recent petrographical research," a subject which Mr. Teall has almost made his own. Papers are expected on East Africa, the new red sandstone of the Midlands, the igneous rocks of Derbyshire, the boulder clays and drifts of the Midlands, the methods and need of teaching geology both as a branch of education and as a valuable training to engineers, miners, and others. Sections C and D will jointly discuss "Fossil and Recent Coral Reefs," both in respect to their origin and in relation to the part which corals have played in the formation of the earth's crust. Sections C and E will also hold a joint meeting for considering the mutual relations of geology and geography.

In Section D Prof. Bohr, of Copenhagen, is expected to communicate the results of researches of great importance on the chemical process of respiration. A discussion will also probably take place on the question how far the fundamental peculiarities of vital processes admit of being explained as merely resulting from the *complication* of the chemical and physical processes of which they consist. It is expected that other moot questions of fundamental importance in biology will also be brought under discussion.

The President of Section E will treat in his address of the Polar Basin, laying stress on some generally forgotten facts and summarising our knowledge of the margin of the Arctic Sea. Mr. W. M. Conway will give an account of his mountaineering experiences in the Karakorum Range. Messrs. Bruce, Burn-Murdoch, and Donald will describe with photographs and paintings the scientific results of a recent sealing expedition to Antarctic waters. Mr. Guy Boothby will describe his journey across Australia from north to south. There will also be papers on the influence of their geographical surroundings upon the people of Northern India, by Mr. E. Henwood, and a similar paper on the Congo Basin by Mr. Herbert Ward. Mr. H. R. Mill will describe the physical geography of the Clyde sea area, and the bathymetrical survey of the English lakes, and Mr. B. V. Darbishire will contribute a paper on some conditions of cartographic representation of distributions.

In Section F the subject of the presidential address will be "The Reaction in favour of the Classical Political Economy." Papers are expected to be read for discussion on the monetary situation by Profs. Foxwell and Cunningham, on agricultural depression by Messrs. H. H. Scott and L. L. Price, on corn averages by Mr. R. Hooker, on Australian banking by Dr. C. Gairdner, on Poor Laws by Dr. F. Wilkinson, on industrial arbitration by Mr. D. Schloss, on the employment of the unemployed, on local industries and the history of Nottingham lace by Mr. Frith and others.

The arrangements for Section G have not been received as yet, but the many promises received from eminent English and foreign engineers to attend the meeting leaves no doubt that the proceedings of this Section will be of unusual interest.

In Section H the subject of the presidential address will be one special phase of man's development. The papers and discussions in this section, always of a diversified and popular character, promise to be of more than usual interest this year. Dr. Hans Hildebrand, Royal Antiquary of Sweden, contributes a paper on "Anglo-Saxon remains, and the coeval ones in Scandinavia," and it is proposed to make his communication the basis of a general discussion, chiefly with the view of defining the special characteristics of Anglo-Saxon remains in this country as distinct from those of Celtic and Scandinavian origin. Another subject, also full of interest and even novelty to English archæologists, is the recently discovered prehistoric lake or marsh village near Glastonbury, which is to be brought before the section by its discoverer, Mr. Arthur Bulleid. As the buried ruins of this village are now being excavated on a larger scale than during the previous summer, it is expected that the amount of industrial remains, already of much archæological value, will be greatly enhanced before the meeting of the Association. It has therefore been suggested that the reading of Mr. Bulleid's report of these researches will be a good opportunity for the eminent archæologists, who have agreed to act as a committee of reference and advice, to discuss the more salient features of this remarkable discovery, and to describe from different standpoints its bearing on the early history of our country. This method of dealing with such a discovery is eminently well adapted both for furthering the objects of the Association and for communicating valuable information to the investigators themselves; and it is earnestly hoped that the committee of experts will find it convenient to be present. Nor do these interesting subjects by any means exhaust the list of the forthcoming materials. Anthropology proper will come largely to the front, and will receive special consideration in the president's opening address to the section, as has been stated above.

Among the more popular scientific communications, the presidential address and the popular evening lectures must take their place. The popular lecturers are Prof. Smithells, who will describe and illustrate his recent researches on "Flame;" Prof. Victor Horsley, who will treat of "The Discovery of the Physiology of the Nervous System;" and Prof. Vivian Lewis, who will lecture to the local working-men on "Spontaneous Ignition." In connection with the last announcement it may be noted that the introduction of the working-men's lecture dates from the last meeting of the Association in Nottingham.

It will probably be possible to make a further communication in our next issue, bringing forward the announcement of the principal arrangements for work and entertainment in a state more nearly approaching completeness and finality. FRANK CLOWES.

MAGNETO-OPTIC ROTATION.

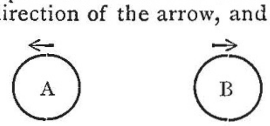
FARADAY'S famous discovery of the rotation of the plane of polarised light by passing the beam through a piece of his heavy glass placed along the lines of force of a magnetic field, was the starting point of the very important department of science now known as electro-optics. From this, as the first observed physical relation between optical and magnetic phenomena, has come the electromagnetic theory of light with all the magnificent researches and discoveries which have marked its experimental verification in recent years. I propose in the present article to give a short account mainly of magneto-optic rotation and the progress which has been made towards its dynamical explanation, followed by a brief discussion of some of the more intimately related phenomena which have been brought to light by recent investigations. It is no part of my plan however to discuss the experimental methods employed in the various researches referred to.

In the first place the magneto-optic relation which Faraday found is to be distinguished from the apparently similar effect which is produced by passing plane polarised light through a plate of quartz cut at right angles to the optic axis, or through a solution of sugar or tartaric acid. In the latter case the turning of the plane of polarisation depends only on the positions of the displaced particles of or in the elastic medium which forms the vehicle of the wave, and not on their motions; in the former the effect is a result of the motions of particles of other matter imbedded in or loading the surrounding ether.

The following illustration is I believe substantially what I have heard given by Lord Kelvin. Imagine two elastic jellies, one bored full of small helical cavities, either all right-handed or all left-handed, and having their axes all in one direction; the other having in it a number of particles endowed with a spinning motion and reacting in consequence of that spinning motion with centrifugal forces against elastic forces of the surrounding medium, and let the direction of axis and of spin be the same in the different cases. The former jelly will transmit circularly polarised waves travelling parallel to the axis of the helix with different velocities according as the helical arrangement of the displaced particles in the wave does or does not agree with the direction of the helical structure, the latter according as the direction of the motion of the particle caused by the wave is with or against the direction of the spin.

This illustration accounts for the essential difference between the results of observation in the two cases. The turning of the plane of polarisation produced by passing the beam through the quartz, or the solution, in one direction, is undone by sending the beam back again; that produced by passing the beam through a proper transparent medium placed along the lines of force in the magnetic field is doubled by reversing the ray after one passage, and returning the light to the side at which it entered.

To understand what takes place in each case we have to consider the nature of a plane polarised ray. According to the electromagnetic theory of light the disturbance in a plane polarized beam consists of an electric displacement in a direction at right angles to the plane of polarisation as defined in the ordinary way by reflection, and a magnetic displacement at right angles to the electric displacement and to the line of propagation, these two actions in a direct unreflected beam having the same phase. It is as yet impossible to say what it is in the ether that dynamically corresponds to these actions; but there can be no doubt that they are phenomena due to motion of some kind of or in the luminiferous ether. In the elastic solid theory of light, which must whether true or false have a certain correspondence with the facts, each part of the ether in a plane polarised beam was supposed to have a vibratory motion in a straight line at right angles to the direction of propagation, the direction of this line being the same along the whole length of the ray. Such a motion as this, it was first shown by Fresnel, may be regarded as the resultant of two oppositely directed circular motions, simultaneously possessed by each moving part of the ether. For consider a motion which would carry a particle round the circle A in a given time T in the direction of the arrow, and another which

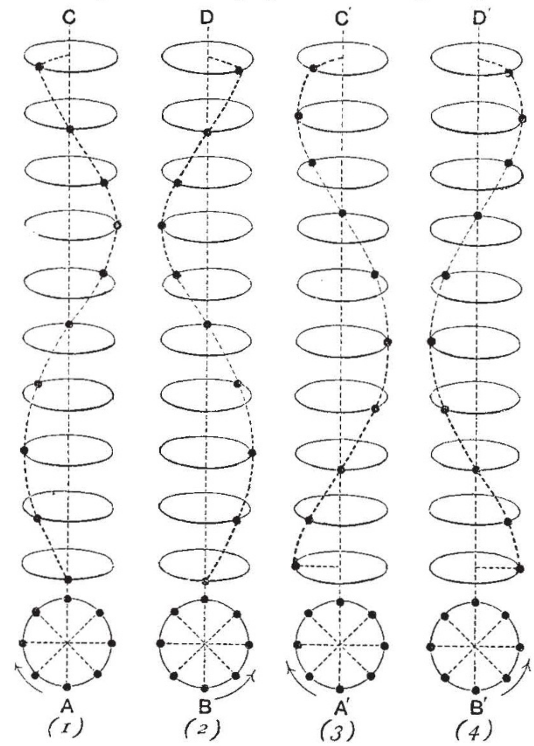


would carry a particle round the equal circle B in the same time in the opposite direction. Imagine two distinct particles to move with equal uniform speeds round the two circles, and suppose that both particles are at the top or at the bottom of their circular orbits at the same time. It is clear that at any given instant both are moving up or both moving down and at the same speed, while when one is moving from right to left the other is moving from left to right with the same speed, and *vice versâ*. Therefore if we conceive these motions united in one particle, the up and down velocities will be simply added together, the right and left motions will cancel one another. Thus the particle will have a simple vibratory motion in a vertical line in the period of the circular motions and with an amplitude of twice the radii of either circle.

Further it is to be noticed that the acceleration of the particle describing this rectilinear motion is the resultant of the accelerations of the particles in the two circular motions and that therefore the force required to maintain the simple harmonic motion is at each instant the resultant of the forces which would have acted on the particles in the circular motions when in the corresponding positions.

Thus the rectilinear vibration of a particle in the luminiferous medium may be regarded as compounded of two circular motions, and the particle as subject to a force compounded of the corresponding forces; and the same may be conceived of each moving particle in the wave.

Now to conceive of the motion in a beam of circularly polarised light and the relative positions of the disturbed particles, let a series of particles initially in a straight line along the direction of propagation be displaced into a helix along that line as represented in the diagram. Let these particles be projected with equal speeds in



the same direction tangential to the surface of the cylinder in which the helix lies, and at right angles to the axis; and further let them be constrained ever after to move with uniform speed in circles round the cylindrical surface. Clearly the helical arrangement will move onward along the cylinder—a circularly polarised wave will be propagated. The helical arrangement, that is the wave, is propagated in one direction or the other, for a given direction of the circular motions according as the helix is right or left-handed, or for the same direction of the helical arrangement according to the direction of the circular motion. Thus the direction of propagation is unchanged if both direction of helix and direction of motion is reversed. All this can be easily made out from diagrams (1), (2) of the figure above. Diagram (1) shows part of a left-handed helical arrangement of particles; (2) part of a right-handed one. Both illustrate the arrangement of particles, originally in a straight line, when disturbed by the passage of a circularly polarised beam. By supposing the particles to have the circular motions indicated below the diagrams, the propagation of the wave can be studied.

It follows therefore that if two such motions co-exist in the same particle both waves will travel in the same direction through the medium. If they travel with the same speed the resulting rectilinear motion of each particle will be the same all along the wave, but if they travel with unequal speeds the direction of this motion will turn round as the wave advances in the direction of the motion of the particles in the more quickly travelling wave, generating if the speeds are constant, the surface of a screw.

To constrain the particles to maintain the circular motions forces must be applied towards the centre of the orbit in each case. The reactions of the particles against these motions are what are properly called the centrifugal forces of the particles. But the different particles are connected by the elastic medium and the required centreward forces are supplied by its rigidity. Thus for given displacements produced by the beam entering the medium the forces due to the medium will be different if the rigidity is less for, say, a left-handed helical distortion than for a right-handed one, and the latter distortion will be propagated with the greater speed.

Now let the wave be reflected after passage, and let the direction of motion of each vibrating particle be reversed in the act of reflection. The direction of the helical arrangement will remain unchanged in each case. The wave which travelled the faster when direct will again do so, but the direction of motion being reversed the direction of motion in the plane polarised beam will turn round in the opposite direction as the wave moves forward, thus undoing the previous turning.

The same thing it is easy to see will take place if the reflection takes place without reversal of motion as at the surface of a rarer medium. In this case the helical arrangement which was left-handed becomes right-handed, and *vice versâ* after reflection. The arrangement which lagged behind before now that is reversed travels the faster and the line of resultant vibration again turns round, but in the direction of the circular motion in that circularly polarised wave which now moves the faster, that is in the opposite direction to that in which it moved before. Diagrams (3) and (4) of the figure show the configurations of parts of (1) and (2) after having been thus reflected.

Now consider the other case. It is observed, we shall suppose, that the right-handed circular ray travels faster than the other, and that whether direct or reversed. As before, the elastic action of the medium on the moving particles can depend only on the displacements of the particles in the helical displacement, and in the absence of any structural peculiarity to produce a difference must react in the same degree on the particles in both circular waves. Thus the centrifugal force reactions being the same for both waves, and the velocity of transmission being different, the luminiferous motions must be unequal, and such that compounded with a motion existing in the medium two motions are produced which exert equal centrifugal force reactions, balancing the equal elastic forces applied in consequence of the equal helical displacements.

According to this theory, which is due to Lord Kelvin, there exists in the medium a motion capable of being compounded with the luminiferous motion of either circularly polarised beam which is therefore a component only of the whole rotational motion. In the passage in which this dynamical explanation is put forward Lord Kelvin goes on to say,

"I think it is not only impossible to conceive any other than this dynamical explanation of the fact that circularly polarised light transmitted through magnetised glass parallel to the lines of magnetising force, with the same quality, right-handed always, or left-handed always, is propagated at different rates according as its course is in the direction or is contrary to the direction in which a north magnetic pole is drawn; but I believe it can be demonstrated that no other explanation of that fact is possible. Hence it appears that Faraday's optical discovery affords a demonstration of the reality of Ampère's explanation of the ultimate nature of magnetism."

A number of interesting conclusions seem to follow from this theory. In the first place the turning effect is not found to any sensible extent unless there is matter of some kind, magnetic or diamagnetic, present in the field. Hence the theory does not point to rotation of the parts of the ether but only to rotational motion of other matter imbedded in it and reacting on the ether in consequence of that motion.

Further, the explanation seems to decide against that view of diamagnetism which regards it as a differential effect due to the greater magnetisation of the surrounding medium. The rotation of the plane of polarisation is found in both paramagnetic and diamagnetic substances, but for the same direction of magnetic field is opposite in the two cases. This points to opposite rotations of the matter in the field according as it is paramagnetised or diamagnetised.

In all ordinary transparent substances which have been experimented on the effect has been found to be small. This of course was what was to be expected from the small amount of magnetisation (or diamagnetisation) produced in such substances even by very powerful fields. As a rule the substances are diamagnetic and give rotation of the plane of polarisation varying directly as the intensity of the magnetic field in which the substance is placed, and directly as the thickness of the medium through which the light is passed. It has been found however by Kundt that the turning produced by passing the light through a thin film of iron or cobalt is very great, a result which forcibly recalls the idea suggested by Lord Kelvin in the paper quoted above, that the moment of momentum of the matter in unit of volume of the magnetised substance might be the proper dynamical measure of the intensity of magnetisation.

Another result found both for magneto-optic rotation and for the turning produced by substances of helical structure is that the effect is greatest for the more refrangible rays of the spectrum, in fact is nearly inversely proportional to the square of the wave length of the light. This is of great importance in connection with the remarkable theory of the production of magneto-optic rotation in a medium having imbedded a large number of very small gyrostats which has been given by Lord Kelvin. In a continuation of the present article I shall endeavour to give a short account of the behaviour of such a medium when subjected to the disturbance due to the passage through it of a beam of plane polarised light. In connection with this theory the fact observed by H. Becquerel, Kundt and others that magneto-optic rotation is produced also in gases is of great interest.

Absolute measurements made by Lord Rayleigh give for bisulphide of carbon ·042 of a minute of angle for the turning of the plane of polarisation of sodium light in passing through a stratum 1 centimetre thick in a field of 1 C.G.S. unit of intensity the temperature being 18° C. A knowledge of this quantity (which is called Verdet's constant for bisulphide of carbon) enables the turning in other substances produced by a given field to be inferred by experiments of comparison. Further the intensities of magnetic fields can be inferred from observed amounts of turning produced by the passage of light through a column of measured length of any substance for which the constant has been determined.

In a succeeding article an attempt will be made to discuss with as little as possible of the aid of technical mathematics the propagation of plane polarised light in a gyrostatically loaded transparent medium, the "Hall effect" which, existing in a transparent dielectric, would there produce magneto-optic rotation, and to indicate shortly some of the bearings of magneto-optic phenomena generally on the electromagnetic theory of light.

ANDREW GRAY.