chetus jubatus) from New Caledonia, presented by Mons. J. M. Cornely, C.M.Z.S.; four Blue Titmice (*Parus cœruleus*), British, presented by Mr. Hanaeur; a Barn Owl (*Strix flammea*), British, presented by Mrs. W. Gittens; a Rhesus Monkey (*Macacus rhesus* ♂) from India, deposited; a Bosman's Potto (*Perodicticus potto*) from West Africa, purchased; a Yellow-billed Duck (*Anas xanthorhyncha*) from South Africa, received in exchange; a Bengalese Cat (*Felis bengalensis*) from India, received on approval; a Zebu (*Bos indicus* ♂), a Collared Fruit Bat (*Cynonycteris collaris*), an Emu (*Dromæus novæ-hollandiæ*), bred in the Gardens.

GEOGRAPHICAL NOTES

ALTHOUGH the Chefoo Convention made with China in 1876 has never been ratified, we are now reaping various advantages from its provisions. With the object of exploring South-Western China, and of watching the possibilities of the development of trade in these regions, it was arranged that an English Consular Agent was to reside at Chung-King in Sze-chuan on the upper waters of the Yang-tse. The officers who have held this post for the past six years have travelled widely through Yunnan, Sze-chuan, Kweichow, and other provinces, and have made most valuable contributions to the geography of China by the reports which have been published by them. Thus we have Mr. Colborne Baber's explorations in South-Western China published by the Royal Geographical Society, Mr. Parker's papers in the *China Review*, which we have already noticed, and now Mr. Hosie has made two reports, which have recently been published as Parliamentary Papers. The last of these deals with a journey of nearly 2000 miles from Chung-King to Chêng-tu, the provincial capital of Sze-chuan, thence by Tali in Yunnan to Yunnan-Fu, the capital of this province, returning to Chung-King by another route. The traveller does not think much of the European maps of these districts, for on p. 58 we find him complaining that "the number of mistakes in these maps, whether as regards boundary lines, names of places, &c., not to mention omissions, is truly alarming. As fairly accurate native maps are procurable, the occurrence of such mistakes as the above is astonishing." Mr. Hosie also gives some account of the aboriginal tribes, who usually avoid the frequented routes, as as they are afraid of being taken by the Chinese. He saw several Lolos, and a Si-fan or "tame wild man," as he is called by a kind of Hibernicism, as well as representatives of several other frontier tribes. There can be little doubt that in a short time, with these able and energetic English officers travelling far and wide from Chung-King as a centre, the geography of the south-western corner of China will be as well known to us as that of the districts adjoining the coast.

AT the opposite corner of the China Seas, another English officer, Consul-General Leys of Borneo, is endeavouring to promote the commercial development of little-visited districts in that wonderful island. He has recently visited the tracts watered by three considerable rivers flowing into Brunei Bay near Labuan, and hopes to get the Chinese merchants of the latter colony, as well as of Singapore, to send trading parties up these rivers. He further suggests the appointment of consular agents in the interior of the dominions of the Sultan of Brunei: a step which cannot fail largely to increase our knowledge of the geography and resources of Borneo.

THE December number of Guido Cora's *Cosmos*, which completes the first series (1873–1883) of that useful publication, contains the first part of Capt. C. F. Crema's journey to Morocco in connection with the Italian Mission under Commander Scovasso in 1882. The text, which gives us a graphic account of the progress of the mission from Tangiers through the maritime provinces southwards to the mouth of the Sebu in the Atlantic Ocean, is richly illustrated with numerous woodcuts from photographs and sketches taken by Crema himself. Some of the heads in these illustrations, such as those of Scovasso, the Kaid Raka, and the Arab Surgeon of Caria-ben-Auda, are capital studies of character and ethnical types. Others vividly reflect the salient aspects of the land, the architecture, and industries of its inhabitants. Conspicuous amongst these is the fine north-west gate of Shella near Rabat, which, with its two hexagonal towers, is the grandest monument of Moorish architecture still surviving in Morocco. The paper is also accompanied with a map to the scale of 1 : 750,000, which, being based on an accurate survey of the route, forms a valuable contribution to geographical exploration. It fills up many blank spaces, and gives numerous rectifications of existing maps, even in districts that have already been frequently visited by European travellers. In the same issue Gustavo Bianchi gives an account of his recent explorations in the Gurageh territory during the spring of the year 1880, accompanied by a useful map of the Galla country to the south and east of Shoa, which, with the exception of Cecchi and Chiarini's expedition in 1878, had been visited by no traveller since the time of Major Harris and d'Abbadie (1843–46).

THE *Boletin de la Sociedad Geografica di Madrid* for December 1883 has a paper by D. José Gomez San Juan, on the Spanish possessions in the Gulf of Guinea. The object of the writer is to establish the exclusive right of Spain to the islands of Annobon, Corisco, and the two Elobeis, as well as to the portion of the opposite mainland stretching from Punta del Campo to Punta Santa Clara on the right bank of the Gaboon. The paper is ably written, and contains much interesting historical and geographical information on the whole of the west coast of Africa from Sierra Leone to the equator.

THE German and Austrian Alpine Club now consists of no less than 100 sections. The last two sections formed were those at Bonn, on the Rhine, and at Schladming Radstadt in the Upper Enns Valley.

THE Stuttgart branch of the Berlin Centralverein für Handelsgeographie contemplates the establishment of a Museum for commercial geography at Stuttgart.

THERE will be several special exhibitions at Munich on the occasion of the fourth German Geographentag. The following are planned: (1) new maps and books; (2) curiosities of cartography and geographical literature; (3) Bavarian maps; (4) maps, reliefs, and books relating to the Alps; (5) maps, reliefs, atlases, and other objects suitable for instruction in geography; (6) work done by pupils in geography, to illustrate the methods of teaching.

LETTERS have been received from Herr Junker and from the Khartoum Consul, Herr Hansal, which, however, do not give satisfactory details about the traveller's doings during the last two years, nor about his present position. They are principally short notes dating from December 1882, August and October 1883, in which he refers to longer letters and reports, which have, however, not yet come to hand. Nevertheless, these notes prove that Junker was in good spirits and health in the Sennis Country at the beginning of October last, and far from being disheartened or disturbed by events in the Soudan, of which he knew, was fully occupied with his travels and the drawing of his maps.

DR. FINSCH of Bremen has now published the "Anthropological Results" of his journey to the Pacific, and they form a valuable addition to anthropological literature. The traveller does not solely rely upon his own researches and observations, but also upon his (according to Virchow) unexampled collection of plaster casts from the faces of living men and women, natives of the islands he visited. This collection consists of no less than 164 casts, and represents natives of sixty-one different islands; besides Polynesians, Micronesians, and Melanesians, it also contains Malays of the Indian Archipelago, for the sake of comparison. Copies of the casts will be a welcome means of instruction in anthropology, and can be obtained through Herr Louis Castan at Berlin (Panopticum).

AN expedition to the North Pole is being prepared by Capt. Fondacaro of the Italian navy. It is several centuries since an expedition to the North Pole was despatched from Italy.

THE SIX GATEWAYS OF KNOWLEDGE[1]

II.

THE sense of sight may be compared to the sense of sound in this respect. I spoke of the sense of sound being caused by rapid variations of pressure. I had better particularise and say how rapid must be the alternations from greatest pressure to least, and back to greatest, and how frequently must that period

[1] An Address at the Midland Institute, Birmingham, October 3, 1883, by Prof. Sir William Thomson, LL.D., F.R.S., president. Continued from p. 440.

occur, to give us the sound of a musical note. If the barometer varies once a minute you would not perceive that as a musical note. But suppose by any mechanical action in the air, you could cause the barometric pressure—the air pressure—to vary much more rapidly. That change of pressure which the barometer is not quick enough to show to the eye, the ear hears as a musical sound if the period recurs twenty times per second. If it recurs twenty, thirty, forty, or fifty times per second, you hear a low note. If the period is gradually accelerated, you hear the low note gradually rising, becoming higher and higher, more and more acute, and if it gets up to 256 periods per second, we have a certain note called C in the ordinary musical notation. I believe I describe it correctly as the low note C, of the tenor voice—the gravest C that can be made by a flute. The note of a two-foot organ pipe open at both ends has 256 periods per second. Go on higher and higher to 512 periods per second, and you have the C above that—the chief C of the soprano voice. Go above that to 1024, you get an octave higher. You get an octave higher always by doubling the number of vibrations per second, and if you go on till you get up to about 5000 or 6000 or 10,000 periods per second, the note becomes so shrill that it ceases to excite the human ear and you do not hear it any longer. The highest note that can be perceived by the human ear seems to be something like 10,000 periods per second. I say "something like," because there is no very definite limit. Some ears cease to hear a note becoming shriller and shriller before other ears cease to hear it; and therefore I can only say in a very general way, that something like 10,000 periods per second, is about the shrillest note the human ear is adapted to hear. We may define musical notes, therefore, as changes of pressure of the air, regularly alternating in periods which lie between 20 and 10,000 per second.

Well now, are there vibrations of thirty or forty or fifty or a hundred thousand or a million of periods per second in air, in elastic solids, or in any matter affecting our sense? We have no evidence of the existence in matter of vibrations of very much greater frequency than 10,000 or 20,000 or 30,000 per second, but we have no reason to deny the possibility of such vibrations existing, and having a large function to perform in nature. But when we get to some degree of frequency that I cannot put figures upon, to something that may be measured in millions, if not in hundred-thousands of vibrations per second, we have not merely passed the limits of the human ear to hear, but we have passed the limits of matter, as known to us, to vibrate. Vibrations transmitted as waves through steel, or air, or water, cannot be more frequent than a certain number, which I cannot now put a figure to, but which, I say, may be reckoned in hundred-thousands or a few millions per second.

But now let us think of light. Light we know to be an influence on the retina of the eye, and through the retina on the optic nerve; an influence dependent on vibrations whose frequency is something between 400 million millions per second and 800 million millions per second. Now we have a vast gap between 400 per second, the sound of a rather high tenor voice, and 400 million millions per second, the number of vibrations corresponding to dull red light—the gravest red light of the prismatic spectrum. Take the middle of the spectrum—yellow light—the period of the vibrations there is in round numbers 500 million millions per second. In violet light we have 800 million millions per second. Beyond that we have something that the eye scarcely perceives—does not perceive at all perhaps—but which I believe it does perceive, though not vividly: we have the ultra-violet rays, known to us chiefly by their photographic effect, but known also by many other wonderful experiments, that within the last thirty years have enlarged our knowledge of light to a most marvellous degree. We have invisible rays of light made visible by letting them fall on a certain kind of glass, glass tinged with uranium—that yellowish green glass, sometimes called canary glass or chameleon glass. Uranium glass has a property rendering visible to us invisible rays. You may hold a piece of uranium glass in your hand, illuminated by this electric light, or by a candle, or by gas light, or hold it in the prismatic spectrum of white light, and you see it glowing according to the colour of the light which falls upon it; but place it in the spectrum beyond the visible violet end, where without it you see nothing, where a piece of chalk held up seems quite dark, and the uranium glass glows with a mysterious altered colour of a beautiful tint, revealing the presence of invisible rays, by converting them into rays of lower period, and so rendering them visible to the eye. The discovery of this property of uranium glass was made by Prof. Stokes, and the name of fluorescence from fluor spar, which he found to have the same property, was given to it. It has since been discovered that fluorescence and phosphorescence are continuous, being extremes of the same phenomenon. I suppose most persons here present know the luminous paint made from sulphides of calcium and other materials, which, after being steeped in light for a certain time, keep on for hours giving out light in the darkness. Persistence in emission of light after the removal of the source, which is the characteristic of those phosphorescent objects, is manifested also, as Edmund Becquerel has proved, by the uranium glass, and thus Stokes' discovery of fluorescence comes to be continuous with the old known phenomenon of phosphorescence, to which attention seems to have been first called scientifically by Robert Boyle about 200 years ago.

There are other rays, that we do not perceive in any of these ways, but that we do perceive by our sense of heat: heat rays as they are commonly called. But in truth all rays that we call light have heating effect. Radiant heat and light are one and indivisible. There are not two things, radiant heat and light: radiant heat is identical with light. Take a black hot kettle into a dark room, and look at it. You do not see it. Hold your face or your hand near it, and you perceive it by what Bunyan would have called Feel Gate; only now we apply the word feeling to other senses as well as Touch. You perceive it before you touch it. You perceive it with the back of your hand, or the front of your hand; you perceive it with your face, yes, and with your eye, but you do not see it. Well, now, must I justify the assertion that it is not light? You say it is not light, and it is not so to you, if you do not see it. There has been a good deal of logic-chopping about the words here; we seem to define in a vicious circle. We may begin by defining light—"It is light if you see it as light; it is not light if you do not see it." To save circumlocution, we shall take things in that way. Radiant heat is light if we see it, it is not light if we do not see it. It is not that there are two things; it is that radiant heat has differences of quality. There are qualities of radiant heat that we can see, and if we see them we call them light; there are qualities of radiant heat we cannot see, and if we cannot see them we do not call them light, but still call them radiant heat: and that on the whole seems to me to be the best logic for this subject.

By the bye, I don't see Logic among the studies of the Birmingham and Midland Institute. Logic is to language and grammar what mathematics is to common sense; logic is etherealised grammar. I hope the advanced student in grammar and Latin and Greek, who needs logic perhaps as much as, perhaps more than, most students of science and modern languages, will advance to logic, and consider logic as the science of using words, to lead him to know exactly what he means by them when he uses them. More ships have been wrecked through bad logic than by bad seamanship. When the captain writes down in his log—I don't mean a pun here, log has nothing to do with logic—the ship's place is so-and-so, he means that it is the most probable position—the position which, according to previous observations, he thinks is the most probable. After that, supposing no sights of sun or stars or land to be had, careful observation of speed and direction shows, by a simple reckoning (called technically the dead reckoning), where the ship is next day. But sailors too often forget that what they put down in the log was not the ship's place, but what to their then knowledge was the most probable position of the ship, and they keep running on as if it was the true position. They forget the meaning of the very words in which they have made their entry in the log, and through that bad logic more ships have been run on the rocks than by any other carelessness or bad seamanship. It is bad logic that leads to trusting to the dead reckoning, in running a course at sea; and it is that bad logic which is the cause of those terribly frequent wrecks; of steamers, otherwise well conducted, in cloudy but perfectly fine weather, running on rocks at the end of a long voyage. To enable you to understand precisely the meaning of your result when you make a note of anything about your own experience or experiments, and to understand precisely the meaning of what you write down, is the province of logic. To arrange your record in such a manner that if you look at it afterwards it will tell you what it is worth, and neither more nor less, is practical logic; and if you exercise that practical logic, you will find benefits that are too obvious if you only think of any scientific or practical subject with which you are familiar.

There is danger then of a bad use of words, and hence of bad reasoning upon them, in speaking of light and radiant heat; but if we distinctly define light as that which we consciously perceive as light—without attempting to define consciousness, because we cannot define consciousness any more than we can define free will—we shall be safe. There is no question that you see the thing; if you see it, it is light. Well now, when is radiant heat light? Radiant heat is light when its frequency of vibration is between 400 million millions per second and 800 million millions per second. When its frequency is less than 400 million millions per second it is not light; it is invisible "infra-red" radiant heat. When its frequency is more than 800 million millions per second, it is not light if we cannot see it; it is invisible ultra-violet radiation, truly radiant heat, but it is not so commonly called radiant heat because its heating effect is known rather theoretically than by sensory perception, or thermometric or thermoscopic indications. Observations which have been actually made by Langley and by Abney on radiant heat take us down about three octaves below violet, and we may hope to be brought considerably lower still by future observation. We know at present in all about four octaves—that is from one to two, two to four, four to eight, eight to sixteen, hundred million millions—of radiant heat. One octave of radiant heat is perceptible to the eye as light, the octave from 400 million millions to 800 million millions. I borrow the word octave from music, not in any mystic sense, nor as indicating any relation between harmony of colours and harmony of sound. No relation exists between harmony of sound and harmony of colours. I merely use the word "octave" as a brief expression for any range of frequencies lying within the ratio of one to two. If you double the frequency of a musical note, you raise it an octave: in that sense I use the word for the moment in respect to light, and in no other sense. Well now, think what a tremendous chasm there is between the 100 million millions per second, which is about the gravest hitherto discovered note of invisible radiant heat, and the 10,000 per second, the greatest number of vibrations in sound. This is an unknown province of science: the investigation of vibrations between those two limits is perhaps one of the most promising provinces of science for the future investigator.

In conclusion, I wish to bring before you the idea that all the senses are related to force. The sense of sound, we have seen, is merely a sense of very rapid changes of air pressure (which is force) on the drum of the ear. I have passed merely by name over the senses of taste and smell. I may say they are chemical senses. Taste common salt and taste sugar—you tell in a moment the difference. The perception of that difference is a perception of chemical quality. Well, there is a subtle molecular influence here, due to the touch of the object, on the tongue or the palate, and producing a sensation which is a very different thing from the ordinarily reckoned sense of touch, in the case now considered, telling only of roughness and of temperature. The most subtle of our senses perhaps is sight; next come smell and taste. Prof. Stokes recently told me that he would rather look upon taste and smell and sight as being continuous because they are all molecular—they all deal with properties of matter, not in the gross, but molecular actions of matter; he would rather group those three together than he would couple any of them with any of the other senses. It is not necessary, however, for us to reduce all the six senses to one, but I would just point out that they are all related to force. Chemical action is a force, tearing molecules apart, throwing or pushing them together: and our chemical sense or senses may therefore so far at least be regarded as concerned with force. That the senses of smell and taste are related to one another seems obvious; and if physiologists would pardon me, I would suggest that they may, without impropriety, be regarded as extremes of one sense. This at all events can be said of them, they can be compared—which cannot be said of any other two senses. You cannot say that the shape of a cube, or the roughness of a piece of loaf sugar or sandstone, is comparable with the temperature of hot water, or is like the sound of a trumpet, or that the sound of a trumpet is like scarlet, or like a rocket, or like a blue-light signal. There is no comparability between any of these perceptions. But if any one says, "That piece of cinnamon tastes like its smell," I think he will express something of general experience. The smell and the taste of pepper, nutmeg, cloves, cinnamon, vanilla, apples, strawberries, and other articles of food, particularly spices and fruits, have very marked qualities, in which the taste and the smell seem essentially comparable. It does seem to me, although anatomists distinguish between them, because the sensory organs concerned are different and because they have not discovered a continuity between these organs, we should not be philosophically wrong in saying that smell and taste are extremes of one sense—one kind of perceptivity—a sense of chemical quality materially presented to us.

Now sense of light and sense of heat are very different; but we cannot define the difference. You perceive the heat of a hot kettle—how? By its radiant heat against the face—that is one way. But there is another way, not by radiant heat, of which I shall speak later. You perceive by vision, but still in virtue of radiant heat, a hot body, if illuminated by light, or if hot enough to be self-luminous, red-hot or white-hot, you see it; you can both see a hot body, and perceive it by its heat, otherwise than by seeing it. Take a piece of red-hot cinder with the tongs, or a red-hot poker, and study it; carry it into a dark room, and look at it. You see it for a certain time; after a certain time you cease to see it, but you still perceive radiant heat from it. Well now there is radiant heat perceived by the eye and the face and the hands all the time; but it is perceived only by the sense of temperature, when the hot body ceases to be red-hot. There is then, to our senses, an absolute distinction in modes of perception between that which is continuous in the external nature of the thing, namely, radiant heat in its visible and invisible varieties. It operates upon our senses in a way that I cannot ask anatomists to admit to be one and the same in both cases. They cannot now, at all events, say that there is an absolute continuity between the retina of the eye in its perception of radiant heat as light, and the skin of the hand in its perception of radiant heat as heat. We may come to know more; it may yet appear that there is a continuity. Some of Darwin's sublime speculations may become realities to us; and we may come to recognise a cultivable retina all over the body. We have not done that yet, but Darwin's grand idea occurs as suggesting that there may be an absolute continuity between the perception of radiant heat by the retina of the eye and its perception by the tissues and nerves concerned in the mere sense of heat. We must be content in the meantime, however, to make a distinction between the senses of light and heat. And indeed it must be remarked that our sense of heat is not excited by radiant heat only, while it is only and essentially radiant heat that gives to the retina the sense of light. Hold your hand under a red-hot poker in a dark room: you perceive it to be hot solely by its radiant heat, and you see it also by its radiant heat. Now place the hand over it: you feel more of heat. Now, in fact, you perceive its heat in three ways—by contact with the heated air which has ascended from the poker, and by radiant heat felt by your sense of heat, and by radiant heat seen as light (the iron being still red-hot). But the sense of heat is the same throughout, and is a certain effect experienced by the tissue, whether it be caused by radiant heat, or by contact with heated particles of the air.

Lastly, there remains—and I am afraid I have already taxed your patience too long—the sense of force. I have been vehemently attacked for asserting this sixth sense. I need not go into the controversy; I need not explain to you the ground on which I have been attacked; I could not in fact, because in reading the attack I have not been able to understand it myself. The only tangible ground of attack, perhaps, was that a writer in New York published this theory in 1880. I had quoted Dr. Thomas Reid, without giving a date; his date chances to be 1780 or thereabouts. But physiologists have very strenuously resisted admitting that the sense of roughness is the same as that muscular sense which the metaphysicians who followed Dr. Thomas Reid in the University of Glasgow, taught. It was in the University of Glasgow that I learned the muscular sense, and I have not seen it very distinctly stated elsewhere. What is this "muscular sense"? I press upon the desk before me with my right hand, or I walk forward holding out my hand in the dark, and using this means to feel my way, as a blind man does constantly who finds where he is, and guides himself, by the sense of touch. I walk on until I perceive an obstruction by a sense of force in the palm of the hand. How and where do I perceive this sensation? Anatomists will tell you it is felt in the muscles of the arm. Here, then, is a force which I perceive in the muscles of the arm, and the corresponding perceptivity is properly enough called a muscular sense. But now take the tip of your finger and rub a piece of sandstone, or a piece of loaf sugar, or a smooth table. Take a piece of loaf sugar between your finger and thumb, and take a smooth glass between your finger and thumb. You perceive a difference. What is that difference? It is the sense of roughness and smoothness. Physiologists and anatomists have used the word "tactile" sense, to designate it. I confess that this does not convey much to my mind. "Tactile" is merely "of or belonging to touch," and in saying we perceive roughness and smoothness by a tactile sense, we are where we were. We are not enlightened by being told that there is a tactile sense as a department of our sense of touch. But I say the thing thought of is a sense of force. We cannot away with it; it is a sense of forces, of directions of forces, and of places of application of forces. If the places of application of the forces are the palms of the two hands, we perceive accordingly, and know that we perceive, in the muscles of the arms, effects of large pressures on the palms of the hands. But if the places of application are a hundred little areas on one finger, we still perceive the effect as force. We distinguish between a uniformly distributed force like the force of a piece of smooth glass, and forces distributed over ten or a hundred little areas. And this is the sense of smoothness and roughness. The sense of roughness is therefore a sense of forces, and of places of application of forces, just as the sense of forces in your two hands stretched out is the sense of forces in places at a distance of six feet apart. Whether the places be at a distance of six feet or at a distance of one hundredth of an inch, it is the sense of forces, and of places of application of forces, and of directions of forces, that we deal with in the sense of touch other than heat. Now anatomists and physiologists have a good right to distinguish between the kind of excitement of tissue in the finger, and the minute nerves of the skin and sub-skin of the finger, by which you perceive roughness and smoothness, in the one case; and of the muscles by which you perceive places of application very distant, in the other. But whether the forces be so near that anatomists cannot distinguish muscles, cannot point out muscles, resisting forces and balancing them—because, remember, when you take a piece of glass in your fingers every bit of pressure at every ten-thousandth of an inch pressed by the glass against the finger is a balanced force—or whether they be far asunder and obviously balanced by the muscles of the two arms, the thing perceived is the same in kind. Anatomists do not show us muscles balancing the individual forces experienced by the small areas of the finger itself, when we touch a piece of smooth glass, or the individual forces in the scores or hundreds of little areas experienced when we touch a piece of rough sugar or rough sandstone; and perhaps it is not by muscles smaller than the muscles of the finger as a whole that the multitudinousness is dealt with; or perhaps, on the other hand, these nerves and tissues are continuous in their qualities with muscles. I go beyond the range of my subject whenever I speak of muscles and nerves; but externally the sense of touch other than heat is the same in all cases—it is the sense of forces and of places of application of forces and of directions of forces. I hope now I have justified the sixth sense; and that you will excuse me for having taxed your patience so long in not having done it in fewer words.

ELECTRICAL STANDARDS[1]

THE Committee report that, in accordance with suggestions made at the last meeting of the British Association, arrangements have now been completed for testing resistance coils at the Cavendish Laboratory and issuing certificates of their value. These arrangements have been made by Lord Rayleigh and Mr. Glazebrook, and the report contains an account by the latter of the methods employed and the conditions under which the testing is undertaken, in order that those who use such coils may have a more exact estimate of the value of the test.

When a coil is to be tested, a suitable standard is chosen, and the two are placed in the water baths and left at least three or four hours—more usually over night. The comparison is then made in the ordinary manner by Prof. Carey Foster's method (*Journal of the Society of Telegraph Engineers*, 1874), and the coils again left for some time without being removed from the water. After this second interval another comparison is made. The temperatures of the water baths are taken at each comparison, and as a rule differ very slightly.

We thus have two values of the resistance of the coil to be tested at two slightly different temperatures.

The mean of these will be the resistance of the coil in question at the mean of the two temperatures.

We are thus able to issue a certificate in the following form:—"This is to certify that the coil No. X has been compared with the British Association Standards, and that its value at a temperature of $A°$ C. is P B.A. Units or P' R. ohms; 1 B.A. Unit being ·9867 R. ohms." We further propose to stamp all coils in the future with this monogram and a reference number.

It will be noticed that nothing is said about the temperature coefficient of the coil or the temperature at which the coil is accurately 1 B.A. Unit. To determine this exactly is a somewhat long and troublesome operation, but at the same time it is one which every electrician, if he knows the value of the coil at one given temperature, can perform for himself with ordinary testing apparatus. It does not require the use of the standards. For many purposes the approximate value of the temperature coefficient obtained from a knowledge of the material of the coil will suffice; we may feel certain that any one requiring greater accuracy would be quite able, and would prefer, to make the measurement himself. We can state with the very highest exactness that the resistance of the coil X at a temperature $A°$ C. is R. To obtain the temperature coefficient accurately requires an amount of labour which may be quite unnecessary for the purpose for which the coil is to be used.

In accordance with the resolution of the Committee, a fee of 1*l.* 1*s.* has been charged for testing single units, and of 1*l.* 11*s.* 6*d.* for others.

The only coils the testing of which is regularly undertaken are single units and multiples of single units by some powers of 10.

But though this is so, two standard ohms have been ordered, using for the value of the B.A. unit ·9867 ohms, and when they arrive and have been tested, it will be easy to determine the value of coils which do not differ much from a real ohm. At present, without these standards—the coils actually used in the recent experiments at the Cavendish Laboratory have a resistance of about ·1, 24, and 168 ohms—the operation is troublesome. The simplest accurate method seems to be to combine in multiple arc the real ohm, and one of the 100 B.A. unit standards, and to compare the combination with a single unit.

[1] Abstract of Report of the Committee, consisting of Prof. G. Carey Foster, Sir William Thomson, Prof. Ayrton, Mr. J. Perry, Prof. W. G. Adams, Lord Rayleigh, Prof. Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. A. Muirhead (Secretary), Mr. W. H. Preece, Mr. Herbert Taylor, Prof. Everett, Prof. Schuster, Sir W. Siemens, Dr. J. A. Fleming, Prof. G. F. Fitzgerald, Mr. R. T. Glazebrook, and Prof. Chrystal, appointed for the purpose of constructing and issuing practical Standards for use in Electrical Measurements.

ON THE MEASUREMENT OF ELECTRIC CURRENTS[1]

PERHAPS the simplest way of measuring a current of moderate intensity when once the electro-chemical equivalent of silver is known, is to determine the quantity of metal thrown down by the current in a given time in a silver voltameter. According to Kohlrausch the electro-chemical equivalent of silver is in C.G.S. measure $1{\cdot}136 \times 10^{-2}$, and according to Mascart, $1{\cdot}124 \times 10^{-2}$. Experiments conducted in the Cavendish Laboratory during the past year by a method of current weighing described in the British Association Report for 1882 have led to a lower number, viz. $1{\cdot}119 \times 10^{-2}$. At this rate the silver deposited per ampere per *hour* is 4·028 grams, and the method of measurement founded upon this number may be used with good effect when the strength of the current ranges from 1/20 ampere to perhaps 4 amperes. It requires, however, a pretty good balance, and some experience in chemical manipulation.

Another method, which gives good results and requires only apparatus familiar to the electrician, depends upon the use of a standard galvanic cell. The current from this cell is passed through a high resistance, such as 10,000 ohms, and a known fraction of the electromotive force is taken by touching this circuit at definite points. The current to be measured is caused to flow along a strip of sheet German silver, from which two tongues project. The difference of potential at these tongues is the product of the resistance included between them and of the current to be measured, and it is balanced by a fraction of the known electromotive force of the standard cell (see figure). With a sensitive galvanometer the balance may be adjusted to about 1/4000. The German silver strip must be large enough to avoid heating. The resistance between the tongues may be 1/200 ohm, and may be determined by a method similar to that of Matthiessen and Hockin (Maxwell's "Electricity," § 352). The propor-

[1] Abstract of a paper read at the Cambridge Philosophical Society.