done in training skilled wireless operators both in the Navy and for the mercantile marine work. Radio-telegraphy, like aviation, is an art as well as a science, hence personal skill is a factor of importance in turning the flank of the difficulties of the moment. Nevertheless, the art and the science of radio-telegraphy are both progressing, and the splendid services already rendered by it in saving life at sea are at once a proof of present perfection and an evidence that the arduous labours of investigators and inventors have borne fruit in yet larger powers to command the great forces of nature for the use and benefit of mankind.

ILLUMINATING ENGINEERING.[1]

THIS society has been founded to bring together all those who are interested in the problems, practical and theoretical, of the *art of directing and adapting light, that prime necessity of* civilised, as well as of uncivilised, *existence, to the use and convenience of man.* To advance the subject of illuminating engineering, to investigate through all its lengthened breadth the facts within its domain, to increase and diffuse knowledge respecting them, and to unite those who are devoting their energies to these things, is the object of the society. The ascertained facts are few—all too few; their significance is immense; their economic and social value is great; but the ignorance respecting them generally is colossal.

For practically a century only have there been any systematic means of illumination in use in any civilised country. Before the year 1800 there were as means of illumination daylight, oil lamps, rush lights, tallow dips, and wax candles. Monarch and peasant, merchant-prince and workman, had alike to depend on individual sources of light at night. Only in the larger towns and cities was there any organised attempt to light the streets by oil lamps. In 1819 the authorities of the day stoutly resisted the proposal to light the then House of Commons by gas—nothing but wax candles could be admitted; but gas lighting was coming in, and Argand and colza oil lamps were the sole competitors until after 1850. Everything else dates since then—practically during the last half-century. For paraffin lamps were not widely spread until the 'sixties. Arc lighting, though tried for spectacular and lighthouse purposes from the 'fifties, did not come into public question until about 1879. Glow-lamps followed three or four years later. Still later came incandescent gas mantles and acetylene gas lights, while the newest things in both gas lighting and electric lighting are affairs of only a year or two ago. Many persons now realise the immense stride made in the introduction of the Auer (Welsbach) mantle for incandescent gas; very many fewer people realise the significance of the corresponding step forward that has been begun by the introduction of the metallic filament glow-lamp. We are on both sides in the very middle of an immense evolution in the art of illumination.

But whilst the means of illumination have thus been developing with amazing strides during a single generation, and the organised systems of distribution by municipal and urban and rural authorities, and by private corporations, have ramified throughout the community and brought supplies of gas and of electricity—shall I also say of oil?—to our doors, there has been another and very different development going on. I refer to the growth of that branch of the science of optics which deals with the measurement of luminous values. Photometry has been growing into an exact science by the explanation of its laws and the improvement of the instruments of measurement. It was not until 1760 that the first real discussion of photometric principles was made known. In that year Lambert, in his "Photometria," laid down the fundamental laws, and likewise in the same year Bonguer gave to the world his "Traité d'Optique," wherein a primitive photometer was described. Rumford's shadow photometer was invented in 1794, and Ritchie's in 1824. Then comes a long gap. Save for Bunsen's over-rated grease-spot instrument, there was no important advance in photometry until the 'eighties, when there were produced many novel forms, some of them, including the now well-known forms of L. Weber, Lummer-Brodhun, and Rood, capable of yielding results of much higher precision in the comparison of different sources of light; also in the 'eighties we meet for the first time with special forms of photometer of the kind destined to play a very important part in the work of our society, many photometers measuring the values, not of the brilliancy of a source of light, but the illumination of a surface.

Our primary concern is the adequate and proper illumination of things; and as we have to reduce the present chaos to an exact science, our first business is to secure some common agreement as to the measurement of illumination and the establishment of reasonable rules as to the amounts of illumination required in different cases.

Foremost, then, in the programme of work for our society we put the question of the units of measurements and the promulgation of the proper definitions of them. We must secure agreement—national and, if possible, international—as to what shall be taken as the unit of light and what as the unit of illumination at a surface.

Happily, the long-standing controversy as to the former appears to be settling itself by at least a preliminary agreement between the standardising laboratories of the great nations. One "candle" is no longer to be a vague and indefinite thing. The new definition provisionally agreed upon is an ideal unit, in terms of which one can describe the several standards in use in different countries. If this provisional *entente* can but be ratified by a little international common sense, we shall have henceforward an international "candle" such that it is the same in England as in America, equal to the *bougie décimale* accepted in France, and related to the Hefner-candle of Germany in the precise proportion of ten to nine.

But we have still to find agreement on the standard of illumination. Here in England, and in the United States, we have already grown accustomed to describe amounts of illumination of surfaces in terms of a British unit—the "candle-foot"—not perhaps a very happy term—one that we would readily exchange for a better—meaning, thereby, the intensity of the illumination at a surface situated at the distance of one foot from a light of one "candle." The source being assumed here to be concentrated at a point, the law of inverse squares holds good.

Adopting the candle-foot as the unit of illumination, one may readily state certain facts with definiteness. All competent authorities are agreed that at night, for the purpose of reading, an illumination is required not less than one candle-foot, some authorities saying $1\frac{1}{2}$ candle-foot. The facts appear to be that reading is impossible with an illumination of one-tenth candle-foot, difficult and fatiguing with one of one-fifth candle-foot, comfortable with from $1\frac{1}{2}$ to 3 or 4 candle-foot, but that if the illumination exceeds 6 or 8 candle-foot, the glare of the page is again fatiguing and dazzling. The page should neither be under-illuminated nor over-illuminated. Something depends, it is true, on the size of the print. Under a feeble illumination of, say, $\frac{1}{2}$ candle-foot, a type of pica size printed in a fount of bold face properly inked is legible when one of long-primer size, printed in a weak way, would be practically illegible. Something also depends on the state of the eye as affected by the general illumination of the surroundings. Very seldom does one find in any ordinary room an artificial illumination exceeding 3 candle-foot. By day, on a writing-table placed near a north window—or near any window not receiving direct sunlight—the illumination may exceed 3, and may even attain 4 or 5 candle-foot.

Until a unit of illumination was thus agreed upon, it was impossible to render any reasonable certainty to estimates of the amount of illumination in any case of dispute. What is the meaning of the term well-lit as applied to any room, building, factory, workshop, or school? Formerly the term was entirely vague. To-day the answer can be given in numerical terms. Formerly judgment had to be made by the unaided eye, and the eye is notoriously a bad judge. As between two different illuminations, the powers of discrimination of the eye are very limited. The eye can equate, but it cannot appraise. It can tell with fair accuracy whether two adjacent patches

[1] Abridged from the inaugural address delivered at the inaugural meeting of the Illuminating Engineering Society held on November 18, by Prof. Silvanus P. Thompson, F.R.S., president of the society.

are equally bright; if they are not equally bright it cannot say with any kind of proportionality what their relative brightnesses are. All photometry depends on the perception of an equality.

Photometers for the measurement of illumination have been mentioned earlier as coming first into notice in the 'eighties. One of the earliest in this country was that constructed by Sir William Preece, with the assistance of Mr. A. P. Trotter, for measurement of the illumination of side-walks and pavements of streets. It has been subsequently developed by Mr. Trotter, and as constructed by Mr. Edgcombe is a most useful and handy instrument, telling the amount of illumination directly in terms of the candle-foot. Another, by Mr. Haydn Harrison, measures the illumination, not on the horizontal, but at 45°. Almost equally early with the Preece-Trotter illumination photometer was the school photometer of Petruschewsky, apparently little known in this country. Most recent of this sort is the form due to Martens.

The principles and construction of photometers are matters that have interested me for nearly thirty years. About 1880 I brought out a form of wedge-photometer (modified from Ritchie's form), in conjunction with Mr. C. C. Starling, for electric light measurements. Later I gave to the Physical Society an investigation of the errors arising in photometry from the almost universal assumption that the law of inverse squares is fulfilled. In 1882, when lecturing at the Crystal Palace Exhibition, I gave diagrams to show the effect of the superposition of illumination from two or more lamps, and discussed the variations of illumination in a street between the places of maximum and the places of minimum illumination. Twelve years ago I described a tangent photometer, which has remained a mere optical curiosity

No one can have worked at the photometry of modern lamps, or of the illumination of surfaces lit by lamps, without becoming conscious how much misunderstanding there is of the elementary laws of illumination. There is Lambert's cosine law, admirable and simple if only it were not in so many cases vitiated by the presence of organised—that is, specular—reflection. There is the law of inverse squares, itself a universal geometrical law of action radiating from a point, so fatally and absolutely misleading if applied to any other case than that of action from a point.

One subject on which more information is badly needed is the specific brightness of surfaces of different kinds when subjected to a standard illumination. For instance, how much light is reflected, per square inch, when illuminated with an intensity of 1 candle-foot, from such materials as oak panelling, whitewash, brown paper, or the surface of a red brick wall? Here in this theatre the walls are tinted of a dark Pompeian red or maroon, which reflects but little light. The extra annual expense on lighting that might be saved had a lighter tint been used is surely worth considering.

The subject of diffuse reflection which here comes into play has indeed been investigated partially by several persons. There are Dr. Sumpner's researches of 1894 and those of Mr. Trotter on white cardboard and other white matt surfaces, but how few others! Again, there is the subject of diffuse refraction, which occurs in ground-glass shades, ribbed and corrugated glass panes, and other devices for diffusing the concentrated light of lamps. Yet how little does any optical book tell us on the subject of diffuse refraction. Reflection and refraction as they occur at dull or irregular surfaces appear to be of no importance to the academic writer of text-books of optics, but they are of vital interest to the illuminating engineer. Again, there are a number of semi-physiological problems that demand investigation and settlement. We all know that our eyes have an automatic diaphragm which stops down the entering light to protect our eyes from glare, rendering us relatively insensitive to bright lights. Does anyone know whether the contraction of the pupil depends on the total amount of light entering the eye or on the intensity of the image on local patches of the retina?

Again, we all know how an unshaded arc-lamp, or even glow-lamp, "cuts" the eyes by the very concentration of its beams, even when it may be many feet away, while the same actual amount of light, if diffused over a greater apparent surface, as by a surrounding globe of ground glass, is quite readily endured, and does not produce the same painful sensation. Does anyone know how great is the specific brightness of surface that the eye will tolerate without experiencing this discomfort? We can look at a white cloud or at the blue sky without pain. Can we endure a specific brightness of so much as one-tenth of a candle per square inch?

Our eyes are provided by nature with a most exquisite and automatic iris diaphragm which opens in the dark and closes in the light, thereby shielding us partially against the evil effects of glare. Putting it in the language which the photographer uses to describe the stopping-down of a camera-lens, the automatic iris of our eye can close the pupil so that while in a comparative darkness the aperture opens to $f/2$ or $f/2{\cdot}5$, it closes, amid a brilliant surrounding illumination, to about $f/20$. Suppose we are looking out in relative darkness, and are confronted with a brilliant patch shining with a specific brightness of one-tenth of a candle per square inch, we shall feel a certain amount of discomfort from its glare, and if we regard it steadily for a second or two will, on closing our eyes or turning away, see those persistent coloured images that trouble us after looking at any very bright light; but now let the same brilliant patch be placed against a bright background. Far more light will enter the eye; the automatic iris of the eye will in a few moments have contracted, stopping down the lens of the eye so that it will be far less sensitive. In these circumstances, will the patch that has a specific brightness of one-tenth candle per square inch pain or dazzle the eye? I ask the question, but I do not know the answer. Does anyone know what the answer ought to be? It is a simple question, and a few experiments would soon settle it. Of course, one must admit that the automatic action of the iris diaphragm, important as it is, does not by any means account for the whole of the facts about the want of proportion between the intensity of a stimulation and the intensity of the resulting sensation. Fechner's logarithmic law of psychophysics gives a clue, but even this does not seem capable of expressing, much less of explaining, the facts about the observed want of proportionality. Why should a light of ten-fold brilliancy not produce a sensation ten times as intense? And why should a greater brightness of the general surroundings relieve us of the annoyance of those coloured after-images? After-images can be seen even under extremely feeble illumination, as I have again and again found. Has anyone discovered any exact law governing their occurrence?

All these queries show that there is plenty of work awaiting us, even in the mere collection and completion of such scattered information as is already available; but there are even more important questions before us, more important, not in science, but in their relation to the public welfare and the economics of the community.

Now that we have a standard of illumination and simple portable instruments that will measure it, there can be no excuse for inaction or ignorance in applying that knowledge to securing proper illumination for public and private buildings.

Let me begin with school buildings. They are the most important; for whatever bad results flow from bad lighting of churches, factories, or railway stations, those which result from the bad illumination of schools are far more to be deplored—they imperil the eyesight of the next generation.

All ophthalmic surgeons agree that the cause which forces the children into increasing shortsightedness is protracted poring over books under an insufficient illumination. Even in what an inspector might call a well-lit school the illumination at the surface of the desk may be quite insufficient if the desks are badly placed, or the windows insufficiently high, or the lamps badly distributed.

All educational authorities ought henceforth to insist on rational requirements as to lighting. Hitherto they have had nothing definite to specify; now that illumination photometers are available, they ought to require a minimum of $1\frac{1}{2}$ candle-foot at the worst-lighted seat in the schoolroom, and not depend on purely architectural rules about heights of windows or areas of window-space. In England the Board of Education, in its Building Regulation (1907), Rule 6, clause *c*, has laid down a foolish rule:—"Skylights are objectionable. They cannot be approved in school-rooms or class-rooms." That perfectly monstrous provision ought to be at once repealed. The universal experience of the textile industries, where adequate lighting of spinning and weaving machinery is a prime necessity, is that no method of lighting is so satisfactory as skylights in roofs specially constructed to receive light from the northern sky.

Hitherto little attention has been paid by either local or central authorities to conditions affecting the lighting of factories and workshops. It is true that the factory inspectors require periodic whitewashing of factories, but that is for sanitary reasons, not primarily to secure better illumination. The Home Office has its regulations as to temperature and degree of moisture required or permissible in the different classes of factories and workshops. Then why not also similar regulations as to the proper amount of illumination? Surely the eyesight of the workers is as well worth protecting from injury as their lungs and their limbs. So far as I am aware, Holland is the only country in which legislation has fixed a statutory amount of illumination in factories, the figure there being from 10 to 15 candle-metre, equivalent, therefore, broadly to the value of 0·9 to 1·35 candle-foot.

Architects are often blamed for deficiencies in the lighting of the buildings they design, perhaps more often for the deficiencies found at night by artificial lighting than for those of the lighting by day. For this the fault rests no doubt largely with the persons who have installed the lighting arrangements, and one must not blame the architect too severely for having been as ignorant as all the rest of the world about the principles of illumination; but henceforward, when once it is known how much illumination is required in the rooms of different kinds, the architect ought in his specification to set down, with appropriate numerical values, what degree of illumination is required in the various parts of his building.

I venture to suggest that it would be a good thing if, in the public interest, our society, or some committee appointed by it, could draw up a model specification, or model clauses for architects to insert in their specifications, in which the proper way of prescribing the requisite amounts of illumination in different classes of cases should be set forth.

Outside all these matters of more public interest, there are topics enough to occupy our society for many months to come. We shall have discussions on several interesting subjects during next spring, and there are many problems awaiting solution. When all else fails us, we can turn to the eternal question of the measurement of colour. We have also the long outstanding problem of the production of light without heat, accomplished in nature by the fire-fly, but unrealised by any artificial lamp. We might turn to discuss special cases, such as the flashing lights of lighthouses, or the special lights needed in the hospital for the detection of rashes or the treatment of disease. Amid such endless ramifications of our subject there is no fear of coming to a premature end of our programme. There is, indeed, abundance of work before us.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Dr. Baker has been appointed chairman of the examiners for part ii. of the mathematical tripos; Mr. A. Hutchinson, chairman of the examiners for the natural sciences tripos; and Mr. H. W. V. Temperley, chairman of the examiners for the economics tripos, 1910.

Mr. A. E. Shipley has been appointed a manager of the Balfour fund.

Mr. J. E. Purvis has been appointed university lecturer in chemistry and physics in their application to hygiene and preventive medicine for five years.

The Walsingham medal for 1909 has been awarded to Mr. L. J. Wills, for his essay entitled "The Fossiliferous Lower Keuper Rocks of Worcestershire," and a second medal to Mr. H. H. Thomas, for his essay entitled "The Leaves of Calamites (Calamocladus section), with Special Reference to the Conditions under which they Grew."

It is proposed that a grant of 100*l*. be made from the Worts fund to Mr. J. Romanes towards defraying the expense of a journey to Costa Rica with the object of studying the geology and geography of that country.

THE Earl of Crewe, chairman of the governors of the Imperial College of Science and Technology, will distribute the diplomas, medals, and prizes to the successful students at the Royal College of Science on Thursday next, December 16. Prof. Adam Sedgwick, F.R.S., will deliver an address.

DR. H. A. MIERS, F.R.S., principal of London University, will distribute the prizes and certificates at the Sir John Cass Technical Institute, Aldgate, on Thursday, December 16. There will be an exhibition of students' work and apparatus in the laboratories, workshops, and other rooms of the institute.

A CONFERENCE to discuss the needs of technical education in Burma was held at Rangoon early in November. We learn from the *Pioneer Mail* that Mr. J. G. Covernton, Director of Public Instruction, in opening the discussion, presented a brief sketch of what had been done in the past in the way of technical education. He divided the work of technical instruction into two main groups:—(1) those connected with scientific professions, especially engineering; (2) those connected with ordinary country and home life. He proposed that a central technical school for industrial education in the vernacular should eventually be opened at Insein in connection with the engineering school, and related to all the selected vernacular schools for technical education which may hereafter be established, and that pupils who showed special aptitude for technical training should be drafted to this central school. The instruction should be in the vernacular, and its aim be to provide for a general technical training for hand and eye. For trained pupils who might hope to be skilled artisans in various crafts and industries there should, the director said, be local industrial schools in local industries.

THE report for 1908–9 on the work of the Department of Technology of the City and Guilds of London Institute has just been published. It abounds in interesting information concerning the useful work being accomplished by the department in the way of improving the technical education of the country. At the last examinations held by the department, 23,399 candidates were presented in technology from 404 centres in the United Kingdom, and of these 13,665 passed. By the aid of advisory committees the institute is enabled, the report points out, to promote useful relations between trade organisations and the schools in which artisans and others receive their technical instruction. The institute, too, has a system of inspection of trade classes by professional experts, and during the session under review 107 centres were visited by members of the institute's staff for the examination, inspection, or organisation of classes. The report also states that the independent criticisms from examiners in wholly distinct subjects show that many teachers, while undoubtedly using their best efforts to acquaint the students with the technical details of their trade, fail to obtain good results owing to their giving instruction on wrong lines, paying too much attention to description and too little to the theory of the subject and to the principles underlying the work in which they are engaged. This may be partially due to lack of experience in teaching and failure to realise the difficulties of their students, and in such cases a visit from an inspector, himself an experienced teacher in the same subject, would often do much to remedy the defects, more especially if the visit can be repeated so as to enable the instructor to avail himself of the inspector's experience from time to time in the difficulties that arise. The institute also concurs in a suggestion, made by its inspectors, that if the education authority could send a comparatively inexperienced teacher to visit some of the schools at which successful classes are conducted and see their methods of work, such a visit would amply repay its cost.