THE UNIVERSE AND THE ATOM

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The Ether Constitution, Creation and Structure of Atoms, Gravitation, and Electricity, Kinetically Explained

BY

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TO

MY WIFE

FOR

LOVE, SYMPATHY AND AID

PREFACE

THE object of the present work is to furnish an explanation of the physical Universe and the Atom on simple mechanical principles. In connection with other work, the writer devoted several years to a study of the wave theory of light and its application to a solution of the great problems of the structure of the ether of space, the kinetic creation of matter, the birth, life and death of suns and worlds, and the forces operating to maintain the cycles of the Universe. As this study progressed from well-trodden paths into new fields, the results reached led to such astounding conclusions, that he could not do otherwise than press the investigations to the developments herein presented.

In order to make the presentation convincing and intelligible, as well to the lay reader as to the advanced scientist, it has been deemed necessary to explain the main features of wave action, and particularly light wave motion, in connection with the physical phenomena which furnish the evidence upon which the wave theory of light rests. The treatment is from the mechanical side rather than from the side of mathematical equations, and certain principles are brought out, a knowledge of which, so far as the writer is advised, has not heretofore been developed.

The exposition of light wave motion is confined to the fundamental principles which are utilized in the subsequent portions of the work dealing with the physical structure of the ether of space, the kinetic creation of ether particles and of material atoms, the cause and operation of gravitation, the mechanical explanation of electricity, and other subjects treated.

Where it has been found necessary to resort to mathematical demonstrations, they have been made without recourse to any higher branches of mathematics than are usually found in elementary works on mechanics.

It is the writer's belief that a real knowledge of the true nature of wave motion and electrical action has been kept from the practical man who could best have utilized it, by reason of the fact that such knowledge has been buried for the most part in the symbols of differential calculus and quaternions, interpretable only by the initiated, and the full duty of mechanical interpretation has not been performed by them.

The writer desires to pay a tribute herein to his old professors of the faculty of the University of Georgia, to whom he is indebted for the inculcation of that spirit for investigation into the laws of nature which has made this work a labor of love; to Professor Williams Rutherford, for encouraging original demonstrations in pure mathematics; to Professor L. H. Charbonnier, who taught that a true understanding of mathematical principles could be reached only in the practical application; to Professor Wm. Leroy Broun, who stressed the necessity of induction in the physical sciences, and at the same time taught the value of imagination in reaching by inductive methods, into fields beyond the limits of experimental verification; and to Professor Henry C. White, who engendered a never satisfied desire to turn an atom inside out.

Some of these great souls have been gathered to their fathers, others still continue, ripe in years and good works.

MARION ERWIN.

GARDEN CITY, L. I.
New York,
July 1, 1915.

CONTENTS

THE UNIVERSE AND THE ATOM

PART I

FIRST PRINCIPLES

To acquire a knowledge of the tools to be used and the materials to be operated upon, is the first step in the successful building of any structure.

CHAPTER I

GENERAL VIEWS OF THE LUMINIFEROUS ETHER

1. In order to explain the transmission of light from the sun and stars to the earth, Sir Isaac Newton supposed that the rays of light consisted of substance discharged from the luminous centre, as a projectile discharged from a gun. This emission theory did not require that there should be any medium in the intervening space, for the purpose of such transmission of light. But when it came to an explanation of the attraction exerted by one body of matter on another through intervening space, he found it necessary to assume the existence of a subtle fluid or medium filling all space to which the name of Ether was applied. The undulatory theory of light subsequently advanced by Huyghens, and developed by Young, Euler, Fresnel, and others, which explains the transmission of light from the sun and stars, through space, by waves passing through Ether, has so satisfactorily accounted for many optical phenomena, not otherwise ex-

plained, that the existence of the substance Ether is generally accepted by scientists. Notwithstanding the weight of scientific authority, which accepts the existence of the ether medium, there are those, who do question its existence. For recent literature on that subject reference may be made to the following articles appearing in recent numbers of *The Popular Science Monthly:*

"The Past and Present Status of Ether," Professor Arthur Gordon Webster, August, 1910; "Recent Developments in Physical Science," Professor Arthur L. Foley, November, 1910; "Attempts to Explain Gravitation," Wilson C. Morris, September, 1911.

Professor Webster concludes his article with the statement, that, "The ether is as good to-day as it ever was."

Sir William Thomson (Lord Kelvin), in his popular lecture on the wave theory of light (1884), said:

"One thing we are sure of, and that is the reality and substantiality of luminiferous ether."

The writer being of the number of those who believe that the underlying facts of science are best explained by the ether theory, and that the existence of the ether is a necessary conception, will, for the purpose of this thesis, after presenting certain evidence in its favor, consider that its existence is accepted as an established fact.

2. The next question which presents itself is, as to the nature of the substance we have designated by the name ether, and whether, as it exists through space, it has either an inherent or acquired structure or constitution.

Since the time of the discovery of the law of gravitation by Sir Isaac Newton, it has been generally accepted that the thing we designate by the name "matter," is endowed with a property which makes every particle of matter attract, at a distance, every other particle of matter.

All the inferences which can reasonably be drawn from the known behavior of the ether in space, such as is exhibited when the planets move through it in their orbits around the sun, lead to the conclusion, that the ether as such, is not endowed with the property of attraction, for matter or for other ether.

The absence of the property of attraction furnishes therefore a line of sharp demarkation, between the thing we have designated "ether" and the thing we have designated "matter."

3. Turning our attention to the properties which ether and matter have in common, we recognize from certain well known phenomena, that each is capable of motion, each may impart motion to similar substance, or to the other, and each has the property of inertia, or of continuous motion in a straight line, until some extraneous cause intervenes. Each may serve as a vehicle by which what we call energy, is conveyed from one place to another. It is because of the possession of the above properties by matter, that we speak of it as a "substance."

Ether, therefore, is entitled, equally with matter, to be designated as a "substance."

There is fundamentally no essential difference between the properties of matter and of ether, except that matter is endowed with the additional property of attraction.

We know that by changing the amount or kind of molecular motion, which may be going on in any particular kind of matter, it may be made to acquire new properties. For instance, by heat we may change a solid into a liquid, and the latter into a gas. Since these new properties are due to the change in the character of the motions taking place in the body of the matter, the inference to be drawn, strongly suggests that matter itself is nothing more than ether in a different form of motion or vibration, from that which it is undergoing in the depths of space.

Before we can advance to a discussion of the processes at work in nature, which may convert ether into matter, it is necessary that we should come to a fair knowledge of the constitution of ether as it exists in space.

Is the constitution of the ether as it exists in space that of a gas, a liquid or a solid? or is there a fourth state in which substance can have an organized constitution? If so, what is that structural constitution, and what are the causes of its existence?

4. From the phenomena of polarized light and other evidence, it has been long demonstrated that the vibrations which take place in a light wave, are transverse to the direction of the wave.

When a ray of ordinary light—R—(Fig. 1) is made to

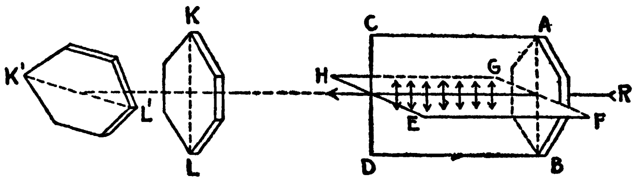

Figure 1

pass through the tourmaline plate AB, which is so cut that the axis of the crystal is parallel to AB, the transmitted light is said to be polarized. It becomes possessed of certain properties it did not possess before. For instance, if the ray be allowed to pass on to a second tourmaline plate KL, whose axis of crystallization is parallel to AB, it will pass through it. But if the second plate be rotated around the direction of the ray as on an axis, until KL takes the position K'L' at right angles to AB, then the ray will not pass through it, and is said to be a polarized ray.

This phenomenon, first discovered by Huyghens, is explained upon the theory that the vibrations of light are transverse to the direction of the ray, and after polarization are confined to vibrations in a single plane. It is then designated plane polarized light.

On the Elastic Theory of light wave motion, we may in a crude way, illustrate the motion taking place in its simplest form both before and after passing through the tourmaline plate as follows:

Tie one end of a short elastic string or cord to a small elastic ball or button. Tie the other end of the cord to the end of a short rod, holding the free end of the rod in the right hand so that the button may swing freely at the end of the cord. Hold the hand with the rod extended horizontally, in front of the body, while in a position of walking forward. Give the hand a slight rotary motion, so that the button will describe a circle around the end of the rod, and in a plane at right angles to the direction in which you advance as you walk forward.

It will be seen that the path of the button will be a spiral curve, illustrated by AB (Fig. 2).

If now when the centre of motion represented by the end of the rod to which the elastic cord is attached, has been ad-

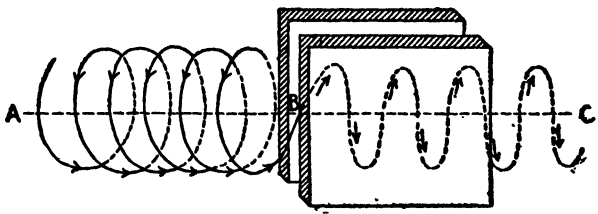

Figure 2

vanced from A to B, we suppose two walls to be suddenly brought very near to each other, closing up the path through which the spiral motion of the button would have been continued, except in the narrow space between them, any further progress in spiral motion will be stopped. And as the advancing point of the rod is carried forward between the walls, from B to C the elastic button will vibrate up and down between the walls, theoretically at least, at right angles to the direction in which the advance movement is progressing.

After passing between the walls, the spiral motion is seen to have been converted into wave motion in a single plane or in parallel planes, and is of the same contour as is exhibited by the profile of a water wave.

5. To make this crude illustration applicable to the motion of an ether wave, we must mentally replace our elastic button by a conception of an ether "particle," the movements of which we can follow with our mental eye. This ether particle need not be conceived of as anything solid, it may not be anything more real than an eddy or centre of gyration in the ether, swept onward as the wave motion advances, the changes in the position of which may be theoretically followed, as the eye may follow the change of position of an eddy or "whirl" floating down a running stream of water. Likewise in lieu of the elastic cord which holds the button to its circular orbit (or spiral path by reason of the advance of the centre of motion), we must conceive that the surrounding ether medium acts like an elastic cushion, which reacts against the centrifugal force of the ether particles, after the fashion in which the cushions of a billiard table throw back the ivory balls which may be hurled against them.

And to make our crude illustration of the walls applicable to the effect on the light ray after passage through the tourmaline plate, we must suppose that after our elastic particle has passed on through the space between the walls of the tourmaline plate, the vibrations up and down at right angles to the direction of the advance, will be continued in one plane. In other words, after the ordinary light wave has been polarized by passing through a tourmaline plate, it continues its progress as a polarized ray.

6. Fresnel assumed that the vibrations take place in the plane ACDB (Fig. 1) containing the ray and the parallel

AB to the axis of the crystal as shown by the small double headed arrows in the figure.

The plane FEHG, drawn through the direction of the ray, and at right angles to the axis of the crystal, is called the plane of polarization.

The ray is said to be polarized in the plane FEHG.

MacCullugh assumed that the vibrations take place in or parallel to the plane of polarization FEHG. That is to say at right angles to the direction in which Fresnel supposed the vibrations take place.

The one theory has been held to best explain certain phenomena of reflection, the other to best explain certain phenomena of refraction. The question has been in dispute among physicists and mathematicians for over fifty years. Lord Kelvin claimed that he had reconciled Fresnel's theory to the requirements of the phenomena of both reflection and refraction (Sec. 39). It is not my purpose to enter on that discussion here.

It is a well known phenomenon, that two water waves can be made to interfere, and thus disappear, by timing them so as to make the crest of one coincide with the trough of the other. So two sound waves can be made to interfere so as to produce silence.

By dividing a ray of light into two rays reflected from the surfaces of two mirrors inclined to each other at a very large angle, and bringing the reflected rays together again on a screen, Fresnel in his celebrated experiment succeeded in retarding one of the rays a half wave length behind the other, so that where the crest of one fell with the trough of the other on the screen they produced darkness. This phenomenon is known as interference. Interference does not take place unless the angle between the two rays at their point of intersection is very small. If the angle is large the rays simply pass through each other without any apparent optical effect at the point of intersection.

When the experiment was performed with two rays of plane polarized light, it was found that two rays polarized in planes at right angles do not produce interference. But two rays polarized in the same plane do interfere like two ordinary rays of light. The fact that two rays of light polarized in planes at right angles do not interfere is a further proof that the direction of vibration in the case of light is transverse to the direction of propagation of the ray.

It was later discovered by Malus, that light could be polarized by reflection.

If, therefore, light may be propagated through the body of the ether of space by vibrations taking place in a single substantial plane and by vibrations transverse to the direction of the ray, what must be the constitution of the ether of space in order that such waves could be transmitted through it?

7. It has been established both mathematically and experimentally that waves with transverse vibrations cannot be propagated through either the body of a gas or the body of a liquid. Matter in form of a solid or jelly, is the only constitution which gives the elastic structure necessary to carry on that kind of motion.

The only parallel we have in the phenomena of matter, is the transmission of such waves through solids, and in that case it is accomplished by the elastic rigidity of the solid. Is the ether then a solid?

Considering the phenomena heretofore described, Sir William Thomson (Lord Kelvin) in his lecture on "The Wave Theory of Light" (1884) said: "The luminiferous ether is an elastic solid, for which the nearest analogy I can give you, is this jelly which you see."

The solid or rigid view of the ether constitution has been accepted by many scientists.

On the other hand, Fitzgerald said:

"I cannot conclude without protesting strongly against Sir William Thomson's speaking of the ether as like a jelly.

It is in some respects analogous to one, but we certainly know a great deal too little about it to say that it is like one."

Alfred Sang in the article on "The Underlying Facts of Science," to which allusion has already been made, says:

"Some of the most eminent physicists have adopted the view that the universal medium must be solid. . . . We are asked to conceive our planet—not to mention our humble selves—moving at the rate of eighteen miles per second through it, and, what is still more incredible, that this takes place without practically any friction. . . . The theory of a solid, or to speak more accurately, a rigid ether does not, as we shall see later, appear to be a necessity, and it presents the great weakness of compelling us to rack our common sense to try and explain the passage of bodies through it, from the lightest comet to the most massive star."

He concludes:

"Perfect elasticity by no means implies a solid or semi-solid state; an atomic structure presents elasticity of volume, but equilibrium in a homogeneous, non-continuous medium, regardless of the spaces which may exist between the component incompressible corpuscles, will supply rigidity and elasticity of shape. Pressure in space does not imply elasticity. If elasticity is a rotational effect, and pressure one of bombardment, they are not necessarily interdependent.

"The fact that there may be pressure in space brings one back to the consideration of a gaseous ether, but cannot pressure exist in a corpuscular medium, and may not the pressure be a manifestation of the immeasurable energies which continually pulsate through space?"

In the above there is a vague suggestion of a corpuscular structure of some sort for the ether, and that the innumerable rays of energy passing through the ether of space, may be a factor in fixing the properties of the ether structure.

Sir William Ramsey, in an article (July, 1911), said:

"It is almost universally held that all phenomena are 'mechanical'; that is, they are the result of matter in motion, and can be pictured to the mind in a concrete form; that some kind of 'machine' can be imagined which, if it existed, would reproduce the phenomena in question."

And speaking of the ether, he said:

"Here we have a question still agitating the minds of men of science. It has *not yet* been found possible to think out a structure and mode of motion of ether which will explain, or make it possible to realize as a kind of machine, all the phenomena in which ether appears to play a part."

8. In order that the ether of space may perform the functions it does perform, in transmitting wave motion in straight lines through space in any direction, J. Clerk Maxwell in his article on Ether (9th Ed. Encyc. Brit.), thus described its necessary qualities:

"We know that ether transmits transverse vibrations to very great distances without sensible loss of energy by dissipation. A molecular medium, moving under such conditions that a group of molecules once near together remain near each other during the whole motion, may be capable of transmitting vibrations without much dissipation of energy, but if the motion be such that the group of molecules are not merely slightly altered in configuration, but entirely broken up, so that their component molecules pass into new types of grouping, then in the passage from one type of grouping to another, the energy of regular vibrations will be frittered away into that of the irregular agitation which we call heat.

"We cannot, therefore, suppose the constitution of the ether to be like that of a gas in which the molecules are always in a state of irregular agitation, for such a medium a transverse undulation is reduced to less than one five hundredth of its amplitude in a single wave length. If the ether is molecular, the grouping of the molecules must remain of the same type, the configuration of the groups being only slightly altered during the motion."

And coming to his suggestion that the constitution of ether is made up of elastic centres or vortices in close proximity, he says:

"If there is any motion of rotation, it must be a rotation of very small portions of the medium each about its own axis, so that the medium must be broken up into a number of molecular vortices. We have as yet no data from which to determine the size or the number of these molecular vortices. We know, however, that the magnetic force in the region in the neighborhood of a magnet is maintained as long as the steel retains its magnetization, and as we have no reason to believe that a steel magnet would lose all its magnetization by the mere lapse of time, we conclude that the molecular vortices do not require a continual expenditure of work in order to maintain their motion, and that therefore this motion does not necessarily involve dissipation of energy.

"No theory of the constitution of the ether has yet been invented which will account for such a system of molecular vortices being maintained for an indefinite time without their energy being gradually dissipated into that irregular agitation of the medium, which, in ordinary media, is called heat. Whatever difficulties we may have in forming a consistent idea of the constitution of the ether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body which is certainly the largest and probably the most uniform body of which we have any knowledge."

9. In the above, we have Maxwell's suggestion that the forces which permanently exist in a magnet, and immediately surrounding it, are maintained by vortex motion of the ether operating on the steel by reason of its peculiar structure; the energy necessary for maintenance being continually drawn from the ether of space. And we have the suggestion that the vortex centres necessary to give the ether a molecular structure, are maintained in the same way. His idea seems

to have been that each individual vortex centre must exist permanently. And he was unable to suggest the nature of the forces operating to maintain them in the homogeneous distribution in which they must exist in the ether to answer the requirements.

The writer hopes to be able, by a considerable modification and expansion of Maxwell's theory, to present a rational hypothesis of the structure of the ether, the causes of that structure, and the source of the forces which maintain it.

CHAPTER II

THE ULTIMATE SUBSTANCE

10. In our preceding discussions, we have dealt with the substance of which the ether is composed, as something capable of receiving motion, and of imparting motion, and as possessed of the property of inertia. We have dealt with it simply under the laws which appear to regulate its behavior as observed in the motions taking place in the ether of space. These observations lead to the conclusion that the ether itself has a structural constitution due to organized forms of motion of some ultimate substance.

From certain astronomical facts hereinafter to be considered (Sec. 106), we are led to the conclusion that there never was a time, when any, even the smallest part of this ultimate substance which fills all space, was not in motion relative to some other adjacent parts of substance.

Nevertheless, since two different parts of this substance are frequently, for a time at least, moving in the same direction and with the same speed, when compared with another part, we can say that the two moving with the same speed are in a state of rest with respect to each other.

More motion and less motion existing successively in the same volume of substance, seems to imply the existence of an ideal state in which substance could be without any motion at all. But this idea may be deceptive, since all our ideas of the motion of anything are drawn from a change of distance —relation of that one thing to some other particular thing.

11. Since, under the fundamental conception of physics, energy does not exist apart from substance in motion, and if all substance is in motion, it would not be difficult to con-

ceive of energy as the one sole thing in the universe, distributed through space in various degrees of activity or motion, the more active parts being capable of affecting the less active parts; and to conceive of what we have called substance as merely space filled with energy in a higher or lower state of activity. Such a conception would make "substance," as we understand it, simply an attribute of energy or state of energy. It would, however, possess no superiority in the way of explaining phenomena over the generally accepted theory of the duality of substance and motion, unless it be a superiority to negative the possible existence of an ideal substance in which there is no motion, and there are serious objections to it.

The universality of the law of "cause and effect" would seem to demand *an ultimate duality.*

There are certain fundamental laws of motion, such as that action and reaction are always equal and in opposite directions, the necessity for which is readily seen when we attribute to the ultimate substance the property of incompressibility.

Notwithstanding that "relativity" seems to be inherent in our ideas of motion, yet when we accept as the fundamental duality in nature, "substance" and "motion" or "substance" and "energy," we at once admit that there must exist at least ideally, if not in fact, a state in which substance would exist, if it were free from all motion.

The surface waters of the ocean are probably never in an absolute state of rest, they are vibrating in response to the action of the winds and the tides, yet we find no difficulty in conceiving that the substance of the water has an identity entirely distinct from the motion set up in it by wind and tide, or from the energy expressed thereby.

For the purposes of the following illustration we may assume that water is an incompressible substance. If we completely fill a cylindrical vessel with water, we cannot thereafter add to the contents more water without allowing for the escape of an equal quantity from that already there. We may, however, by suitable appliance set up a rotation of the water within the cylinder, and any number of subsidiary rotations, thereby increasing the amount of energy within the cylinder to any desired extent. From which we draw the conclusion that incompressibility is a quality attaching to substance independently of energy, and that compressibility is a property of energy, that is to say of substance in motion. Indeed, compressibility is closely related to elasticity, and the latter, as we shall later see, is ultimately due to circular motions of substance in the ether structure.

The latest conclusion of the modern scientists is, that the *mass* of any given body of substance is dependent upon the quantity of energy expressed by the sum of its internal movements and of its velocity in space. It is the conclusion which the writer reaches also from the analysis which will be subsequently made of the structure of the thing which we have so far designated vaguely as an ether "particle," "eddy," or "whirl."

If that conclusion be correct, mass is one form in which energy is manifested. In other words it is a composite property of substance and motion.

It has been frequently said that *inertia* is one of the properties peculiarly differentiating matter from other substance. We do not agree with that statement, if we use the term "matter" in the sense to which we limit it in this treatise. The movements taking place in a light-wave traveling through space are subject to the laws of inertia, and the light wave particle is not matter within the meaning of the term as here used. As we shall later point out, the law of inertia is a direct consequence of the action of continuous flows of energy surging through the ether structure, and by passing in and out of a particle, automatically maintaining rotation therein when particle rotation is once set up.

12. Motion in Incompressible Substance.—Among the mathematicians it is generally conceded that the ultimate substance of which the ether is composed is incompressible. By incompressible we mean, that when a given volume of space is occupied by substance it so completely fills it, that no other substance can be put into that space at the same time. If new substance is moving into such volume of space, the substance formerly occupying it must at the same time be moving out. Since the entire space of the universe is conceived to be completely filled with substance, it follows that the movement of a given volume of substance into a new space, must be accompanied by a simultaneous movement of substance formerly occupying that space, into some other space, and by a chain of exchanges, the space out of which the movement first took place, must have been filled by substance moving into it.

The quality of incompressibility at once excludes elasticity as a property of ultimate substance, and makes it an attribute of energy or mode of motion, as was suggested by Lord Kelvin.

In our investigations into the possible motions which may take place in such ultimate substance *in its ideal* state, we can start out with the following tentative premises:

That it is structureless.

That the ideal substance is incompressible.

That it is motionless, but capable of taking on motion.

That it is non-elastic.

That it is capable of indefinite subdivision, and that the subdivided parts can be moved over each other without friction.

There are certain principles which we can carry into this new field, by which to test our tentative assumptions, which are, so far as human observation goes, of universal application to all substance.

These will give us certain controlling additional premises applicable to motion of such substance, which will force us presently to abandon some of the above premises except as an ideal.

These principles are:

The law of inertia, known as Newton's first law of motion:

"Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state."

That substance in motion is capable of imparting that motion to other substance by impact, and in so doing parts with energy.

That in such impact, no energy is ever lost. That the thing called kinetic energy represented by $\frac{1}{2}M\ V^2$ where M is the mass and V the velocity, of the moving body, is indestructible, and is simply passed on in whole or in part, to the body to which motion is imparted.

The above conditions, at once put a limitation on the nature of the motions which can take place in the ideal incompressible substance.

13. We will first observe, that the law of inertia requires that if a block of substance be set in motion in a given direction, its motion would be continued in a straight line, and since the ideal substance is structureless, it would have no means of distributing obliquely or at right angles to the line of pressure, motion applied to it in one direction. In this it would differ from liquids (Sec. 19) and from gases (Sec. 17).

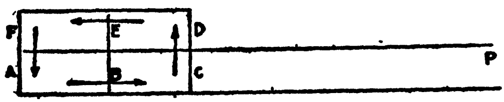

Figure 3

If we imagine a block of this ideal substance AB (Fig. 3) surrounded on all sides by similar substance extending to infinity and in an absolute state of rest, then if it could be applied, any pressure of the block AB, in the direction of

AP, could only be transmitted to the substance BP in front of it, and since, under the supposition, BP contains an infinite block of motionless structureless substance, the block AB could not move into the space BP at all. We see therefore that in order that AB can move into BP, there must in some way be a lateral removal out of BP of substance BC equal to AB, into the space DE, and that this must be accomplished by some force with a component operating at right angles to BC, which component cannot be derived from a simple pressure or movement in the direction AB.

Moreover since all space is completely filled, the substance formerly occupying ED must move into EF, and the substance formerly occupying EF must move into the space formerly occupied by AB. The route might be somewhat more circuitous, but the principle illustrated would be the same.

In other words any motion in such a substance would have to be in the nature of a rotation, by which, substance removed from the front is carried to the rear.

Principle of Action and Reaction.—Moreover, we see that the same amount of energy is required to remove DE into EF as is required to move AB into BC, and the same amount of energy is required to remove EF into AB as was required to remove BC into DE. In other words, we see, so far as motion in ultimate substance is concerned, why it is, that action and reaction must be equal and in opposite directions. The principle rests basically upon the incompressibility of ultimate substance.

14. In the illustration given, we assumed that the transfer of substance from front to rear of the moving block of substance, takes place in one plane. Motion in one plane or lamina, is all that is required, but of course it might take place in more than one plane.

The movement in one plane could best be illustrated by a revolving wheel of substance, moving as if it were a solid, but possessing no cohesion of particles.

Let O (Fig. 4) be the centre of such a revolving wheel of substance, possessing no internal elasticity, and surrounded by similar structureless, motionless substance, to an infinite distance on all sides. Let TB be the periphery of the revolving substance. Then any substance moving in the periphery at the point T, is moving in the tangent NP and in the direction TP. But because there is an infinite line of non-moving substance in the direction TP, the substance in that direction cannot be set in motion. Now under the law of inertia, the substance at T, must continue to move in the straight line TP, unless some extraneous force is applied to alter the direction of that motion. Under the supposition that the substance surrounding the wheel is inelastic, and that there are no forces operating through it, there would be no force operating on the moving substance at T, at right angles to the tangent, to turn the course of the substance at T, out of the tangent, and keep it moving in the periphery; and since it cannot continue its motion in the tangent against an infinite resistance, the energy would be annihilated, and the revolution of the wheel would cease. Now we know that no energy is ever destroyed. Consequently if the revolution of the wheel is to be continued, it requires the operation of forces through the surrounding substance, acting at right angles to the tangent at each and every point of the periphery. And this, in case of a circular wheel, requires that the direction of all these forces must pass through the centre.

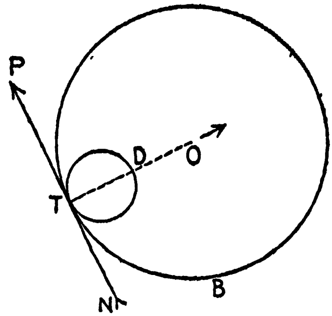

Figure 4

We see, therefore, that no such revolution of substance could take place, unless the substance of the wheel were elastically organized, or unless the surrounding substance, through some elastic structure, or otherwise, were transmitting motion to the periphery in the direction of the centre, or at least perpendicular to the tangent at every point of the periphery.

In other words, motion in one part of substance implies that all surrounding substance should have motion of some sort going on in it. Consequently we must conclude, as well on mechanical principles, as from the astronomical considerations, to which reference has been made, that each and every part of the substance of the universe must have, and must always have had, motion going on in it. We see, therefore, that substance without motion in each and every part, can exist only as an ideal, and never could have existed as an actual fact at any time. Substance and energy are one and inseparable, yet each has an individuality of its own.

15. Let us, however, imagine that the surrounding space be motionless and non-elastic, but that there are internal motions taking place in the substance of the revolving wheel. For instance, we might suppose a revolution to be going on in the small interior wheel (Fig. 4), giving simple harmonic motion in DT, so that a component of force would always be operating at right angles to the tangent, and the energy impinging upon the non-elastic wall of the surrounding substance at T, would rebound, furnishing the centripetal force, which with the tangential force due to the revolution of the wheel as a whole, would sustain the continuity of the wheel motion. This would give a perpetual vortex motion, maintained by the original energy which in imagination we have bottled up within the wheel. But the universality of energy and its general transfusion would seem to negative the idea that there are or ever were any such isolated perpetual motion vortices.

The possible existence of the hypothetical indestructible vortex ring atom of Lord Kelvin rests upon certain mathematical deductions predicated upon what the mathematicians designate the "equation of continuity," and this latter is premised upon the medium being elastic though incompressible. The same objection as above stated, exists to that conception. Besides the developments of the last few years point to the conclusion that the atom is not indestructible.

The existence of vortex motion, maintained for an indefinite time, by the constant flow of energy through such centres from surrounding space, as Maxwell seems to have had in mind in the case of permanent magnets, is much the more rational theory. The origin and operation of these forces we will consider later.

This to the Mathematicians: It is to be observed that the writer does not question the equation of continuity of disturbances traveling automatically through space; but that equation rests upon the assumption of a continuous flow of substance taking place in and out of the elementary parallelopiped as it advances through space, without accounting for the cause of the flow. When that is accounted for as we hereinafter do account for it, we must reach the conclusion that a particular rotation can be set up or destroyed in the ether at any time, because rotation is inherent in the structure of the medium; and this negatives the existence of any indestructible vortex atom.

CHAPTER III

THE CONSTITUTION OF MATTER, IN ITS THREE STATES. GASES, LIQUIDS, AND SOLIDS

16. Before we come to a consideration of the constitution of that mysterious substance which is supposed to fill the depths of space, since we are best acquainted with substance in the form of matter, it will be found advantageous to consider the principal structural states in which we know matter can exist, and the relation of those structures to the kind of wave motions which it is possible to propagate in matter, as it exists in those respective states.

These structural states are—the gaseous, the liquid, and the solid.

In this stage of our discussion, we can only deal with the present subject in the most general way, in order to lay the foundation for what will come afterward.

17. **Gas Constitution.**—In the theory of gases generally accepted by scientists, it is assumed that each molecule of matter of which the gas is composed, is separately elastic. If we consider any inclosed space, as for instance a room filled with gas, each molecule acts as if it were a small blind moth flying in a straight line, until it comes in collision with another. Taken collectively, the molecules are flying promiscuously in every direction, continually bumping into each other, and being reflected by their elasticity in another direction. It is the bombardment of the walls of the room by these flying molecules, which causes the pressure of confined gas against the walls.

It is easily shown that under such conditions the molecules would distribute themselves through the room, so as to give the gas an average uniform density. And for this reason, constant pressure applied in one direction so as to condense the gas in one portion of a confined body of gas, would be quickly distributed, and act as pressure in all directions throughout the body.

18. When we speak of collision between two molecules of gas we mean that the centres of the molecules have reached that degree of proximity at which further approach, under the operation of the forces bringing them together, is arrested by something equivalent to forces of repulsion brought into play between the molecules by such approach.

The origin of these repulsive forces and the mechanism by which they are brought into play, are questions which belong to the problems we reserve for final solution.

As a familiar instance in which two bodies may collide and be elastically reflected, without coming into substantial contact, we may cite the case of two pith balls, both negatively electrified, or both positively electrified. It is a familiar principle that they repel each other with a force inversely proportional to the square of the distance. If they are thrown toward each other in a straight line, their approach is arrested elastically when they are at a certain distance apart, by the electric repulsion called into play, and they are turned back in their courses, as if their surfaces had come into collision.

We may fasten one of the pith balls, which we will speak of as the "first ball," to a non-conducting table surface, and place the second pith ball on the table a short distance from the first ball. The repulsion between the balls will tend to push the second ball away. We may apply just enough pressure to the second ball, in the direction of the first, to keep the second ball in equilibrium.

We may imagine a sphere to be drawn around the first ball with a radius just equal to the distance from the centre of the first ball to the centre of the second ball in the position of equilibrium above described. We may now move our second ball to any position on the surface of our sphere, and so long as the external pressure is the same as in the first position, and is directed toward the centre of the sphere, the second ball will be in equilibrium. We could therefore regard the surface of this sphere as an artificial surface of the first pith ball, under the given external pressure proceeding from every direction toward the centre of the sphere. If the external pressure be increased, the radius of the surface of the sphere of equilibrium is shortened.

The illustration is not intended to indicate that the repulsion set up between gas molecules when in close approach, is electrical. It is intended merely to illustrate the variability of the thing we call "surface of contact" when used in connection with bodies in collision.

19. **The Liquid Constitution.**—It may be assumed that the molecules of matter as they exist in a liquid, in respect to their contact with each other, are, or act as if they were, little spheres.

If there were a certain quantity of gas confined in a closed vessel, we could, as has been done in the case of air and other gases, compress the sides of the vessel, until the volume of the receptacle containing the gas would be much reduced. This would result in shortening the length of the average path the molecules of gas would have to travel between collisions. These collisions, therefore, would be more frequent, and there would be much greater bombardment on the sides of the vessel. This would be evidenced by greater molecular motion of the particles of the material composing those sides, and would be interpreted by us as a rise in the temperature of the contents of the vessel communicated to the sides. By use of cold applications to the exterior of the sides of the vessel, the energy represented by the molecular motion of the particles composing the sides, passes out of it, into the cold application, and the reaction or "bounce" of the molecules of gas within, from the sides of the vessel is greatly weakened, and very shortly the average velocity of the molecules of gas in the vessel, or as we say, the temperature of the gas, is lowered.

By combining the process of pressure and of cooling, we can finally bring the little gas atoms so near together that they can roll around each other. There is no longer collision and reflection going on, and the gas becomes liquid, in which at that temperature there is no tendency of the molecules to fly away.

The essential nature of the liquid state, is therefore the absence of the condition in which the molecules are in heterogeneous flight, and the existence of a condition in which the molecules can roll around freely among themselves, without any rigidity to the system of balls.

The liquid state can be well illustrated by a box full of billiard balls. If we apply pressure downward to one ball, the pressure will be distributed through the entire body of balls, in every direction, even moving some of them upward. This is due to the spherical shape of the balls, and the fact that when in close contact, the centres of the balls arrange themselves in equilateral triangle positions, causing a resolution of the force of pressure in any one direction, through the points in which the surfaces of the balls are in contact.

20. An explanation of the operation of the forces which tend to keep these primary molecules of matter in spherical shape, belongs to the final problems we have reserved for later solution.

It is sufficient to say at this time, that the spherical shape is probably due to the revolution of the atoms composing the molecule, about a centre, whatever other motions may be taking place in the molecule itself.

If, holding one end of a string, the other end of which is attached to a small ball, we cause the ball to revolve around our hand as a centre, the faster we cause the ball to revolve, the stronger we feel the pull on the string. The tendency of the ball to fly off radially, away from the centre, or contrifugal force, is just balanced by the pull on the string toward the centre. If, while a certain speed of revolution is being maintained, we shorten the length of the string, we find that the pull on the string is perceptibly increased, and therefore the centrifugal force, or tendency to fly off radially, is increased.

We know from the principles of physics that this centrifugal force is measured by $\frac{MV^2}{R}$, where M is the mass or weight of the ball, V the velocity of the ball in its orbit, and R the radius.

In the case of our spherical molecule, any material particle in the surface revolving around the centre of the molecule, must be kept in its circular path, either by some internal force continually pulling it toward the centre, or by external forces operating on it at every point in its path tending to push it toward the centre. In either case if the particle keeps its path in the surface, the centripetal force must be just balanced by the centrifugal force created by the revolution of the particle around the centre.

If, therefore, we suppose that some additional external pressure be applied to a surface particle, sufficient to shorten the radius of revolution, such shortening will be resisted elastically by an increase of the centrifugal force, until that increase, caused by continual shortening, becomes sufficient to balance the applied pressure. If the additional applied pressure be then removed, the centrifugal force would immediately move the particle outward to the original length of the radius, where the former balance of forces would be restored.

We see, therefore, that such a spherical molecule would act elastically.

We also see from the mathematical formula above, that when by external pressure we have shortened the radius, if we could by suitable appliances decrease the velocity of the particle in its orbit sufficiently, we could restore the balance between the centripetal force originally operating, and the centrifugal force operating for the shortened radius, so that if the applied pressure be removed, the particle would continue in the smaller orbit, and there would be no tendency of the sphere to regain its original size.

The velocity of the particle represents temperature, and the decrease of that velocity is accomplished by cooling.

Water for ordinary purposes is regarded as incompressible, but even water is capable of being compressed into a smaller volume under great pressure. When the pressure is removed it regains its former volume.

21. **The Solid Constitution.**—It would be premature to enter upon a discussion of the solid constitution of matter at this place, but it is advantageous to have some idea of what is meant by elastic rigidity, which all solids possess to a greater or less degree.

Suppose we float in a basin of water, three similar small corks, through the centre of each of which, small magnetic rods have been inserted vertically, so that all the negative poles are up, and the positive poles are down. Since like poles repel and unlike attract, with intensities inversely proportional to the square of the distance apart, the corks will be repelled and tend to float away from each other. If now we suspend a larger magnet over the centre of the basin, so that its positive pole is downward, and a little above the level of the negative poles of the small magnets, it will tend to attract all the corks toward the centre of the basin. But the nearer the corks approach each other, the stronger will be the repulsion which each will exert upon the other. The result will be that they will float toward the centre of the basin and arrange themselves in the form of an equilateral triangle around the centre, and come to rest in stable equilibrium at just that distance from the centre, at which the attraction of the central positive magnet, for each of the negative poled magnets projecting above the corks, is balanced by the resultant repulsion outward exerted by the small magnets in the corks, on each other.

If, after the corks have assumed their position of equilibrium in the triangular position, we give one of them a slight blow toward the centre, it will be seen that each of the corks will be affected, and the triangular formation will be for an instant distorted, so that the form will not be an equilateral triangle. But they will immediately fly back to their positions of stable equilibrium in equilateral form. We might add additional corks and build up a system of triangles.

It is seen that the balance existing between the forces of attraction and repulsion in the illustration taken, gives rise to a certain fixed arrangement of the corks, and the form assumed possesses elastic rigidity. There is elastic resistance to the displacement of one of them from its position of equilibrium, followed by its restoration to the position from which it was displaced, unless the force applied is so great as to break up the arrangement. A body composed of particles arranged with only such partial stability, would be said to be a *quasi-labille* medium.

22. If, in the illustration taken, we could set the equilateral triangle, as a whole, rotating on the surface of the water around its centre, we would develop a centrifugal force tending to drive the corks away from the centre, and therefore further apart, and the position of equilibrium would be a larger equilateral triangle, according to the rapidity of the rotation. In molecular motion, such an increase in rapidity of rotation would be called a rise in temperature.

23. Had we, in the experiment, used four similar corks instead of three, the arrangement for stable equilibrium would have been in the form of a square. With five corks,

the form might have been a five sided polygon, but that would not have been quite so stable as in form of a square with one cork in the centre. We will reserve further combinations for further discussion.

We may regard a molecule of matter, as made up of some such combination of atoms, in rotation, but not necessarily confined to motion in a single plane.

And we may regard a solid body, as made up of an aggregation of such molecules, held together by mutual attraction.

24. The explanation of the forces of attraction and repulsion existing between atoms or molecules of matter, from the mechanical standpoint, will be taken up later. It must not be thought, however, that, because in the illustration of the corks we supplied the interacting forces by magnetic attraction and repulsion, the forces of attraction and repulsion acting between atoms or molecules, to create elastic rigidity, are necessarily either magnetic or electric.

At present we are concerned only with forming some kind of a mechanical conception of what must be the constitution of an elastic solid, in order that we may understand the means by which wave motion is propagated through such a medium. We see that a body may possess elastic rigidity, and yet a molecule or particle may perform motions of its own, within the limits of the restraint imposed upon it by the forces operating upon it from the surrounding particles.

CHAPTER IV

THE DIFFERENT KINDS OF WAVE MOTION AS AFFECTED BY THE MEDIUM OF TRANSMISSION

25. A wave in material substance may be defined as a disturbance, which, originating among the particles of the body, at or about some particular point, travels from that point outward through the body, while the particles which are concerned in the successive disturbances in the path of the wave, after performing a certain small amount of motion in a limited space, resume their positions of rest.

26. **Longitudinal Waves.**—The simplest form of wave motion may be illustrated as follows: Place a number of billiard balls of equal size, A, B, C, D, E, F, G (Fig. 5), in

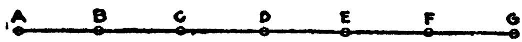

Figure 5

a straight line, equidistant from each other, on a smooth table.

If a sudden sharp blow be given with a cue to the ball A, in the direction AG, the ball A, will roll forward and strike B, in its centre, the ball A, will come to rest; and the ball B, will roll forward and strike C, in its centre, the ball B, coming to rest; while the ball C, will roll forward. And so the motion or disturbance will be carried forward through the entire series of balls, while each individual ball will travel through but a very small space.

The series of balls as a whole, would represent the body through which the wave is propagated.

In the above illustration, the balls are supposed to be in perfect alignment, and the shot perfectly directed, so that each ball strikes the next one in line, exactly in the centre.

27. It will be observed that in the positions in which we placed the balls along the line, they were not held in restraint by any force whatever, so that any extraneous force applied to any one of them would have freely rolled it backward or forward in line or out of alignment, and there is no other force operating to return it to its former position if once displaced. In other words we were not dealing with balls held in position under a rigid elastic system, as explained in Section 21. The only elastic reaction called into play in the illustration, is that arising from the collision of the balls in the line of propagation of the wave. Elastic rigidity of the system is therefore not a necessary property of the body through which a longitudinal wave is propagated. It is only necessary that the particles themselves be elastic.

We would naturally expect, therefore, that longitudinal waves could be propagated through gases or liquids, and such is shown, experimentally and mathematically, to be the case.

28. On the other hand, if we imagine the same experiment modified, by supposing that forces are in operation between the respective balls, which make them repel each other, say inversely as the square of the distance, the balls in alignment will be held in their equidistant positions with elastic rigidity. And if, under those circumstances the first ball is given a blow at its centre in the direction of the line of propagation, the wave motion must be transmitted longitudinally as before.

There would seem to be, therefore, no intrinsic reason why bodies possessing elastic rigidity should not be able to transmit longitudinal waves.

29. Sound Waves Are Longitudinal Waves and We Know That They May Be Propagated through Gases, Liquids, or Solids.—In the case of a gaseous medium, such as air, we have to deal, not with the progressive collisions between balls previously at rest and arranged in perfect alignment (as in the billiard ball illustration), but with the transmission of the disturbance through a medium composed of particles flying in every direction, although distributed with average density. Waves in such a medium, pass outward from the centre of disturbance, radially in every direction.

The progress of the wave along any radius is marked, at any point at a given instant, by a condensed aggregation of the particles of gas, followed by an excess diffusion of particles or rarefaction, with the final result that as the wave front passes on, the space left behind is refilled with particles of the average density as at first. There is a restoration of average density in the medium, but never a restitution of any particle to its former position. Nevertheless it is the *disturbance* which travels forward and not the gas particles. Such waves are also called *waves of compression.*

30. **Transverse Waves.**—The simplest form of waves of transverse vibration, may be illustrated as follows: Place a number of billiard balls—M, N, O, P, Q, R, and S (Fig. 6)—

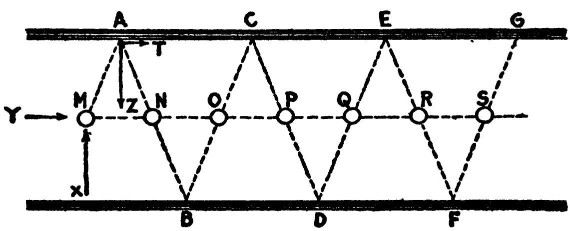

Figure 6

spaced equidistant apart along the centre line MS of a wide trough, the parallel sides of which are elastically cushioned, as are the sides of a billiard table.

Suppose now, that the ball M is simultaneously subjected to two blows, which we will represent by the force lines XM at right angles to MS, and YM in the direction MS.

The ball M will take the resultant direction MA and when it impinges on the cushion at A, it will be reflected by the elastic cushion in such a manner that the angle of reflection will be equal to the angle of incidence, and will proceed in the direction AN. It will come to rest when it strikes the ball N, and the latter will take up the motion and be reflected from the cushion at B, and proceed in the direction BO. It will come to rest when it strikes the ball O, and the latter will take up the motion and be reflected from the cushion at C, and proceed in the direction CP. And so the motion will be carried forward through the entire series of balls. In this case, however, the continuity of that kind of wave motion is dependent upon the elastic rigidity of the sides of the trough. It will be seen that the ball M moves under the operation of two forces YM, operating uniformly, in the direction of the propagation of the wave, and XM at right angles to that direction. But XM is totally overcome when the ball strikes the cushion at A. In being overcome, however, it compresses the cushion at A, and the elastic reaction of the cushion against the ball, tends to hurl it back in a line perpendicular to the side of the trough, with a force AZ equal to XM, but operating in the opposite direction. At the same time the momentum of the ball, given by the force YM, will still be operating, and may be represented at the instant the ball is leaving the cushion at A by the force AT, so that the path of the ball will be in the direction AN. We see, therefore, that it is the elastic rigidity of the cushion which furnishes the force of restitution which brings the ball back into the line of the propagation of the wave.

31. Now instead of billiard balls, we may imagine a homogeneous isotropic arrangement of molecules or particles of matter, held in elastic rigidity by the forces of attraction and repulsion existing between them as explained in Section 21.

The elastic rigidity of the system of particles lying on either side of any line along which any such wave is started, would take the place of the cushion in the above illustration, which would continue the propagation of the wave in that line.

But again in this billiard ball illustration, the forces—YM and XM—operate uniformly from the time of the blows until the ball travels all the way from M to A, so that the path is a straight line MA. But if we suppose that the cushion at A were replaced by another ball held in elastic rigidity by the system of balls behind it, and further suppose that all the balls repel each other inversely as the square of the distance between them respectively, then it can easily be shown that the path of the ball M will not be the straight lines MA–AN, but will be a curve.

In the case of particles of matter, however, the disturbance would be occasioned not by the motion of a single particle, but of very many particles, and the reaction which would furnish the force of restitution would be the reaction of very many particles, so that what we really have to deal with, is the average behavior of the particles, or the behavior of the average particle.

We would not expect, therefore, that the transverse path of the average particle would be in straight lines, as in the billiard ball and cushion illustration.

32. Moreover, in solids the particles or molecules are arranged in elastic rigidity in space of three dimensions, while in our illustration we only considered wave motion in a single plane.

For reasons to be more fully considered hereafter, the generally accepted theory is, that in waves of transverse vibrations, of simplest form, traveling through a solid, the path of the average particle is, as in the case of simple light waves as illustrated in Figure 2, a spiral around the line of the direction in which the wave is propagated, but with the capacity of having the motion continued, under certain conditions, as transverse vibrations in a single plane. In either case, however, the wave is propagated under the operation of a steady force or pressure in the direction of the line of propagation, and of forces of displacement and restitution, operating at right angles to the axis of the spiral or line of propagation of the wave.

33. Because of the fact that gases and liquids are without a structure possessing elastic rigidity, it has been demonstrated both mathematically and experimentally, that waves of transverse vibration cannot be propagated through them. But transverse vibrations can be propagated at the surface of a liquid as we shall later see.

Both mathematically and experimentally it has been determined that both longitudinal and transverse waves can be transmitted through a solid. But the longitudinal or compression waves in the same medium travel faster.

34. As already seen, the evidence is entirely satisfactory, that light travels through the ether medium in transverse waves. Showing that the medium possesses elastic rigidity of structure. But there is no evidence in optical phenomena from which physicists have been able heretofore to draw the conclusion that longitudinal waves are propagated through the ether medium.

35. **The Solid Elastic Theory of Light.**—The fact that light waves travel in transverse vibrations, showing that the medium possesses elastic rigidity, has led a great many scientists to classify the ether as a solid or jelly-like substance.

Notwithstanding the fact that it has taxed our confidence to admit that the world and planets could, without friction, plunge through such a solid, and pursue their courses around the sun, without apparent obstruction or delay, that fact has never seemed to trouble the mathematicians and physical scientists half so much, as the absence of any evidence that longitudinal waves are transmitted through and by the ether medium.

In other words, the disturbances started in the sun or other source of illumination, which create waves of transverse vibration which we call light, should, if the ether be a solid, give rise at the same time to waves of longitudinal vibrations after the manner of sound waves, and traveling faster even than light, but it has been considered that there is no evidence of the actual existence of such waves.

The great mathematicians of the early half of the last century accepted the absence of longitudinal waves in the ether medium as a fact, accounting for it by supposing that the ether was incompressible, in which case the velocity of the longitudinal wave as given by the mathematical formulæ would be infinite and the effect disappear. They then developed the mechanical principles controlling transverse wave motion in elastic solids, and deduced the mathematical equations applicable thereto.

Under the treatment of Fresnel, Airy, Tait and others, the elastic solid theory was made to give us a wonderful insight into the mechanical movements taking place in these transverse waves.

The solid elastic theory explained wonderfully well, most optical phenomena, but nevertheless, certain phenomena of reflection and refraction were not explained by it in a manner entirely satisfactory to the mathematicians.

George Green and James MacCullagh, each in a little different way, found explanations which, to their own satisfaction, reconciled these seeming inconsistencies, without impairing the fundamentals of the theory.

36. **Maxwell's Electromagnetic Theory of Light Waves.**—In his "Treatise on Electricity and Magnetism," Clerk Maxwell gave to the world (1873) what has since been known as the "Electromagnetic Theory of Light." It does not purport to explain the motions taking place in a light wave, by following the movements consequent upon the displacement and restitution of an ether particle. It does not pur-

port to tell us what electricity is. But the ether medium is supposed to be composed of small vortex particles (Sec. 8) and these are supposed to be in a state of electric equilibrium until the disturbance passes on from one particle to another as an electric "charge." As the wave advances there is a "displacement of electricity" on the particles in the wave front, and this displacement is at right angles to the direction of the propagation of the wave. This electrical displacement is supposed to create a magnetic force at right angles to both the line of electrical displacement and to the line of the wave direction. Both the electric displacement and the magnetic force being in the wave front. The theory calls also for the existence of a pressure in the direction of the propagation of the wave.

Under the theory, a light wave becomes an electrical and magnetic vibration propagated through the medium.

37. The theory may be graphically illustrated as follows: Suppose we are dealing with a plane polarized ray, and

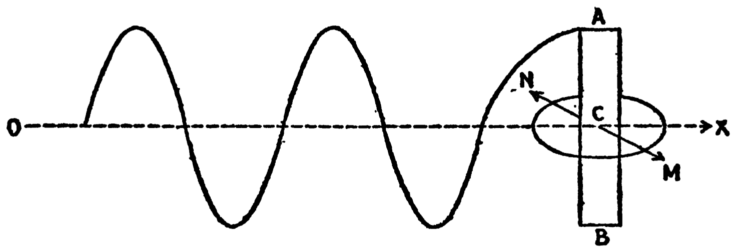

Figure 7

that the light or electric wave be moving in the direction OX (Fig. 7).

As the wave passes through the point C, an electrical displacement is supposed to take place in the small cylinder AB of the medium, at right angles to OX; the displacement will be alternately in the direction AB and BA. The effect will be as if a current of electricity were passing through a wire from A to B and as is well known from electrical phenomena, that will produce a system of magnetic lines of force, arranged in circles, of which the centres lie in A B, and the circles lie in planes perpendicular to AB. Or more accurately speaking, the circle representing the magnetic line of force at any particular instant, will travel up or down the cylinder with the electric displacement in AB, and at any other instant, will be in a plane parallel to its former position, and therefore at right angles to AB. When the direction of the electric displacement is reversed after a half vibration, as from A to B, the direction of the magnetic force in the circle will be reversed in its direction. Thus the elastic pulsation in AB is accompanied by a magnetic pulsation in the circle of magnetic force.

If we imagine that the wave front is made up of a number of such parallel cylinders, in which the elastic displacements are taking place simultaneously and in the same phase, the magnetic forces created in the space between them, being in opposite directions, will be neutralized by each other, the effective force left being only the magnetic force operating at right angles to AB. So that the advance of the light wave, by reason of the electric and magnetic pulsations taking place at right angles to each other, will be accompanied, by the creation at the wave front of two waves sent off through the surrounding medium, at right angles to each other and at right angles to the direction of the ray.

38. We will endeavor to point out later (Secs. 62–63) that in the case of plane polarized light the two pulsating forces in the wave front operating at right angles to each other, and to the direction of the ray, must exist under the solid elastic theory, as well as under the electric theory. So that there ought not to be any necessity for burying the mechanical idea, under the names of "electricity," "electric charge," "electric displacement" and "magnetic force," the meaning

of which Maxwell himself did not attempt to translate into the simple terms which define substance and motion.

Notwithstanding this, Maxwell's electrical theory as to the manner in which light and electrical waves are transmitted through the ether, has been demonstrated to be correct as a working hypothesis, and has produced a wonderful development of modern knowledge in electrical science, and finally in the hands of Hertz, it led to the discovery of the Hertzian waves, and the development of wireless telegraphy by Marconi.

These results have caused an almost total abandonment of the elastic solid theory of light, and a general acceptance of the electrical theory. But the trouble with it is that it does not explain.

We can have no more quarrel with Maxwell as to this, than Newton had with himself, for his inability to explain *the why* of gravitation, the laws controlling which he discovered, and while expressing the belief that there existed an explanation, he admitted that he could not find one.

We know that by a simple mechanical arrangement we can convert the fall of a cubic foot of water over a dam, into so much electricity, and that too without converting any material into the electricity produced; nothing is used up, other than the energy represented by the change of the position of the water from the top to the bottom of the dam. From which, the inference has long since been drawn, that electricity is simply substance in a different form of motion from motion of substance in a straight line. And, therefore, instead of having other things defined in terms of electricity, electric displacement and electric charge, we have a right to demand an explanation of those terms, in terms applicable to substance undergoing rectilinear motion.

The discovery, within the last few years, of the existence of the small particle to which has been given the name corpuscle, or electron, and its identification with negative electricity, has given a "material" aspect to electricity, which adds to the call for a reëxamination of the solid elastic theory of the ether, and of the mechanical operations involved in ether waves. If the chemical atom is to be regarded as an aggregation of electrons, there is so much the more reason for not accepting the electron as the final thing, and for discovering if possible, the mode of motion of substance which makes the electron.

Maxwell elaborated his theories by use of quaternions, a method of mathematical treatment then but little understood, and which even now, is not to be interpreted by mathematicians of ordinary attainments.

It is probable that it was for this reason that the value of his work for a long time remained not fully appreciated.

39. Translated into simple mathematical language, the formula conceived by Maxwell for expression of light wave motion on the electrical theory, can be made to conform exactly to that reached on the elastic solid theory. But the symbols in the respective equations do not represent the same things. (See Professor Lorenz on reconciliation. Light. Ency. Brit. 11th Ed. p. 622.)

In an article in the *American Journal of Science*—Series 3, Vol. 37, pp. 139–144 (Feb. 1889)—in which a critical mathematical comparison is made between the elastic and electrical theories of light waves, Professor J. Williard Gibbs refers to what he denominates "A remarkable paper by Sir William Thomson in the November number of the *Philosophical Magazine* which has opened a new vista in the possibilities of the theory of an elastic ether."

By supposing that the ether extends all through boundless space, and attributing to it certain unstable elastic rigidity, it is shown that the velocity of the longitudinal wave or wave of compression, may be zero, and its disappearance in ether phenomena accounted for. The ether thus organized is designated as a *quasi-labile* medium. Professor Gibbs says: "This renders possible a very simple theory of light, which has been shown to give Fresnel's laws for the intensities of reflected and refracted light and for double refraction, so far as concerns the phenomena which can be directly observed. The displacement in an aeolotropic medium (a medium not conducting light equally in all directions) is in the same plane passing through the wave normal as was supposed by Fresnel, but its position in that plane is different, being perpendicular to the ray instead of to the wave-normal. It is the object of this paper to compare this new theory with the elastic theory of light.

"In the limiting cases, that is, when we regard the velocity of the missing wave in the elastic theory as zero, and in the electric theory as infinite, we shall find a remarkable correspondence between the two theories, the motions of monochromatic light, within isotropic (media having the same physical properties in every direction) or aeolotropic media of any degree of transparency or opacity, and at the boundary between two such media, being represented by equations absolutely identical, except that the symbols which denote displacement in one theory, denote force in the other, and vice versa." After making the mathematical comparison, by use of quaternions, the article concludes as follows:

"It is evident that the electrical theory of light has a serious rival, in a sense in which, perhaps, one did not exist before the publication of Sir William Thomson's paper in November last. Nevertheless, neither surprise at the results which have been achieved, nor admiration for that happy audacity of genius, which, seeking the solution of the problem precisely where no one else would have ventured to look for it, has turned half a century of defeat into victory, should blind us as to the actual state of the question."

We shall later on, examine into the causes which operate to give to the ether a *quasi-labile* constitution.

We have said this much on the subject of the elastic theory of light waves, solely to justify us, in returning with the greater confidence, to an examination of the mechanical motions taking place in an ether wave on the elastic theory.

40. **Wave Motion on the Surface of Liquids.**—There is probably no branch of physics, mechanics or applied mathematics, in which more profound research has been made than that of wave motion. When we consider the number of particles, the independent motions of which are more or less constrained by some law, so that as a whole, the motion exhibited is that, for instance, of a wave on the surface of water, we at once see, that to arrive at an understanding of the law controlling wave motion, we must study the behavior of the average particle, or the average behavior of a particle, and in this way eliminate the minor causes which work for irregularity.

In their admirable treatise on "The Elements of Mechanics" (Macmillan & Co., New York, 1909), Franklin and MacNutt state the difficulties which hedge this subject, and the basis upon which we must rest the wave theory of light, very aptly as follows:

"In undertaking to establish the more important ideas of wave motion, we are confronted with a serious difficulty, namely, that water waves, the only kind of waves with which one is familiar, are excessively complicated; invisible sound waves in the air, and the even more intangible light waves in the ether, in their more important aspects, at least, are extremely simple in comparison. The wave theory, however, originated in the application, to sound and light, of the ideas which grew out of a familiarity with the behavior of water waves, and in attempting to establish the wave theory, one is obliged to base it upon the familiar phenomena of wave motion as exemplified by water waves."

It is not the writer's purpose to enter into any exhaustive discussion of wave motion, but the logical development of our hypothesis, requires that the reader should carry in his mind as clear an idea of wave motion as may be attained by a restatement of certain well established principles, and that the attention be directed to certain phenomena illustrative of those principles of which use is to be subsequently made.

41. **Water Waves.**—A wave on the surface of water is carried on by vibrations transverse to the direction of the propagation of the wave. As already pointed out (Sec. 30), such a wave cannot be carried on unless under the operation of alternate forces of displacement and restitution. In waves on the surface of water, the action af gravity operating to restore the water level, when disturbed, gives rise to the alternative forces of displacement and restitution.

The weight of a given volume of air is much lighter than that of a similar volume of water. The average pressure of air at the surface of the earth is 15 pounds to the square inch, and that is due to the weight of a vertical column of air having a base of one square inch and reaching up to the confines of the air regions, estimated at say, 45 miles above us. A column of water thirty-four feet in height would weigh as much. In order that a body of water held at rest by the force of gravity, should remain in a state of equilibrium, it is necessary that the pressure should be the same on each particle of water lying in the same horizontal plane, otherwise, since pressure in a liquid is transmitted equally in every direction, there would be a movement of the particles from a point of greater to one of less pressure. It is thus that the air pressure tends to keep the surface of the body of water, on the same level, or as we may say, in the same horizontal plane, if we ignore the curvature of the earth.

42. Let AB (Fig. 8) represent the plane surface of the water at rest.

Now suppose we create a disturbance in the water by suddenly dropping into it, say, a cylindrical body represented by C. The effect will be that the liquid will be heaped up in the form DEF, at the same time taking on a forward movement,—the force causing this forward movement operating on any particle, say, at the crest E, being represented by EL. Gravity then commences to pull the particle E downward to the water level with a force represented by EK. The two forces EL and EK will be equivalent to a resultant force EM. But as the particle E falls toward the water level it acquires velocity and momentum, which sweep it along the curved path EFG, carrying it down to G, below the water level and creating the trough FGH. But from the time the particle passed

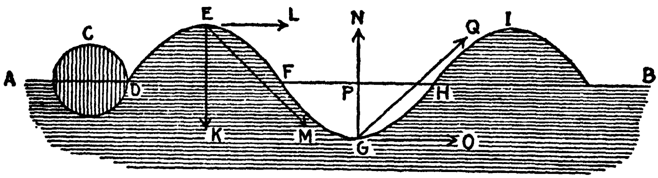

Figure 8

through F it has been operating against the upward pressure of the body of water from below the water level, so that by the time the particle reaches G, its downward momentum has been overcome, but it is still operated on by the forward impetus now represented by GO. Now when the particle is at G it is below the water level by the distance GP. There is, therefore, brought into play an upward pressure GN on the particle at G equal to what would be the downward pressure of a column of water PG, if it were present. The forces GO and GN will give the resultant GQ which will take the particle through the curved path GHI, to the new wave crest at I.

But from the time the particle passed through H, it has ceased to be operated upon by any accelerating force due to the pressure of the water seeking its level, and by the time it reaches I the accelerating force of gravity operating downward has overcome the upward momentum acquired in moving from G to H, and therefore, at I the new crest is formed. In the same way the motion is continued and the wave is carried on, by the forces of displacement and restitution, created by gravity. The distance from E to I is called the wave length.

In the foregoing illustration we assumed that the particle starting at E actually itself traveled through the path EFGHI. This is not strictly correct. There is an interchange of particles, the motion of the one being taken up by another, but that does not affect the manner in which the motion is carried forward by the operation of the forces of displacement and restitution through gravity. As we shall presently see, the real path of any individual particle from the time it leaves its position of equilibrium until its return to its position of rest is circular or elliptic.

It is apparent that gravitational waves must be purely surface waves. The forces of displacement and restitution would not exist except at the surface separating two media of different densities or weights, as in the case of water and air. Hence below the rolling billows of the ocean, the sea is calm.

43. By use of a long trough with glass sides, nearly filled with water, through which had been scattered small particles of amber, which were so nearly of the same specific gravity as water that they remained suspended therein, H. and W. Weber were able to examine the motions of the particles involved in simple water waves. A wave was created by immersing one end of a glass tube below the surface of the water, and by suction, raising a column of water in the tube a few centimetres high, and then letting the column of water fall. The wave thus formed traveled down the length of the trough, and careful observations were made through the sides of the trough of the motions of the amber particles.

In the typical case, the particles in the surface of the water described closed curves, which were elliptical or circular in form, the diameter of the circle being equal to the vertical distance between the crest and hollow, or height of the wave. In the upper part of the circle, the particle moved in the direction in which the wave was moving, in the lower part of the circle, in the opposite direction. It was thus found, that while apparently the water composing the wave rolled on through the full length of the trough, that as a matter of fact, the particles composing the wave at any instant were performing a circular motion in their own little orbits, and returned to a state of rest, at least approximately, at the positions from which they started, while the wave motion was carried forward by the succeeding particles which were taken up by that motion, until they too had performed their orbital motions.

44. If we are considering a single wave, the distance through which a wave progresses, during the time required for a particle taken up at the surface to make one complete revolution in its orbit, is called a wave length. Where there is a train of waves, the wave length is measured from crest to crest.

In the case of a wave traveling on the surface in deep water, the individual particles describe circles in vertical planes as illustrated in Figure 9.

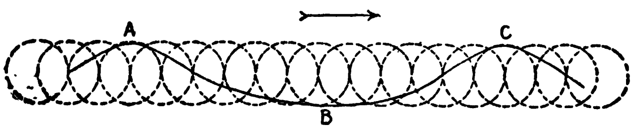

Figure 9

When a particle is on the crest A, of the wave, it is moving in the direction in which the wave is moving. When it is in the trough B, it is moving in the opposite direction to that in which the wave is moving.

As we go down from the surface, the particles still move in circles, but the radii grow smaller and smaller, till at a depth equal to the wave length the radius of the circle is only about $\frac{1}{500}$th of what it is at the surface. In shallow vater the paths of the individual particles are ellipses with heir major axes horizontal. In the case of shallow water, the iorizontal axes of the ellipses are approximately the same for he particles at all depths. The vertical axes, however, decrease with the depth, until at the bottom they vanish, and he particles move backward and forward along straight ines.

The velocity of progression Z of gravitational waves on he surface of deep water is given by the formula

$$Z^2 = \frac{g\lambda}{2\pi}$$

For the derivation of this formula see Appendix, section 198. For its limited applicability to light waves see Appendix, section 200; also see section 145.

CHAPTER V

THE GENERAL THEORY OF WAVE MOTION

45. Position of the Circle of Revolution in Respect to the Direction of the Wave.—We know that the motions which take place in a water wave, repeat themselves every wave length. The same is true in regard to light waves. In other words, the motion is periodic.

We may assume that the simplest form of such wave motion consists of the revolution of a particle in a circle, while the centre of the circle moves with uniform velocity along a straight line, which we may designate as the line of progression.

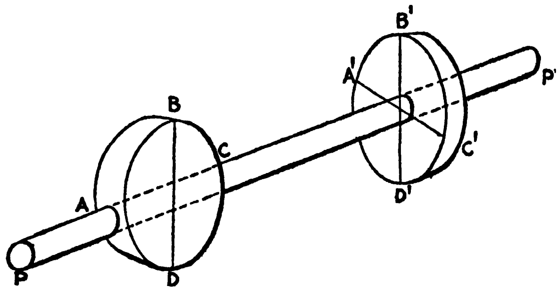

Figure 10

There are but two positions in which we can place the plane of the circle in reference to the line of progression so as to make their relation symmetrical.

One position is when the line of progression lies in the plane of the circle, as illustrated by the circle ABCD (Fig. 10) where PP is the line of progression. The other is when the line of progression is perpendicular to the plane of the circle, as illustrated by the circle A′B′C′D′ and line PP.

The first is represented by water waves, and by polarized rays, the latter representing the simplest or ordinary form of light wave motion.

If you hold with your hand one end of a short string, to the other end of which is attached a small weight or button, having your arm extended horizontally, straight out in front of your body, with a slight motion of the hand, you can set the button revolving in a vertical circle, the plane of which passes through your eye. If now, while the button is so revolving, you walk forward, you will observe that periodically the button reaches the highest point or crest of the circle, and the distance you walk between each recurrence of the crest, represents a wave length. This illustrates water-wave motion, except that the motion is carried on by a succession of particles, instead of by one, the motion having been imparted from one to another, as we have heretofore seen. It illustrates also the motion in a polarized light ray.

Commencing the experiment over again, you can set the button revolving in a vertical circle, the plane of which is at right angles to the arm extended in front of your body. While walking forward you will observe that the button describes a spiral curve. The button will reach the highest point or crest of the circle, periodically as before, and the distance you have walked between each recurrence of a crest, will represent the wave length. With the same limitations as above, relative to the interchange of particles, this would represent light wave motion in its simplest form.

If the plane of the circle of the revolving particle were set at an acute or an obtuse angle to the line of progression, the forces at work in the circle would not be acting in lines symmetrical to the line of progression, and the direction of the wave would be changed. So that on the principle of symmetry, we have only to deal with the two cases above described.

In dealing with wave motion, therefore, the first thing to examine into is motion in a circle.

46. **Simple Harmonic Motion.**—In gravitational waves, as we have seen, the forces of displacement and restitution act vertically,—while any given particle performs a circular orbit. It has been found convenient for certain purposes, to treat the motion of the particle as taking place up and down only in the vertical line, having the motion in the vertical line controlled by the position of the particle actually revolving in the circle with uniform speed. The utility of the idea is not confined to gravitational waves.

Simple harmonic motion is the motion of the projection on a fixed straight line, of a particle moving uniformly in a circle.

Suppose a particle P′, starting from D (Fig. 11), is moving with uniform velocity in the circle of radius A, in the direction of the hands of a clock, at the speed of n revolutions per second, the point P which is the projection of P′ on the line FG, is said to perform simple harmonic motion in the line FG. When P′ reaches the position Q′, the point P will have traveled to Q. When P′ reaches G, P will have reached G. When P′ passes through G, P will start back in the line GF, meeting P′ again at F. When P′ reaches its starting point D, P will have reached O, etc.

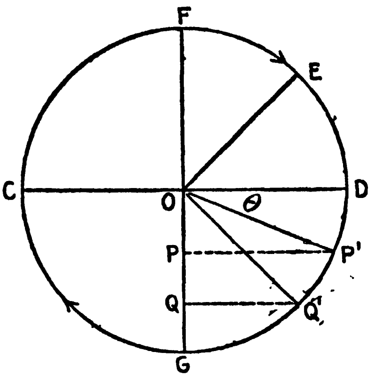

Figure 11

47. **Phase.**—When the particle traveling in the circle is in the position P′, the displacement angle DOP′$= \theta$ is the phase, provided we take D as the starting point.

Epoch.—It is sometimes convenient to commence the count from some other point, as from E. In which case the angle DOE is the epoch, usually represented by the letter E. And in that case the angle P′OE is the phase ϕ. So that $\theta = \phi - E$.

Vibration or Cycle.—One complete up and down movement of the point P, is called a vibration or cycle.

Frequency.—The number n of vibrations, or cycles per second, is called the frequency of the oscillations of the point P. This is the same as the number of revolutions per second of the point P′.

Period.—The time required for the particle to complete one whole vibration or cycle is called the *period* of the Harmonic motion, and is usually represented by the Greek letter τ.

It is obvious that if n vibrations take place in a second, then one vibration takes place in $\frac{1}{n}$ seconds. That is to say:

$$\tau = \frac{1}{n} \text{ or } n = \frac{1}{\tau}$$

Equilibrium Position.—O is the position of equilibrium of P.

Amplitude.—The maximum distance from O, reached by the vibrating particle P is called the amplitude of its oscillations. This amplitude is equal to the radius A.

Displacement.—OP is the displacement of the particle P at the time t.

Phase Difference.—If two points P′ and Q′ are both revolving in the same circle with the same velocity, the angle Q′OP′ will be constant, and that angle is called their phase difference.

48. In the general theory of wave motion, it has been usual to suppose that the revolution of the particle P′ takes place in a direction contrary to that of the hands of a clock.

As it is customary to represent water waves as progressing to the right, and in such case, since it is known that the revolution of a particle is clock-wise, we have found it convenient to suppose the revolution as taking place clock-wise in the above illustration, so taking it, the angular velocity w, will have a negative sign, because positive angles are always measured to the left, and when the particle moving in the circumference reaches P′ in time t, we will have:

$$\theta = -wt + E \text{ or } -\theta = (wt - E)$$

And the displacement $OP = A \sin \theta$ or:

$$(1)\quad y = A \sin (wt - E).$$

On the other hand, if the revolution be considered as taking place in the opposite direction to that of the hands of a clock, which is the usual way we measure angles geometrically, then w will be positive, and $\theta = (wt + E)$ and we have for the displacement $OP = y$ the value—

$$(2)\quad y = A \sin (wt + E).$$

If we desire to change our starting point for angular measurements from D to G, the end of the diameter on which we are measuring the displacements, the value of E would be increased by 90°. That is the new value of $E = E + \frac{\pi}{2}$.

This value substituted for E in (2) gives—

$$y = \sin \left(wt + E + \frac{\pi}{2}\right) \text{ or}$$
$$(3)\quad y = \cos (wt + E)$$

The latter is the usual equation of circular motion used for working out the equation of light wave motion.

Of course, as many reasons can be assigned why the particles of a light wave, moving through an isotropic medium, should revolve to the right, as to the left, and we have reason to believe that some waves revolve in one direction and some in the other.

Now let us suppose that while the particle P′ (Fig. 11) is revolving around O in the plane of the paper, that the centre O is itself traveling through space, with velocity Z, in a line of progression perpendicular to the plane of the paper, and that the progression of the centre carries the entire circular motion of the particle with it. It is evident that the particle P′ would describe a spiral around the axis of progression: that at each interval τ in which P′ makes a complete revolution around the axis, a wave length is demarked on the axis, and the circular motion of the particle again goes through the same succession of phases. It is evident that there must be some definite relation existing between the circular motion around the axis of progression, the volocity Z of the centre of the circle of revolution, along the line of progression, and λ, the wave length. To arrive at that relation we have only to combine in a proper way, the mathematical expression for circular motion expressed by equation (3) with conditions imposed by giving the centre of the circle a velocity of Z in the line of progression.

We have shown how this has been done in Appendix, Section 193. The resulting equation is as true for the case where the circular revolution is taking place in a plane coinciding with the line of progression as at right angles to it.

49. **Construction of the Curve of Sines or Simple Harmonic Curve.**—Suppose we have a number of particles arranged, when at rest, at equal distances along a line AB (Fig. 12), and that these particles all execute Simple Harmonic motion of equal amplitude and period, along lines at right angles to AB, but in such a way that the phase of each successive particle, counting from A, differs from that of the preceding particle by a constant amount. For convenience we will take the difference in phase as 30°, which is $1/12$ of 360°.

In the case of waves on the surface of water, where the progression is assumed to be to the right, to make the direction of revolution conform to the observed facts, we will have to assume that the particle is revolving in the circle in the same direction as the hands of a clock.

The figures 1, 2, 3, 4, 5, etc., on the circle, show the position of a particle on the circumference of the circle in which the revolution of the particle is taking place for each interval of 30° corresponding to $1/12$ of the periodic time. While this revolution is going on, the centre of the circle is progressing with uniform velocity along AB.

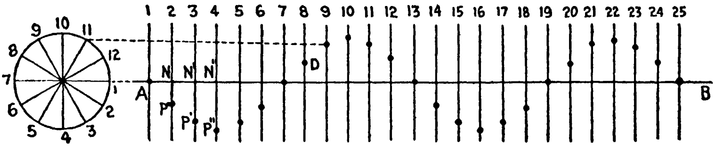

Figure 12

The dots in the vertical lines show the corresponding positions of the particle on the harmonic curve, or wave line.

By construction, $NP = -A \sin \phi$, $N'P' = -A \sin 2\phi$, $N''P'' = -A \sin 3\phi$, etc. For the point "8" on the circle, the angle is $180° + \phi$, and by trigonometry—$\sin (180° + \phi) = -\sin \phi$, and therefore, for the ordinate given by the equation $y = -A \sin (180° + \phi)$ we have, $y = A \sin \phi$, which gives the point D above the line AB, etc.

Such a wave is called a *curve of sines.*

Fourier has shown that every curve in which the same form is periodically repeated, can be either represented by a simple curve of sines, or constitutes a composition of a number of such simple sine curves.

If T be the period of the complex periodic wave, then from Fourier's theorem, the periods of the constituent simple harmonic curves will be included in T, T/2, T/3, T/4, etc.

50. Composition of Wave Motion in a Single Plane.—We are all familiar with the fact that when two water waves of the same period and amplitude running in the same direction, are brought into one line, the effect is to double the height of the wave, provided the crests coincide. If the crest of one of the waves is half a wave length behind the other, however, the crest of one falls into the trough of the other, and the two waves "interfere" and apparently destroy each other.

Fresnel was the first to point out that the forces operating to cause the vertical displacement in such waves, could be added or subtracted, or otherwise combined to give a resultant, just as other forces are combined when we are dealing with forces operating in straight lines.

Composition of wave motions taking place in the same plane is merely composition of the vertical displacements which go to make up the waves, as we have just seen.

If two systems of waves coexist in the same body, the displacement of any particle affected simultaneously by the forces operating in each wave, at any instant, will be the algebraic sum of the displacements due to the systems taken separately.

If the curve of displacements be drawn for each system with the displacements represented by ordinates at right angles to the line of progression, the algebraic sum of the ordinates will give the ordinates of the curve representing the actual displacements, which make the combination wave.

51. Figure A, Plate I, shows the graphic method of combining two waves, which have the same period and which are in the same phase.

The dotted line, and the slightly shaded line, represent the two constituent waves, and the heavily shaded line represents the actual or combination wave.

In the illustration, we have taken the amplitude of one of the constituent waves as being twice as great as the amplitude of the other, which makes the amplitude of the combined waves three times as great as that of the smaller of the constituent waves.

52. Figure B, Plate I, illustrates the combination of the same two waves of the same period, but being in different phases—being one-fourth of a period apart.

53. Figure C, Plate I, illustrates the combination of two waves of the same period and same amplitude, but having their phases differing by one-half period.

It will be seen at once that the algebraic sum of the ordinates representing the vertical displacements for every point is zero, and the combination wave is reduced to the surface line AB. That is to say, so far as any up and down movement is concerned, the water is apparently at rest. If the two trains of waves are proceeding in the same direction, that condition must continue. The condition which thus arises is called *interference,* and is a phenomenon common to water waves, sound waves, and light waves.

It must not be understood, however, that when two waves interfere the energy in them is destroyed. The manner in which the energy is being exerted has been changed, and that is all. Nevertheless, the interference of two water waves which are thrown together so as to make the crest of one fall into the trough of the other, produces, apparently at least, a surface rest.

Two sound waves proceeding in the same direction, and one being half a wave length behind the other, produce silence. This is easily shown by turning a vibrating tuning fork around at a certain angle, when the respective prongs will send off waves in the direction of the ear, which will interfere, being a half wave length different in phase, and in that position the sound ceases.

Fresnel's famous experiment demonstrated that two light waves proceeding in the same direction, where one is half a

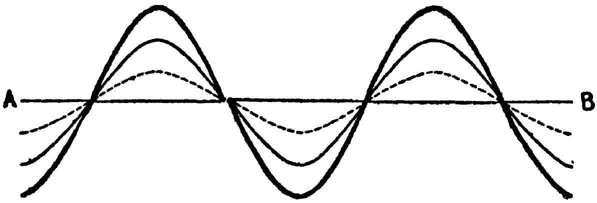

Fig. A.

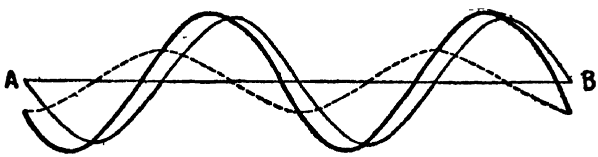

Fig. B.

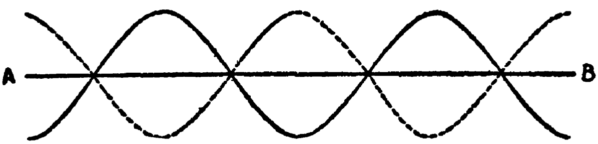

Fig. C.

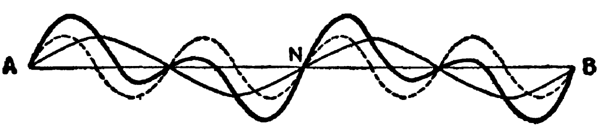

Fig. D.

Plate I

wave length behind the other, produces darkness (Ganot's Physics, Sec. 583).

54. Figure D, Plate I, represents the combined wave resulting from two waves having the same amplitudes, but the wave-length of one of the constituent waves being twice the length of that of the other constituent wave. It will be noticed that the resultant wave is periodic, that is to say—the part of the curve between N and B is a repetition of the part between A and N. But while periodic, it is no longer a simple sinusoid curve.

55. **Stationary Water Waves. Loops and Nodes.**—When two non-elastic substances of the same magnitude, proceeding in opposite directions at the same speed, come in direct collision, they are brought to rest, and the rectilinear motion is apparently destroyed. We know, however, that no energy is destroyed, that the rectilinear motion has simply been converted into vibratory motion of the particles of the colliding bodies, as manifested by their increase of temperature.

When two similar water waves proceeding in opposite directions meet, they simply pass through each other and go on their way as if nothing had happened. But while passing through each other, there is a local effect, caused by a composition of the vertical displacements taking place in the waves, precisely as in the case of waves proceeding in the same direction. In either case the combination affects both the apparent wave length at the place of passage and the vertical displacement.

56. Every observant person who has had the opportunity of that experience, has noticed that when a train of waves is thrown off from a passing steamboat, the advance wave, with those following, can be seen rolling in toward the river bank. If the direction of the wave progression is perpendicular to the bank, each wave as it strikes the bank, is reflected back, and a return train of waves is sent out through the oncom-

ing waves. When this takes place the waves rise to twice their former height, and they no longer appear to be coming in or going out, but the crests rise and fall. At one instant the surface becomes level, and at the next, the crests rise again, and this motion is repeated as long as the two oppositely directed trains of waves are passing through each other. This motion is exhibited in the bobbing up and down of any canoe which may be near the bank, and in the path of the waves. This phenomenon is explained by the formation of stationary waves.

It is one of the most interesting and important phenomena connected with wave motion, and its significance has never been fully appreciated.

57. The following graphic explanation of the formation of stationary waves is after Dr. W. Watson. Do not fail to get a clear understanding of it. It furnishes a key to the vortex structure of the ether of space.

Let AB (Plate II) represent a vertical section of the reflecting surface, and let the wave line CD represent a section through the incident train of waves. Each of these waves, as it reaches the obstacle, will be reflected, so that we shall have a train of reflected waves traveling away from AB, which for clearness are shown separate at EF.

Since it is evident that when a crest of the incident waves reaches the obstacle, a crest will be produced on the reflected wave, and as at the instant for which the figure is drawn, a crest on the incident wave is at C, we must have a crest on the reflected wave at E. Owing to the combined action of the incident and reflected waves, the form taken by the water surface is shown at GH, in which the displacement at any point is the sum of the displacements due to the two systems of waves separately.

If T is the period of the waves, then in time T/4, the incident waves will have moved through the distance equal to a quarter of the wave length λ, to the left, for the wave travels over a space equal to the wave-length, during the period; also the reflected waves will have traveled through the distance $\lambda/4$ to the right, as shown at C′D′ and E′F′.

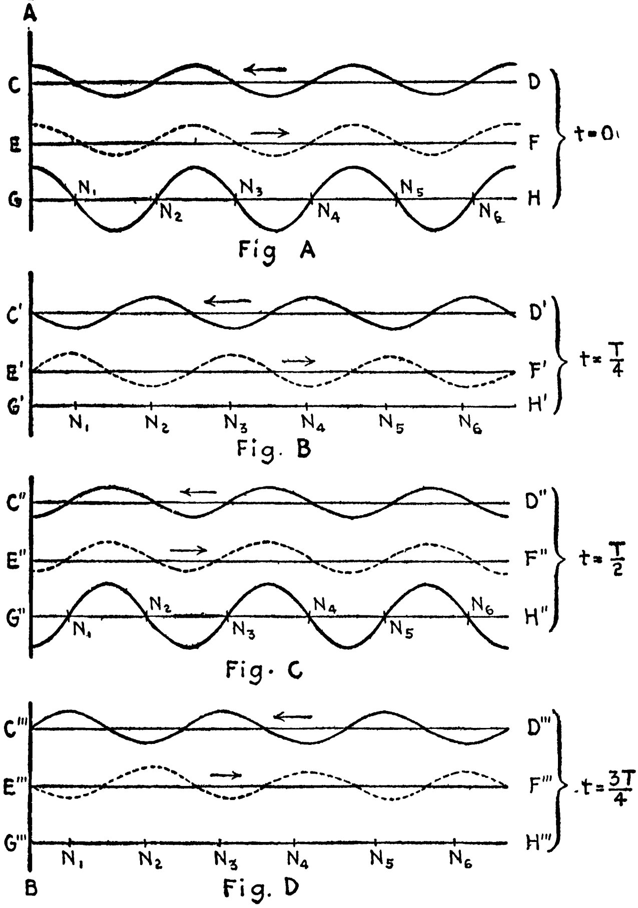

Plate II

Under the combined action of the two sets of waves, the whole surface will be momentarily in its position of rest, as shown at G′H′, for it will be noticed that the effect of the reflected waves is just to neutralize the displacement due to the incident waves. Similarly, the actual state of the water-surface, at times T/2, and 3T/4, is shown at G″H″ and G‴H‴. If these curves are examined, it will be seen that there are certain points, N_1, N_2, N_3, etc., on the surface of the liquid, which remain permanently at rest, owing to the interference between the incident and reflected waves. These points are called *nodes.* Half way between each node, the water surface swings up and down to a maximum extent, and these points are called *loops* or antinodes.

The portions of the surface between the nodes and the loops move up and down, the amplitude of the movement gradually decreasing from the loop to the node. Thus at one instant, we have a series of alternate crests and troughs at the loops, then the surface flattens out, and immediately after, a series of troughs and crests appear at the loops, and so on; and the character of the disturbance is quite different from ordinary waves, for there is no progressive movement of the crests and troughs. These waves which retain their position unaltered are called *stationary waves,* and, as we shall find later, they play an important part in many phenomena which involve wave motion.

It is immediately evident from Plate II, that the distance between consecutive nodes is equal to half the wave length.

Hence, if we measure the distance between the nodes, and know the frequency of the waves, we can calculate the velocity with which they travel.

The nodes are points at which the disturbance due to the reflected waves is *always* equal and opposite to that due to the incident waves. The loops, on the other hand, are points where the disturbance due to the reflected, is equal to, and in the same direction as that due to the direct waves. A consideration of the figure will show that the portions of the medium on opposite sides of a node are always moving in opposite directions, or are displaced on opposite sides of their positions of rest.

58. **Stationary Light Waves.**—*Lippman's Color Photography.*—As is well known, light waves of different colors have different wave lengths. The red ray wave-length is the longest of the visible rays—the violet is the shortest.

The wave length of red rays at the typical Fraunhofer line B of the spectrum, is given by Ganot as 0.0000271 of an inch. For line H of the violet ray, 0.0000155. The other colors have intermediate wave lengths. Compared with the length of a wave of light, the thickness of a film of collodion used on a plate for photography is very large. In passing through such a film, a wave of light of any color would have many periods or wave lengths.

Lippman filled a square glass jar with mercury, to give the sides of the jar a mirror effect. One side of the jar was then coated with a thin film of collodion, or other photographic emulsion, and an image of an object in front of the jar, with ordinary white light, which contains light of all colors, was thrown on the plate so prepared, as in the case of ordinary picture taking with a camera. For each color represented, a train of waves which penetrated through the film, was reflected back on its path, and passing through the film in the opposite direction, met the oncoming train, and formed stationary waves, with nodal points spaced half a wave length apart, precisely as in the case of water waves.

As is well known, the amount of chemical action produced by light in a collodion film is proportional to the intensity of light. This chemical action causes a deposit in the film of metallic silver from the material of the collodion. This chemical action being greatest between the nodes, it causes layers of metallic silver to be deposited from the collodion, at regular intervals through the thickness of the film for each half wave length of each of the respective colors of light rays. When the exposure is sufficient, the plate is then developed, as in ordinary photography. If now a beam of white light is made to fall incident on the developed plate, each of the layers of metallic silver in the film, the deposit of which has been caused by a ray of any particular wave length, will reflect light only of that wave length or color, and the color of the light returned by reflection from the plate for any particular point of the image on the plate, will correspond to the color of the rays which originally impinged on the plate at that point. Lippman was thus able to obtain beautiful photographs in natural colors. The process is cited here, as strongly confirmatory of the wave theory of light, and as showing the close analogy between the behavior of light waves and of water waves. It is also a demonstration that two trains of light waves moving in opposite directions are not destroyed, but pass through each other, and in so doing they form stationary waves.

As we shall later point out, the phenomena above described, demonstrating the conditions under which stationary waves (vortex centres) are formed in the other structure when two trains of light waves are passing through each other in opposite directions, will, when certain other facts are considered therewith, furnish an explanation of the isometric arrangement of the vortex centres of which Maxwell conceived that the ether structure necessarily must be composed, and indeed, through it we will arrive at the necessary conception of standard vortex centres or standard ether particles, which is the basis of all matter.

CHAPTER VI

COMPOSITION OF SIMPLE HARMONIC MOTIONS, AND SOME OF ITS RESULTS

59. Composition of Simple Harmonic Motions in the Same Direction.—When two similar waves proceeding in the same direction coincide in the same phase, any particle, which, acting under the forces in operation in the one wave, would describe a circle of a certain radius, will under the forces acting in both waves, describe a circle of double the radius, and therefore the height of the crest of a composition wave in which two such circular motions are superimposed would be double.

To follow the path of a particle when acted upon simultaneously by two independent sets of forces, each of which would separately make it describe a circle, is in effect to make a composition of two Simple Harmonic Motions.

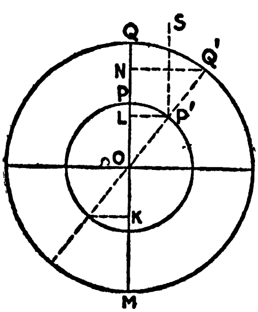

Figure 13

Thus if we have the coincidence of two waves going in the same direction, with the same amplitudes, and in the same phase, then any particle P (Fig. 13) is being operated on by a force in one wave, which at P′, would give it a vertical displacement OL, and the exactly similar force in the other wave operating by itself, would give that particle a vertical displacement equal to OL. The two acting together would give a vertical displacement $2.OL = ON$.

This double displacement is exactly the same as if the radius OQ′ of the circle of reference for the combined motions were twice as great as in the case of only one of the two equal component motions.

If the phases of the two rotations differed by 180 degrees, the forces in one wave would tend to give the particle the vertical displacement OL upward, and the forces operating in the other wave would tend to give the particle the equal vertical displacement OK downward, so that they would neutralize each other.

Where, as in the illustration (Fig. 13), the two circular motions are going on in the same direction, with the *same angular velocity*, even though the amplitudes be different, we may regard Q the resultant position of the particle, as revolving around P, while P is revolving around O. For if in a given time P has revolved through the angle POP′, and be at P′, we may draw P′S parallel to OQ, and Q will have revolved through an angle SP′Q′= POP′ Consequently O, P′ and Q′ will be in the same straight line, and the actual path of Q will be the circle QQ′M, with the radius OP′+ P′Q= OQ.

If the phases of the two motions differed so that the vertical components representing the respective displacements are, one above O, and the other below O, so that one is negative and the other positive at a given instant, the vertical components must be added in the algebraic sense, that is to say, the less is subtracted from the greater, to get the value and proper size of the resultant vertical component representing the combined displacement.

It is an important principle that, when the particles in two waves brought into composition are revolving with the same angular velocity, the resultant path of the particle will be the same as that of a second particle, if we had a first particle revolving just as it would under the action of one wave, and a second particle under the influence of a second wave, revolving around the first particle while the first is so moving.

It is apparent that composition of Simple Harmonic motion is as much applicable to the case of water waves in which the circular motion is going on in the plane passing through the line of progression, as to the case of light waves in which the circular motion is in a plane at right angles to the line of progression.

60. **Combination of Harmonic Motions in Opposite Directions.**—When the periods of the two harmonic motions are the same, but the direction in which the respective revolutions are taking place is opposite, there is presented an extremely important and interesting case.

We will suppose that P (Fig. 14) revolves to the right around O, and that Q revolves to the left around P, in the same period, therefore having the same angular velocity.

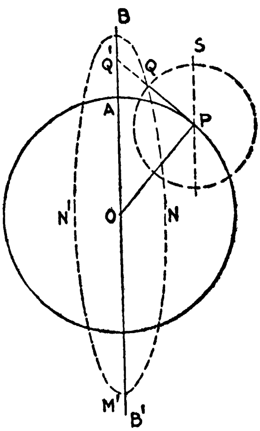

Figure 14

Professor Tait in his article on Mechanics (Encyc. Brit., 9th Ed.), discusses the proposition thus:

"It is obvious there must now be positions in which OP and PQ are in the same straight line. Let OA, AB, be one of these. Then in any other position, OP and PQ are equally inclined to OA. (This follows because the angular velocities are the same, and angle SPQ′=AQ′P.) The path of Q is an ellipse, of which the major semi-axis is the sum of the radii, and the minor axis, their difference. Hence, when the radii are equal, the resultant is simple harmonic motion in the line OBB′.

"Thus we have the proposition of very great importance in optics, that a simple harmonic motion may be looked upon

as the resultant of two equal and opposite circular motions in one plane."

61. From the above it is apparent, that when the two constituent circular motions taking place in opposite directions have different amplitudes (radii) the actual path of a particle moving under the combined action of the two is an ellipse BNM′N′ and that the direction of the motion in the periphery of the ellipse, will correspond to the direction of rotation of that one of the constituent circular motions which has the greater amplitude. In that case the motion of the particle may be illustrated by that of a house-fly on the rim of a wheel which is revolving with uniform velocity, the fly walking down one of the spokes of the wheel a certain distance toward the hub, and back again, so as to be at the rim at the end of each half revolution of the wheel. The path of the fly will be an ellipse.

When the amplitudes of the two constituent circular motions taking place in opposite directions are equal, since for any value of the angle AOP we must have angle OQ′P = SPQ = AOP, therefore we must have PQ′ = OP, and Q′ must be in the line BB′ whatever may be the angle through which the revolution has proceeded. That is to say, in such case the actual path of the particle is the straight line BB′. The particle simply oscillates up and down between BB′ with simple harmonic motion.

62. **Secondary Waves.**—Let us now consider the effect of a light wave on the elastic medium through which it is passing.

Suppose the ray to be proceeding from underneath, perpendicular to the plane of the paper, so that it would pass through the paper and reach the eye looking down on the paper. At the instant under consideration, the particle in the wave front is revolving in the circle BDAG in the plane of the paper, as illustrated in Figure 15.

In passing around the circle from B to A, the forces operating on the particle in the direction BA, are equivalent, as we have seen, to the forces which would take the particle directly in the line BA, if the particle BA were performing simple harmonic motion. The pulsation of the particle from B to A is overcome at A by operating against the elastic rigidity of the medium, the force imparted to the medium at A being represented by the line AF. At the same time there is a tangential force operating on the medium at A, represented by AT, due to the revolution of the particle in the circle. We have, therefore, operating on a particle of the surrounding medium at A, two forces acting simultaneously and at right angles to each other, which on the principles stated in section 30, should give rise to the wave of transverse vibration AMNS. This secondary wave proceeds from the wave front of the ray and at right angles to the line of progression of the ray. Let us hold our conclusions in abeyance as to whether the secondary wave AMNS proceeds radially in the direction AF or tangentially in the direction AT.

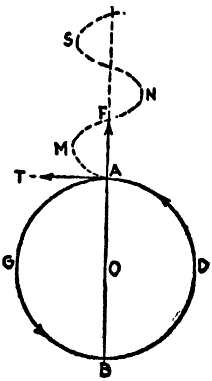

Figure 15

But what is true of the vibrations taking place in BA is true for each and every diameter of the circle of revolution, and therefore as any principal wave progresses, with a circular wave front, there must be generated waves sent off radially from the end of every diameter of the circle, and all of these secondary waves must lie in a plane in the wave front and at right angles to the line of progression of the ray.

The analogy between these secondary waves with which we are now dealing, and the waves sent off radially from a wire through which an electric vibration is sent, as in the case of wireless telegraphy, is striking.

63. **Motion in the Polarized Ray.**—Let us return now, to a consideration of the manner in which an ordinary light wave, by passing through a tourmaline plate, is converted into a plane polarized ray, as explained in section 4 and Figure 2. The particle revolving in circular orbit at right angles to the line of progression of the ray, on entering between the walls of the plate, can no longer progress in a *spiral* path, but continues its progress through the plate in wave motion, in which the vibrations are transverse, and in a single plane, between the walls of the plate, and after passing through the plate, continues in that motion.

Now let us examine into the causes at work to accomplish this change in the form of motion.

We may attach one end of a steel spring rigidly to a firm support, and against its elastic resistance we may push the other end so as to make the spring bend through a certain angle. In so doing, we have expended a certain amount of energy, and have stored up in the spring a certain amount of power or "potential energy," which (disregarding friction) is capable of doing just as much work or overcoming just as much resistance in swinging back to its former position of equilibrium.

The energy expended in moving the spring against its elastic resistance is denominated "kinetic energy." It follows that in all such movements involving action and reaction in a perfectly elastic medium, at any instant considered, one-half the energy is kinetic energy and the other half, potential energy.

As stated by Maxwell in his explanation of the undulatory theory of the passage of light waves through the ether:

"Half of this energy is in the form of potential energy, due to the distortion of elementary portions of the medium, and half in the form of kinetic energy, due to the motion of the medium."

Let us suppose a ray is proceeding from underneath, perpendicular to the plane of the paper, the wave front represented by the circle (Fig. 16) in which the particle is revolving, lying in the plane of the paper. We will suppose that the particle so revolving has just entered between the walls AB and CD of the tourmaline plate. We must consider that the space between the walls is filled with ether.

When the particle P revolving in the circle strikes the wall AB at M, it is reflected back to N, where it strikes the wall CD and is reflected back toward M, etc. But in the meantime, when the particle reached the position P it commenced to be operated upon in the direction PQ by the elastic reaction of the medium represented by the arrow S, due to the potential energy stored up in the surrounding elastic medium by the previous semi-revolution of the particle from Q to P. This reaction will be exactly equal and opposite to the force vibration through the diameter which created the elastic strain in the surrounding medium, and therefore the particle at P, oscillating between the walls, will perform simple harmonic motion between P and Q.

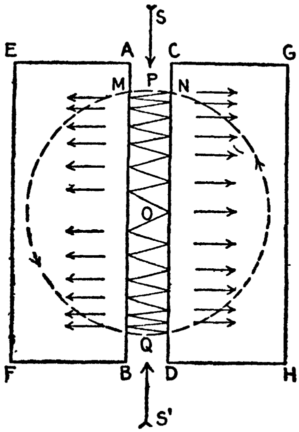

Figure 16

We may consider that the particle in its oscillations does not actually come in contact with the material substance of the walls, but is only reacted upon by the ether strata lying against the walls, for which the walls serve as a rigid background. And we may consider that when the particle P strikes the wall at M and is reflected back toward N it will cause a particle at M to vibrate and on the return oscillation of the latter will start a wave following P toward N, so that when P strikes N and starts back by reflection toward M, it will meet the similar new wave from M.

On the principle stated in section 60, the particle must then perform simple harmonic motion in PQ. But the real forces which make the particle vibrate in PQ are the forces SP and S′Q operating alternately, representing the potential energy stored up in the surrounding medium on the preceding revolution of the particle in the circle.

It is apparent that the particle oscillating between the walls will be performing simple harmonic motion between P and Q, and that these oscillations will be giving off waves alternately in the direction PS and QS. It is also apparent that the small oscillations at right angles to the walls will be giving off through the tourmaline plate, alternate vibrations at right angles to PQ, and represented by the small parallel arrows.

Now, before the revolving particle passed into the tourmaline plate, the reaction of the surrounding medium was from all sides directed toward the centre of the circle. After the passage of the particle into the tourmaline plate, the only lines of force from the surrounding medium, operating on the particle, are in the one diameter PQ, being the two alternating forces SP and S′Q, and at right angles to PQ are the small vibrations reacting against the walls AB and CD.

When the ray has passed through the tourmaline plate, the same figure may represent the wave front just emerging from the plate.

There are no forces to change the reaction forces operating transversely and at right angles to the direction of the ray, back into forces operating toward the centre, and therefore the ray must continue to progress as a plane polarized ray. Now we have seen that while vibrating between P and Q the particle is performing simple harmonic motion in PQ. It must not be overlooked, however, that while the particle is making one complete vibration from P to Q and return, that the wave has progressed through one complete wave-length; the path of the particle is therefore a perfect sinusoid curve formed precisely as illustrated for water waves in Section 49. The conclusion is irresistible that the particle in the polarized ray is in circular revolution in the plane passed through PQ and the line of progression of the ray. In other words it is behaving precisely like the amber particle examined by the Webers (Sec. 43) in the water-wave behaved, and the profile of the polarized ray would be the same as the profile of a water-wave.

What we have really accomplished by polarizing the ray is therefore the change of the direction of the plane in which the particle is revolving, from a position perpendicular to the line of progression of the ray, to a position coinciding with the line of progression. The first position is illustrated by A′B′C′D′ and the second by ABCD (Fig. 10, sec. 45).

The vibration taking place in a plane polarized ray is generally stated to be in a straight line perpendicular to the direction of the ray. This is perfectly true if we are considering not the actual path of the particle, but the direction of the operating forces which cause the vibration, as in the case of the operation of gravity in maintaining water waves.

After polarization the theoretical particle performs simple harmonic motion in a line perpendicular to the line of progression, and at the same time the perpendicular line moves forward parallel to itself, causing the theoretical particle in its up and down motion to describe the sinusoidal curve. The mathematical inferences to be drawn from Fourier's Theorem (sec. 49) leave us no other conclusion than that the actual motion of the particle in the simplest form of plane polarized light is in a circle the plane of which coincides with the line of progression of the ray.

In other words, the motion in a plane polarized ray is practically the same as that in a water wave.

64. All Forces Act through Impulses.—Professor Ganot (Physics, sec. 54) has said:

"When a force acts on a body for an inappreciably short time, and yet sensibly changes its velocity, it is termed an *instantaneous* or *impulsive* force. Such a force is called into play when one body strikes against another. A force of this character is nothing but a finite though a very large force, acting for a time so short, its duration is nearly, or quite, insensible."

Professor W. Watson (Physics, sec. 62) says:

"In certain cases, the force acts for so short a time that we are unable, either to measure its magnitude, or the time during which it acts. . . . Forces of short duration, as for example, that exerted by a blow of a hammer, were originally called impulsive forces; and it was in this connection that the term impulse was originally used. There is, however, no essential difference between such a force and forces which last for a longer interval, the only distinction being that in the one case, from lack of experimental means, we are unable to make the necessary measurements. The term impulse is, therefore, now used in the more general sense, as applicable to the product of any force into its time of action."

Professor W. F. Magie (Elements of Theoretical Physics, p. 8) says:

"In the theory of motion we use the word *force* to designate the causes known or unknown, of a change in the motion of a body. If a body at rest is set in motion, or if a moving body comes to rest, these changes are ascribed to the action of force. If the change is sudden, the force acting on the body is called an instantaneous force or *impulse*. *Close examination shows, however, that finite changes in the motion of a body are never instantaneous,* but occur only in finite time. This may, in many cases, be very small."

We may consider, therefore, that the application of any impulsive force to a body consists of a bombardment by a succession of small impulses rapidly succeeding each other, and the whole occurring in such a short period of time as to appear instantaneous. That all forces act by vibrations or minute impulses has long been recognized. Later on we shall endeavor to show that there is a fundamental heart-throb or pulse of the universe, which regulates the minute pulses in all forces, and to show its origin. At present we are dealing with the proposition as an empirical fact.

Because of the above facts, the ordinary method adopted to represent the composition of forces, whether by the graphic treatment or by mathematical equations, while it may accurately describe the path of the particle and the final resultant position of the particle, fails to wholly account for the vibratory energy created by the conversion of a large part of the rectilinear motion into vibratory motion, when there is a composition of forces. Thus if a force of 5 units is operating in one direction, and another force of 3 units is operating on the same particle in the opposite direction, we say they are equivalent to a force of $5 - 3 = 2$ units of force operating in the first direction. We mean by that the particle would move from its first position, in the direction impelled by the greater force, and behave as if it were acted upon only by a force of 2 units. This is all that composition of forces gives us, but it does not speak the full event. It makes 3 of the greater units of force annihilate the 3 units of force operating in the opposite direction. Now force represents energy, and energy is never destroyed.

We may illustrate what has happened in this way:

Let P (Fig. 17) be a particle operated on by two forces, each composed of three units of force, acting in opposite di-

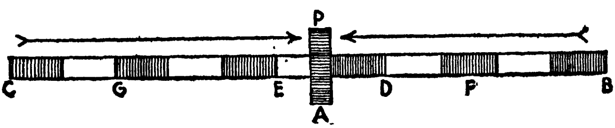

Figure 17

rections. The unit D coming in contact with the particle first, will impart its energy to it—moving it to E, when the unit E coming in contact with it, will move it back to A, by which time the unit F will have moved into the space AD and will move the particle back to E, etc.

In other words, the impulses acting successively will give the particle a vibratory motion in the space AE. In this vibration the energy apparently destroyed as linear motion is stored as vibratory energy.

65. **Composition Force Lines.**—By an arrangement of two plane mirror surfaces so placed that the angle between them was very nearly 180°, upon which two rays of light, proceeding from a point of the same luminous source, were allowed to fall and be reflected to a screen, Fresnel, by his famous experiment, demonstrated that two similar light waves progressing in the same direction—but the one, proceeding a half-wave length behind the other, so that the trough of one coincided with the crest of the other—would produce interference, the composition of the two light rays in such opposite phases producing darkness.

A pair of plane polarized rays in opposite phases can be made to interfere in the same way, provided they are polarized in the same plane.

The composition of the displacements in such case is explained in section 53, and illustrated in Plate I, Figure C, where the revolution of the particle is taking place in a plane passing through the line of progression, and it is shown that the path of the particle in such case is no longer a *wave curve,* but becomes a *straight line.*

Now we know in general, that a composition of two waves proceeding in the same direction does not increase the velocity of progression. We know also that no energy is ever destroyed, and since we know that the vibration of the particle up and down represents energy, the question is, what has become of that energy, when on composition of the two waves in opposite phases, the displacements above and below the line of progression have disappeared?

The answer is found in the fact that no force ever acts instantaneously, but only appears to do so. It is well established that all forces act in successive impulses, although the time between two successive impulses may be so short as to defy our detection or measurement.

The force which, in a given time, would displace a particle upward through a certain distance, is made up of a large number of impulses, and if there be a similar force simultaneously operating in the opposite direction, which would give the same particle an equal displacement downward, an upward and then a downward impulse operates alternately as one beat, through an extremely short space of time, compared with the time required to accomplish a full wave displacement. The result is that the particle makes many very short alternate oscillations up and down, at right angles to the line of progression, during the time which would have been required for a full wave displacement. Yet these oscillations are so exceedingly small that for all practical operations the motion of the particle may be considered as being confined to the line of progression, which thus becomes a force line. Nevertheless, the rapidity of these minute oscillations must be such that there would be as much energy expressed thereby, in the given time, as would be involved in the full displacement up and down in such time, had there been no composition, and each force had acted separately. This follows because no energy can be destroyed.

66. If we have a great number of such pairs of waves—such as water waves or polarized light waves in the same plane—proceeding in the same direction, in the line of progression, the waves of each pair being in opposite phases, as illustrated in Figure 18, it is evident, since the composition of the two waves of each pair would give a force line, that the composition of all of them would give the force-line AB. We would understand, however, that this force-line has a certain minute breadth, and that intense oscillations of

the particle are taking place in it as illustrated. Such a force line would carry very much more enegy than any of the single visible waves which entered into its composition.

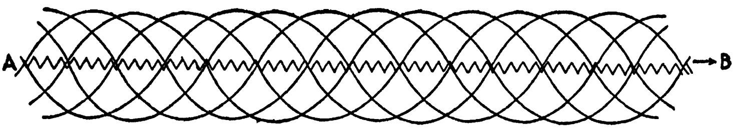

Figure 18

67. If we were dealing with the composition of two ordinary light waves proceeding with the same velocity in the same direction, in which the particles are revolving with the same angular velocity, in circles at right angles to the line of progression, and the direction of revolution being the same, but the difference in the phases of the two waves being 180°, the composition would be made of the motions in the circle as explained in section 59. There would be theoretically no displacement of the particle from the centre of the circle, but practically, taking into consideration the principle of impulses as before, the particle would revolve in a minute circle around the same centre, and its path would be a minute spiral around the axis of progression. The composition wave would be an invisible force-ray.

The foregoing considerations lead to the conclusion that if we had a light ray composed of any number of waves paired in opposite phases, and of an additional unpaired wave, or of a number of unpaired waves, the visibility of the ray would be due entirely to the latter, while the bulk of the energy conveyed would be in the force rays. We are further led to conclude that two rays, even of the same wave lengths, may have the same visual intensities and yet the intensities of the energies carried may be different. These two kinds of intensities are quite different.

If, in the composition above referred to, the particles were revolving in the opposite directions, we would have the cases illustrated in section 60, one special case of which results in the plane polarized ray, and another gives an elliptical orbit.

68. We are thus led to the conclusion that the invisible composition force rays are in fact light waves in which the amplitude of the vibration is reduced to a minute size, with a corresponding increase in the rapidity of vibration. And since in the ordinary light wave, the transverse vibrations taking place send off through the surrounding medium minute waves in planes at right angles to the line of progression, the same thing must be true in regard to the invisible force rays, except that the waves sent off in planes at right angles to the force line must be still more minute.

If therefore the ether medium, in order to transmit ordinary light wave vibrations in straight lines for millions of miles, requires us to conclude with Maxwell, that it is organized in vortex particles of extremely uniform and definite size, *there must exist in the medium, lower orders of vortex centres,* or a succession of lower orders of vortex particles, whose magnitudes range from the size involved in ordinary light wave motion, down to zero, in order that the miniature wave motion of the force lines may be carried on.

A proper conception of the origin, character and functions of the composition force lines is a key which ought to unlock the outer door to the mysteries of the physical universe.

CHAPTER VII

CIRCULARLY POLARIZED LIGHT. CREATION OF VORTEX CENTRES. PARTICLES OF SUCCESSIVE ORDERS. REPULSION OF PARTICLES

69. **Circularly and Elliptically Polarized Light.**—Suppose we have a pendulum (Fig. 20) suspended by a fine thread from the fixed point A and swinging through the small arc PBQ. If, when at its lowest position B it receives a blow at right angles to the direction of its motion, it will then as a result of the composition of velocities, vibrate in a new arc P′Q′ inclined at a certain angle to the arc PQ in which it was at first vibrating. If the blow communicated a velocity equal to that with the bob was moving when passing through B, the angle of inclination PBP′ would be 45 degrees.

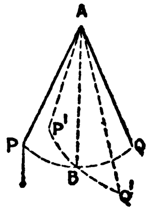

Figure 20

Again, we may suppose the blow to be struck when the bob is at its highest point P or Q, the blow being just sufficient to communicate a velocity V equal to the velocity of the bob when at B. The bob will then describe a horizontal circle, as illustrated (Fig. 21). So moving, it is called a conical pendulum. If the blow is struck when the bob is at any other point in the arc PQ, the bob will describe an ellipse.

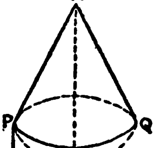

Figure 21

70. We have already referred to the fact, that by Fresnel's method, two plane polarized rays of light, when polarized in the same plane, can be made to interfere, as in the case of

common light, but that two rays polarized in planes at right angles do not produce interference under the circumstances in which two rays of ordinary light would interfere. In the latter case, however, certain other phenomena take place, which are of importance.

As already seen, in the case of plane polarized light (if we ignore the progression of the ray), the particles are vibrating in straight lines at right angles to the line of progression of the ray; in that respect its movement is like the swing of a simple pendulum—to and fro—except that the bob of the latter moves in an arc, while the particle moves in a straight line.

Now suppose that two rays of light, polarized respectively in perpendicular planes, be made to coincide. Where the lines of vibration cross each other, the same particle would be acted upon by forces operating at right angles to each other, and we have the same three cases which arise in the case of the pendulum. 1st. If the vibrations are in the same or opposite phases, the light resulting from the composition is still plane polarized. 2nd. If the rays are of equal intensity, and their phases differ by 90°, or quarter of a complete vibration, the resulting path of the particle is a circle, and it is called circularly polarized light. 3rd. Under any other circumstances of coincidence, the resultant path of the particle is an ellipse, and the light is said to be elliptically polarized.

Circularly polarized light has been obtained from plane polarized light in this way. In the case of circularly polarized light the revolution of the particle is in a plane at right angles to the line of progression. (The above as after Ganot.)

71. Plane polarized light may be produced in other ways beside those hereinbefore mentioned. It is produced in more or less large qauntities when ordinary light is reflected from any surface, but is at a maximum when the ray incident to the surface makes a certain angle to the surface, which angle

varies according to the material of which the surface is composed. This angle is called the polarizing angle of the particular substance. We have an evidence of polarization when we allow light to fall obliquely on a glossy sheet of writing paper, and notice the change in the sheen when the obliquity reaches the polarizing angle.

Circularly and elliptically polarized light can also be produced by methods other than those above referred to. All these different forms of light waves have their own respective peculiarities.

Following Stokes and Verdet, Lord Rayleigh in his mathematical treatment of the "Wave Theory of Light" (Encyc. Brit., 9th ed.) shows that, in general, a stream of light may be regarded as composed of one stream of natural light, and of another stream of polarized light, the polarized rays being either elliptically, circularly or plane polarized.

Natural light being made up of the composition of a great number of rays from an infinite number of luminous points, is, as Lord Rayleigh points out, essentially irregular, and the resultant vibration lacking periodicity. Absolutely homogeneous light is necessarily elliptically polarized. Circularly polarized and plane polarized light are special cases of elliptically polarized light.

Professor Tait, in his article on "Light" (Ency. Brit., 9th ed.), says:

"The fact that where homogeneous light is used, Newton's rings have been counted up to the 7000th, shows that whatever be the actual nature of the vibrations of unpolarized light, they must for at least 7000 waves in succession be almost precisely similar to one another. Then for other 7000 waves or so, we may have a totally different type of vibration. But in the course of $\frac{1}{7}$th of a second at the utmost, vibrations must have been almost uniformly distributed over all directions perpendicular to the ray."

The fact that no train of waves of natural light is continuous except for very short intervals, and that such rays are compositions of light from many independent sources, makes it impossible to look into its details otherwise than through the law of average and mean results on the theory of probabilities. However, in the light wave in its simplest circular form, and in elliptically, circularly or plane polarized light, present in general, in every light stream, we have the types of motion with which we have to deal.

72. The Formation of Circularly or Elliptically Polarized Light, from Intersecting Plane Polarized Light, Is the Creation of a Traveling Vortex Centre.—Let us suppose that two plane polarized light rays are proceeding coincidently in the same direction perpendicular to the plane of the paper, and that the two rays are polarized in planes at right angles to each other. The vibrations will be taking place at right angles to each other as in AB and CD (Fig. 22).

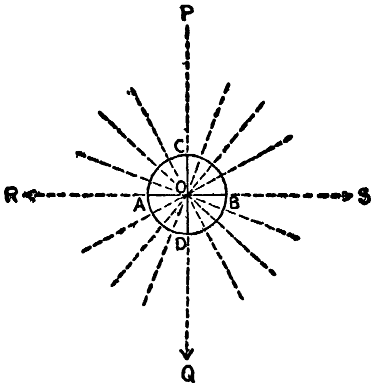

Figure 22

Now if we consider the vibrations taking place in AB to and fro, there are force rays passing through O alternately in opposite directions. But the same thing may be said because of the alternate vibrations in CD through O. That point is therefore a force centre.

We have already seen (sec. 70) that the effect of the composition of the two rays polarized in planes at right angles to each other, is to set all particles which meet each other at the crossing and which are in phases, differing by one quarter of vibration, to revolving in a circle. In other words, the resultant path of the particle due to the two motions at right angles, is the circle ADBC. But in order that the particle may describe the circular path ADBC, the reaction of the elastic medium surrounding the circle must be directed toward the centre O, and since action and reaction are equal and in opposite directions, there must be force lines radiating into space from O in every direction.

We may, therefore, regard the mechanism for the production of circularly polarized light as the instrumentality by which energy, proceeding in force lines of magnitude, crossing each other at right angles, is converted into circular motion, and the energy is distributed into force lines radiating in every direction from the force centre.

The same thing would be true in regard to elliptically polarized light, only the distribution of the radiations would not be quite so symmetrical.

73. In the foregoing illustrations, we supposed that the two plane polarized rays brought into composition were proceeding in the same direction, the consequence of which would be that the revolving wheel is carried forward as the ray progresses through space. But if the two plane polarized rays are proceeding in opposite directions, then on the principles heretofore stated (secs. 55–58) the light waves become stationary waves, and the revolving wheel does not progress, but remains stationary so long as the same trains of rays are proceeding in opposite directions.

The phenomena of circularly and elliptically polarized light are important as illustrating one way, at least, in which a rotation not previously existing can be experimentally set up in the ether medium as it actually is constituted.

74. Particles of the First, Second, Third and Successive Orders.—Let us now consider the mechanism by which a wave is carried forward through the ether medium. For simplicity we will take the case of circularly polarized light.

In the first place we have a particle revolving around the rectilinear line of progression of the wave in a circle at the wave front. This circle with the particle or particles traveling around its circumference and constituting its rim, we will designate as a particle of the *First Order.*

Now, a light wave, while ordinarily progressing in a straight line, can be made to travel in a curved path. We also know that the radius of the circle at the front of some light waves is very large compared with that of other light waves. In fact, the radii (amplitude) of some light or force waves are so small, that the rays are invisible. The amplitude of some rays, such as X-rays, goes down to the infinitesimal. What then must be the nature of the particle which is revolving in the circumference of the particle of the First Order? It can be nothing else than a smaller particle revolving in a circle of small radius, around the circumference of the particle of the First Order as an axis, and for which that circumference is the line of progression, around which it traverses a spiral path. In other words it is a minute light wave which we designate as a force wave, having a small "wheel" at the front, which we may denominate a particle of the *Second Order.* If the principal light wave were not progressing, that is to say, if the particle of the First Order were a stationary wave, then the path of the particle of the Second Order would be the circular rim of the particle of the First Order.

A particle of the First Order having a radius R, may therefore be considered as formed by a light or force wave traveling in its circumference with a circular wave front composed of a particle of the Second Order having a smaller radius r_1.

The particle of the Second Order must be considered as formed by a force wave traveling in its circumference, with a circular wave front composed of a still smaller particle of the *Third Order* having a still smaller radius r_2.

Similarly there must be a particle of the *Fourth Order,* etc., etc., down to the infinitesimal.

It is not necessary, however, that we should conclude that there must be an unlimited number of orders of particles in which the radius of the final particle is zero. The limit may be, instead of circular motion, a small rectilinear vibration, as is the case of the limiting motions of the particles at the bottom of water waves in shallow water. (Sec. 44.)

We have discussed the question as if there were but one particle of the Second Order revolving in the circumference of the particle of the First Order. There might be more than one, as in a light wave train. That is unimportant for the purposes of our present discussion.

For the purpose of illustrating the above discussion, let the large circle ABCDEF, Figure 23, represent the circular orbit of the particle of the First Order, as for instance the circular orbit in the wave front of a ray of circularly polarized light, the line of progression of the light ray being perpendicular at O to the plane of the paper in which the large circle lies.

The next smaller circles MN, M′N′, etc., represent particles of the Second Order whose centres revolve in the orbit ABCDEF.

The circles MN, M′N′, etc., lie in planes perpendicular to the plane of the paper, and the traces of these planes intersect at O. The revolution of the particles MN, M′N′, etc., in the orbit ABCDEF carves out the rim of the particle of the First Order. The small circles KL, K′L′, etc., represent the particles of the Third Order. The centre S of the particle KL revolves in the circumference of MN. It will be observed that twice during a complete revolution of S in MN, the particle KL is brought into the plane of the paper, i.e., into the plane of the particle of the First Order. While the centre A of the particle of the Second Order is revolving around the circumference AFEDCB of the particle of the First Order, the centre S of the particle of the Third Order describes the spiral path illustrated at the side of the figure. We must conceive that,

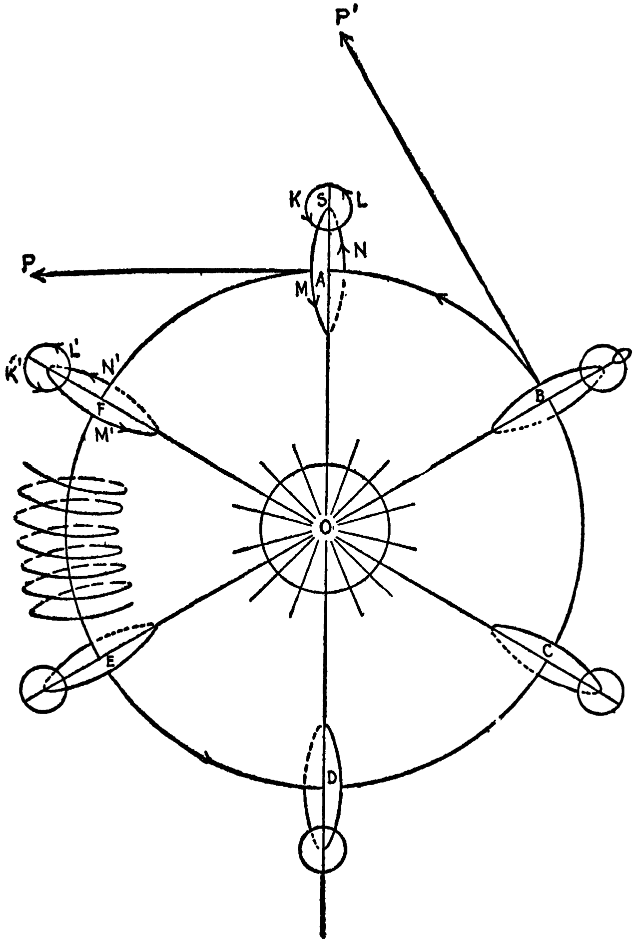

Figure 23

for precisely similar reasons, the centre of the particle of the Fourth Order describes a spiral path of smaller amplitude around the circumference MN of the particle of the Second Order, etc., etc., down to the infinitesimal.

The foregoing analysis of what must be the structure of the ether particle or particles involved in wave motion, is a logical deduction by the writer from what is the generally accepted wave theory of light. To one accepting the wave theory of light as developed by the master minds of the last century, there should be no difficulty in conceding this, since what we are now calling by the name "particles," consists merely of traveling "vortex centres" or "eddies" caused by circular motion set up in the ultimate substance. Naturally, as in the case of water eddies, they would vary in size according to the amount of energy involved in their motion. Later on we will have reason to conclude that there is a standard normal size for the vortex particles involved in the ether structure, and that these fix the standard sizes of the successive lower orders of particles, as well as higher orders. Indeed we will be able in a subsequent chapter to determine the exact mathematical relations which must exist between the radii of the successive orders of particles in order that the automatic action in a wave of any amplitude may be continued, and we will be able to demonstrate the correctness of our deductions, by their application to certain phenomena, with the most astounding results. We must, however, lay the foundation for this.

75. Referring to Figure 23, since the centre S of the particle of the Third Order KL is revolving around the centre A of the particle of the Second Order, while the centre A is itself revolving around the centre O of the particle of the First Order, we see that the conditions are such that the face MN of the particle of the Second Order in contact with the ether medium, will set up a whirl in the ether, and send off a wave in the direction AP tangent to the orbit of the particle of the First Order. Such waves will be sent off continuously as the centre travels around its orbit. For similar reasons

waves of smaller amplitude will be sent off from S, the centre of the particle of the Third Order, and these waves will be sent off tangent to MN, the circumference of the particle of the Second Order. But these waves will be sent off in the plane of MN, and as S revolves the waves will be distributed in every direction in that plane. We have already seen that this plane will always be perpendicular to the plane of the particle of the First Order. For similar reasons there will be still smaller waves sent off tangentially to the circumference of the particle of the Third Order, from the face of the particle of the Fourth Order. These minute waves, however, will lie in the plane of the first particle of the First Order.

The source of the energy which supplies these radiations, as well as the nature of the centripetal forces which operate to compel the particles to maintain their circular orbits, are subjects which must be treated later.

76. Let ABCDEF (Fig. 24) be a particle of the First Order whose radius is OA. The principal radiations from the particle will be tangential as illustrated in the figure. If P be any distant point the radiations from the particle which will reach it, will proceed from A. When AP is very great compared with OA, the practical effect will be the same as if the radiation proceeded from the centre O. That is to say, in considering the radiation effect of a particle at a distance, we may ignore the fact that the particle has a radius, and regard the radiations as proceeding

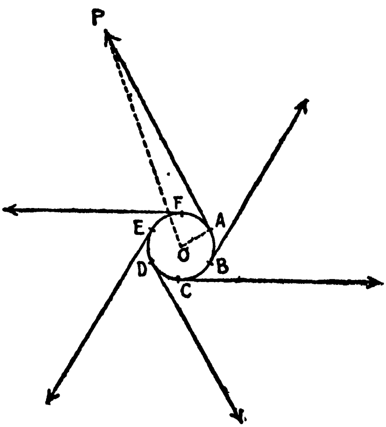

Figure 24

from a point or centre of force which distributes the energy radially.

77. Repulsion of Force Centres—Automatic Arrangement in Equilateral Triangle Systems.—We know both from theory and experiment that rays of light exert a pressure in the direction of propagation. Maxwell predicted it from mathematical considerations, and Lebedew and subsequently Nichols and Hull verified the fact in the case of sunlight. The pressure of sunlight on the whole of the earth's surface was shown to be about 70,000 tons; a very small amount of pressure indeed, but existing and measureable. As we have already seen, every force line is a diminutive light ray.

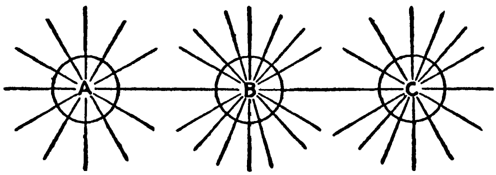

Figure 25

Therefore every force line radiated from a force centre exerts a pressure in the direction of radiation, and this must consist of minute bombardments of the small waves of which they are composed. Now let us suppose that we have three such force centres A, B and C situate in the same plane and in the same straight line ABC (Fig. 25).

It is obvious that the force rays from A operating on the particles of the Second Order revolving in the circle around B, and *vice versa,* will make the force centres act repulsively toward each other, and tend to drive them apart. This would be true, because if the particles of the Second Order are held to revolution in a circle of given radius, by the elastic reaction of the surrounding medium, an additional pressure against the particles of the Second Order would shorten the radius of revolution, unless the centre of the particle of the First

Order responded and moved back; motion of the centre being necessary in order to preserve the circular shape and balance of forces maintaining the integrity of the particle of the First Order.

Since the radiations from a centre in all directions in a plane spread over a larger circumference as they proceed outward from the centre, and circumferences are proportional to their respective radii, the intensity of the radiation for the unit surface on which it falls decreases with the distance, and therefore two particles will repel each other with a force which decreases with the distance the particles are placed apart.

We may reserve the question for the present as to whether the repulsion is inversely as the distance or inversely as the square of the distance. If we were dealing with energy distributed radially in one plane only as above illustrated, the repulsion would be inversely as the distance. If we take into consideration that the energy radiated from the centre of the particle of the First Order passes to the centre of the particle of the Second Order, and is there again distributed by the revolution of that particle in a plane at right angles to the plane of the particle of the First Order, the decrease of energy in the plane of the particle of the First Order at any point exterior to the particle of the Second Order will be inversely as the square of the distance. This subject will be explained more fully later. The point we are at present dealing with is simply to show that two particles of the same order in the same plane must repel each other, and this repulsion decreases with the distance.

If now the particles A and C were fixed in position, and were of the same repulsive power, the particle B would tend to move to the middle position between A and C. Similarly if we had a number of such particles of the First Order of equal repulsive power, and confined them to a limited area of a plane surface, their mutual repulsions would force them into an equilateral triangle formation. This would be true because that formation would enable them to move furthest away from each other and reduce the pressure to its lowest value consistent with the limited area to which we have supposed the aggregation of particles to be confined. This proposition is of the highest importance and on it depends the physical structure of the ether of space, as we shall later show. The conclusion we above reach as to the particles automatically arranging themselves in equilateral triangle formation under the conditions stated, hardly needs a demonstration, but a short geometrical proof for the benefit of those to whom it is not self evident is appended. (Appendix, sec. 197.)

CHAPTER VIII

SOME OF THE THINGS WE CAN DO WITH A RAY OF LIGHT WHICH DISCLOSE ITS PHYSICAL ATTRIBUTES

78. **Light Compared to an Elastic Hoop.**—If we consider only what is taking place at the wave front of an advancing ray of light, we may regard it in its simplest form as an elastic hoop revolving in a plane at right angles to the line of ray progression, with its centre in that line.

Ordinary light also contains plane polarized rays in which the revolution of a particle is in a plane coinciding with the line of progression; for all such rays the plane of the "hoop" is in the line of progression.

When this hoop strikes a polished surface it is bounced off, so that the angle of reflection equals the angle of incidence. An ordinary material hoop will do the same thing, provided it is thrown against the floor properly, but if it is thrown so that the plane of the hoop when it strikes the floor is not perpendicular to the plane of the floor, it will fall over and not be reflected. In the same way, when the hoops of light in a ray fall upon a polished surface at the polarizing angle, the only ones of them reflected are those in one plane, and we get a plane polarized ray.

In a stationary wave we have the progress of the hoop through space arrested. It maintains its position, as an ordinary material hoop would do, should we stand the latter up on edge on the floor in a balanced position.

We are in the habit of thinking of a ray of light only as a train of waves, and feeling that the continued existence of any single wave of the train depends upon the connection it has, either with the waves in front or the waves behind. But there is no such dependence.

We know that in the ordinary wave, the motion of the wave front consists of a revolution in which one side of the "wheel," like an auger, has a boring effect against the elastic medium. Where two similar waves meet, going in opposite directions, the stationary-wave formed must be symmetrical in respect to both its sides.

From the phenomena of reflection, and principles already stated, we know that the "wheel" can be pushed entirely out of the line of the ray to which it originally belonged. In other words, we see that the "wheel" has forces at operation within it which give it shape and form, and this shape and form are automatically maintained by the action of such internal forces on the surrounding elastic medium and the reaction of the medium on the "wheel."

79. **Rotation of a Plane Polarized Ray by Magnetic Force.**—Faraday discovered that when polarized light passes through certain substances in a magnetic field, the plane of polarization is rotated through a certain angle.

If a ray of plane polarized light is passed through a tube containing water, or better, bisulphide of carbon, around which tube there is wound a coil of insulated wire, and if a current of electricity is passed through the coil, it is found on testing the ray with a Nicol analyzer, after its passage through the tube, that the plane of polarization has been rotated through a certain angle. If the direction of the current of electricity is reversed the direction of rotation is reversed.

If the ray of light, after having once passed through the tube of water, is reflected back along its course, it will be again rotated in the same direction, as far as the coil is concerned, as during its first passage, that is to say, the rotation is doubled.

As is well known, an electric current passing through the wire of such a coil creates a magnetic field within the tube, in which the lines of magnetic force are parallel to the axis of the tube. *When the current is passing through the wire the effect is as though the medium through which the light is passing were rotated around an axis parallel to the lines of force, and carrying with it the plane of vibration.* The explanation generally suggested for this (Maxwell and Lord Kelvin) is that the ether is actuated by circular or vortical motion, all in the same direction, and in planes at right angles to the lines of magnetic force, and this would account for the rotational effects of the magnetic field upon the plane of polarized light.

Verdet has found, in general, that if ϕ is the angle of rotation of the plane, L the length of the medium traversed by the light, H the strength of the magnetic field, and j a constant, dependent upon the nature of the medium and the wave-length of light employed, then

$$\phi = j\,L\,H.$$

From which it would appear that the size of the angle of rotation for a single passage of a ray through the tube, other things being constant, depends upon the strength of the magnetic field.

The researches of Kundt indicate, however, that the angle of rotation does not increase so rapidly as the magnetic force, and that as the latter increases, the angle of rotation reaches a maximum, indicating that the rotation is proportional to the intensity of magnetization, and not to the magnetic force.

80. Let us now analyze the nature of the mechanism called into action by the rotation of the plane polarized ray, as described in the preceding section.

We have already seen (sec. 63) that the motion taking place in a plane polarized ray is constituted by the revolution of a particle (or particles) in a circle the plane of which is in the line of progression of the ray.

Let ABCD (Fig. 26) be the cross section of the tube around which the coil is wound, through which the current of electricity is to be passed. This cross section is in the plane of the paper. PQ, MN, RS, etc., are the parallel planes in which the plane polarized rays are proceeding through the tube parallel to the axis of the cylinder. The particular ray proceeding perpendicular to the plane of the paper at J, will be represented by the revolution of a small particle in the circle KL. The plane of this small circle will lie in the plane MN, and be perpendicular to the plane of the paper. For perspicacity we have represented it as a small oval, although in a strictly correct drawing we would see it only edgewise and the circular shape would not show.

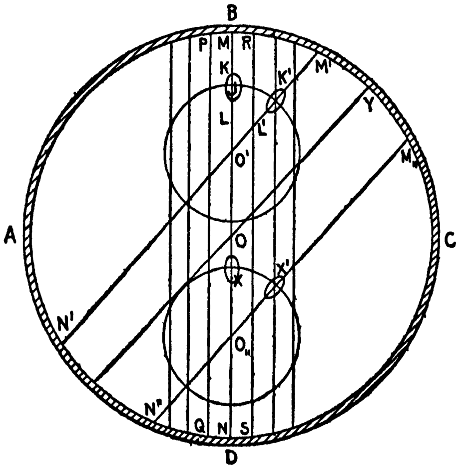

Figure 26

When the current passes through the coil, the planes of the polarized rays which are passing through the tube in the parallel planes MN, PQ, RS, etc., are shown to have been rotated, through the angle MOY, since the Nicol analyzer shows that it must be shifted through that angle, in order that the rays may pass through the Nicol. The particular ray at J represented by the small particle revolving in the circle KL is shifted to the plane M′N′. The circle KL has actually been revolved about an axis at a point O′, and with radius O′J into the new position K′L′; and if a sufficient magnetic force is applied, and the length of the tube be sufficient, it can be made to perform a complete revolution about O′, and continue to so revolve. We have therefore the circular motion in the circle KL, of which our ray is constituted, performing the functions of a particle of the Second Order in respect to the newly created particle of the First Order constituted by the revolution of the particle of the Second Order around the centre O′.

Similarly if there be another polarized ray proceeding perpendicular to the plane of the paper at x, the small "wheel" of which it is composed, is revolved around the centre O″ to the position x′, and as in the other case the "wheel" becomes a particle of the Second Order in respect to the particle of the First Order whose centre is O″.

On principle, if we had two similar polarized rays proceeding in opposite directions, so as to form stationary waves, and a sufficient magnetic field be applied, the result ought to be the creation of an independent particle of the First Order not in flight, and which should possess, as we shall later see, the essential qualities of an atom. We do not intend to anticipate here, but attention is called to the fact that the essential principle demonstrated experimentally by the phenomenon of electric rotation of the plane of the polarized ray, is that the revolution of the particle of the Second Order as illustrated in Figure 23, and described in section 74, can be set up and maintained by natural forces, and the particle of the First Order can be so created and maintained. The phenomenon is an experimental demonstration that we can by an appropriate application of forces, take one "wheel" out of a ray of light, and treating this wheel as a particle, make it as a whole revolve around an exterior axis as illustrated in Figure 23, section 74, without destroying the autonomy or automatic maintenance of the "wheel."

81. The power of rotating the plane of polarization in a magnetic field has been shown to be possessed by all refract-

ing substances, whether they are in the solid, liquid or gaseous state.

82. **The Kerr Effect.**—John Kerr found that if plane polarized light is reflected from the polished pole of a strong magnet, the plane of polarization is rotated. The direction of rotation being clockwise, when the light is reflected from a north pole, that is, in the opposite direction to that in which a current would have to flow round a coil so as to produce the magnetization of the magnet.

83. These phenomena show that the revolving "hoop" of light may bore its way through space for millions of miles without having its autonomy destroyed. It may be stopped and made to stand still. It may be bounced, like an ordinary hoop from a surface, and finally, in the form of the polarized ray, the hoop may be made to act as a particle, and be made to rotate around an external point as a centre of revolution. Under all these circumstances, the revolution of the particles in the hoop, and the vibrations taking place radially from the centre, are sending off waves through the elastic medium, and it is the reaction of the elastic medium which preserves the hoop as a conservative system.

CHAPTER IX

BALMER'S FORMULA, A KEY TO THE STRUCTURE OF THE ATOM AS WELL AS OF ETHER. THE SPECTRUM OF THE HYDROGEN ATOM

84. We are all familiar with the fact that when a ray of sunlight is allowed to pass through a glass prism, the light is dispersed, and if it is allowed to fall and be spread over a surface it forms what is called a spectrum, exhibiting all the colors of the rainbow. We know that this effect is due to the fact that ordinary white light is composed of a number of primary rays of different wave lengths, which causes them to be unequally refracted or bent out of the straight course in passing into and out of the prism.

The visible rays range through the primary colors red, orange, yellow, green, blue, indigo and violet. As these colors shade off into each other without any precise line of demarcation, so the wave length of the light waves represented by the colors decreases in length from the bright red colors down to the violet. By photography it has been demonstrated that there are in ordinary beams of white light other rays which are invisible, some of which have wave-lengths longer than the red rays, and some having wave-lengths shorter than the violet. Our eyes are so constituted, however, that they are affected only by light waves having wave-lengths not greater than the red nor less than those of the violet rays. The defect of our eyesight is such that it may be compared with the defect of the hearing of a person who is so deaf that he can only hear the notes proceeding from the keys of one octave of a piano, although he may know in other ways that there are notes of a higher and of a lower pitch than those he hears.

By a combination of prisms suitably arranged (the spectroscope) scientists have been enabled to separate the rays of light composing white light with great precision, and to study in detail the spectra of light proceeding from different kinds of luminous bodies.

85. **Fraunhofer's Lines.**—When light given out by glowing gases or vapors is examined in the spectroscope, the spectrum produced is found not to be continuous, but to consist of a number of bright lines in various parts of the spectrum.

Fraunhofer, a celebrated optician of Munich, first studied these lines, and they bear his name. The position and number of these lines vary for the different chemical elements in the luminous gas or vapor which is emitting the rays. The number of lines visible with any given metal depends, to a certain extent, on the temperature of the flame, but although new lines may make their appearance as the temperature is raised, the position of the lines already present in the spectrum does not vary.

It was demonstrated that each of the chemical elements had its own series of lines, which are peculiar to that element.

When strong white light is passed through an incandescent gas or vapor composed of any particular element, and the transmitted light is examined in the spectroscope, it is found that dark lines or dark bands appear in the spectrum just where bright lines would have appeared if the light had proceeded alone from the incandescent gas or vapor composed of the particular element or elements which give those lines. This is generally explained on the principle that bodies absorb most strongly that kind of vibratory motion which they are themselves capable of giving out. We think it may also be explained on the principle of composition, and will refer to this later on.

The fact that each chemical element has its own series of

Fraunhofer lines has enabled the scientist through an examination of the light from those sources to determine the chemical elements existing in the Sun and even in distant stars. It has furnished a method of determining the chemical composition of substances known as *spectral analysis.* Indeed, it has led to the discovery of many new elements of the existence of which we had no previous knowledge. Helium, for instance, was known to exist in the Sun before any of it was ever found on the Earth.

86. **The Hydrogen Spectrum.**—There are 29 known Fraunhofer lines in the spectrum of the hydrogen atom. The wave-lengths of the waves proceeding from luminous hydrogen gas have been measured at each of these lines in the spectrum.

Balmer in 1885 discovered that there is a certain curious relation existing between the wave-lengths expressed in centimetres for the series of hydrogen lines, which is given in close approximation by the formula:

$$\lambda = h \frac{R^2}{R^2 - 4} \times 10^{-8} \text{ cm.}$$

where h is a constant which Balmer took to be 3645.

By substituting in the formula for h the value 3645, and for R, successively the numbers 3, 4, 5, 6, etc., etc., there were obtained successive values of λ for the successive lines of the hydrogen spectrum, which agreed in a most surprising way with those actually measured. Proof was thus furnished that the wave-lengths of the respective rays corresponding to the hydrogen lines are functions of successive whole numbers, that is to say, the lines of the hydrogen spectrum form a series, and the wave-lengths of any line can be expressed as a simple function of its number in the series.

The following wave-length measurements of the hydrogen lines, obtained by Evershed [Phil. Trans. 197 A 381 (1901) and 201 A 457 (1903)] from photographs of the solar eclipse of Jan. 22, 1898, and reduced to vacuum, are given in comparison with the corresponding values calculated by Balmer's formula, in which h is put equal to 3646.13. The last column gives the differences between the observed and the calculated values.

HYDROGEN SPECTRUM

DESIGNATION	R	CALCULATED	OBSERVED	DIFFERENCE
α	3	6563.03	6563.07	+ 0.04
β	4	4861.52	4861.57	+ 0.05
γ	5	4340.63	4340.53	— 0.10
δ	6	4101.90	4102.00	+ 0.10
ϵ	7	3970.22	3970.33	+ 0.11
ζ	8	3889.20	3889.15	— 0.05
η	9	3835 53	3835.51	— 0.02
θ	10	3798.04	3798.00	— 0.04
ι	11	3770.77	3770.73	— 0.04
κ	12	3750.30	3750.27	— 0.03
γ	13	3734.51	3734.53	+ 0.02
μ	14	3722.08	3721.98	— 0.10
ν	15	3712.11	3712.13	+ 0.02
ξ	16	3704.00	3704.01	+ 0.01
o	17	3697.29	3697.28	— 0.01
π	18	3691.70	3691.70	∓ 0.00
ρ	19	3686.97	3686.96	— 0.01
σ	20	3682.95	3682.94	— 0.01
τ	21	3679.49	3679.52	+ 0.03
υ	22	3676 50	3676.51	+ 0.01
ϕ	23	3673.90	3673.87	— 0.03
χ	24	3671.48	3671.53	+ 0.05
ψ	25	3669 60	3669 55	— 0.05
ω	26	3667.82	3667.83	+ 0.01
	27	3666 24	3666.25	+ 0.01
	28	3664.82	3664.74	— 0.08
	29	3663.54	3663.55	+ 0.01
	30	3662.40	3662.36	— 0.04
	31	3661.35	3661.31	— 0.04
	$\propto$	3646.13	Theoretical limit	

87. It will be seen that if we substitute for R the value 2 in Balmer's formula, we get $\lambda = \propto$, and any value of R less than 2 will give negative values of λ.

As we increase the value of R above 3, the nearer $\frac{R^2}{R^2-4}$

approaches unity, and therefore when R is very large $\lambda = h = 3646.13$.

It will be seen from the above table, that as we advance in the series towards the ultra-violet, the values of the wave-lengths approach nearer and nearer to an equality until the theoretical limit is reached.

The agreement between the calculated and observed values is wonderfully close.

This formula by Balmer was derived entirely by trial from the observed wave-lengths of the first fifteen lines of the hydrogen series. It has so far been regarded as entirely an empirical formula which expresses a fact, without any one being able to state why the relation expressed by the formula should exist.

As the number of hydrogen lines was extended into the ultra-violet from their discovery in the stars, in the solar prominences and in the "flash" spectrum, and as their wave-lengths were better determined, the greater verity has been given to Balmer's formula.

We shall in a subsequent part of our present undertaking endeavor to demonstrate that Balmer's formula has for its fundamental basis the fact that:

(a) the ether of space has an isometric, equilateral triangle structure, and

(b) the hydrogen atom is composed of a series of particles revolving in concentric rings in a plane, the radii of the rings running 3, 4, 5, 6, etc., etc., to a certain limit.

We shall be able to actually derive Balmer's formula from the calculated light waves sent off from the particles revolving in these concentric rings. When we do that it will be the supreme test of the correctness of the kinetic theory underlying our present work. We merely anticipate for the purpose of emphasizing the importance to be attached to Balmer's formula, as throwing light upon the structure of the ether and of the atom.

88. Rydberg, Kayser and Runge have each by trial worked ut formulæ which express with a considerable degree of ccuracy the wave-lengths which belong to the series of lines f other elements besides hydrogen. These formulæ have all een shown to be substantially the same as Balmer's formula, vith the constants changed to give the proper results for the articular chemical element under consideration. See vol. 2, Enc. Britannica, 11 ed., p. 792, and Spectroscopy (Baly-Ramsay) p. 561.

The fact that the wave-lengths of the spectrum lines, for ll the elements so far known, conform to Balmer's law, with nly a change of constants in the formula, is a proof that he atoms of all the elements have substantially the same ind of structure, though varying in certain details.

PART II

THE PAN CYCLE HYPOTHESIS

Invisible Composition Light-waves, the Warp and Woof of the Ether-structure, and of All Things Material.

CHAPTER X

EXTENT OF THE PHYSICAL UNIVERSE

89. The question of the extent of the physical universe, meaning by that the extent to which matter is distributed throughout space, while an old one, has been a subject of debate among scientists of our own time.

The argument in favor of the contention that there is a limit to the distribution of suns and stars in space, advanced by the Herschels, and for a long time regarded as unanswerable, is summed up in a popular way by the late Professor Simon Newcomb in "Side Lights on Astronomy" (1906), and given a new vigor by the allegiance so recently expressed by this great scientist. Since it stands in the way of our present hypothesis, it must be stated and met.

The argument is this: The Milky Way or Galaxy divides the heavens into two parts. It passes as a girdle entirely around the celestial sphere, cutting out a circle on the sky vault. The centre of this circle is the standpoint of the observer. A line, perpendicular to the plane of the galactic circle, and passing through its centre, pierces the celestial sphere in two points which are known as the galactic poles.

By dividing the sky surface into small squares of equal area, a careful count of visible stars shows there is an apparent sparseness in the distribution of stars in any square of sky-surface about either of the galactic poles: That there is a gradual and steady increase in the apparent number of stars distributed in any equal square of sky-surface as we pass, in our count from either galactic pole toward the galactic circle, until finally in the belt of the circle, or Milky Way itself, there is apparently the greatest number of stars in each equal square of sky-surface. This phenomenon is explained upon the theory that the visible stars may be considered as being contained in the interior of an imaginary hollow shell, having the general shape of a grindstone.

Within this shell the stars are distributed so as to give, for any considerable space, an average density in their distribution throughout the interior of the shell. Our Sun, as one of these stars, is so placed that we may consider it (and the Earth as well) as being situate on the axis and at or about the centre of the grindstone. Looking out from such central standpoint, toward the rim of the "grindstone," the stars would appear as densely packed, and the mass of the stars in the structure would be projected upon the background of the sky, as a belt closely studded with stars, girdling the heavens, and presenting the appearance of the Milky Way.

On the other hand, the distance from the centre of the grindstone, measured along its axis, to the surface, in either direction, being comparatively much shorter than is the distance from the same point to the rim, there would be a comparative sparseness in the number of stars seen, as projected on the background of the sky, when the view is directed from the same central standpoint in the direction of either galactic pole. For similar reasons, there would be a gradual thickening in the number of stars appearing as projected upon the background of the sky, in passing from the galactic poles toward the galactic belt, when viewed from the same central standpoint.

Because of the great distance of most of the stars, the astronomers have been able to determine the distances of but comparatively few of them. It is pointed out, however, that as far as appears from determinations of the approximate distances and distribution of those stars for which such determinations have been made, the results seem to sustain the view that there is approximately a uniform distribution of stars through this "grindstone" region of space.

It is next argued, from the fact that the light from the nearest star, traveling at the rate of 186,000 miles per second, takes not less than four years to reach us, and that light coming from stars, probably distant so far, that it would require over 3000 years to reach us, can be seen by use of the telescope, that a ray of light once started through space, unless it meets with some obstruction, will continue forever as a visible ray of light. It is also said, that the physicist of to-day cannot admit that there could be any loss of light in passing through an absolute vacuum of any extent, without impairing the fundamental principles (embodied in certain mathematical formulæ) controlling the vibration of light.

It is further claimed, upon the above premise, that it can be mathematically demonstrated, that were the universe infinite in extent, and the stars scattered equally through all space, the whole heavens would blaze with the light of countless millions of distant stars, separately invisible even with the telescope.

This reasoning may be made apparent in the following way: If you gaze into the depths of a forest in which the trees are sparsely scattered, the trees in the foreground will appear separate and distinct, but in the background the trees seem to lose their identity and to close up as a solid wall. So if there were an unlimited number of stars scattered throughout all space, *and if* visible rays could reach us from the most distant, the heavens would present the appearance of a solid wall of light. Since the sky does not present such an aspect, the conclusion is drawn that beyond the stars visible in the telescope, there are no stars, and that the space beyond is without matter and void.

90. Upon the assumption that the above conclusions are justified, Professor Newcomb, by a very pretty process of reasoning, and calculation based upon the law of probabilities, placed the probable boundary of the physical universe, at approximately 200,000,000 times the distance of the Sun from the Earth, or say 3,300 Light years. A Light year is the distance through which light would travel in one year, traveling at the rate of 186,000 miles per second.

Professor Newcomb appears to have been inclined to accept the theory of a limited physical universe, and refers, in support of that theory, to certain papers published by Lord Kelvin in 1901. However that may be, Sir William Thomson (Lord Kelvin) in his lecture, delivered at Philadelphia, on the "Wave Theory of Light," expressed the view that the conception of a physical universe in which matter comes to an end in space is incomprehensible.

91. Other astronomers, while accepting the view that the visible stars, in the main, belong to a system within the bounds of our Milky Way, reject the theory that there are not other stars and other systems of stars lying in the regions of space beyond the bounds of our own galaxy system, and point to the fact that certain nebulæ under powerful telescopes, resolve themselves into star-clusters, as indicative of the existence of such other systems.

It is admitted by the advocates of the theory of a limited universe, that the basis upon which it rests is shattered if the light coming from the outer stars in some way becomes extinguished or obstructed in passage.

Now we know that our ability to see a ray of light depends upon the retina of the eye. We know that there are light rays beyond the red waves of the spectrum, the wave lengths of which are too long to be visible, and there are rays beyond the violet waves of the spectrum the wave lengths of which are too short to make any visible impression upon the retina of the eye. We see only the rays having such wave lengths as are included in the red to violet octave. And yet we know that the invisible rays of short wave-length beyond the violet end of the spectrum, carry in them great energy, and have a powerful effect on a photographic plate. We can speak of these invisible rays as force rays, in order to distinguish them from the visible rays.

92. **Why the Sky Does Not Appear as a Blaze of Light.** —The writer suggests as probably the principal cause for the invisibility of the rays coming from the most distant stars, that they have been converted from visible rays into force rays, on the principle of composition.

The principle formulated by Huyghens, and considered well established, that every point in the wave-front of a light ray as it progresses through space becomes a new centre of disturbance from which visible rays must proceed in every direction outward, for a time made it impossible to explain why visible light rays always proceed in straight lines. It checked the general acceptance of the wave theory of light. When the explanation (See Watson's Physics, sec. 379) came it was convincing. It was demonstrated mathematically, to state it briefly, that there was composition between the rays sent off laterally from any point in the wave front with those which started laterally the instant before. Such lateral rays would cross each other in phases half a wave length behind each other, and thus all the rays which would have proceeded as visible lateral rays, have their visibility destroyed by composition. The physicists have apparently been satisfied with destroying the visibility of the side rays, taking small account of the fact that energy is never destroyed, and that it is the after history of those waves when they become invisible that is of most interest.

In our theory of organized force-rays by composition, we are not advocating anything fundamentally new, we are simply making a new application of recognized principles.

Let us suppose that there are a large number of neighboring luminous points which are emitting rays of light to one distant point, the distance being sufficiently great to make the lines of wave-progression coincide as one line at the distant point. The revolving particles in each wave may then be considered as all revolving in the plane of the same circle around the common line of progression, that plane passing, at the instant of time under consideration, through the point considered, and at right angles to that line. Since the number of luminous points which are the sources of the waves are very large, the average distribution of the particles in the circle under consideration will be nearly uniform, on the doctrine of probabilities. In other words, there will be a large number of the waves in opposite phases, and these will pair by composition, and by interference produce invisible force rays (sec. 66). But there will be also a large number of the waves not in opposite phases, which will therefore not interfere, but will strengthen the visible effect of each other.

Let l equal the number of luminous points, each sending a wave to the distant point. Let p equal the number of waves which will pair, and q equal the number of waves which will not pair, reaching the distant point at a given instant. Then:

$$l = p + q$$

Now we may suppose that the number of the unpaired or q waves are sufficiently great to make such an average distribution of phases represented in the circle of revolution, that the addition of any other single wave to the composition, in whatever phase it might be, would find some one of the q waves in exactly the opposite phase, or so nearly in the opposite phase as to pair and make interference.

Let us now bring into play a wave from another luminous point in the neighborhood of the others, and sending a wave which reaches the distant point at the same time as the p and q waves reach it. The number of q waves being large, under the supposition, this new wave will find a mate and will pair with some one of the q waves, and the composition of the two will make an invisible force line (sec. 66).

The effect, therefore, of bringing into the composition the wave from the additional luminous point, has been to increase the number of invisible p rays and to decrease by one, the number of visible q rays.

We may continue to bring into play additional luminous points, and thus continue to reduce the number of unpaired or visible rays, until the number of phases represented by what are left are so few that the wave from the next *new* luminous point added, on the doctrine of probabilities, will not find an unpaired wave in a phase opposite to itself, and therefore, the number of visible rays will have been increased by one.

From which we conclude that when the visible waves in any composition ray have been reduced by such composition to a certain minimum number, they will be maintained at or about that number, which we may call the standard limit, notwithstanding that waves from other neighboring luminous points are brought into the composition. And we conclude that an increase in the number of luminous neighboring points brought into play will increase tremendously the energy in the invisible force rays, without increasing the visibility of the composition ray beyond the standard limit above referred to.

93. Let us now apply the foregoing principles to the composition of light waves coming from very distant stars.

Let R, P, M, N, Q, S (Fig. 27), be neighboring luminous stars, and let A be a point sufficiently distant from them to make the angle MAN so small that interference between the rays MA and NA can take place, but not sufficiently distant to make the angle PAQ small enough to permit of interference between the rays PA and QA. The composition at A will be solely between the rays MA and NA, and there will be a certain number of paired rays which will interfere and proceed

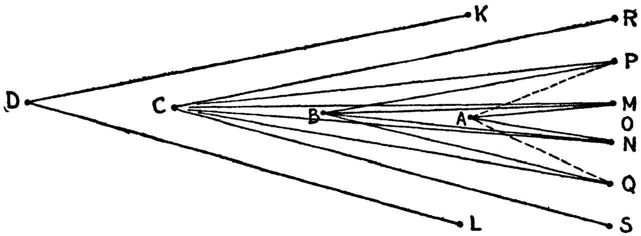

Figure 27

thereafter as force rays, but there will be also a certain number of unpaired rays which will continue to proceed as visible rays.

We will suppose that at the point A the number of unpaired rays are greater than the "standard limit."

Now consider the composition which will take place at the point B taken at such distance from O that the angle PBQ equals MAN.

The rays PB, MB, NB, and QB may now all go into composition at B and suffer interference.

On the principles heretofore stated, the number of visible rays will be reduced by the composition, and we will suppose that at that point the reduction of the number of visible rays has reduced the number to the "standard limit."

At the point C, the rays RC and SC will be brought into composition. But on the principles heretofore established, the number of unpaired or visible rays already at the "standard limit" will not have been decreased by the additional waves brought in. The latter will add to the number of visible rays, but they will not have their origin from the same original sources.

Now let us suppose that K and L are two stars in the foreground, sending a copious supply of visible rays to the point D which have not been reduced to the minimum limit, as has been the case with the light waves coming from the greater distance. Rays from R, P, M, N, Q, and S will also pass through D, but by composition the number of visible rays represented by them will be at the minimum standard limit, and there being so few of them compared with the larger number of visible rays coming from K and L, practically all the old visible rays will be paired with visible rays from K and L.

Similarly, when other rays are brought into the composition from other stars still further in the foreground, the last one of the visible rays proceeding from the distant stars R, P, M, N, Q, and S will have been paired and converted into force rays, and those stars in the background will have disappeared.

Not even a powerful telescope could bring them into view again, because the power of the telescope to bring into view objects, the light from which is too faint to be perceived by the naked eye, arises from its ability to gather up rays proceeding in *divergent* lines *from the same luminous point,* and concentrating them again at one point, in the same phase, so that in the composition which takes place at the point of concentration, the amplitude of the resulting wave is increased, and therefore the visibility.

94. This brings us to the consideration of a second cause operating to make very distant stars invisible.

The principle of light wave interference as illustrated in Fresnel's experiment, heretofore discussed, clearly shows that visibility depends upon the wave having a sufficient amplitude. But we know from experiment also, that visibility depends upon the intensity of the light, which represents energy. Like all forces radiating from a centre, since the same energy is spread out over a greater sphere-surface as the radius increases—and the surface of a sphere increases as the square of the radius—it follows that the intensity of light must be inversely proportional to the square of the distance from the centre of luminosity. That is:

$$\text{Intensity} = \frac{\text{Constant}}{D^2}$$

But Lord Raleigh ("Wave Theory of Light," Ency. Brit., 9th ed.) concludes that the luminous intensity is necessarily proportional to the *square* of the amplitude of the light wave. That is:

$$\text{Intensity} = \text{Constant} \times A^2 \qquad \text{where } A \text{ is the amplitude}$$

Therefore $\quad \text{Constant} \times A^2 = \dfrac{\text{Constant}}{D^2} \quad$ or—

$$A = \frac{\text{Constant}}{D} = \text{visible effect.}$$

Since the amplitude must be of finite size to make the wave a visible ray (sec. 66), it follows that when D is very great A becomes very small, and finally the wave makes no impression on the retina, and the ray is invisible.

The invisibility in this case, however, arises solely from the dispersion of the energy, radially from the point of luminosity, leaving the amplitude of the wave proceeding along any one radius, too small to create the visual impression. However, by concentrating a number of such divergent rays proceeding from one luminous point, the telescope brings them into composition in the same phase and thus increases the amplitude and intensity to the point of visibility.

95. We know that the gravitational influence at a distance is inversely proportional to the square of the distance. That is:

$$\text{Gravitational influence} = \frac{\text{Constant}}{D^2}$$

Comparing this with the preceding expression:

$$\text{Visible effect} = \frac{\text{Constant}}{\text{D}}$$

we see that the relative decrease in the gravitational influence proceeds with immensely greater rapidity than does the decrease in visibility. Consequently, the distance at which the gravitational effect would be practically zero, is much shorter than the distance at which the amplitude of the light wave becomes practically zero. It is to be expected, therefore, that light should reach us from the stars situate far beyond the gravitational system to which our sun belongs.

96. There is still a third influence at work tending to extinguish the light waves which would otherwise reach us from the most distant stars.

Through the discoveries made by Professor Barnard, and the work of other astronomers, it has been demonstrated that there are dark stars scattered through the heavens as well as luminous stars—suns which have lost their energy and gone to a kinetic death. Such dark stars would act as screens, cutting off the light rays coming from the luminous stars in the beyond.

In a recent number of the *Popular Science Monthly* (March, 1913), Dr. Frank W. Very advances the theory that within our own Galaxy system there is a greater accumulation of cosmical dust than exists in space in general outside of this and other similar systems, and that this dust acts as an absorber of the fainter rays.

It is probable that each of these causes in operation which we have mentioned contributes to the extinguishment of the visual rays coming from the stars in the infinite regions of space, thus preventing the skies from appearing as a solid blaze of light.

To the writer, the theory of the composition of the visible rays seems to furnish the most satisfactory explanation, but he does not know of its having been advanced heretofore. However that may be, we are not driven, by the fact that the heavens are not a blaze of light, to the conclusion that there is any limit to the distribution of stars throughout endless space. There are other controlling reasons to which we will later refer, which lead to the opposite conclusion.

97. It may be observed also, that our Milky Way system has been shown to be not nearly so simple as the advocates of the theory of a limited universe present the case.

There is strong evidence indicating that the Milky Way system is really double. The theory has been presented, that it is composed of two hoop or ring systems of stars which have drifted into each other. Where the rings cross each other, there is an appearance as if the galaxy has branches. "The Megellanic Clouds" in the Southern Hemisphere resemble detached portions of the Milky Way.

The ring of the Galaxy is very irregular, and in places it is partly broken. Professor Garrett P. Serviss, in "Curiosities of the Sky" (1909), thus describes it:

"Although to the casual observer it seems but a delicate scarf of light, brighter in some places than in others, but hazy and indefinite at best, such is not its appearance to those who study it with care. They perceive that it is an organic whole, though marvelously complex in detail. The telescope shows that it consists of stars too faint and small through excess of distance, to be separately visible. Of the hundred million suns which some estimates have fixed as the probable population of the starry universe, the vast majority (at least thirty to one) are included in this strange belt of misty light. But they are not uniformly distributed in it; on the contrary, they are arrayed in clusters, knots, bunches, clouds, and streams. The appearance is somewhat as if the galaxy consisted of innumerable swarms of silver winged bees, more or less intermixed, some massed together, some crossing the paths of others, but all governed by a single purpose which leads them to encircle the space in which we are situated."

There is a famous star-vacancy or "coal sack" which exists in the Milky Way, adjacent to the "Southern Cross," which is thus described by Professor Serviss:

"All around, up to the very edge of the yawning gap, the sheen of the Milky Way is surpassingly glorious; but there, as if in obedience to an almighty edict, everything vanishes. A single faint star is visible within the opening, producing a curious effect upon the sensitive spectator, like the sight of a tiny islet in the midst of a black, motionless, waveless tarn. The dimensions of the lagoon of darkness, which is oval or pear-shaped, are eight degrees by five, so that it occupies a space in the sky about one hundred and thirty times greater than the area of the full moon."

There is quite an assemblage of small "coal sacks" in the Northern Hemisphere, in the constellation of the "Swan" or "Northern Cross."

There is quite an assemblage of small "coal sacks" in the Milky Way, in the regions lying over and between the constellations of the "Scorpion" and the "Archer," commonly known as the "Milk Dipper."

The great question has been, whether these apparent star vacancies are windows to our physical universe, looking out into absolute void space, indicating that the physical universe has a finite boundary, or whether there may not be stars in the beyond, so distant that their light has become invisible before it has reached us, or whether there may not be some obstruction which shuts off the light of the stars beyond, if there be such.

98. Based upon the demonstrated existence of dark suns and dark nebulæ in space, Professor Barnard has advanced the theory, that the seeming gaps, or many of them, are not openings at all, but opaque screens of dark nebulæ cutting off the light of the stars behind them.

Professor Serviss says:

"But while it seems certain that some of the obscure spots in the Milky Way are due to the presence of dark nebulæ, or concealing veils of one kind or another, it is equally certain that there are many which are true apertures, however they may have been formed, and by whatever forces they may have been maintained. These, then, are the veritable windows of the Galaxy, and when looking out of them, one is face to face with the great mystery of infinite space."

But Professor Serviss finds the human intellect in revolt against the thought that there is nothing but a void in the space beyond.

He concludes:

"From such conclusions the mind instinctively shrinks. It prefers to think that there is something beyond, though we cannot see it. Even the Universe could not bear to be alone, a Crusoe lost in the Cosmos. . . . We are driven then to believe that the universal night which envelops us is not tenantless; that as we stare out of the star framed windows of the Galaxy and see nothing but uniform blackness, the fault is with our eyes, or is due to an obscuring medium. Since our universe is limited in extent, there must be other universes beyond it on all sides."

99. Professor Arrhenius, in his notable work, "Worlds in the Making" (1907), comes to the conclusion that there are many "systems" of star clusters, similar to our "Galaxy," scattered through infinite space. He says:

"In parts of the heavens where stars are relatively sparse (as at a great distance from the Milky Way), most of the nebulæ observed exhibit stellar spectra. They are nothing but star clusters, so far removed from us that the separate stars can no longer be distinguished. That single stars and gaseous nebulæ are so rarely perceived in these regions is no doubt due to their greater distance."

In another place he says:

"The opinion that all the solar heat radiated into infinite space is wasted, starts moreover from an hypothesis which is not proved, and which is highly improbable—namely, that only an extremely small portion of the sky is covered with celestial bodies. That might certainly be correct if we assumed, as has formerly been done, that the majority of the celestial bodies must be luminous. . . . We have, therefore, to imagine that there are bodies all through infinite space, and about as numerous as they are in the immediate neighborhood of our solar system. Thus every ray from the sun, of whatever direction, would finally hit upon some celestial body, and nothing would be lost of the solar radiation, nor of the stellar radiation."

Again he says:

"If the stars were crowded together in a huge heap, and only infinite empty space outside this heap, the dust particles ejected from the suns during the past ages by the action of the radiating pressure would have been lost in infinite space, just as we imagined that the radiated energy of the sun was lost. If that were so, the development of the universe would long since have come to an end, to an annihilation of all matter and energy. Herbert Spencer, among others, has explained how thoroughly unsatisfactory this view is. There must be cycles in the evolution of the universe, he has emphasized. That is manifestly indispensable if the system is to last."

100. It seems to the writer that this last argument against the theory of a physical universe limited to our Galaxy system is conclusive of the subject.

If we had only a one Galaxy system, and all the outside space be void, all the suns in that system would have long since radiated all their heat into space, and by loss of kinetic energy the entire system would be non-luminous and dead. If there are processes going on which will inevitably bring the entire physical universe to a kinetic death at some definite time in the future, since time in the past is unlimited, the human mind cannot escape the conclusion that the death event should have happened long ago. Nor does it aid us to imagine a beginning of the process, unless we assume that we have under consideration only one system of a still larger universe, and that in this endless universe there is going on by operation of natural laws, an endless cycle of birth, life, death, and resurrection of systems. If one system is going to its death, as it must be, because of the gradual loss of kinetic energy through radiation outward into space, there must be another system in process of building elsewhere.

Professor Arrhenius has given us, from an astronomical standpoint, a wonderful insight into the marching of this great cycle—operating in the birth, life, death, and resurrection of worlds. He has not turned his wonderful powers on an analysis of the processes which are operating in this cycle, in the creation, life, and death of matter itself, and which the latest discoveries indicate must logically be included in the premises of an endless cycle; he takes matter as he finds it, as material in hand for the building of worlds and suns and deals with the cycle changes in these systems.

101. As a basis of the hypothesis which is to come, let us conceive of an endless universe of suns, of stars, of clusters of stars, and of worlds; and let us draw on the imagination for a conception of it.

It is related in the account accepted by the faithful of Islam, that when Mahomet Ibn Abdallah, the prophet, was starting upon his nocturnal journey through the heavens, accompanied by the Angel Gabriel, a jar containing water was accidentally struck by the Angel's wing, and commenced to topple over. Mahomet, mounting the celebrated winged mare Al Borak, and guided by the Angel, with the rapidity of lightning, soared to Jerusalem; thence, mounting by a ladder of light, he sped from heaven to heaven, seeing many wondrous sights, until at last he reached the seventh heaven.

There Allah communicated to him numerous of the divine doctrines embodied afterward in many chapters of the Koran. Returning by the same route to the place from which he originally started, Mahomet found himself back in time to prevent the complete overturn of the jar, from which only a small portion of its contents had escaped.

After the manner of the Prophet, let us then in thought mount Al Borak and, leaving the Earth, speed through space with a velocity far transcending that of light, taking for our guide the laws of our limited system, to be the Interpreter of the wondrous sights which are to be found in the space beyond our Galaxy. We will proceed in our journey toward an endless depth of scintillating stars. We will pass nebulæ, star-clusters, and stars, some of which would pale the brilliance of our Sun. Here and there in the depths of space we will encounter stars whose energy has been dissipated, looming up, bright only by reflected light, and here and there we will pass through a star-cluster system which has gone to a kinetic death. Occasionally we will witness the momentous collision of two of these dark suns, resulting in the conversion of the rectilinear motion of the bodies into vibrations of their particles, and liberating a kinetic energy, disrupting the bodies, and in a flash of gorgeous light, causing a magnificent gaseous nebula to extend itself for millions of miles through space—to take up again the processes of evolution through which, by radiation of energy, are kept alive the brilliance of the living suns. And if, after speeding thus for a million years, we halt Al Borak at the confines of some star-cluster and inquire of our Interpreter the road to the limits of the physical universe, the reply would be: "You are as yet but at the beginning of your journey, the road ahead lies straight —it has no end."

It is necessary that we allow our imaginations to soar, in order that we may even apprehend an unlimited universe.

102. The writer has deemed it necessary to make this brief

review of the evidential facts in favor of the view that there is no limit to the distribution of the stars through space, because it is upon the assumption that there is such an unlimited distribution, that the hypothesis for the genesis of matter, which he proposes to present, is predicated.

CHAPTER XI

ORGANIZATION OF THE ETHER BY FORCE RAYS

103. **Space and Matter.**—Let us now contemplate how small is the volume of the space of the universe occupied by matter, compared with the great voids of space not so occupied. The diameter of the sun has been computed to be about 864,000 miles. We might suppose, distributed close around the surface of the sun, all the matter in the planets, and throw in the moon, the asteroids, and all the roving meteors in the solar system; and a sphere whose radius is less than one-half a million miles would, on a safe estimate, contain it all.

The distance from the Sun to Neptune, the most distant from the Sun of the eight Planets, is given as 2,796 million miles. If we imagine a great sphere with a radius of 2,796 million miles, circumscribed about the Sun as a center, its volume would be 174,000 times greater than the volume of the sphere of half million mile radius—estimated to be sufficient in size to contain all the matter of the solar system. This gives us some idea of the relatively small part of the space of the solar system occupied by matter.

Light travels the 93 million miles from the Sun to the Earth in a little more than eight minutes. The Sun's nearest neighbor is *α Centauri,* which is separated from it by about 25,110,000,000,000 miles, a space which it is calculated it would take light four years to traverse, traveling at the rate of 186,000 miles per second.

It is considered by astronomers fairly certain that not more than six stars lie within twice this distance from the

Sun. The vast majority of the visible stars are very many times more distant.

We must conclude, therefore, that the volume of the space of the universe occupied by matter is insignificant, compared with the space void of matter.

Nevertheless, since space is boundless, and the distribution of matter throughout all space is unlimited, we must conceive that if we could proceed in any given direction into the depths of space, and travel far enough, we would at last necessarily reach some star. However sparse the distribution of stars might be, if the means of seeing were not limited by distance, the effect of looking into the depths of space would be the same as when we look into the depths of a forest composed of scattered trees—the aspect would be that of a solid wall. But the luminous wall would be composed of separate points of various degrees of luminosity.

104. Observation of the surface of the ocean the world over shows that it is, in general, in a state of agitation or wave motion. If we should have before us as an original problem, the ascertainment of the causes of that agitation, and the character of that motion, from a study of the phenomena themselves, our first procedure would be to eliminate the effect of all local causes, such as the waves from passing vessels, and those created by temporary winds. And when we find that the agitation comes on periodically with a tide, and is independent of all local causes, and is world-wide in its operation, the mind would be led to the great sources of force operating through gravity upon the Earth, and we would naturally find the operating cause in the influence of the Moon and Sun on the Earth and its waters. In like manner, when we seek to ascertain the constitution of the ether medium, or its normal condition of agitation, fixed as it must be by the force rays which are passing through it in every direction from the stars of a boundless universe, we must eliminate from our consideration the influences of our Sun,

and of the stars of our Galaxy system, as if they were passing vessels on an ocean of ether, and study the operation of the force rays which come from the Great Beyond.

105. Between the celestial bodies of the smallest size and the stars of the largest size, there must be stars of mean or average size and mass, and the same forces at work to maintain throughout the universe an average distribution of stars must also be at work to maintain the average size and mass. Observation teaches us that there must be a maximum size and mass, although we may not know all the causes which operate to fix that limit. We know that the cause which effects the aggregation of the smaller masses of matter into larger bodies is gravitation, and that gravitation itself has its limitations, in respect to the distance through which it can effectively operate, and its power is also affected by the internal heat or temperature of the body. We know also, in respect to roving bodies, that the size increases the chance of collision. However these causes may accomplish the result, we may safely conclude that in the depths of space, in whatever direction we may turn, there is an average distribution of stars of average size and mass.

106. As a foundation for any helpful cosmos hypothesis, it is not only necessary to arrive at a proper understanding of the constitution or structure of the medium which serves as the vehicle for conveying light vibrations through space, but also to ascertain the general causes which operate eternally to maintain that constitution.

Let us now, in imagination, consider that we are at the centre of a sphere, whose radius is so long that it reaches to the most distant visible star, and we will call into service our most powerful telescope, and extend the radius of our sphere to take into its boundary the most distant star that can be thus seen. Since space is infinite, the length of the radius so taken will even then be infinitesimally short compared with the depths of the infinite space beyond.

Also, the amount of matter located within the boundaries of our supposed sphere will be infinitely small compared with the amount of matter distributed through the Infinite Beyond.

We know that when light leaves the Sun it takes a certain length of time to reach the Earth. Between the time of leaving the Sun and the time of arrival at the Earth it must exist in the ether as energy, as pointed out by Maxwell, manifesting itself by vibrations taking place in the ether, and carried forward in waves.

The same must be true relative to light proceeding from every luminous star. If, therefore, we consider the effect of the intermingling in any great region of space, of all the radiations of energy proceeding into that region from all the stars of the universe, we can readily appreciate that the ether occupying such a region of space must have some kind of general constitution markedly different from what it would have if these agitations were not going on at every instant at every point in space.

Indeed, if we conclude that there always was, and always will be, such an average uniform distribution of stars through space as there is now, some going to pieces while others are being built up, it follows that there is no small part of the ether substance in space which ever was, or ever will be, in an absolute state of rest. A state of rest, therefore, could exist only in a relative sense.

The primary influence of our Sun or other particular stars, or clusters of stars, on the state of the ether, is local, and in arriving at the normal state of agitation which must exist in the great unfilled regions of space, the influence of the stars in a particular region must be considered as insignificant when compared with the mighty currents of energy flowing from a universe of stars scattered through an infinity of space.

The normal constitution of the ether in our supposed great sphere would be fixed by the energy proceeding from the stars of the Infinite Beyond, and for the determination of that normal constitution we must eliminate the influence of the stars within our supposed great sphere.

The starting point of our inquiry into the normal constitution of the ether of space must be in the investigation of light rays coming into finite space from luminous sources at infinite distances, or distances approximating the infinite. We could limit the distance to the point where, if our vision were not limited, the apparently luminous wall would be. From beyond that wall no direct rays could come into the particular space we are considering. Nevertheless, the distance so limited would be infinite compared to the small quantities which we will presently have under consideration.

107. **Causes Checking Decrease of Light Intensity in Space.**—We know that light proceeds in every direction from a luminous point. If the luminous point be placed at the centre of a sphere of one foot radius, the light from it would be distributed with a certain intensity over the inner surface of the sphere. If the sphere be two feet in radius, the same amount of light which started from the luminous point would have to be distributed over the larger surface. But surfaces of spheres increase as the squares of their radii, and therefore the surface of the sphere of two feet radius would be four times larger than the surface of the sphere of one foot radius. So that the light from the luminous point, being distributed over four times as much surface, only one-fourth of the quantity of light falls upon the same amount of surface of the second sphere as in the case of the first sphere. In other words, the intensity of light proceeding from a luminous point decreases inversely as the square of the distance from the luminous centre.

This does not imply that the intensity of light decreases in the same geometric ratio for equal distances traveled as it proceeds from its source. If we represent the intensity of light at a unit of distance from the source by K, at a certain distance from the source represented by m times this unit distance, the intensity would be $\frac{K}{m^2}$. If we take another point a unit distance further on the distance to it would be m+1, and the intensity at that point would be $\frac{K}{(m+1)^2}$. The loss of energy in passing over this added unit of distance would be

$$\frac{K}{m^2} - \frac{K}{(m+1)^2} = \frac{K}{m^2}\frac{(2m+1)}{(m+1)^2}.$$

It will be readily seen that the value of the fraction $\frac{(2m+1)}{(m+1)^2}$ rapidly decreases as m increases. When m is very great the relative loss of intensity in passing over each additional unit of distance becomes inappreciable.

In other words, when a light ray has traveled to any great distance, and has a certain intensity at that point, it can travel further to other great distances without the same relative fractional loss of intensity as in the earlier stages of its journey.

We have already shown (sec. 92) that visible rays of light proceeding from neighboring stars to a common point at a very great distance, are by composition converted into invisible force rays, and that the further the ray proceeds through space, the greater will be the number of rays from other luminous points, brought into the composition, and converted into the composition force rays.

It follows, that after a ray has proceeded to a very great distance, while it will continue to lose the energy with which it originally started, inversely as the square of the distance, this loss of energy will more and more be compensated for by the rays from other neighboring stars, which will be brought into composition with it.

It is a fundamental conception of physics, that no energy is ever destroyed, or created. The same amount of kinetic energy existing in the universe to-day, always existed, and ever will exist. This principle is known as the conservation of energy.

From Physics, we know that the measure of this indestructible entity is expressed by the formula, $\frac{1}{2} M V^2$, where M is the mass of the moving body, and V is the velocity with which it is moving.

108. The question has often been asked, what becomes of all the energy in the light rays which are radiated by luminous bodies into space?

Were there but a single luminous body in all space, the question as to what would become of all the rays radiated into space from it, would not be difficult of answer from the mathematical standpoint. Since the intensity of light diminishes inversely as the square of the distance, it would be zero at infinity. In other words, a finite quantity of energy, being scattered over an infinite surface, the amount of energy falling upon a finite surface would be infinitely small compared with the total quantity radiated.

It must not be overlooked, however, that such decrease of intensity is due to subdivision of the energy in the rays, as they spread out radially from the luminous centre.

When we consider that there are other neighboring luminous sources, sending other rays into the same regions of space, and that at very great distances from these neighboring sources, two rays which cut each other, will be traversing practically the same path, we can readily see that at very great distances the energy of a ray from any one source will be joined by the energy proceeding in the same direction from innumerable sources. It is a well established principle of wave motion, that when two waves cross each other at a large angle, they pass through each other. But when two waves proceeding with the same velocity, whose paths lie in the same straight line, are superposed, they will or can, proceed together as one wave, although the conformation of the wave surface is different from either, separately considered. There is a combination of energy, but a difference in the details of wave motion taking place.

The principle of ray-combination at great distances, and the results necessarily proceeding therefrom, are too important to be passed without illustration.

109. **Forces at Work for Uniformity.**—Let A, C, D, E, F, G, and B (Fig. 28) be luminous points in the neighborhood of each other. Let the rays DO, EO, and FO cut each other in O. Then EO being comparatively short, the angle DOE will be comparatively large, and the rays DO, EO, and FO

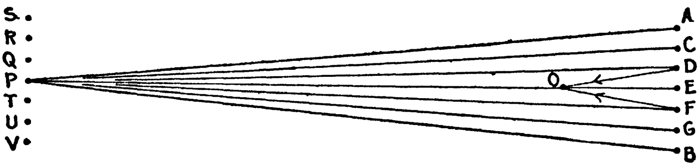

Figure 28

will simply pass through each other, with only local effects at O, the point of crossing. But if we increase the distance EO, the angles DOE and FOE become smaller, and when EO approaches infinity, the angles DOE and FOE approach zero in value, and the lines DO, EO, and FO will, at this approach to infinity, be following the same path. Therefore, if P be such a point, at practically an infinite distance from E, the energy passing through P in the direction EP, is made up of the combined rays proceeding from each of the points A, C, D, E, F, G, and B, and pursuing the same path, the pencil of rays will proceed as one resultant ray. Moreover, the phase of the wave at P at any instant of time must be the phase of a resultant wave or the group of waves produced by a combination of numerous waves.

Such a combination must exist in every ray of light which reaches us from the Sun, since it must be made up of innumerable rays originating in independent centres of luminosity, in the neighborhood of each other on the surface of the Sun, and because at the distance of ninety-three million miles such rays would be practically parallel.

If we consider any number of other points, Q, R, S, T, U, and V, in the finite neighborhood of P, it is evident that the energy arriving at any one of them would be proceeding in one substantial line, and would be made up of a combination of rays, as before, from each of the luminous points A, C, D, E, F, G, and B. We may, therefore, lay it down as a necessary principle, that light coming from any direction in space to any point, from an infinite distance, is made up of a combination of rays from many sources. Necessarily, therefore, there must be a diffusion into each resultant ray, of the energy from each source contributing to that resultant ray, and each point in any surface normal (perpendicular) to the direction of such rays, would secure a ray into which is diffused an average intensity, representing the contribution from all sources.

Again, we see that while the ray EO continues to lose its energy inversely as the square of the distance from E, up to a certain point, that after it has traveled a great distance EP, it commences to receive accretions of energy from sources of rays in the field surrounding E, which in part at least will furnish compensation for further losses.

110. We have heretofore seen that the simplest form of light-wave motion is represented by the revolution in a circle of a particle around the axis of progression of the ray, and that when the centre of revolution advances, the path of the particle is a spiral around the axis of progression. We have also seen that in a composition ray, the circular path of the particle around the axis is modified, in accordance with the laws of composition of Simple Harmonic Motion, and the

contour of the path may be more complicated, as for instance (sec. 60), it may become an elliptical spiral.

Now, since all the waves which enter into the composition are individually periodic, i.e., return to the same phase periodically, all of them, of any one wave length, will together produce the same joint phase effect at each such wave length; and where there are a great many wave-trains of various wave-lengths, which enter into the composition ray, if we eliminate from consideration all the waves whose wave-lengths have the relation to each other required by Fourier's Theorem (sec. 49), the joint phase effect of the remaining waves will, under the law of probabilities, give an average uniformity of phase at every point in the line of progression; or in other words, the combination effect is the interference effect, or strictly speaking—force-ray. Nevertheless, such a ray would be sending off radiations of minute vibrations in every direction, at right angles to the axis of the ray, and from every point in the axis.

If now we consider as superposed upon the effect just considered, all the waves of wave-lengths which have the relation required by Fourier's Theorem, they will in composition, give a periodic recurrence of alternate wave-crests and troughs, sending off from the axis, at periodic intervals, lateral radiations of larger transverse vibrations, than the minute ones hereinbefore considered. A longitudinal section through the axis of such a train of composition waves would give a periodic wave profile as explained (sec. 54) and illustrated for a special case (Fig. D, Plate I).

It is apparent from the foregoing, that if we consider any point through which such a composition train of waves were passing, as each periodic wave-crest passes through the point, there would be a maximum pulsation radiation at right angles to the axis of the ray.

111. If now we consider a large number of rays sent off from any central luminous point, it is plain, on the principles

stated (sec. 77), since the cross section of each ray is a force centre, that the rays will laterally repel each other, and tend to open out radially as they progress. But on the principle of what is known in Physics as Huyghen's construction for the wave front, every point in the wave front may be regarded as a new centre of disturbance, and this results in a continual subdivision of the rays as they progress outward from the original centre of disturbance.

112. We may now consider a large number of adjacent parallel rays, which have proceeded from infinity, in the same direction, and are therefore composition rays from the same sources of luminosity and of the average resultant kind. It is evident that such rays would possess uniformity in a great degree. If now we pass a plane perpendicularly through such a bundle of parallel rays, the cross section will contain a force centre of the first order or centre of radiation for each point where a ray pierces the plane. Each of these force centres must repel the other, and the resultant effect must be to arrange the force centres of the first order in equilateral triangular formation (sec. 77, and Appendix, sec. 197).

Similarly, if we consider the rays coming into the given space from infinity, in the opposite direction to those above considered, they likewise, by mutual repulsion, would tend to arrange themselves so that their force centres in any cross section would give the equilateral triangle formation. But the rays of the system proceeding in one direction would laterally repel the rays of the other. Now the only positions in which we can arrange the force centres of the two systems in equilateral triangular formation with respect to each other, and at the same time place the centres of repulsion the furthest distance apart, and therefore in the positions of most stable equilibrium, is when the centres of force of the one triangular system coincide with the centres of force of the other triangular system. In other words, the minimum lateral strain in the medium exists when a ray of one system is pursuing the same path as a ray coming from the opposite direction.

But when two trains of rays are proceeding through each other on the same axis in opposite directions, they form stationary waves along the axis (sec. 55).

Considering, therefore, for the present, only the parallel force rays coming from infinity from opposite directions, they would give to the ether medium a stationary-wave structure (Fig. 29), in which the force centres, vortices or stand-

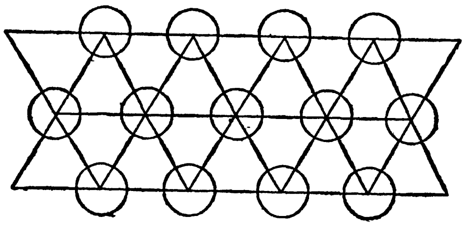

Figure 29

ard ether particles are arranged in equilateral triangles, in planes at right angles to the direction of the parallel force rays under consideration.

Reasoning that in the infinite there must be uniform distribution of luminous stars, and that the force rays are composition rays from all the stars sending from the infinite parallel rays into the field of the plane to which they are perpendicular, the effect ought to give to the force centre structure of the plane under consideration, almost perfect homogenity and isotropy.

113. The causes which fix the average magnitude of these force centres, and their distances apart, are of universal operation. They are the average magnitude and average distribution of the stars in infinity; the average intensity of the force rays, brought about by composition, and the mutual repulsion between force rays; the minute impulses of the force ray, which in its last analysis must represent the resultant of

all the impulsive outbreaks of the various sources of luminosity, from which rays are brought into the composition. There must be an average for these, which fixes the heart-throb of the universe. We feel as certain that the magnitude and positions of these centres of force are fixed by an average uniform distribution of the stars in infinity, as we are certain that the average of the velocities of each separate molecule of gas in a given volume fixes its temperature.

We know, however, that individual sources of light vary in intensity during short intervals, and we know the corresponding fact, that a visible ray of light representing a wave-train, does not proceed regularly in periodic recurrence of phase but for short intervals of time (sec. 71). These causes, working for irregularity, must keep the centres of force in a state of oscillation in the axis of the ray, so that the position of the stationary wave "wheel" revolving around the axis would be moved backward and forward, passing in and out of any plane fixed at right angles to the axis of the ray. But the taking of any one or more of the force centres out of a plane in which they help to maintain by repulsion the equilateral triangular formation (Fig. 29), would at once set the other centres to forming another equilateral triangular arrangement through mutual repulsion. Even if the displacement of the particles remaining in that plane be but slight, before there is a return of the absent force centres to that plane, it would be sufficient to keep the force centres oscillating in the plane. We must, therefore, regard the equilateral triangular formation as the ideal position of stable equilibrium for the force centres, which their mutual repulsion is always endeavoring to make them assume, but that they make small oscillations through these ideal positions, as a pendulum swings through its lowest point, which is its ideal position of stable equilibrium.

114. It must not be imagined, however, that the causes to which we have referred as operating to make the position of

the force centre oscillate in the axis of the ray, operate to make abrupt changes of position in the case of force rays, as they do in the case of ordinary visible rays. And this, because the force ray is essentially a composition ray, in which individual fluctuations of luminosity in any one source, sending rays into the composition, are set off by fluctuations in other sources, and the fluctuations of the energy passing in a force ray must represent the average of all fluctuations in the sources of luminosity, and tend to uniformity in magnitude as well as periodicity.

Thus (Fig. 28), if the luminous points A, C, D, E, F, G, and B are sending rays to the point P, giving a certain composition effect at P, and practically the same composition effect at the points S, R, Q, T, U, and V, and if we suppose that a change of luminosity occurs in A, then since AS is shorter than AP, the effect will be felt first in the composition ray at S, and will pass successively to the points R, Q, P, T, U, and V. Similarly, a change of luminosity in B would be felt in the composition rays successively at V, U, T, P, Q, R, and S. Where a large number of changes of luminosity are taking place in the sources, the composition effect would create small periodic oscillations of the force centres, and not abrupt changes of state. Oscillations of the force centres will not affect the general direction of the force rays of which they are composed, because the plane of revolution is not changed, and because of the same principle which holds a rotating rifle ball to its course.

115. From our previous discussion we must conclude that if we consider the force-line passing, perpendicular to the plane, through any force centre or stationary wave, there will be similar force centres or stationary waves at periodic intervals along that force line. And the same is true of other parallel force lines passing through adjacent force centres. In other words, the equilateral triangular arrangement of force centres will be in parallel planes with small intervals

between them, which represents the wave-length periodicity of the force rays.

116. Now what is true of any system of parallel rays coming from infinity, and of the parallel rays meeting them, coming from the opposite direction, must be true for every such system of parallel rays, from whatever direction they may come. So that if we select any particular point in space, and pass any number of planes through it in different directions, the triangular arrangement of force centres would be true for each of such planes. It does not follow, however, that the point we selected would be at a force centre of any one of those planes. Moreover, since the sources of luminosity, whose composition rays fix, at any given instant, the position of the force centres in each plane, are entirely independent, it does not follow, and the chances are against, the coincidence of a force centre of one plane with that of another. And the chances that any number of force centres belonging to different intersecting planes would coincide at any one point at a given instant, are extremely remote. The medium, therefore, is not organized so that pressure applied in one direction is transmitted in all directions, as in the case of a fluid (sec. 19). Indeed, these force centres of the first order being circular motions, confined to a single plane (sec. 74), their elasticity exists only in the plane of rotation, except as distribution of force is made through the force centres of the second order in the plane passing through the direction of the ray and perpendicular to the primary plane (sec. 74).

117. We have now reached the point where we can assign to the ether medium a comparatively simple mechanical structure. That structure consists of the force centres shown by the circles cut out as cross sections by any plane passed perpendicularly to a bundle of parallel rays proceeding from infinity. All such circular vortices in the same plane arrange themselves by mutual repulsion in equilateral triangle forma-

tion. Each force centre consists of circular or vortex motion in the plane of the triangle. These vortex centres are fed and maintained by the composition force rays coming from the stars in the Infinite. For that reason they are of average uniform magnitude. Force centres or vortices in the same plane repel each other, and for that reason they react elastically, and resist elastically, any displacement from their relative equilateral triangular positions. They give to the ether an elastically rigid structure, and therefore make it a medium capable of transmitting transverse wave motion.

118. Having now determined upon the normal structure of the ether medium as fixed by the controlling influence of the unnumbered stars of an endless universe, we might consider next what effect the disturbances occurring in some nearby star would have upon the ether structure in regions in the approximate neighborhood.

We know that such disturbances set up light wave motion in the elastic medium. We know that the amplitude of the vibrations is very much greater in these luminous waves than in the force rays we have been considering. A single vibration in a luminous wave may involve very many of these ether vortices. We thus have the new light waves riding, as it were, on the backs of innumerable expiring light waves, which have reduced their amplitudes and become mere invisible force rays, in their flight across the depths of space.

119. We are now prepared to outline the life history of a ray of light:

When it has gotten well started on its journey, it consists, in cross-section, of circular vibrations of large amplitude, representing the visible rays, with a core of invisible force rays in which the amplitude of vibration is extremely minute. These force rays carry great energy. As the wave progresses in a straight line, the energy is dispersed inversely as the square of the distance. This reduces the amplitude of the visible rays, as well as the intensity of the composition force rays, until a point is reached where all the rays become invisible, except by use of a telescope. After a time, the ray has again progressed to such an immense distance from its starting point, that luminous points in the finite neighborhood of the source of our ray send rays which join it at this distant point, also traveling in the same path, and enter into composition with it; so as our ray travels on, other rays join it, until finally all the visible rays with which we started have been converted into force rays. By dispersion through subdivision, these force rays will finally be reduced to waves whose amplitudes approximate zero. A long time prior to this, however, the amplitude of the force waves will have been reduced to that average size, which as force centres, fix the normal structure of the ether medium. The force rays then, furnish in their cross sections, which vary from the average size down to zero, the force centres or vortices, which enter as elastic elements, and take their part along with other such force centres, in the larger vibrations of some new light wave, which embraces them, and then treads upon them in its flight. But however spurned, and however robbed in the continuation of its course of its luminosity, and diminished in size to the vanishing point, our force ray must still persist as circular motion, and thus keep the ether elastic in every core and fiber.

Thus, in the broader sense, the ether may be considered as a medium made up of eddies, down to its most infinitesimal parts, and it is not an anomaly to consider such an eddy as an ether particle. It is something which has a definite form, shape, size, and elasticity, and is capable of receiving and imparting motion and of change in its own position, and in light wave motion, shows an automatic capacity for maintaining itself beyond anything with which we are familiar in the phenomena of matter. Nevertheless, at the small end of the rays when their journey is ended, they die; but the energy which once vitalized them lives in the new born rays which scintillate their youth in the colors of the rainbow.

CHAPTER XII

PECULIARITIES OF THE ETHER STRUCTURE

120. The Standard Ether Flow.—Referring to Figure 30, in which the triangular system is intended to represent the equilateral triangle structure of the medium, caused by the location of the standard ether particles, we will find it convenient to refer to that system as the standard equilateral triangles.

A little consideration of the lines will show that the system may be considered as formed by three sets of parallel lines proceeding from infinity. On the other hand, if we consider the position of any one standard particle, as that at O, we see that it may be considered as a centre of force through which or from which radiate six great lines of force which extend to infinity.

Let A, B, C, D, E, F, and O be standard ether particles situate at the corners of the standard equilateral triangles of the ether structure, the six triangles having their vortices at O.

Since flows of energy in the lines of force from infinity are traveling in opposite directions, we may consider that the points ABCD, etc., are the positions in which the stationary waves are formed, and we may consider that the particles A, B, C, D, E, F are traveling in the sides of the equilateral polygon or hexagon ABCDEF, and in effect moving in the periphery of the polygon about the position of the particle at O. There will be particles moving in both directions in the sides of the polygon, and passing through each other at the corners, at which times radial impulses will be sent down the six principal lines of force to the centre O. It will make no difference for our present purposes, whether we consider that the stationary waves formed at A, B, C, D, etc., which we have denominated as standard ether particles, actually travel in the sides of the polygon, or only particles sent off by them as wave impulses.

We might have considered with equal propriety that F was the central particle, and that the flow was around the

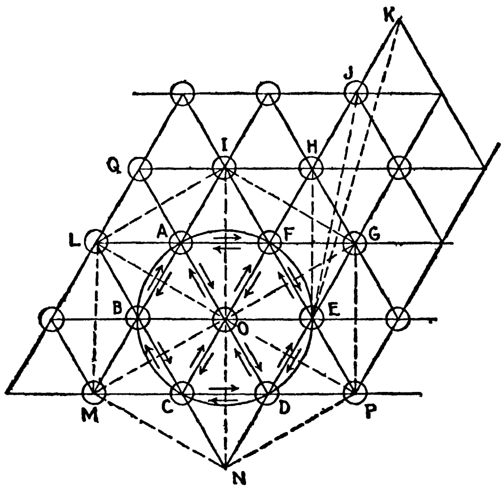

Figure 30

sides of the polygon AOEGHI, and reached the same conclusion as to it.

We may therefore regard the stability of the equilateral system as maintained by a steady flow of energy with velocity $V = 1$ along the sides of the equilateral triangles in both directions as indicated by the small arrows in Figure 30. The length of the side of the standard triangle we take as unity.

The result reached is identical with that reached by the methods of higher mathematics for a surface element. (Elements of Theoretical Physics, Christiansen-Magie, p. 20).

121. The Ether Medium Is Under High Pressure and Possesses a Quasi-rigidity.—By reason of its uniform or isotropic structure and the repulsion existing between its particles in every plane which can be passed through it, there must exist throughout the entire ether medium, in its normal state, a very high degree of pressure, and this must be in general uniform throughout, except where disturbed by the extra normal motions which may be propagated through it. This pressure constitutes the driving force of the universe.

The appreciation of the fact that the ether is organized in planes is the key to the atomic structure of matter.

So far as the pressures existing between standard particles rotating in the same plane are concerned, it is apparent that their repulsive radiations will tend to enforce the equilateral triangle structure, and give to the ether at least a quasi-rigidity (sec. 21).

A consideration of the repulsion which must arise between a system of particles in triangular arrangement in one plane, and another such system in a nearby parallel plane, by reason of inter-radiations from their particles of the Second Order, will lead to the conclusion that their respective triangular systems operate to laterally "brace" each other, after a manner which we may liken to the trusses of a bridge.

Thus if A, B, C (Fig. 31), be standard particles in the equilateral triangle system ABC, so that their particles of the Second Order are revolving in planes perpendicular to the plane of ABC, and so that the centres A, B, C, may be considered as revolving around O, the particles of the Second Order will be emitting rays of repulsion from A, B, C, respectively, when at those points, in the planes AOD, BOD, and COD, the resultant pressure tending to operate in the direction OD. So that any standard particle at, say, the point D, if revolving in either of the planes AOD, BOD, or COD, would get the repulsive effect of the particle A, B, or C only in the plane in which it was revolving. But if D be the centre of a standard particle revolving in a plane parallel to ABC, its particle of the second order will emit and receive repulsive radiations as it revolves, successively, to and from A, B, and C. The repulsive effect, as heretofore pointed out, is an elastic effect due to the shortening of the radius of revolution of the particle acted upon, or change of the position of its centre by pressure, and therefore its operative effect takes place only from rays proceeding in the plane of revolution, either of the particles of the First or Second Orders.

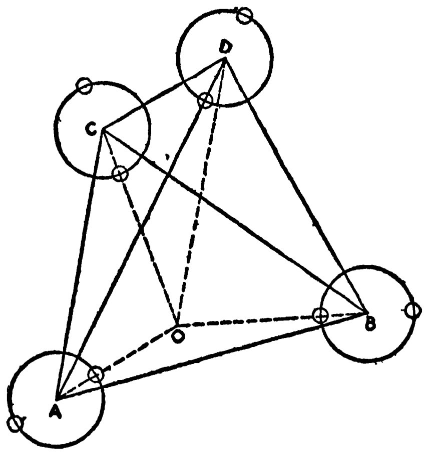

Figure 31

The foregoing considerations lead to the conclusion that in an infinitely extended ether formed with the equilateral triangle structure in every plane, the triangular structure will be braced laterally by interaction between their particles of the lower orders.

Inasmuch as the pressures which create the equilateral triangle systems are due to radiations between particles of the First Order, while the lateral pressures we have above considered are due to radiations of the particles of the Second Order, the writer does not think that the arrangement of the standard particles of the ether structure is tetrahedral. He is inclined to think that the tetrahedral arrangement called for in matter by certain principles of higher mathematics, arises only in combinations of higher particle-motion to constitute matter as hereinafter considered. But these reasons do not necessarily exclude that idea.

These conclusions will be strengthened when we come to consider that all the phenomena seem to require organization of the ether in planes cutting in every direction, and that structure responds apparently to all requirements.

122. **Stress Lines and Lines of Least Action.**—Referring again to Figure 30 we see that the greatest stress between the standard particles of the ether medium when in the equilateral triangle positions must exist in the line of the sides of the standard equilateral triangles. This follows because the particles repel each other inversely as the the distance. This conclusion means that the greatest amount of flow of energy must be going on in the sides of the standard equilateral triangles. It follows that if a motion be started, timed with and following a flow, the line of least action, or the easiest road to travel, will be in these principal stress lines, or lines of flow of the First Order. If not timed with the general flow of energy which is taking place periodically in these principal lines of flow, some other line will or may be the line of least action.

We may look upon the side of the standard equilateral triangles as tubes of sufficient size to admit of the passage through them of a standard ether particle, and that flows of energy are taking place through them in uniform periodic beats, in both directions. Each standard particle being an elastic ring, there would be no difficulty in the passage of one ring through the other, where the nature of the flow requires it. The action would be similar to the passage of vortex smoke rings through each other as illustrated in Helmholtz's and Lord Kelvin's experiments.

For precisely the same reason, there is a line of stress between E and H, but the flow is of less magnitude than between E and F, and we therefore may regard EH as a line of flow of a lower order; or as a tube for the passage of particles of a smaller diameter.

It will be observed that EH is tangent at E to the circle

ABCDEF, and if we can consider that the particle E is revolving around O, in that circle or in the hexagon, under the principles stated in section 75, the waves sent off by the particle when at E will be in that tangent.

For similar reasons there is a line of flow of a still lower order between E and J, and another of a still lower order between E and K, etc., etc., but these lines are not tangent to the same circle at E. Nevertheless, these lines of flow of lower orders will play an important part when we come to consider atomic structure.

123. **Hexagons of Ascending Magnitude.**—If in Figure 30 we consider the points G, I, L, M, N, P, we see that they are naturally arranged so as to form a perfect hexagon of a higher order than the standard hexagon ABCDEF, being based upon the equilateral triangle OGI.

From the right angle triangle OIH we have $OI^2 = OH^2 - IH^2$. And if $OF = 1$,

$$OI = \sqrt{(2)^2 - (1)^2} = \sqrt{3} = 1.7320508$$

As we pass outward from O, we see that by connecting the particles properly situate, there is in the ether structure a succession of hexagons in which the sides or radii are successively of greater length, the next one being the hexagon whose basic triangle is OIIQ, etc., etc. The length of these sides or radii is of great importance to the subject we must later consider, but we pass that for the present.

We know that a light wave in general consists of a wheel of ether particles revolving at right angles to the line of progression.

In the normal state of the ether, we may consider that the particles forming the hexagon ABCDEF, revolving only in unison with the flow, form a stationary wave, in which the amplitude is OF, since, as we have heretofore seen, each of the standard particles A, B, C, D, E, F, is a stationary wave.

Now if by some torsional force, we could set the particles in the hexagon ABCDEF, to revolving in one direction around O, at a higher rate of speed than the regular ether flow, we may conceive that the particles composing this hexagon would be started off as a traveling wheel or ray of light or electric wave.

The same proposition would apply to the particles forming any of the larger hexagons.

If two of such traveling waves met each other traveling in opposite directions on the same axis and in the appropriate phase, we would again have a stationary wave. But such stationary wave would possess qualities which would differentiate it entirely from the surrounding ether structure. In the first place, it would represent a stationary particle revolving with very much higher velocity, and certainly as to the larger hexagons of much greater magnitude than the universe of particles of the lower orders surrounding it. For that reason we would expect such higher order particles to have properties different from those of the standard particles, and that their action on particles of like kind would be different from the action of the normal ether particles.

124. **Hexagons of Descending Magnitude.**—Because of the fact that in the ether structure there are, as we have heretofore seen, lower orders of ether particles with magnitudes below that of the standard particles, and from a consideration of that structure itself, it can be easily demonstrated that there must be a descending system of hexagons, or a succession of lower orders of equilateral triangles in the structure, running downward on the same mathematical scale that the others run upward from the standard triangles. For instance, just as the standard particle at F (Fig. 30) is at the centre of the larger triangle OGI, there must be a particle of the second lower order at the centre of the standard triangle OFA, and another at the centre of AFI, etc., etc., so that these lines of flow of lower orders such as OI and IG really belong to the lower systems of particles. We

can readily conceive, therefore, that if a standard particle is driven through a line of flow of a lower order, as from I to G, the particle must have its radius elastically compressed, and its velocity in IG increased.

This at least may be inferred from analogy to the behavior of a fluid flow through a pipe having a contracted throat, known as Bernouilli's principle—the flow is faster through the throat, and with less pressure against the sides of the throat.

In order not to leave the proposition as rested upon mere analogy to fluid motion, we will anticipate the results of a principle established in a subsequent chapter. It will be there shown that in such automatic revolution of a particle which is revolving around a centre O with tangential velocity V_1, in a circle or polygon, and which particle is itself rotating with velocity W_1, and has a radius of r, the relation $V_1 = \frac{W_1}{r_1}$ must exist. We see from the equation that if W_1 be constant, a decrease of r_1 increases the value of V_1. That is to say, if the standard particle is elastically compressed and forced through the line of flow of a lower order, it must, if W_1 remains constant, travel at a higher velocity.

We will return to the subject of particles formed on the successive hexagonal systems of the ether structure later.

CHAPTER XIII

CERTAIN LAWS OF FLUID MOTION

125. The Ether Only Partially a Fluid.—Let ADBC, Figure 32, be a traveling light "wheel" or particle of the First Order. The centre O, of this particle is progressing in the axis XY, and the plane of the particle is perpendicular to that axis. There must be a particle of the Second Order FEG whose centre C is revolving in the circumference of the particle of the First Order. The axis of progression X′Y′ of the particle of the Second Order is tangent to the circumference of the particle of the First Order. There must also be a particle of the Third Order whose centre E is revolving in the circumference of the Second Order. The axis of progression X″Y″ of the particle of the Third Order is, at the instant represented, parallel to XY. The centripetal forces which work to keep the centre C in its orbit, operating in the direction CO, in part at least may be considered as a flow from C to O meeting another flow from D to O, and passing out of the particle at O into the axis XY, the line of pressure of the energy being shifted at right angles to CO, and appearing as action and reaction in that axis. The action may be the forward movement or progression of the particle itself, in the direction OY, and the reaction may be a flow or "jet" of energy in the direction OX, or in other words a light or

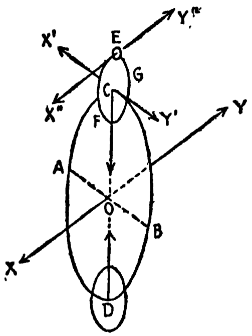

Figure 32

force wave. We will deal with this more particularly hereafter. The point to which we direct attention is that the operation of the centripetal forces in the plane of the particle is shifted at the centre, at right angles to the plane of the particle, and since action and reaction are equal and in opposite directions, if one-half of this energy is doing the work of moving the particle forward, the other half must pass off in the opposite direction as a flow, jet, or wave. For precisely similar reasons, the operation of the centripetal forces in the particle of the Second Order FEG, must be shifted at the centre C into pressures, flows, jets, or waves in the axis X′Y′. These jets or waves will be sent off at right angles to the axis of the particle of the First Order. The same must be true of the particle of the Third Order, but the jets or waves sent off by it will proceed in a plane passing through C the axis of the particle of the First Order.

The same conclusions must be reached relative to the forces operating in the standard ether particles or stationary waves of the ether structure.

The converse of the foregoing proposition must also be true, that pressures in the axis XY may be diverted at the centre O of a revolving particle, and radiated at right angles to the axis, outward to the particles of the Second, Third, etc., Orders. Where a flow is taking place between two points the direction of the flow must be toward the point of lowest pressure.

126. Sufficient has been said to show that pressures are not transmitted through the particles of the ether structure, in every direction, in the same sense as is the case with water and other fluids with which we are most familiar.

Pressures in the ether structure operate in straight lines, or radially in a plane from a centre, and are shifted from such plane only at centres of gyration, whether of a particle of a higher or of a lower order.

If we look upon a molecule of water as a perfect sphere, we would for the purposes we now have under discussion, regard an ether particle as a thin disk.

If a number of billiard balls be placed in juxtaposition and piled upon each other in a bucket, and if we put a pressure downward upon one of them, the pressure would be transmitted through the entire series in every direction, so that even some of the lower balls would be pushed upward. This would represent fluidity in all directions.

If, on the other hand, we place in juxtaposition a number of billiard balls on a table, a horizontal pressure applied to one of them at the height of its radius above the surface of the table will be transmitted from ball to ball as if they were constructed of the disks, which would be cut out by a horizontal plane passed through their centres. The pressure would all be confined to the one horizontal plane. This would represent fluidity confined to one plane.

There are certain laws of ordinary fluid motion, arising under phenomena where the fluid action is essentially confined to a plane, which on principle must be equally applicable to the particles of the ether structure.

127. **Unit Definitions.**—Problems involving the equilibrium of fluids (Hydrostatics), or fluid motions (Hydrodynamics), must be considered through certain standard units, of which it is necessary that we have an understanding.

Force, in general terms, is that which imparts or is capable of imparting motion to or in substance.

Pressure is force, Weight is force, Momentum is force.

The measure of a force F is the magnitude of the velocity acceleration f it will impart to a given mass M in a given unit of time. That is:

$$F = Mf$$

If we are dealing with the force of gravity we express the same thing by:

$$\text{Weight} = Mg$$

where g represents the velocity acceleration which gravity will impart to a falling body in one second of time, which is approximately 32 feet.

The symbol G is generally taken to represent the weight of a cubic foot of water which at 53° Fahr. is 62.4 lbs. So that taking the cubic foot as the unit of volume:

$$G = Mg$$

represents the unit weight for the unit volume. From which we see that the mass for the unit volume is:

$$M = \frac{G}{g}$$

Under the metric system, where the unit volume is taken as the cubic centimetre, and the weight of that volume of water at its maximum density is taken as the unit weight, and g is taken in centimetres, we substitute unity for G in the above formula, and have for the unit mass

$$M = \frac{1}{g}$$

128. **Action of an Accelerating Force.**—When a force or pressure acts continuously upon a body of unit mass, so as to give an additional velocity of f to the body in each unit of time, f is called the acceleration of velocity or acceleration.

If t be the time consumed, S the space traveled from the start in that time, and V the final velocity, then from purely mathematical considerations it is a well established law of physics that the following relations must exist:

$$V = ft$$
$$S = \tfrac{1}{2} ft^2$$
$$V^2 = 2fs$$

Gravity is such a force continuously operating upon a body allowed to fall from a position of rest, and experiment has shown that the velocity acquired at the end of one second of time is 32.1912 feet or more accurately 980.965 centimetres. This acceleration is usually represented by the letter g.

If H be the height through which the body falls, it corresponds to the S of the above formula, and

$$V = gt$$
$$H = \tfrac{1}{2}gt^2$$
$$V^2 = 2gH$$

Pressure.—In a general sense Pressure is momentum, and where we are dealing with a mass M moving with a velocity V, is measured by MV. When $M = 1$ or we are dealing with the unit mass, the velocity measures the impact or pressure at a particular instant.

If we are, however, considering the measure of pressure occasioned by the continuous impact of a steady flow with velocity V and unit sectional area, not at an instant of time, but during the whole of a unit of time, the volume of the flow in the units time would be equal to the velocity V, the mass would be $V \times \frac{1}{g} = \frac{V}{g}$ and the pressure P or momentum during the units time would be

$$P = \frac{V}{g} \times V \qquad \text{or} \qquad P = \frac{V^2}{g}$$

where g represents the acceleration of gravity, or the acceleration of any other force operating which might be taken as a standard.

129. **Torricelli's Theorem.**—Torricelli demonstrated that if an orifice be cut in the side of a vessel near the bottom, and the vessel be filled with water to a height H (Fig. 33) above the centre of the orifice (ignoring friction), a jet of water will flow from the orifice with a velocity expressed by

(1) $$V^2 = 2gH$$

or (2) $$H = \frac{V^2}{2g}$$

where g is the acceleration of gravity and H the head of liquid above the centre of the orifice. And this velocity of efflux as we see, is precisely the velocity a body would have acquired by falling through the distance H.

The motion here considered is to all intents and purposes motion confined to the vertical plane AOB. It is practically as if there were a linear flow from AO, shifted at right angles at O, in the direction OB, with a reaction in the direction OR.

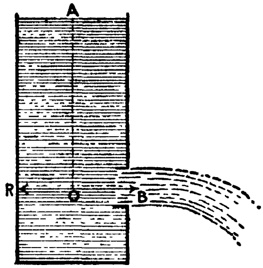

Figure 33

Using gravitation units as in the metric system, H represents the pressure at O due to the weight of the column of fluid AO of unit section. The volume of flow discharge per unit section and per unit of time is V. The mass of the discharge per second is $V \times \frac{1}{g}$. The momentum of discharge per second is, mass $\times V = \frac{V^2}{g}$.

The horizontal force or reaction P acting on the side of the vessel opposite to the orifice, and equal and opposite to the force producing the momentum is therefore

(3) $$P = \frac{V^2}{g} = 2H.$$

That is to say, the horizontal pressure of reaction is twice the pressure due to the weight of the units in a line of the height. It is twice the head due to the velocity of flow or twice the pressure due to the flow at the orifice. This is the result reached by Rankine (12 Enc. Brit. p. 514, 9th Ed., Hydromechanics) where we put $G = 1$, $\omega = 1$, as there used, to make the formula conform to the metric system.

130. **Bernouilli's Theorem.**—The following principles were demonstrated by Bernouilli (12 Enc. Brit. 466, 9th Ed., or 14 Idem. p. 42, 11th Ed.).

Let AB, Figure 34, be one elementary stream in a steadily

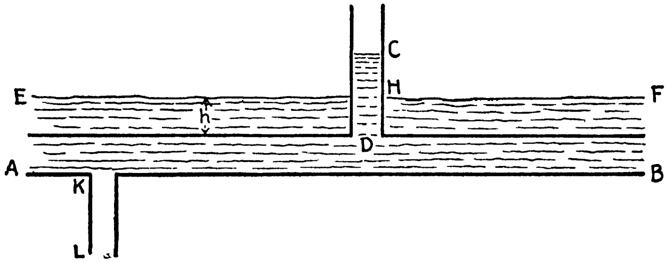

Figure 34

moving mass, which is moving with velocity V, and let h be the depth of the stream considered, below the free surface of the fluid; the fluid being acted upon by a continuously accelerating force like gravity. Then at any point in the stream where the pressure is P:

$$\frac{V^2}{2g} + \frac{P}{G} - h = \text{constant.} \tag{1}$$

We may simplify this by supposing the stream to lie at the surface, where $h = O$, and we may place $G = 1$ for the metric system, and we have

$$\frac{V^2}{2g} + P = \text{constant.} \tag{2}$$

Now $\frac{V^2}{2g}$ is the head due to the velocity of flow, and P is the pressure, or head equivalent to the pressure. Therefore the expression $\frac{V^2}{2g} + P$ is the total head due to the velocity of flow and to the pressure.

If a small vertical pipe CD is introduced into the stream, the fluid will rise to a height H corresponding to the pressure at D. That is, $H = P$.

We see from (2) that an increase of V, the velocity of flow, necessarily decreases the lateral pressure P, since the sum of the two pressures is constant.

We may draw some important conclusions from these principles long established, which will be put in use hereafter.

If the small vertical pipe be inserted into the stream as at KL, so that the acceleration of gravity would be acting in the direction KL, it would cause a continuous flow through KL, the pressure at K in the direction LK would be negative, and equation (2) would become

$$\frac{V^2}{2g} - p = \text{constant.} \tag{3}$$

This theorem of Bernouilli's appears to have an important bearing upon the fact that the velocity of progression of all light waves is the same, and that the velocity of the ether flow is constant.

131. **Barker's Mill.**—The automatic action of the ether particle, as we shall hereafter show, depends upon the same principles as those controlling the reaction wheel, as illustrated by what is commonly known as Barker's Mill, or, in a little different form, the principle of the revolving lawn sprinkler.

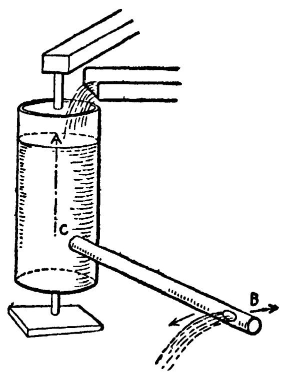

Figure 35

Let A, Figure 35, be the surface of the water in the vertical cylinder. $AC = H$ is the vertical height of the surface above the orifice. $CB = R$ is the radius from the axis of rotation to the centre of the orifice. V is the velocity of discharge through the jet issuing from B. The reaction from this discharge drives the arm CB around the centre C. V_1 is the tangential velocity of B in the opposite direction from the direction in which the jet is flowing.

Aside from any pressure due to the head $AC = H$, the water at the orifice being forced to flow in the direction of the jet, would issue from the orifice with velocity V_1, due merely to the rotation of B in the opposite direction with the velocity V_1. This velocity of issue, due entirely to rotation, may be expressed (sec. 129) by

$$(1) \qquad V_1^2 = 2gh$$

where g is the acceleration of gravity, and h is such a height that water falling from it under gravity would produce a velocity of V_1. That is, h is the head or pressure which would produce that velocity. From which we have

$$(2) \qquad h = \frac{V_1^2}{2g}$$

But if the machine is forcibly prevented from revolving, the water which will flow from the jet will be caused to flow entirely by the head $AC = H$. So that the total pressure at the orifice while the wheel is in rotation, will be due to what is equivalent to two heads, or $(H + h)$ acted on by the acceleration g, so that we have for the velocity V of outflow of the jet:

$$(3) \qquad V^2 = 2g(H + h) = 2g\left(H + \frac{V_1^2}{2g}\right)$$

$$(4) \qquad V^2 = 2gH + V_1^2 \quad \text{or} \quad (5) \qquad V = \sqrt{2gH + V_1^2}$$

This is the form in which we will have the most use for the formula. It gives the velocity of flow *measured from the orifice, which is itself in motion.*

If a be the angular velocity of the machine, then the tangential velocity V_1 at B is equal to aR. That is, $V_1 = aR$, and equation (5) becomes

$$(6) \qquad V = \sqrt{2gH + a^2R^2}$$

This is the result reached by a little different method of reasoning in 12 Enc. Brit. 9th Ed. p. 524, or 14 Idem. 11th Ed. p. 97.

If we could imagine that the arm at B had another orifice cut opposite to the one from which the jet was issuing, but that the arm was revolving with such speed in that direction as to keep up with the flow which would otherwise issue from that orifice, there would always be maintained between the two orifices a certain amount of fluid under pressure, which we could identify as a particle; at the same time there would be a continuous flow from one side of this particle, supplied by the flow into the particle from the centre of rotation.

We shall endeavor to show later that this is substantially the operating principle of the ether particle, and the principle upon which atomic structure is predicated and maintained.

CHAPTER XIV

THE RELATION OF FLOWS AND PRESSURES IN THE ETHER STRUCTURE

132. Linear Squares and Cubes.—Referring to Figure 36, let us suppose that there is a certain continuous force line (or stream line) flow through BO, greater in the direction BO, than the normal ether flow in that direction. There will be a lateral outflow from BO into the stress lines BG — $M_1M'_1$ — $M_2M'_2$ — OF. If we consider only the particular part of the flow which started at B at a given instant, when it arrives at O, it will have been diminished in intensity of pressure. But since action and reaction are equal and opposite, simultaneously with the starting from B of that flow, there starts from O in the direction OB a reaction flow. The intensity at O in the lateral pressure of this reaction flow together, with the intensity which the direct flow from B would have at O, must make the unit lateral pressure of the ether flow in the standard stress line BO. The same would be true for any point between B and O.

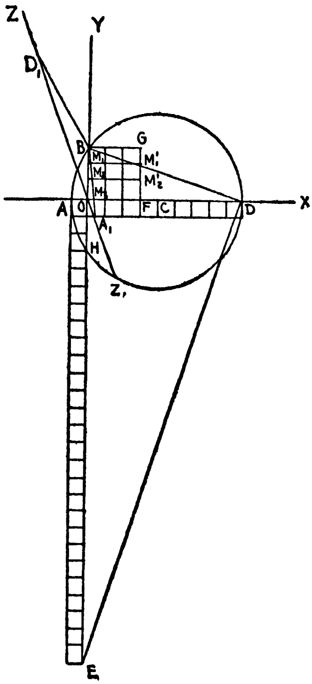

Figure 36

The result would be that in the time it takes the direct flow to travel from B to O the outflow in BG traveling with the uniform velocity of the ether flow, would travel to G, so that $BG = BO$. And in the same time the reaction flow reaches B, and the outflow from it at O, in OF, has reached F, so that $BO = OF$. In that time therefore the pressure in BO has diffused itself through the entire square BGFO, the diffusion being in the lines $BG — M_1M'_1 — M_2M'_2 — OF$.

There must be also diffusion in the lower orders of the stress lines, which have systems of parallel lines much closer spaced apart than the standard stress lines.

We may therefore consider that the pressure in the large square BGFO is distributed through the smaller squares composing it. The area of the square BGFO will therefore represent the pressure in the square constructed on BO due to the diffusion of pressure from the rectilinear flow in BO. If we take the distance between the stress lines as unity, the entire pressure P in the stress line BO, may be represented by the number of linear units in BO. That is:

$$BO = P$$

The pressure in the square BGFO, due to continuous flow through BO, will be

$$P \times P = P^2$$

In the drawing we have only taken $BO = 3$, therefore the pressure in the entire square is $3 \times 3 = 9$. If we had taken $BO = 4$, then we would have the pressure in the square equal 16, etc., etc.

Lay off $AO = 1$ to represent the standard flow in the stress line OX. Connect AB, and draw BD perpendicular to AB cutting OD in D. Then ABD will be a right angle triangle.

We may put the linear measure of $BO = y$. It will also represent the linear pressure in BO.

Put $OD = x$.

From a well known theorem of geometry, we may with $AC = \frac{AD}{2}$ as a radius describe a circle as indicated about C as a centre, and this circle will pass through A, B and D, and from the same theorem we will have:

$$OD \times AO = BO^2$$

or (1) $x \times 1 = y^2$

or (2) $x = y^2$

or (3) $x = P^2$

That is to say, the total pressure in the square represented by the sum of pressures making up the square, is equal to the number of linear units of pressure in OD.

The result is the same as if there were no lateral flow occurring between B and O, and there were an accelerating force $AO = 1$, operating with P times the frequency of the standard flow, which turns the flow in BO, at O, in the direction OD at right angles to its former course, and, in the time the standard flow would travel from B to O, and which it would have taken to fill the stress lines of the square BGFA, has carried the flow to D.

If there is the mechanism in the ether structure to accomplish such a result, and called into play under certain conditions, as we shall show there is, then we see that area pressure, or pressure in two directions in a plane, can be converted into rectilinear pressure, and *vice versa.*

133. From (2), $x = y^2$, we have

$$y = \pm \sqrt{x}$$

or $$BO = \pm \sqrt{OD}$$

If we were given the length of OD and desired to extract the square root of it geometrically, we would lay off $AO = 1$, and draw the axis EY perpendicular to AX at O, and with the radius $AC = \frac{AD}{2}$ describe the circle, which would cut the axis EY in two points B and H, the one above, the other below the horizontal axis AX, but both in the plane of the paper. Which shows that AD has two square roots, OB positive and OH negative. Which being interpreted means that a pressure BO diffused through BOFG would give the linear flow AD equal to BO^2, or a pressure $HO = -BO$ diffused through the square on HO, would give the linear flow AD or be equivalent thereto.

Again draw DE perpendicular to BD, and let us suppose that there was a reaction flow from D to O, just equal to $OD = y^2 = P^2$, and that the flow $BO = P$ acted as the accelerating force to turn the flow DO in the direction OE. Then from the right angle triangle BDE we have:

$$OE \times BO = OD^2$$

or

$$OE \times y = y^4$$

or

$$OE = y^3 = P^3$$

That is to say, the line OE in direction and length represents not only the cube of BO, but, if we regard BOFG as a planular layer of lines or as an area, OE represents a pile of these layers stacked up with a units distance between them as high as the length of BO, so as to form a cube each side of which is equal to BO. It appears as if what the average man from general experience has been locking upon as a solid of three dimensions is after all composed of mere lines of force,—a proposition which at first blush appears to take the ground from under our feet. But after all it is not so startling in this day of the aeroplane.

134. Again suppose that the accelerating force $AO = 1$, instead of operating in the plane of the paper as we have represented it, was operating on O, from the point A_1 below O, in the axis zz, which is supposed to be drawn perpendicular to the plane of the paper; if we made a similar geometric construction on it and BO, as we did with AO and BO, then

that would throw the point D straight up in the air to the position D_1.

Now we may represent by the symbol $i = \sqrt{-1}$ the fact that the accelerating force A_1O is operating at right angles to the plane of the paper and above or below it instead of in it. If so, equation (1) becomes

$$(4) \qquad OD_1 = y^2 = \pm x\sqrt{-1}$$

or

$$y^2 = ix$$

which is a so called imaginary square. The result reached is imaginary only in the sense that $y^2 = OD_1$ does not lie in the plane of the paper, but in a plane perpendicular to that plane. This principle is made the basis of Sir W. R. Hamilton's quaternions.

135. There is no simple geometrical device *by use of only dividers and straight ruler,* which will enable us to extract the cube root of a line by construction. That is one of the standing unsolved problems handed down to us from antiquity. It involves the same question as the tri-section of an angle. The trouble is that, just as the extraction of the square root gives two roots, so the extraction of the cube root gives three roots. The dividers and straight ruler will solve the problem of finding the two square roots as we have seen.

If we were given the problem of extracting the cube root of the line OE, and the known unit of measure, and the privilege of using draftsman's triangles, the construction can be made. We would construct the axes as indicated in Figure 36. We would lay off $AO = 1$. We could then take two transparent draftsman's triangles, and by trials adjust them in reference to the axes so as to make their right-angles corner at B and D, respectively, at the same time that their respective sides just touched respectively at A and E. In this way we would locate the points B and D, which gives:

$$OB = \sqrt[3]{OE}$$

That would give one of the cube roots sought. The correctness of the result would depend on our ability to adjust the triangles accurately. There are several mechanical devices which will accomplish more perfectly the same ends.

We may express this value by $u = a$ where $u^3 = a^3$.

The value of the other two roots can be determined by algebra when the value of the one is known, as follows:

If a is the value of the known root, then we may place:

$$u^3 - a^3 = 0$$
$$u - a = 0$$
$$\frac{u^3 - a^3}{u - a} = 0$$

performing the division we get

$$u^2 - au + a^2 = 0$$

or (5) $$u = a\left(-\tfrac{1}{2} \pm \tfrac{1}{2}\sqrt{-3}\right)$$

or (6) $$u = a\left(-\tfrac{1}{2} \pm \frac{1.732}{2}\sqrt{-1}\right)$$

From which it will be seen that these other two roots are what we call imaginary. In fact they represent as much reality as does the other; they simply do not line in the same plane.

We can construct these two roots from equation (5) as follows:

Draw the axes XX and ZZ at right angles to each other (Fig. 37). We will understand that OZ stands straight up in the air, so to speak, lying in the present plane of the paper, and perpendicular to the plane of the paper as we considered it when getting the so called real root. We can see only the trace of the former plane, or plane of reality in the line XX. $OD = a$ will represent the real cube root of a^3.

With the radius $OA = 1$ describe the circle as indicated. Step off the chords $AM = AN = 1$. The angle $AOM =$

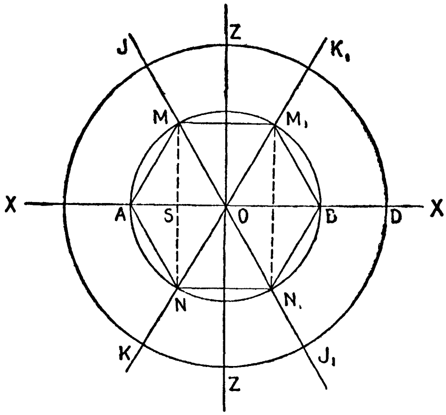

Figure 37

AON and each will be 60°, since they are spanned by the radius. For which reason OS equals half the radius, or

$$OS = \tfrac{1}{2}$$

$$SM = \sqrt{OM^2 - OS^2} = \sqrt{1 - \tfrac{1}{4}} = \tfrac{1}{2}\sqrt{3}$$

or
$$SM = \tfrac{1}{2}\sqrt{-3}$$

when we take into consideration the direction, and

$$SN = -\tfrac{1}{2}\sqrt{-3}$$

(7) $$OS + SM = -\tfrac{1}{2} + \tfrac{1}{2}\sqrt{-3}$$

(8) $$OS + SN = -\tfrac{1}{2} - \tfrac{1}{2}\sqrt{-3}$$

Equality here must be interpreted in the sense of *equivalent*. That is to say, if we suppose that a flow which, starting out from O, would have proceeded to A, but had its direction changed at S, so as to produce two flows in the directions SM and SN, they would in the given time reach M and N respectively. We may consider that OS and SM are simply component forces the resulting action of which is to take one flow from O to M in the path OM. Similarly we may regard

OS and SN simply as component forces which take the other branch flow from O to N in the path ON. So that if we regard these roots as resultant positions due to flows, then

$$OM = -\tfrac{1}{2} + \tfrac{1}{2}\sqrt{-3}$$
$$ON = -\tfrac{1}{2} - \tfrac{1}{2}\sqrt{-3}$$

We may lay off $OJ = OK = OD = a$ the value of the real root first found, and we will have

$$OD = a$$
$$(9) \qquad OJ = a\left(-\tfrac{1}{2} + \tfrac{1}{2}\sqrt{-3}\right)$$
$$(10) \qquad OK = a\left(-\tfrac{1}{2} - \tfrac{1}{2}\sqrt{-3}\right)$$

We see therefore that the other two cube roots formerly thought to be imaginary have precisely the same vector length as the real root, and they are measured from the same origin, but their direction is in planes inclined at angles of 60° to the so called plane of reality.

Had we taken $u^3 = -a^3$, the first root would be $u = -a$, and equations (9) and (10) would become:

$$(11) \qquad OJ_1 = a\left(\tfrac{1}{2} - \tfrac{1}{2}\sqrt{-3}\right)$$
$$(12) \qquad OK_1 = a\left(\tfrac{1}{2} + \tfrac{1}{2}\sqrt{-3}\right)$$

It will be noticed that these three cube roots have a close relation to the equilateral triangle structure of the ether.

The above principles lead us to the curious thought, that, perhaps all of our mathematical principles are but expressions of the manner in which the flows in the ether structure take place.

136. **Reciprocal Relation Between Action and Reaction Flows in the Stress-lines.**—We have heretofore seen that every standard stress-line of the ether structure is composed of two flows passing through it in opposite directions. Since the circular motion is at right angles to the direction of the flow, the lateral pressure in the stress-line is due to the com-

bined pressures of the two flows. Between any two points in the stress-line where there is no loss of energy, we may regard the stress-line as a tube, at every cross-section of which the total pressure or energy within the cross-section is constant, but the configuration of the cross-section may be different. We may designate the flow in one direction as the direct flow, and that in the opposite direction as the reaction flow. For simplicity of illustration we may suppose that the cross-section of the stress-line is rectangular.

Let ABCD, Figure 38, be the cross-section of such a stress-line, of which BC is a unit's length.

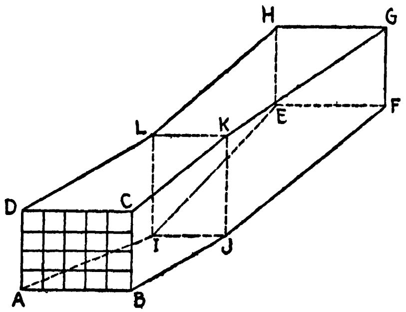

Figure 38

On the principle of the resolution of forces, we may consider that the forces operating in the area ABCD are resolved in two directions at right angles to each other, and we may consider that the pressure P in the line AB is due to the lateral pressure in the direct flow passing through the tube in the direction BF, and that the linear pressure Q in the line BC is due to the lateral pressure in the reaction flow through the tube in the direction FB. By reason of the diffusion of the energy through the small stress-lines the pressure represented in the whole area ABCD will be represented by AB $\times$ BC, or by P $\times$ Q, or PQ.

We may represent this constant lateral pressure in the standard stress-lines by unity, and we will have on the principles of section 132

$$PQ = 1 \qquad \text{or} \qquad Q = \frac{1}{P} \qquad \text{or} \qquad P = \frac{1}{Q}$$

And we will have also

$$P^2Q^2 = 1 \qquad \text{or} \qquad Q^2 = \frac{1}{P^2} \qquad \text{or} \qquad P^2 = \frac{1}{Q^2}$$

That is to say, the pressures of the action and reaction flows in the stress-lines at any cross-section are the reciprocals of each other.

This is a very important proposition, and the verification of it will be found in the results hereinafter reached from applications of the principle. It rests fundamentally upon the fact that there can be no vacant space, and that the uniformity of the lateral pressures in the stress-lines will be maintained by the controlling flows coming from a universe of stars in infinity. Thus we may increase the direct flow passing through the tube of the stress-line in one direction, and this will decrease the reaction flow passing through the same tube in the opposite direction.

Since action and reaction are equal and in opposite directions, it follows that where the direct flow in any particular tube is increased from the normal, that part of the equal reaction flow which does not pass through that particular tube must pass in its appropriate direction in a parallel tube, or more frequently in a roundabout way.

We are accustomed to think of a uniform tube as of equal sectional area. We can think of the tube of the standard stress-lines as having a constant unit lateral areal pressure in any cross-section, but configuration of the cross-section varying as P and Q vary.

If BF represents a unit length of the stress-line, the total energy or pressure represented in that much of the stress-line would be

$$PQ \times 1 = 1 \qquad \text{or} \qquad PQ = 1$$

That is to say, $PQ = 1$ will represent also the whole energy in a unit length of the stress-line.

In the foregoing discussion, for simplicity we took the cross-section of the stream line tubes to be rectangular, or square.

The same principles would apply if we assume that the cross-section is elliptical or circular, which is more in accord with symmetry.

Thus, if the cross-section of the tube is an ellipse, the major and minor axes represent the linear pressures P and Q, and we have for the area A of the ellipse, representing the total or areal pressure

$$\pi PQ = A \qquad \text{or} \qquad PQ = \frac{A}{\pi}\text{, constant.}$$

We may take this pressure, which is constant for all the standard stream lines of the ether structure, to be unity, and thus, as before, we have—

$$PQ = 1 \qquad \text{or} \qquad P = \frac{1}{Q}$$

If now we suppose that under certain conditions, more than the normal amount of direct flow is forced into the tube, it proportionally shuts out the reaction flow, and when

$$Q = 0 \quad P = \frac{1}{0} = \propto$$

That is to say—when the minor axis of the ellipse becomes zero, the major axis becomes infinity. Which is another way of saying that when the tube of the flow becomes blocked so that the direct flow fills the whole unit capacity of the tube, the pressure is irresistible in a line at right angles to the former direction of the flow, and the flow proceeds in that direction.

It is also important to bear in mind that when two flows P_1 and P_2 proceeding in the same direction, are forced into the same tube, the resultant pressure is $P_1 \times P_2$, and it is found by multiplication and not by addition. The square of a pressure may not always mean an increase of pressure, since the number squared may be a fraction, in which case squaring it would give numerically a smaller value.

136 (a). The principle of the reciprocal relation between the direct and reaction lateral pressures in a flow in the ether stress lines, can be predicated upon Torricelli's theorem:

$$2gH = V^2, \text{ or } (2H)g = V^2$$

where $2H = Q$ represents (sec. 129) the reaction pressure due to head, and $g = P$, represents the accelerative pressure operating laterally in the flow.

For the normal flow in the ether stress lines, we have $V = 1$, and $2H = Q$, is represented by the constant lateral pressure, existing in the ether medium (sec. 121) against the sides of the flow in the stress lines, while $g = P$ is represented by the accelerative force operating laterally in the flow due to the impulses which drive the current. As we shall later see, these impulses are automatically evolved and continue in operation in the jets or waves sent off by and when an ether particle is set in revolution around a centre; that is to say, when such particle is performing one of the functions of a material atom. Substituting for V the value $V = 1$; for 2H the value Q, and for g the value P, we have $PQ = 1$.

The principles expressed by the Torricelli and Bernoulli theorems will enable us when we know the accelerative force and pressure in a flow in one direction, to calculate the acceleration and velocity of flow when the current is by some supervening cause shifted at right angles.

CHAPTER XV

THE ETHER PARTICLE IN MOTION AS AN AUTOMATIC MACHINE

137. **Motion in a Circle or Polygon** (after Ganot).—Where a particle is traveling in the tangent to a circle at a given instant with velocity V, in the absence of a pull toward the centre of the circle there must be a continual application of force from the outside directed toward the centre, in order to swerve it from the tangential course and make it follow the circumference as a path. This force is measured by the amount of velocity it would impart to a particle of unit mass in the direction of the centre of the circle in a unit of time and is represented by f, called the radial acceleration. If the mass of the particle contains M units of mass, the whole force exerted is Mf.

There are several different ways in which the relation between f the radial acceleration and V the tangential velocity of the particle can be determined.

The following is adopted from Ganot, because it enables us to have a picture in our mind of what must be the operation of the force required to maintain either polygonal or circular motion, when we apply the principles involved to our subject.

Let ABCD (Fig. 39) be a regular polygon inscribed in a circle whose centre is O. Draw the diameter BOM. Produce AB to H, making BH equal to AB, join CH. This line is parallel to BO. Draw CK parallel to BH, and CL at right angles to BO. Join CM.

Suppose a body whose mass is M to describe AB with a velocity V in a time t, and suppose that at B there is suddenly communicated to it in the direction BO, a velocity $V = ft$, which is the same velocity as a force Mf would communicate gradually in the same time t, it will move during the next short time t, with the velocity compounded of V and ft; now, since BH equals Vt, if f is such that BK equals Vt or, which is the same thing, ft^2, the body will describe BC in the second interval.

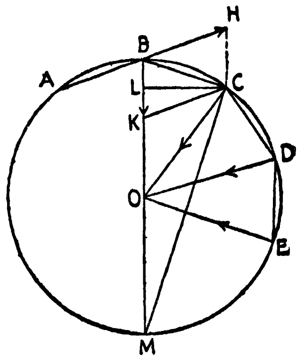

Figure 39

It will be observed that as BC and AB are equal and are described in equal times t, the velocity along BC is the same as along AB, that is, the effect of the composition is to change the direction but not the amount of the velocity. When the body is at the point C we may suppose a velocity $V = ft$ to be communicated to it in the direction CO, and then at the end of the third interval the body will be at D. On this supposition therefore the body will describe the polygon ABCD with a uniform velocity V. Now from similar triangles MCB, BCL, we have

$$MB : BC :: BC : BL$$
$$2R : Vt :: Vt : \tfrac{1}{2}ft^2$$

therefore

$$(1) \qquad f = \frac{V^2}{R}$$

The whole force would be $Mf = \dfrac{MV^2}{R}$

These conclusions are true for all values of t, and therefore also when t is infinitely small.

Now by diminishing t we merely increase the number of sides of the polygon; therefore when t is infinitely small, the motion takes place in the circle, and the force Mf, or acceleration f, acts continuously toward the centre.

The above determination of what must be the value of the radial acceleration in terms of the tangential velocity and radius, in order that the particle or body shall be made to revolve in a circle, is based solely on mathematical considerations, and does not undertake to account for the origin of the centripetal forces which may perform the required duty. It is true for all cases irrespective of the means used for creating the centripetal force. That force may be supplied by the pull of a string, to the end of which a small weight has been attached and made to revolve around a centre to which the other end of the string is attached. Whatever may be the nature of the force of gravity, it performs the same function in making the moon revolve around the earth. If water contained in a circular basin is set to revolving, the reaction of the rim of the basin against the water toward the centre, is centripetal force, and is measured by $\frac{V^2}{R}$

The foregoing demonstration from Ganot shows that centripetal force, instead of being applied continuously, may be applied at intervals of time, in which case the orbit of the particle instead of being a circle will be along the sides of an equilateral polygon inscribed in the circle the circumference of which passes through the corners of the polygon.

The big question up to which we are leading is the origin and operation of the centripetal force in the ether medium. We are seeking to determine the conditions under which if revolution of a particle around a centre O, with radius R and velocity V be set up, it will be maintained automatically, and the mechanism by which it is maintained.

Whether the revolution be that of a "traveling wheel" or a light wave, or whether it be that of a stationary wave formed by two such traveling wheels meeting from opposite directions, constituting stationary particles of the first higher order, the problem is the same. Obviously the mechanism must be such that the amount of energy radiated from the wheel must be exactly counterbalanced by the work done in forcing the particle to keep the circular path.

We will presently examine that mechanism.

138. **The Machinery of Reaction.**—The machinery by which reaction is accomplished when a flow takes place through the ether medium may be illustrated as follows:

Suppose (Fig. 40), there be a flow of small sectional area, which we may conceive of as a traveling light wheel moving in the direction OA and passing successively through the centres of stationary particles BDE, FGH, etc., the planes of these particles being perpendicular to OA. The increase of pressure at C due to the flow of energy in OC to that point, would be partly relieved at C, by reason of the fact that

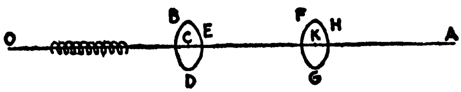

Figure 40

the revolution of the particle BDE around the axis OA, would cause a distribution radially of the extra energy arriving at C, around the circumference of BDE. It would cause an increase in the centrifugal force operating in BDE, and theretofore in equilibrium with the centripetal force. It would therefore increase the radius of the particle, in effect storing up potential energy or elastic energy above the normal.

As the remaining part of the flow passes out of the section OC into CK, the pressure in OC would be lowered. This would cause a reverse flow from the regions of higher pressure into those of lower pressure. The potential energy represented by the elastic increase of radius of BDE, would react from all sides in the plane of BDE, and the energy being forced back to the centre C would flow out into CO, the section of low pressure, thus restoring normal conditions. In the meantime that part of the flow which started at O, and which was not dissipated in its passage through BDE, passes on to the centre K of FGH, where similar action takes place.

That the uniform arrangement of the standard particles in the ether medium, and as well the uniform arrangement of the particles of lower orders to that of the standard particles, afford the machinery by which reaction is accomplished, and the dissipation of energy takes place when a light wave travels through space, can not be doubted.

We must bear in mind that every light wave, besides carrying particles revolving in a plane at right angles to the line of progression, also carries particles revolving in planes passed longitudinally through the axis of progression of the wave, in other words, polarized rays (sec. 71); and this must be true down to the minutest force waves or bundle of stream lines which constitutes a flow as we have used the term.

It is the polarized ray and the particles of the second order, which furnish the machinery of the longitudinal pressure in the light rays, and this action is due as we shall later see to the elastic action of centripetal and centrifugal force in the particles revolving in the longitudinal planes. It also furnishes the machinery for the phenomenon of reflection, and for the return or reaction flow. On the other hand it is the revolution in the planes at right angles to the axis of progression, and the transverse vibrations, which give rise to the lateral pressures in the wave. The transverse shuttle movement enables waves moving in opposite directions to pass through each other. And when the tube of passage in the line of progression is blocked, it is the interaction of the revolutions in the longitudinal planes and in the planes at right angles which operate to shift the direction of the flow at right angles to the line of progression, and temporarily stores the energy by expansion of the radii of the standard particles through which the wave passes at the intersection of the standard stress lines. And it is the elastic reaction of such standard particles which forces the continuance of the motion in the line of progression of the wave. This will be more apparent when we have shown the origin and operation of centripetal force in the ether structure, and the relations between the radii of particles of the First and Second Orders.

139. **Transference of Pressure From a Centre of Radiation.**—Suppose a source of energy at O (Fig. 41) be sending off waves in every direction. For simplicity we will consider

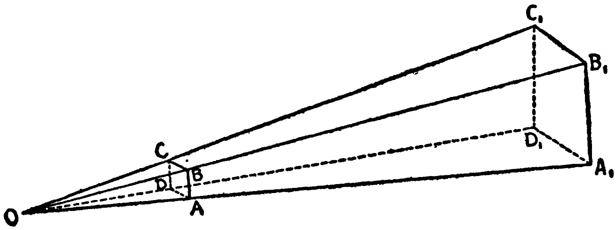

Figure 41

a pencil of rays which at the distance $OA = 1$ covers the sectional area ABCD in which we may take $AB = AD$, and since light rays proceed in straight lines, must at the distance $OA_1 = D$ cover the sectional area $A_1B_1C_1D_1$.

The energy radiated had its origin in the motion in a plane or planes, and we may resolve all the pressures operating in the area ABCD into two pressures in axes at right angles to each other, and at right angles to the line of progression of the waves.

Since we are taking the case where the distribution of radiation is uniform, we may take the pressure in the line AB due to direct flow as P, and that in the line AD also as P.

The pressure in the area ABCD due to the combined action of the two systems of radiation will be P^2 (secs. 132 and 136).

In proceeding outward the energy which was spread over the surface ABCD is, when it reaches A_1, spread over the much larger surface $A_1B_1C_1D_1$.

The pressure P which was distributed through AB is now distributed through A_1B_1, so that the amount of energy or pressure in AB and in A_1B_1 per unit length will be inversely proportional to the lengths of AB and A_1B_1. If P_1 be that pressure per unit length of A_1B_1 then

$$P_1 : P :: AB : A_1B_1$$

But

$$OA : AB :: OA_1 : A_1B_1$$

$$1 : AB :: D : A_1B_1$$

or

$$A_1B_1 = AB \times D$$

$$P_1 : P :: AB : AB \times D$$

or

$$P_1 = \frac{P}{D}$$

Similarly the pressure in A_1D_1 is

$$P_1 = \frac{P}{D}$$

On the principles of section 136 the whole pressure in $A_1B_1C_1D_1$ due to direct flow is:

$$(1) \qquad P_1^2 = \frac{P^2}{D^2}$$

That is to say, the intensity of pressure per unit area which at A was P^2 decreases inversely as the square of the distance.

If now we suppose that the radiations from O take place under conditions which confine the divergence of the rays to a single plane, as for instance if we were dealing with radiations sent off by a single particle which was distributing them radially in the single plane A_1OB_1 and if P be the pressure in AB, we would have as before

$$P_1 = \frac{P}{D}$$

as the formula for transference of pressure in a single plane.

This transference of pressures from one point to another where the distribution of radiation is being made in one plane is of high importance, and may be expressed by

(2) $$P_1 = \frac{P}{D}$$

or (3) $$P = P_1 D$$

Since the relation between the direct and reaction pressure is always expressed by $PQ = 1$, we also must have

$$Q_1 = \frac{D}{P}$$

or (4) $$Q_1 = QD$$

or (5) $$Q = \frac{Q_1}{D}$$

We may express these in the form of a rule as follows:

Where pressures are being distributed by flows in one plane only:

(a) *For the direct pressure, in passing from a centre of high pressure to a point of low pressure we divide the pressure at the high point by the distance between the points, to get the pressure at the point of low pressure.*

(b) *For the direct pressure, in passing from a point of low pressure to a centre of high pressure we multiply the pressure at the low point by the distance between the points, to get the pressure at the point of high pressure.*

(c) *For the reaction pressure we do just the reverse of the above.*

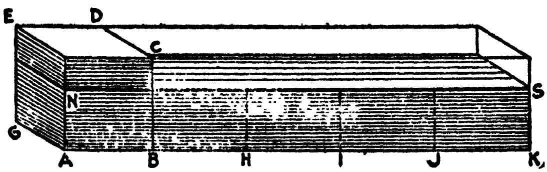

Figure 42

The mechanical proposition involved in the above rules may be physically illustrated as follows:

Suppose that a certain amount of energy represented by M completely fills the rectangular parallelopiped ABCDG (Fig. 42). Make $GA = AB = BH = HI = IJ = JK = 1$. We may put the lateral pressure $BC = P$, then

$$M = GA \times AB \times BC = 1 \times 1 \times P = P$$

If now the same amount of energy is allowed to flow through the conduit and distribute itself with uniform intensity in the parallelopiped AKSNG, we will have

$$M = GA \times AK \times KS = 1 \times R \times P_1 = P_1R$$

Equating the two values of M, we have

$$P = P_1R \qquad \text{or} \qquad P_1 = \frac{P}{R}$$

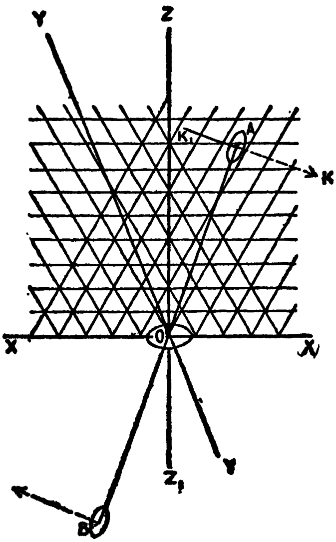

Figure 43

The rule is after all based on the old proposition that "water will seek its level."

140. Origin and Maintenance of Centripetal Force.—Let us suppose that we have a particle of the Second Order whose centre A, Figure 43, is revolving around a centre O, in the plane of the paper with velocity V_1. We have drawn the small parallel and obliquely parallel lines, in the plane of the paper, to represent the standard stress lines of the ether. The motion of A around O carves out a particle of the First Order, and if this particle be a stationary particle of the First Order, there must be two equal and opposite flows passing out of its centre O in the directions OZ and OZ_1 in the line perpendicular to the plane of the paper.

These flows must be supplied by a flow from A to O and from B to O which are shifted at right angles at O, and pass out as two equal wings in the directions OZ and OZ_1.

We have seen that in order to keep the particle A of the unit mass in its circular path around O there must be operating on A, in a unit of time, in the direction AO, a centripetal force $f = \frac{V_1^2}{R}$. We have also seen that the ether medium is itself under great uniform pressure in all directions. It follows that if there is a flow from A to O, and the pressure at that point by any means is relieved by the shifting of the flow at right angles and out of the plane of revolution, the exterior pressure of the medium on A toward O would push A toward that centre, and there would be automatic continuance of revolution of A, provided the relief of pressure at A is just equivalent to $\frac{V_1^2}{R}$ in a unit of time.

In a unit of time, however, the particle A will have traveled through a certain distance $AK = V_1$, and if we desire to get the pressure due to centripetal force in any given radius AO at *a particular instant,* we must divide the centripetal force $\frac{V_1^2}{R}$ operating for the unit of time by V_1. So doing, we get $\frac{V_1}{R}$ as the pressure at A toward the centre O which must be relieved by a flow in the radius AO toward the centre at the given instant.

Now this radial flow toward the centre is brought about by the low pressure at O, due to the flow shifted out of the plane of the paper at O into OZ and OZ_1, at right angles to the plane of the paper. It may therefore be considered as a reaction flow which gets an increase of energy from every stress-line which it cuts between A and O. The transfer of the pressure $\frac{V_1}{R}$ from A to O will therefore be controlled by rule (c) reverse of (a) (sec. 139). That is to say, the pressure P_1 at a unit's distance from O will be

$$P_1 = \frac{V_1}{R} \times R = V_1.$$

Or if we want the value of this pressure through a unit of time it will be $P_1^2 = V_1^2$.

That is to say, the centripetal force, exactly sufficient to keep the particle A in a circular orbit, will be maintained when the velocity of the radial flow toward the centre O, measured at a unit's distance therefrom, is equal to V_1^2, the square of the tangential velocity of the particle A.

The question naturally suggests itself, what is the nature of the force or forces which cause the shifting of the radial flow at right angles out of the plane of revolution of the revolving particle?

If we suppose two particles A and B forming a couple revolving around O, the radial flows from them would meet at O in collision, and at the same time each would block the other, which must cause a shifting at right angles on the principle of section 136. Something similar to this is what takes place when a jet of water impinges on a plane surface in a direction normal to the plane (Hydrodynamics, Enc. Brit., 9th Ed., p. 512).

We have every reason to believe that there are six particles of the Second Order forming three couples, revolving in the periphery of every particle of the First Order, due to the hexagonal structure of the ether.

If we impose the condition that the outflows in OZ and OZ_1 shall be the unit flows of the standard stress lines, we can obtain the values of the pressures in OZ and OZ_1 derived from the radial flows shifted through O, by Torricelli's formula $V^2 = 2\,gh$.

By section 136, $gh = 1$ for the standard flow. Therefore, under that condition,

$$V_1^2 = 2 \qquad \text{or:}$$
$$V_1 = \sqrt{2}$$

If we desire to give expression to the idea that the flows in OZ and OZ_1 are at right angles to the plane of the particle of the First Order, we may put:

$2\,gh = -2$, and make $g = h$, for the standard flow. So we have:

$$g^2 = -1$$
$$g = \pm \sqrt{-1}$$

This expresses the unit flow shifted into OZ and OZ_1 at right angles to the plane of revolution.

It is evident that the value of V_1 will be at a maximum when $V_1 = \sqrt{2}$ because the outlet, at right angles to the plane of the particle of the First Order at O, for the pressure occasioned thereby, will be blocked when the pressures due to the outflow in OZ and OZ_1 are equal to unity, the standard flow in the stress lines. Any further pressure applied suddenly and periodically on the exterior of the particle of the first order, directed toward O, must result in a train of jets or waves being sent off either from the centre of the particle of the Second or Third Order. But that subject will be considered later.

It will be observed that the pressure in the flow sent off from the centre of the particle of the First Order is independent of the value of R.

If, therefore, $V_1 = \sqrt{2}$ so that the outflow from the centre of the particle of the First Order shall be the unit flow in the stress lines of the normal ether structure, we may state that:

(a) A standard ether particle revolving around a centre, and whose automatic revolution is maintained only by the standard flow from the surrounding field, sends off a flow from the centre of revolution at right angles to the plane of revolution, and the intensity of this flow equals unity, whatever be the length of the radius of revolution.

(b) *If there are a number n of such particles revolving in the same plane, around the same centre, though each may have a different radius of revolution, the intensity of the whole flow at the centre would be n.*

We have thus reached the conclusion that in order that the motion of the particle shall be maintained continuously by the regular flow of the ether medium, the tangential velocity V_1 of the centre of the particle of the Second Order, at least for one value, is independent of the value of R_1, the radius of the particle of the First Order, and is, in fact, equal to the square root of 2.

The essential feature for the maintenance of automatic action is, as we have seen, that the pressure for a unit's time in the flow passing into the centre of the particle of the First Order at a unit's distance from that centre is equal to the square of the tangential velocity of the centre of the particle of the Second Order in its orbit.

141. The Relations of the Radii of the Particles of the Successive Orders to Each Other.—Let us suppose that ADBE, Figure 44, is a particle of the Second Order the plane of which is perpendicular to the plane of the paper. The centre C of this particle is revolving around O in the plane of the paper with radius $OC = R_1$ in the direction CX with tangential velocity V_1. It is the sweep of this radius which carves out the particle of the First Order. FGHI is the particle of the Third Order whose centre A is traveling with tangential velocity W_1 in the circumference ADBE. The plane of FGHI is always perpendicular to the plane of ADBE, and twice in one revolution around C, that is, once at A and once at B, the plane of FGHI coincides with the plane of the paper, or plane of the particle of the First Order. There is a particle of the Fourth Order H whose centre is traveling with tangential velocity W_2 in the circumference of FGHI, etc., etc., to the infinitesimal.

We may place $CA = r_1$, $AH = r_2$. The tangential velocity of the point A in the direction AY may be designated as V_2.

Let us assume, as in section 140, that the conditions exist for maintenance of the circular motion of C about O, in the

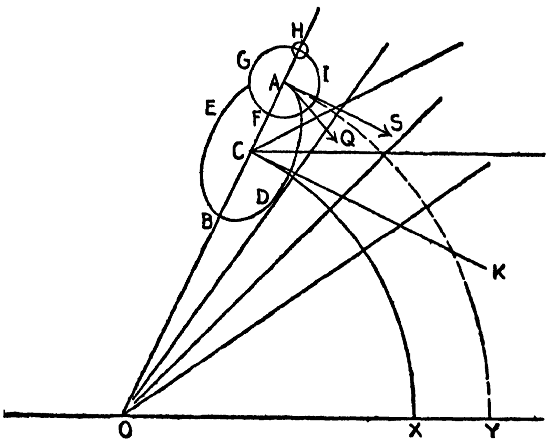

Figure 44

plane of the paper, that is to say, that the flow is toward O, and that the pressure P_1, at an instant of time at a unit's distance from O is equal to V_1. That is $P_1 = -V_1$.

Under the principles established in section 140, the pressure at C, as affected by the relief of pressure at O, will be $P_2 = \frac{-V_1}{R_1}$. By reason of the revolution of the particle ADBE around C, this pressure P_2 will be distributed radially around the circumference of ADBE.

On the principles of section 133, the pressure P_3 at any point A in the circumference ADBE, at a particular instant, will be: $P_3 = \frac{P_2}{r_1}$. And since the particle at A is revolving with velocity W_1 in AQ, the pressure in a unit of time, or centripetal force f_1 operating in the circle ADBE will be:

$$f_1 = P_3 W_1 \quad \text{or} \quad f_1 = P_2 \frac{W_1}{r_1} = -\frac{V_1}{R_1} \times \frac{W_1}{r_1} \text{ or:—}$$

$$(1) \qquad f_1 = \frac{-V_1 W_1}{R_1 r_1}.$$

Now we know that the point A is revolving in the circle ADBE, so that r_1 is constant, and C and A maintain the same distance between them. The pressures, therefore, operating at these two points interacting between them must be equal. We must have $f = f_1$. But the pressure at C per unit of time is:

$f = \frac{-V_1^2}{R_1}$ and that at A is: $f_1 = \frac{-W_1^2}{r_1}$ and therefore:

$$\frac{V_1^2}{R_1} = \frac{W_1^2}{r_1} \qquad \text{or}$$

$$(2) \qquad V_1^2 = \frac{R_1}{r_1} W_1^2.$$

But we must have also:—

$$f_1 = -\frac{V_1^2}{R_1} = -\frac{V_1 W_1}{R_1 r_1} \qquad \text{or:—} \qquad V_1 = \frac{W_1}{r_1} \qquad \text{or:—}$$

$$(3) \qquad V_1^2 = \frac{W_1^2}{r_1^2}. \quad \text{Therefore:—}$$

$$\frac{R_1}{r_1} W_1^2 = \frac{W_1^2}{r_1^2}. \quad \text{Or:—}$$

$$(4) \qquad R_1 r_1 = 1$$

or $$r_1 = \frac{1}{R_1}$$

or $$R_1 = \frac{1}{r_1}$$

(a) *In other words, the radii of the particles of the First and Second Orders are reciprocals.*

If in equation (2) we substitute for r_1 its value $r_1 = \frac{1}{R_1}$, we get

$$(5) \qquad W_1 = \frac{V_1}{R_1}$$

(b) *That is to say, the tangential velocity of the particle of the Second Order is equal to the angular velocity of the particle of the First Order.*

Again, $AH = r_2$, the radius of the particle of the Third lower Order, must bear the same relation to r_1, the radius of the particle of the Second lower Order, that the latter bears to R_1, the radius of the particle of the First Order. That is:

$$r_2 : r_1 :: r_1 : R_1$$

or $$r_2 = \frac{r_1^2}{R_1}$$

or since $$r_1^2 = \frac{1}{R_1^2},$$

we have (6) $$r_2 = \frac{1}{R_1^3}$$

(c) *That is to say, the radius of the particle of the Third lower Order is the reciprocal of the cube of the radius of the particle of the First Order.*

Similarly we obtain the values $r_3 = \frac{1}{R^5}$, $r_4 = \frac{1}{R^7}$ etc., etc.

Again, if W_2 be the tangential velocity of a point H moving in the circumference of the particle of the Third Order, then because the particle of the Third Order bears the same relation to the particle of the Second Order that the latter bears to the particle of the First Order, on the principle stated in (b) above, we must have

$$W_2 = \frac{W_1}{r_1}$$

or by substitution from (4) and (5)

$$(7) \qquad W_2 = V_1$$

(d) *That is to say, the minute particle of the Fourth Order at H has the same tangential velocity V_1 in the circle FGHI that C has about O.*

There is nothing in what we have already said to determine whether the particle of the Fourth Order moving in H is revolving in the same direction as C is revolving, say to the right, or whether it is revolving in the opposite direction, say to the left.

If we regard the particle of the Third Order as a small wheel rolling against the wall of the ether medium, the direction of motion of the particle of the Fourth Order moving in its circumference would be to the left.

Now the point A has the same angular velocity about O in the plane of the paper as the point C has, and therefore the tangential velocities *to the right* at these two points are proportional to their radii. That is,

$$V_2 : V_1 :: (R_1 + r_1) : R_1$$

or (8)

$$V_2 = \frac{V_1(R_1 + r_1)}{R_1}$$

or since $r_1 = \frac{1}{R_1}$

$$(9) \qquad V_2 = V_1 + \frac{V_1}{R_1^2}$$

Now when R_1 is much greater than unity, $\frac{1}{R_1^2}$ is very small, and therefore V_2 differs very slightly in value from V_1. It follows that for large radii of the particles of the first order, we may regard A as revolving to the right with practically the same tangential velocity V_1 as C has.

If we compute in the same way the tangential velocity V_3 which a point at the centre of the particle of the Fourth Order would have to the right by reason of the revolution of the particle of the First Order, we would have

$$V_3 = \frac{V_1(R_1 + r_1 + r_2)}{R_1}$$

or (11)

$$V_3 = V_1 + \frac{V_1}{R_1^2} + \frac{V_1}{R_1^4}$$

For large radii $\frac{V_1}{R_1^2}$ and $\frac{V_1}{R_1^4}$ would be negligible, and the velocity of the particle H to the right, by reason of the revolution of A to the right, would be practically V_1. But we have seen (d) above that the particle H by reason of the revolution of FIGH to the left has a velocity of V_1 to the left.

(e) *It follows that for large radii of the particles of the First Order, at least, the particle H of the Fourth Order is not moving either to the right or to the left, at the particular instant that the particle of the Third Order is in the plane of the paper, that is, in the plane of the particle of the First Order.*

It is without tangential velocity in the same sense, that where a wheel is being rolled over a smooth surface, we say that the particular point on the circumference of the wheel, which at a particular instant is in contact with the surface, has no tangential velocity for that instant.

This proposition is very important, and enables us to treat the motion of H at the particular instant it is in the plane of the paper as negligible. I am inclined to the belief that the proposition is true even for short radii because of subsequent considerations, the corrections to make it so being due to the increase of the lengths of the radii of the second, third, and higher orders of particles when the value of R is decreased, which follows from the expression $r_1 = \frac{1}{R_1}$

142. Equation (9) of the preceding discussion may be put under the form

(12) $V_2 = V_1 \frac{(R_1^2+1)}{R_1^2}$ where V_2 is the tangential velocity of A in the direction AY.

If f_2 be the distance per unit of time through which A must be deflected from the tangent AS in order to keep it to the circular path AY, it represents the centripetal force in respect to the circular path AY which must be operating on the particle A at the particular instant that the particle is in the plane of the paper, and its value at that instant must be

$$f_2 = \frac{V_2^2}{R_1+r_1} = \frac{R_1V_2^2}{R_1^2+1}$$

Substituting the value of V_2 from (12) and reducing, we get

$$(13) \qquad f_2 = \frac{V_1^2}{R_1} + \frac{V_1^2}{R_1^3}$$

Since this force is operating toward the centre O it must have the negative sign, that is

$$(14) \qquad f_2 = -\frac{V_1^2}{R_1} - \frac{V_1^2}{R_1^3}$$

Now we have already shown that the force operating at A in a unit of time, in the direction AC, due to the flow out of the particle at the centre O is only $-\frac{V_1^2}{R_1}$, it follows that there is another force operating at A in the direction AO from a different source, and which must give the acceleration $-\frac{V_1^2}{R_1^3}$.

We must endeavor to find it.

Let us recall the principle of Barker's Mill (sec. 131). The centre A of the particle FGHI is revolving about the centre C, and that particle in its movement through the medium is in the situation of a fan having an orifice at the centre revolving rapidly through the air. There is a pressure at the centre due to that revolution precisely as in the case of Barker's Mill. We may consider the effect for present purposes as if the particle were stationary and there were a flow through it with the tangential velocity W_1 which is the velocity of A in the circumference ADBE. This force will be operative at the instant under consideration in the line of intersection of the plane of ADBE and the plane of the paper, that is in the line OH, and the flows representing the action and reaction will be in the two opposite directions AF and AH, and will be equal.

The particle at H is not moving tangentially in the plane of the paper, and yet it is under pressures which would give it tangential velocities of V_1 in opposite directions, as we have seen.

The entire energy of that particle, represented by V_1^2 is concentrated in a pressure at H in the line AH by the flow from H to A, which must pass out of the centre A as a jet or wave perpendicular to the plane of the particle of the First Order, and perpendicular to OH at A. We shall have more to say about that later.

Now if $P = V_1^2$ be the pressure at H, the value of this pressure at A at the distance $AH = r_2$, see (b), section 132, is $P_1 r_2$, or $V_1^2 r_2$, or since $r_2 = \frac{1}{R_1^3}$, see (c), section 141, the value of the pressure at A in the direction AO is:

$$(15) \qquad P = -\frac{V_1^2}{R_1^3},$$

which is exactly the additional amount of acceleration in the direction AO required to make the path of A in the direction AY circular, as shown by equation (14).

In thus accounting for the origin and operation of centripetal force we have a wonderful verification of the correctness of our hypothesis as to the nature of the ether structure and of particle mechanism. It will receive a still greater verification when we apply the results here established of the reciprocal relation of the radii of the particles of the several orders to the solution of other questions, which have heretofore been inexplicable.

CHAPTER XVI

STANDARD PARTICLES SET IN MOTION IN A PLANE AROUND A CENTRE IN THE ETHER STRUCTURE. DERIVATION OF BALMER'S FORMULA

143. Let us lay out the equilateral system of the ether structure as illustrated in Figure 45.

At every corner of the equilateral triangles there is a standard ether particle.

Let us suppose that one or more of a series of particles whose centres are A_1, A_2, A_3, A_4, A_5, etc., could, by the application of some extraneous force not usual to the ether structure in its normal condition, be set in revolution around the centre O. From our previous investigations we have seen that there are conditions affecting the relations of the tangential velocity of the particle, and the length of the radius, which would cause that revolution to be maintained automatically by the regular unit's flow of the ether in the stress-lines.

Each of the successive rings would be, according to the general nomenclature we have been using, a particle of the First Order, and the particles whose centres are at A_1, A_2, A_3, etc., would be particles of the Second Order.

If we consider the path of revolution of any one of these particles of the Second Order, say A_3, we see that it would come into collision with the particles B_3, C_3, D_3, E_3, and F_3, situate at the corners of the polygon B_3, C_3, D_3, E_3, F_3, and A_3, if only the particle A_3 were in revolution. But since each of these particles of the Second Order has the same mass, a collision between A_3 and B_3 would, under the law of elastic collision bring A_3 to a complete stop in the position of B_3, and B_3 would take up the motion precisely as if it were A_3, etc. Or we might consider that the particles would behave as vortex smoke rings, i.e., B_3 expands and A_3 passes on through its centre, any loss of energy which A_3 may have sustained in passing from the position A_3 to B_3 being sup-

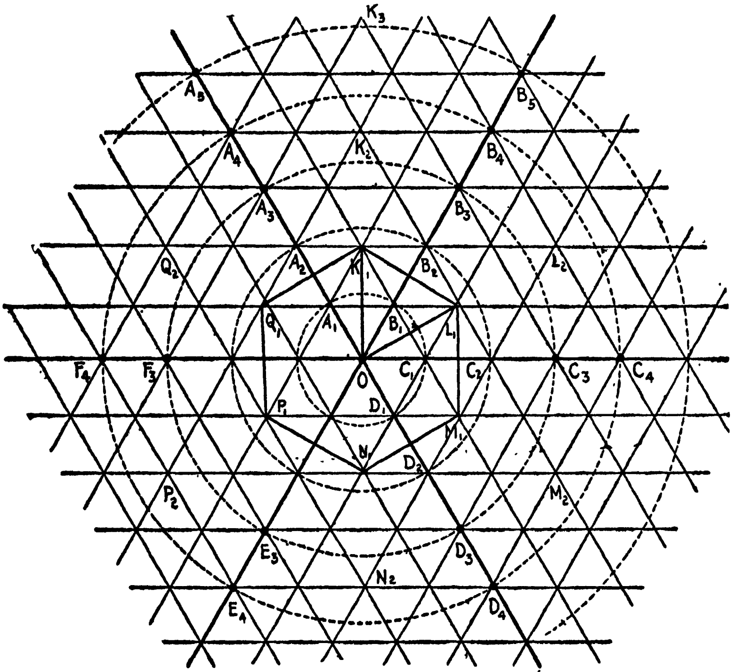

Figure 45

plied from the pressure of the surrounding medium through the stress lines at B_3 and through the pressure to which A_3 is there subjected.

On the other hand we may consider that each of the six particles in the polygon is in revolution with the same velocity around O, and that after they were set in revolution the general flow in the stress lines has established other standard particles in their former places.

It is not necessary at this time to settle that question; it is sufficient for our present purposes to say that we have established that the revolution of a single particle such as A_3 (belonging to a couple), when set up, will be automatically maintained. Therefore we will for the present, for simplicity, treat the matter as if only one particle were in revolution in any one orbit.

144. Wave Lengths of the Waves Sent Off by an Ether Particle Set in Revolution.—We may now consider that any one of the centres of the particles of the second order A_1, A_2, A_3, etc. (Fig. 45), corresponds to the centre C of the particle of the Second Order ABCDE (Fig. 44 of sec. 141), and we will recur to the motions and flows taking place as therein we found necessary in order that the automatic action of the particle in revolution should be maintained.

By reason of the revolution of C about O (Fig. 44) there is a lateral pressure in the orifice C equivalent to a flow. And by reason of the revolution of A about C there is a lateral pressure in the orifice A equivalent to a flow. As already seen (sec. 141, (e)) the particle H is stationary in respect to moving either to the right or left for the instant of time that it lies in the plane of the paper, and this is the precise instant of time when, as we shall see, the impulse arising from the reaction flow passing from C to A, due to the centripetal force, is shifted at A, and passes out of the orifice at A at right angles to the plane of the paper, as a jet or light wave, in the opposite direction to that in which the centre A is revolving in ADBE. The problem is to find the equation of this wave so sent off into space.

The problem is practically the same as that involved in finding the velocity of the water jet sent off from a revolving lawn sprinkler or Barker's Mill (sec. 131).

We have heretofore seen that in order that the centre C shall, while in revolution, be continuously deflected from the tangent CK and forced to follow the circular path CX, that there must be operating at C in the direction AC a centripetal flow or pressure equal to $\frac{V_1^2}{R_1}$ per unit of time. This flow comes from the orifice A of the particle of the third order. Transferring this pressure from C to A by the principles of section 139 and representing this component at A by the symbol g_1, we have

$$(1) \qquad g_1 = \frac{V_1^2}{R_1} \times r_1 = \frac{V_1^2}{R_1} \times \frac{1}{R_1} = \frac{V_1^2}{R_1^2}$$

We have heretofore seen (sec. 141, equation, (5)) that A is revolving in ADBE in the direction AQ with a velocity $W_1 = \frac{V_1}{R_1}$. This revolution creates a lateral relief of pressure at the orifice A_1 which is equivalent to the pressure which would be created if there were no revolution, and there were a flow through the orifice with velocity W_1. We may represent this lateral pressure due to revolution by h_1.

Against this flow through the centre A there is operating the continuous pressure $g_1 = \frac{V_1^2}{R_1^2}$ acting as an acceleration, while h_1 acts as head pressure. So that by Torrecilli's formula $V^2 = 2\,g_1 h_1$ we have:

$$(2) \qquad W_1^2 = 2g_1h_1 \qquad \text{or:}$$

$$(3) \qquad \frac{V_1^2}{R_1^2} = 2\,\frac{V_1^2}{R_1^2}\,h_1 \qquad \text{or:}$$

$$(4) \qquad h_1 = \frac{1}{2}.$$

These pressures g_1 and h_1 are lateral pressures at A in the intake flow due to the component of centripetal force and revolution, and operate in opposite directions, so that if we represent by h_2 the total effective lateral pressure at the orifice A of the intake flow, we have:

$$(5) \qquad h_2 = h_1 - g_1 \qquad \text{or:}$$

$$(6) \qquad h_2 = \frac{1}{2} - \frac{V_1^2}{R_1^2} \qquad \text{or:}$$

$$(7) \qquad h_2 = \frac{R_1^2 - 2V_1^2}{2R_1^2}$$

145. Now, since there must be a reaction flow for every direct flow, there must be passing out of the orifice A in the opposite direction to AQ a wave or jet sent off into space.

We may represent by h_3 the pressure in this reaction flow at the orifice A, and on the principles of section 136, h_3 will be the reciprocal of h_2, and we have:

$$(8) \qquad h_3 = \frac{1}{h_2} = \frac{2R_1^2}{R_1^2 - 2V_1^2}$$

If we represent by g_2 the acceleration operating on this outflow wave, for similar reasons it will be the reciprocal of g_1 the acceleration on the intake flow, and we have:

$$(9) \qquad g_2 = \frac{1}{g_1} = \frac{R_1^2}{V_1^2}$$

Let Z_1 be the velocity of the jet, or velocity of progression of the wave sent off through A, actuated by the head pressure h_3 and acceleration g_2, then by Torrecelli's formula we have:

$$(10) \qquad Z_1^2 = 2g_2h_3 \qquad \text{or:}$$

$$(11) \qquad Z_1^2 = \frac{2R^2}{V_1^2}\left(\frac{2R_1^2}{R_1^2 - 2V_1^2}\right) = \frac{4R_1^4}{V_1^2(R_1^2 - 2V_1^2}$$

Or we may for convenience retain for $\frac{R_1^2}{V_1^2}$ the symbol g denoting the operative acceleration g_2, and put the equation under the form:

$$\text{(12)} \qquad \frac{Z_1^2}{g} = \frac{4R_1^2}{R_1^2 - 2V_1^2}$$

In the above equation $\frac{Z_1^2}{g}$ is, according to section 129, the pressure due to the velocity of flow of the outgoing wave.

Now from the general equation expressive of the relations existing between acceleration, wave length, and velocity of progression, which must exist in all transverse wave motion (Appendix, 198–200) where Z_1 is the velocity of the wave progression, g is the acceleration operating in the wave, and λ the wave length, and which is applicable to light waves, at least at their launching (sec. 200), we had:

$$Z_1^2 = \frac{g\lambda}{2\pi} \qquad \text{or}$$

$$\text{(13)} \qquad \frac{Z_1^2}{g} = \frac{\lambda}{2\pi}$$

Equating (12) and (13) we obtain:—

$$\text{(14)} \qquad \lambda = 8\pi\left(\frac{R_1^2}{R_1^2 - 2V_1^2}\right)$$

For the purpose of identification for future reference, we will designate equation (14) as Erwin's Formula, expressive of the wave lengths of the radiations sent off by standard ether particles revolving around a centre for any assigned value of the radius of revolution of the particle of the First Order.

146. We have heretofore seen (sec. 136 (a)) that in order that the flow from the centre of the particle of the First Order shall be equal to unity or the normal flow in the stress lines of the ether structure, we must have $V_1 = \sqrt{2}$.

Substituting this value of V_1 in (14) and we have

$$\text{(15)} \qquad \lambda = 8\pi\left(\frac{R^2}{R^2 - 4}\right)$$

But this is precisely Balmer's formula (sec. 86) except that the constant 8π is expressed in the fundamental units of the ether structure, that is the sides of the standard equilateral triangle, whereas the same thing is expressed in centimeters in Balmer's formula:

$$\lambda = 3646.13 \left(\frac{R^2}{R^2 - 4}\right) \times 10^{-8} \text{ c.m.} \tag{16}$$

We conclude, therefore, that:

8π standard linear ether units $= 3646.13 \times 10^{-8}$ c.m.

One standard linear ether unit $= \frac{3646.13}{8\pi} \times 10^{-8}$ c.m.

One standard linear ether unit $= 145.07 \times 10^{-8}$ c.m.

In other words, we have measured the length of the side of the standard equilateral triangle of the ether structure.

147. **Why Light-waves of All Wave Lengths Have the Same Velocity of Progression.**—The general equation applicable to all waves carried on by transverse vibrations (sec. 198) and which we have utilized in equation (13) of section 145 is:

$$Z_1{}^2 = \frac{g\lambda}{2\pi}$$

in which Z_1 represents the velocity of progression and λ the wave-length. We see that Z_1 varies as λ varies. But, as pointed out in section 200, light waves of all wave lengths travel with the same velocity of progression. This apparent contradiction has been a puzzle to physicists and mathematicians for more than a century. Observed facts, as well as Balmer's formula, which we have reached and justified, show that light waves of different colors have and must have different wave-lengths.

Let us see if we can find a satisfactory explanation of this seeming inconsistency.

Referring to section 136, we there showed that the relations of the direct and reaction pressures in the standard unit volume of the standard stress lines of the ether structure is expressed by

$$P \times Q = 1$$

or
$$P = \frac{1}{Q}$$

If we suppose that the unit volume or tube of the standard stress line is, if it could be, at any instant entirely filled by the direct flow then $Q = 0$ and $P = \propto$.

It follows that for that instant any effort of any other flow to enter that sectional tube of the stress-line under consideration would be resisted by an infinite pressure.

Now referring to Figure 40, section 138, we may suppose that KC is the unit sectional tube between the standard particles FGH and BED situate at the corners of our standard equilateral triangle system, and that the regular standard flow is moving in the direction KC, and that at the particular instant under consideration the flow represented by equation (11) is at C moving in the direction OC. Under the conditions stated, the entire flow represented by (11) would be diverted at C at right angles to OA and by reason of the revolution of BED would be distributed radially in the plane of BED.

By reason of the relations

$$R_1 = \frac{1}{r_1}, \quad W_1 = \frac{V_1}{R_1}, \quad f = \frac{V_1^2}{R_1}$$

as applied to the particle BED, if the obstruction ahead were only partial there would be a temporary storing up of the energy which passes into that particle, and as soon as the standard flow has partially relieved itself of pressure by passing into the section CO, the potential energy stored up in BED would elastically force a reaction flow into CK. This reaction flow is to all intents and purposes a continuation of the same flow represented by (11). It has simply lost a portion of its energy by the diversion at C.

It is thus seen that although Z_1, the velocity with which the wave represented by (11) is launched, may vary in value, the progress of the wave through space is absolutely fixed by the standard ether flow. That is, the velocity of all light waves must be the same.

It must be remembered that automatic action of each ring of an atom requires that it should send off two distinct kinds of emanations or flows, (a) the flow to the centre, where it is shifted and sent off at right angles to the plane of revolution of the particle of the first order or ring, and such flow from the centre is the unit flow of the ether structure for each particle in the ring, and (b) there is the light wave sent off from the particle of the Third Order, intermittently, that is to say, every time the particle of the Third Order, in its revolution around the centre of the particle of the Second Order comes into the plane of the particle of the First Order. These are the Z-waves by which we arrived at Balmer's formula. It follows that the Z-waves are also sent off at right angles to the plane of the rings. As they leave the atom the Z-waves are superposed upon the flows from the centre, and the vibrations of the Z-waves are carried forward with the velocity of the regular unit flow of the ether structure sent off from the centre. We have a situation which allows of a close analogy to the operation of the telephone.

In the case of the telephone, when we make the connection, there is proceeding a constant flow of electrical current through our machine and on through the circuit. When we speak, our voice sets the metal disk against which the sound waves impinge, into vibrations. This disk is fixed in front of a magnet around which is wound the wire through which the current from the battery is passing. The vibrations of the disk affect the magnet, and this in turn superposes small magnetic vibrations upon what would otherwise be the uniform current passing like a ribbon through the machine. These vibrations cut scallops, as it were, in the ribbon current. The distance to which these vibrations are carried, and the velocity of progression, depend upon the current from the battery, and not upon the initial velocity of the magnetic vibrations caused by the voice.

This furnishes a very satisfactory explanation of why light waves of different wave lengths progress through space with the same velocities.

148. It will be observed that Z_1 was measured from the orifice A (Fig. 44, sec. 141) of the particle of the Third Order, while A was in revolution in ADBE with tangential velocity $W_1 = \frac{V_1}{R_1}$, and that in (4), section 144, we reduced this velocity to an equivalent pressure:

$$h_1 = \tfrac{1}{2} \text{ in the intake flow at A.}$$

The reciprocal of this pressure is

$$h = 2$$

and this entered as a constituent part of the pressure h_2 from which we derived equation (11).

We may find the velocity V_2 in the outflow due to h alone, from Torricelli's formula $V^2 = 2g_2h$, remembering that the acceleration in the outflow jet was $g_2 = \frac{V_1^2}{R_1^2}$, and have

$$V_2^2 = \frac{2R_1^2}{V_1^2} \times 2 = \frac{4R_1^2}{V_1^2}$$

$$V_2 = \frac{2R_1}{V_1}$$

Since the intake flow was on the opposite side from A to the operation of the pressure h_1, the reaction pressure h_2 will be opposite to the direction of the outflow; that is to say,

Z_1 and V_2 are in opposite directions, and are two opposed velocities operating on the same substance. If therefore Y_1 be the absolute velocity of the substance represented in equation (11), then

$$Y_1 = Z_1 - V_2$$

Taking the value of Z_1 from (11) and the value of

$$V_2 = \frac{2R_1}{V_1},$$

as above, we have

$$Y_1 = \frac{2R_1^2}{V_1 \sqrt{R_1^2 - 2V_1^2}} - \frac{2R_1}{V_1}$$

Or, substituting $V_1 = \sqrt{2}$, we have

$$Y_1 = \frac{2R_1^2}{\sqrt{2}\ \sqrt{R_1^2 - 4}} - \frac{2R_1}{\sqrt{2}}$$

or

$$Y_1 = \frac{R_1^2 \sqrt{2}}{\sqrt{R_1^2 - 4}} - R \sqrt{2}$$

When R is very large, $R_1^2 - 4$ differs inappreciably from R_1^2, and we may put $\sqrt{R^2 - 4} = R_1$
and we would have

$$Y_1 = R_1 \sqrt{2} - R_1 \sqrt{2} = 0$$

That is to say, for very large radii the absolute velocity of launching is zero. In other words, no waves are sent off from the particle of the Second Order for very large radii.

CHAPTER XVII

APPLICATION OF THE FOREGOING PRINCIPLES TO THE SPECTRUM OF THE HYDROGEN ATOM

149. We had from section 146:

$$(15) \qquad \lambda = 8\pi \frac{R^2}{R^2 - 4}$$

or

$$(16) \qquad \lambda = 3646.13 \left(\frac{R^2}{R^2 - 4}\right) \times 10^{-8} \text{ c.m.}$$

Although this equation is identical with Balmer's formula, we found it was of general application, expressing the relation of the wave length of any wave sent off by a revolving standard particle in which R is the radius of revolution in standard units.

We may suppose tentatively that the hydrogen atom is composed of a certain number of these particles revolving in a plane around a common centre in concentric circles of different radii, but each with the same tangential velocity $V = \sqrt{2}$. They would therefore be revolving around their common centre with different angular velocities. But we may, on the principles of sec. 59, consider that the particle of an exterior ring is revolving around the moving particle of the next interior ring, and then each would have the same angular velocity $\sqrt{2}$ about its respective moving centre.

As is well known, the Fraunhofer lines peculiar to each element appear in the spectrum when light from a flame of that substance is passed through the incandescent gas of that element. The fact that two waves of equal amplitude and opposite phases will interfere, and in the composition be reduced to force waves, furnishes a complete explanation of the existence and appearance of the Fraunhofer lines under the conditions stated. The waves from the incandescent gas would have the same amplitude as the waves from the flame of the same element passing through the gas, and there would be complete interference between all the waves in opposite phases, and all such composition would reduce those waves to invisible force waves.

It is evident that if the rays came from the flame of numerous elements, and passed through incandescent gas of only one of them, the maximum composition would take place of the rays coming from the element which is the same as the gas through which the combined rays pass.

The structure of the atom would also account for its absorption by an incandescent gas of the rays of the same wavelengths it emits.

There are very strong reasons for believing that the hydrogen atom is what might be called in a certain sense a double atom. It is so regarded by the chemists. But aside from that nearly all the elements of higher atomic weights show that their spectra have a double series of Fraunhofer lines. Some of them have triplets.

150. The following considerations tend strongly to show that the 29 values of λ, observed in the spectrum of Hydrogen (sec. 86), should be arranged in at least two, if not three series instead of one, and is the result of more than one particle movement.

We had

$$(16)\qquad \lambda = 8\pi\left(\frac{R^2}{R^2-4}\right) = 3646.13\left(\frac{R^2}{R^2-4}\right)\times 10^{-8}\ \text{cm.}$$

which was derived as a general formula, applicable to all waves sent off by a revolving particle.

Let us conceive that this for the hydrogen atom represents the wave sent off by the combined action of two particles revolving around the same centre or around two centres near together with radius a, so that $R = 2a$. Substituting this value in (16) we have

$$(17)\quad \lambda = 8\pi\left(\frac{a^2}{a^2-1}\right) = 3646.13\left(\frac{a^2}{a^2-1}\right) \times 10^{-8} \text{ cm.}$$

Now let us suppose that one series of rings commenced with $a = 1.5$ and the value of a, for the successive rings for that series increased by unity, and that for the other series the first ring commenced with $a = 2$ and the value of a for the successive rings of this series increased also by unity.

We may in (17) substitute for a the values 1.5, 2.5, 3.5, 4.5, etc., and the values 2, 3, 4, 5, etc., and arrange the series alternately and we obtain the following results, bringing into the table Evershed's observed values of λ (sec. 86) for comparison.

HYDROGEN

	λ *Calculated*	*Observed*	*Difference*
$a = 1.5$	6563.04	6563.07	+ 0.03
$a = 2$	4861.54	4861.57	+ 0.03
$a = 2.5$	4340.63	4340.53	— 0.10
$a = 3$	4101.90	4102.00	+ 0.10
$a = 3.5$	3970.23	3970.33	+ 0.10
$a = 4$	3889.20	3889.15	— 0.05
$a = 4.5$	3835.53	3835.51	— 0.02
$a = 5$	3798.05	3798.00	— 0.05
$a = 5.5$	3770.78	3770.73	— 0.05
$a = 6$	3750.30	3750.27	— 0.03
$a = 6.5$	3734.52	3734.53	+ 0.01
$a = 7$	3722.09	3721.98	— 0.11
$a = 7.5$	3712.14	3712.13	— 0.01
$a = 8$	3704.00	3704.01	+ 0.01
$a = 8.5$	3697.30	3697.28	— 0.02
$a = 9$	3691.70	3691.70	∓ 0.00
$a = 9.5$	3686.98	3696.96	— 0.02
$a = 10$	3682.96	3682.94	— 0.02
$a = 10.5$	3679.50	3679.52	+ 0.02
$a = 11$	3676.51	3676.51	∓ 0.00
$a = 11.5$	3673.91	3673.87	— 0.04
$a = 12$	3671.62	3671.53	— 0.09
$a = 12.5$	3669.61	3669.55	— 0.06

	λ *Calculated*	*Observed*	*Difference*
$a = 13$	3667.83	3667.83	$\mp$ 0.00
$a = 13.5$	3666.24	3666.25	+ 0.01
$a = 14$	3664.82	3664.74	— 0.08
$a = 14.5$	3663.55	3663.55	$\mp$ 0.00
$a = 15$	3662.40	3662.36	— 0.04
$a = 15.5$	3661.37	3661.31	— 0.06
Theoretical limit	3646.13	......	......

The differences are slightly less in the above. (See sec. 86.)

This is very strong evidence that the hydrogen lines are in two or three series, as was suggested by Professor Pickering and others.

In 1896 Pickering discovered in the spectrum of the star ζ Puppis, which shows the hydrogen spectrum strongly, a new series of Fraunhofer lines which is clearly related to the known hydrogen spectrum. (Baly Spectroscopy, p. 580.)

If in (16) we put $R = \frac{b}{2}$, it becomes

$$\lambda = 3646.13 \frac{b^2}{b^2 - 16} \tag{18}$$

Commencing with $b = 6$ and increasing by twos each time, that is, substituting for b the successive values 6, 8, 10, 12, etc., we obtain the same successive wave-lengths as in section 86, where we used the regular Balmer's formula, and commenced with 3 and increased by unity each time.

Pickering found that the new (Puppis) series gave wave-lengths, the values of which could be obtained by substitution for b in (18) the values $b = 11, 13, 15, 17$, etc., successively.

We notice that for R in the regular Balmer's formula, in order to obtain the three formulæ (including the standard) we substituted the values 2R, R, $\frac{R}{2}$, respectively. The second value is obtained by dividing the first by 2, and the third is obtained by dividing the first by 4.

The three values of R appear to be fundamental in the atom structure, as we shall presently see.

CHAPTER XVIII

THE MAXIMUM AND MINIMUM LIMITS OF LENGTHS OF RADII OF THE RINGS OF THE HYDROGEN ATOM

151. The Minimum Limit.—If we examine the formula (sec. 146),

$$(15) \qquad \lambda = 8\pi\left(\frac{R^2}{R^2 - 4}\right)$$

we see that when $R = 2$ the value of λ is infinity. This indicates that when $R = 2$ the wave sent off becomes merely a flow or stream line. Also that the atom hydrogen has two interior rings missing, or at least particles in two rings which do not send off waves which give Fraunhofer lines.

There ought to be a reason for this inferior limit, founded upon the ether structure. By reference to Figure 45 we see that around any centre O, the arrangement of the standard ether particles is such that we have a succession of hexagons, each exterior hexagon increasing in length of radius over that of the next interior one, and each hexagon having only six standard particles in its periphery.

Now the radius of the standard particle revolving as a particle of the second order in the periphery of the hexagon or circle whose radius is $OA_2 = 2$, in order to maintain automatic action, is given by the formula $r = \frac{1}{R}$ or $r = \frac{1}{2}$. The diameter of the particle of the second order so revolving in that periphery is therefore 1.

As we shall later show, the hydrogen atom made up of a succession of rings is formed under conditions of pressure on the exterior rings toward the centre. Let us suppose that the six standard particles of the hexagon next exterior to the hexagon whose radius is 2, have such pressure put upon them that they are forced into the periphery of the hexagon whose radius is 2. We will then have 12 standard particles in the periphery of the latter. The length of this periphery is 12 standard units, and the diameters of the 12 particles together make 12 units; so that the 12 particles will be touching each other. Revolution of the particles in the periphery will be stopped. Moreover the contact of the particles would form substantially a solid ring, which would resist any further compression toward the interior. In fact the hexagon whose radius is 2 would form the cross-section of a tube, through which the flows from the exterior rings toward the centre, when shifted at the centre, pass out of the atom at right angles to the plane of the atom. These flows which pass out of the atom through these tubes at the centre, may be looked upon as stream lines of a higher order than those represented by the standard stress lines.

The above considerations would point to the conclusion that the stream lines represented by the standard stress lines are probably formed in the same way, on some lower equilateral triangle system, so that we have very strong reasons for considering the standard stress lines as "tubes" through which energy is passing.

152. **The Maximum Limit.**—There is nothing in formula (15) above suggestive of any finite maximum limit which may be assigned to R. In other words, the formula does not fix the number of rings which the hydrogen atom must have. If there is such a limit, we must look for it in the structure of the ether itself. Undoubtedly it is so fixed.

Lay out the standard equilateral system as illustrated in Figure 46.

Let O be the centre around which a system of standard particles A_1, A_2, A_3, A_4, etc., spaced one unit apart, are revolving. Let O_1 be the centre around which a second system of standard particles, B_1, B_2, B_3, B_4, etc., are revolving.

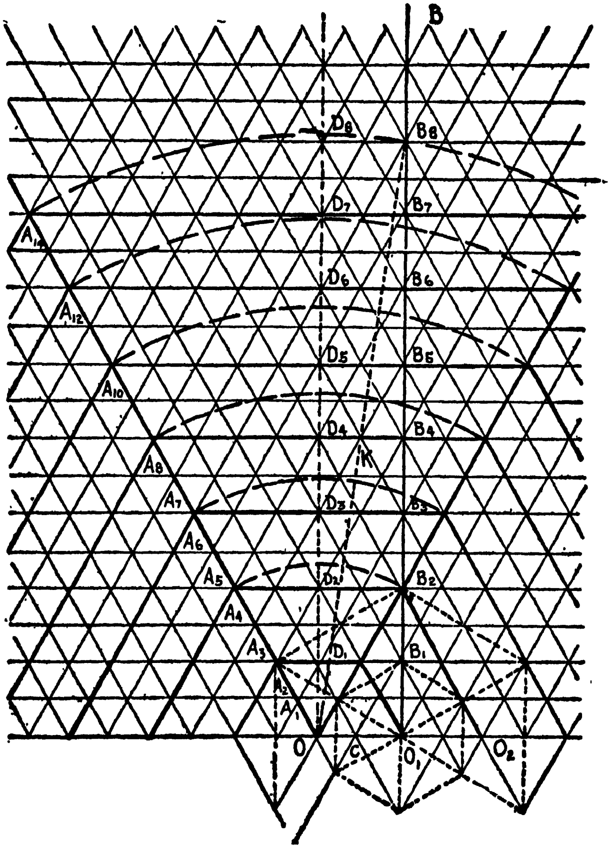

Figure 46

$$O_1B_1 = \sqrt{CB_1^2 - CO_1^2} = \sqrt{4-1} = \sqrt{3}$$
$$O_1B_2 = 2\sqrt{3}$$
$$O_1B_3 = 3\sqrt{3},$$
$$OB_4 = 4\sqrt{3} \text{ or in general } O_1B_n = n\sqrt{3}$$

We may represent the hypothenuse distances OB_1, OB_2, OB_3, OB_4, etc., by a_1, a_2, a_3, a_4, etc., respectively, or in general by a. So that we will have in general

$$a^2 = (2)^2 + (n\ \sqrt{3})^2$$

or

$$a^2 = 4 + 3n^2$$

We may represent the radii OA_1, OA_2, OA_3, OA_4, etc., by R_1, R_2, R_3, R_4, etc., or in general by R. It is obvious not all of these particles, A_1, A_2, A_3, A_4, etc., in their revolution will pass through any of the points B_1, B_2, B_3, B_4, etc. But for such as do so pass, we must have

$$R^2 = 4 + 3n^2 \tag{19}$$

and for such coincidences both R and n must be integral, or whole numbers. At such points there would be interference.

We may place the above expression under the form

$$3n^2 = R^2 - 4$$

The expression $\left(\frac{R^2}{R^2 - 4}\right)$ in the equation (15) would have the same value as $\frac{R^2}{3n^2}$ and geometrically would be represented by the same thing as is represented by the latter expression for our figure.

Let us now determine by substitution, the points of coincidence.

$$R^2 = 4 + 3n^2 \tag{19}$$

$n = 1$	$R^2 = 7$	R not exact
$n = 2$	$R^2 = 16$	$R = 4$ *exact*
$n = 3$	$R^2 = 31$	R not exact
$n = 4$	$R^2 = 21$	R not exact
$n = 5$	$R^2 = 79$	R not exact
$n = 6$	$R^2 = 112$	R not exact
$n = 7$	$R^2 = 151$	R not exact
$n = 8$	$R^2 = 196$	$R = 14$ *exact*

Further substitutions give no exact coincidences or interferences, which will satisfy the equation (19).

153. In section 150 it was shown that if we substituted for R the value $R = 2a$, Balmer's formula became

$$\lambda = 3646.13 \left(\frac{a^2}{a^2 - 1}\right)$$

and satisfied the hydrogen spectrum in two series, one commencing with $a = 1.5$ and increasing by unity, and the other commencing with $a = 2$ and increasing with unity.

For that formula, we have the same construction as above, except that the centre O is placed at C in the diagram, so that $OO_1 = 1$ and equation (19) becomes

$$R^2 = 1 + 3n^2 \tag{20}$$

and the exact coincidences are

$n = 1$	$R^2 = 4$	$R = 2$
$n = 4$	$R^2 = 49$	$R = 7$

from which it will be perceived that the coincidences are proportionally at the same points as before, we simply reduced the base of the right-angle triangle by half, and this cuts the altitude in half, the triangles being similar.

It was also shown in section 150 that if we substituted for R the value $R = \frac{b}{2}$ in Balmer's formula we would have

$$\lambda = 3646.13 \left(\frac{b^2}{b^2 - 16}\right) \times 10^{-8} \text{ cm}$$

and this satisfied the hydrogen spectrum, commencing with $b = 6$, 8, 10, 12, etc., and also satisfied the ζ Puppis series discovered by Pickering when $b = 11$, 13, 15, 17, etc., but each series increasing by 2 instead of unity.

For that formula, we have the same construction as before, except that the centres O and O_1 must be separated by a distance of four units. Equation (19) then becomes

$$(21) \qquad R^2 = (4)^2 + 3n^2 = 16 + 3n^2$$

and the exact coincidences are

$n = 4$	$R^2 = 64$	$R = 8$
$n = 16$	$R^2 = 784$	$R = 28$

These variations, as we shall later show, belong rather to elemental substances other than the hydrogen atom; they are the basic units on which certain other elements are formed. They coincide however with the ring structure of the hydrogen atom at those even multiples.

It all points to the fact that Balmer's formula as we derive it is generic, and is more definitely applicable to the hydrogen atom because the latter is the first in the constructive series which is built up on the hexagons of the standard equilateral triangular system, and with 2 as the base.

154. In the foregoing discussion we have treated the standard ether particles A_1, A_2, A_3, A_4, etc., simply as material points in revolution about the centre O in the plane of the paper. We must not overlook the fact that each of these particles is a particle of the Second Order, each of which is composed of a particle of the Third Order revolving in a plane perpendicular to the plane of the paper and which passes through the centre O, and each of these particles of the Second Order when in revolution must have a radius $r = \frac{1}{R}$ and therefore of smaller size as R increases.

Mathematical evidence shows that there would be an interlocking of ring-motion of the standard particles revolving respectively around two centres, separated by a base of 2, the radii of the particle of the first order being multiples of the second prime radius $\sqrt{3}$ (that is to say, with radii $n\sqrt{3}$), when $n = 24$ or $R = 24\sqrt{3}$.

We may assume—the reason for the assumption being later made to appear—that the maintenance of automatic revolution in any exterior ring of the atom depends upon the existence of revolution in the next interior ring. So that any condition, which at a certain distance from the centre would break up automatic revolution of the ring with that exterior radius, would fix the exterior limit of the rings of the atom.

We will show later that $R = 24\sqrt{3}$ accords exactly with certain experimental determinations which fix the exterior limit of the rings of the hydrogen atom.

The situation which brings about interference is illustrated by Figure 47.

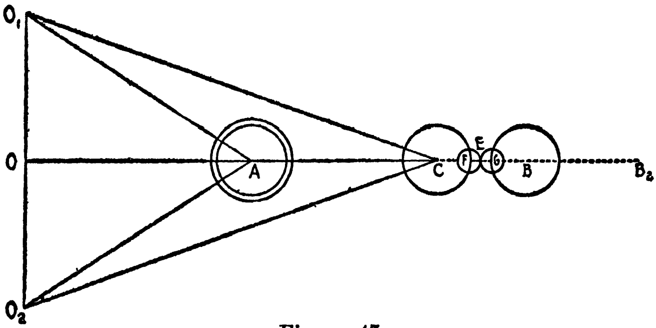

Figure 47

Let O_1 be a centre around which a particle A is revolving in a plane perpendicular to the plane of the paper, with the radius R, and let O_2 be a centre around which another particle is revolving in a plane passed through O_2A perpendicular to the plane of the paper, and also with radius $O_2A = R$, and we will suppose that at the particular instant under consideration the two particles have become concentric at A, and revolving in the same direction. The radius of each particle at A will be the reciprocal of R, that is, each will be $\frac{1}{R}$. We have shown in the diagram the two concentric circles at

A, as if they had radii of different lengths, merely to indicate that there are two particles at A, but it will be understood that they have equal radii. We have heretofore pointed out (sec. 112) that two particles in the same plane concentrically situate, occupy in respect to each other a position of least pressure. They do not repel each other. They become interlocked as it were. Under the conditions illustrated, the two particles will revolve together as if around the centre O, which is half way between O_1 and O_2. Putting $O_1O = b$, then $OA = \sqrt{R^2 - b^2}$.

Whatever real value we may assign to OA there will be nothing to prevent the continuance of the revolution of the concentric particles around the centre O, unless the value assigned is such that it brings them in contact with some one or other of the successive particles of the ether structure which, as we have seen, are distributed along the line OC in multiples of the prime radii of the hexagons formed around the centre O in the plane passed through OC perpendicular to the plane of the paper. We will see where such interference will take place.

Let us suppose that the position of the two concentric particles is at C, such that they are just in contact with a particle B which is itself revolving around the centre O, and so that $OB = O_1C = R$. The radii CF and GB will each be $r = \frac{1}{R}$. The particles C and B will be in contact at E where their particles of the lower orders are just in contact.

Let us at first ignore the particles of orders below the second. That is, treat the matter as if $FG = 0$ so that the ends of the radii CF and BF would just touch.

Then $CB = \frac{2}{R}$ $\quad OC = R - \frac{2}{R}$ $\quad OO_1 = b$

$$OC^2 = O_1C^2 - O_1O^2$$

$$\left(R - \frac{2}{R}\right)^2 = R^2 - b^2$$

$R^2 - 4 + \frac{4}{R^2} = R^2 - b^2$ from which we get—

$$(1) \qquad R = + \frac{2}{\sqrt{4 - b^2}}$$

From which it is seen that for any value of $b > 2$ the value of R is imaginary.

If $b < 2$ it gives real values of R, but we have heretofore seen (sec. 151) that the radius of the interior ring of an atom formed of standard particles cannot be less than 2. If there are such values of $b < 2$ it would have to be for atoms formed on the basis of particles of some lower or different order to that of the standard particles.

This brings us to the conclusion that the value of b for the hydrogen atom must be 2.

But if $b = 2$ equation (1) becomes—

$$R = \frac{2}{0} = \propto$$

That is to say, there would be no rim interference for any value of R whatever when $b = 2$ unless it takes place through contact of the particles of the 3rd or lower orders.

Let us now take into consideration the distance FG (Fig. 47) which we know must be made up of twice the sum of the radii of the 3rd, 4th, 5th, etc., orders.

Put $FG = a$ then $CB = \frac{2}{R} + a$

$$OC = R - \left(\frac{2}{R} + a\right)$$

$$OC^2 = O_1C^2 - OO_1^2$$

$$\left\{R - \left(\frac{2}{R} + a\right)\right\}^2 = R^2 - 4$$

$$R^2 - 2R\left(\frac{2}{R} + a\right) + \left(\frac{2}{R} + a\right)^2 = R^2 - 4$$

From which we get by reduction

$$(2) \qquad a = \frac{(R^2 - 2)}{R} \pm \sqrt{R^2 - 4}$$

Now the prime radius of the first hexagon system above the standard is, as we have seen, based upon $R_2 = \sqrt{3}$. We may therefore take for the hydrogen atom, which is the atom of lowest atomic weight, the value $OB = R = n\sqrt{3}$. This value in (2) gives—

$$a = \frac{3n - 2}{n\sqrt{3}} \pm \sqrt{3n^2 - 4} \qquad \text{or—}$$

$$(3) \qquad a = \frac{(3n^2 - 2)\sqrt{3}}{3n} \pm \sqrt{3n^2 - 4}$$

We may assume that the first contact between the particles will take place when a has its minimum numerical value. Therefore we give $\sqrt{3n^2 - 4}$ the negative value so that the two parts of a, given by (3), will subtract. That is, we have:

$$(4) \qquad a = \frac{(3n^2 - 2)\sqrt{3}}{3n} - \sqrt{3n^2 - 4}$$

Now we cannot use the method of differential calculus to find the minimum value of a, because we must impose the further condition that we want the value of a, which will be a minimum of the values which will be obtained from (4) when for n we substitute successively the integral members 1, 2, 3, 4, 5, 6, etc.

If we substitute for n the value $n = 1$ the first value of a is imaginary.

$n = 2$ gives $a = .0383242$

If we substitute for n the successive values 3, 4, 5, 6, etc., up to and including $n = 23$, we obtain a gradual decrease in the value of a, which, however, up to that point remains positive.

n = 23 gives $a =$ .0000315
n = 24 gives $a =$ .0000278
n = 25 gives $a = -$ .0000422

If we continue to substitute greater values than 25 the value of a will continue negative and continue numerically to increase in value.

We see therefore that a has its minimum value, evidenced by the change of signs when n = 24, at which place:

$$(5) \qquad a = .0000278 +$$

and

$$(6) \qquad R = n\sqrt{3} = 24\sqrt{3}$$

Now to determine whether the particles of the lower orders will be in contact when $R = 24\sqrt{3}$, we will proceed as follows:

We know (sec. 141) that:

$$r_1 = \frac{1}{R} \qquad r_2 = \frac{1}{R^3} \qquad r_3 = \frac{1}{R^5} \qquad r_4 = \frac{1}{R^7}$$

By reference to Figure 47 we see that:

$$a = 2\left(\frac{1}{R^3} + \frac{1}{R^5} + \frac{1}{R^7}\right), \text{ etc.} \qquad \text{or:—}$$

$$(7) \qquad a = 2R\left(\frac{1}{R^4} + \frac{1}{R^6} + \frac{1}{R^8} \text{ etc.}\right)$$

$$R^2 = (24\sqrt{3})^2 = 1728$$

$$a = 48\sqrt{3}\left\{\frac{1}{(1728)^2} + \frac{1}{(1728)^3} + \frac{1}{(1728)^4}\right\}$$

The fractions after the first term are so small we may ignore them, and have:

$$(8) \qquad a = \frac{48\sqrt{3}}{(1728)^2} = .0000278 +$$

Which agrees with the value in (5) at least through seven decimal places.

We have thus found the maximum limit of the exterior ring of the hydrogen atom to be, as hereinbefore stated, $R = 24\sqrt{3}$.

154A. **Centre Radiations.**—We have heretofore seen that each of the successive rings of an atom, whatever may be its radius, in which there is a "couple" of particles revolving, sends a flow to the centre, which is there shifted and sent off at right angles with the value of the unit flow of the ether structure, so that the length of the radius of the exterior ring represents numerically the number of unit flows sent off by all the rings. This conclusion was reached when we were considering revolution of particles in a single plane. In the case of double particle action as illustrated in Figure 47 the situation is modified. We may consider that one of the concentric particles at A is revolving around O_1 with radius $AO_1 = R$, or we may consider that it is revolving around O_1 with the equivalent bent radius $AO + OO_1$.

So we may consider that the other one of the concentric particles is revolving around O_2 with the bent radius $AO + OO_2$.

We may express these values as follows:

$$AO + OO_1 = n\sqrt{3} + \sqrt{-2}$$
$$AO + OO_2 = n\sqrt{3} - \sqrt{-2}$$

And this will be true for each one of the successive rings of the atom between O and the limit of the exterior ring.

We may take the numerical value of each of these exterior radii as representing the sum of all the unit flows represented by all the successive rings making up such radius for each of the concentric particles.

Now by reason of the atoms being concentric there is a double flow being forced all the time through the tube line

AO. The pressure or flow in the same tube is, as we have heretofore seen (sec. 136), obtained by multiplication.

Therefore we have:

Total value of combined flow at the centre for all the rings of the atom $= \left(n\sqrt{3} - \sqrt{-2}\right)\left(n\sqrt{3} + \sqrt{-2}\right) = 3n^2 + 4$.

Taking $n = 24$ for the radius of the exterior ring of the hydrogen atom, we have:

Total value of flow shifted and sent off at right angles from the centre of the hydrogen atom $= 1728 + 4 = 1732$ unit flows of the ether structure.

We shall later show that the gravitational influence of the atom is caused by and proportional to the amount of flow shifted and sent off at the centre at right angles to the plane of revolution of the atom.

154B. **Valency.**—Referring again to Figure 47 we assumed in our foregoing discussion that the particle B was one of the six particles which would naturally belong to the hexagon of radius R of the ether structure, which lies in a plane passed through OB perpendicular to the plane of the paper. But we also imposed the condition that it should be revolving automatically around O. This last supposition was made in order that the radius of B should have the same value as that of C; i.e., $r = \frac{1}{R}$. By reason of the fact that the normal condition of automatic action of every atom is constantly being disturbed by radiations passing through it from other atoms which tend to increase or diminish the velocity of revolution of the particles in the rings, and that automatic continuance of revolution is maintained by adjustments of the relative values of R and r through the relation $r = \frac{1}{R}$, and since the particles B and C are in elastic contact, it follows that the particle B would naturally be in a state of continued vibratory rebound from the point of contact with the particle C.

The next standard particle B_2 of the ether structure, in the line OB extended, is situate a distance equal to $\sqrt{3}$ beyond B, and it may well be that the particle B instead of revolving around the centre O is simply vibrating elastically between the positions B and B_2, and that EB represents the length of the radius of B when most shortened by collision with the concentric particles at C. Or it may be that B partakes of both kinds of motion, i.e., it may be in revolution around O and at the same time elastically vibrating between the outer ring of the atom and the six particles of the next exterior hexagon. In any event the kind of motion it is undergoing is essentially different from that of the particles bounded by the exterior ring of the atom.

Now for automatic action the hydrogen atom would only necessarily require in its outer ring the two concentric particles at C and two other concentric particles on the opposite side of O in a negative direction at a distance equal to OC, forming a "couple," so that the flows meeting at the centre O will be there shifted at right angles. There might, however, be either two or three of such couples revolving around the same centre O, according as they were arranged at 90° or 60° apart.

Since there are six particles in the hexagon, of which B is one, the revolution of the atom may involve the motion of either two or four or six of the particles in the hexagon of which B is one, dependent upon whether the atom itself is composed of one or two or three couples.

The electro-physicists tell us that there are from one to six electrons revolving around every atom, according to the valency of the particular element.

The writer is not prepared to identify the functions performed by the particle B or the other five similar particles in the hexagon to which B belongs, as the electrons to which reference is above made, but points out that this is probably the case.

155. Fresnel's mirror experiment demonstrated that

when two rays of light from a common source are separated and then by reflection brought to intersection at an acute angle in opposite phases, they interfere and produce darkness at the point of crossing, while when the angle is greater they pass through each other without the interference effect.

Undoubtedly interference at the acute angle is due to the interlocking of the particles of the second or third orders in the respective rays. At the point of crossing of the two rays their particles of the first order will be revolving almost on a common axis, since the angle between the axes of the respective rays is very acute. This would throw their particles of the second order in contact or nearly so, and quite so if the angle is taken sufficiently acute.

It would be interesting to work out this limiting angle for the relations $r_1 = \frac{1}{R}$, $r_2 = \frac{1}{R^3}$, etc., as we have done in the case of the maximum ring of the hydrogen atom, and to compare the theoretical with the observed results. The writer has not sufficient data in hand to make the comparison, but such as he has indicates a close agreement by rough comparison. It would be a diversion from our main purpose to take it up at this time.

CHAPTER XIX

THE BIRTH OF THE ELECTRON OR CORPUSCLE

156. Let us consider the operation of a simple magneto-electrical machine, which is an apparatus for turning mechanical energy into an electric current.

Let MNPS, Figure 48, be an iron plate or armature mounted on an insulated platform or table JJ.

EGF is a bar of magnetic iron bent in the shape of a

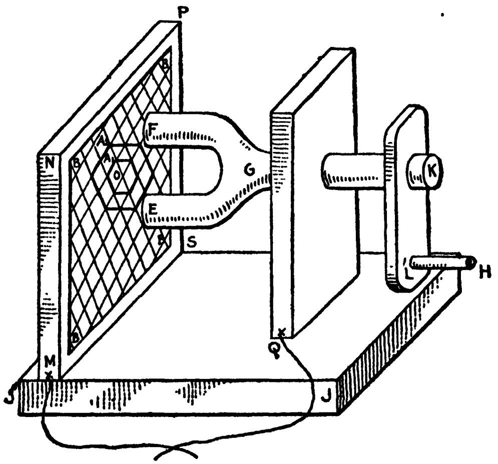

Figure 48

horseshoe, the bend of the horseshoe being fastened to the axle GK, which is mounted perpendicular to the iron plate. To the end of the axle is fastened an insulated crank KL-H. When the crank is turned the ends of the horseshoe are revolved in front of the iron plate or armature as it is called. The surfaces of the two ends or poles of the magnet are made smooth and true so that when the magnet is mounte in the frame the ends come very near but not quite t touching the iron plate.

The support Q is a conductor connected with the axle M and Q have wires attached so that when desired they ma be joined to form a circuit. At first we will conside them as disconnected.

Now, as is well known, when a magnet is so mounted, b induction it immediately magnetizes the iron plate or arma ture or sets up induction currents in the surface of th plate, and this induced magnetism reacts back and make the magnetism in the poles E and F still stronger. Th poles E and F being positive and negative, there are cor responding negative and positive poles created in the sur face of the plate.

It is fully established that the whole space between th poles of the magnet and plate becomes filled with lines o force or "flows" of energy passing from pole to pole, an there is created in the space between the poles of the magne a field of high magnetic pressure.

If now the wires are joined to make the circuit, and th crank is rapidly turned, a current of electricity is sen through the wire, and the intensity of the current, and there fore its capacity to do work, is in proportion to the spee with which the crank is turned. In turning the crank i is found that "something" opposes a powerful resistance and this resistance increases with the speed. If the iro plate or armature is removed, the resistance disappears The electrical current produced in such a machine constructe with a little more of detail than we have found it necessar to describe, can be made to light a burner, run a small sew ing machine or do other work, and yet when the turning o the crank is stopped nothing apparently has been consume or used up except the energy represented by the turnin of the crank.

Now what is it that offers the resistance, and what is the electric current or flow?

Let us suppose that BBBB represents a plane in the ether structure lying next to the surface of the iron plate, and that the parallel lines drawn thereon, so as to form triangles, represent the standard equilateral triangle system of the ether structure. Of course these triangles would be infinitesimally small and invisible.

The standard ether particles are at the corners of each triangle, and by reason of the magnetic field the whole plane is under high pressure. If now we consider any centre at O at which the magnetic pressure from the pole of the magnet and the pole in the plate neutralize each other so that the pressure is not changed immediately by the commencement of the revolution of the pole of the magnet opposite to it, while we may suppose that the change in the position of the pole of the magnet throws the lines of magnetic force immediately against the standard particles at $A_1A_2A_3A_4$, etc., then some one or more of these particles would be set in revolution around the centre O according to the strength of the force applied. The standard particle A_1 or A_2 or A_3, etc., as the case may be, would be a particle of the Second Order, and the revolution of that particle in the plane under consideration with radius R_1, R_2, R_3, etc., as the case may be, would make the particle created one of the First Order.

When any one of these rings is set in revolution it would be a "traveling wheel," which we may suppose travels in the ether stress lines along the surface of the armature, and taking the wire at M passes along the stress lines in the surface of the wire and around to Q and back into the magnet, unless en route the energy has been taken out of it to maintain an incandescent burner or do other work.

From the principles heretofore established, no such particle could so travel unless it were continually sending off a reaction "flow" through its centre in the opposite direction to that in which it was traveling, because action and reaction must be equal and opposite.

This reaction flow through the centre must be composed of what we may call a "bundle" of stream lines, each one of which is a traveling "wheel," the radius of which is very minute as compared with the radius of the electrical particle which we now have under consideration. Nevertheless we can come to no other conclusion than that each such stream line is, in its last analysis, nothing but an electrical current in which the size of the traveling particle is dependent upon a triangular system in the ether structure of a lower order than that of the standard triangular system, which, as we shall presently show, is the basis of the electron.

The scientific development of the last ten years has demonstrated that negative electricity has as its basis an actual particle, which has been identified with the "corpuscle" or "electron."

By certain experiments the atomic weight of the electron has been approximately computed.

Now returning to the process by which the electrical particles are created by the twist given by the revolving magnet to the triangular arrangement of the standard particles in the ether plane considered, it is clear that the regular flow of the ether in the stress lines of that plane would immediately restore the structure, so that as long as the magnet be revolving there would be a continuous current of electrical particles created and sent off to the armature and around the wire, and at the same time a continuous stream line flow to the magnetic poles and around the other way.

For the purpose of illustration it is convenient to picture the ether plane from which the particle is wrenched as being parallel to the plate. The principle sought to be explained would be equally true if the plane considered be perpendicular to the plate, since the diameter of the ether particle is very small compared with the distance between the end of the magnet and the plate. That would simply affect the manner in which the magnetic force lines are applied to the particle in the plane, and we are not entering upon the details of that matter at present.

157. It may be said that this theory as to the creation of electrons and of the nature of the electric current looks reasonable, but what evidence have we that it is possible with the aid of magnetic force to set a particle of the Second Order in revolution around a centre, thus forming a particle of the First Order?

The answer is found in section 80, where is explained a phenomenon in regard to polarized light which shows that a particle of the First Order can be created by rotating a particle of the Second Order in a magnetic field. Although this phenomenon received profound attention from scientists, its real significance appears to have been heretofore overlooked. It was the study of that phenomenon which gave the writer his first conception of the existence of particles of the successive orders, as an interpretation of light wave motion. That phenomenon is so nearly similar to the production of electricity in the manner illustrated in Figure 48, although the machinery for creating the magnetic field is different, that the marvel is that some one has not before seen that they illustrate but two phases of the same process, that is to say, the first step in the creation of matter.

A modern dynamo with all its complicated parts is after all but a perfected form of the machine above crudely described, and we must understand that there is constantly taking place both creation and disintegration of matter.

158. **The Atomic Weight of the Electron.**—From the time of Dalton down to about fourteen years ago, the theory was generally accepted, among chemists at least, that the

chemical elements of matter were primary and indestructible atoms, of which hydrogen possessed the least atomic weight of any known.

In 1891 Dr. G. Johnstone Stoney applied the name "electron" to the natural unit of negative electricity to which he had called attention in 1874.

If an induction coil be connected with metallic terminals fused into a glass bulb, so arranged that the air can be gradually withdrawn, certain very startling and beautiful phenomena can be made to take place, of which we will describe only one.

Professor Crookes in 1879 showed that if a small object (he used a small Maltese cross made of mica) be placed in the bulb between the negative (cathode) pole and the positive (anode) pole, and the current is turned on and the air is withdrawn until it reaches the proper degree of exhaustion, the Maltese cross casts a perfect shadow of itself against the anode end of the bulb, the position of the shadow showing that the rays which cause it proceed radially from the cathode. Crookes suggested that the rays so proceeding were streams of negatively electrified particles projected normally from the cathode with great velocity. He found also that the direction of these rays could be deflected by a magnet.

Professor (now Sir) J. J. Thomson proved in 1897 that the cathode rays consisted of "electrons" or electrical unit particles, to which he gave the name "corpuscles." It was found that the electron was not only identified as the unit "charge" of negative electricity, but that such particles were apparently disintegrated from matter in every gaseous flame.

We have all noticed that when an ordinary candle is burning the flame separates into two wings. It was found that in such cases the "electrons" escaping from the burning matter passed out through one wing of the flame and as "negative" electricity repelled the particles of gas negatively electrified in the other wing.

Just what "positive" electricity is, the scientists were unable to explain and have not to this day explained. Unlike negative electricity, there did not seem to be any "particle" in its make-up, and it did not appear to have any mass. Our previous discussion ought now, we think, to make plain why this is so. It is due to the fact that positive electricity is composed of minute force rays. In such a ray the traveling particle is very much smaller than the electron, since it is a particle of the wave sent off by the electron itself.

It was found also that if a newly cleaned surface of zinc be charged with electricity and exposed to the ultra-violet rays from an arc lamp electrons are given off.

The phenomenon already noticed, that the cathode rays (electrons in flight) can be deflected from their paths by magnetic force, furnished a basis upon which the physicists proceeded to estimate the mass of an electron, the amount of the deflection being proportional to the strength of the magnet used.

The earlier determinations placed the mass of the electron at $\frac{1}{1000}$ part of that of the hydrogen atom.

The determination made by J. J. Thomson (Enc. Brit., 11th Ed., Vol. 17, p. 351) was about $\frac{1}{1700}$ of that of hydrogen.

From a slightly different method adopted by H. A. Wilson it is stated by Professor Millikan in *Popular Science Monthly* of May, 1912, the determination was $\frac{1}{1760}$ part of the mass of the hydrogen atom.

If we assume that the average of the last two determinations is approximately correct, we would have $\frac{1}{1730}$ part of the mass of the hydrogen atom as the mass of the electron, We notice here a curious correspondence between the 1730 and the particles 1728 + 4 in the hydrogen molecule as we have heretofore found them to be. It may, of course, be a mere coincidence, but we will have less difficulty in concluding that the exact determination ought to have brought out that average result.

Let us recur to certain principles established in section 140 as necessary to the automatic maintenance of the revolution of a standard ether particle to constitute it a particle of the First Order, and on the basis of which we arrived at Balmer's formula. These principles were that:

(1) *A standard ether particle revolving around a centre, and whose automatic revolution is maintained only by the standard ether flow, from the surrounding field, sends off a flow from its centre at right angles to the plane of revolution, and the intensity of this flow equals unity (the flow in the standard stress lines) whatever be the length of the radius of revolution.*

(2) *If there be a number n of such particles revolving in the same plane, around the same centre, though each may have a different radius of revolution, the intensity of the whole flow at the centre would be n.*

Applying the above principles to the "electron" particle created and sent off as an electric current by means of the magneto-electrical machine illustrated by Figure 48 or other suitable machine, we see that the unit electron would consist of two or six standard particles in revolution, making one "ring," and that the intensity of the flow at the centre would be equal to unity for that ring irrespective of the radius of revolution. Also that the shifting of this flow at the centre would give off two flows of unit intensity at right angles to the plane of the particle.

The particles created and sent off may therefore be of different radii without any change in the intensity of the reaction flow from the centre which constitutes the positive electric current.

Moreover, if the strength of the magnetic field and the force of the revolution applied to the magnet were such as to set in revolution around the centre O more than one ring at the same time, the particle sent off would be composed of more than one ring. If there were n rings, since each sends off a unit's flow from the centre, the intensity of flow in the particle sent off would be n. The current would be a higher tension current. But in that case the particle would not be the unit electron, but would be equivalent to a number of unit electrons. It is the unit electron whose atomic weight Thomson and others determined to be about $\frac{1}{1730}$ part of the atomic weight of the hydrogen atom.

We have found that the hydrogen atom in its primordial or planular form is composed of the equivalent of $1728 + 4 = 1732$ rings, in each of which rings six standard particles are revolving with tangential velocity equal to $\sqrt{2}$, around the common centre. Also that this revolution sends out a unit's flow through the centre at right angles to the plane of revolution in both directions. It follows that the intensity of the whole flow through the centre in either direction is, for the hydrogen atom, 1728 or 1732.

The hydrogen atom, as we have seen, is giving off two equal flows in opposite directions through its centre. It is therefore a stationary wave or combination of stationary waves whose automatic integrity is maintained by the flows into it from the standard stress lines of the ether structure. It can therefore be set in motion as a whole without destroying its character as a stationary wave in respect to the general ether structure and flows.

159. The electron created in the manner illustrated in Figure 48 is put in revolution by the magnetic force lines

proceeding from the poles of the horseshoe magnet revolving in one direction, and the magnetic force lines proceeding from the armature or plate in which two poles are created by induction, as we have heretofore seen, and these weaker force lines are pulling in the opposite direction from those proceeding from the poles of the magnet. The particle created is undoubtedly a stationary wave in respect to the ether flow since each of the standard particles of which it is composed is a stationary wave in that sense. But there is a difference in pressure on the opposite sides of the particle created which must determine the direction in which the particle will go when twisted out of the plane of the ether structure. The velocity with which the electron, created in the manner above described, will travel in the circuit will depend upon the magnetic pressure which sets it in motion, and therefore the velocity of the electric currents so created vary according to those forces. Electricity, therefore, does not travel with one uniform velocity for currents of different intensities, as is the case with light.

Since action and reaction are equal and in opposite directions, it follows that when an electron is created and set in motion as a traveling wheel there must be a reaction flow through its centre in the opposite direction from that in which the particle is traveling and which flow must increase as the velocity of progression of the particle increases.

If the gravitational effect, and therefore the atomic weight, of a particle is directly proportional to the intensity of the "flow" through its centre, as we shall later see that it is, it follows that the atomic weight or mass of the electron moving as a current of electricity would vary according to the velocity of the current. The true atomic weight would be found only under conditions when the electron was not traveling as an electric current, or, in other words, when the particle was stationary or moving with the ordinary finite velocities not sufficiently great to appreciably affect the flow through its centre.

If we should disconnect the circuit, so that when we turned the crank no current is passed, there would be an accumulation of electrons on the plate or armature and these would be stationary electrons. Any movement would be due to repulsion between the electrons.

Now we can conceive theoretically at least of a modification of the magneto-electrical machine in which the armature is replaced by another horseshoe magnet exactly similar to the first one considered, and that the construction and arrangement was such that the ether plane from which the particle is to be twisted is operated upon by exactly equal and contrary magnetic forces created by the revolution of the similar magnets. In such a case the particle created would have no tendency to travel over the wire in either direction. The machine would simply manufacture stationary corpuscles or electrons.

160. Doubtless every dynamo incidentally is turning out more or less of these stationary electrons, which are carried along by those which form the current.

Although stationary electrons have not to our knowledge been created and collected that way, they have been collected from the disintegration of burning matter, and in other ways.

Sir J. J. Thomson and other eminent electro-physicists have performed certain experiments which point to the conclusion that when a gas proceeding from a jet is set in flame there is a release of certain particles very much smaller than the atoms of the ordinary chemical elements. These particles are distributed all through the incandescent gas of the flame: Under certain conditions the gas in the flame will exhibit negative electrical effects, or positive electrical effects, or it may be that neither effect may be exhibited. But in the latter case if the flame be put between two separated parallel plates which have been oppositely electrified it will be seen to separate into two incandescent wings, one of which when tested will show the negative and the other positive electrification. This indicates that under ordinary circumstances the things which cause positive and negative effects are produced in equal quantities by the process of combustion, and neutralize each other, but that they may be separated as above described. The thing or things which give the electrical effects can be strained out of the gas by passage through "glass-wool" and in certain other ways.

The thing which produces the *negative* electrical effect has been by Thomson and others actually isolated as the "electron" or "corpuscle" and its mass determined by certain ingenious apparatus and mathematical laws, which it is unnecessary to enter upon here. The general reader is referred for details to Jones' "Electrical Nature of Matter" (D. Van Nostrand Co., N. Y.), and Duncan's "New Knowledge" (A. S. Barnes & Co., N. Y.). The intent of those works is to reduce all things to an electrical basis. The intent of the writer is to go a step further and explain electricity itself as a mechanical operation.

It has not been found possible to say definitely whether there is any distinct *positive* electrical particle, nor to determine its mass if it has mass. So the question has arisen, what is positive electricity?

When an electric discharge is sent through oxygen, nitrogen, helium or other gas, positively charged particles having the mass of the hydrogen atom or cation are found.

Through a similar method to that by which the mass of the electron particle in the rays proceeding from the cathode was determined, there was discovered by Goldstein certain particles in rays proceeding from the anode. By use of a perforated iron cathode through which the anode rays could pass through any attenuated gas it was found that a phosphorescence was produced on the walls of the glass tube behind the cathode, and the mass of the particle therein was determined to be of the same order of magnitude as the hydrogen atom although varying somewhat for different gases. From experiments of Goldstein, Wien, Stark, Thomson and others, it has been sought to draw the conclusion that the particles of positive electricity are identical with the hydrogen atom or hydrogen cation.

It would seem to the writer that the phenomena described rather point to the conclusion that under the conditions described the hydrogen atom is disintegrated from the gas or from the anode material, or created from the strain of the ether, and floated through the perforations of the cathode by the flow of the positive current. The writer is inclined to follow what he understands to be Sir William Ramsey's line of thought as to these phenomena. Sir J. J. Thomson seems to consider the question of the mass of the particle of positive electricity, still debatable in his article on "Matter" in the 11th Ed. Ency. Brit. If the writer's view of positive electricity is correct, the absence of an electron from the normal structure of the hydrogen atom, would make an unbalanced positive flow from or into the remainder of the structure, or cation, which would cause us to confound the hydrogen atom or cation with the particle of positive electricity.

The electro-physicists generally have, it would seem, adopted the view that a material atom (according to the nature of the chemical element) has normally from one to six electrons revolving around it; that it may be deprived of one or more of these under certain conditions, leaving the deficient atom as a "cation," and that this cation exhibits the positive electrical manifestation merely by reason of the fact that the atom has been deprived of an electron; also that the normal atom may under certain conditions acquire an extra electron, in which case it becomes an "anion" and exhibits negative electric properties. Both "anion" and "cation" are embraced in the comprehensive term "ion" as used in the nomenclature of the electron theory.

In that theory the conception is that the electron is not only the ultimate particle out of which material particles are built up, but this particle is identical with what is denominated the electric "charge," and that this can only be defined as a unit of "electricity" which is made the ultimate thing in nature.

161. While the writer does not question the results of the experiments referred to, and the intermediary conclusions, he does question the propriety of the conception of "electricity" as the ultimate thing in nature. The word itself has obtained a fixed definition in accepted physics as representing a particular kind of manifestation of energy. Heat, light, and electricity and the motion of a ball through a rectilinear path in space, have been demonstrated to be only different kinds of motion of substance. Electricity is a compound idea, a particular form of energy. To stop our explanations at the electron, call it "electricity" and treat it as the ultimate thing, leaves us but a little better off than were our early scientists who explained fire by the escape of "phlogiston" from matter.

To make electricity the ultimate thing is the same as making energy the ultimate thing in nature. It also fails to account for the law of the equality of action and reaction which is fundamental to all motion, and which is fully accounted for by the conception of an ideal incompressible substance in motion in all its parts.

If the reader has followed the course of our deductions from the particle structure and particle motion in the ether, he will see that we agree with those who hold to the electron theory in accepting the electron or corpuscle as the basis of the structure of the material atom. We, however, show how the electron is formed as an ether particle from ultimate substance on the wave-theory of light. We agree that the negative electric current consists of one or more electrons moving as traveling wheels through space. But on the principle of the equality of action and reaction, we consider that no such electron particle could so continue to travel in one direction unless it were at the same time sending off reaction flows in the opposite direction. In other words, the positive current is accounted for by flows composed of minute force rays in which particles of a lower order of magnitude than the electron constitute the traveling wheels which are at the basis of all wave motion. Thus, while the relation between the mass of a material atom and that of the electron is sufficiently finite to yield to experimental determination, we would not expect it would be so in regard to ether particles of the lower order which must be the basis of the positive electric current. Moreover, when we come to consider the ring structure of the material atom, and the passage through such structure of radiations of a lower order, which is, as we shall show, the basis of gravitation, we arrive at a suggestive reason for the phenomenon of the attraction of unlike, and repulsion of like electricities.

The electric current is the motion of a train of electrons through space, the mechanical action involved being the forward motion of the electrons constituting the negative current, and the reaction flow of minute force rays constituting the positive current. The electric current is essentially a light wave, except that its traveling wheel is of greater amplitude than the traveling wheel of visible light waves. But that difference accounts for many things.

CHAPTER XX

GRAVITATION EXPLAINED

162. Referring to section 139, and Figure 41, we there pointed out that if energy was being radiated from a point in every direction, the pressure at a unit's distance in the unit sectional area, taken as unity, may be represented by the product of the direct and reaction pressures P and Q, so that $PQ = 1$. And at the distance D from the center of radiation, the direct pressure P_1^2 on the unit sectional area would be

$$(1) \qquad P_1^2 = \frac{P^2}{D^2}$$

or, in other words, the pressure per unit area decreases inversely as the square of the distance. Or we may express it by $P_1 = \frac{P}{D^2}$ if we understand that we are dealing with the unit areal pressure.

Now the larger the value of D the nearer the radii drawn to the opposite sides of the unit area situate at the distance D approach to parallel lines. At the limit infinity the flow in the unit area becomes the stream line or ether flow in which the flows are equal and opposite, or $P = Q$.

For certain purposes a flow so started as a divergent radiation, so far as it may have effect upon such a finite thing as an atom situate at any great distance from the centre of radiation, may be regarded as proceeding through the distant atom in parallel lines, or as a stream line in which P and Q are not, however, equal. The value of P the direct pressure determines and carries forward the flow, and fixes the value of Q, the reaction flow from the formula $PQ = 1$.

Let MM, Figure 49, be an atom which, considered as a particle of the First Order, has its plane of revolution perpendicular to AO, and which, by reason of the revolution of

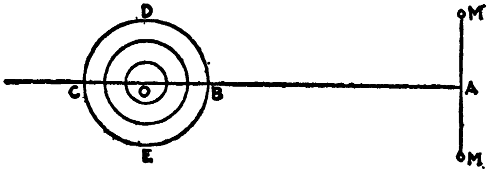

Figure 49

the particles in its rings, is sending off flows through its centre perpendicular to its plane of revolution, that is, in the direction AO.

Let BDCE be another atom situate at a great distance D from A, and we may suppose that this atom is made up of one or more rings, in which particles are revolving as in the case of the hydrogen atom. We will suppose that the plane of this revolution is the plane of the paper, so that the flows proceeding from A will pass through these rings in the plane of revolution. By reason of symmetry we need not consider the effect of any of the flows from A falling on either side of B, but only the flow passing through the centre O. We may take the direct areal pressure in the flow from A at the unit's distance from A as P. The value of this pressure P_1 at B will be

$$(2) \qquad P_1 = \frac{P}{D^2}$$

In order that the atom BDCE may maintain its autonomy there must be (sec. 140) two flows from B and C, respectively, which meet at O, and are there shifted at right angles, because of the fact that each flow completely fills the unit tube of the stress lines at that point, and these flows pass out of the atom each with the unit pressure at right angles to the plane of the atom.

The collision of the opposing flows at O creates a "whirl" or "force centre" at O (sec. 140). Because the direction of the outflow is at right angles to the plane of the atom, the whirl or force centre at O must lie in the plane of the atom. It will therefore respond elastically to any unbalanced force which may operate upon it in the plane of the atom, and is thus capable of having its position displaced in that plane by such an unbalanced force. When the atom is not being operated upon by any extraneous force, the forces operating automatically on this force centre are in balance, and it maintains its fixed position. Now when the flow measured by the pressure P_1 at B reaches O its value (sec. 139), as we have seen is $\frac{P_1}{R}$. Therefore the loss of pressure between those two points is $P_1 - \frac{P_1}{R}$. This loss of pressure has been occasioned by outflows, from the flow considered, into the circular stress-lines or rings, which are cut at right angles in passing from B to O, and to that extent has relieved the pressure in both directions in the line BO.

Now by reason of passing from the centre of the rotating atom outward due to the ordinary pressures therein, the value of the pressure $\frac{P_1}{R}$ in the flow at O, would be $\frac{P_1}{R} \times R = P_1$, at C. And when that flow passed out of the atom at C, the equal and opposite reaction at C against the atom in the direction CO would be P_1, the same as the original pressure at B. So that considering alone that component of the flow which passes straight through the atom, and which is not diverted laterally, the passage would not cause any permanent displacement of the atom in either direction; the actions and reactions would just balance. The original flow would have passed through the atom without diminution of intensity other than it would have experienced in passing through an equal distance through the ether.

But the action of the component flow which, as we have seen, is diverted laterally into the ring stress lines between B and O, must be traced and considered.

This lost pressure by reason of the revolution of the particles in the rings is carried around the rings as circular flows therein in two directions (the atom being a stationary particle) and, cutting OC at right angles, will this time be diffused into the line CO equally in two directions, that is, toward C in the continuation of the direct flow, and toward O in a reaction flow. The value of each of these flows will be:—

$$\frac{1}{2}\left(P_1 - \frac{P_1}{R}\right).$$

We thus have an unbalanced flow or pressure which we may designate by G_1 operating upon the force centre or whirl at O, in the direction OA, and which will tend to displace it in that direction, and will do work. We will thus have

$$G_1 = \frac{1}{2}\left(P_1 - \frac{P_1}{R}\right) = P_1\left(\frac{R-1}{2R}\right) \tag{3}$$

We may substitute for P_1 its value from (2) and we have

$$G_1 = \frac{P}{D^2}\left(\frac{R-1}{2R}\right) \tag{4}$$

If instead of a single atom situate at the distant point A there should be a cluster M of similar atoms, each sending off similar flows of radiant energy, and each producing its independent effect on the atom at O, we would have for the combined effect G:

$$G = \frac{MP}{D^2}\left(\frac{R-1}{2R}\right) \tag{5}$$

That is to say, the effect of the cluster of atoms at A on the atom at O would be the same as if they exerted an attractive force upon the latter directly proportional to the mass of the atoms at A, and inversely proportional to the square of the distance.

In other words we have the mechanical operation of Newton's universal law of gravitation.

163. We have heretofore pointed out, section 120, that by reason of the equilateral triangle structure of the ether, and the continuous flow taking place in all the standard stress lines, that the ether structure in any plane may be considered as being made up of hexagons of unit radii in which the flows are taking place in the periphery of the hexagons. Therefore to determine whether radiations from matter passing through the ether would have any gravitational effect on one of these hexagons of the ether structure we may substitute for R in equation (5) the value $R = 1$. We then obtain

$$G = 0$$

In other words, there is no gravitational effect.

Gravitation therefore is wholly an effect of matter on matter. The effect arises from the successive ring structure. The property of so-called attraction, therefore, differentiates matter from ether, and atoms from ether particles, although the one is constructed from the other.

164. If for any reason the centre O could not be moved any nearer to A, because of the operation of other forces, as, for instance, where one body is fixed in position relative to the other, there would be no work done, in moving the atom as a whole, and the entire flow of energy, except that represented by an increase of temperature, would pass through the interposing atom and have the full effect on the atom beyond. In other words, one atom does not shield another from the operation of the gravitational influence.

Since the extraneous flow passes through the atom without sensible loss of energy, and yet work is done in moving the atom, it follows that the energy that does the work is supplied from the atom itself. Therefore the same process which draws atoms into an aggregation would operate to reduce their temperature, unless the lost energy was supplied from the ether flows.

We have accustomed ourselves to imagining that gravitation acted as if it was a powerful cable reaching out from the Sun to the Earth, and exerting an immense pull upon it, which constrains the Earth to its circular or elliptical orbit. On our present view however, the radiations of force rays from the Sun which penetrate each atom of matter of which the Earth is composed, merely exercise a directive influence upon the movements of such atoms. The power which makes the Earth swerve from the tangential path and pursue the circular path is furnished by the energy in the atoms themselves. This energy would of course be quickly dissipated were it not that the energy consumed in the work of moving the atom is being continuously supplied to it from the ether. The centre of the atom may move, but automatically its form, shape and size are preserved by the flows of energy coming to it from the ether.

A torpedo propelled by a gasoline engine can be made to follow a circular orbit on the water, by wireless waves sent to it which through suitable apparatus in the torpedo regulate its rudder. In such case, it is the gasoline engine which furnishes the centripetal force, and not the source of the wireless waves.

165. We may consider what gravitational effect the atom in the position BDCE would have on the atom in the position MM, Figure 49. The radiations would not pass through the rings of which MM is composed. In that position, therefore, MM would exert a gravitational influence on BDCE, but the latter would exert none on MM. It does not follow, however, that the means are not at hand

for the accomplishment of an equivalent result indirectly.

Again, suppose that the two atoms under consideration have their centres in the same line, and their faces parallel to each other, as at MM and NN in Figure 50, in which the particles of the second order for one ring are shown at M and M, and at N and N for the respective atoms. The centres are supposed to be placed at great distances apart.

It is plain that in such case the radiations from the centres of the atoms at right angles to their face will not cut across any rings of the opposite atom. Because the distance is great, radiations from NN will pass through M and M, and radiations from MM will pass through N and N. But these

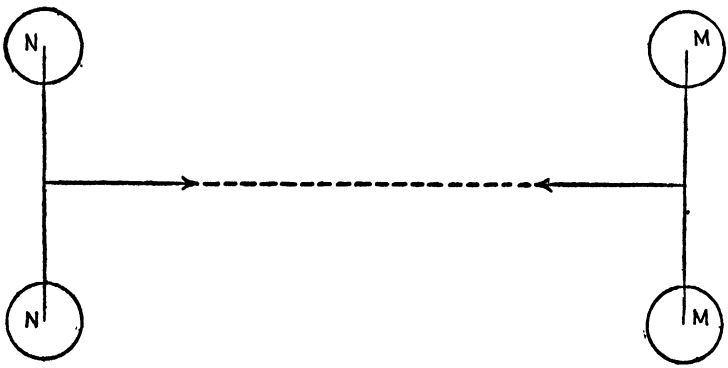

Figure 50

are particles of the second order. The atoms therefore in that position would not exert any gravitational influence on each other. But again we say it does not follow that the means are not at hand for the accomplishment of an equivalent effect indirectly, as we shall presently see.

166. **Influence of Repulsion.**—Let us suppose that the source of radiation is the atom MM (Fig. 51) whose centre is at A, and that there is another atom BDCE whose centre O is not so far distant from A but that radiations from A can exert a repulsive effect upon the particle BDCE when the

respective atoms are in proper positions in respect to each other.

(a) If the plane of BDCE coincided with the line AO it is clear that the repulsive effect of the radiations from A would be simply to push the centre O further away from A.

(b) If, however, the plane of BDCE lies oblique to the line AO, the radiations from A will have no effect on BDCE, except when the particles of the second order revolving around O in the circumference of BDCE are in certain positions.

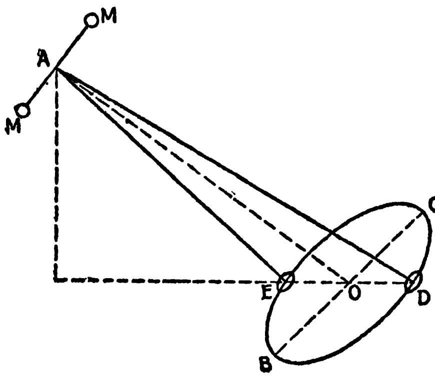

Figure 51

Whatever may be the obliquity of AO to the plane of BDCE, we can always pass a plane through AO such that it will be perpendicular to the plane of BDCE, and which will cut the circumference BDCE in two points D and E. Since the plane of a particle of the second order always passes through the centre of the particle of the first order and is perpendicular to the plane of the particle of the first order, it follows that when in their revolution around the circumference BDCE the particles of the second order are at D and E, the radiations from A will pass through them in the planes of the particles of the second order, and will then exert a repulsive effect on them.

Since AE is shorter than AD, and the repulsive effect is inversely proportional to the square of the distance, it follows that since the atom BDCE forms a conservative system and will automatically preserve itself, the general effect of the radiations from A will be to bring the plane of BDCE into a position parallel to the plane of the atom MM. If we were dealing with a large cluster of such atoms in which the formation had commenced and, fortuitously or otherwise, a majority of them had their planes lying in one plane or in a system of parallel planes, the radiations interacting between the atoms lying in the parallel planes, and those lying oblique, would tend to bring all the planes of the atoms into the system of parallel planes, and to a lesser extent under proposition (a) above to keep some of them lying in planes at right angles to the parallel planes referred to. The general effect taken in connection with the gravitational effect would be to arrange the cluster in disk shape. And if we take into consideration the centrifugal force developed as the atoms are brought toward the common centre of gravity we would get the spiral nebulous conformation.

167. **Symmetrical Atoms in Three Dimensions.**—Let us suppose that by the operation of causes operating locally, such as intense radiations from already existing matter, there has been formed a great cluster of atoms in their primary form, that is, standard particles set in revolution around centres. By action of the radiations from the centres of atoms passing through the rings of all other atoms in the plane of the radiations the atomic members of the cluster would be forced by pressure closer and closer together. This would operate to increase the repulsion between the atoms.

Where the pressure is sufficiently great the atom BDCE (Fig. 49) would have its centre driven to the position A, the centre of the atom MM. That would be a position of least pressure, because there neither of the atoms as particles of the first order would exert either a gravitational or repulsive effect on each other. It is true such of their particles of the second and lower orders as come into the same plane in the course of their revolutions would repel each other, but that could only operate to make the two atoms assume symmetrical positions in respect to each other. Thenceforward the two atoms would act as one body. So that if one was moved it would carry the other with it.

The limitation of the number of planular atoms which could be thus pushed into concentric positions would depend upon the amount of pressure, and the repulsive resistance offered by the atoms already there, through their particles of the second and lower orders, according to the rigidity of the symmetrical form in which they had arranged themselves.

The simplest combination would be three planular atoms passed into each other at right angles each to the other, which would give the basic cubic construction.

Such a combination atom would not be subject to the disabilities of the single planular atoms as pointed out in section 165. Such a combination atom would not only occupy space in three dimensions, but would, acting as one body, attract as well as be attracted by another similar combination atom.

Such a combination atom would exist, however, only because of the fact that planular revolutions of standard ether particles were taking place in it, and because these were being maintained continuously by the flows in the standard stress lines of the ether structure, fed by the energy coming from the stars in infinity.

Such a conception of a combination atom, while it is the basis of that solidity in space of three dimensions which is so essential to our ordinary conception of matter, does not militate against the proposition that the motions taking place is in planes and the structure of the atom is planular.

We conceived that the simplest form of combination atom would be composed of three planular atoms concentrically arranged at right angles. The symmetrical arrangement, however, which would possess the greatest rigidity would be that formed on the equilateral triangle system. That is to say, the centre would be the apex of each of 20 tetrahedrons. But in that case the standard particle could not make a complete revolution around the centre in one plane. It would revolve through 60 degrees in the plane side of one tetrahedron, and pass at an angle into the plane side of the next one, etc., etc. Its course would be over a corrugated path. It is evident that that formation would only be forced under the greatest pressure, if at all.

168. **The Nebula Hypothesis.**—In the foregoing discussion we have given the mechanical operation of the forces, which without detail of mechanism is made the basis of Newton's law of Gravitation, and of Laplace's Nebula Hypothesis. The latter, commencing with the nebula, undertook to account for the evolution of suns, worlds, and satellites through the operation of gravity, centrifugal force, and loss of heat by radiation.

Suppose we had to deal with only two of our combination atoms in repulsive as well as of gravitational reach of each other. The gravity influence would bring them nearer and nearer together, until at some point the repulsive force becomes equal to the force of gravity; there equilibrium would be established, and the two atoms would be held in elastic rigidity as one body by the forces operating between them. If there were a number of such atoms they would all be drawn together, and if each has the same mass (or energy in automatic motion as an atom) they would tend to arrange themselves in equilateral triangle formation (secs. 77 and 197). If they were of different masses they would tend to arrange themselves in such formations as would maintain equilibrium between them in respect to their mutual attractions and repulsions.

Again, if there were such a cluster of atoms being drawn to their common centre of gravity, and if there were other clusters of atoms at a distance sending radiations into the cluster under consideration, each of the atoms composing the latter would be operated on differently gravitationally by these radiations, according to their respective distances and situation in respect to the sources of these outside radiations. The result would be that the atoms in the cluster under consideration would not approach their common centre of gravity in a straight line. Tangential motion would be set up, and the atom would approach the common centre of gravity in a spiral path. This would at once bring centrifugal force into play, and from the relation $f = \frac{V^2}{R}$ we know that the centrifugal force would rapidly increase as the atom approached the common centre of gravity. This would be true of all the atoms in the cluster. We see, therefore, that when equilibrium is reached there would be two forces operating against gravity, one due to repulsion between the atoms, the other due to centrifugal force.

169. In certain particulars in regard to the separation of the planets from the interior nebulous mass by ring formation, the method of evolution of planets and satellites as formulated by Laplace has been apparently successfully challenged by the mathematicians, but fundamentally the evidence in favor of the course of nebulous evolution is as good to-day as it ever was.

Whether the planets were thrown off from the central nebulous mass through the forces brought into play by the approach of some celestial body belonging to some other system, as Professor Chamberlain has suggested, or whether the separation was produced as Laplace supposed, while of the highest importance in the ascertainment of exact knowledge and truth, is a mere incident to the broader principles covered by the hypothesis. The scope of the present undertaking is to account for the creation of atoms and nebulæ, and for gravity itself, and ends where the nebular hypothesis begins.

Nor does the scope of the present undertaking trench upon the grounds occupied by Arrhenius in his "Worlds in the Making," in which he so forcibly marshals the evidence showing the manner in which worlds and suns in space are being built up from "cosmic dust," and old worlds and suns are going to their deaths and destruction—the evidence in favor of the endless cycle of Herbert Spencer. Arrhenius assumes that the ultimate material atoms are indestructible and always existed. Our present undertaking is to bring the atoms of matter within the cycle, and to marshal the evidence showing that matter begets matter, and that matter is at all times in process of creation, and is capable of being destroyed by the reverse of the forces and conditions which brought it into existence.

170. **Creation and Effect of Fields of Force.**—It will be remembered that in arriving at the formula for the wave-lengths of the Fraunhofer lines of the hydrogen atom

$$\lambda = 8\pi\left(\frac{R^2}{R^2-2V^2}\right) = 8\pi\left(\frac{R^2}{R^2-4}\right)$$

as we did in section 144, we assumed that the field in which the standard ether particles were set in revolution was the ordinary field of the ether structure, in which the flows in the stress-lines was the ordinary standard unit flow of the ether.

Suppose now we consider the conditions which would exist in the interior of a great cluster of primordial atoms formed and in process of formation. The opposition forces of gravity, repulsion, and centrifugal force would necessarily create great pressures between the atoms and tend to increase the velocity of revolution of the particles, and the intensity and velocity of the flows passing in the stress-lines within the field under consideration.

We would have conditions under which instead of the flow in the stress-lines being unity, the prime radius of the standard system, the velocity of the flow for that particular field would be some multiple of the prime radius 1, or would be based on some of the other prime radii corresponding to the side of some larger equilateral triangle or hexagon system and to the state of the pressure in that particular field.

We thus have the basis for the creation of elements of higher atomic weight than hydrogen, according to the state of pressure in the particular field in which the revolution of the standard particles is set up.

We have illustrations of the existence of such fields of force in miniature in the magnetic fields of force created by magnets or electrical currents. In the case of natural magnets the field of force is automatically maintained.

Magnetic Fields of Force.—It is generally considered established in the theory of electricity that in the phenomena exhibited by what we call the passage of a current through a wire, the path of the disturbance or of the electric particle is in fact a spiral around the wire, and that this disturbance takes place in the dialectic medium surrounding the wire, whether that dialectic be air, paraffin or other non-conducting material; at least the contact of the dialectic with the surface of the wire furnishes a line of least action which determines the path of the electric particle spirally around the wire. If we regard the electric particle as a particle of the second order, then one lap of the spiral around the circumference of the wire would represent a particle of the first order in respect thereto. Such a particle of the first order would be a force centre, from which radiations would be sent out in a plane at right angles to the direction of the wire, and this accounts for the so-called magnetic waves sent out in planes at right angles to a wire through which a current is passing.

Let us now refer to the phenomena explained in sections 79, 80, and Figure 26, and to save repetition we will suppose the reader has refreshed his mind as to what was there said. The rim ADCD of the section of the cylinder (Fig. 26) will represent one lap of the wire through which the current is passing around the cylinder. There are many laps of the spiral path of the particle in one lap of the wire around the cylinder.

Any lap of the spiral path of the electric particle as at M, acting as a force centre, will be sending radiations toward the centre O. Similarly every lap of the spiral path of the electric particle around the wire forming the circumference of one section of the cylinder will be sending radiations toward the centre O. Thus the entire interior of the section of the cylinder will be put under high pressure or created into a field of force, called a magnetic field of force, the strength of which will be dependent, among other things, upon the driving or electromotive force in the electric current passing through the wire. The pressure in the interior of the cylinder would be different from the standard pressure of the ether medium, and therefore the velocity of flow in the stress lines within the interior of the cylinder would not be the unit velocity flow represented by the side of the standard triangles of the ether structure, but would correspond to some one or other of the sides of the larger triangular systems which are fixed by the positions of the standard particles in the ether structure. See Figure 55, post page 274.

Under the conditions of the experiment the interior of the cylinder is filled with some material substance, such as water, bisulphide of carbon, or a gas. Whatever the substance used, it is composed of molecules, and these molecules are composed of atoms, and as a finality these atoms are composed of particles in ring motion, as in the case of the hydrogen atom.

Now when the radiations from each lap of the path of the electric particle are sent toward the centre of the section of the cylinder, they pass through the rings of the atoms of the particular material within, and necessarily affect the motions taking place therein. Moreover the flow of the current around the cylinder means the forceable moving of each lap of the spiral forward in the direction of the flow of the current. The radiations from the electric particles would therefore tend to set up revolution of substance within the cylinder. This revolution might be of all the substance within the section of the cylinder around the centre, as where the entire volume of water within a circular basin is set in motion by friction with its outer rim which is set in rotation; or the revolution set up might be of the molecules of the particular matter in the interior of the cylinder, each molecule merely turning on its own axis; or the rings of the atoms composing the molecules, acted upon by the repulsive effect of the radiations, may revolve the atoms about their centres. The phenomenon seems to show that the latter effect is what actually takes place.

This is shown by the fact that the particle KL, of polarized light, is revolved through the angle to the position K^1L^1, only when matter of some kind occupies the interior of the cylinder; and that the light-wave particle is moved by repulsion, would require radiations from particles of the same order of magnitude, which would only exist, under the circumstances, in the radiations from the particles of the lower orders of the rings of the atoms so set in revolution.

Now the radius of the light-wave particle KL will depend upon the color of the light which is used in the experiment. We may represent that radius by r, and if that particle be set to revolving as a particle of the second order around the centre O′, such that $O'J = R$, then in order that automatic action shall be maintained, we must have on the principles of section 141:

$$R = \frac{1}{r}$$

In which equation unity will represent the side of the triangular system fixed, among other things, by the electromotive force of the current. When that is known, and r is known, it fixes the value of R, that is to say, it fixes the length of the radii of the vortex motions which are set up in the interior of the cylinder.

There is room here for much experiment in order to determine the values of the constants which enter into any such phenomenon, but undoubtedly we have an explanation of magnetic fields of force, which must be substantially correct, and gives such an insight into the mechanism involved as has not heretofore been furnished.

Such a field of magnetic force ought to be a very appropriate laboratory in which the creation or transmutation of the chemical elements might be accomplished. Whether such a field could be created artificially of sufficient strength, and the mechanical connections made to accomplish the desired results, is another question.

170A. **Transmutation of Elements.**—Sir William Ramsey, by passing an electric current through a bulb containing only attenuated hydrogen gas, under test conditions, claims that he has accomplished the synthesis of Lithium, either from the hydrogen atom or from the electric current itself. If the results claimed be confirmed, the writer would infer that it was by setting in revolution the particular hexagon of the ether structure whose prime radius corresponds to the atomic weight of Lithium, although the presence of the hydrogen atoms may have been an essential of the process. We will refer to this correspondence later.

Recent chemistry assures us that the strongly radio-active elements, which all have the highest atomic weights of any of the elements, are in process of spontaneous disintegration. Uranium breaking up into radium and helium, and again radium into niton and helium, and lastly niton into helium and perhaps something else. We would naturally expect that the elements of highest atomic weights, which could only have been formed in the fields of force of the greatest strength, would, if any, be subject to spontaneous disintegration. We would also naturally conclude that if artificial synthesis of the elements can be brought about it would be as to those elements possessing the lowest atomic weights, because they are evidently formed in fields of force of lower strength.

It is not within the limits set for the present work to go into the treatment of all electric and magnetic phenomena. The application to them of the ideas herein advanced will not change the fundamental results of experiments which have become embodied in the settled formulæ of electrical science, but would interpret them under new mechanical concepts.

CHAPTER XXI

THE "HOT" FORM OF THE HYDROGEN ATOM

171. Let us return to a consideration of equation (11), section 145.

$$Z^2 = \frac{4R^4}{R^2V^2 - 2V^4} \tag{11}$$

in which Z is the velocity of progression of the light wave sent off by a standard particle revolving with radius R in a plane around a given centre with velocity V.

We have determined that, in order that automatic action shall be maintained solely by action of the standard unit flow at the centres of intake, we must have $V^2 = 2$.

It is one of the peculiar features of mathematical formulæ derived from the imposition of conditions prescribing one way in which the relations comprehended arise, that they frequently point out that there are other ways in which the same thing may be accomplished.

An inspection of (11) shows that there are two values of V^2 which will give the same value of Z^2. Let us therefore determine the other value of V^2 which pairs with the value $V^2 = 2$, and see under what conditions this other velocity of revolution can be maintained automatically.

Substituting in (11) the values $V^2 = 2$, we have

$$Z^2 = \frac{4R^4}{2R^2 - 8}$$

Equating this value of Z^2 with (11), we have

$$\frac{4R^4}{2R^2-8} = \frac{4R^4}{R^2V^2-2V^4}$$

r

$$V^4 - \frac{R^2V^2}{2} = -R^2 + 4$$

Solving by quadratics, we obtain the two values:

$$V_1^2 = 2 \tag{21}$$

$$V_2^2 = \frac{R^2}{2} - 2 \tag{22}$$

Since the sign of V merely indicates the direction in which he particle of the First Order is turning, we may conclude hat there are in fact but two different numerical values of which will give the same values of Z^2.

It will be noted that the second value of V is not inde- endent of R. We had, section 145, equation (14)

$$\lambda = 8\pi \left(\frac{R^2}{R^2 - 2V^2}\right) \tag{14}$$

ubstituting the value of V^2 from (22) in (14), we obtain

$$\lambda = 8\pi \frac{R^2}{4}$$

nd since (sec. 146) $8\pi = 3646.13 \times 10^{-8}$ cm., we have:

$$\lambda = 911.54R^2 \times 10^{-8} \text{ cm.} \tag{23}$$

It will be observed from (23) that the wave length of the ave sent off when the revolving particle has this second elocity *increases* directly as the square of the radius of evolution, whereas the wave length of the wave sent off hen $V = \sqrt{2}$, which corresponds to the wave lengths of he hydrogen spectrum equation (15), section 145, *decreases* s R increases.

From the facts referred to in section 84, it appears that whatever may be the number of rings in the hydrogen molecule, the retina of the eye is so constituted that it does not take cognizance, at least ordinarily, of any waves except those lying inclusively between the red and violet of the spectrum, the maximum of value λ given by Balmer's formula for the red being $\lambda = 6563.07$ when $R = 3$.

Nevertheless ("Baly Spectroscopy," p. 602), Paschen, by use of photography, has observed an infra-red line for hydrogen having the value

$$\lambda = 18751 \text{ approximately.}$$

Now if in equation (23) we substitute for R the values 2, 3, 4, 5 successively, we obtain

$$\begin{aligned} \lambda &= 3646.13 \\ \lambda &= 8203.86 \\ \lambda &= 14584.52 \\ \lambda &= 22788.50 \end{aligned}$$

It will be observed that 3646.13 is beyond the violet wavelengths on the one side, and 8203.86 is beyond the red on the other side of the visible spectrum.

We know that the heat rays are from the long wavelengths of the spectrum, and especially at the end of and beyond the red.

Assuming that the conditions could arise under which stability of form and automatic continuance of the motions taking place in the atom could be had with velocity $V^2 = \frac{R^2}{2} - 2$, it would mean that those conditions give rise to heat waves, and waves of longer length, electrical and magnetic waves.

It seems somewhat against preconceived notions that the heat rays are a result of a higher velocity of revolution of the particle than light rays. The order of succession, in observed phenomena, is that matter gets hot, then red-hot, and then breaks into incandescence.

We must remember, however, that the molecules of ordinary matter are held together under great pressure by the force of gravity. The first work done in the application of energy (by heating or otherwise) to ordinary matter is to separate the molecules, and necessarily a large number of the independent atoms are set free, and as a consequence the velocity may be decreased to the normal value $V = \sqrt{2}$, at which reduced velocity we get the light effect.

If in the expression $V^2 = \frac{R^2}{2} - 2$ we make $R = 2$ we have $V = 0$. But $V = 0$ means that the particle in the ring with radius 2 is not revolving at all, and the energy of the particle would have returned to the regular rate of flow of the stress lines of the ether, which is what we denominate the absolute "cold" of outer space.

172. Let us consider in what way the mechanism of our revolving particle could be so affected that a velocity of revolution given by $V^2 = \frac{R^2}{2} - 2$ could be imparted to it and automatic action be still maintained.

Suppose that the particle of the First Order now under consideration is situate in a field in which it is surrounded by a great cluster of similar particles formed and in process of forming. Such a field would be presented in the exterior of a nebula, in exterior portions of a cooling sun, or in an ordinary flame or magnetic field, the amount of gravitational or other pressure varying according to the conditions. Under such conditions the pressure due to reaction between the atoms of the cluster would be great.

Since velocity increases with the force applied, and since from the expression $V^2 = \frac{R^2}{2} - 2$ we see that V increases with R, it follows that particles revolving in the rings of small radius would take on the velocity $V^2 = \frac{R^2}{2} - 2$ much sooner than those revolving in the rings of larger radius, and there would be a growth of the acquired velocity from the interior rings outward toward the limit of the particle rings fixed by the ether structure.

We may place the expression for this new velocity under the form

$$V = \sqrt{\frac{R^2 - 4}{2}} \tag{24}$$

173. Let us now interpret the motions indicated by the above expression for the velocity of revolution in the light of the double particle motion.

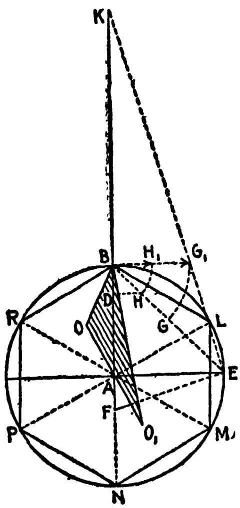

Figure 52

Suppose the line OO_1 (Fig. 52) is drawn through A, perpendicular to the plane of the paper, and that $OA = O_1A = 2$. We can express the idea that these distances are measured at right angles to the plane of the paper by putting

$$OA = \quad 2\sqrt{-1}$$
$$O_1A = -2\sqrt{-1}$$

We are supposed to be seeing the triangle OBO_1 in perspective.

Suppose that there are two standard particles in contact at B, which had been previously revolving around O and O_1, and each of which at the instant of contact would be traveling in the line BH_1, which would be in the plane of the paper, and tangent at B both to radii BO and BO_1. By reason of the contact, the flows in OB and O_1B

to the two particles would brace them laterally, and the two particles would together revolve in the circle BLMNPQ around the new centre A in the plane of the paper. Nevertheless, each would maintain its radial distance BO and BO_1, respectively, from O and O_1.

We may put $BO = BO_1 = R$ and $BA = m$.

Since BAO is a right angle

$$BA^2 = BO^2 - OA^2$$

or

$$m^2 = R^2 - 4$$

$$m = \sqrt{R^2 - 4}$$

From the right angle triangle BAE we have

$$BE^2 = 2m^2$$

$$BE = m\sqrt{2}$$

If

$$BD = BH = 1$$

then

$$BH_1 = BH = \sqrt{2BD^2} = \sqrt{2},$$

would represent, as we have heretofore seen, the velocity at which a single particle would require to move in order to maintain automatic action, whatever may be the radius AB of revolution.

Take

$$BG = \frac{BE}{2} = \frac{m\sqrt{2}}{2}$$

$$BG = \frac{\sqrt{2}}{2}\sqrt{R^2 - 4} = \sqrt{\frac{R^2 - 4}{2}}$$

Lay off $BG_1 = BG = V$, and we have

$V = \sqrt{\frac{R^2 - 4}{2}}$, which gives the construction of (24), and BG_1 represents the tangential velocity of the double particle at B when revolving at B, or in other words, the velocity of the particles when giving off heat waves.

If the flows take place from A to O and to O_1 respectively, then

$$\text{Linear pressure in BAO} = m + 2\sqrt{-1}$$
$$\text{Linear pressure in } BAO_1 = m - 2\sqrt{-1}$$

And the combined or areal pressure P due to the two particles will be

$$P = (m + 2\sqrt{-1})\ (m - 2\sqrt{-1})$$

or $$P = m^2 + 4$$

Lay off $AF = 1$, and construct the right angle triangle FEK cutting AB extended at K.

then $$AF \times AK = AE^2 = AB^2$$
or $$AK = m^2$$
$$AK + 4 = m^2 + 4 = R^2 = P$$

That is to say, the pressure of the flow through the centre A would be the same for the double particles revolving around A, with radius $AB = m$, as is represented in a continuous linear flow from KA, on the principles of section 132, and is equivalent to the square of $BO = BO_1$, the radius with which the particles are revolving around the centres O and O_1.

174. The foregoing considerations, taken in connection with those discussed in chapters xiv and xxi, lead toward the following conclusions:

(a) That the hydrogen atom in its primordial form is composed of a succession of rings the radii of which commencing at the inferior limit 2 increase by unity outward toward an exterior limit.

(b) That in the double particle construction formed under pressure, it is disk shaped, the length of the axis of the disk being 4 standard units, and its radius measured from the centre of the axis to the outer ring is $24\sqrt{3}$ units, and that in that form, the flows from the centre, on which its atomic weight and gravitational influence depend, are the same as if it was composed of $(24\sqrt{3})^2 + 4$ or 1732 rings, and the revolution was in one plane.

(c) That in a field of pressure the minimum pressure would be attained when several of these disks were forced into each other so as to become concentric, and the most simple form which would accord with the symmetry which

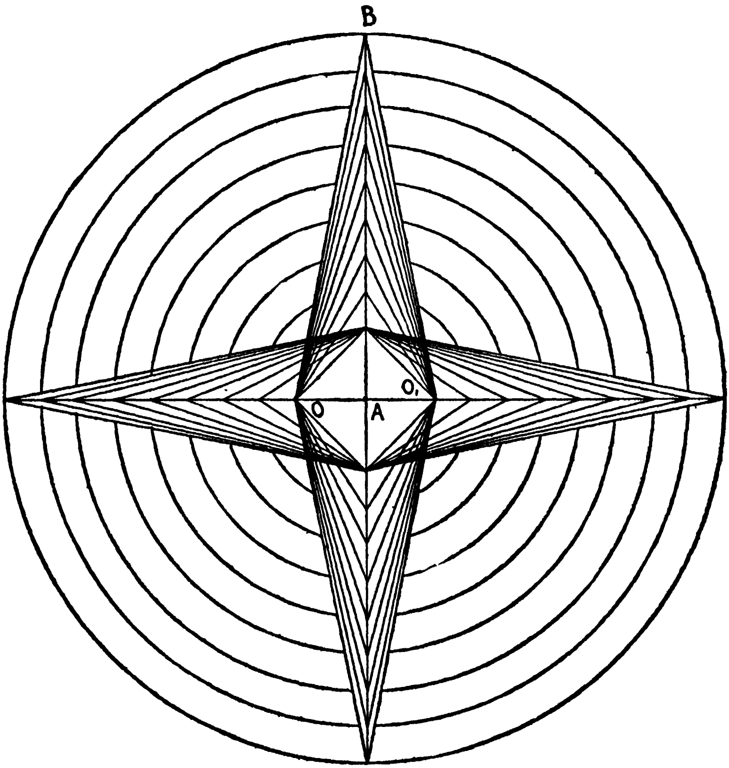

Figure 53

would be enforced by the repulsion of its particles of the Second and Third Orders indicates that the complete atom would be composed of three concentric disks, the central planes of which would be at right angles to each other. The general result would be spherical and give the fluid effect.

Subject to the variations which might occur by reason of the number and position of the disks forced into symmetrical concentric positions as indicated in section 169, the general form of the complete combination atom may be represented in cross section as two disks, and side view as to the other disk by Figure 53. The central planes of the three disks are placed at right angles to each other.

For the hydrogen atom $AB = 24\sqrt{3}$, and $OB^2 = AB^2 + OA^2 = 1728 + 4 = 1732 = R^2$.

(d) If by any means (cooling) the internal energy be extracted from the fluid atom while the external pressure is increased, we can conceive that the path of the standard particles rėvolving around the centre A (Fig. 52) might be changed from the circular into the periphery of the hexagon BLMNPR, and so that its velocity $V = BL = R$.

From what we know of crystalline structure, and from the analogy of the flows which take place in the sides of the standard equilateral triangles or hexagons of the ether structure, where $R = 1$ and $V = 1$, there is strong reason for believing that in the solid state of the hydrogen atom the particle is moving in the nature of a flow in the side of the hexagon formed on $AB = \sqrt{R^2 - 4}$, with velocity $V = \sqrt{R^2 - 4}$. But $BL = R$ is greater than $BG_1 = \sqrt{\frac{R^2 - 4}{2}}$.

If we substitute for V_1 the value $V_1 = R$ in equation (14), section 138, we get

$$\lambda = -8\pi$$

and if we substitute for the value $V_1 = R$ in equation (11), of section 138, we get

$$Z = \pm 2\sqrt{-1}$$

in which Z represents the velocity of progression of the wave sent off.

This would indicate that in the solid form the direction of the flows out of the particle of the second order heretofore considered are reversed.

The foregoing discussion of the hot form of the hydrogen atom is to a certain extent speculative, and therefore we regard it as subject to modification, but it indicates a line of investigation which promises more certain results in regard to the conditions under which the liquid and solid forms are produced.

CHAPTER XXII

THE ATOMIC WEIGHTS OF THE ELEMENTS. THE PERIODIC LAW

175. From the time of John Dalton's investigations and discoveries in the beginning of the last century, our chemists have been engaged in the discovery of new chemical elements and in the determination of their respective atomic weights. The element of the smallest weight, hydrogen, being taken as unity, the relative weights of the other known elements were determined with a fair degree of accuracy from the proportions in which any two elements combined and from the proportion of one element which was required in chemical reactions to replace any other element in a compound of two elements.

William Prout advanced the hypothesis that all the other elements were made up of condensed hydrogen. This view was largely accepted in the scientific world until more exact methods of determining the atomic weights showed that the atomic weights of a very large number of the elements were not exact multiples of the atomic weight of the hydrogen atom. Thus, for instance, most of the text books of even the latter part of the last century, on the basis of the atomic weight of hydrogen being taken as unity, gave the atomic weight of oxygen as exactly 16. It has since been determined by a very large number of different investigators and by different methods that the true atomic weight of oxygen is 15.87 on the basis of hydrogen 1 (Ostwald). The facts to which we above alluded led a great many thinkers to the conclusion that while all the other elements might not be made up of hydrogen atoms, that the probability is that all the elements including hydrogen are made up of specially arranged clusters of some primordial atom, perhaps very many times smaller than even the hydrogen atom. The breaking up of the recognized chemical elements into any smaller particles, however, defied all chemical processes, and the indestructibility of the recognized chemical elements became an accepted dogma of our text books. Indeed, for any thinker to seriously advance the idea that man might yet be able to bring about a transmutation of one element into another in those days would have at once placed him in the class of the cranks who were endeavoring to construct what was then regarded as such an impossible thing as a flying machine.

Later investigations brought to the knowledge of the scientists that if instead of comparing the atomic weights of all the other elements with hydrogen as unity, which makes oxygen 15.87, we take the atomic weight of oxygen at 16, which would make the hydrogen atom 1.008 +, that a larger number of the atomic weights of the elements as then determined would be expressed in exact whole numbers. It was not believed that this was a mere coincidence, but that it was due to some fundamental relationship in the structure of the elemental atoms themselves.

For this reason there came into use two methods of expressing the relative atomic weights of the elements, one based on the hydrogen atom as unity, which makes oxygen 15.87, and the other system based on hydrogen as 1.0008 + equivalent to oxygen 16.

Notwithstanding the improved methods of the last few years, on account of the difficulties involved, especially in reference to the determination of the atomic weights of certain of the elements, new research and experiment are continually causing the chemists to change their tables of atomic weights. These changes in the last few years in the main have been but slight. On this subject, Dr. Ostwald, in his article on the elements in the Enc. Brit., 11th ed., says:

"These numbers undergo incessant small variations because of new work done for their determination. To avoid the uncertainty arising from this inevitable state of affairs an international committee was formed by the coöperation of the leading chemical societies all over the world, and an international table of the most probable values is issued every year."

176. **Triads of Dobereiner.**—Early in the last century J. W. Dobereiner of Jena noticed that certain of the chemical elements arranged in triads possessed very similar properties, and their atomic weights were in certain peculiar mathematical relations to each other. Thus the triad elements calcium, strontium and barium are very similar in their chemical properties.

The same is true of the triad elements chlorine, bromine and iodine.

The same is also true of the triad elements sulphur, selenium and tellurium.

According to the International atomic weights for 1913, on the basis of oxygen 16, the atomic weights of the above elements are as follows:

Calcium	40.07	Chlorine	35.46	Sulphur	32.07
Strontium	87.63	Bromine	79.92	Selenium	79.02
Barium	137.37	Iodine	126.92	Tellurium	127.5

The atomic weights of the middle element in each triad is approximately the arithmetical mean of the other two. Thus

$$\frac{40.07 + 137.37}{2} = 88.72$$

$$\frac{35.46 + 126.92}{2} = 81.19$$

$$\frac{32.07 + 127.5}{2} = 79.78$$

FIGURE 54. TABLE OF THE PERIODIC LAW. MENDELEEFF 1904 (ATOMIC WEIGHTS 1913—O = 16)

Series	Zero Group	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII			
0												
1		Hydrogen 1.008										
2	Helium 3.99	Lithium 6.94	Beryllium 9.1	Boron 11	Carbon 12	Nitrogen 14.01	Oxygen 16	Fluorine 19				
3	Neon 20.2	Sodium 23	Magnesium 24.32	Aluminum 27.1	Silicon 28 3	Phosphorus 31.04	Sulphur 32.07	Chlorine 35 46				
4	Argon 39.88	Potassium 39.10	Calcium 40.07	Scandium 44 1	Titanium 48.1	Vanadium 51.	Chromium 52.	Mangenese 54.93	Iron 55.84	Nickel 58.68	Cobalt 58.97	Copper 63.57
5		(Copper) 63.57	Zinc 65.37	Gallium 69.9	Germanium 72.5	Arsenic 74.96	Selenium 79 2	Bromine 79.92				
6	Krypton 82.92	Rubidium 85.45	Strontium 87.63	Yttrium 89.	Zirconium 90.6	Columbium 93.5	Molybdenum 96		Ruthenium 101.7	Rhodium 102.9	Palladium 106.7	Silver 107.88
7		(Silver) 107.88	Cadmium 112.40	Indium 114.8	Tin 119.	Antimony 120.2	Tellurium 127.5	Iodine 126.92				
8	Xenon 130.2	Caesium 132.81	Barium 137.37	Lanthanum 139.	Cerium 140.25							
9												
10				Itterbium 172.		Tantalum 181.5	Tungsten 184.		Osmium 190 9	Iridium 193.1	Platimum 195.2	Gold 197.2
11		(Gold) 197.2	Mercury 200.6	Thallium 204.	Lead 207.1	Bismuth 208.						
12			Radium 226.4		Thorium 232.4		Uranium 239.5					

177. Newlands' Series of Sevens.—In 1863 J. A. R. Newlands pointed out that if commencing with the atomic weight of hydrogen as 1, the chemical elements be arranged in an ascending series according to their successive atomic weights, placing the elements which had similar properties under each other, they naturally arranged themselves in series of sevens. That is to say, the successive members of the same group of similar elements are recurrent as the octaves in music. Lothar Meyer and Mendeleeff still further developed these and similar relationships, and demonstrated the proposition that:

"The properties of an element are a periodic function of its atomic weight."

178. Table of the Periodic Law.—The table, Figure 54, gives the arrangement of the then known elements, as placed by Mendeleeff in 1904, but the atomic weights have been made to conform to the determinations as given in the "International Atomic Weights" for 1913, on the basis of $O = 16$.

The following rare or recently discovered elements are not included in the table but would naturally fill in appropriate vacancies in the groups.

Phaseodymium 140.6, *Neodymium* 144.3, *Samarium* 150.4, *Europium* 152, *Gadolinum* 157.3, *Dysprosium* 162.5, *Holmium* 163.5, *Eubium* 167.7, *Thulium* 168.5, *Luticium* 174, *Niton* (Radium emanation) 222.4.

It will be observed from the table that the elements are arranged in horizontal lines called series, and in vertical columns called groups.

The column of the "Zero" group contains those elements, Helium, Neon, Argon, Krypton, and Xenon which absolutely refuse to enter into chemical composition with any of the elements of that or any other group.

The Hydrogen heads Group 1, but it stands in a series all by itself. It will be noticed that Newlands' series of "sevens" runs through the whole table, but in the fourth series, a new group called "Group 8" commences.

In general it may be said that:

"The actual position of any one element in the table is fixed solely by the weight of its atom; and once so fixed, its other properties follow as a matter of necessity from its series and group relations."

This may not be strictly true, because we are not quite sure of the absolute accuracy of the determination of the atomic weights of all the elements. For instance, the table of International Atomic Weights for 1913 gives Tellurium 127.5, Iodine 126.92, a slight change from former values, which would make the two swap places in Groups 6 and 7. This seems to be one exception to the general law, but it may be that there has been some slight error in the determination of the atomic weights of either one or both of those elements, or there may be some special cause operating to bring about that result which makes the exception to the law.

It is one of the statements of the law that the elements whose places in the table lie in one horizontal line or "series," although they vary step by step, are yet markedly different from each other.

On the other hand the elements whose place lie in the same vertical column or group, while they vary progressively from top to bottom of the column, yet they very closely resemble each other and are of the same type.

Again it is one of the statements of the law that each group may be divided into two sub-groups, in which the resemblance between the members of each sub-group is still more striking.

Thus, Group 3 may be divided into two sub-groups as follows:

Sub-group A	*Sub-group B*
Calcium	Beryllium
Strontium	Magnesium
Barium	Zinc
	Cadmium

Group 7, known as the family of the Halogens, is divided into two sub-groups as follows:

Sub-group A	*Sub-group B*
Fluorine	Manganese
Chlorine	Samarium
Bromine	
Iodine	

In the language of Prof. R. Kennedy Duncan in "New Knowledge,"

"If fluorine will do a certain thing, chlorine will do it more, bromine still more, and iodine most. Or it may be the other way: if fluorine will do a certain thing, chlorine will do it less, bromine still less, and iodine least of all. The important thing is that as the elements vary, they vary progressively in steps as the atomic weight rises. . . .

"Now what holds good for Groups 2 and 7, holds equally good for every other group of the system. As a matter of fact, the elements of matter fall naturally into a series of groups. Each group falls naturally into two sub-groups, which have in certain properties an unmistakable relation to each other, while the constituent members of each sub-group resemble each other to an extent so remarkable that in general terms it may be said that what one will do the others will do, and that in their very differences they vary progressively in different steps. Furthermore, all these relations are true because of the law that the properties of an element are a periodic function of its atomic weight."

When Mendeleeff first announced the periodic law, the spaces in this table now filled by scandium, gallium and germanium were not filled, because the existence of those elements was not then known. But on the basis of this law he predicted in 1871 that such elements would be discovered, and what the atomic weight of each would be, and the chemical properties each would have.

In 1875 gallium was discovered in France; in 1879 Scandium in Scandinavia, and 1886 Germanium in Germany, and each had the respective atomic weights and properties so predicted by Mendeleeff.

179. It looks as if the truth of the law could not be more firmly established, and yet there are evidently irregularities in its operation which are not yet explained.

Dr. Ostwald in his article on the elements (Enc. Brit., 11th ed.) says:

"Upon closer investigation, it must be confessed that these regularities can be called only rules and not laws. In the first line one would expect that the steps in the values of the atomic weights should be regular, but it is not so. There are even cases when it is necessary to invert the order of the atomic weights to satisfy the chemical necessities. Thus argon has a larger number than potassium, but must precede it in order to fit into its proper place. The same is true of tellurium and iodine. . . . It looks as if some very important factor regulating the whole matter is still unknown, and before this has been elucidated no satisfactory treatment of the matter is possible."

Notwithstanding the above, we agree with Professor Duncan that Mendeleeff and others, working on the same lines, have established the general truth of the law beyond question. They have failed, however, to get at the fundamental reasons for the existence of the law, and therefore are unable to explain the " perturbations " which appear in the operation of the law.

We shall endeavor later on to elucidate an "important factor" which ought to regulate the whole matter, feeling assured that in the end it can be used to clear up all the problems of the "Periodic Law," although we may not be able to accomplish so much within the scope of our present undertaking.

CHAPTER XXIII

THE ATOMIC WEIGHTS OF THE CHEMICAL ELEMENTS ARE CLOSE MULTIPLES OF THE PRIME RADII OF THE HEXAGONS OF THE ETHER STRUCTURE WHOSE PRIME RADII LIE BETWEEN 1 AND 7

180. In Figure 55 we have represented the standard triangular system of the ether structure, and have drawn a few of the successive hexagons of the ascending series in relation to the central position O, commencing with the standard hexagon $A_1B_1C_1D_1E_1F_1$ the side A_1B_1 or radius OA_1 of which represented by R_1 we take as equal to unity.

Since the side of each hexagon is exactly equal to its radius (what would be the radius of the circumscribed circle) we can select these radii by inspection, and easily calculate their lengths. Also since the figures are hexagons, each one of them is obliged to have at least one corner lying within the sixty degree angle AOB.

Within that angle, as we pass outward from O every standard particle successive in distance from O, and at the corners of the equilateral triangles, forms one of the six corners of a new hexagon. We have only to compute the distances from O to these respective positions of the standard particles to obtain the radii of the respective ascending hexagons. It will be observed that the radii of most of the larger hexagons are simple multiples of some one or other of the radii of the smaller hexagons. Thus for instance, the radius of the hexagon of which G_2H_2 is the side, is $OG_2 = 2OG_1$. If we take $OA_1 = R_1 = 1$, the lengths of the radii for the successive hexagons are easily computed from the right angle triangle formations, and are as follows up to the point given:

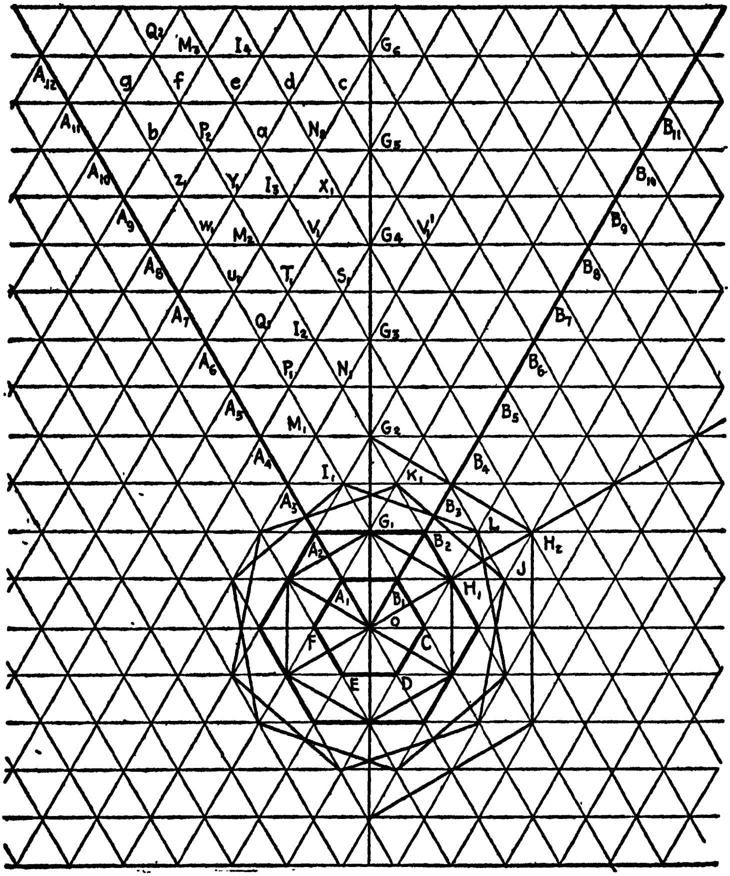

Figure 55

$$OA_1 = R_1 = 1$$
$$OG_1 = R_2 = \sqrt{(2)^2 - (1)^2} = \sqrt{3} = 1.7320508$$
$$OA_2 = R_3 = 2 = 2.$$
$$OI_1 = R_4 = \quad = \sqrt{7} = 2.6457513$$

$OK_1 = OI_1$ (double hexagon)			
$OA_3 = R_5$		$= 3.$	
$OG_2 = R_6 = 2R_2$	$= 2\sqrt{3}$	$= 3.4641016$	
$OM_1 = R_7$	$= \sqrt{13}$	$= 3.6055513$	(double hexagon)
$OA_4 = R_8$	$= 4$	$= 4.$	
$ON_1 = R_9$	$= \sqrt{19}$	$= 4.3588989$	(double hexagon)
$OP_1 = R_{10}$	$= \sqrt{21}$	$= 4.5825757$	(double hexagon)
$OA_5 = R_{11}$	$= 5$	$= 5.$	
$OG_3 = R_{12} = 3R_2$	$= 3\sqrt{3}$	$= 5.1961524$	
$OI_2 = R_{13} = 2R_4$	$= 2\sqrt{7}$	$= 5.2915026$	(double hexagon)
$OQ_1 = R_{14} =$	$= \sqrt{31}$	$= 5.5677644$	(double hexagon)
$OA_6 = R_{15} =$	$= 6$	$= 6.$	
$OS_1 = R_{16} =$	$= \sqrt{37}$	$= 6.0827625$	(double hexagon)
$OT_1 = R_{17} =$	$= \sqrt{39}$	$= 6.2449980$	(double hexagon)
$OU_1 = R_{18} =$	$= \sqrt{43}$	$= 6.5574385$	(double hexagon)
$OG_4 = R_{19} = 4R_2$	$= 4\sqrt{3}$	$= 6.9282032$	
$OV_1 = R_{20} =$	$=$	$= 7.$	(triple hexagon)
$OV_1 = R_{20} =$	$=$	$= 7.$	
$OA_7 = R_{20} =$	$=$	$= 7.$	

It will be observed that when we reach the magic number seven we have the coincidence of a triple system of hexagons of the same radius. And this does not occur again except in multiples of seven.

Of course all the hexagons which have sides the lengths of which are expressed by integers have radii which are multiples of the radius of the standard hexagon, because the radius of that is unity. The prime radii will be those which are not multiples of the preceding ones, and selected from the above are as follows:

TABLE OF PRIME RADII

$OA_1 = R_1 =$	$= 1.$	(single hexagons)
$OG_1 = R_2 =$	$= 1.73205$	(single hexagons)
$OI_1 = R_4 =$	$= 2.64575$	(double hexagons)
$OM_1 = R_7 =$	$= 3.60555$	(double hexagons)
$ON_1 = R_9 =$	$= 4.3589$	(double hexagons)
$OP_1 = R_{10} =$	$= 4.58257$	(double hexagons)
$OQ_1 = R_{14} =$	$= 5.56776$	(double hexagons)
$OS_1 = R_{16} =$	$= 6.0827$	(double hexagons)
$OT_1 = R_{17} =$	$= 6.245$	(double hexagons)
$OU_1 = R_{18} =$	$= 6.5574$	(double hexagons)
$OX_1 = R_{19} =$	$= 7.8102$	(double hexagons)

$OY_1 = R_{20} =$	$= 8.1854$	(double hexagons)
$OZ_1 = R_{21} =$	$= 8.544$	(double hexagons)
$Oa = R_{22} =$	$= 8.888$	(double hexagons)
$Ob = R_{23} =$	$= 9.5394$	Quadruple hexagons
$Oc = R_{23} =$	$= 9.5394$	
$Od = R_{24} =$	$= 9.8488$	(double hexagons)

For present purposes it is not necessary to carry the computation of all the possible hexagons further, because, as we shall see later, the atomic weights of all the known elements of matter are either exact multiples of the lengths of the prime radii of some one or other of the first few hexagons occurring between the ranges of radius 1 and radius 7, or approximate to that result so closely that it does not seem possible that it should be a mere coincidence.

Before we pass on to that crucial test, there are one or two points well to be borne in mind.

181. Consider first the motion which must take place if a standard particle at the corner of the hexagon of the first higher order whose side is G_1H_1 is set in revolution in such a way that the standard particle is forced to travel in the line G_1H_1. We could conceive that, with a moderate amount of compression and pressure, that would take place, because G_1H_1 is a line of flow of the next order below the standard lines of flow represented by the sides of the standard equilateral triangles.

So again, if a standard particle at the corner of the hexagon whose side is G_2H_2 is set in revolution, so that the standard particle is forced to travel in G_2H_2, that being a line of flow of precisely the same order as G_1H_1, there would be no more difficulty in that case than in the other. The same would be true of any of the ascending hexagons whose radii are multiples of the radius of the hexagon whose side is G_1H_1, or radius OG_1.

Whether the revolution of the particle be strictly in the side of the hexagon considered, or be in a circular path based on the radius of the hexagon, the facility of motion of the particle would be influenced by the state of pressure in the stress lines to which that path approximates.

Again, let us consider the case of the hexagons whose radii are respectively OI, OM_1, ON_1, OP_1, OQ, OU_1, OW_1. All of these radii lie in the lines of flow of successively lower orders below the order of the line of flow to which G_1H_1 belongs. The same is true of the *sides* of the hexagons to which the above radii belong. It follows that it becomes more and more difficult to force the standard particles to travel through these "tubes of flow" as the length of the radius is increased, unless the radius of increased length is a multiple of the radius of a smaller hexagon of the ether structure.

Therefore we would naturally expect that, in the processes by which the different elements of matter are formed from the ether, through the operation of successively higher fields of pressure (sec. 170), the atoms of short radius and therefore of lightest weight would be formed first, and be found to exist in the greatest abundance. Also that as standard particles at the corner of hexagons of larger radius are set in revolution, their radii of revolution would be multiples of the radii of some one or other of the smaller hexagons. It must be borne in mind that, when revolution is set up, it must be maintained automatically by the regular flow of energy in the standard stress lines of the ether structure, and this is the circumstance which makes the radius of the atom definitely conform to the radius of some hexagon of the ether structure.

182. Atomic Weights of the Elements Based Upon the Atomic Weight of the Electron.—We have therefore seen (sec. 158) that the flow which is given off from the centre of the electron or corpuscle, upon which its gravitational effect depends, is the unit flow of the standard stress lines of the ether structure, and that the flow from the centre of the hydrogen atom upon which its gravitational effect depends is $1728 + 4 = 1732$.

We may represent the atomic weight of the electron by $OA_1 = R_1 = 1$; the atomic weight of the hydrogen atom will be 1×1732.

The atomic weight of oxygen on the basis of hydrogen $= 1$ is 15.87.

Turning to our table of prime hexagon radii (sec. 180) we see that $R_4 = \sqrt{7}$, and $6\sqrt{7} = 15.87$. So that the atomic weight of oxygen based upon the electron as unity would be $1732 \times 6R_4 = 1732 \times 15.87$.

Whether the exactness of this correspondence is due to the fact that the atomic weight of oxygen has been determined with greater nicety and certainty than that of any other element (sec. 175) or whether to some other cause, the close correspondence between the atomic weights of all the other elements and some multiple of some one or other of the first few prime radii of the ascending series of hexagons, taken in connection with the fact that Balmer's formula with a mere change of constants has been shown to be applicable to the spectra of the other elements besides hydrogen, would seem to point conclusively to the fact that the correspondence is not mere coincidence.

If the experimental determinations of the atomic weights of all the elements were more certain, we could be more certain of our conclusions as to the particular prime radius upon which a particular atomic weight is based.

In most instances the atomic weights correspond closely to the multiples of more than one prime radius. Indeed coincidences in the multiple radii would seem to be a determining factor in fixing the radial limit of the atom, and therefore its atomic weight. Such a correspondence in multiple radii would imply that the standard particle revolving with that radius would have to pass through more than the regular number of hexagon corners, and this would subject the particle revolving in that ring to a different kind of acceleration from the particles revolving in corresponding interior rings, and tend to fix the limit of the atom at that exterior radius.

In the appendix (sec. 203) will be found a table of the International Atomic weights for 1914, in which the values of the multiple radii corresponding are shown.

183. There are certain of the elements whose atomic weights do not appear to be constructed on the same basic principle as the hydrogen atom.

It will be recalled by reference to section 154, that the maximum radius of the hydrogen atom was fixed by a coincidence between its particles of the Second Order (Fig. 47) by which their particles of the Third Order come into collision with particles of the ether structure.

By reference to section 152 it will be recalled that where the particles were revolving around centres distant two units apart and lying in the plane of revolution, there were exact coincidences between the centres of the particles of the Second Order when $R=4$ and $R=14$.

These values correspond to the atomic weights respectively of Helium, which belongs to the zero group of elements, having no combining power, and of Nitrogen, which has little combining power.

The members of the zero group other than Helium have the following atomic weights according to the 1914 table of atomic weights based on hydrogen $=1$, to wit, Neon 20.2, Argon 39.88, Krypton 82.92, Xenon 130.2. These are not exact multiples of either 4 or 14. Whether they are atoms formed on a triangular base of 1 instead of 2 as discussed in section 153, or on a triangular base of 4 instead of 2 as discussed in section 153, might be worth while considering.

184. This subject deserves a much more extended investigation than the writer could give it. The big proposition

which we have demonstrated is that we have in the ether structure itself the basis for the creation of the different chemical elements and for the determination of their atomic weights based on that structure; the determination of details will come when further investigations are made and the results systematized.

The writer has deemed it more important to give others the benefit of the results so far obtained than to attempt to do more at this time.

CHAPTER XXIV

RÉSUMÉ

185. The reader has had presented the evidence, which to the writer seems conclusive, of the distribution of stars through an unlimited universe. Each of the stars, like our Sun, is radiating light waves in every direction through space, and, at infinite distances from their sources, all rays from neighboring sources, coming into any finite field, must proceed in parallel lines, and become by composition and diminution of amplitude invisible force rays.

We reached the conclusion that to determine the normal condition of the ether, the influence of rays proceeding from nearby suns and stars must be eliminated from consideration, as we would eliminate the waves from a passing steamer if we were studying the effect of tidal waves on the surface of the ocean.

We reached the conclusion that the invisible force rays, coming into any given finite space, from every direction from the stars scattered with an average distribution in infinity, must, by reason of lateral pressure, organize the ether structure in systems of standard equilateral triangles arranged in planes. The sides of the equilateral triangles are formed by the stream lines passing in opposite directions. There is a uniform constant standard flow of energy through the sides of the triangles passing in throbs, and supplied by radiations from the stars in infinity. At the corners of these triangles are situate normally the stationary waves formed by the flows passing in opposite directions through the stream lines or stress lines of the ether structure.

These stationary waves at the corners of the standard triangles are ether particles of standard size under normal conditions.

186. The ether particle in its simplest form we have found to consist of an "eddy" or "whirl" of substance, the centre of which is itself revolving around a centre, the whole thus forming a particle of the First Order. The "eddy" or "whirl" is a particle of the Second Order. It consists, in the same way, of a particle of the Third Order, or still smaller whirl, revolving around the centre of the particle of the Second Order. The particle of the Third Order consists of a still smaller particle of the Fourth Order revolving around the centre of the particle of the Third Order, etc., etc., to the infinitesimal.

We have demonstrated that, in order that autonomy of the particle shall be maintained, the radii of particles of the successive orders which enter into its structure must bear certain definite relations to each other. We have shown that the radius of the particle of the Second Order must be normally the reciprocal of the radius of the particle of the First Order. The radius of the particle of the Third Order must be the reciprocal of the cube of the particle of the First Order.

187. We have shown that, besides the standard system of equilateral triangles formed by the flows of energy from infinity, and passing in the standard stress lines, there are a succession of lower orders of stress lines, forming lower orders of successively smaller equilateral triangles in the ether structure.

As we consider them in succession, a lower equilateral triangle system bears a certain definite relation to the equilateral triangle system above it, as well in the length of the triangle side as in position.

We found that the standard equilateral triangle formation of the ether, when considered from any point at which six triangles "corner," as a centre, naturally arranges the structure in systems of hexagons, the successive hexagons having longer radii as we proceed outward from the given point taken as the centre, and each hexagon having but six standard particles in its periphery.

188. We have been able to show from certain phenomena that local causes, such as radiations from nearby luminous matter, or magnetic forces, are capable of setting the standard particles in any given hexagon in revolution around the centre of the hexagon, and we were able to determine the conditions under which, when such revolution is once set up, automatic action will be maintained by the constant flow of energy coming from infinity and passing through the standard stress lines.

We have been able to determine from the equations of light wave motion, the wave lengths of the waves which would be sent off by standard particles set in revolution around the centre of a hexagon of any given radius, and we have demonstrated that such wave length is given by the formula

$$\lambda = 8\pi\left(\frac{R^2}{R^2 - 4}\right)$$

We found this exactly agrees with the empirical formula derived by Balmer, expressive of the relationship existing between the wave lengths of light at the different successive Fraunhofer lines in the spectrum of the hydrogen atom, when we substitute for R in the formula, the successive numerals 3, 4, 5, 6, 7, etc., etc., for the 29 known Fraunhofer lines of the hydrogen spectrum, and when we substitute for 8π the value of 3646.13×10^{-8} cm.

We were able to determine that the length of the side of the standard equilateral triangle of the ether structure is 147.07×10^{-8} cm.

189. Newton was never able to explain the why of gravi-

tation, but when he had worked out the existence of the law, and applied it to the determination of the positions of the seven planets in their orbits at given times, and found the results reached answered to the theory, he considered this a demonstration of what we now recognize as a law.

We have found on our theory of the ether structure, that the atoms formed by standard particles in the periphery of the successive hexagons of the ether structure, having radii increased by the unit length of the side of the standard equilateral triangle, will, when revolving automatically, send off light waves having wave lengths corresponding to the wave lengths of light for the 29 known Fraunhofer lines of the hydrogen spectrum, and with a degree of exactness which eliminates any mere chance of coincidence. It would seem that we are entitled to claim a demonstration of the fundamental proposition.

190. From the successive ring formation of the atom we were able to arrive at a very simple explanation of the reason for the law of gravitation on simple mechanical principles, and to show why two atoms of matter attract, or behave as if they attract, each other, and why the more simple ether particles do not attract, and are not attracted, by each other or by matter.

191. We have been able to arrive at a very simple explanation of electricity on mechanical principles, and to show how electrons are created by setting standard ether particles in revolution in one ring, and to show that the calculated gravitational effect would be $\frac{1}{1732}$ part of that of the hydrogen atom, which corresponds to the experimental determinations with reasonable exactness, allowing for experimental error.

We found that the maximum radius of the hydrogen atom is $(24\sqrt{3})^2 + 4 = 1728 + 4 = 1732$. That is to say, that the gravitational effect of the hydrogen atom is the same as if it were composed of 1728 rings with the usual six standard particles revolving in each ring.

192. We have found that in the ether structure, besides the system of hexagons having radii increasing by unity, there are other similar hexagon systems based on prime radii having certain definite relations to the radius of the hexagon of unit length, and that the atomic weights of all the known chemical elements, respectively, are multiples of these prime radii, indicating that the structure of all the chemical elements are substantially the same as that of the hydrogen atom, the difference being due to the length of the prime radii of the hexagons which form the basis of their organization.

These are some of the important propositions which we have endeavored to cover. A book could be written on almost every subject treated by chapter. We could deal only with the principles underlying the fundamental propositions sought to be established.

CHAPTER XXV

CONCLUSION

193. It has been considered incredible that the ether could exist as a medium possessing elastic rigidity and yet oppose no obstruction to the passage through it of the earth and planets as they whirl in their orbits around the central sun. The explanation is now quite simple and comprehensible. The elastic rigidity of the ether structure is the effect of the flow of energy coming from the stars in infinity and passing through the stress lines of that structure. As the earth passes through space, the structure of the ether, with the energy represented by it, enters into the structure of the matter of which the earth is composed, and passes out again. It is no more difficult to understand than to comprehend how it is that an "eddy" or "whirl" can continue its course on the surface of a running stream. We understand in the latter case that the density of the water does not operate against the passage of the "whirl," because the substance of the water enters into and becomes the structure of the "whirl" or "eddy."

194. It will be observed that in this book we have dealt only with phenomena arising out of the behavior of inanimate substance or matter. We have not considered any of the phenomena of life or mentality. We have not discussed the possibility of the existence of a fundamental principle, other than substance and motion, which may enter into the phenomena of life, the exercise of judgment and direction, and manifest itself through reaction on matter and substance. The subject must therefore be left as an open one, the elucida-

tion of which is not within the scope of our present undertaking.

195. Scientists have long sought for an explanation of the fact that for millions of years our sun has been radiating energy into space and yet maintains its heat.

One explanation which has been offered is that its heat is maintained by the impact of meteors drawn into the central orb by gravitation.

Another is that a continuous but extremely small contraction of the radius of the sun is going on all the time, and this develops the heat radiated.

A theory lately advanced is that the sun has a great deal of radium in its composition, and that the heat is maintained by radiations from it.

Upon the hypothesis which we have endeavored to establish, the explanation is very simple.

The sun is continuously fed with energy from the radiations proceeding to it from all the stars in infinity. These radiations reach it as invisible force rays, and, passing into the material particles of which it is composed, they maintain those material particles in their automatic revolutions, and are sent off again after conversion into waves of much greater wave-lengths, that is, into visible light waves, heat waves, electric waves and magnetic waves. The process is exactly similar to what takes place when invisible electric waves are brought over a wire into an incandescent electric light bulb. The carbon filament serves as the mechanism by which the invisible electric energy which reaches it over the wire from the distant dynamo, is converted into visible light waves.

The mystery is that there should ever be any decrease through the ages in the heat of the sun at all. The condition of our moon, and the geologic evidence furnished by our earth, furnishes strong evidence that there has been a slow decrease in the sun's heat through a great period of time.

We must consider that at all times, through all regions of space, particles of matter must be in process of creation from standard ether particles set in revolution by disturbing radiations, passing through from luminous matter already in existence. Gravitation will at once draw these new born atoms into clusters; the larger clusters will gather up the smaller, and thus meteoric matter will be formed. The sun must be continually gathering up this diffused matter from space by gravitation. This action of gravitation must therefore be an influence continuously operating to change the balance between the amount of energy going into the sun as invisible force rays, and the amount of energy radiated off as heat and visible light rays. The result appearing from the evidential facts is a gradual loss of capacity to convert the invisible rays which reach it into heat and light waves. In other words, cooling and condensation by gravity gradually converts a luminous sun into what may be termed a "dead" or dark sun.

196. We know that our sun is bowling through space at a high velocity in a path which it is believed leads towards the constellation Lyra, but to what fate it is going we do not know. All the stars are in motion, although they are so far away from us that their positions in their respective constellations have changed but little in three thousand years.

Arrhenius, in his "Worlds in the Making," has pointed out that, however long the time, the final catastrophe must come to every sun, when it will collide with some other sun, and by that collision the energy represented by the rectilinear velocity of the masses bowling through space will be converted into vibratory motion of the atoms of which they are composed, and those atoms will be scattered through millions of miles of space as a great nebula.

Experiments with radium have demonstrated that even under conditions capable of being brought about in the laboratory, certain elements of matter can be decomposed into other elements.

If matter is being created in nature all the time under certain conditions, it follows that the reversal of those conditions, and change in the operation of the forces which tend to maintain automatic continuance of atom revolution, would result in the destruction of the atom as a material particle, and reconvert it into the standard ether particles of space.

We must therefore conceive that in the universe matter is being created by radiations from other matter all the time; that there is going on all the time the gathering up of this new born matter by gravitation into clusters and suns; that in time these suns go to a kinetic death, and finally the matter of which they are composed is converted again into ether substance. Thus we have an endless cycle of births, lives, deaths and resurrections in the material universe.

APPENDIX

APPENDIX

197. Similar Particles Acting Repulsively Toward Each Other, When Confined to a Limited Surface, Will Take Up the Equilateral Triangle Formation.—If we have a number of similar particles of like magnitude which exercise repulsion toward each other, the force of which decreases with the distance between the particles, and we place them at the same time promiscuously on a plane surface of limited dimensions, as on a table having a rim which would prevent the outlying particles from being pushed over the edge, then it is evident that the particles would push away from each other to positions where the pressure between the respective particles would be at a minimum. That is to say, the particles would move as far apart as possible, and because they are supposed to possess the same repulsive power, they would tend to space themselves equi-distantly apart. This last condition requires that they arrange themselves either in squares or in equilateral triangles.

We may suppose, first, that the arrangement is in small squares, and that the particles are located at the corners of the squares. The aggregate of the areas of all the squares makes up the area of the whole table surface.

Let ABDC (Fig. 56) be one of these small squares, in which $AB = AC = a$. With A and B as centres and radius a, describe circles cutting each other in E, and making the equilateral triangle AEB, and complete the parallelogram AEFB. Draw the perpendicular EG. Then

$$AG = \frac{a}{2}$$

$$EG^2 = a^2 - \frac{a^2}{4}$$

$$EG = \frac{a}{2}\sqrt{3}$$

$$\text{Area } AEFB = AB \times EG = \frac{a^2}{2}\sqrt{3} = .866\ a^2$$

But $\quad$ Area ACDB $= a^2$

Therefore if we compare the positions of the four particles when placed at A, E, F, B, with their position if placed at A, C, D, B, we see that none of them are nearer to each other than the original distance a, and collectively they occupy a less area since $.866a^2 < a^2$.

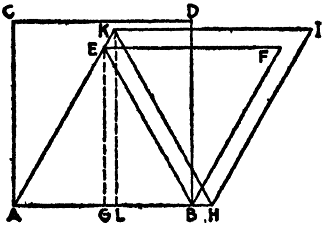

Figure 56

Let us now extend AE to a point K, such that when we complete the equilateral triangle AKH, the area of the parallelogram AKIH shall be the same as that of the square

ACDB $= a^2$. Let AK $=$ AH $=$ b,

then
$$AL = \frac{b}{2}$$

$$KL^2 = b^2 - \frac{b^2}{4}$$

$$KL = \frac{b}{2}\sqrt{3}$$

$$\text{Area} \quad AKIH = AH \times KL = \frac{b^2}{2}\sqrt{3} = .866b^2 = a^2$$

from which we get $\quad b = 1.07a = a + .07a$

That is to say, the four particles can move further apart to the extent of $.07a$ to the positions A, K, I, H, and yet collectively they occupy precisely the same area as they did when they were arranged in form of the square. Therefore for the whole table surface, the equilateral triangle arrangement would be taken up naturally by the particles, since they would be thus spaced equi-distantly apart, and in the positions of minimum pressure.

In the case of the standard ether particles, since they extend throughout all space, if we consider any small area of a plane in which such particles lie, we may consider that the pressure of the similar particles outside of the limited area under consideration will act as the table rim. If we were dealing with a real table rim in the illustration above made, we would have to take into account certain other considerations which are eliminated from the problem as it is presented in a limited area of a plane in the ether, where the same kind of particle distribution is extended to infinity.

198. **Velocity of Gravitational Waves in Deep Water.** (*After Watson.*)—Let ABCD (Fig. 57) be a water wave in which B is the crest and D the trough. The radius OB = A is the amplitude. τ is the period of one revolution of the particle in its circular orbit. The angular velocity of revolution in the circle will be equal to $\frac{2\pi}{\tau}$. The tangential velocity for the particle due to that revolution will be $\frac{2\pi A}{\tau}$. Let Z be the velocity with which the wave is progressing to the right.

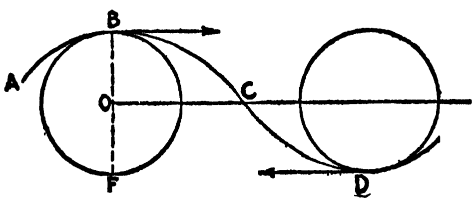

Figure 57

We may imagine that, independently of the wave motion taking place in it, the body of the water itself is flowing to the left with a velocity Z just equal to the velocity with which the wave is progressing to the right. In this way we can examine the relation of the forces carrying on the wave motion as if the progression of the wave were stopped while the forces which make the wave continued in action right before us.

Under that supposition, since in water waves the revolution is clockwise, the actual velocity Z_1 of the particle when at D would be

$$Z_1 = Z + \frac{2\pi A}{\tau}$$

The actual velocity Z_2 of the particle when at B would be

$$Z^2 = Z - \frac{2\pi A}{\tau}$$

The kinetic energy of a particle of unit mass is, from principles of mechanics, always one-half of the square of the velocity it possesses at the instant considered.

The kinetic energy K_1 of a particle of unit mass at D would therefore be

$$K_1 = \frac{1}{2} Z_1^2 = \frac{1}{2}\left(Z - \frac{2\pi A}{\tau}\right)^2 = \frac{Z^2}{2} + \frac{2\pi^2 A^2}{\tau^2} + \frac{2\pi AZ}{\tau}$$

The kinetic energy K_2 of the same particle when at B would be

$$K_2 = \frac{1}{2} Z_2^2 = \frac{1}{2}\left(Z - \frac{2\pi A}{\tau}\right)^2 = \frac{Z^2}{2} + \frac{2\pi^2 A^2}{\tau^2} - \frac{2\pi AZ}{\tau}$$

Hence the loss of kinetic energy which the particle sustains in changing its position from D to B is:

$$K_1 - K_2 = \frac{4\pi AZ}{\tau}$$

But when the particle has been changed in its position from D to B, it has been lifted against gravity through a height $FB = S = 2A$. It has therefore stored up potential energy equal to the kinetic energy it would acquire in a fall without opposition through the distance BF.

From the law of falling bodies, one-half of the square of the velocity (which is the kinetic energy for a unit of mass) acquired by the fall of the particle through space S, is equal to gS. Hence the potential energy stored up in the particle when it reaches B is measured by $gS = 2gA$. And since energy is indestructible, the gain of potential energy by the particle in passing from D to B must be equal to its loss of kinetic energy, and therefore

$$2gA = \frac{4\pi AZ}{\tau}$$

or

$$Z = \frac{g\tau}{2\pi}$$

Now if λ is the wave length, it is the distance the wave travels in time τ. So that $\lambda = Z\tau$ or $\tau = \frac{Z}{\lambda}$

Substituting this value of τ above, we have

$$Z = \frac{g\lambda}{2\pi Z}$$

or (1)

$$Z^2 = \frac{g\lambda}{2\pi}$$

or (2)

$$Z = \sqrt{\frac{g\lambda}{2\pi}}$$

199. In the case of liquids, there is another factor which affects the velocity of progression when the wave length is very small, as in the case of ripples on the surface of water. This is due to what is called surface tension of the surface film of the liquid. This acts as if there were a thin elastic skin stretched over the liquid surface, having the effect of creating an additional force of restitution. It is only when the wave length is very small, making the curvature of the wave large, that surface tension has any appreciable effect. For our present purposes it is not neces-

sary for us to consider surface tension, because it does not exist in a frictionless medium such as ether.

Nor is it necessary for us to consider the particular case of waves in shallow water.

Referring to equation (2) above, it will be seen that the velocity of progression of the wave increases with the wave length.

200. **Velocity of Light Waves.**—We have heretofore pointed out (sec. 63) that the revolution of particles in a polarized ray are in circles in the plane coinciding with the line of progression, and that the motion is identical with that of water particles in water waves on the surface of deep water. From which it would be naturally inferred that the formula of the last section

$$(2) \qquad Z^2 = \frac{g\lambda}{2\pi}$$

would be applicable at least to polarized rays.

Since the velocity of progression of any wave must be due to the component of forces operating in the direction of progression, we may, for ordinary light waves, eliminate from consideration all transverse forces which give the particle a revolution around the axis of progression, and consider only the components of the operating forces which may be resolved into a particular plane lying in the plane of progression. So considered, we would be dealing only with forces which operate to carry on the progression as in a polarized ray. In other words the motions carrying on progression for any kind of light rays would be those illustrated by Figure 57. Moreover ordinary light rays are composed of rays in which the revolution of the particle is around the line of progression as well of polarized rays in which the revolution is in a plane passing lengthwise in that line (sec. 70). There is no evidence that these two different kinds of waves to each of which the above formula would give different velocities of progression for different wave lengths, become separated in passing from distant stars through space to reach us.

Airy first, and Newcomb afterwards, has pointed out that if there were a difference of one hour in the times of the blue and red rays reaching us from Argol, this star would show a well marked colorization in its phases of increase and decrease of luminosity, but no such coloration appears. (See Wave-theory, 24 vol., Enc. Brit., 9th ed. 458.)

The evidence therefore at first blush would seem to disprove the conclusion that the formula (2) is applicable to light waves traveling through the ether of space. Mathematically considered, however, the formula *must* apply, and, as Airy has pointed out, there must be in operation some additional factor affecting the velocity of progression which has not been taken into consideration in arriving at formula (2). He suggested that since the energy in the wave decreases with the distance traveled, we might suppose that the coefficient of elasticity of the ether medium which we may represent by E, varies inversely as λ, that $E = \frac{c}{\lambda}$, where c represents some constant quantity dependent upon the nature of the ether medium. That would give, in place of (2)

$$Z^2 = \frac{c}{2\pi}$$

constant for all wave lengths.

This of course was merely a suggestion which has not been followed up by any demonstration. The writer in the body of the present work (sec. 145) has demonstrated that formula (2) *is applicable* to the velocity with which light waves of all wave-lengths are *launched,* and that the fact that the velocity of progression is reduced to one uniform rate for all wave-lengths is due (sec. 147) to the structure of the ether itself, and to the existence of a flow of energy at a uniform rate which is taking place in that structure.

201. **General Equation of Wave Motion.**—Let us suppose that the revolution of the particle which gives rise to the simple harmonic motion is, as illustrated in Figure 11, taking place in a direction contrary to that of the hands of a clock, and at that instant the centre of revolution is at O (Fig. 58).

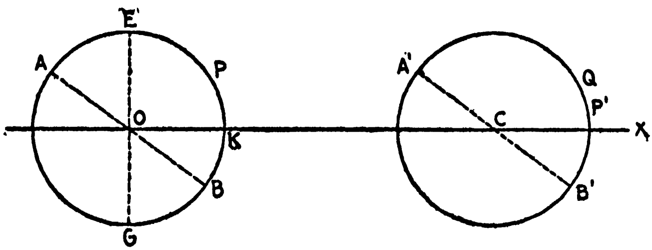

Figure 58

The state of the motion represented by the displacement y, for any particle P, at the instant of time t, would be given (secs. 47 and 48) by the equation

$$y = A \cos (w t + E) \text{ in which } w = \frac{2\pi}{\tau}$$

That is to say, we would have

$$(1) \qquad y = A \cos \left(\frac{2\pi t_1}{\tau} + E\right)$$

in which y is the displacement measured on some diameter AB as illustrated in Figure 58.

Let us suppose that the centre of the circle of revolution has advanced with uniform velocity of progression V in some direction OX, which may or may not lie in the plane in which the particle is revolving. Let OC = x.

The time represented in the progression of the centre from O to C is $\frac{x}{V}$.

If t represent the time the revolution has been in progress, then $t - \frac{x'}{V} = t_1$, in which equation t^1 represents the time when the phase of the particle moving in the circle whose centre is C, agrees with the phase it would have had if no time had been added in the wave progression. Substituting this value of t_1 in equation (1), we therefore have

$$y = A \cos \left\{ \frac{2\pi}{\tau} \left(t - \frac{x}{V} \right) + E \right\}$$

Also since one wave length λ is completed in the period τ, and the velocity of progression is V, we must have

$$\lambda = V\tau$$

or

$$V = \frac{\lambda}{\tau}$$

Substituting this value of V in the above equation, we get

$$(2) \qquad y = A \cos \left\{ \frac{2\pi}{\lambda} (Vt - x) + E \right\}$$

for the general expression of a train of waves.

The equation is precisely that given by Lord Rayleigh as representing a train of light waves. (Wave Theory of Light, 9th ed., Enc. Brit.)

Now the manner in which we arrived at the above equation leaves several important questions open, the most important of which is the value to be attributed to the angle of inclination which the plane in which the particle is revolving makes with OX, the line in which the wave is progressing.

202. Position of the Plane of Rotation.—Referring now to Figure 11 from which we derived the equation

$$y = A \cos (t w + E)$$

and to the manner in which in section 201 we derived from the above, the equation

$$(2) \qquad y = A \cos\left\{\frac{2\pi}{\lambda}(Vt - x) + E\right\}$$

there was no particular reason arising from any condition imposed, why the plane, in which the revolution of the particle represented by equation (2) is taking place, should be inclined to the axis OX, at one angle rather than at another. The principle of symmetry as applied to a wave moving through a homogeneous medium would, however, require that the plane in which the revolution of the particle takes place must pass either through the direction of wave-progression, or be at right angles to that direction. In water waves and in polarized light waves, we know the line of wave progression lies in the plane in which the revolution takes place, and in water waves this plane is perpendicular to the free surface of the water. We know also that gravitation acts on the water particles in vertical lines, the displacements taking place up and down.

As shown by Fresnel and Arago, the phenomena of elliptically and circularly polarized light (Ganot's Physics, sec. 605), is taken to have demonstrated that in those kinds of light waves at least, the rotation takes place in a plane at right angles to the direction of the ray, and the path of the particle is an ellipse or circle as the case may be.

Circular or elliptical polarization may be either right-handed or left-handed.

In accordance with section 60, we may regard such elliptically polarized light as the composition of two similar rays of unequal amplitude, in which the revolution is taking place in opposite directions.

It is not within the scope of our present undertaking, to enter upon the mathematical treatment of light wave motion, and composition of light waves from the standpoint of equations. The subject has been exhaustively treated by great mathematicians in works which may be easily consulted.

We have accepted the results established, and in the main have confined our attention to an interpretation of those results from the mechanical side.

INTERNATIONAL ATOMIC WEIGHTS 1914 AND OTHER DATA

Chemical Elements	Symbol	1914 Atomic Weights O = 16	1914 Atomic Weights H = 1	Valencies	Metals = M Non-metalic = N	Corresponding Multiples of Prime Radii
Hydrogen	H	1.008	1	2	N	$R_1 = 1$
Helium	He.	3.99	3.96	0	N	$4R_1 = 4$
Lithium	Li.	6.94	6.88	1	M	$2R_3 = 2\sqrt{3} = 6.93$
(Glucinum) Beryllium	Be	9.1	9.03	2	M	$2R_{10} = 2\sqrt{3}\ \sqrt{7} = 2\sqrt{21} = 9.16$
Boron	B	11.	10.91	3	N	$3R_7 = 3\sqrt{13} = 10.81$
Carbon	C	12.	11.9	2	N	$2R_{16} = 2\sqrt{37} = 12.16$ $7R_3 = 7\sqrt{3}\ 12.12$
Nitrogen	N	14.01	13.9	1	N	$3R_{10} = 3\sqrt{21} = 13.74$ $14R_1 = 14$
Oxygen	O	16.	15.87	2	N	$6R_4 = 6\sqrt{7} = 15.87$ $16R_1 = 16$
Fluorine	F	19.	18.85	1	N	$11R_3 = 11\sqrt{3} = 19.05$ $3R_{17} = 3\sqrt{39} = 18.74$
Neon	Ne.	20.2	20.04	0	N	$20R_1 = 20$
Sodium	Na.	23.	22.81	1	M	$5R_{10} = 5\sqrt{3}\ \sqrt{7} = 5\sqrt{21} = 22.91$
Magnesium	Mg.	24.32	24.12	2	M	$14R_3 = 14\sqrt{3} = 24.25$ $4R_{16} = 4\sqrt{37} = 24.33$
Aluminum	Al.	27.1	26.88	3	M	$3R_{22} = 3\sqrt{79} = 26.66$ $6R_9 = 6\sqrt{19} = 26.15$ $4R_{18} = 4\sqrt{43} = 26.23$
Silicon	Si.	28.3	28.07	4	N	$5R_{14} = 5\sqrt{31} = 27.84$ $16R_3 = 16\sqrt{3} = 27.71$
Phosphorus	P	31.04	30.79	5	N	$18R_3 = 18\sqrt{3} = 31.17$ $6R_9 = 6\sqrt{19} = 30.51$
Sulphur	S	32.07	31.81	1	N	$12R_4 = 12\sqrt{7} = 31.75$
Chlorine	Cl.	35.46	35.17	1	N	$8R_9 = 8\sqrt{19} = 34.77$
Potassium	K	39.10	38.78	1	M	$7R_{14} = 7\sqrt{31} = 38.97$ $6R_{17} = 6\sqrt{39} = 38.47$

Argon	A	39.88	39.56	0	N	$11R_7 = 11\sqrt{13} = 39.66$
Calcium	Ca.	40.07	39.74	2	M	$11R_7 = 11\sqrt{13} = 39.66$ $15R_4 = 15\sqrt{7} = 39.69$
Scandium	Sc.	44.1	43.74		M	$10R_9 = 10\sqrt{19} = 43.59$
Titanium	Ti	48.1	47.71	2 or 4	M	$18R_4 = 18\sqrt{7} = 47.62$ $11R_9 = 11\sqrt{19} = 47.95$
Vanadium	V	51.	50.59	3	M	$14R_7 = 14\sqrt{3} = 50.47$ $11R_{10} = 11\sqrt{21} = 50.40$
Chromium	Cr.	52.	51.58	2 or 3	M	$6R_{21} = 6\sqrt{73} = 51.26$
Manganese	Mn	54.93	54.48	2	M	$9R_{16} = 9\sqrt{37} = 54.74$ $7R_{10} = 7\sqrt{21} = 54.99$
Iron	Fe.	55.84	55.39	2 or 3	M	$32R_2 = 32\sqrt{3} = 55.42$ $21R_4 = 21\sqrt{7} = 55.56$
Nickel	Ni	58.68	58.20	2	M	$22R_4 = 22\sqrt{7} = 58.20$
Cobalt	Co.	58.97	58.48	2	M	$34R_2 = 34\sqrt{3} = 58.89$
Copper	Cu.	63.57	63.05	2	M	$24R_4 = 24\sqrt{7} = 63.49$ $36R_2 = 36\sqrt{3} = 62.35$
Zinc	Zn	65.37	64.84	2	M	$18R_7 = 18\sqrt{13} = 64.9$
Gallium	Ga	69.9	69.33		M	$16R_9 = 16\sqrt{19} = 69.72$ $40R_2 = 40\sqrt{3} = 69.28$
Germanium	Ge.	72.5	71.91		M	$20R_7 = 20\sqrt{3} = 72.11$ $11R_{18} = 11\sqrt{43} = 72.13$
Arsenic	As.	74.96	74.35	3 or 5	M	$43R_2 = 43\sqrt{3} = 74.47$ $17R_9 = 17\sqrt{19} = 74.1$
Selenium	Se	79.2	78.55		N	$18R_9 = 18\sqrt{19} = 78.46$ $12R_{18} = 12\sqrt{43} = 78.69$
Bromine	Br.	79.92	79.27	1	N	$30R_4 = 30\sqrt{7} = 79.37$ $22R_7 = 22\sqrt{13} = 79.32$
Krypton	Kr.	82.92	82.25	0	N	$31R_4 = 31\sqrt{7} = 80.02$ $18R_{10} = 18\sqrt{21} = 82.48$
Rubidium	Rb.	85.45	84.76	1	M	$32R_4 = 32\sqrt{7} = 84.66$ $39R_2 = 49\sqrt{3} = 84.87$
Strontium	Sr.	87.63	86.92	2	M	$24R_7 = 24\sqrt{13} = 86.53$ $19R_{10} = 19\sqrt{3}\,\sqrt{7} = 19\sqrt{21} = 87.07$ $50R_2 = 50\sqrt{3} = 86.6$
Yttrium	Yt	89.	88.28		M	$51R_2 = 51\sqrt{3} = 88.33$ $20R_9 = 20\sqrt{19} = 87.18$
Zirconium	Zr.	90.6	89.86		M	$52\sqrt{3} = 90.06$ $34R_4 = 34\sqrt{7} = 89.95$
(Niobium) Columbium	Cb	93.5	92.74		M	$35R_4 = 35\sqrt{7} = 92.60$
Molybdenum	Mo	·96.	95.21		M	$55R_2 = 55\sqrt{3} = 95.26$ $36R_4 = 36\sqrt{7} = 95.25$
Ruthenium	Ru.	101.7	100.87	2 or 3	M	$22R_{10} = 22\sqrt{21} = 100.81$ $28R_7 = 28\sqrt{13} = 100.96$

203 INTERNATIONAL ATOMIC WEIGHTS 1914 AND OTHER DATA

Chemical Elements	Symbol	1914 Atomic Weights O = 16	1914 Atomic Weights H = 1	Valencies	Metals = M Non-metalic = N	Corresponding Multiples of Prime Radii
Rhodium	Rh	102.9	102.06	2 or 3	M	$59R_2 = 59\sqrt{3} = 102.19$
Palladium	Pd	106.7	105.83	2 or 4	M	$40R_4 = 40\sqrt{7} = 105.83$ $61R_2 = 61\sqrt{3} = 105.65$
Silver	Ag	107.88	107.	1	M	$62R_2 = 62\sqrt{3} = 107.39$ $12R_{23} = 12\sqrt{79} = 106.65$
Cadmium	Cd	112.40	111.49	2	M	$31R_7 = 31\sqrt{13} = 111.97$ $20R_{14} = 20\sqrt{31} = 111.35$ $17R_{18} = 17\sqrt{43} = 111.47$
Indium	In.	114.8	113.87	3	M	$26R_9 = 26\sqrt{19} = 113.33$ $43R_4 = 43\sqrt{7} = 113.76$
Tin	Sn	119.	118.03	2 or 4	M	$68R_2 = 68\sqrt{3} = 117.78$
Antimony	Sb	120.2	119.22	3 or 5	M	$45R_4 = 45\sqrt{7} = 119.06$
Iodine	I	126.92	125.89	1	N	$35R_7 = 35\sqrt{13} = 126.19$
Tellurium	Te.	127.5	126.46		N	$73R_2 = 73\sqrt{3} = 126.44$ $29R_4 = 29\sqrt{19} = 126.41$
Xenon	Xe.	130.2	129.14	0	N	$49R_4 = 49\sqrt{7} = 129.64$ $36R_7 = 36\sqrt{13} = 129.80$
Caesium	Cs.	132.81	131.73	2	M	$76R_2 = 76\sqrt{3} = 131.63$
Barium	Ba	137.37	136.25	2	M	$38R_7 = 38\sqrt{13} = 137.2$ $79R_2 = 79\sqrt{3} = 136.82$ $16R_{21} = 16\sqrt{73} = 136.7$
Lantharum	La.	139.	137.87		M	$52R_4 = 52\sqrt{7} = 137.58$ $30R_{10} = 30\sqrt{21} = 137.47$ $21R_{18} = 21\sqrt{43} = 137.7$ $32R_9 = 32\sqrt{19} = 139.48$
Cerium	Ce	140.25	139.11		M	$25R_{14} = 25\sqrt{31} = 139.19$
Phraseodymium	Pr.	140.6	139.46		M	$32R_9 = 32\sqrt{19} = 139.48$
Neodymium	Nd	144.3	143.12		M	$54R_4 = 54\sqrt{7} = 142.87$
Samarium	Sa.	150.4	149.18		M	$86R_2 = 86\sqrt{3} = 148.96$

Europium	Eu.	152.	150.76		M	$87R_2 = 87\sqrt{3} = 150.69$ $57R_4 = 150.80$
Gadolinium	Gd	157.3	156.02		M	$59R_4 = 59\sqrt{7} = 156.10$ $90R_2 = 90\sqrt{3} = 155.88$
Terbium	Tb	159.2	157.93		M	$91R_2 = 91\sqrt{3} = 157.61$ $26R_{16} = 26\sqrt{39} = 158.14$
Dysprosium	Dy.	162.5	161.18		M	$93R_2 = 93\sqrt{3} = 161.08$ $61R_4 = 61\sqrt{7} = 161.39$
Holmium	Ho.	163.5	162.17		M	$45R_7 = 45\sqrt{13} = 162.25$
Erbium	Er.	167.7	166.34		M	$96R_2 = 96\sqrt{3} = 166.28$
Thulium	Tm.	168.5	167.13		M	$30R_{14} = 30\sqrt{31} = 167.03$ $63R_4 = 63\sqrt{7} = 166.68$
Ytterbium	Yb.	172.	170.62		M	$37R_9 = 37\sqrt{19} = 169.6$ $26R_{18} = 26\sqrt{43} = 170.49$ $20R_{21} = 20\sqrt{73} = 170.88$
Lutecium	Lu.	174.	172.59		M	$31R_{14} = 31\sqrt{31} = 172.60$
Tantalum	Ta	181.5	180.02		M	$104R_2 = 104\sqrt{3} = 180.13$ $68R_4 = 63\sqrt{7} = 179.91$
Tungsten	W	184.	182.50	2	M	$69R_4 = 69\sqrt{7} = 182.56$
Osmium	Os.	190.9	189.35	1	M	$34R_{14} = 34\sqrt{31} = 189.30$
Iridium	Ir.	193.1	191.53	2, 3 or 4	M	$44R_9 = 44\sqrt{19} = 191.79$
Platinum	Pt	195.2	193.61	2 or 4	M	$31R_{17} = 31\sqrt{19} = 193.59$ $111R_2 = 111\sqrt{3} = 193.99$
Gold	Au.	197.2	195.6	1 or 3	M	$113R_2 = 113\sqrt{3} = 195.72$ $74R_4 = 74\sqrt{7} = 195.78$ $23R_{21} = 23\sqrt{73} = 196.51$ $24R_{20} = 24\sqrt{67} = 196.45$
Mercury	Hg.	200.6	198.97	1 or 2	M	$75R_4 = 75\sqrt{7} = 198.43$ $115R_2 = 115\sqrt{3} = 199.18$
Thallium	Tl	204.	202.34	1 or 3	M	$117R_2 = 117\sqrt{3} = 202.65$ $30R_{19} = 30\sqrt{61} = 203.06$
Lead	Pb	207.1	205.42	1	M	$57R_7 = 57\sqrt{13} = 205.52$
Bismuth	Bi.	208.	206.31	3	M	$78R_4 = 78\sqrt{7} = 206.47$ $45R_{10} = 45\sqrt{21} = 206.21$
(Radium Emanation) Niton	Nt.	222.4	220.59			$227R_2 = 227\sqrt{3} = 219.97$ $61R_7 = 61\sqrt{13} = 219.93$ $83R_4 = 83\sqrt{7} = 219.60$ $48R_{10} = 48\sqrt{21} = 219.96$
Radium	Ra	226.4	224.56		M	$85R_4 = 85\sqrt{7} = 224.88$ $49R_{10} = 49\sqrt{3}\sqrt{7} = 224.54$
Thorium	Th.	232.4	230.49		M	$133R_2 = 133\sqrt{3} = 230.36$ $87R_4 = 87\sqrt{7} = 230.18$ $64R_7 = 64\sqrt{13} = 230.75$
Uranium	U	238.5	236.56	2	M	$137R_2 = 137\sqrt{3} = 237.29$ $38R_{17} = 38\sqrt{37} = 239.31$

INDEX

References are to sections

THE END