Mansfield

18

Proof no 14

Registering Sun Dial.

Contrived 1853.4.–

Paper as written for Good words, May 1879 –

28. Proofs got. June 14 –

June 15. 16. copies. disposed of. having got a letter from the Sub Editor saying that it did not matter.

notes to connect text and ideas which prompted some of the sentences.

notes from time to time on the blank side of the pages.

(No 14) 9 Jan 13 1879.

29 Pages of the paper as I got it

as rescued from ~~Clark Dorcha Clann Dottleir~~, & Lear of Clouds.

CAMPBELL'S REGISTERING SUN-DIAL.

AT some time in March or April, 1879, some gentlemen, and some ladies too, were very much amazed to find their writing-desks and tables smoking. They wrote to the papers about it. Under the heading, "An unsuspected danger," a series of letters appeared in the leading journals. Certain transparent glass balls, now commonly used as paper-weights, being set in sunshine, "acted like a burning-glass" on tables and table-covers, to the astonishment of their owners. They are burning-glasses. In daily life theory very seldom is practised; knowledge very seldom is used. Though "optics" are taught in schools and colleges, very few people realise that things polished and transparent, with surfaces shaped so as to condense light, are instruments which may set combustibles on fire.

"Burning-glass" was defined in the "Encyclopædia Britannica" in 1797, as "A convex glass, commonly spherical, which, being exposed directly to the sun, collects all the rays falling thereon into a very small space called the focus, where wood or any other combustible matter being put, will be set on fire." In the article quoted Sir David Brewster tells what had been done with burning-glasses. We have all been taught that Archimedes burned the Roman fleet at Syracuse with sunshine, about 2,090 years ago. The writer's family and Sir David Brewster were friends, and he had the great advantage of knowing that distinguished philosopher, and of learning curious knowledge from him in conversation. Some fifty years ago somebody gave a child an optical toy, a glass like the bulb and stem of a big thermometer filled with water. He then learned experimentally that a transparent ball is a magnifier, and burns fingers. Ever since that childish lesson was learned, as boy and man the writer has been striving to learn more about "burning-glasses." Nevertheless he too was caught unawares by sunshine. In April, 1879, an innocent egg-shaped water-bottle burned a hole in a toilet-table, which happened to be set in a new place where the sun happened to shine upon it at the hour when the focus of this burning-glass happened to be at the table on which the bottle stood. That particular combination may not happen again for a year, but every time such a combination does occur danger recurs, from the misuse of a bottle. The associate of this criminal found guilty of arson being suspected, a tumbler was tried and convicted of the same offence. Dragged into light he too burned wood. A knot in a pane of glass is a "lens;" a finger-glass, a wine bottle, a tumbler, a wine glass, a globe for gold fish, a chemist's window ornaments, any glass or glass vessel full of clear fluid and properly shaped, may happen to be so placed as to concentrate sunshine at some hour of the day, on some day in a year, upon a combustible, when a breeze of wind may kindle a blaze, and burn a house or a ship unexpectedly and unsuspected. Knowing something of this, about 1853 the writer tried to use some of the small amount of knowledge which he had picked up. Amongst other contrivances, he then invented a very simple instrument founded upon two facts, (1) a transparent ball is a burning-glass; and (2) the world turns round. This paper is an attempt to describe the principle of the contrivance which a child of six years old understood some fifty years ago.

A billiard ball is a "sphere." Slices cut off it are bounded by circles. All sides of it are alike. On it, or any other "sphere," great or small, may be drawn the lines and scales which are drawn upon school globes. A transparent sphere placed where any sort of light shines upon it presents the same curves to the "rays," and bends them to corresponding places on the opposite side, where the rays cross at a "focus." Whether a sphere is turned end for end, or capsized, spun, or rolled, the focus for parallel rays always is opposite to the source of light, and at a certain distance from the surface. A spherical bottle is a lens; and so is the atmosphere. When a transparent sphere is set out of doors all the shining bodies that stud the visible sky shine through it to opposite foci. Each forms an image of itself and a cone of light, which may be cut by a surface placed in the cone. The lens of a photographic camera is founded upon the principle. The sensitive screen cuts cones of light. The writer has got images of the stars, the moon, and the sun, by photography. But the screen of a camera is flat, not spherical. Distances measured upon it are unequal, and drawings are out of perspective, and out of proportion. The stars and the moon draw, but the sun is so hot that the image "burns." For many years a lens has been set at Paris so as to focus the sun's rays upon gunpowder, at noon, and so fire a small cannon. Gun-

This was struck out by the Editor Mac Cloud *

little sense, so asked for proofs remaining as I left the paper, & got them.

* As the whole thing is founded upon the principle of Concentric Spherical surfaces. This was like reducing the play of King Lear to the part of "Poor Tom". Sphere. Slope. Cone gone

Copies given.

June 13. 1. Sirikennette Mackenzie } given in the
14. 2. Julia Cole ———————— } house 15th
15th. 3. William Ellis Greenwich.
4. The Astronomer Royal. ditto
(5) 10. Professor Roscoe.
11. Scott. Meteorological department. acked 17
12. Chance ———————— acked 19th June
13. Self — Small publication
14. This copy.
15. Dr. Cumming
16. Spottiswoode. Royal Society. acked 16th
17. Armstrong
June 23. ~~18.~~ Powell glassworks Whitefriars returned
June 28. 18. Stuck into journal.
July 7. 19 Stamford Publisher.

1879 June 18. Dined with Spottiswoode and sat beside Lady Thomson. Sir William, her husband, has done a paper for Good Words on the Compass. Told him that I had the honor of following him. & spoke of his dodges at Inveraray.

The Lady knows Donald Macleod. The magazine she sees everywhere about on tables. asked her what sort of public take it. "Where there are children" said said she". "Intelligent boys & girls" Said I. "yes" said she. For special I wrote this. I never see the mag. anywhere" ^of mechanics Said I. "For instance I never see it at Clubs." "Oh no" said she. "It never goes to such places." Sir William thinks it fit for servants but I find it far above them generally." I was right to tell Donald that this might introduce his magazine to a different class of readers. —

19th Chance is pleased, & will get me a ball. Khani Ram thugged the Thugs.

Draper present who has come to London to study sunshine. He has probably come to be observed. Cardwell, and Cyril Graham. Spoke of clear skies powder explodes at 700°, which is hot. But that sort of lens must be turned towards the source of light so as to get a focus. Telescopes and microscopes, and such like, are made with very small arcs of spherical surfaces, which must be aimed at the object whose rays are to be focussed. After some thought and sundry failures, a transparent globe was seen to be the thing needed for the purpose wanted. But in 1853 no glass globes were to be got in Paris. Hollow glass globes, blown for lampshades, were to be had in abundance. These spherical bottles were then commonly used in Parisian workshops to concentrate lamp light upon work, and to save working eyes from dazzling and from darkness. Through life the writer has been given to expedients. When he could not get what he wanted, he did the best he could without it. He wanted a spherical lens, and could not get anything better than a bottle-stopper made of solid glass. So he found out a maker of lampshades and fraternized with him in his workshop, where he lived with a wife, and a tame squirrel, and a canary, and some flowers, at the top of a high house where the sun shone cheerily. A capital water-lens was got for a franc. The diameter was six inches, the radius of the sphere three, and a cone of sunlight stretched three inches from the glass to the place where the sun's image burned. "My faith!" said the Frenchman, when he saw what his glass bottle could do in sunshine, "you do not sleep all night long." A London turner was set to make a bowl of hard wood ;—a hollow half-sphere, with a radius of six inches, and a diameter of twelve. The lamp-glass was set upon a tumbler three inches high, in the bowl of wood, in a window facing the south, and this "sun-dial," in various shapes, has gone on working for the inventor ever since. Anybody can make it, or use it; anybody may, it is not a "patent." One added to one makes two. One fact added to another makes an "invention." It does not make the matter clearer to express it by figures, $1+1=2$, or by Algebra.

This contrivance is an astronomical engine, and the first of its kind. A graving tool is set to draw circles upon a sphere. It is a "pencil of rays" as thick as the diameter of the transparent lens, with a conical point about half a radius long, when the globe is of solid glass. The centre of the globe answers to the "rest" of a turning lathe; the earth's rotation is the machinery in motion. The long end of the lever reaches from the sun to the centre of the lens; the short end is the hot cone, which burns wood like iron heated to 700°. The invention is a simple application of natural force and movement. Like the application of steam or water-power or the wind to move engines, there is nothing new in the invention, except the new combination of a transparent sphere, with a spherical surface so fitted that one concentrates a cone of sunshine which the other cuts at right angles, where it is hottest, whatever may be the sun's altitude or declination while it shines upon the glass sphere. All other dials work on the same principle: this one uses light instead of shade, and registers natural phenomena. As the world turns, the dial turns with it Eastwards. The hot sun appears to travel from east to west in the sky, the hot image of it travels from west to east, and engraves the path which the sun describes, measure for measure and rate for rate. If a cloud stops sunshine during four minutes of time, the circle drawn with the hot pencil is broken for a space of one degree on the circle. No matter what the radius may be, the angular space is measured by the world's movement. If the sun shines for an hour, the arc drawn is fifteen degrees, measured astronomically for time and for angular distance. If sunlight is hindered, the hot image is not so hot; the point of the pencil is shortened, the power to sink into wood is less, and the mark engraved is shallower. It has been found experimentally that the power is greater, and the mark deeper, the nearer the sun is to the zenith. The nearer the sun is to the horizon, the shallower is the mark. Apparently the reasons are that the lower air contains more matters which stop light, because there is more of the atmosphere in the way at sunrise and sunset and in winter, and because spaces between clouds are narrower when light strikes through layers horizontally, instead of vertically; level, instead of downwards. As the world goes round the sun, lines described on the dial are those which are expressed on some school globes between the tropics, and are measured upon the "Ecliptic." But these being drawn *astronomically*, are accurately engraved. If only the surfaces are made true, the engraving must be more accurate than anything drawn by hands, or by clockwork, or by dividing engines. No matter how minute the scale may be, the work done must be done exactly; because the world moves, the dial and sunlight engraves it.

I can think of nothing better for the purpose of registering sunshine than well-made glass spheres, and well-turned bowls of hard wood. The bowl can be set level by filling it with water, which gives the plane of the geometrical horizon. So set, anywhere in sunshine, and left alone, the dial works for six months, while the sun travels forty-seven degrees, from one tropic to the other between the solstices. The register proves its own latitude by the angle which the planes of the circles described make with the plane of the horizon of the bowl. which is the edge of it. The record gives the *mean* result engraved upon wood. The wood is not set on fire. Portions of wood are destroyed instantaneously; and other portions are charred, as if by a hot wire. The air does not get at the place, so as to light the fire or keep it smouldering. No bowl tried since 1853 has burned or smouldered. Casts made with gutta-percha come out clear, sharp copies of the cones of light which engraved the intaglio. That being the principle of the contrivance, these are some of the uses to which it may be put.

In April, 1857, the contriver wrote a description of the invention for the Meteorological Society, who printed it. One of the writer's ideas then was to use the dial to map out the clear and cloudy regions of the world for the benefit of people in search of climates for the sake of health. The most important and least studied branch of Meteorology, the science of weather and climate, is sunshine. It works in the air, the ocean, and the earth to considerable depths, as a mechanical force, and otherwise. It reaches thermometers at Greenwich buried 25·6 feet. Concentrated with big instruments sunlight has fused the most refractory metals and minerals; it turns water and diamonds to vapour, it burns fingers, it boils an egg, cooks a steak, it would kill a man who should put his eye at the "focus." With part of a lighthouse apparatus the writer once kindled a blaze. As a matter of geological speculation a deeper clear atmosphere would concentrate more sunlight upon the solid world; as a matter of fact, the presence or absence of vapour in the atmosphere over a place alters the climate.

Sunshine is a system of waves. All waves need a shore to show their force, and their force is hindered by any impediment. The strongest burning focus does nothing perceptible to clear air. Atlantic billows do little to boats in a calm. But when waves in water or in light are stopped, then they work mechanically, in proportion to their size and swiftness. Light waves which are hindered in the air and do work there, expend force before they reach the solid world. Chemical and other waves of light affect plants and animals, crops, and men. Where there is superabundance of sunshine, men have to shield their heads from a deadly stroke; there the earth is parched and plants are scorched. In Calcutta, even omnibus horses wear sun-shields, because without them they are often slain. It is important to know where the needful light waves reach the earth and its people. With some notion of the nature and power of sunshine, the writer wanted something to record and measure the work of it as a barometer weighs air, and a thermometer measures heat. So he contrived a dial twenty-six years ago. He told the Meteorological Society all he knew in 1857, and ever since he has been using a burning-glass as a test of climate.

Since 1857 he has travelled far, armed with divers instruments, always observing climate, while learning lessons which make travelling a pleasure and a gain instead of a grievous bore.

In January, 1878, the writer went to Egypt, where a cloud is a rarity. In the same season of 1879 he lived in London, where sunshine like that of Egypt never has been seen. In December, 1876, the sun was above the horizon of Greenwich for 242 hours and forty minutes, but the dial used at the Observatory registered only six hours and-a-half of sunshine, which is patriotically styled "bright" in the report. In January, 1878, the light was so brilliant in Egypt, that northern eyes could not endure it without a black shade. In the same season of 1879 the darkness at noonday in London often was like that miraculous Egyptian darkness which is recorded in Holy Writ as a plague and a punishment. The light in the sky about 2 P.M. was found experimentally on one day to be hardly so bright as a white marble bust placed some eighteen feet from a single bat's-wing gas light. The gas bill was enormous, because of the clouds, fogs, and vapours which stopped waves of light in our climate. The cause of the clouds is evaporation from the Western Atlantic, which is warmed by the sun. That sort of important difference in climate the dial records, and a burning-glass shows to a passing traveller. In Java the climate is that of the torrid zone, close to the equator. The sun always is near the zenith at noon, in the best position for shining through the estimated depth of forty miles of air. But that part of the atmosphere which is over Java and Singapore is

28th Old Chance sent a bulb of such bad glass that I sent it back with a note inside the box for the Glass works. I have received nothing since

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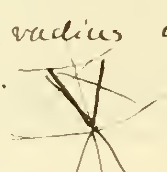
29th Got from Argyll lodge an old Bowl & ball given to the Duke in 1855 or 6. It was placed upon a low wall where the children got at it & it was turned round & round for twenty years. The stand was lost & the ball stood upon the bottom of the bowl; - eccentric instead of concentric.

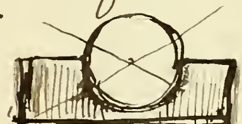
a Ball 4 inches in diameter burned away an inch of wood; That is half a radius, and something more. The diameter of the bowl was originally 5½ inches to give a focal length of 3/4 and a Radius of 2 3/4. In other bowls of like size the point burned 1/4 into the wood: which gives an inch or half a radius as the length of the burning cone.



To get the full power of it the radius of the Bowl ought to be 1/4 Radius of the glass.

5) To get a neat line, on clear days only, half a radius as in the metal bowl given to Greenwich Observatory.

June 29. By way of experiment set the old scratched argyll wedge 4 inch ball in a spoiled bowl of a little more than 4 inches diameter



in front of Mrs Campbell's window on the verandah top where people cannot easily get at it to move it. If it is possible to set wood on fire this ought to do it by burning through bowl below so as to let in a draught. It is so placed that a fire could hardly do harm to the house if lit, for it is on zinc above a metal roof.

LONDON WEATHER.—The meteorological records kept at the Royal Observatory, Greenwich, show that in the first half of the year 1879—the 26 weeks ending with Saturday, the 28th of June—there were only 471 hours of sunshine registered there. In the corresponding period in last year there were 643 hours of sunshine. The deficiency in 1879 occurred in the second quarter of the year. The 133 hours of sunshine in the first quarter of 1879 were only about seven hours less than in the first quarter of 1878, but the 338 hours of sunshine in the second quarter of 1879 are far below the 503 hours registered in the second quarter of 1878. The Registrar-General's returns, from which these figures are obtained, are not made for calendar months, but for weeks, and the fortnight ending on 28th of June, 1879, is shown to have had but 50 hours of sunshine, to compare or contrast with 116 hours in the corresponding period of last year. June, 1878, was spoken of at the time as a sunless June, but it had a fraction over 181 hours of sunshine in the four complete weeks, and the corresponding period of 1879 had not quite 119 hours of sunshine. The rainfall at Greenwich is stated at 17·57 inches in the 26 weeks ending 28th June, 1879. In the four weeks ending 28th June, 1879, there fell $4\frac{1}{4}$ inches of rain; and the Registrar-General reported last year that the 4·6 inches of rain which then fell in June were more than double the June average for the last 63 years. In every week of the half-year of 1879, except two in February and four in June, the number of deaths in London has been above the last ten years' average, after allowing for increase of population, leaving a balance of some thousands on the wrong side at the close of the half-year.

Times. July 7. 1879

643
471
—172 hours minus

116
50
—66 minus

full of the vapour of an ocean which is heated at the surface to 80° or more, though cold as ice at the bottom. The light is so hindered by its own work that a burning-glass would hardly act at all. So it has been found experimentally elsewhere between the tropics, in damp, steamy, hot climates. In Japan, where the mountain air was cold and clear and dry in winter, because dried air is flowing from the Arctic regions of Asia, the traveller lit his pipe daily with a crystal ball about one inch in diameter, which was meant to be the eye of an idol. Generally it has been found experimentally, that where the air is clear the climate is dry. In California the sky is clear for months, and the land is dusty. In Oregon the sky generally is cloudy, and the land is chiefly mud. In the central regions of North America the air is clear, and the sun scorches the ground and dries it to make a desert. About the borders of Thibet the rainfall is slight, and the sun shines through clear, frosty air brilliantly. The purest and clearest air will be found about places marked "rainless" in a physical atlas, and there burning-glasses act best. There also eyes see best into space through the hollow sphere of the atmosphere, with and without optical aids, from spectacles up to astronomical telescopes. Probably the clearest and purest part of the earth's outer shell is over that great band of dry sandy deserts which extends from the Atlantic coast of Africa through Arabia, and nearly to the Indus. The Nile crosses that belt. The narrow strip of river mud which is kept damp and is watered by the river which brought it, is a strip of marvellous fertility, suited to the growth of that ancient civilisation which flourished in Egypt six thousand years ago, and would flourish there still if rulers would let it flourish. The damp land is not broad enough for vapours to rise in sufficient quantity to hinder sunshine, so Egypt is a land of brilliant light. There the ancients adored the sun, whose power for good they knew by daily experience. We might as well adore the fire, like our Aryan ancestors, who hymned Agni (the fire) and Indra (the sun). Their ancient country, in Central Asia, is near "a rainless district," and so the worship of the sun and of fire seems to belong to people who felt the sun's power through a clear part of the atmosphere. A burning-glass tests that clearness roughly; a registering dial measures it, and so it will map out clear and cloudy climates, when it comes to be used.

A description of the dial and some of the work done with it is in the report of the Commission on Warming and Ventilation, which was ordered by the House of Commons to be printed in 1857. The object then aimed at was to estimate the ill effects of wasting fuel in thick smoke. "The abolition of the smoke nuisance" was the desire of that Commission, but their end has not been attained. It never will be attained till coals are dear in England.

Dial observations were continued at the office of the General Board of Health long after the assistant-secretary left that department to serve the Lighthouse Commission as secretary. The records of London sunshine, engraved upon a series of wooden bowls, were handed over to the Meteorological department of the Board of Trade, when it was instituted. Mr. Scott, the head of the State Weather Office, which began to publish forecasts April 1st, 1879, handed over the London dial records of sunshine to Professor Roscoe, of Owen's College, Manchester, who is an authority in such investigations. In 1875 he compared the half-yearly mean results by weighing and measuring the work. He found (1) that more sunshine had reached the place of observation after the longest day in each year. That result is confirmed by means of a vast number of thermometer observations recorded at Greenwich Observatory.* He found (2) that most dial work had been done during years when sun spots were most abundant. Thermometers at Greenwich also recorded more or less solar radiation as temperature (see Plate X., *op. cit.*) in years between 1847 and 1873. Upon facts ascertained, it is supposed that solar radiation varies periodically. Upon that theory, which is based upon facts, Mr. Jevons has founded his published theory of recurring periods of agricultural and commercial prosperity and depression.

When the sun radiates more than the average, lands everywhere on earth produce more. Because growers then are richer they buy more. Because of greater demand makers of goods make more, and trade prospers. When the sun radiates less, trade and prosperity decrease, and so wax and wane with sunshine. More dial records would help to settle the question of periodical increase and decrease in solar radiation.

On the 17th of June, 1875, a paper by Professors Roscoe and Balfour Stewart was

* "Reduction of Greenwich Meteorological Observations, &c." London: Eyre and Spottiswoode, 1878. Published by order of the Board of Admiralty.

read at the Royal Society, about the dial and its work, and the results obtained from means engraved half-yearly at the office of the Board of Health. "There is a distinct connection between the sun's burning power and his maximum and minimum spot period," which the dial recorded. The paper is printed in the proceedings of the Royal Society.

The dial was again mentioned in the second volume of the report of the Lighthouse Commission, 1861, at page 629. It is important not to place a coast light where clouds are apt to condense. It has been done unawares, and a site has been changed from the top of a cliff to a rock at the base. The instrument would have given warning of the condensation, and would have saved the cost.

Some of the work done with a glass sphere is described and printed in a work called "Frost and Fire," vol. ii., page 480, 1865.

Some years ago Mr. Chance, of the Birmingham Glass Works, got a ball of good glass cast and polished for the inventor. He has never seen another like it. Sir William Armstrong got a metal bowl turned at his Newcastle workshops, to fit the glass. The object was to cut the cone of light where it is a fine point so as to make fine work. The instrument was tested and found to work well upon black Indian-rubber cloth fixed upon the metal surface, with a waterproof solution, and changed daily. The circles drawn were very clear and very fine. But such daily observations belong to an observatory, so the instrument, with the motto, "Horas non numero nisi serenas," engraved upon it, was handed over to the Astronomer Royal. Under his able superintendance it has worked at Greenwich since May, 1876, watched by Mr. Ellis and his assistants, with the rest of the family of contrivances over which they exercise careful supervision. When a paper was read before the Royal Society about the dial and its work, the dial was promoted, and the inventor was gratified. The results of the Greenwich observations are published in the yearly reports; by the Registrar-General in his reports; and by sundry newspapers. The authorities are content with the instrument, and it is seen by the visitors at their yearly visitation of Greenwich Observatory.

A Slope. The inventor of the dial, however, was not satisfied with the form of it, for the purpose of registering sunshine daily at an observatory. The surface of the bowl is spherical, but the surface turned by the point of a pencil of rays is not. When the spherical surface is wood, the pencil point engraves it to considerable depths. The surface measures a cross section of the conical point, the depth measures the length of the point, which varies continually. A cast of a bowl exposed for six months gives some notion of the mean surface which would result from exposure for much longer times. The curve so turned I am not able to describe scientifically, but it would come out as a regular curve if there were no clouds in the way. Each circle is cut by the point at sunrise or soon after, and the curve drawn daily by the point cuts deeper towards noon, and fades away towards sunset. The curve drawn at the tropic which is opposite to the sun in winter at noon, grows deeper till the sun is at the summer tropic. The result is the rotation of an eccentric figure which is not a circle, upon a surface which results from the rotation of a circle, and is a sphere. When the surface of the bowl is metal, it is not engraved at all. It is necessary to line the bowl with something more fusible or combustible, to be marked by a pencil of rays. It is difficult to cut anything flat so as to make it fit a sphere. That any child will discover who puts a leathern cover upon a hand-ball made of worsted, wound round a cork. The thing wanted at an observatory is some plane surface, like this sheet of paper, to be taken out of the bowl and filed in a book daily. That is done by cutting cloth, leather, or cardboard, on the plan by which school globes are covered with paper, and fives-balls and golf-balls, and hand-balls with leather. But the result is a drawing upon a spherical surface, and the curve which a cone of rays describes on wood has been found experimentally to be some other figure which seems to be part of a spheroid more flattened than the earth is by its rotation.

It has also been proved experimentally by many trials, that planes which are bounded by figures engraved as already described, are nearly parallel to the equatorial plane at all seasons. They must be so, because they result from the earth's daily rotation, modified by the earth's daily change in its yearly path round the sun. Vertical and horizontal planes are at right angles, like the covers of a book half open. The plane of the equator is somewhere between them, like a leaf in the half-open book. In latitude $51\frac{1}{2}°$ the plane of the equator makes an angle of $51\frac{1}{2}°$ with the vertical plane, and one of $38\frac{1}{2}°$ with the horizontal plane, which coincides with the surface of a glass of water practically. The two angles make up $90°$, and four such angles make a

That is right. I said an expert astronomer at Greenwich June 1879. When he saw my blocks. He wrote a glass Cylinder. For boys ye

square. The object desired was to get a slope made and placed parallel to the plane of the equator. A beam of wood was squared by a carpenter, and then sawn off at an angle of 38½ or 51½ slantwise. Placed upon one side, the slope of the beam was parallel to the earth's axis. Placed on the other, it was parallel to the equatorial plane. Placed together, the surfaces make a right angle, whose sides are set to the horizontal plane at an angle which varies with the latitude. The block sawn out and roughly planed was set north and south in the plane of the meridian and levelled. The slope was then East and West, and parallel to the plane of the equator so far as could be done with the tools, materials, and aids available. "If you can't get what you want, try to do the best you can with anything handy," is a good maxim for inventors and travellers. A spherical lens was set upon the level top of the beam, so that the cone of light passed over the edge of the slope, where it described figures about the centre of the glass sphere. Anything flat laid parallel to the slope may be placed in this astronomical turning-lathe, so as to be in the burning point of a pencil of rays edgewise or otherwise. The setting of the engine is done by sliding the glass along the flat top of the squared and levelled beam, or by lifting or lowering it. At an observatory this should be made accurately of white stone, with screws for setting the work and the glass. Such is the mechanical force of sunlight, that a squared beam of wood bends, and curls, and splits, and throws everything out of gear.

A book with paper edges set in the cone as wood is set for a circular saw, or iron in a turning-engine at an engine shop, is engraved in this solar turning-lathe edgewise. The work is seen by opening the book. A circular arc cut out of stiff cardboard at a given radius presents an edge to the graving tool, which edge corresponds to part of a spherical bowl. That also is engraved edgewise, and may be filed daily. In May, 1879, a few days of sunshine occurred in London. On the third, a wood-engraver's block, inked to blacken it, was set on the rude slope described, in the cone of a cast glass sphere, which cost three shillings, and was set to work in 1858. That lens was set upon the screw-stand of an old microscope, and moved till the black plane surface of boxwood cut the cone, so as to make an elliptical section of the point. That figure revolved about the lens upon the plane. As soon as the sun got out of the eastern haze, about half-past ten, the hot pencil began to engrave. As often as a cloud or any other obstruction got in the way, it either altered the length of the ellipse or cut the long lever end of the pencil of rays and stopped the engraving. When the hindrance or stoppage passed and the sun shone, the engraving began again further on. Thus the sun's power at given moments was measured upon a surface fit for printing in GOOD WORDS, and for the first time on this new contrivance of a slope set equatorially. After four hours the sun had moved 60°, and the point went off the wood. The block was taken to a neighbouring printer, inked, and pressed. It was taken back and set to be engraved again later in the day. A neighbouring carpenter was got to saw off the engraved edge, and this woodcut is the result of that experiment in "THERMOGRAPHY."

New name for this new art

P.M.  A.M.

Fig. 1.—3-inch lens. May 3, 1879. Four hours' exposure, 60°. Passing clouds and bright sunshine.

The work done in an hour on the 3rd of May with a lens of four inches diameter, and work done with the smaller lens on the 5th, was sawn off the block on the 6th, and here is the result.

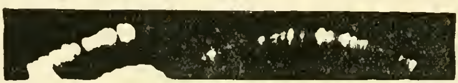
P.M.  A.M.

Fig. 2.—May 3 and May 5, 1879. 4-inch lens, 1 hour, 15°. 3-inch lens, 4 hours, 60°. Passing clouds and bright sunshine.

On the 5th of May the sun shone and seemed to shine with equal brilliancy. A block was set in the cone of a lens nearly six inches in diameter. The result shows that the sun's power varied from moment to moment.

I meant them to saw these blocks to fit these Columns. Being Blockheads, they did not do as they were told.

P.M.  A.M.

Fig. 3.—May 5, 1879. Two hours exposure, 6-inch lens, 30°. Passing clouds. The slope being out of position the burning point got over the edge, and burned under the printing surface at the left side in the figure.

That night and next day the clouds condensed into heavy rain.

The blocks ought to be cut out in arcs of circles to show the whole work of a day. These are enough to show that the day's work of registering sunshine may be printed after sunset; and published next day in a newspaper, which was the object of this experiment. A book set with the side towards the cone is a plane set at a tangent to a sphere, and cuts the cone at varying angles. Accordingly the cone cuts through a varying number of pages. A block of wood set in the same position is pierced to varying depths, as shown in section on Figs. 1, 2, 3. As the sun moves, the section of the cone at the printing surface changes till the last point that is hot enough to mark goes off in a hair line. The depth is not shown in printing. This is the sort of work which a bottle or a paper weight makes upon a table.

P.M.  A.M.

Fig. 4.—June 4, 1879. A four-inch lens standing upon a printer's block of boxwood. Depth of slot ¼in. to nothing.

Sheets of gutta-percha placed in the same positions are moulded by the conical point of the pencil of rays, but the shapes will not print. So are sheets of wax laid upon paper. By these and by other such expedients it is easy to get engravings, casts, and pictures of sections of a cone of light, so as to estimate the force of sunshine by shapes in substances marked by the waves, as waves mark a beach.

The cone of light formed by a sphere is a very complicated structure, which is not easy to understand or to explain. The central point on the surface of the ball opposite to the sun lets through a straight line of light, which goes straight on till it is stopped. It is like a ray of light shining through a pinhole. Take a school globe for illustration, call that point the pole, and the line the axis. A ring of the glass surface close to the point bends the waves of light into a cone which crosses the axis at a distant point. Larger outer rings, comparable to parallels of latitude, bend "rays" or waves to points upon the axis nearer and nearer to the glass, and the outermost rings, which refract, or bend rays or waves, bring them together close to the glass. A whole series of circular discs, images of the sun, or "foci," are strung upon the central line like buttons on a string. All these images which together answer to the lead in a pointed drawing pencil are hot, and the hottest are those which are formed by the largest rings, which are the farthest from the pole. The ring between latitude 45° and 50° is far larger than between 85° and 90°. In a cone an inch and a half long, and about an inch wide at the glass which has a diameter of nearly six inches, that part which answers to the lead in a pencil, and is hot enough to burn blackened cardboard, was found experimentally to be nearly an inch long about noon, on a clear London day at the end of April. On the 29th a hot point pierced twenty-two sheets of a notebook. It scorched the first sheet to a width of six-tenths of an inch. On the 17th the cone pierced fourteen sheets and scorched the fifteenth. That is a measure "of longitudinal spherical aberration," which is explained scientifically in works on Optics, and was proved experimentally in April, 1879. But there is a further complication in the cone. Waves of light of different measured lengths, which are detailed in scientific works, give different colours, and meet upon the axis at distances proportioned to their "refrangibility." The red rays, or the rays which seem red to human eyes, cross farther from the glass than the rest of the visible rays. But invisible hot rays cross still farther away. That "chromatic aberration" belongs to each focus in the series of images which result from "spherical aberration," that is from the shape of a glass which is a sphere, or part of a sphere. I have found that within a conical figure, an inch and a half long and an inch wide at the base, heat varies from 110° to 700° at least. By wearing black spectacles a good deal of this may be seen upon paper screens in safety. By casting shadows with pins stuck into paper set to cut the cone lengthwise, the direction taken by the light in the cone, before and after the waves have

crossed, may be seen also. Mathematicians may be able to explain the whole. That I cannot do. But I have set the point of a pencil of light to engrave, to model, and to make pictures of itself, and to teach me a lesson practically. It seems now that the jostling of light waves where they meet is the power which works in a cone of light by separating particles. The rays seem to do little work when they diverge after they have crossed the axis.

"What are you trying to find out?" said a friend one day. "If I knew everything, I would not try any more." I don't know what more I may happen to find in the focus of a burning-glass! A good many people have found things there which they did not know till they had tried experiments. They found the spectrum, and lines in it, and part of their meaning; they found out how to make spectacles, and telescopes, and microscopes, and lighthouse apparatus, "dioptric and catadioptric;" they found out Daguerreotypes, and photography, and other arts. Like other seekers after knowledge I have been seeking light; and haply, by perseverance, anybody may discover something besides danger even in a paper-weight. Let me add one word of warning. It is very dangerous to "play with fire," and still more dangerous to play with sunshine or bright lights. The writer damaged his own eyes seventeen years ago by looking at the electric light with a lens, to see what was going on between the carbon points. To look at the sun through a burning-glass would destroy an eye in a moment, or possibly kill a seeker after knowledge, devoid of caution. A hot poker thrust into an eye would be "dangercus," and the focus of a big lens is as hot as red iron. The focus of a big lighthouse apparatus will now do all the work that was detailed in Sir David Brewster's article on "Burning instruments." Part of that work was to fuse platinum, which melts at 3280°, according to a table constructed by Dr. Alfred S. Taylor in 1845. Therefore take warning from a burnt child who dreads fire, that good servant, who is a bad master and a worse divinity, RA,

A.M. 9.30.

P.M.

Fig. 5.—Block engraved by the sun upon an equatorial slope, with a sphere 4·8 inches in diameter, June 4, 1870. Set 9.30 A.M.; moved 3 p.m.; proved and sent to the Editor of GOOD WORDS at 5 p.m. Niddry Lodge, Kensington, London, W. Blue sky; passing clouds; fresh breeze N.W., the first fine day in the year.—J. F. CAMPBELL.

The thing wanted is a sphere of clear good glass turned twice. 10.

Sent to the glass [illegible]

Pd. This is published. Private

CAMPBELL'S REGISTERING SUN-DIAL.

AT some time in March or April, 1879, some gentlemen, and some ladies too, were very much amazed to find their writing-desks and tables smoking. They wrote to the papers about it. Under the heading, "An unsuspected danger," a series of letters appeared in the leading journals. Certain transparent glass balls, now commonly used as paper-weights, being set in sunshine, "acted like a burning-glass" on tables and table-covers, to the astonishment of their owners. They are burning-glasses. In daily life theory very seldom is practised; knowledge very seldom is used. Though "optics" are taught in schools and colleges, very few people realise that things polished and transparent, with surfaces shaped so as to condense light, are instruments which may set combustibles on fire.

"Burning-glass" was defined in the "Encyclopædia Britannica" in 1797, as "A convex glass, commonly spherical, which, being exposed directly to the sun, collects all the rays falling thereon into a very small space called the focus, where wood or any other combustible matter being put, will be set on fire." In the article quoted Sir David Brewster tells what had been done with burning-glasses. We have all been taught that Archimedes burned the Roman fleet at Syracuse with sunshine, about 2,090 years ago. The writer's family and Sir David Brewster were friends, and he had the great advantage of knowing that distinguished philosopher, and of learning curious knowledge from him in conversation. Some fifty years ago somebody gave a child an optical toy, a glass like the bulb and stem of a big thermometer filled with water. He then learned experimentally that a transparent ball is a magnifier, and burns fingers. Ever since that childish lesson was learned, as boy and man the writer has been striving to learn more about "burning-glasses." Nevertheless he too was caught unawares by sunshine. In April, 1879, an innocent egg-shaped water-bottle burned a hole in a toilet-table, which happened to be set in a new place where the sun happened to shine upon it at the hour when the focus of this burning-glass happened to be at the table on which the bottle stood. That particular combination may not happen again for a year, but every time such a combination does occur danger recurs, from the misuse of a bottle. The associate of this criminal found guilty of arson being suspected, a tumbler was tried and convicted of the same offence. Dragged into light he too burned wood. A knot in a pane of glass is a "lens;" a finger-glass, a wine bottle, a tumbler, a wine glass, a globe for gold fish, a chemist's window ornaments, any glass or glass vessel full of clear fluid and properly shaped, may happen to be so placed as to concentrate sunshine at some hour of the day, on some day in a year, upon a combustible, when a breeze of wind may kindle a blaze, and burn a house or a ship unexpectedly and unsuspected. Knowing something of this, about 1853 the writer tried to use some of the small amount of knowledge which he had picked up. Amongst other contrivances, he then invented a very simple instrument founded upon two facts, (1) a transparent ball is a burning-glass; and (2) the world turns round. This paper is an attempt to describe the principle of the contrivance which a child of six years old understood some fifty years ago.

A billiard ball is a "sphere." Slices cut off it are bounded by circles. All sides of it are alike. On it, or any other "sphere," great or small, may be drawn the lines and scales which are drawn upon school globes. A transparent sphere placed where any sort of light shines upon it presents the same curves to the "rays," and bends them to corresponding places on the opposite side, where the rays cross at a "focus." Whether a sphere is turned end for end, or capsized, spun, or rolled, the focus for parallel rays always is opposite to the source of light, and at a certain distance from the surface. A spherical bottle is a lens; and so is the atmosphere. When a transparent sphere is set out of doors all the shining bodies that stud the visible sky shine through it to opposite foci. Each forms an image of itself and a cone of light, which may be cut by a surface placed in the cone. The lens of a photographic camera is founded upon the principle. The sensitive screen cuts cones of light. The writer has got images of the stars, the moon, and the sun, by photography. But the screen of a camera is flat, not spherical. Distances measured upon it are unequal, and drawings are out of perspective, and out of proportion. The stars and the moon draw, but the sun is so hot that the image "burns." For many years a lens has been set at Paris so as to focus the sun's rays upon gunpowder, at noon, and so fire a small cannon. Gun-

June 23. 1879. J. F. Campbell. Belongs to return when read. J.F.C. Niddry Lodge Kensington London W. Sent to Lady Ruthven and returned by Miss Imlach July 24 1879

powder explodes at 700°, which is hot. But that sort of lens must be turned towards the source of light so as to get a focus. Tele scopes and microscopes, and such like, are made with very small arcs of spherical surfaces, which must be aimed at the object whose rays are to be focussed. After some thought and sundry failures, a transparent globe was seen to be the thing needed for the purpose wanted. But in 1853 no glass globes were to be got in Paris. Hollow glass globes, blown for lampshades, were to be had in abundance. These spherical bottles were then commonly used in Parisian workshops to concentrate lamp light upon work, and to save working eyes from dazzling and from darkness. Through life the writer has been given to expedients. When he could not get what he wanted, he did the best he could without it. He wanted a spherical lens, and could not get anything better than a bottle-stopper made of solid glass. So he found out a maker of lampshades and fraternized with him in his workshop, where he lived with a wife, and a tame squirrel, and a canary, and some flowers, at the top of a high house where the sun shone cheerily. A capital water-lens was got for a franc. The diameter was six inches, the radius of the sphere three, and a cone of sunlight stretched three inches from the glass to the place where the sun's image burned. "My faith!" said the Frenchman, when he saw what his glass bottle could do in sunshine, "you do not sleep all night long." A London turner was set to make a bowl of hard wood ;—a hollow half-sphere, with a radius of six inches, and a diameter of twelve. The lamp-glass was set upon a tumbler three inches high, in the bowl of wood, in a window facing the south, and this "sun-dial," in various shapes, has gone on working for the inventor ever since. Anybody can make it, or use it; anybody may, it is not a "patent." One added to one makes two. One fact added to another makes an "invention." It does not make the matter clearer to express it by figures, $1+1=2$, or by Algebra.

This contrivance is an astronomical engine, and the first of its kind. A graving tool is set to draw circles upon a sphere. It is a "pencil of rays" as thick as the diameter of the transparent lens, with a conical point about half a radius long, when the globe is of solid glass. The centre of the globe answers to the "rest" of a turning lathe; the earth's rotation is the machinery in motion. The long end of the lever reaches from the sun to the centre of the lens; the short end is the hot cone, which burns wood like iron heated to 700°. The invention is a simple application of natural force and movement. Like the application of steam or water-power or the wind to move engines, there is nothing new in the invention, except the new combination of a transparent sphere, with a spherical surface so fitted that one concentrates a cone of sunshine which the other cuts at right angles, where it is hottest, whatever may be the sun's altitude or declination while it shines upon the glass sphere. All other dials work on the same principle: this one uses light instead of shade, and registers natural phenomena. As the world turns, the dial turns with it Eastwards. The hot sun appears to travel from east to west in the sky, the hot image of it travels from west to east, and engraves the path which the sun describes, measure for measure and rate for rate. If a cloud stops sunshine during four minutes of time, the circle drawn with the hot pencil is broken for a space of one degree on the circle. No matter what the radius may be, the angular space is measured by the world's movement. If the sun shines for an hour, the arc drawn is fifteen degrees, measured astronomically for time and for angular distance. If sunlight is hindered, the hot image is not so hot; the point of the pencil is shortened, the power to sink into wood is less, and the mark engraved is shallower. It has been found experimentally that the power is greater, and the mark deeper, the nearer the sun is to the zenith. The nearer the sun is to the horizon, the shallower is the mark. Apparently the reasons are that the lower air contains more matters which stop light, because there is more of the atmosphere in the way at sunrise and sunset and in winter, and because spaces between clouds are narrower when light strikes through layers horizontally, instead of vertically; level, instead of downwards. As the world goes round the sun, lines described on the dial are those which are expressed on some school globes between the tropics, and are measured upon the "Ecliptic." But these being drawn *astronomically*, are accurately engraved. If only the surfaces are made true, the engraving must be more accurate than anything drawn by hands, or by clockwork, or by dividing engines. No matter how minute the scale may be, the work done must be done exactly; because the world moves, the dial and sunlight engraves it.

I can think of nothing better for the purpose of registering sunshine than well-made glass spheres, and well-turned bowls of hard wood. The bowl can be set level by filling it with water, which gives the plane of the geometrical horizon. So set, anywhere in sunshine, and left alone, the dial works for six months, while the sun travels forty-seven degrees, from one tropic to the other between the solstices. The register proves its own latitude by the angle which the planes of the circles described make with the plane of the horizon of the bowl, which is the edge of it. The record gives the *mean* result engraved upon wood. The wood is not set on fire. Portions of wood are destroyed instantaneously; and other portions are charred, as if by a hot wire. The air does not get at the place, so as to light the fire or keep it smouldering. No bowl tried since 1853 has burned or smouldered. Casts made with gutta-percha come out clear, sharp copies of the cones of light which engraved the intaglio. That being the principle of the contrivance, these are some of the uses to which it may be put.

In April, 1857, the contriver wrote a description of the invention for the Meteorological Society, who printed it. One of the writer's ideas then was to use the dial to map out the clear and cloudy regions of the world for the benefit of people in search of climates for the sake of health. The most important and least studied branch of Meteorology, the science of weather and climate, is sunshine. It works in the air, the ocean, and the earth to considerable depths, as a mechanical force, and otherwise. It reaches thermometers at Greenwich buried 25·6 feet. Concentrated with big instruments sunlight has fused the most refractory metals and minerals; it turns water and diamonds to vapour, it burns fingers, it boils an egg, cooks a steak, it would kill a man who should put his eye at the "focus." With part of a lighthouse apparatus the writer once kindled a blaze. As a matter of geological speculation a deeper clear atmosphere would concentrate more sunlight upon the solid world; as a matter of fact, the presence or absence of vapour in the atmosphere over a place alters the climate.

Sunshine is a system of waves. All waves need a shore to show their force, and their force is hindered by any impediment. The strongest burning focus does nothing perceptible to clear air. Atlantic billows do little to boats in a calm. But when waves in water or in light are stopped, then they work mechanically, in proportion to their size and swiftness. Light waves which are hindered in the air and do work there, expend force before they reach the solid world. Chemical and other waves of light affect plants and animals, crops, and men. Where there is superabundance of sunshine, men have to shield their heads from a deadly stroke; there the earth is parched and plants are scorched. In Calcutta, even omnibus horses wear sun-shields, because without them they are often slain. It is important to know where the needful light waves reach the earth and its people. With some notion of the nature and power of sunshine, the writer wanted something to record and measure the work of it as a barometer weighs air, and a thermometer measures heat. So he contrived a dial twenty-six years ago. He told the Meteorological Society all he knew in 1857, and ever since he has been using a burning-glass as a test of climate.

Since 1857 he has travelled far, armed with divers instruments, always observing climate, while learning lessons which make travelling a pleasure and a gain instead of a grievous bore.

In January, 1878, the writer went to Egypt, where a cloud is a rarity. In the same season of 1879 he lived in London, where sunshine like that of Egypt never has been seen. In December, 1876, the sun was above the horizon of Greenwich for 242 hours and forty minutes, but the dial used at the Observatory registered only six hours and-a-half of sunshine, which is patriotically styled "bright" in the report. In January, 1878, the light was so brilliant in Egypt, that northern eyes could not endure it without a black shade. In the same season of 1879 the darkness at noonday in London often was like that miraculous Egyptian darkness which is recorded in Holy Writ as a plague and a punishment. The light in the sky about 2 P.M. was found experimentally on one day to be hardly so bright as a white marble bust placed some eighteen feet from a single bat's-wing gas light. The gas bill was enormous, because of the clouds, fogs, and vapours which stopped waves of light in our climate. The cause of the clouds is evaporation from the Western Atlantic, which is warmed by the sun. That sort of important difference in climate the dial records, and a burning-glass shows to a passing traveller. In Java the climate is that of the torrid zone, close to the equator. The sun always is near the zenith at noon, in the best position for shining through the estimated depth of forty miles of air. But that part of the atmosphere which is over Java and Singapore is

full of the vapour of an ocean which is heated at the surface to 80° or more, though cold as ice at the bottom. The light is so hindered by its own work that a burning-glass would hardly act at all. So it has been found experimentally elsewhere between the tropics, in damp, steamy, hot climates. In Japan, where the mountain air was cold and clear and dry in winter, because dried air is flowing from the Arctic regions of Asia, the traveller lit his pipe daily with a crystal ball about one inch in diameter, which was meant to be the eye of an idol. Generally it has been found experimentally, that where the air is clear the climate is dry. In California the sky is clear for months, and the land is dusty. In Oregon the sky generally is cloudy, and the land is chiefly mud. In the central regions of North America the air is clear, and the sun scorches the ground and dries it to make a desert. About the borders of Thibet the rainfall is slight, and the sun shines through clear, frosty air brilliantly. The purest and clearest air will be found about places marked "rainless" in a physical atlas, and there burning-glasses act best. There also eyes see best into space through the hollow sphere of the atmosphere, with and without optical aids, from spectacles up to astronomical telescopes. Probably the clearest and purest part of the earth's outer shell is over that great band of dry sandy deserts which extends from the Atlantic coast of Africa through Arabia, and nearly to the Indus. The Nile crosses that belt. The narrow strip of river mud which is kept damp and is watered by the river which brought it, is a strip of marvellous fertility, suited to the growth of that ancient civilisation which flourished in Egypt six thousand years ago, and would flourish there still if rulers would let it flourish. The damp land is not broad enough for vapours to rise in sufficient quantity to hinder sunshine, so Egypt is a land of brilliant light. There the ancients adored the sun, whose power for good they knew by daily experience. We might as well adore the fire, like our Aryan ancestors, who hymned Agni (the fire) and Indra (the sun). Their ancient country, in Central Asia, is near "a rainless district," and so the worship of the sun and of fire seems to belong to people who felt the sun's power through a clear part of the atmosphere. A burning-glass tests that clearness roughly; a registering dial measures it, and so it will map out clear and cloudy climates, when it comes to be used.

A description of the dial and some of the work done with it is in the report of the Commission on Warming and Ventilation, which was ordered by the House of Commons to be printed in 1857. The object then aimed at was to estimate the ill effects of wasting fuel in thick smoke. "The abolition of the smoke nuisance" was the desire of that Commission, but their end has not been attained. It never will be attained till coals are dear in England.

Dial observations were continued at the office of the General Board of Health long after the assistant-secretary left that department to serve the Lighthouse Commission as secretary. The records of London sunshine, engraved upon a series of wooden bowls, were handed over to the Meteorological department of the Board of Trade, when it was instituted. Mr. Scott, the head of the State Weather Office, which began to publish forecasts April 1st, 1879, handed over the London dial records of sunshine to Professor Roscoe, of Owen's College, Manchester, who is an authority in such investigations. In 1875 he compared the half-yearly mean results by weighing and measuring the work. He found (1) that more sunshine had reached the place of observation after the longest day in each year. That result is confirmed by means of a vast number of thermometer observations recorded at Greenwich Observatory.* He found (2) that most dial work had been done during years when sun spots were most abundant. Thermometers at Greenwich also recorded more or less solar radiation as temperature (see Plate X., *op. cit.*) in years between 1847 and 1873. Upon facts ascertained, it is supposed that solar radiation varies periodically. Upon that theory, which is based upon facts, Mr. Jevons has founded his published theory of recurring periods of agricultural and commercial prosperity and depression.

When the sun radiates more than the average, lands everywhere on earth produce more. Because growers then are richer they buy more. Because of greater demand makers of goods make more, and trade prospers. When the sun radiates less, trade and prosperity decrease, and so wax and wane with sunshine. More dial records would help to settle the question of periodical increase and decrease in solar radiation.

On the 17th of June, 1875, a paper by Professors Roscoe and Balfour Stewart was

* "Reduction of Greenwich Meteorological Observations, &c." London: Eyre and Spottiswoode, 1878. Published by order of the Board of Admiralty.

read at the Royal Society, about the dial and its work, and the results obtained from means engraved half-yearly at the office of the Board of Health. "There is a distinct connection between the sun's burning power and his maximum and minimum spot period," which the dial recorded. The paper is printed in the proceedings of the Royal Society.

The dial was again mentioned in the second volume of the report of the Lighthouse Commission, 1861, at page 629. It is important not to place a coast light where clouds are apt to condense. It has been done unawares, and a site has been changed from the top of a cliff to a rock at the base. The instrument would have given warning of the condensation, and would have saved the cost.

Some of the work done with a glass sphere is described and printed in a work called "Frost and Fire," vol. ii., page 480, 1865.

Some years ago Mr. Chance, of the Birmingham Glass Works, got a ball of good glass cast and polished for the inventor. He has never seen another like it. Sir William Armstrong got a metal bowl turned at his Newcastle workshops, to fit the glass. The object was to cut the cone of light where it is a fine point so as to make fine work. The instrument was tested and found to work well upon black Indian-rubber cloth fixed upon the metal surface, with a waterproof solution, and changed daily. The circles drawn were very clear and very fine. But such daily observations belong to an observatory, so the instrument, with the motto, "Horas non numero nisi serenas," engraved upon it, was handed over to the Astronomer Royal. Under his able superintendance it has worked at Greenwich since May, 1876, watched by Mr. Ellis and his assistants, with the rest of the family of contrivances over which they exercise careful supervision. When a paper was read before the Royal Society about the dial and its work, the dial was promoted, and the inventor was gratified. The results of the Greenwich observations are published in the yearly reports; by the Registrar-General in his reports; and by sundry newspapers. The authorities are content with the instrument, and it is seen by the visitors at their yearly visitation of Greenwich Observatory.

A Slope. The inventor of the dial, however, was not satisfied with the form of it, for the purpose of registering sunshine daily at an observatory. The surface of the bowl is spherical, but the surface turned by the point of a pencil of rays is not. When the spherical surface is wood, the pencil point engraves it to considerable depths. The surface measures a cross section of the conical point, the depth measures the length of the point, which varies continually. A cast of a bowl exposed for six months gives some notion of the mean surface which would result from exposure for much longer times. The curve so turned I am not able to describe scientifically, but it would come out as a regular curve if there were no clouds in the way. Each circle is cut by the point at sunrise or soon after, and the curve drawn daily by the point cuts deeper towards noon, and fades away towards sunset. The curve drawn at the tropic which is opposite to the sun in winter at noon, grows deeper till the sun is at the summer tropic. The result is the rotation of an eccentric figure which is not a circle, upon a surface which results from the rotation of a circle, and is a sphere. When the surface of the bowl is metal, it is not engraved at all. It is necessary to line the bowl with something more fusible or combustible, to be marked by a pencil of rays. It is difficult to cut anything flat so as to make it fit a sphere. That any child will discover who puts a leathern cover upon a hand-ball made of worsted, wound round a cork. The thing wanted at an observatory is some plane surface, like this sheet of paper, to be taken out of the bowl and filed in a book daily. That is done by cutting cloth, leather, or cardboard, on the plan by which school globes are covered with paper, and fives-balls and golf-balls, and hand-balls with leather. But the result is a drawing upon a spherical surface, and the curve which a cone of rays describes on wood has been found experimentally to be some other figure which seems to be part of a spheroid more flattened than the earth is by its rotation.

It has also been proved experimentally by many trials, that planes which are bounded by figures engraved as already described, are nearly parallel to the equatorial plane at all seasons. They must be so, because they result from the earth's daily rotation, modified by the earth's daily change in its yearly path round the sun. Vertical and horizontal planes are at right angles, like the covers of a book half open. The plane of the equator is somewhere between them, like a leaf in the half-open book. In latitude $51\frac{1}{2}°$ the plane of the equator makes an angle of $51\frac{1}{2}°$ with the vertical plane, and one of $38\frac{1}{2}°$ with the horizontal plane, which coincides with the surface of a glass of water practically. The two angles make up $90°$, and four such angles make a

square. The object desired was to get a slope made and placed parallel to the plane of the equator. A beam of wood was squared by a carpenter, and then sawn off at an angle of 38½ or 51½ slantwise. Placed upon one side, the slope of the beam was parallel to the earth's axis. Placed on the other, it was parallel to the equatorial plane. Placed together, the surfaces make a right angle, whose sides are set to the horizontal plane at an angle which varies with the latitude. The block sawn out and roughly planed was set north and south in the plane of the meridian and levelled. The slope was then East and West, and parallel to the plane of the equator so far as could be done with the tools, materials, and aids available. "If you can't get what you want, try to do the best you can with anything handy," is a good maxim for inventors and travellers. A spherical lens was set upon the level top of the beam, so that the cone of light passed over the edge of the slope, where it described figures about the centre of the glass sphere. Anything flat laid parallel to the slope may be placed in this astronomical turning-lathe, so as to be in the burning point of a pencil of rays edgewise or otherwise. The setting of the engine is done by sliding the glass along the flat top of the squared and levelled beam, or by lifting or lowering it. At an observatory this should be made accurately of white stone, with screws for setting the work and the glass. Such is the mechanical force of sunlight, that a squared beam of wood bends, and curls, and splits, and throws everything out of gear.

A book with paper edges set in the cone as wood is set for a circular saw, or iron in a turning-engine at an engine shop, is engraved in this solar turning-lathe edgewise. The work is seen by opening the book. A circular arc cut out of stiff cardboard at a given radius presents an edge to the graving tool, which edge corresponds to part of a spherical bowl. That also is engraved edgewise, and may be filed daily. In May, 1879, a few days of sunshine occurred in London. On the third, a wood-engraver's block, inked to blacken it, was set on the rude slope described, in the cone of a cast glass sphere, which cost three shillings, and was set to work in 1858. That lens was set upon the screw-stand of an old microscope, and moved till the black plane surface of boxwood cut the cone, so as to make an elliptical section of the point. That figure revolved about the lens upon the plane. As soon as the sun got out of the eastern haze, about half-past ten, the hot pencil began to engrave. As often as a cloud or any other obstruction got in the way, it either altered the length of the ellipse or cut the long lever end of the pencil of rays and stopped the engraving. When the hindrance or stoppage passed and the sun shone, the engraving began again further on. Thus the sun's power at given moments was measured upon a surface fit for printing in GOOD WORDS, and for the first time on this new contrivance of a slope set equatorially. After four hours the sun had moved 60°, and the point went off the wood. The block was taken to a neighbouring printer, inked, and pressed. It was taken back and set to be engraved again later in the day. A neighbouring carpenter was got to saw off the engraved edge, and this woodcut is the result of that experiment in "THERMOGRAPHY."

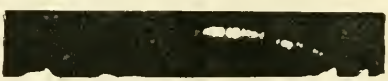
P.M.  A.M.

Fig. 1.—3-inch lens. May 3, 1879. Four hours' exposure, 60°. Passing clouds and bright sunshine.

The work done in an hour on the 3rd of May with a lens of four inches diameter, and work done with the smaller lens on the 5th, was sawn off the block on the 6th, and here is the result.

P.M.  A.M.

Fig. 2.—May 3 and May 5, 1879. 4-inch lens, 1 hour, 15°. 3-inch lens, 4 hours, 60°. Passing clouds and bright sunshine.

On the 5th of May the sun shone and seemed to shine with equal brilliancy. A block was set in the cone of a lens nearly six inches in diameter. The result shows that the sun's power varied from moment to moment.

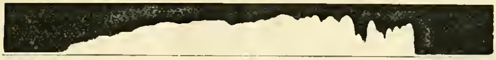
P.M.  A.M.

Fig. 3.—May 5, 1879. Two hours exposure, 6-inch lens, 30°. Passing clouds. The slope being out of position the burning point got over the edge, and burned under the printing surface at the left side in the figure.

That night and next day the clouds condensed into heavy rain.

The blocks ought to be cut out in arcs of circles to show the whole work of a day. These are enough to show that the day's work of registering sunshine may be printed after sunset; and published next day in a newspaper, which was the object of this experiment. A book set with the side towards the cone is a plane set at a tangent to a sphere, and cuts the cone at varying angles. Accordingly the cone cuts through a varying number of pages. A block of wood set in the same position is pierced to varying depths, as shown in section on Figs. 1, 2, 3. As the sun moves, the section of the cone at the printing surface changes till the last point that is hot enough to mark goes off in a hair line. The depth is not shown in printing. This is the sort of work which a bottle or a paper weight makes upon a table.

P.M.  A.M.

Fig. 4.—June 4, 1879. A four-inch lens standing upon a printer's block of boxwood. Depth of slot ¼in. to nothing.

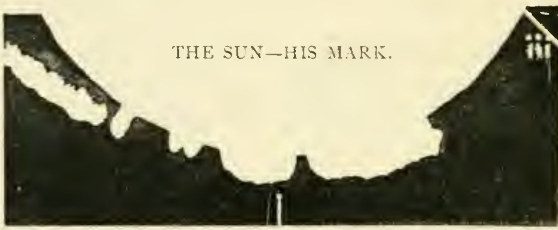
Sheets of gutta-percha placed in the same positions are moulded by the conical point of the pencil of rays, but the shapes will not print. So are sheets of wax laid upon paper. By these and by other such expedients it is easy to get engravings, casts, and pictures of sections of a cone of light, so as to estimate the force of sunshine by shapes in substances marked by the waves, as waves mark a beach.

The cone of light formed by a sphere is a very complicated structure, which is not easy to understand or to explain. The central point on the surface of the ball opposite to the sun lets through a straight line of light, which goes straight on till it is stopped. It is like a ray of light shining through a pinhole. Take a school globe for illustration, call that point the pole, and the line the axis. A ring of the glass surface close to the point bends the waves of light into a cone which crosses the axis at a distant point. Larger outer rings, comparable to parallels of latitude, bend "rays" or waves to points upon the axis nearer and nearer to the glass, and the outermost rings, which refract, or bend rays or waves, bring them together close to the glass. A whole series of circular discs, images of the sun, or "foci," are strung upon the central line like buttons on a string. All these images which together answer to the lead in a pointed drawing pencil are hot, and the hottest are those which are formed by the largest rings, which are the farthest from the pole. The ring between latitude 45° and 50° is far larger than between 85° and 90°. In a cone an inch and a half long, and about an inch wide at the glass which has a diameter of nearly six inches, that part which answers to the lead in a pencil, and is hot enough to burn blackened cardboard, was found experimentally to be nearly an inch long about noon, on a clear London day at the end of April. On the 29th a hot point pierced twenty-two sheets of a note-book. It scorched the first sheet to a width of six-tenths of an inch. On the 17th the cone pierced fourteen sheets and scorched the fifteenth. That is a measure "of longitudinal spherical aberration," which is explained scientifically in works on Optics, and was proved experimentally in April, 1879. But there is a further complication in the cone. Waves of light of different measured lengths, which are detailed in scientific works, give different colours, and meet upon the axis at distances proportioned to their "refrangibility." The red rays, or the rays which seem red to human eyes, cross farther from the glass than the rest of the visible rays. But invisible hot rays cross still farther away. That "chromatic aberration" belongs to each focus in the series of images which result from "spherical aberration," that is from the shape of a glass which is a sphere, or part of a sphere. I have found that within a conical figure, an inch and a half long and an inch wide at the base, heat varies from 110° to 700° at least. By wearing black spectacles a good deal of this may be seen upon paper screens in safety. By casting shadows with pins stuck into paper set to cut the cone lengthwise, the direction taken by the light in the cone, before and after the waves have

crossed, may be seen also. Mathematicians may be able to explain the whole. That I cannot do. But I have set the point of a pencil of light to engrave, to model, and to make pictures of itself, and to teach me a lesson practically. It seems now that the jostling of light waves where they meet is the power which works in a cone of light by separating particles. The rays seem to do little work when they diverge after they have crossed the axis.

"What are you trying to find out?" said a friend one day. "If I knew everything, I would not try any more." I don't know what more I may happen to find in the focus of a burning-glass! A good many people have found things there which they did not know till they had tried experiments. They found the spectrum, and lines in it, and part of their meaning; they found out how to make spectacles, and telescopes, and microscopes, and lighthouse apparatus, "dioptric and catadioptric;" they found out Daguerreotypes, and photography, and other arts. Like other seekers after knowledge I have been seeking light; and haply, by perseverance, anybody may discover something besides danger even in a paper-weight. Let me add one word of warning. It is very dangerous to "play with fire," and still more dangerous to play with sunshine or bright lights. The writer damaged his own eyes seventeen years ago by looking at the electric light with a lens, to see what was going on between the carbon points. To look at the sun through a burning-glass would destroy an eye in a moment, or possibly kill a seeker after knowledge, devoid of caution. A hot poker thrust into an eye would be "dangerous," and the focus of a big lens is as hot as red iron. The focus of a big lighthouse apparatus will now do all the work that was detailed in Sir David Brewster's article on "Burning instruments." Part of that work was to fuse platinum, which melts at 3280°, according to a table constructed by Dr. Alfred S. Taylor in 1845. Therefore take warning from a burnt child who dreads fire, that good servant, who is a bad master and a worse divinity, RA,

A.M. 9.30.



P.M.

Fig. 5.—Block engraved by the sun upon an equatorial slope, with a sphere 4·8 inches in diameter, June 4, 1879. Set 9.30 A.M.; moved 3 p.m.; proved and sent to the Editor of GOOD WORDS at 5 p.m Niddry Lodge, Kensington, London, W. Blue sky; passing clouds; fresh breeze N.W., the first fine day in the year.—J. F. CAMPBELL.