on his wheat, that has inspired the German farmer to greater efforts during the last ten years. The need for well-educated men as managers of estates is more commonly recognised in Germany than in England; hence a career is open to successful students from the training institutions of Prussia, while the English student who lacks the capital to farm on his own account must look abroad for an outlet for his knowledge of practical agriculture.

Mr. Middleton believes that our system of education, though starting thirty years behind that of Germany, mainly wants time to grow. It is unfortunate that it had only just started before the war and that results will be sought at a time when patience will be necessary but very difficult to exercise. The chief immediate cause of the increased productivity of German soil is the increase in the use of artificial manures. The German farmer is no more skilful than the British, but his natural obedience to authority leads him to apply artificial manures in such quantities as his instructors, relying on the systematic work of the experiment stations, may from time to time direct. Twice as much nitrogen, one-third more phosphate, and five times as much potash are used in Germany as on an equal area of our cultivated land. As regards the two former manures, we import nearly three tons more feeding stuffs per one hundred acres than the Germans, and this should balance to some extent the smaller amounts of nitrogen and phosphate applied direct to the soil; but careless storage of farmyard manure results in the loss of some 50 per cent. of the nitrogen and a good deal of the phosphate, so that far less than the theoretical amount ever gets to the growing crop. Germany is fortunate in that she has not only immense deposits of potash salts, but also vast areas of light soils able to give abundant returns from these manures when skilfully applied. This combination plays an important part in the recent progress of German farming.

THE ROYAL AIRCRAFT FACTORY INQUIRY.

THE whole question of the Royal Aircraft Factory administration and cost seems to turn on whether it is to be regarded as an experimental or a productive concern. If it is to be regarded as a factory for the production of service machines, then there is little doubt that it is not administered as efficiently as it might be. But if it is to be regarded as a purely, or at least chiefly, experimental establishment, then the case is completely altered. In the development of a new industry, such as aeronautics, there must be a certain amount of experiment, and in modern times the tendency is to arrive at a satisfactory result by the application of science to the fullest possible extent, rather than to attain that result by a lengthy process of trial and error. The inevitable result of the scientific method is that it appears as though a considerable amount of money is being wasted with no appreciable result, but in reality the money is being well spent if it leads to scientific results of a widely useful nature. The Royal Aircraft Factory should therefore be judged by its achievements in the advance of aeronautical science rather than by its actual output of machines for service use. There can be no doubt at all that the work done at the factory, in conjunction with the model experiments and mathematical investigations at the National Physical Laboratory, has elucidated many questions of vast importance concerning the design and stability of aeroplanes in a way which would perhaps never have been done by private firms, where output is the primary consideration. Once it is admitted that this scientific information is needed, the Royal Aircraft Factory stands justified by its past work. By all means reorganise, if by such reorganisation increased efficiency can be obtained, but let it not be at the expense of the exceedingly valuable experimental work which is being done, and which can be done in no other way at the present time.

It is often argued that private firms can produce machines equal to those of the Factory, without spending so much time and money on the experimental side. This is by no means true, since the results of such experimental work at the Factory and elsewhere have always been available to a large extent to any who cared to avail themselves of them, and many good points in proprietary machines are indirectly due to this fact. There is still an inclination on the part of some firms to view the scientific side of the subject with suspicion, and even to depreciate experimental aeronautics altogether, but surely the sooner experimental results become more widely known the better it will be for the future development of the aeronautical industry. In the provision of these scientific fundamentals of aeronautics the Royal Aircraft Factory has played, and is playing, an important part, and any attempt at reorganisation which would impair its utility as an experimental establishment, and reduce it to the level of a productive factory for existing designs, would be a great mistake at the present early stage of aeronautical development.

LORD KELVIN AND TERRESTRIAL MAGNETISM.[1]

LIKE most branches of physics, terrestrial magnetism has associations with the name of Kelvin, and, characteristically enough, these associations are at the two confines of the subject, the immediately practical, and the speculative. Lord Kelvin, I need scarcely remind you, introduced important changes of design into compasses, and the construction of compasses was an important object of the Glasgow firm which eventually bore his name.

The other point of contact between Lord Kelvin and terrestrial magnetism, as already mentioned, relates to theory. All here know that there occur from time to time phenomena known as magnetic storms, during which there are difficulties in carrying on ordinary telegraphy. There has long been a belief that the sun is the principal, if not the only, source of magnetic storms, and of the less striking regular changes every day visible. Lord Kelvin directed attention to the difficulties in the way of accepting any sensible *direct* magnetic action between the sun and the earth. His earliest remarks on the subject, to which I shall refer, are contained in a short note on p. 154 of vol. iv. of his "Mathematical and Physical Papers." "The sun's magnetisation," he said, "would . . . need to be 120 times as intense as the earth's to produce a disturbance of 1′ in declination even by a *complete reversal* in the most favourable circumstances."

The much later communication, to which I next refer, was made in 1892 to the Royal Society, on an occasion—a presidential address—when original contributions to science are unusual. Lord Kelvin, however, devoted fully half his address to terrestrial magnetism. After referring to various solar and terrestrial magnetic phenomena he adds (*loc. cit.*, p. 307):—"But now let us consider . . . the work which must be done at the sun to produce a terrestrial magnetic storm." He then quotes from a paper by the late Prof. W. G. Adams data relating to a magnetic storm of June 25, 1885, and proceeds:—"To produce such changes as these by any possible dynamical action

[1] Abridged from the Seventh Kelvin Lecture delivered before the Institution of Electrical Engineers on February 17, by Dr. C. Chree, F.R.S.

within the sun, or in his atmosphere, the agent must have worked at something like 160 million million million million horse-power. . . . This result, it seems to me, is absolutely conclusive against the supposition that terrestrial magnetic storms are due to magnetic action of the sun; or to any kind of dynamical action taking place within the sun, or in connection with hurricanes in his atmosphere, or anywhere near the sun outside. It seems as if we may also be forced to conclude that the supposed connection between magnetic storms and sun-spots is unreal, and that the seeming agreement between the periods has been a mere coincidence. We are certainly far from having any reasonable explanation of any of the magnetic phenomena of the earth; whether the fact that the earth is a magnet; that its magnetism changes vastly, as it does from century to century; that it has somewhat regular and periodic . . . solar diurnal . . . variations; and (as marvellous as the secular variation) that it is subject to magnetic storms."

To-night I shall confine myself to three of the outstanding problems enumerated by Lord Kelvin: the secular change, the solar diurnal variation, and the phenomena of magnetic disturbances.

Secular Change.

Our knowledge of secular change prior to the nineteenth century is confined to declination and dip. For these elements we have in some districts data covering more than three centuries.

The total range of D (declination) observed in London has exceeded 35°. The only actual turning point observed, 24·6° W., presented itself about 1818, the direction of secular change then altering from westerly to easterly. We have no idea how the value, $11\frac{1}{4}$° E., observed in 1580 stood to the previous turning point. The declination was approximately the same as at present in 1730. When, if ever, it will have the same value again, we have not the ghost of an idea. The change in each of the centuries 1600 to 1700 and 1700 to 1800 was about 16°, whereas during the last hundred years the change has been only about 9°. The rate of change has, however, markedly increased of late years, as may be recognised on consulting Fig. 1, which shows the change at Kew during the last fifty years.

The turning point in the dip, when it attained its highest value, presented itself about 1723, or nearly a century before the turning point in D. The dip in London is now lower than it has been since observations began. Of late years the rate of change has been very small, but whether this heralds the near approach of a minimum, or is merely a temporary slackening, we do not know.

The intensity of magnetic force changes as well as the direction. Thus at Kew between 1890 and 1900 H (horizontal force) increased from 0·18169 to 0·18428 c.g.s. When dealing with such small changes as ordinarily present themselves in terrestrial magnetism, it is convenient to employ as unit 1γ, or 0·00001 c.g.s. Thus the mean annual rise of H from 1890 to 1900 was 26 γ. After 1900 the rate of increase of H rapidly fell off, and the element seems to have attained a maximum and begun to diminish. V (vertical force) has been diminishing for some time.

Diurnal Variation.

To give a full account of the diurnal variation as it presents itself at different parts of the earth would require a large treatise. Here I shall confine myself to data from two stations, and to certain aspects only of these data. The one station, Kew, is fairly representative of the British Isles. The other station is that used in 1911–12 as the base station of the National Antarctic Expedition under the late Captain Robert Falcon Scott, R.N. The reduction of the Antarctic observations has been prosecuted at Kew Observatory for the last two years under my supervision. For permission to make a free use of existing data I am indebted to the committee of the Captain Scott Antarctic Fund.

The tragic fate of Captain Scott is still no doubt fresh in your memories. It produced a great impression on his countrymen, who saw in it evidence that the characteristics on which the nation prided itself in more warlike times still survived. The appreciation of courage is practically universal, but even a scientific audience may have to be reminded that the prosecution of pure science under the arduous conditions prevailing in the Antarctic calls for no small measure of pluck and endurance. It also calls, if success is to be attained, for other qualities, which though making less appeal to the public imagination, are perhaps of equal value for the welfare of a nation, viz., scientific knowledge and forethought. If I am able tonight to mention important deductions from the Antarctic observations, it is to the physical observers, Dr. Simpson, F.R.S., and Mr. C. S. Wright, that recognition is in the first place due. In spite of the

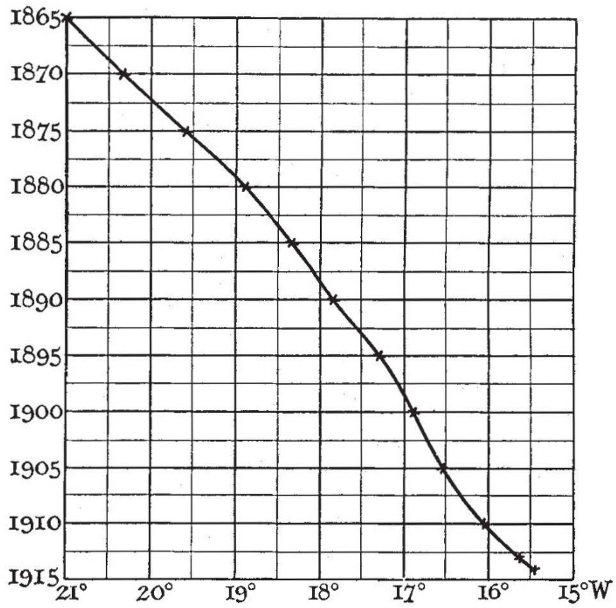

FIG. 1.—Changes of westerly declination at Kew since 1865. Change in the last fifty years $5\frac{3}{8}$°. Present annual change 9′.

great difficulties arising from the low temperature and the extraordinarily disturbed magnetic conditions, they secured an almost unbroken record for a period of nearly twenty-two months.

In Fig. 2 the vector diagrams refer to mean results from the whole year. The full-line diagram represents at either station results based on all, or all but highly disturbed days, the dotted-line diagram results from quiet days only, the origin, the centre of the cross, being the same for the two. The Antarctic quiet days (selected by myself) were ten a month, as against five at Kew (international quiet days). Thus *a priori* we should have expected less difference between the two Antarctic diagrams than between the two Kew ones. As regards type, there is, in fact, less difference in the Antarctic, but as regards amplitude the difference at Kew is slight, and not always in favour of the all-day vector, whereas in the Antarctic the excess of the all-day vector is conspicuous at every hour.

The great difference in amplitude between the Antarctic diurnal inequalities from all and from quiet days suggested a comparison between inequalities from highly disturbed days, on the one hand, and quiet days on the other. To secure a demonstrably impartial selection, I took for each month the five international quiet days selected at De Bilt and the five days which had the largest "character" figures on the international list. "Day" in this connection means a period of twenty-four hours commencing at Greenwich midnight. Thus Greenwich civil time has been used in the curves in Fig. 3, which embody the results obtained for the two sets of days in the Antarctic. When comparing Antarctic results in Figs. 2 and 3, it must be remembered that 11h. on the former answers to 0h. on the latter.

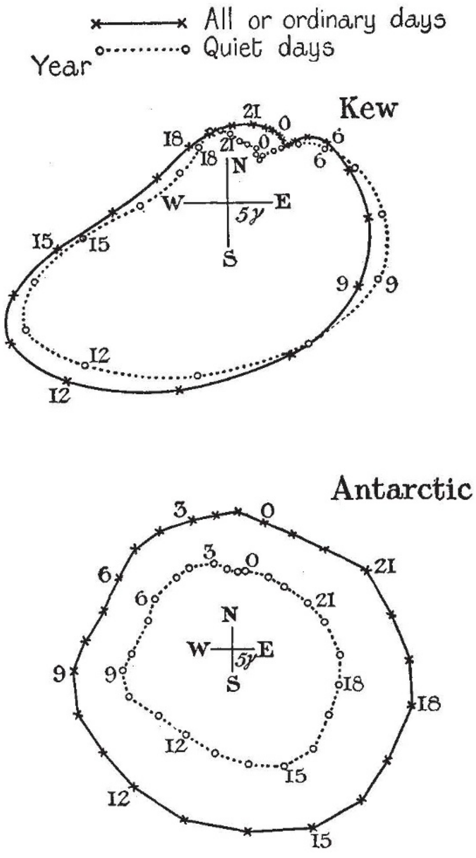

FIG. 2.—Diurnal variation.

Fig. 3 is confined to the four midwinter months, May to August.

Large as was the difference between the all and quiet-day vectors in Fig. 2, it is quite eclipsed by the difference between the disturbed and quiet-day vectors in Fig. 3. In the latter figure the amplitude of the disturbed-day vector averages about four times that of the quiet-day vector. In fact, the vector for the disturbed winter day averages about the same as the vector of the ordinary summer day.

While opinions may differ as to what the phenomena shown by Figs. 2 and 3 really imply, it can scarcely be questioned that they have an important bearing on theories which attempt to account for the diurnal variation. A difference in type between simultaneous diurnal inequalities at different places is a natural enough consequence of difference of geographical position. But the influence of disturbance is out of all proportion greater in the Antarctic, and presumably also in the Arctic, than in the temperate latitudes of Europe, and no mathematical formula which contains only geographical co-ordinates and sun's position can adequately meet the case of diurnal inequalities the ratio of the amplitudes of which at different places varies from day to day according to the prevalence of disturbance.

The 27-Day Period.

A remarkable feature in magnetic disturbance is the so-called 27-day period. This seems to have been first noticed by J. A. Broun[2] in 1858, but the phenomenon for some reason was practically overlooked until rediscovered by W. Maunder[3] in 1904 in Greenwich magnetic storms, and about the same time or a little earlier by A. Harvey[4] in Toronto disturbances.

All I think we are really entitled to say is that if a certain day is disturbed, days from twenty-five to thirty days later have more than the usual chance of being

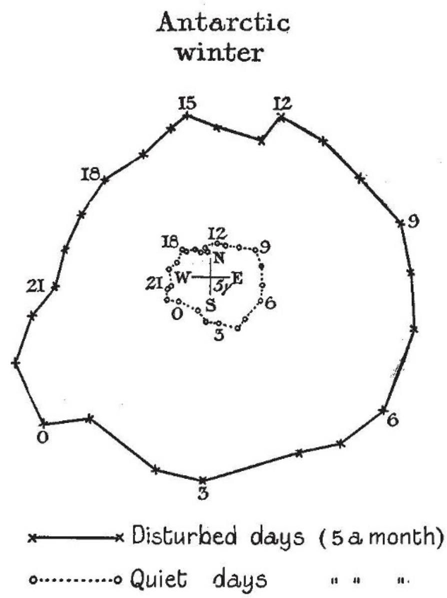

FIG. 3.—Diurnal variation.

disturbed, and this probability is greater for the twenty-seventh day than for the twenty-sixth or twenty-eighth.

If we confine our attention to large magnetic disturbances an obvious difficulty arises. Large disturbances are rare, and if all but large disturbances are disregarded, a very inadequate supply of data remains. If, on the other hand, we count a large number of disturbances as magnetic storms, numerous chance repetitions in twenty-seven, or any other specified number of days, must be expected; and in the absence of any precise definition of what constitutes a storm—and none commands general respect—claims as to repetitions in twenty-seven days naturally fail to carry conviction. There are, however, ways of testing the existence of the period less exposed to criticism, and those I have tried point to the real existence of a 27-day period in a certain sense of the term.

The first thing is to get what will be generally accepted as an impartial measure of disturbance, so that days may be selected as representative of dis-

2 *Philosophical Magazine*, August, 1858.
3 R.A.S. Notices, vol. lxv., pp. 2 and 538, etc.
4 Proceedings of the Royal Astronomical Society of Canada, 1902–3, p. 74.

turbed conditions, and every day may have a numerical measure attached to its disturbance. International "character" figures naturally suggest themselves for the purpose.

The "character" figures were entered in successive columns, representing from so many days before to so many days after the representative disturbed day. The successive columns were summed, and the resulting means taken as a measure of the average disturbance presented from so many days before to so many days after the representative day.

The days recognised by Maunder as magnetic storms average only about one a month, and were much more numerous in some years than others. If the 27-day period had been a phenomenon confined to such highly disturbed days, the procedure adopted here could scarcely have brought it into evidence, except in disturbed years. It proved, however, to be as much in evidence in the less disturbed as in the more disturbed years. This suggests that it is not peculiar to disturbed conditions, a conclusion which is strongly supported by Fig. 4, which shows the results of applying the procedure explained above to the international quiet days as well as to the representative disturbed days of the nine years 1906 to 1914. The representative days in each category were five a month. The normal line in Fig. 4 represents the mean "character" figure, 0·60$_4$, of all days of the nine years. Above this normal line we have the primary and secondary pulses associated with the representative disturbed day, the "character" figure of which was 1·26, and below it are the primary and secondary pulses associated with the representative quiet day, the "character" figure of which was 0·11. The secondary pulse associated with the representative quiet day is not quite so deep as that associated with the representative disturbed day, but the same is true and to a like extent of the primary pulses.

The graphical representation of the results for the individual years in Fig. 4 is confined to days 0 and 27. The extreme top and bottom of the lines represent the "character" figures on the representative disturbed and quiet days, on the same scale that serves for the nine years combined. The top and bottom of the thickened portions of these lines represent the "character" figures on the days which are twenty-seven days subsequent to the representative disturbed and quiet days respectively. The total length of the vertical line may be regarded as a measure of the primary difference pulse (disturbed less quiet), and the length of the thickened portion as a measure of the corresponding secondary pulse. The short horizontal line shows the "character" level of the average day of the year. The lengths of thickened line above and below this level may thus be regarded as representing respectively the amplitudes of the secondary pulses of disturbed and quiet conditions. Above the nine lines are given Wolfer's mean sun-spot frequencies for the respective years.

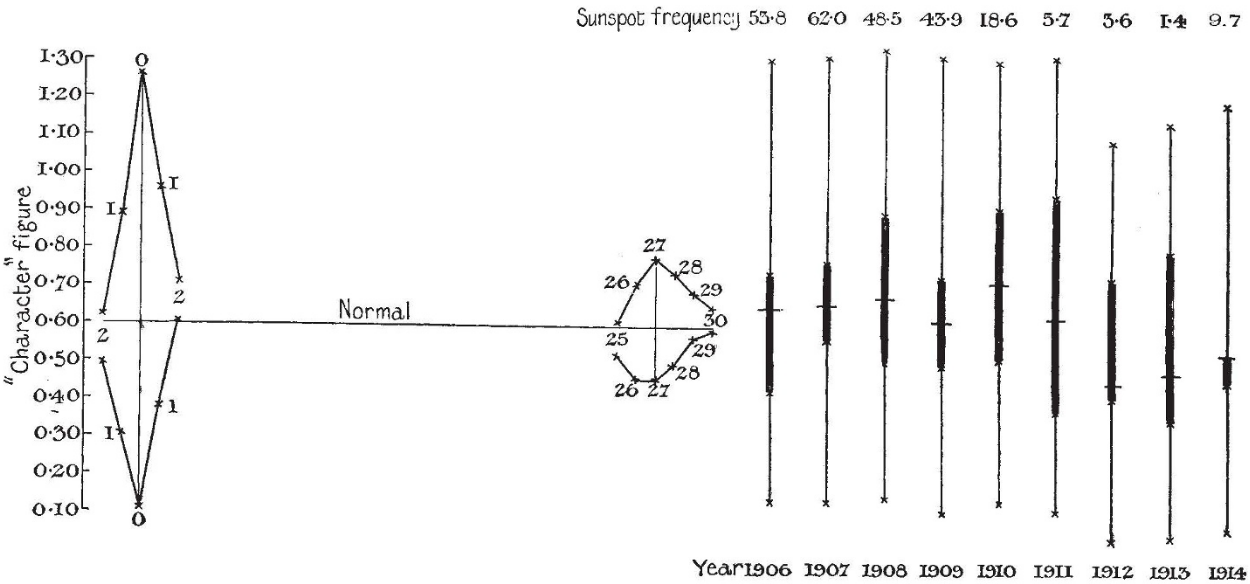

FIG. 4.—27-day period. International "character" figures 1906 to 1914.

The 27-day period is conspicuously shown in Fig. 4 in every year except 1914, where the secondary pulse associated with the representative disturbed day is abnormal. The two years in which the 27-day period is most in evidence are 1911 and 1913, both, especially the latter, years of few sun-spots; while 1907, the year of sun-spot maximum, shows it less than any other year except 1914. In 1912 the secondary disturbed pulse is much better developed than the secondary quiet pulse, and 1913 shows the same phenomenon to a minor extent. In 1906, on the other hand, the secondary quiet pulse is the more prominent. In the years 1907 to 1911 the development of the two secondary pulses is very similar.

A good deal probably remains to be done to unravel the exact nature of the relationship between sun-spots and magnetic phenomena. There can scarcely be any doubt that the range of the mean diurnal variation for the whole year varies from year to year in almost exactly the same way as the mean sun-spot frequency or the sun-spot area. Also the two phenomena exhibit a 27-day period, and to approximately the same extent. In the average year of an 11-year period, 1890 to 1900, the daily range of H at Kew showed a decided tendency to be above its mean value during several successive days subsequent to the appearance of exceptionally large sun-spot area, the maximum in the range following four days after the maximum in the area. The phenomenon, however, did not seem to arise from special disturbance, but rather to be a variant of the phenomenon of large regular diurnal variation in years of many sun-spots. As regards disturbance, in some years there seems a clear connection with sun-spots, in others little, if any. This is what we might expect to happen if the 27-day periods in the two elements in one year tended to be in phase, and in another year did not. But the 27-day period may be prominent in magnetic phenomena in years when there are almost no sun-spots. Also the 27-day period is exhibited by magnetic calms as well as by magnetic storms, and no one has suggested that limited solar areas can exercise a calming influence on terrestrial magnetism.

On the question naturally of most interest to my audience, whether terrestrial magnetism has any direct bearing on the problems of electrical engineering, a few words must suffice. If wireless phenomena are affected, as has been suggested, by the greater or less conductivity of the upper atmosphere, one would expect them to have certain features in common with magnetic phenomena. In particular, the 11-year period and the 27-day period might be expected to disclose themselves. If these periods affect wireless to anything like the same extent as they do terrestrial magnetism, there should be no great difficulty in establishing the fact, if systematic observations were directed to that end. Another possibility is that means may be developed for utilising some of the power that now goes to magnetic storms. This would naturally be most feasible in high latitudes where aurora and magnetic disturbance are most in evidence.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

WE learn from the *British Medical Journal* that Prof. Charles Richet, of the University of Paris, has been awarded the State prize for poetry. The subject was "The Glory of Pasteur."

EXAMINATIONS in biological chemistry, bacteriology, fermentation and enzyme action, and in chemical technology will be held in connection with the Institute of Chemistry in October next. The lists of candidates will close on September 12.

DR. A. LAUDER, of the Edinburgh and East of Scotland College of Agriculture, has been elected honorary secretary of the Edinburgh and East of Scotland section of the Society of Chemical Industry, in succession to Dr. J. P. Longstaff, now general secretary of the society in London.

MISS S. E. S. MAIR and Mrs. A. M. Chalmers Watson, on behalf of women medical graduates, students, and their friends, have offered to pay to the Edinburgh University Court within a year the sum of 4000*l*. to defray the cost of undertakings intended to facilitate the medical education of women.

THE following Edgar Allen entrance scholarships are being offered by the University of Sheffield:—Two open to men and women, and two restricted to the "sons of workmen earning daily or weekly wages and foremen of workmen and managers." Each scholarship is of the annual value of 100*l*., and is tenable for three years.

THE part of the forthcoming calendar for 1916–17 of University College, London, dealing with the faculty of engineering has been published in advance as a booklet. This faculty, including the departments of civil, mechanical, electrical, and municipal engineering, is intended to provide for students wishing to devote themselves to engineering as a systematic training in the application of scientific principles to industrial purposes. The courses of work are suited to the requirements of students who intend to enter for appointments in the Indian Public Works Department, Engineering Department of the General Post Office, Department of the Director of Engineering and Architectural Works in the Admiralty, Patent Office, and other similar services. Facilities are provided also in the engineering departments for post-graduate and research work in all subjects of engineering. The more important engineering institutions grant various exemptions to holders of the different certificates awarded by the college. All communications from intending students should be addressed to the Provost.

THE calendar for the session 1916–17 of the North of Scotland College of Agriculture is now available. The classes of the college are held in the buildings of the University of Aberdeen, except those in agricultural engineering, which are held at Robert Gordon's Technical College. The college farm at Craibstone, about five miles from Aberdeen, includes experimental plots, an experimental and demonstration garden, and a horticultural department. Field experiments and demonstrations are carried out on ordinary farm crops. Feeding and other experiments upon stock are conducted, and there are extensive woods, including both conifers and hardwood trees, on the estate, which are being utilised for the purposes of the forestry department. It is proposed to institute a school of rural domestic economy for girls. There is a large mansion-house on the Craibstone estate which will be equipped as a residence in which classes will be carried on. It is proposed to provide courses of instruction suitable for those who intend to spend their lives on farms and crofts. For the instruction of classes in nature-study and school gardening, two acres of ground at Kepplestone, Rubislaw, have been laid out as a demonstration garden.

THE valuable series of papers on the better co-ordination of science and industry read during the last six months before the American Chemical Society was followed by the appointment of a committee, who have now presented a report based on the examination of the subject from three different points of view, viz. those of the university, of the industries, and of the consulting chemists. The report is classified under findings, conclusions, and a single recommendation to the effect that a permanent central committee should be created and appointed by representatives of the universities and the industries to study opportunities and make public recommendations. The distinction is drawn between industrial problems which are common to specific industries, so that research on them can be carried out in universities and published, and those problems which cannot properly be published, and are, therefore, not adapted to university treatment. On the other hand, the industries are asked to make known to the universities problems which are not of sufficient importance to the industry to undertake their solution directly so that the universities can use them as live material on which the students can be trained. The recognition by the university that the industry alone is in a position to state its problems, and by the industry that it should be prepared to give the necessary financial assistance to the university to investigate these, is an important step towards the desired co-ordinated effort. It is pointed out that no matter how efficiently the university may train its men, the industries that take up such men must be prepared to expend much time, effort, and money in training them for the specific work before them, but it is agreed that co-operation between the university and the works as to the requirements of the latter in the fundamentals of instruction seems possible, feasible and mutually profitable. The findings deal with certain controversial points in the education