypothetical reality in miniature must therefore be constructed above the threshold of appearance of the natural units and this is of
course only possible for very small sections of reality such for instance as the picturing of the atom as a miniature solar system. Transformations of this kind are most successful when comparing very gross with fine grained entities.

The definitions and units of science can be selected in a number of ways and until the experimental fields have been carried into the finest grained structures the framework of science cannot be said to be complete. The following treatment is to be considered as suggestive of the way the axioms of science will be laid when we know the structure of the ether and of radiation.

The smallest known element in the laboratory is the electron, $e$. Evidence is accumulating that the atomic nuclei may be composed of hydrogen and helium. For simplicity consider the atoms to consist of elements, $h$, and to be endowed with the properties that we ascribe to positive electricity. The $h$ element is much less mobile than the $e$ element. Experiments indicate that ordinary matter atoms, $M$, possess the structure $M = xe^{-} + [yh + e(x - y)]$, the part within the nucleus being represented by the term in the brackets. This equation will be called condition or law 1.

\[ \text{Law 1. } M = x(e^{-}) + [y(e^{+}) + (x - y)(e^{-})] \]

The ether ($S$) will be considered as analogous and a more fine grained structure than neutral matter and its elements will be the electroethons, $ee^{+}$ and $ee^{-}$ similar to $e$ and $h$.

\[ \text{Law 2. } S = \Sigma x (ee^{+}) + \Sigma x (ee^{-}) \]

The radiation or energy elements ($r$) will be considered as the finest grained of all the structures and they are assumed to possess conserved extension properties and will be denoted by $eee + x$, $eee + y$, $eee + z$, $eee - x$, $eee - y$, and $eee - z$ as previously described.

\[ \text{Law 3. } r = \Sigma eee's \]

For the ether we have the condition law of the neutralization of $ee^{+}$ and $ee^{-}$. For radiation the law 3 of the neutralization of elements.

A point is defined as the “location” of an $r$ element in the ether lattice framework or in space, $A$ point at rest in the location of a neutralized set of $r$ elements preferably as simple as possible. The points are to be considered as without size or shape or struc-
ture because there is no means for indicating such qualities as the points are not the source or sink of any radiation.

The function of the ee ensemble is that of the electromagnetic medium, it being here assumed that phenomena such as gravitation are of this type. These phenomena are considered as due to electroethon collisions and that the history of these collisions is given by the interchanges of the \( r \) contents of the electroethons during collision.

The path of any moving point of an \( r \) carrier that does not receive or lose any \( r \) elements is defined as a straight line. Possibly the lattice structure of the ee ensemble could also serve to define straight lines and directions. These properties have however been assigned to the \( r \) elements. The path of a light ray in the ee ensemble could be used to define a straight line and this is constantly done in surveying. A line of force in the ether field such as the plumb line is adapted for this service. The opportunity of using different methods makes it possible to check the definitions whenever the laboratory facilities are developed sufficiently.

Rotations require the flow of radions due to their varying density in the force fields. Thus the radion maintains its own energy as regards direction and magnitude unchanged. The magnitude of its energy is assumed to be \( ic^2 \) and its direction is employed to define the extension directions, these directions to harmonize with directions as given by the ether lattice.
In the time of Newton, one of the most serious objections offered to the wave theory of light was its apparent failure to explain the formation of shadows. Sound and water waves were known to show diffraction, whereas at that time all evidence favored the view that the propagation of light was rectilinear. This objection was removed by Huyghens and Fresnel.

Huyghens regarded every vibrating point on the wave front as the center of a new disturbance. These secondary disturbances travel with the same velocity and are enveloped by a surface which is identical with the surface from which the secondary disturbances started. The enveloping surface forms the new wave front. This view of wave propagation is Huyghen's principle. Using the principle of interference discovered by Young, by which is meant the fact that two luminous vibrations may destroy each other, Fresnel explained the phenomena of shadows on the theory that there was destructive interference between the secondary wavelets in the region of the shadow.

The secondary wave apparently lies wholly in front of the plane tangent to the wave front at the center of the wavelet and the effect is supposed to be greatest on the normal to the wave surface drawn to the center of the wavelet. This applies to a medium that is transparent.

The presence of charges in a medium either as ions or electrons, that can be set into vibration by the light wave, results in absorption. This absorption may be considered as the frittering away of the light energy which is necessary to overcome the friction that accompanies the motion of the ions. In the equations from which the dispersion formulae are derived, all that is necessary to assume is that the motion of the ions is accompanied by damping. As to the nature of this transformation of energy nothing is assumed, although it can be shown that the vibrations of electrons may be damped during molecular impacts.

The radiation from the ions set into vibration by the light wave is emitted in all direction, and thus differs essentially from the secondary waves of Huyghens. Planck has treated this
subject and shows how the energy of the advancing wave is reduced by the back radiation of the electrons. This absorption would not be a transformation of the energy into kinetic energy of molecular motion. In the treatment of Planck the phase of the vibrating ion is considered as lagging a quarter of a period behind that of the exciting waves besides the lagging of the radiation of the electron itself by a quarter of a period behind its own vibration. Planck applies his theory in general to resonators, so that we may use the term resonator in place of that of the electron or ion. The wave emitted by a system of resonators will thus be a half wavelength behind that of the exciting waves, and will be in a condition to produce interference. Planck's treatment differs from that of Drude in that the damping is referred to radiation entirely.

Since the work of Huyghens, the wave theory of light, based on an elastic or electromagnetic ether, has been found to be in such good accord with experiment that the old emission theory of Newton was abandoned. The work of Maxwell and Hertz has given the wave theory an electromagnetic interpretation. The theory as thus modified explains reflection, refraction, interference, polarization, etc. The theory has recently been modified again by the addition of the relativity hypothesis in order to explain aberration, the experiments of Airy, Fizeau, and Michelson and Morley. This hypothesis states that the equations representing the laws of nature remain the same, whether the system of coordinates remains at rest or in motion. These theories view electromagnetic radiation as continuous.

On the other hand, there are reasons for assuming the radiation of energy to be in elements of an electromagnetic nature somewhat resembling material particles. Planck assumes that a radiating body contains a large number of resonators and that these may lose or gain energy in finite amounts, the portions of energy $\epsilon$ depending on the frequency of the resonators $\nu$ and a universal constant $\hbar$,

$$\epsilon = \hbar \nu.$$ 

The ionization produced by x-rays and ultraviolet light would be expected to be distributed uniformly over the wave surface, all the atoms exposed to the radiation suffering the same change. As this is not the case it has been suggested by Thomson and others, that the energy is not uniformly distributed on the wave front but that it is concentrated into various points
on the wave surface. This kind of distribution of energy in the wave front would result in the same effect as would be expected from the hypothesis that energy is radiated in finite magnitudes.

One of the difficulties confronting the theory of finite elements of energy is its apparent irreconcilability with the Maxwellian equations of electrodynamics. In the earlier forms of the theory of elementarquanta the emission of the elements of energy is assumed to be excited by the continuous absorption of energy from the incident radiation upon one of the assumed oscillators. Planck has also assumed that absorption and emission are entirely independent. Emission is assumed to take place spontaneously in amounts $\epsilon = h\nu$. The calculus of probabilities can then be applied and the probability of the emission of an element $\epsilon$ by an oscillator of frequency $\nu$ in a time $dt$ (which is small compared with the interval between two successive emissions), is $\eta n dt$, $\eta$ being a constant of the oscillator and $n$ the number (a positive integer) of elements of energy originally contained in the oscillator. If $u$ is the vibrational energy of the oscillator, $n$ will be such that $\left(\frac{u}{\epsilon} - n\right)$ is a positive real proper fraction.

The energy absorbed in a time $dt$ cannot be equated to the energy emitted in the same time if the former varies continuously and the latter by increments. Let $\varphi$ be the entropy of the oscillator, and $w$ the probability of the oscillator having an amount of energy $u$, then $\varphi = k \log w$ where $k = 1346(10)^{-16}$ erg/degree. The new hypothesis gives the mean value of $u$, $\bar{u}$, at the absolute temperature $T$ as being

$$\bar{u} = \frac{h\nu e^{h\nu / kT} + 1}{1 / \frac{h\nu}{e^{h\nu / kT} - 1}}$$

This value of $\bar{u}$, differs from that of the old theory by the appearance of the additive constant $\frac{h\nu}{2}$.

The theory involves the emission of energy in quanta in case of electronic motions as well as radiation and the apparently constant energy of the $\alpha$ and $\beta$ particles confirm this hypothesis.

The problem of the equipartition of energy between the various degrees of freedom is one that remains unsolved. One way of avoiding the problem is to consider that the degrees of freedom that are connected with radiational phenomena are in-
operative under ordinary thermal conditions. The “steady” supply of energy of one form and the steady loss in another form under experimental conditions is given by Planck’s law for the distribution of energy among the various wavelengths of radiation. Planck attributes the failure in the application of the law of equipartition to the nature of energy itself, some degrees of freedom absorbing no units of energy and other freedoms absorbing an unequal number of units in some cases. Planck’s theory leads to the law for the distribution of energy among the various wavelengths in black body radiation. It may also mean that molecular and atomic motions must be discontinuous.

Planck’s theory represents the radiation coming from a solid as due to a very great number of Hertzian resonators. Each resonator has its own characteristic period, and emits a rigorously monochromatic radiation. In consequence of the changes of energy between the resonators, there is established a partition of energy following a certain law, and there also results a certain distribution of radiant energy throughout the spectrum, although the resonators neither absorb nor emit any radiation except that which is characteristic to them. The exchange of energy takes place by the Döppler principle, either the resonators being in motion, or the radiation is reflected, refracted, diffracted or diffused by bodies in motion; and by mechanical phenomena such as collisions. It is not supposed that the resonators have any direct influence on each other, but that the exchanges of energy will be made through the interaction of matter.

The relation between the radiation formulae of Wien and Rayleigh were indicated by Planck who imagines an enclosure filled with black body radiation and bounded by perfectly reflecting walls. Within the enclosure the linear electromagnetic oscillators of frequency $\nu$ are in equilibrium with the black body radiations. The energy of any radiator $E_\nu$ and the energy per unit of volume $e_\nu$ of radiation of frequency $\nu$ is

$$E_\nu = \frac{c^3}{8 \pi \nu^2 \lambda_\nu}.$$  

Now assume that $E_\nu$ is composed of an integral number of elementary units of energy $\varepsilon$. From a consideration of the number of oscillators and the number of elementary units of energy it follows that the value of the entropy of the system is:

$$\varphi = F \left( \frac{E}{\varepsilon} \right)$$
The Theory of Elementarquanta

From the second law of thermodynamics as applied by Wien

\[ \varphi = F\left(\frac{E}{\nu}\right). \]

Hence it follows that the elementary unit of energy is proportional to the natural frequency of the oscillator, \( \epsilon = h\nu \), \( h \) being a universal constant.

Planck then derives his formula,

\[ l_\nu = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{h\nu/kBT} - 1}, \]

or

\[ E_\lambda = \frac{2c^2h}{\lambda^5} \frac{e^{ch}}{\left(e^{h\lambda T} - 1\right)} \]

For small values of \( \lambda \) this becomes Wien's equation

\[ E_\lambda = \frac{2c^2h}{\lambda^5} \frac{e^{ch}}{k\lambda T} \]

and for large values of \( \lambda T \) Rayleigh's equation, \( E_\lambda = \frac{2c\lambda T}{\lambda^4} \).

From the theory a correct energy distribution curve is obtained and the value of the unit charge of electricity can be calculated from the radiation constants.

The theory of elementarquanta has been developed as essentially related to the problems of radiation and the picture of the resonators has not been correlated with the nature of the atom structures as we know them. The theory is susceptible to a much wider interpretation than that of explaining the variation of radiation with temperature.

Assume that the atomic structure of energy is ultimately kinetic, conserved and constituted of directed radions. Then Planck's \( \epsilon \)'s are the "molecules" of energy and the law is \( \epsilon = h\nu = n\lambda \) where \( n \) is a positive integer. Then the partition of energy would take place only during the collisions of portions of matter either in the neutral or electrical states or in the so-called unstable or radiating states of matter due to collisions or to ether transmission. Assuming electroethons we can make partition of radions a collision phenomena. Fields of force become regions where there is not an equilibrium state of the radions and a flow of radions takes place to matter or electrical charges in these regions. The process is so fine grained that we must consider
this picture as saying the same thing as is done in speaking of forces and force fields. The advantage of either view is at present a matter of convenience.

The wide applicability of many of the laws of classical mechanics in the electrical and radiation world also seems to indicate that these laws apply to the whole realm of energy changes of radions just as the electrical laws apparently apply to the whole electron realm.

According to one form of elementarquanta theory it follows that no atomic vibrator can absorb energy except in units of size $h\nu$. A diatomic gas cannot absorb energy from molecular impacts unless the energy of these impacts exceed $h\nu$. It begins to absorb when the energy exceeds this value and this absorption increases rapidly with rise of temperature. The atomic vibrators of Cl$_2$ and Br$_2$ begin to do this at low temperatures because the intraatomic bonds are weak and their frequency values are small. The fact that H$_2$ acts like a monatomic gas below 60° absolute is explained on the same basis. Dulong and Petit's law of the equality of atomic heats and Kopp's law of the additive properties of atomic heats in compounds have been interpreted by Boltzmann as being due to the fact that atoms of solids may have natural periods of vibration and that these atoms are in thermal equilibrium with a gas when their mean vibratory kinetic energy is the same as the mean translatory energy of the gas molecules. The energy content of an atom of a solid would therefore be twice that of a monatomic gas molecule. The fact that elements of low atomic weight such as C, Bo, Si at ordinary temperatures and many other elements at low temperatures behave abnormally is explained by some on the elementarquanta theory. Linde- mann has obtained the relation between $\nu$ and the melting point $T$ of any substance, its atomic weight $m$ and its atomic volume $V$,

$$\nu \propto \sqrt[2]{\frac{T}{mV^2}}$$

The approximate validity of this formula is favorable to the quanta theory.

The limit of visibility to the eye is about a sixth magnitude star or about 0.003 microlux while a surface becomes invisible when its luminosity is less than $4(10)^{-10}$ candles per square cen-
timeter. The minimum flux of light perceptible to the eye is about 8.5(10)^{-14} lumen or 1360(10)^{-12} ergs per second. The potassium photo-electric cell approaches an efficiency equal to that of the eye. Planck’s energy quantum is 3.8(10)^{-12} erg for the frequency 0.58(10)^{-15} of maximum visibility. The number of quanta received by the eye when receiving the minimum visible light is about 360 per second. Any instrument a thousand times as sensitive as the eye should indicate discontinuities in the light emission. It seems that the selenium cell would be sufficiently sensitive to indicate variations of this kind.

The explanation of the atomic heats of solids has been explained on the theory of agglomerates. Benedicks derives Planck’s law on the assumption that the energy (W) of a molecule of crystallized solid is equal to 3RT (the energy if the atoms were free) — W₀ (the energy of agglomeration when T = 0) + F(T) (where the disintegration of the aggregate due to the rise of temperature is taken care of). The factors influencing F(T) are cohesion (a vectorial quantity for crystals) and thermal motion. Assuming a formula obtained by Langevin for the action of a magnetic field on a paramagnetic gas, Planck’s law can be derived without recourse to any quanta theory.
23. THE RELATIVITY THEORY

The general consensus of opinion at present is that the fundamental facts of electromagnetism, the aberration of light, and many optic phenomena require the assumption that the ether does not partake of the motion of material bodies which pass through it. For example, the experiment of Fizeau, in which the velocities of light were compared when going with, and when going against, a stream of water, was interpreted by Fresnel as indicating that the ether was in part dragged along with the water. This view was based upon his theory of refraction, which assumed that the ethereal density was increased in material media, and only the excess of ether was carried by the matter. On any resonance theory of dispersion and refraction there is no excess density of the ether in matter, and so Fizeau’s experiment requires a stationary ether. The theory of the stagnant ether requires, however, a positive result in the experiments of Michelson and Morley, Trouton and Noble, etc. The only satisfactory hypothesis to account for the negative results obtained by these observers is to assume that the dimensions of a body parallel to the direction that it is moving in the ether is contracted by an amount $\sqrt{1 - \beta^2}$. This shortening is very small, in the case of the earth moving in its orbit it would be about 6.5 cm.

The theory of the foreshortening of a body in the direction of its motion through the ether is justified by other reasons than that of explaining the negative results of Michelson and Morley, Trouton and Noble, etc. The electrical forces between charged bodies for instance are modified by the motion of these charges through the ether. Now it is a fundamental theorem in electrostatics that a charged system can be in equilibrium only when the electrical forces are balanced by other forces. If the inter-electronic forces are ethereal in origin and subject to the same laws as the electromagnetic forces, then the Michelson and Morley experiments afford evidence for believing that the inter-atomic and intermolecular forces are ethereal in their nature. Lorentz has shown that the electrons must themselves undergo a
foreshortening. Rayleigh and Brace have shown that there is no double refraction due to action depending upon the earth's motion. This implies that the periods of vibration of the electrons in the line of motion must be equal and in order that this be so, the longitudinal and transverse masses of the electron must be altered by the motion in the same manner as the forces in these directions. Neither the rigid spherical electron of Abraham nor the constant-volume electron of Bucherer satisfy these requirements. The electron of Lorentz satisfies the requirements if when at rest it is a sphere of radius \( a \), and when moving with a velocity \( v \) it becomes an ellipsoid of revolution with its shorter axis in the direction of motion. If \( m_0 \) is the mass at rest, \( m_1 \) the longitudinal and \( m_2 \) the transverse mass, then \( m_1 = m_0(1 - \beta^2)^{-\frac{3}{2}} \) and \( m_2 = m_0(1 - \beta^2)^{-\frac{1}{2}} \) as we have seen.

At present there are two theories which attempt to explain the optical and electrical properties of systems in relative motion. These theories are the Lorentzian theory of a stagnant ether, and the Principle of Relativity. The deductions from the two theories are very similar and agree with many if not all of the experiments that have been performed. The necessity that gave rise to these theories was the accumulation of the unsuccessful experiments to detect the earth's motion through space by its effect on terrestrial phenomena.

In the theory of relativity there are two postulates. The first postulate states that the uniform translatory motion of any system cannot be detected by an observer in the system, making his observations on it alone. In other words, any law or any theory deduced from any set of laws is the same for all systems between which there is no relative acceleration. Ordinary experimental laws hold until the relative velocity of any parts in a system reach \((10)^8\) cm. per second. Such a system may be considered as quiet and for it the Newtonian mechanics will apply approximately.

The first proposition assumes that the velocity of light is a magnitude that is "physically infinite" so that the addition or subtraction of finite velocities does not change its magnitude. This condition is a sort of definition similar to the absolute zero of temperature and the use of the velocity of light as an infinite quantity may be interpreted physically as being equivalent to stating that it is impossible to give any material particle a
velocity equal to that of light just as it is impossible to cool any body to the temperature of absolute zero.

The main object of the Principle of Relativity is to establish a relation between the laws of a quiet system and those of a system which is moving relatively to it. This Einstein was able to do by introducing certain propositions that do not concern the laws of any quiet system. In the theory, space is considered homogenous and three-dimensional. Time is homogenious and unidimentional. This means that the transformation of space and time coördinates between systems that are in relative motion are linear transformations. It is also assumed that it does not matter upon which system an observer may be situated, the measured relative velocity between two systems will be the same. The word “stationary” is only a relative term and anything that can be said about a moving system with reference to a “stationary” system (by definition) can also be said about the “stationary” system with reference to the moving system.

The second postulate becomes necessary when it is required to determine when two events occur simultaneously in two different systems, a quiet and a disturbed system. A method of making comparisons of this kind is to send light signals between the two systems. It is then necessary to make assumptions as to the space velocity of light and the second postulate of relativity assumes that the velocity of light is independent of the relative velocity of the source of light and the observer and is always constant in a homogenous medium.

The further development of the Principle of Relativity is mainly a mathematical one. The results are somewhat as follows. Suppose $L_1$ and $L_2$ are two quiet systems whose relative velocity is $v$. An observer is situated in $L_1$ and has instruments for measuring $x, y, z, t, P, Q, R$—where $P, Q, R$ are certain physical quantities that may be functions of the coördinates and the time. A similar observer in $L_2$ measures corresponding quantities, $x', y', z, t', P', Q', R'$. . . . The known laws of each quiet system give relations of the following:

$$f(x, y, z, t, P, Q, R, \ldots) = 0.$$  
$$f(x', y', z, t', P', Q', R', \ldots) = 0.$$  

From the Principle of Relativity it follows that the relations
between the coördinates are as follows, $\beta$ being the ratio $\frac{v}{c}$, $c$ being the velocity of light in space.

$$ (x', y', z', t') = \left[ \frac{(x - vt)}{\sqrt{1 - \beta^2}}, y, \frac{(t - \frac{vx}{c^2})}{\sqrt{1 - \beta^2}} \right]. $$

The laws or equations of electromagnetism are simply relations between the coördinates of certain so-called rigid bodies referred to standard frames of reference, time as defined by clocks and certain electromagnetic processes. One of our first problems is that of defining time. Our judgments of time depend on determining the simultaneity of occurrence of two events. "A friend leaves the house at four in the afternoon," simply means that the leaving of the house by this friend happened at the same time that the hour-hand of the clock pointed to four. The question of simultaneity is not a difficult one when the events happen in the same place. When the events happen at a distance from one another it is no longer an easy matter to say when two events are simultaneous. The relations between the time recorded in two systems is given under the section describing units.

In order to define when two events are simultaneous (for it has been shown that the coincidence of two events depends upon whether the observer is moving along with the system or not), it being possible for two events to be simultaneous when regarded in one coördinate system and not being simultaneous from a coördinate system moving with respect to the first, Einstein has defined two widely separated clocks $A$ and $B$, as being together when the time required for light to pass from $A$ to $B$ ($T_B - T_A$) is the same as the time for the light to pass from $B$ to $A$ ($T_A' - T_B'$). Under these conditions the unit of time of a "moving" system appears longer to an observer who considers himself to be "stationary"—and the leading clock is behind time. The unit of length in the "moving" system appears shorter.

Local time according to Lorentz is the time measured by a set of observers who are moving uniformly in a straight line relative to a standard set of observers. The relation of local and standard time is a reciprocal one, the local time of one set of observers being the standard time of the other set of observers, and _vice versa._

Proper time (Eigenzeit of Kowski) is defined for each particle,
and may be considered as the age of the particle. When a particle is in motion, its increase of age depends on the increase of the standard time and its velocity. If the particle is moving uniformly, the increase of age is equal to the increase in local time. The age of a particle will thus depend on the nature of its path and upon its velocity while traversing this path.

In the case of linear translation we have seen that this can be transformed away so that no trace remains. The transformation that does away with rotation alters the equations of relative motion in a definite manner indicating that its magnitude is a physical constant.

As regards gravitation let us consider the acceleration $a$ of a gravitation field in the direction of a coordinate $x_1$ such that $\frac{d^2x_1}{dt^2} = a$. Introduce new variables $x_2, t_2$ such that $a = 0$ and then $\frac{d^2x_2}{dt_2^2} = 0$ and we would describe the appearance by saying there was no gravitation at the point. The Einstein view of gravitation is somewhat like this: in a space free of gravitation and other forces a material point describes a straight line and in $xyst$ space its "world line" is also straight defined by $g_{ij}$. Introduce gravitation and the definition $(g_{ij})$ of the world line (still straight) becomes more complex and involves functions of $(x, y, z, t)$. No arbitrary constants are involved and gravitation is made a property of space. As the $xyst$ space is the vehicle of all physical phenomena so these must all be affected by gravitation. There are ten $g_{ij}$ coefficients and only six equations to determine them. Four conditions can therefore be arbitrarily chosen. Were there ten equations there would be an absolute space and time.

The relativity theory appeared after a long period during which scientists had agreed to consider length, mass and time as absolutely invariant magnitudes. As long as atoms were the eternal rigidly material bodies that chemists believed they were, it was natural to believe that the mechanics of rigid bodies was a sufficient explanation for all phenomena. The relativity theory gives us a more proper view of length, mass and time as magnitudes used by the laboratory rather than fundamental magnitudes of nature. In the discussion of the fundamental units (in so far as our experimental knowledge extends) of electrical charge, velocity of light and energy the "relative" theory developed from the use
of these units was found to follow naturally. There is therefore nothing mysterious about the theory so far as experiments cover the field. When we try to extrapolate beyond the region of experiment we may obtain curious results. To see the experimental application of relativity let us consider a few applications.

To describe the relativity effects introduced by laboratory conditions let us consider several systems in relative and unaccelerated motion. System 1 consists of submarines in water; system 2 of aeroplanes in the air; system 3 of molecules of air; system 4 of planets in the ether; system 5 of electrons in the metals; system 6 of alpha particles in the ether; system 7 of electroethons in the ether; system 8 of bullets in the air; system 9 of elementarquanta in the ether, and system 10 of waves in the ether.

The laboratory observers in these different systems wish to communicate with each other and to compare their standards and the laws which they have measured. Evidently the conditions of the medium must be such that they know the laws of the medium as regards energy or other transmission. The bullet type of communication for example, is found to be an accelerated motion for material media.

The condition of relativity imposes approximations in that the means of communication between the laboratories, the signals, must first be studied by the laboratories before their units are compared and under conditions that may be local. Consider aeroplanes in air with the experimenter exposed and using sound as the signalling means. He may conclude that the sound transmission depends upon the direction of the sound and of the aeroplane flight. If he encloses his laboratory and experiments with sound transmission in this space without measuring the air pressure he will find the velocity of sound to depend upon the direction the sound is measured (provided the velocity of the aeroplane and his altitude above the earth) is sufficiently great.

Let us assume that systems 1, 2 and 3 can only signal by using sound waves that have been found to possess a constant velocity $S$. This condition we can imagine to be comparatively easy for submarines because they are observing in an almost incompressible medium. Systems 4, 5, 6, 7, 8 and 9 employ light waves whose velocity we will also call $c$. Because the observers are assuming the velocity of the free medium to be constant its velocity could be used as a definition. Interesting questions can be asked whether any system can move with a greater velocity
than c through a medium without experiencing acceleration. What phenomena takes place when the velocity c is approached?

When referring to any system S will be used—when to any particular system as a submarine in water, S₁ and when to different laboratories (A, B, C, . . .) in any system Sₐ, S₋, S₃, etc., or to any particular system as the experiments of Michelson and Morley with reference to the relative motion of the earth and the ether, S₄ₐ, S₄ᵦ.

As regards the equipment of the laboratories it can only be suggested that the science of laboratories has not been advanced sufficiently for to indicate a general set of apparatus and units. Experiments indicate that neutral atoms become ionized when their velocity is increased sufficiently and corresponds to the motion of ions through about 500 volts. It follows that apparatus such as clocks are only adapted to conditions where the relative velocities are small.

Now it is evident that the laboratories of those systems employing sound for signalling purposes will meet very peculiar problems when they compare their experimental data if the relative velocity of the systems approach that of sound. Indeed if the relative velocity of two submarines in the water was greater than that of sound it would be impossible for them to communicate with each other. The problem of different laboratories established on different air molecules would present very unique problems too. Here we would find sudden changes in the velocity of the laboratory such as would apparently introduce a "very intricate physics" for molecular laboratories. An electron laboratory introduces us to a new world on account of the intense electric field about the electron. Bullets in air are mentioned because these may possess a velocity greater than sound and suggest that particles may move through the ether with a velocity greater than that of light.

The kernel of the new science is to be found in the requirement of a laboratory meaning for all definitions, terms, units and laws. You speak of the longitudinal diameter of the electron with a velocity approaching that of light. The attitude of the new science is to require a definition of the above terms. And the difficulty of doing this is certainly apparent after our brief discussion of the c e r units and the ten systems considered. And unless length, time and mass can be given "laboratory" definitions they are meaningless. Many of the "peculiar"
results of the relativity theory are thus meaningless because
terms, definitions, units and laws were discussed for conditions
where laboratory experiments have never been made.

These are some of the laboratory fields remaining to be ex­
plored. We should feel cheered that the discoveries of the
past have been so rich in permitting us a vista of the whole
history of phenomena as a single whole; the elements themselves
apart from our minds for which the consciousness of space and
time may not exist; the laws like Hamilton's principle that con­
sists in a relation between the whole system of configurations
which their past contains; and for which as far as we can deter­
mine the future and the past are interchangeable. True it is
that when we reenter the laboratory the stern sphynx of nature
holds her secrets hidden but the vision that she has given us of a
possibility of comprehending at one glance the world line of all
phenomena in a generalized "space" of the fundamental ele­
ments of the universe is indeed manna from heaven. It brings
us into a deep harmony with the Great Intelligence and we see
in the way our efforts has rewarded us the measure of our image
of Him and that it is the duty of man and of all his organizations
to be blessed by the fullest communion and harmony with the
Divine Plan.