to this very subject, he wrote as follows: "Go on and prosper, there is nothing in the world of science half so good as an earthquake hypothesis, even if it only serve to show how firm are the foundations on which we build." I have given you the earthquake hypothesis; it is for those of you who oppose my conclusions, to prove the firmness of your foundations.

## *PHYSICS AT THE BRITISH ASSOCIATION.*

PERHAPS Section A does not discuss the question of science teaching in schools so often as Section B does. But the many teachers of science who listened to the address of the President (Prof. J. J. Thomson) on Thursday, must have heard with pleasure the testimony of so competent an authority that the teaching of physical science in schools has greatly improved in recent years. Very welcome, too, was his advice as to the importance of experimental work and method in teaching, and his warning as to the danger of trying to cover too much ground. The Section was favoured with the presence of physicists from various foreign countries, including Profs. Kohlrausch (Director of the Reichsanstalt), Lenard (Aachen), Bjerknes (Stockholm), J. E. Keeler (Pittsburg), Max Wolf (Heidelberg), and Elster and Geitel (Wolfenbüttel). The mention of Prof. Lenard's name in the President's address was the signa for very hearty applause.

After the President's address, the Section adjourned from the Arts Theatre to the Physics Theatre. The Report of the Committee on the Establishment of a National Physical Laboratory was presented by Sir Douglas Galton, who gave details of the cost of the Reichsanstalt, where the capital expenditure has amounted to £200,000, and the annual working expenses are £14,500. The Committee was appointed last year (see NATURE, September 26, 1895) to consider—or rather to reconsider—a suggestion made by Prof. Oliver Lodge at the Oxford meeting. It now proposes that the Kew Observatory at Richmond be extended so as to include a nucleus for the suggested National Physical Laboratory, and that the Government be approached with a request for the modest sum of about £20,000 for buildings and equipment, and £3000 per annum for maintenance. The control of the laboratory should be vested in a Council of Advice appointed by the Royal Society, either alone (like the present Kew Committee) or in conjunction with one or more of the chief scientific bodies in the country; but the immediate executive and initiative power should be vested in a paid chief or director of the utmost eminence attainable. The functions of the institution would include an extension of certain branches of work now performed by the Kew Observatory, such as the verification of standards and comparisons of length, weight, capacity, gravity, sound, light, &c., and variations of conditions due to temperature, vibrations, or other causes, as well as quality of materials. Research work of the following types should also be undertaken: (1) observations of phenomena, the study of which must be prolonged through periods greater than the average duration of life; (2) testing and verification of instruments for physical investigation, and the preservation of standards for reference; (3) systematic determination of physical constants and numerical data which may be useful for scientific or industrial purposes. In the discussion which followed, Lord Kelvin, Profs. Lodge, Ayrton, Fitzgerald, Rücker, and S. P. Thompson, and the Director of the Reichsanstalt took part. Dr. Isaac Roberts read a paper, in which he dealt with the analytic and synthetic methods of tracing the evolution of stellar systems. Very beautiful photographs of stars and nebulæ (taken with about four hours' exposure) were projected on the screen. Prof. G. H. Darwin read a paper on periodic orbits, which Lord Kelvin characterised as a monument of skilful and painstaking calculation. In the afternoon Prof. McKendrick gave a most interesting demonstration of a method of transcribing wave forms from a phonograph cylinder to paper, with other experiments illustrating his researches on the phonograph. During the week a number of instruments and exhibits were on view in the physical laboratory. These included the apparatus with which Dr. Lodge has sought to determine whether a moving body sets the ether in its neighbourhood in motion; X-ray tubes and photographs taken with them; a large influence machine; Prof. Lodge's electrostatic model; and Mr. Barlow's model illustrating the nature of homogeneity in crystals.

On Friday there was a joint discussion with Section B on Röntgen rays and allied phenomena. The interest felt in these was evidenced by the large attendance, many members having to content themselves with seats in the gallery of the large lecture theatre of University College. The subject was appropriately introduced by Prof. P. Lenard, who described his researches on kathode rays, and his views as to their nature. The separation of these rays was made possible by Hertz's discovery that they can pass through thin plates or films, *e.g.* of aluminium. Lenard's discharge tube had an aluminium window at the end opposite the kathode. Aluminium is a turbid medium for these rays, so that in passing through the window they are diffused. They are almost invisible in air, which is only very faintly illuminated by them; they are also largely absorbed by air, so that their intensity diminishes very quickly. If the tube is continued beyond the aluminium window, and the pressure of the air in this second chamber is reduced, the rays travel much further. This favours the view that they are not due to projected matter, but are of the nature of ether-waves. By placing a second screen with a diaphragm beyond the aluminium window a more distinct beam is obtained, and this is allowed to fall upon a phosphorescent screen. By introducing plates of metal in the path of the rays, it is found that their opacity is roughly proportional to their superficial density (gm. per sq. cm.). The same is true for gases; air can be made as transparent as hydrogen by reducing its pressure. Kathode rays exhibit differences in degree analogous to those of differently coloured lights; these differences can be exhibited by varying the pressure in the discharge tube, and observing the different amounts of deflection produced by a magnet. By reducing the pressure we get less deflectible rays; these are the least absorbed by ordinary matter, and are the easiest to investigate. X-rays are of this nature; they travel easily through air, and may be regarded as kathode rays which can only be very slightly affected by a magnet. They were probably present in Lenard's experiments, but must have been very faint, for the aluminium window was small and (on account of the pressure) not very thin. Prof. Lenard subsequently exhibited his experiments in the physical laboratory.

In the discussion which followed, Sir George Stokes maintained the view that the rays are due to projected matter. The inside of the aluminium window is bombarded by molecules of gas or by particles discharged from the electrode. Why should not this bombardment give rise to a corresponding projection of molecules from the outside of the window? It is not necessary to suppose that they pass through the window. We have an analogue in the electrolysis of copper sulphate between copper electrodes. If a third (idle) electrode is introduced between them, we find that copper ions are deposited on one side of it and removed from the other. The absence of diffraction effects and other properties favour the view that X-rays are due to sudden and non-periodic disturbances. Prof. Fitzgerald congratulated Prof. Lenard on his skilful investigation, and pointed out that, whereas Röntgen's experiments had soon been repeated by hundreds of observers, Lenard's earlier experiments were of such a difficult nature that no one had since repeated them. Although Hertz held that the kathode rays were due to ethereal vibrations, his own suggestion that their deflection by a magnet may be analogous to the Hall effect tells against this view; for the Hall effect only occurs when matter is present. Again, Hertz found support for his views in his remarkable discovery that a magnet was not deflected by kathode rays. He does not seem to have considered that corresponding to the direct conduction current in the tube there must be a reverse convection current outside. Would not this back current neutralise the effect of the first convection current? Or the explanation may simply be that the effect upon a magnet is so slight that we cannot detect it. Prof. J. J. Thomson gave an account of experiments, made by himself and Mr. E. Rutherford, on the laws of conduction of electricity through gases exposed to the Röntgen rays. These rays convert gases into conductors, and the gas retains its conducting power for some time after the rays have ceased to pass. When the gas is forced through a wire gauze or muslin strainer into another vessel, it still conducts; but filtering through glass wool removes the conducting power, and so does bubbling through water. It is remarkable that the passage of a moderate electric current through the gas entirely destroys the conductivity; even very small currents reduce it considerably. This seems to indicate that the conduction is electrolytic. A theory based on this assumption has been tested by quantitative measurements, and the results are in satisfactory accordance with the theory. For an E.M.F. of 1 volt per cm. the ionic velocity is between 1 mm.

and ⅓ mm. per sec. (or of that order). There are extraordinary differences between the rates of leakage in different gases; roughly they follow a density law. Thus mercury vapour (which is one of the best insulators) is here found to become the best conductor. Chlorine, bromine, and iodine come next. Sulphuretted hydrogen conducts better than oxygen. But the rates depend on the slope of potential used, and the order may even be reversed (as in the case of air and hydrogen). Another remarkable result of the experiments is to show that the conductivity under the action of X-rays increases when the length of the column of gas between the electrodes is increased; this is intelligible on the electrolytic theory just referred to and is, indeed, required by it. Prof. Ayrton pointed out that a similar phenomenon is observed in arc lamps worked at a constant potential; when the length of the arc is increased, the current at the same time increases. Prof. Rücker made a preliminary communication on measurements of transparency of glass and porcelain to Röntgen rays, made by himself and Mr. Watson. A colour-patch photometric method was employed, in which the light produced by the rays on a phosphorescent screen was compared with light from an arc lamp which had passed through two thicknesses of cobalt glass. Assuming the law of inverse squares, it is found for glass that the intensity of the transmitted light is given by $I = I_0 (A + B^t)$ where $I_0$ is the intensity of the incident light and $t$ the thickness of the glass. Certain kinds of china are almost as transparent as glass; but others, in the manufacture of which bone ash is used, are very opaque. This method of examination may prove of service to collectors of porcelain and china. Lord Kelvin made a preliminary communication on measurements (by himself, Dr. Bottomley, and Dr. Maclean) of electric currents through air at different densities down to one five-millionth of the density of ordinary air. At a distance of 1·5 mm. between needle-points an E.M.F. below 1000 volts produces no current. 2000 volts produces an appreciable current which increases rapidly from 2000 to 8000 volts. A curve having volts as abscissæ, and galvanometer readings as ordinates, is always convex to the axis of abscissæ. The above measurements were made at the ordinary pressure; at a pressure of one-thousandth of an atmosphere (0·75 mm.) a few score of volts would start a current. Dr. F. T. Trouton communicated the results of experiments on the duration of X-radiation at each spark, made by rotating a wheel between the discharge tube and a sensitive plate. The duration varies between 1/300th and 1/10,000th of a second, but the results are dependent on the nature of the plate used. Prof. S. P. Thompson read a paper on the relation between kathode rays, X-rays, and Becquerel's rays. Interesting experiments were described in which various screens and obstacles were introduced inside a Crookes tube. In one of these the discharge from a concave kathode was allowed to fall on a flat anti-kathode inclined at 45°, and then on to two aluminium wires as obstacles in front of the wall of the bulb. At a low degree of exhaustion kathode rays are produced which throw shadows of the wires on the bulb, but no shadow on a fluorescent screen outside. The position of the shadows on the bulb can be shifted by a magnet. At a high degree of exhaustion we get X-rays which throw shadows on a fluorescent screen outside. These are not shifted directly by a magnet, excepting that the magnet shifts the hot point of the kathode rays on the anti-kathode. At an intermediate degree of exhaustion both shadows can be seen simultaneously. The kathode shadows contract when the wires are electrified positively, and expand when they are electrified negatively; the X-shadows are not affected by electrifying the wires.

On Saturday the Section divided into two departments. In the department of Physics the Report of the Committee on the Comparison and Reduction of Magnetic Observations was presented. Prof. Rücker presented the Report of the Committee on Magnetic Standards. A survey instrument previously compared with Kew has been taken to three observatories and compared with the instruments at these. Prof. Rücker visited Falmouth, and Mr. W. Watson Valencia and Stonyhurst. The differences from Kew are given below:

| | Falmouth. | Stonyhurst. | Valencia. |
|---|---|---|---|
| Declination ... ... | − 0·2 ... | + 1·1 ... | ± 0·0 |
| $H \times 10^{-5}$ C.G.S. ... | − 18 ... | − 6 ... | + 29 |
| Dip ... ... ... ... | − 1′·6 ... | + 2′·2 ... | − 1′·8 |

In the course of the adjourned discussion on Prof. S. P. Thompson's paper (read on Friday), Prof. V. Bjerknes stated that M. Birkeland (of Kristiania) had recently observed a discontinuous line spectrum of kathode rays produced by magnetic deflection. The rays are allowed to pass through an aperture in a metallic screen inside the tube, and their position, after deflection, is observed by means of the fluorescence on the wall of the tube. When the pressure is high only a single line is observed, but when the pressure is reduced new lines make their appearance. The spectrum is not continuous, as Lenard had supposed, but is discontinuous like the line spectrum of a gas. This supports the view that the rays are due to ethereal vibrations. The observations are rather difficult on account of flickering. Three or four bright lines are distinctly seen, but probably there are thirty or forty present. Prof. S. P. Thompson read a further paper on "hyper-phosphorescence"—the term hyper-phosphorescent being applied to bodies which, after due stimulus, exhibit a persistent emission of invisible rays not included in the hitherto recognised spectrum. In endeavouring to shorten the time of exposure in photographing with X-rays, the action of fluorescent substances, such as calcium sulphide, zinc sulphide, and fluoride of uranium and ammonium, was tested. The plates were found to become fogged by these materials, although they had been kept in the dark long enough for all visible phosphorescence to disappear. Even after being kept in the dark for six weeks calcium sulphide actively emits rays that affect a photographic plate. Experiments were made to test whether sunlight, or the light from an arc lamp, contains any radiation which will pass, like the X-rays, through opaque bodies. From an arc lamp, with an exposure of two hours, photographic shadows of pieces of metal were obtained through pine-wood several millimetres thick; but aluminium was quite opaque to everything radiated from the arc and to sunlight. Fluorescent substances were next placed on top of an aluminium plate below which was a photographic plate; and the whole was exposed to dull sunlight for several hours. Photographic action was found to have taken place (through the aluminium) behind the portions where uranium nitrate and uranium ammonium fluoride had been placed. These effects are inconsistent with a law enunciated by Stokes—but which he has since modified. When they were communicated to Sir George Stokes, he drew the speaker's attention to the remarkable results obtained by Becquerel in the same direction. The Becquerel rays differ from the X-rays in that they can be refracted and polarised; they are probably transverse waves of an exceedingly high ultra-violet order.

In the department of Mathematics a Report was presented on the G ($r$, $\nu$) Integrals; also the Report of the Committee on Bessel Functions and other Mathematical Tables. Papers were read by the Rev. R. Harley, on results connected with the theory of differential resolvents; by Lieut.-Colonel A. Cunningham, on the connection of quadratic forms; by Mr. H. M. Taylor, on great circle sailing; by Mr. S. H. Burbury, on the stationary motion of a system of equal elastic spheres; and by Mr. G. H. Bryan, on some difficulties connected with the kinetic theory of gases.

On Monday the Section again met in two departments. In the Physics Theatre, Lord Kelvin gave an account of experiments made by himself, Dr. Maclean and Mr. Galt, on the communication of electricity from electrified steam to air; and also contributed a paper on the molecular dynamics of hydrogen gas, oxygen gas, ozone, peroxide of hydrogen, vapour of water, liquid water, ice, and quartz crystal. Taking hydrogen and oxygen and their compounds first, it is assumed that there are two kinds of atom, $h$, $o$, with the distinction that the force between two $h$'s and the force between two $o$'s and the force between an $h$ and an $o$ are generally different. The mutual force between two $h$'s is always the same at the same distance; so is the force between two $o$'s and between an $h$ and an $o$. The atoms are considered as points acting on one another with forces in the lines joining them; no further assumption is made beyond the conferring of inertia upon these Boscovich atoms. It is shown that the known chemical and physical properties of the substances named can be explained by making H consist of two Boscovich atoms ($h$, $h$) and O of two others ($o$, $o$). This makes $H_2$ consist of four $h$'s at the corners of an equilateral tetrahedron, and $O_2$ a similar configuration of four $o$'s. It naturally shows ozone as six $o$'s at the corners of a regular octahedron; and peroxide of hydrogen as a tetrahedron of $h$'s symmetrically placed within a tetrahedron of $o$'s. It makes $H_2O$ (gaseous) consist of two $o$'s, with two $h$'s attached to one of them and two other $h$'s to the other; the $h$'s of each $o$ getting as near to the other $o$ as the mutual repulsion of the $h$'s allows. Models of this configuration and of the modification which it experiences in the formation of ice-crystals were shown; also of right- and left-handed quartz molecules and rock-crystal. The crystalline molecule of quartz is supposed to consist of three of the chemical molecules (OSiO). Mr E. Rutherford exhibited, by a number of interesting experiments, a method of detecting electro-magnetic waves. The detector consists of a group of fine steel wires about 1 cm. long, insulated from each other by shellac. These are first magnetised, and then inserted in a coil of many turns of wire provided with a suspended magnet and mirror. The passage of Hertzian waves alters the magnetism of the group of magnets, and shifts the position of the spot of light. For long waves the detector is very sensitive, and has been found to respond to waves produced half a mile away (with houses between); but for short waves a coherer is much more sensitive. The method has been used for measuring the resistance of a spark-gap: for short sparks this is very slight, but increases much more rapidly than the length of the gap. The apparent resistance of iron wires to Hertzian waves is found to be from 10 to 100 times that for steady currents. Prof. J. Chunder Bose exhibited a very neat and compact apparatus for studying the properties of electric waves. With this he has verified the laws of reflection and refraction, determined refractive indices and wave-lengths (by curved gratings), and exhibited polarisation and double refraction by pressure and unequal heating. The gratings used consist of tinfoil strips on ebonite. Between crossed gratings tourmaline exhibits little or no depolarising effect; the difference of transparency for the two vibrations at right angles is nothing like what it is for light. Very good depolarisation is produced by beryl and by serpentine; the latter makes a good electrical tourmaline. So also does a block of jute compressed by hydraulic pressure. Vegetable fibres and locks of human hair produce very striking polarisation effects, the vibrations along the fibres being absorbed, and those at right angles transmitted.

Department II. met in the Physics class-room to consider reports and papers on Meteorology. Reports of four Committees were submitted: on Meteorological Observations on Ben Nevis; on Solar Radiation; on Seismological Observations; and on Meteorological Photographs. Mr. A. W. Clayden's report on the application of photography to the elucidation of meteorological phenomena stated that the work of the Committee during the past year had been almost entirely confined to the determination of cloud altitudes by the photographic method. The two observing cameras are stationed 200 yards apart, and are electrically connected by telegraph wires. Exposures of quarter of a second and less are used. Each negative contains an image of the sun. The altitude and azimuth of this are first determined, and the coordinates of a selected point in the cloud-image are measured with reference to this. Among the greatest altitudes measured are the following (in miles):—Mackerel sky, 7·25; cirro-stratus, 9·63; cirrus, 11·62; upper level cirrus, 17·02. The results show that clouds forming exhibit a general tendency to rise, and this is also true of the ascent of general cloud-levels towards the early afternoon. Papers were read by Prof. Rambaut, on the effect of refraction on the diurnal movement of stars, and a method of allowing for it in astronomical photography; by Mr. G. H. Bryan, on the sailing flight of birds; by the Rev. R. Harley, on the Stanhope arithmetical machine of 1780; and by Mr. A. L. Rotch, on the exploration of the upper air by means of kites.

In the adjourned discussion on Prof. Bose's paper, on Tuesday, Prof. Oliver Lodge exhibited the coherer, "copper hat," &c., which he had used in studying electric waves some three years ago. He characterised his apparatus as being rather unmanageable and very cumbersome as compared with that of Prof. Bose; but members who were present at the Oxford meeting will remember with gratitude Prof. Lodge's interesting address, and the very successful experiments with which it was illustrated. Mr. W. H. Preece made a brief statement as to telegraphy by Hertzian vibrations. Signals have been transmitted (by Signor Marconi, working with Mr. Kempe) across a distance of one and a quarter miles on Salisbury Plain; further experiments are to be made on the Welsh hills. Reports were submitted by the Committee on Electrolysis and the Electrical Standards Committee. At the Ipswich meeting (see NATURE, September 26, 1895) the choice of a thermal unit was referred to this Committee, which has since communicated with physicists in various foreign countries on the matter. For many purposes heat is most conveniently measured in ergs. The name Joule has been given to $10^7$ ergs. A certain number of Joules may be selected as a secondary or practical thermal unit, and called a Calorie. According to the best determinations made, 4·2 Joules are required to raise the temperature of 1 gm. of water from 9°·5 C. to 10°·5 C., measured by a hydrogen thermometer. The Committee recommend that this be adopted as the secondary thermal unit. More accurate determinations of J, and of the variations of the specific heat of water, may necessitate a slight alteration in the mean temperature at which the rise of 1° takes place; but the definitions and the number (4·2) of Joules in a Calorie would otherwise remain unaltered. It is now proposed to issue a circular requesting international co-operation and agreement. Mr. W. N. Shaw read a paper on the total heat of water. Rowland's measurements give us data for finding the specific heat of water from 0° to 35°; and his measurements, together with those of Regnault, enable us to calculate it from 100° to 180°. What is now needed is a series of determinations from 35° to 100°. Mr. E. H. Griffiths exhibited a special form of resistance box (which admits of easy recalibration of all the coils in the box without requiring any other special instruments), and briefly communicated the results of his measurements of electrical resistance. It is of extreme importance that no shoulders should form on the brass plugs. Standard coils of the B.A. pattern (with wires imbedded in paraffin) only acquire the temperature of the surrounding medium very slowly; it is impossible to make accurate determinations with them when the temperature of the room differs from that of the bath by more than the fraction of a degree. In Mr. Griffiths' box all the coils are of naked wire wound on mica, and immersed in a hydrocarbon oil which is stirred from the outside. Mr. S. A. Sworn communicated the results of long and careful researches on absolute mercurial thermometry, and emphasised the importance of capillary corrections.

On Wednesday the Section again divided into two departments. In the Physics class-room the Report of the Committee on the sizes of pages of periodicals was presented, and papers were read by Mr. W. H. Preece, on disturbance in submarine cables; by Mr. W. M. Mordey, on carbon megohms for high voltages, and on an instrument for measuring magnetic permeability; by Mr. A. P. Trotter, on a direct-reading form of Wheatstone Bridge; and by Prof. F. Bedell, on the division of an alternating current in parallel circuits with mutual induction.

In the Physics Theatre Prof. J. E. Keeler described his method of measurements of the velocity of rotation of the planets by the spectroscopic method. Profs. Elster and Geitel described their investigations as to the cause of the surface colourisation of colourless salts (KCl, NaCl) by the kathode rays discovered by Goldstein. In this process the inside of the exhausted tube becomes coated with a layer which looks as if it might be metallic potassium or sodium. If so, it should be incapable of retaining a negative charge under the influence of violet light; this was tried, and found to be the case. In the case of rubidium and cæsium, gas-light was enough to cause leakage. But Goldstein finds that the salts retain their superficial tints in air for months; so the effect can scarcely be due to free alkali-metals on the surface. Probably the molecules of the metal are driven by the kathode rays into the salt, forming a solid solution in van 't Hoff's sense. It has been shown that the salts become alkaline after kathodic radiation, and this indicates that chlorine has been driven off. No chemical test has shown the presence of free chlorine; but this is not surprising when we consider the difficulty of proving its presence after light has acted upon silver chloride. A paper by Mr. J. Burke, on change of absorption accompanying fluorescence, dealt with a number of experiments made with the view of detecting whether the coefficients of absorption of uranium glass, and some other substances for the rays they emit, are altered in the act of fluorescence. The experiments, which were described at length, showed that a marked difference existed in the two cases, the absorption being greater when fluorescing and when not. Comparisons were made photographically as well as photometrically. Mr. W. Barlow read a paper on homogeneous structures and the symmetrical partitioning of them, with application to crystals.

The interest of the sectional meetings was much enhanced by the discussions following the papers, in which the President, Lord Kelvin, Sir George Stokes, and Prof. G. F. Fitzgerald frequently took part. So also did Prof. Oliver Lodge, who placed at the disposal of the Section all the conveniences of his lecture-rooms and laboratories, and also attended to the comfort and convenience of members in other ways.