PHILOSOPHICAL

TRANSACTIONS.

XIX. *Experiments on the solar, and on the terrestrial Rays that occasion Heat; with a comparative View of the Laws to which Light and Heat, or rather the Rays which occasion them, are subject, in order to determine whether they are the same, or different.* By William Herschel, *LL. D. F. R. S.*

Part II.*

Read November 6, 1800.

In the first part of this Paper it has been shewn, that heat derived immediately from the sun, or from candent terrestrial substances, is occasioned by rays emanating from them; and that such heat-making rays are subject to the laws of reflection, and of refraction. The similarity between light and heat, in these points, is so great, that it did not appear necessary to notice some small difference between them, relating to the refraction of rays to a certain focus, which will be mentioned hereafter. But the next three articles of this Paper will require, that while we shew the similarity between light and heat, we should at

* For the First Part of this Paper, see page 293.

the same time point out some striking and substantial differences, which will occur in our experiments on the rays which occasion them, and on which hereafter we may proceed to argue, when the question reserved for the conclusion of this Paper, whether light and heat be occasioned by the same or by different rays, comes to be discussed.

ARTICLE IV.—*Different Refrangibility of the Rays of Heat.*

We might have included this article in the first part of this Paper, as a corollary of the former three; since rays that have been separated by the prism, and have still remained subject to the laws of reflection and refraction, as has been shewn, could not be otherwise than of different refrangibility; but we have something to say on this subject, which will be found much more circumstantial and conclusive than what might have been drawn as a consequence from our former experiments. However, to begin with what has already been shewn, we find that two degrees of heat were obtained from that part of the spectrum which contains the violet rays, while the full red colour, on the opposite side, gave no less than seven degrees;* and these facts ascertain the different refrangibility of the rays which occasion heat, as clearly as that of light is ascertained by the dispersion and variety of the colours. For, whether the rays which occasion heat be the same with those which occasion the colours, which is a case that our foregoing experiments have not ascertained, the arguments for their different refrangibility rests on the same foundation, namely, their being dispersed by the prism; and that of the rays of light being admitted, the different

* See 2d and 4th experiments, pages 258 and 259.

refrangibility of the rays of heat follows of course. So far then, a great resemblance again takes place.

I must now point out a very material difference, which is, that the rays of heat are of a much more extensive refrangibility than those of light. In order to make this appear, I shall delineate a spectrum of light, by assuming a line of a certain length; and, dividing it into seven parts, according to the dimensions assigned to the seven colours by Sir ISAAC NEWTON, in the fourth figure of the second part of his Optics, I shall represent the illuminating power of which each colour is possessed, by an ordinate drawn to that line. And here, as the absolute length of the ordinates is arbitrary, provided they be proportional to each other, I shall assume the length of that which is to express the maximum, equal to $\frac{27}{33}$ of the whole line.

Thus, let GQ * represent the line that contains the arrangement of the colours, from the red to the violet. Then, erecting on the confines of the yellow and green, the line LR $= \frac{27}{33}$ of GQ, it will represent the power of illumination of the rays in that place. For, by experiments already delivered, we have shewn that the maximum of illumination is in the brightest yellow or palest green rays.† From the same experiments we collect, that the illuminations of yellow and green are equal to each other, and not much inferior to the maximum; this gives us the ordinates K and M. Then, by the rest of the same experiments, we obtain also the ordinates H, I, N, O, P, with sufficient accuracy for the purpose here intended. All these being applied to the middle of the spaces which belong to their respective colours, we have the figure GRQG, representing what may be called the spectrum of illumination.

* See Plate XX.

† See page 262.

We are now, in the same manner, to find a figure to express the heating power of the refracted prismatic rays, or what may be called the spectrum of heat. In order to determine the length of our base, I examined the extent of the invisible rays, and found, that at a distance of two inches beyond visible red, my thermometer, in a few minutes, acquired $1\frac{1}{4}$ degree of heat. The extent of the coloured spectrum at that time, or the line which answers to GQ in my figure, measured 2,997 inches. If two inches had been the whole of the extent of the invisible part, it might be stated to be in proportion to the visible one as 2 to 3; but we are to make some allowance for a small space required beyond the last ordinate, that the curve of the heating power drawn through it may reach the base; and indeed, at $2\frac{1}{4}$ inches beyond visible red, I could still find $\frac{1}{2}$ degree of heat. It appears therefore sufficiently safe, to admit the base of the spectrum of heat AQ, to be to that of the spectrum of light GQ, as $5\frac{1}{4}$ to 3; or, conforming to the NEWTONIAN figure before mentioned, the base of which is 3,3 inches, as $57\frac{3}{4}$ to 33. Now, if we assume for the maximum of heat, an ordinate of an equal length with that which was fixed upon for the maximum of light, it will give us a method of comparing the two spectra together. Accordingly, I have drawn the several ordinates B, C, D, E, F, G, H, I, K, L, M, N, O, P, of such lengths as, from experiments made on purpose, it appeared they should be, in order to express the heat indicated by the thermometer, when placed on the base, at the several stations pointed out by the letters.

A mere inspection of the two figures, which have been drawn as lying upon one another, will enable us now to see how very differently the prism disperses the heat-making rays, and those which occasion illumination, over the areas ASQA, and GRQG, of our two spectra! These rays neither agree in their mean refrangibility, nor in the situation of their maxima. At R, where we have most light, there is but little heat; and at S, where we have most heat, we find no light at all!

21st Experiment. The Sines of Refraction of the heat-making Rays, are in a constant Ratio to the Sines of Incidence.

I used a prism with a refracting angle of 61 degrees; and, placing the thermometer No. 4 half an inch, and No. 1 one inch, beyond the last visible red colour, I kept No. 2 by the side of the spectrum, as a standard for temperature.

	At ½ inch. No. 4.	At 1 inch. No. 1.	Standard. No. 2.
0′	64	64	63½
2	67	66	63½
5	69	67	63½
8	69½	67½	63½

Here, in eight minutes, the thermometer at half an inch from visible colour, rose 5½ degrees; and, at one inch from the same, the other thermometer rose 3½; while the temperature, as appears by No. 2, remained without change.

I now took a prism with an angle of forty-five degrees, and, placing the thermometers as before, I had as follows:

55	55	55
59	57	54¾
61	58	55
62	58¾	55

Here we likewise had, in 10 minutes, a rise of 7 degrees in the thermometer No. 4, and of $3\frac{3}{4}$ in No. 1; while No. 2 remained stationary.

I tried now all the three angles of a prism of whitish glass: they were of 63, 62, and 55 degrees; and I found invisible rays of heat to accompany all the visible spectra given by these angles.

I tried a prism of crown glass, having an angle of 30 degrees; and found invisible heat rays as before.

I tried a prism of flint glass, with so small an angle as 19 degrees, and again found invisible heat rays.

I made a hollow prism, by cementing together three slips of glass of an equal length, but unequal breadth, so as to give me different refracting angles: they were of 51°, 62° 30′, and 66° 30′. Then, filling it with water, and receiving the spectrum, when exposed to the sun, as usual, on the table, I placed the thermometer No. 1 at ,45 inch behind the visible red colour, and No. 5 in the situation of the standard. The refracting angle of the prism was 62° 30′; and, in five minutes, the thermometer received $1\frac{5}{8}$ degrees of heat from the invisible rays. On trying the other angles, I likewise found invisible heat rays, in their usual situation beyond the red colour.

Now, setting aside a minute inquiry into the degrees of heat occasioned by these invisible rays, I shall here only consider them as an additional part, annexed to the different quantities of heat which are found to go along with the visible spectrum; in the same manner as if, in the spectrum of light, another colour had been added beyond the red. Then, as from the foregoing experiments it appears, that a change of the refracting medium, and of the angle by which the refractions were made, occasioned no alteration in the relative situation of the additional part AG, with respect to GQ; and, as the part GQ is already known to follow the law of refraction we have mentioned, it is equally evident, that the additional heat of AG must follow the same law. We do not enter into the dispersive power of different mediums with respect to heat, since that would lead us farther than the present state of our investigation could authorise us to go; the following experiment however will shew that, as with light so with heat, such dispersive power must be admitted.

22d Experiment. Correction of the different Refrangibility of Heat, by contrary Refraction in different Mediums.

I took three prisms; one of crown glass, having an angle of 25 degrees; another of flint glass, with an angle of 24; and a third of crown glass, with an angle of 10 degrees. These being put together, as they are placed when experiments of achromatic refractions are to be made, I found that they gave a spectrum nearly without colour. The composition seemed to be rather a little over adjusted; there being a very faint tinge of red on the most refracted side, and of violet on the least refracted margin. I examined both extremes by two thermometers; keeping No. 3 as a standard, while No. 2 was applied for the discovery of invisible rays; but I found no heat on either side. After this, I placed No. 2 in the middle of the colourless illumination; and in a little time it rose two degrees, while No. 3 still remained unaltered at some small distance from the spectrum. This quantity was full as much as I could expect, considering the heat that must have been intercepted by three prisms. Thus then it appears, that the different refrangibility of heat, as well as that of light, admits of prismatic correction. And we may add, that this experiment also tends to the establishment of the contents of the preceding one; for the refrangibility of heat rays could not be thus corrected, were the sines of refraction not in a constant ratio to those of incidence.

23d Experiment. In Burning-glasses, the Focus of the Rays of Heat is different from the Focus of the Rays of Light.

I placed my burning lens, with its aperture reduced to three inches, in order to lessen the aberration arising from the spherical figure, in the united rays of the sun; and, being now apprised of the different refrangibility of the rays of heat, and knowing also that the least refrangible of them are the most efficacious, I examined the focus of light, by throwing hair-powder, with a puff, into the air. This pointed out the mean focus of the illuminating rays, situated in that part of the pencil which opticians have shewn to be the smallest space into which they can be collected. That this may be called the focus of light, our experiments, which have proved the maximum of illumination to be situated between the yellow and green, and therefore among the mean refrangible rays of light, have fully established. The mean focus being thus pointed out by the reflection of light on the floating particles of powder, I held a stick of sealing wax 1″,6, or four beats of my chronometer, in the contracted pencil, half an inch nearer to the lens than the focus. In this time, no impression was made upon the wax. I applied it now half an inch farther from the lens than that focus; and, in 8-tenths of a second, or two beats of the same chronometer, it was considerably scorched. Exposing the sealing wax also to the focus of light, the effect was equally strong in the same time; from which we may safely conclude, notwithstanding the little accuracy that can be expected, for want of a more proper apparatus, from so coarse an experiment, that the focus of heat, in this case, was certainly farther removed from the lens than the focus of light, and probably not less than $\frac{1}{4}$ of an inch; the heat, at half an inch beyond the focus of light, being still equal to that in the focus.

ARTICLE V.—*Transmission of heat-making Rays.*

We enter now on the subject of the transmission of heat through diaphanous bodies. Our experiments have hitherto been conducted by the prism, the lens, and the mirror; these may indeed be looked upon as our principal tools, and, as such, will stand foremost in all our operations; but the scantiness of this stock cannot allow us to bring our work to perfection. Nor is it merely the want of tools, but rather the natural imperfection of those we have, that hinders our rapid progress. The prism which we use for separating the combined rays of the sun, refracts, reflects, transmits, and scatters them at the same time; and the laws by which it acts, in every one of these operations, ought to be investigated. Even the cause of the most obvious of its effects, the separation of the colours of light, is not well understood; for, in two prisms of different glass, when the angles are such as to give the same mean refraction, the dispersive power is known to differ. Their transmissions have been still less ascertained; and I need not add, that the internal and external reflexions, and the scattering of rays on every one of the surfaces, are all of such a nature as must throw some obscurity on every result of experiments made with prisms. A lens partakes of all the inconveniencies of the prism; to which its own defects of spherical aberrations must be added. And a mirror, besides its natural incapacity of separating the rays of light from the different sorts of heat, scatters them very profusely. But, if we have been scantily provided with materials to act upon rays, it has partly been our own fault: every diaphanous body may become a new tool, in the hands of a diligent inquirer.

My apparatus for transmitting the rays of the sun is of the following construction.* In a box, 12 inches long, and 8 inches broad, are fixed two thermometers. The sides of the box are $2\frac{1}{4}$ inches deep. That part of the box where the balls of the thermometers are, is covered by a board, in which are two holes of $\frac{3}{4}$ inch diameter, one over each of the balls of the thermometers; and the bottom of the box, under the cover, is cut away, so as to leave these balls freely exposed. There is a partition between the two thermometers, in that part of the box which is covered, to prevent the communication of secondary scatterings of heat. Just under the opening of the transmitting holes, on the outside of the cover, is fixed a slip of wood, on which may rest any glass or other object, of which the transmitting capacity is to be ascertained. A thin wooden cover is provided,† that it may be laid over the transmitting holes, occasionally, to exclude the rays of the sun; and, on the middle of the slip of wood, under the holes, a pin is to be stuck perpendicularly, that its shadow may point out the situation of the box with respect to the sun. The box, thus prepared, is to be fastened upon two short boards, joined together by a pair of hinges. A long slip of mahogany is screwed to the lowest of these boards, and lies in the hollow part of a long spring, fastened against the side of the upper one. The pressure of the

* See Plate XXI. Fig. 1. † See Fig. 2.

spring must be sufficiently strong to keep the boards at any angle; and the slip of mahogany long enough to permit an elevation of about 85 degrees.

In order to see whether all be properly adjusted, expose the apparatus to the sun, and lift up the board which carries the box, till the directing pin throws the shadow of its head on the place where the point is fastened. Then hold a sheet of paper under the box, and, if the thermometers have been properly placed, the shadow of their balls will be in the centre of the rays passing through the transmitting holes to the paper.

A screen of a considerable size,* with a parallelogrammic opening, should be placed at a good distance, to keep the sun's rays from every part of the apparatus, except that which is under the cover; and no more sun should be admitted into the room, than what will be completely received on the screen, interposed between the window and the apparatus.

As one of the thermometers is to indicate a certain quantity of heat coming to it by the direct ray, while the other is to shew how much of it is stopped by the glass laid over the transmitting hole, it becomes of the utmost consequence to have two thermometers of equal sensibility.† The difficulty of getting

* See Plate XXII. Fig. 1.

† The theory of the sensibility of thermometers, as far as it depends on the size of the balls, may be considered thus. Let D, d, S, s, T, t be the *diameters*, the points on which the *sun* acts, and the points on which the *temperature* acts, of a large and a small thermometer having spherical balls; and let $x : y$ be the intensity of the action of the sun, to the intensity of the action of the temperature, on equal points of the surface of both thermometers. Then we have $s : S :: d^2 : D^2$, and $t : T :: 4d^2 : 4D^2$. The action of the sun therefore will be expressed by $d^2 x$, $D^2 x$; and that of the temperature by $4d^2 y$, $4D^2 y$; and the united action of both by $\overline{x - 4y} \times d^2$, $\overline{x - 4y} \times D^2$; which are to each other, as $d^2 : D^2$. Now, the total effect being as the squares of the

such is much greater than can be imagined: a perfect equality in the size and thickness of the balls is, however, the most essential circumstance. When two are procured, they should be tried in quick and in slow exposures. These terms may be explained by referring to fire heat; for here the thermometers may be exposed so as to acquire, for instance, 30 degrees of heat in a very short time; which may then be called a quick exposure: or they may be placed so as to make it require a good while to raise them so many degrees; on which account the exposure may be called slow. It is true, that we have it not in our power to render the sun's rays more or less efficacious, and therefore cannot have a quick or slow exposure at our command; but a great difference will be found in the heat of a rising, or of a meridian sun: not to mention a variety of other causes, that influence the transmission of heat through the atmosphere. Now, when thermometers are tried in various exposures, they should traverse their scales together with constant equality; otherwise no dependance can be placed on the results drawn from experiments made with them, in cases where only a few minutes can be allowed for the action of the cause whose influence we are to investigate.

The balls must not be blacked; for, as we have already to encounter the transmitting capacity of the glass of which these balls are made, it will not be safe to add to this the transmitting disposition of one or more coats of blacking, which can never

diameters, while $x : y$ remain in their incipient ratio, and the contents of the thermometers being as the cubes, the sensible effect produced on the particles of mercury, must be as $\frac{d^2}{d^3} : \frac{D^2}{D^3} :: \frac{1}{d} : \frac{1}{D}$; that is, inversely as the diameters. The small thermometer therefore will set off with a sensibility greater than that of the large one, in the same ratio.

be brought to an equality, and are always liable to change, especially in very quick exposures.

Transmission of Solar Heat through colourless Substances.

24th Experiment.

I laid a piece of clear transparent glass, with a bluish-white cast, upon one of the holes of the transmitting machine: the faces of this glass are parallel, and highly polished. Then, putting the cover over both holes, I placed the machine in the situation where the experiment was to be made, and let it remain there a sufficient time, that the thermometers might assume a settled temperature. For this purpose, an assistant thermometer, which should always remain in the nearest convenient place to the apparatus, will be of use, to point out the time when the experiment may be begun; for this ought not to be done, till the thermometers to be used agree with the standard. In order not to lose time after an experiment, the apparatus may be taken into a cool room, or current of air, till the thermometers it contains are rather lower than the standard; after which, being brought to the required situation, they will soon be fit for action.

All these precautions having been taken, I began the experiment by first writing down the degrees of the thermometers; then, opening the cover at the time that a clock or watch shewing seconds came to a full minute, I continued to write down the state of the thermometers for not less than five minutes. The result was as follows.

	No. 5. Sun.	No. 1. Bluish-white glass
0′	67	67
1	$68\frac{3}{4}$	$68\frac{1}{8}$
2	$70\frac{1}{8}$	$69\frac{1}{8}$
3	$71\frac{3}{8}$	70
4	$72\frac{3}{8}$	$70\frac{7}{8}$
5	73	$71\frac{1}{2}$ . . . $6 : 4\frac{1}{2} = ,750$

Here the sun communicated, in 5 minutes, 6 degrees of heat to the thermometer No. 5, which was openly exposed to its action; while, in the same time, No. 1 received only $4\frac{1}{2}$ degrees by rays transmitted through the bluish-white glass: then, as $6 : 4\frac{1}{2} :: 1 : ,750$. This shews plainly, that only $\frac{3}{4}$ of the incident heat were transmitted, and therefore that $\frac{1}{4}$ of it was intercepted by the glass.

I shall here, as well as in the following experiments, point out the difference between heat and light, in order, as has been mentioned before, to lead to an elucidation of our last discussion. To effect this, therefore, I have ascertained, with all the accuracy the subject will admit of, the quantity of light transmitted through such glasses as I have used; but, as it would here interrupt the order of our subject, I have joined, at the end of this Paper, a table, with a short account of the method that has been used in making it, wherein the quantity of light transmitted is set down; and to this table I shall now refer.

To render this comparative view more clear, we may suppose always 1000 rays of heat to come from the object: then, 750 being transmitted, it follows, that the bluish-white glass used in our experiment stops 250 of them; and, by the table at the end of this Paper, it stops 86 rays of light; the number of them coming from the object also being put equal to 1000.

It should be remarked, that when I compare the interception of solar heat with that of the light of a candle, it must not be understood that I take terrestrial to be the same as solar light; but, not having at present an opportunity of providing a similar table for the latter, I am obliged to use the former, on a supposition, that the quantity stopped by glasses may not be very different.

25th Experiment.

I took a piece of flint glass, about $2\frac{1}{2}$ tenths of an inch thick, and fastened it over one of the holes of the transmitting apparatus.

No 5.	No. 1.
Sun.	Flint glass.
$69\frac{3}{4}$	$69\frac{3}{4}$
$71\frac{1}{4}$	71
$72\frac{5}{8}$	$72\frac{1}{8}$
$74\frac{1}{8}$	$73\frac{7}{8}$
$74\frac{7}{8}$	74
$75\frac{1}{4}$	$74\frac{3}{4} \ldots 5\frac{1}{2} : 5 = ,909$

Here the heat-making rays gave, in 5 minutes, $5\frac{1}{2}$ degrees to the thermometer No. 5; and, by transmission through the flint glass, 5 degrees to No. 1. Then, proceeding as before, we have $\frac{5}{5\frac{1}{2}} = ,909$; which shews that 91 rays of heat were stopped. In the table before referred to, we find that this glass stops 34 rays of light.

Before I proceed, it will be necessary to adopt a method of reducing the detail of my experiments into a narrower compass. It will be sufficient to say, that they have all been made on the same plan as the two which have been given. The observations were always continued for at least five minutes; and, by examining the ratios of the numbers given by the thermometers in all that time, it may be seen that, setting aside little irregularities, there is a greater stoppage at first than towards the end ; but, as it would not be safe to take a shorter exposure than five minutes, on account of the small quantity of heat transmitted by some glasses, I have fixed upon that interval as sufficiently accurate for giving a true comparative view. The experiments therefore may now stand abridged as follows.

26*th Experiment.*

I took a piece of highly polished crown glass, of a greenish colour, and, cutting it into several parts, examined the transmitting power of one of them, reserving the other pieces for some other experiments that will be mentioned hereafter.

	Sun.	Greenish crown glass.
0′	$66\frac{1}{4}$	$66\frac{1}{4}$
5	73	$71\frac{1}{4} \ldots 6\frac{3}{4} : 5 = ,741$

This glass therefore stops 259 rays of heat, and 203 of light.

27*th Experiment.*

I cut likewise a piece of coach glass into several parts, and tried one of them, reserving also the other pieces for future experiments.

	Sun.	Coach glass.
0′	$68\frac{7}{8}$	$68\frac{7}{8}$
5	$75\frac{7}{8}$	$74\frac{3}{8} \ldots 7 : 5\frac{1}{2} = ,786$

It stops 214 rays of heat, and 168 of light.

28th *Experiment.*

I examined a piece of Iceland crystal, of nearly two-tenths of an inch in thickness.

	Sun.	Iceland crystal.
0′	67	67
5	$72\frac{5}{8}$	$71\frac{1}{4} \ldots 5\frac{5}{8} : 4\frac{1}{4} = ,756$

It stops 244 rays of heat, and 150 of light.

29th *Experiment.*

	Sun.	Talc.
0′	$67\frac{1}{2}$	$67\frac{1}{2}$
5	72	$71\frac{3}{8} \ldots 4\frac{1}{2} : 3\frac{7}{8} = ,861$

It stops 139 rays of heat, and 90 of light.

30th *Experiment.*

	Sun.	An easily calcinable talc.
0′	50	50
5	$54\frac{3}{4}$	$53\frac{7}{8} \ldots 4\frac{3}{4} : 3\frac{7}{8} = ,816$

It stops 184 rays of heat, and 288 of light.

Transmission of solar Heat through Glasses of the prismatic Colours.

31st *Experiment.*

	Sun.	Very dark red glass.
0′	73	73
5	$79\frac{1}{4}$	$74\frac{1}{4} \ldots 6\frac{1}{4} : 1\frac{1}{4} = ,200$

This glass stops 800 rays of heat, and 9999, out of ten thousand, rays of light; which amounts nearly to a total separation of light from heat.

32d *Experiment.*

	Sun.	Dark-red glass.
0′	$68\frac{3}{8}$	$68\frac{3}{8}$
5	$72\frac{1}{2}$	$70 \ldots 4\frac{1}{8} : 1\frac{5}{8} = ,394$

This red glass stops only 606 rays of heat, and above 4999, out of five thousand, rays of light.

33d *Experiment.*

	Sun.	Orange glass.
0′	$67\frac{3}{4}$	$67\frac{3}{4}$
5	$74\frac{3}{8}$	$70\frac{3}{8} \ldots 6\frac{5}{8} : 2\frac{5}{8} = ,396$

This orange-coloured glass stops 604 rays of heat, which is nearly as much as is stopped by the last red one; but it stops only 779 rays of light.

34th *Experiment.*

	Sun.	Yellow glass.
	$70\frac{1}{2}$	$70\frac{1}{2}$
	$74\frac{1}{4}$	$73 \ldots 3\frac{3}{4} : 2\frac{1}{2} = ,667$

It stops 333 rays of heat, and 319 of light.

35th *Experiment.*

	Sun.	Pale-green glass.
0′	$70\frac{1}{2}$	$70\frac{1}{2}$
5	$74\frac{1}{4}$	$71\frac{7}{8} \ldots 3\frac{3}{4} : 1\frac{3}{8} = ,367$

It stops 633 rays of heat, and only 535 of light.

36th *Experiment.*

	Sun	Dark-green glass.
0′	$67\frac{1}{2}$	$67\frac{1}{2}$
5	$74\frac{1}{8}$	$68\frac{1}{2} \ldots 6\frac{5}{8} : 1 = ,151$

This glass stops 849 rays of heat, and 949 of light. This accounts for its great use as a darkening glass for telescopes.

37th Experiment.

	Sun.	Bluish-green glass.
0′	$69\frac{3}{8}$	$69\frac{3}{8}$
5	$76\frac{3}{8}$	$71 \ldots 7 : 1\frac{5}{8} = ,232$

It stops 768 rays of heat, and 769 of light.

38th Experiment.

	Sun.	Pale-blue glass.
0′	$70\frac{3}{4}$	$70\frac{3}{4}$
5	$76\frac{3}{4}$	$71\frac{7}{8} \ldots 6 : 1\frac{1}{8} = ,188$

The pale blue glass stops not less than 812 rays of heat, and only 684 of light.

39th Experiment.

	Sun.	Dark-blue glass.
0′	71	71
5	$76\frac{7}{8}$	$74\frac{3}{4} \ldots 5\frac{7}{8} : 3\frac{3}{4} = ,638$

The dark-blue glass stops only 362 rays of heat, and 801 of light.

40th Experiment.

	Sun.	Indigo glass.
0′	$61\frac{3}{4}$	$61\frac{3}{4}$
5	$67\frac{7}{8}$	$64 \ldots 6\frac{1}{8} : 2\frac{1}{4} = ,367$

This glass stops 633 rays of heat, and 9997, out of ten thousand, rays of light.

41st Experiment.

	Sun.	Pale-indigo glass.
0′	62	62
5	$67\frac{7}{8}$	$64\frac{3}{4} \ldots 5\frac{7}{8} : 2\frac{3}{4} =$,468

It stops 532 rays of heat, and 978 of light.

42d Experiment.

	Sun.	Purple glass.
0′	$61\frac{3}{4}$	$61\frac{3}{4}$
5	$67\frac{3}{4}$	$64\frac{1}{4} \ldots 6 : 2\frac{1}{2} =$,417

It stops 583 rays of heat, and 993 of light.

43d Experiment.

	Sun.	Violet glass.
	$62\frac{1}{4}$	$62\frac{1}{4}$
	$68\frac{1}{8}$	$65\frac{1}{4} \ldots 5\frac{7}{8} : 3 =$,511

It stops 489 rays of heat, and 955 of light.

Transmission of Solar Heat through Liquids.

I took a small tube, $1\frac{1}{2}$ inch in diameter,* and fixed a stop with a hole $\frac{3}{4}$ inch wide at each end, on which a glass might be fastened, so as to confine liquids. The inner distance, or depth of the liquid, when confined, is three inches. Placing now the empty tube, with its two end glasses fixed, upon the transmitting apparatus, I had as follows:

44th Experiment.

	Sun.	Empty tube, and two glasses.
0′	53	53
5	59	$55\frac{3}{4} \ldots 6 : 2\frac{3}{4} =$,458

* See Plate XXII. Fig. 2.

These glasses, with the intermediate air, stop 542 rays of heat, and 204 of light.

45th Experiment.

I filled the tube with well-water, and placed it on the transmitting apparatus.

	Sun.	Well-water.
0'	$52\frac{1}{4}$	$52\frac{1}{8}$
5	$58\frac{3}{4}$	55 . . . $6\frac{1}{2} : 2\frac{7}{8} = ,442$

Here two glasses, with water between them, stopped 558 rays of heat. The same glasses, and water, stop only 211 rays of light. If we were to deduct the effect of the empty machine, there would remain, for the water to stop, only 16 rays of heat, and 7 of light; but it cannot be safe to make this conclusion, as we are not sufficiently acquainted with the action of surfaces between the different mediums on the rays of heat and light; I shall therefore only notice the effect of the compound.

46th Experiment.

I filled now the tube with sea-water, taken from the head of the pier at Ramsgate, at high tide.

Sun.	Sea-water.
$54\frac{1}{2}$	$54\frac{1}{4}$
60	56 . . . . $5\frac{1}{2} : 1\frac{3}{4} = ,318$

The compound stops 682 rays of heat, and 288 of light.

47th Experiment.

	Sun.	Spirit of wine.
0'	$51\frac{5}{8}$	$51\frac{5}{8}$
5	$57\frac{3}{4}$	54 . . . $6\frac{1}{8} : 2\frac{3}{8} = ,388$

The compound stops 612 rays of heat, and 224 of light.

48th Experiment.

	Sun.	Gin.
0'	52	52
5	$57\frac{3}{4}$	$53\frac{1}{2} \ldots 5\frac{3}{4} : 1\frac{1}{2} = ,261$

This compound stops 739 rays of heat, and 626 of light.

49th Experiment.

	Sun.	Brandy.
0'	56	56
5	$60\frac{1}{4}$	$56\frac{7}{8} \ldots 4\frac{1}{4} = ,206$

This stops 794 rays of heat, and 996 rays of light.

Other liquids have also been tried; but the experiments having been attended with circumstances that demand a further investigation, they cannot now be given.

Transmission of solar Heat through scattering Substances.

50th Experiment.

I rubbed one of the pieces of crown glass, mentioned in the 26th experiment, on fine emery laid on a plain brass tool, to make the surface of it rough, which, it is well known, will occasion the transmitted light to be scattered in all directions. Supposing that it would have the same effect on heat, I tried the transmitting capacity of the glass, by exposing it with the rough side towards the sun, over one of the transmitting holes of the apparatus.

	Sun.	Crown glass; one side rubbed on emery.
0'	67	67
5	74	$70\frac{3}{4} \ldots 7 : 3\frac{3}{4} = ,536$

The glass so prepared stops 464 scattered rays of heat, and 854 of light. Now, as the same glass, in its polished state, transmitted 259 rays of heat, and 203 of light, the alteration produced in the texture of its surface acts very differently upon these two principles; occasioning an additional stoppage of only 205 rays of heat, but of 651 rays of light.

51st Experiment.

One of the pieces of coach glass, mentioned in the 27th experiment, was prepared in the same manner.

	Sun.	Coach glass; one side rubbed on emery, the rough side exposed.
0′	$66\frac{1}{2}$	$66\frac{1}{2}$
5	$73\frac{1}{2}$	$69\frac{1}{2} \ldots 7 : 3 = ,429$

It stops 571 scattered rays of heat, and 885 of light; so that the fine scratches on its surface, made by the operation of emery, have again acted very differently upon the rays of heat, and of light, occasioning an additional stoppage of 375 of the former, but of no less than 717 of the latter.

52d Experiment.

I took another of the pieces of crown glass, mentioned in the 26th experiment, and rubbed both sides on emery.

	Sun.	Crown glass; both sides rubbed on emery.
0′	$69\frac{1}{2}$	$69\frac{1}{2}$
5	$75\frac{1}{2}$	$71\frac{1}{2} \ldots 6 : 2 = ,333$

The glass thus prepared, stops 667 scattered rays of heat, and 932 of light.

53d Experiment.

Another piece of coach glass, one of those that were mentioned in the 27th experiment, was prepared in the same manner.

	Sun.	Coach glass; both sides rubbed on emery.
0′	$69\frac{5}{8}$	$69\frac{5}{8}$
5	$75\frac{3}{4}$	$71\frac{1}{4} \ldots 6\frac{1}{8} : 1\frac{5}{8} = ,265$

It stops 735 scattered rays of heat, and 946 of light.

54th Experiment.

I placed now the coach glass, one side of which had been rubbed on emery, upon the transmitting hole, and over it the crown glass prepared in the same manner, both with the rough side towards the sun; but two slips of card were placed between the glasses, to keep them from touching each other.

	Sun.	Crown glass. Coach glass. } One side of each rubbed on emery.
0′	67	67
5	$73\frac{5}{8}$	$69 \ldots 6\frac{5}{8} : 2 = ,302$

These glasses stop 698 scattered rays of heat, and 969 of light.

55th Experiment.

I placed now the coach glass, with both sides rubbed on emery, on the transmitting hole, and over it the crown glass prepared in the same manner, with two slips of card between them, to prevent a contact.

	Sun.	Coach glass. Crown glass. } Both sides of each rubbed on emery.
0′	$69\frac{5}{8}$	$69\frac{5}{8}$
5	$75\frac{7}{8}$	$70\frac{7}{8} \ldots 6\frac{1}{4} : 1\frac{1}{4} = ,200$

These glasses stop 800 scattered rays of heat, and 979 of light.

56th Experiment.

I used now all the four glasses; placing them as follows, and putting slips of card between them, to prevent a contact.

	Sun.	Crown glass; the rough side to the sun. Coach glass; ditto. Crown glass; rough on both sides. Coach glass; ditto.
0′	$57\frac{3}{8}$	$57\frac{1}{2}$
5	$62\frac{1}{2}$	$58\frac{1}{4} \ldots 5\frac{1}{8} : \frac{3}{4} = ,146$

These four glasses stop no more than 854 scattered rays of heat, and 995 of light.

57th Experiment.

I used now a piece of glass of an olive colour, burnt into the glass, in the manner that glasses are prepared for church windows, which transmits only scattered light.

	Sun.	Olive-coloured glass.
0′	69	69
5	$76\frac{3}{4}$	$70\frac{1}{4} \ldots 7\frac{3}{4} : 1\frac{1}{4} = ,161$

This glass stops 839 scattered rays of heat, and 984 of light.

58th Experiment.

	Sun.	Calcined talc.
0′	$51\frac{3}{8}$	$51\frac{3}{8}$
5	$55\frac{1}{8}$	$51\frac{7}{8} \ldots 3\frac{3}{4} : \frac{1}{2} = ,133$

This substance stops 867 scattered rays of heat, and so much light that the sun cannot be perceived through it.*

59th Experiment.

	Sun.	White paper
0′	63	63
5	68	$63\frac{3}{4} \ldots 5 : \frac{3}{4} = ,150$

This substance stops 850 scattered rays of heat, and 994 of light.

* See the 175th Experiment.

60th Experiment.

	Sun.	Linen.
0′	63	63
5	69	$63\frac{1}{2} \ldots 6 : \frac{1}{2} = ,0833$

White linen stops 916 scattered rays of heat, and 952 of light.

61st Experiment.

	Sun.	White persian.
0′	70	70
5	$76\frac{1}{4}$	$71\frac{1}{2} \ldots 6\frac{1}{4} : 1\frac{1}{2} = ,240$

This thin silk stops 760 scattered rays of heat, and 916 of light.

62d Experiment.

Sun.	Black muslin.
$64\frac{3}{4}$	$64\frac{3}{4}$
70	$66\frac{1}{4} \ldots 5\frac{1}{4} : 1\frac{1}{2} = ,286$

This substance stops 714 scattered rays of heat, and 737 of light.

Transmission of terrestrial Flame-heat through various Substances.

My apparatus for the purpose of transmitting flame-heat is as follows.* A box 22 inches long, $5\frac{1}{2}$ broad, and $1\frac{3}{4}$ deep, has a hole in the centre $1\frac{1}{10}$ inch in diameter, through which a wax candle, thick enough entirely to fill it, is to be put at the bottom; the box being properly elevated for the purpose. There must be two lateral holes in the bottom, 2 inches long, and $1\frac{1}{4}$ broad, one on each side of the candle, to supply it with a current of air, as otherwise it will not give a steady flame, which is absolutely necessary. At the distance of $1\frac{3}{10}$ inch from the candle, on each side, are two screens, 12 inches square, with

* See Plate XXIII. Fig 1.

a hole in each, $\frac{3}{4}$ inch in diameter, through which the heat of the candle passes to the two thermometers, which are to be placed in opposite directions, one on each side of the table. Care must be taken to place them exactly at the same distance from the centre of the flame, as otherwise they will not receive equal quantities of heat. The scales, and their supports also, must be so kept out of the way of heat coming from the candle, that they may not scatter it back on the balls, but suffer all that is not intercepted by them to pass freely forwards in the box, and downwards, through openings cut in the bottom. Before the transmitting holes, between the two wooden screens, must be two covers of the same material, close to the openings; * and it will be necessary to join these covers at the side, by a common handle, that they may be removed together, without disturbing any part of the apparatus, when the experiment is to begin.

The glasses are to be put before the thermometer, close to the transmitting hole, by placing them on a small support below, while the upper part is held close to the screen by a light plummet, suspended by a thread which is fastened on one side, and passes over the glass, to a hook on the other side.

In making experiments, many attentions are necessary, such as, keeping the candle exactly to a certain height, that the brightest part of the flame may be just in the centre of the two transmitting holes: that the wick may be always straight, and not, by bending, approach nearer to one thermometer than to the other: that the wax-cup of the candle be kept clean, and never suffered to run over, &c.

Before, and now and then between, the observations also, the thermometers must be tried a few degrees, that it may be seen

* See Fig. 2.

whether they act equally; and the candle, during the time they cool down to the temperature, must be put out by an extinguisher, large enough to rest on the bottom of the box, without touching any part of the wax. Many other precautions I need not mention, as they will soon be discovered by any one who may repeat such experiments.

63d Experiment.

	Candle.	Bluish-white glass.	
0′	$59\frac{3}{8}$	$59\frac{1}{2}$	
5	$62\frac{3}{8}$	$60\frac{5}{8}$	. . . $3 : 1\frac{1}{8} = ,375$

From this experiment we find, that while the rays of the candle gave 3 degrees of heat to the thermometer openly exposed to their action, the other thermometer, which received the same rays through the medium of the interposed glass, rose only $1\frac{1}{8}$ degrees. Hence we calculate, that this glass stops 625 rays of flame-heat, out of every thousand that fall on it. It stops only 86 rays of candle-light; but this, having been referred to before, will not in future be repeated.

64th Experiment.

	Candle.	Flint glass.	
0′	$59\frac{7}{8}$	$59\frac{5}{8}$	
5	$62\frac{5}{8}$	$60\frac{3}{4}$	. . . $2\frac{3}{4} : 1\frac{1}{8} = ,409$

It stops 591 rays of flame-heat, and light as before.

65th Experiment.

	Candle.	Crown glass.	
0′	$59\frac{7}{8}$	$59\frac{7}{8}$	
5	$62\frac{5}{8}$	$60\frac{7}{8}$	. . . $2\frac{3}{4} : 1 = ,364$

It stops 636 rays of flame-heat.

66th Experiment.

	Candle.	Coach glass.
0′	60	$60\frac{3}{8}$
5	63	$62 \ldots 3 : 1\frac{5}{8} = ,542$

It stops 458 rays of flame-heat.

67th Experiment.

	Candle.	Iceland crystal.
0′	$58\frac{3}{4}$	$58\frac{3}{4}$
5	$62\frac{1}{8}$	$60\frac{3}{8} \ldots 3\frac{3}{8} : 1\frac{5}{8} = ,484$

It stops 516 rays of flame-heat.

68th Experiment.

	Candle.	Calcinable talc.
0′	$58\frac{7}{8}$	$58\frac{7}{8}$
5	$61\frac{7}{8}$	$60\frac{3}{4} \ldots 3 : 1\frac{7}{8} = ,625$

This substance stops only 375 rays of flame-heat.

69th Experiment.

	Candle.	Very dark red glass.
0′	$60\frac{3}{8}$	$60\frac{3}{8}$
5	$63\frac{1}{8}$	$61\frac{3}{8} \ldots 2\frac{3}{4} : 1 = ,364$

This glass stops 636 rays of flame-heat.

70th Experiment.

	Candle.	Dark red glass.
0′	$60\frac{3}{4}$	$60\frac{3}{4}$
5	$63\frac{1}{8}$	$61\frac{7}{8} \ldots 2\frac{3}{8} : 1\frac{1}{8} = ,474$

It stops 526 rays of flame-heat.

71st Experiment.

	Candle.	Orange glass.
0'	$60\frac{1}{4}$	$60\frac{1}{4}$
5	$63\frac{3}{8}$	$61\frac{5}{8} \ldots 3\frac{1}{8} : 1\frac{3}{8} = ,440$

It stops 560 rays of flame-heat.

72d Experiment.

	Candle.	Yellow glass.
0'	$60\frac{5}{8}$	$60\frac{5}{8}$
5	$63\frac{5}{8}$	$61\frac{7}{8} \ldots 3 : 1\frac{1}{4} = ,417$

It stops 583 rays of flame-heat.

73d Experiment.

	Candle.	Pale-green glass.
0'	$60\frac{7}{8}$	$60\frac{7}{8}$
5	$63\frac{7}{8}$	$62\frac{3}{8} \ldots 3 : 1\frac{1}{2} = ,500$

It stops 500 rays of flame-heat.

74th Experiment.

	Candle.	Dark-green glass.
0'	$61\frac{1}{8}$	$61\frac{1}{8}$
5	64	$61\frac{7}{8} \ldots 2\frac{7}{8} : \frac{3}{4} = ,261$

It stops 739 rays of flame-heat.

75th Experiment.

	Candle.	Bluish-green glass.
0'	$61\frac{1}{8}$	$61\frac{1}{8}$
5	64	$62\frac{1}{8} \ldots 2\frac{7}{8} : 1 = ,348$

It stops 652 rays of flame-heat.

76*th Experiment.*

	Candle.	Pale-blue glass.
0′	$61\frac{1}{2}$	$61\frac{1}{2}$
5	$64\frac{3}{8}$	$62\frac{5}{8} \ldots 2\frac{7}{8} : 1\frac{1}{8} = ,391$

It stops 609 rays of flame-heat.

77*th Experiment.*

	Candle.	Dark-blue glass.
0′	$61\frac{7}{8}$	$61\frac{3}{4}$
5	$64\frac{1}{2}$	$62\frac{3}{4} \ldots 2\frac{5}{8} : 1 = ,381$

It stops 619 rays of flame-heat.

78*th Experiment.*

	Candle.	Indigo glass.
0′	$61\frac{7}{8}$	$61\frac{7}{8}$
5	$65\frac{3}{8}$	$63 \ldots 3\frac{1}{2} : 1\frac{1}{8} = ,321$

It stops 679 rays of flame-heat.

79*th Experiment.*

	Candle.	Pale indigo glass.
0′	$62\frac{1}{8}$	$62\frac{1}{8}$
5	$64\frac{3}{4}$	$63\frac{1}{4} \ldots 2\frac{5}{8} : 1\frac{1}{8} = ,429$

It stops 571 rays of flame-heat.

80*th Experiment.*

	Candle.	Purple glass.
0′	$61\frac{7}{8}$	$61\frac{7}{8}$
5	65	$63\frac{3}{8} \ldots 3\frac{1}{8} : 1\frac{1}{2} = ,480$

It stops 520 rays of flame-heat.

81*st Experiment.*

	Candle.	Violet glass.
0′	$59\frac{7}{8}$	$59\frac{7}{8}$
5	$63\frac{3}{8}$	$61\frac{5}{8} \ldots 3\frac{1}{2} : 1\frac{3}{4} = ,500$

It stops 500 rays of flame-heat.

82*d Experiment.*

	Candle.	Crown glass; one side rubbed on emery; the rough side exposed.
0′	60	60
5	$63\frac{3}{8}$	$60\frac{7}{8} \ldots 3\frac{3}{8} : \frac{7}{8} = ,259$

This glass, so prepared, stops 741 scattered rays of flame-heat.

83*d Experiment.*

	Candle.	Coach glass; one side rubbed on emery; the rough side exposed.
0′	$59\frac{5}{8}$	$59\frac{5}{8}$
5	$63\frac{3}{8}$	$60\frac{7}{8} \ldots 3\frac{3}{4} : 1\frac{1}{4} = ,333$

It stops 667 scattered rays of flame-heat.

84*th Experiment.*

	Candle.	Crown glass; both sides rubbed on emery.
0′	$59\frac{3}{4}$	$59\frac{3}{4}$
5	63	$61 \ldots 3\frac{1}{4} : 1\frac{1}{4} = ,385$

It stops 615 scattered rays of flame-heat.

85*th Experiment.*

	Candle.	Coach glass; both sides rubbed on emery.
0′	$59\frac{7}{8}$	$59\frac{3}{4}$
5	63	$60\frac{3}{4} \ldots 3\frac{1}{8} : 1 = ,320$

It stops 680 scattered rays of flame-heat.

86*th Experiment.*

	Candle.	{Crown glass. Coach glass.} One side of each rubbed on emery.
0′	$55\frac{7}{8}$	$55\frac{7}{8}$
5	59	$56\frac{3}{4}$ . . . $3\frac{1}{8} : \frac{7}{8}$ = ,280

These glasses stop 720 scattered rays of flame-heat.

87*th Experiment.*

	Candle.	{Crown glass. Coach glass.} Both sides of each rubbed on emery.
	$55\frac{7}{8}$	$55\frac{7}{8}$
	$59\frac{1}{4}$	57 . . . $3\frac{3}{8} : 1\frac{1}{8}$ = ,333

These glasses stop 667 rays of flame-heat.

88*th Experiment.*

	Candle.	{Crown glass; the rough side to the candle. Coach glass; ditto. Crown glass; rough on both sides; Coach glass; ditto.}
0′	$56\frac{3}{4}$	$56\frac{7}{8}$
5	$59\frac{5}{8}$	$57\frac{1}{4}$ . . . $2\frac{7}{8} : \frac{3}{8}$ = ,130

These four glasses stop 870 scattered rays of flame-heat.

89*th Experiment.*

	Candle.	Olive-colour, burnt in glass.
0′	60	60
5	63	$60\frac{5}{8}$ . . . $3 : \frac{5}{8}$ = ,208

This glass stops 792 scattered rays of flame-heat-

90*th Experiment.*

	Candle.	White paper.
0′	$57\frac{3}{8}$	$57\frac{1}{4}$
5	$60\frac{3}{8}$	$57\frac{7}{8}$ . . . $3 : \frac{5}{8}$ = ,208

This substance stops 792 scattered rays of flame-heat

91st Experiment,

	Candle.	Linen.	
0′	$57\frac{3}{8}$	$57\frac{3}{8}$	
5	61	$58\frac{1}{2}$	. . . $3\frac{5}{8} : 1\frac{1}{8} = ,310$

It stops 690 scattered rays of flame-heat.

92d Experiment.

	Candle.	White persian.	
0′	$57\frac{1}{8}$	57	
5	$60\frac{1}{2}$	$58\frac{3}{8}$	. . . $3\frac{3}{8} : 1\frac{3}{8} = ,407$

It stops 593 scattered rays of flame-heat.

93d Experiment.

	Candle.	Black muslin.	
0′	$57\frac{3}{4}$	$57\frac{3}{4}$	
5	$60\frac{5}{8}$	59	. . . $2\frac{7}{8} : 1\frac{1}{4} = ,435$

It stops 565 scattered rays of flame-heat.

Transmission of the solar Heat which is of an equal Refrangibility with red prismatic Rays.

The apparatus which I have used for transmitting prismatic rays, is of the same construction as that which has already been described under the head of direct solar transmissions; * but here the holes in the top of the box are only two inches from each other, and no more than $\frac{3}{8}$ths in diameter.† On the face of the box are drawn two parallel lines, also $\frac{3}{8}$ths of an inch distant from each other, and inclosing the transmitting holes: they serve as a direction whereby to keep any required colour to fall equally on both holes. The distance at which the box is to be

* See Plate XXI. † See Plate XXII. Fig. 3.

placed from the prism, must be such as will allow the rays to diverge sufficiently for the required colour to fill the transmitting holes; and the balls of the thermometers placed under them ought to be less than these holes, that the projected rays may pass around them, and shew their proper adjustment. The diameters of mine, used for this purpose, are $2\frac{1}{4}$ tenths of an inch.

94th Experiment.

I placed my apparatus at five feet from the prism, and so as to cause the red-making rays to fall between the parallel lines, in order to find what heat-making rays would come to the thermometer along with them.

	Red rays. Therm. A.	Bluish-white glass. Therm. B.	
0′	$75\frac{5}{8}$	$75\frac{3}{8}$	
5	$77\frac{5}{8}$	$76\frac{5}{8}$	... $2 : 1\frac{1}{4} = ,625$

From this experiment it appears, that when a thousand red-making rays fall on each transmitting hole, 375 of them, if they also be the heat-making rays, are stopped by the bluish-white glass which covers one of these holes; or, what requires no other proof than the experiment itself, that 375 rays of heat, of the same refrangibility with the red rays, are intercepted by this glass.

95th Experiment.

Red rays.	Flint glass.	
$75\frac{3}{4}$	$75\frac{3}{8}$	
$77\frac{1}{2}$	$76\frac{7}{8}$	... $1\frac{3}{4} : 1\frac{1}{2} = ,857$

This glass stops only 143 rays of heat which are of the same refrangibility with the red rays.

96th *Experiment.*

	Red rays.	Crown glass.
0′	$75\frac{7}{8}$	$75\frac{5}{8}$
5	78	$77\frac{1}{8}$ . . . $2\frac{1}{8} : 1\frac{1}{2} =$,706

This glass stops 294 rays of the same sort of heat.

97th *Experiment.*

	Red rays.	Coach glass.
0′	$54\frac{3}{8}$	$53\frac{3}{4}$
5	$55\frac{5}{8}$	$54\frac{3}{4}$ . . . $1\frac{1}{4} : 1 =$,800

It stops 200 rays of the same sort of heat.

98th *Experiment.*

	Red rays.	Iceland crystal.
0′	$76\frac{1}{8}$	$75\frac{3}{4}$
5	78	$77\frac{1}{4}$ . . . $1\frac{7}{8} : 1\frac{1}{2} =$,800

This substance stops 200 rays of the same sort of heat.

99th *Experiment.*

	Red rays.	Calcinable talc.
0′	$51\frac{3}{4}$	$51\frac{1}{4}$
5	$53\frac{5}{8}$	$52\frac{7}{8}$ . . . $1\frac{7}{8} : 1\frac{5}{8} =$,867

It stops 133 rays of the same sort of heat.

100th *Experiment.*

	Red rays.	Dark-red glass.
0′	$76\frac{1}{2}$	$76\frac{5}{8}$
5	$78\frac{1}{8}$	$77\frac{1}{8}$ . . . $1\frac{5}{8} : \frac{1}{2} =$,308

This glass stops 692 rays of the same sort of heat.

101*st* Experiment.

	Red rays.	Orange glass.
0′	75	$74\frac{3}{4}$
5	77	$75\frac{3}{4}$ . . . 2 : 1 = ,500

It stops 500 rays of the same sort of heat.

102*d* Experiment.

Red rays.	Yellow glass.
$75\frac{3}{8}$	75
$76\frac{7}{8}$	$75\frac{7}{8}$ . . . $1\frac{1}{2} : \frac{7}{8}$ = ,583

It stops 417 rays of the same sort of heat.

103*d* Experiment.

	Red rays.	Pale-green glass.
0′	$74\frac{1}{4}$	$74\frac{1}{8}$
5	$76\frac{3}{8}$	75 . . . $2\frac{1}{8} : \frac{7}{8}$ = ,412

It stops 588 rays of the same sort of heat.

104*th* Experiment.

	Red rays.	Dark-green glass.
0′	$68\frac{3}{4}$	$68\frac{7}{8}$
5	$70\frac{1}{2}$	$69\frac{1}{4}$ . . . $1\frac{3}{4} : \frac{3}{8}$ = ,214

It stops 786 rays of the same sort of heat.

105*th* Experiment.

	Red rays.	Bluish-green glass.
0′	69	$68\frac{7}{8}$
5	$70\frac{5}{8}$	$69\frac{3}{4}$ . . . $1\frac{5}{8} : \frac{7}{8}$ = ,538

It stops 462 rays of the same sort of heat.

106*th Experiment.*

	Red rays.	Pale-blue glass.
0′	$69\frac{5}{8}$	$69\frac{1}{2}$
5	$70\frac{7}{8}$	$69\frac{7}{8} \ldots 1\frac{1}{4} : \frac{3}{8} = ,300$

It stops 700 rays of the same sort of heat.

107*th Experiment.*

	Red rays.	Dark-blue glass.
0′	67	$67\frac{1}{4}$
5	$68\frac{3}{4}$	$68\frac{7}{8} \ldots 1\frac{3}{4} : 1\frac{5}{8} = ,929$

This glass stops only 71 rays of the same sort of heat.

108*th Experiment.*

	Red rays.	Indigo glass.
0′	$68\frac{1}{2}$	$68\frac{1}{4}$
5	$70\frac{1}{2}$	$69\frac{1}{2} \ldots 2 : 1\frac{1}{4} = ,633$

It stops 367 rays of the same sort of heat.

109*th Experiment.*

	Red rays.	Pale-indigo glass.
0′	69	$68\frac{5}{8}$
5	71	$70 \ldots 2 : 1\frac{3}{8} = ,687$

It stops 313 rays of the same sort of heat.

110*th Experiment.*

	Red rays.	Purple glass.
0′	$56\frac{1}{4}$	56
5	$58\frac{1}{2}$	$57\frac{1}{4} \ldots 2\frac{1}{4} : 1\frac{1}{4} = ,556$

It stops 444 rays of the same sort of heat.

111*th Experiment.*

	Red rays.	Violet glass.
0′	$57\frac{3}{8}$	57
5	$59\frac{1}{4}$	$58\frac{1}{8} \ldots 1\frac{7}{8} : 1\frac{1}{8} = ,600$

It stops 400 rays of the same sort of heat.

112*th Experiment.*

	Red rays.	Crown glass; one side rubbed on emery, rough side exposed.
0′	$49\frac{3}{4}$	49
5	52	$50\frac{3}{8} \ldots 2\frac{1}{4} : 1\frac{3}{8} = ,611$

This glass, so prepared, stops 389 scattered rays of the same sort of heat.

113*th Experiment.*

	Red rays.	Coach glass; one side rubbed on emery, rough side exposed.
0′	$53\frac{3}{8}$	$52\frac{7}{8}$
5	$55\frac{1}{8}$	$53\frac{3}{4} \ldots 1\frac{3}{4} : \frac{7}{8} = ,500$

It stops 500 scattered rays of the same sort of heat.

114*th Experiment.*

	Red rays.	Crown glass; both sides rubbed on emery.
0′	$50\frac{5}{8}$	$49\frac{7}{8}$
5	$52\frac{3}{4}$	$51 \ldots 2\frac{1}{8} : 1\frac{1}{8} = ,529$

It stops 471 scattered rays of the same sort of heat.

115*th Experiment.*

	Red rays.	Coach glass; both sides rubbed on emery.
0′	$54\frac{1}{8}$	$53\frac{3}{4}$
5	$55\frac{5}{8}$	$54 \ldots 1\frac{1}{2} : \frac{1}{4} = ,167$

It stops 833 scattered rays of the same sort of heat.

116th Experiment.

	Red rays.	Calcined talc.
0′	$51\frac{1}{8}$	$50\frac{1}{2}$
5	$53\frac{1}{2}$	$51\frac{1}{8} \ldots 2\frac{3}{8} : \frac{5}{8} = ,263$

This substance stops 737 scattered rays of the same sort of heat.

Transmission of Fire-Heat through various Substances.

When the same fire is to give an equal heat to two thermometers, at some short distance from each other, it becomes highly necessary that there should be a place of considerable dimensions in its centre, where it may burn with an equal glow, and without flame or smoke. To obtain this, I used a grate 19 inches broad, and $8\frac{3}{4}$ high, having only three bars, which divide the fire into three large openings. In the centre of the middle one of these, when the grate is well filled with large coals or coke, we may, with proper management, keep up the required equality of radiance.

The apparatus I have used is of the following construction.* A screen of wood, 3 feet 6 inches high, and 3 feet broad, lined towards the fire with plates of iron, has two holes, $\frac{3}{4}$ of an inch in diameter, and at the distance of $2\frac{1}{2}$ inches from each other, one on each side of the middle of the screen, and of a height that will answer to the centre of the fire. $2\frac{1}{4}$ inches under the centre of the holes is a shelf, about 22 inches long and 4 broad, on which are placed two thermometers, in opposite directions, fixed on proper stands, to bring the balls, quite disengaged from the scales, directly 2 inches behind the transmitting

* See Plate XXIV.

holes. A small thin wooden partition is run up between the thermometers, to prevent the heat transmitted through one hole from coming to the thermometer belonging to the other.

The screen is fixed upon a light frame, which fits exactly into the opening of the front of the marble chimney-piece; and the ends of the frame are of a length which, when the screen is placed before the fire, will just bring the transmitting holes to be $6\frac{1}{2}$ inches from the front bars of the grate.

A large wooden cover, also plated with iron, shuts up the transmitting holes on the side next to the fire; but may be drawn up by a string on the outside, so as to open them when required.

Two assistant thermometers are placed on proper stands, to bring their balls to the same distance from the screen as those which receive the heat of the fire; but removed sideways as far as necessary, to put them out of the reach of any rays that pass obliquely through the transmitting holes. They are to indicate any change of temperature that may take place during the time of the experiment: for, notwithstanding the largeness of the screen, some heat will find its way round and over it; and this acting as a general cause, its effect must be allowed for.

117*th Experiment.*

Having tried the apparatus sufficiently to find that the thermometers exposed to the transmitting holes would generally receive 20 or more degrees of heat, without differing more than sometimes $\frac{1}{8}$ or at most $\frac{1}{4}$ of a degree, I now placed the bluish-white glass of the 24th experiment upon a support prepared for the purpose, so as closely to cover one of the transmitting holes. A small spring, moveable on its centre, is always turned against the upper part of the transmitting glasses, to keep them in their situation.

	Fire.	Bluish-white glass.
0′	66	66
5	86	71 . . . 20 : 5 = ,250

This glass stops 750 rays of fire-heat. By looking through it, at the same place in the fire, after the screen was removed, in order to cool the apparatus for the next experiment, I found that this glass can hardly be said to stop any of the light of the fire.

118*th Experiment.*

	Fire.	Flint glass.
0′	67	67
5	87	72 . . . 20 : 5 = ,250

It stops 750 rays of fire-heat.

119*th Experiment.*

	Fire.	Crown glass.
0′	67	67
5	$86\frac{3}{4}$	$72\frac{1}{2}$ . . . $19\frac{3}{4}$: $5\frac{1}{2}$ = ,278

It stops 722 rays of fire-heat.

120*th Experiment.*

	Fire.	Coach glass.
0′	$67\frac{1}{2}$	$67\frac{1}{2}$
5	$86\frac{3}{4}$	73 . . . $19\frac{1}{4}$: $5\frac{1}{2}$ = ,286

It stops 714 rays of fire-heat.

121*st Experiment.*

	Fire.	Iceland crystal.
0′	68	68
5	$90\frac{1}{2}$	$73\frac{1}{2}$ . . . $22\frac{1}{2}$: $5\frac{1}{2}$ = ,244

This substance stops 756 rays of fire-heat.

122d *Experiment.*

I took now the piece of talc used in the 30th experiment, and, placing it over the transmitting hole, I had the following result. But, as the unexpected event of a calcination, which took place, was attended with circumstances that ought to be noticed, I shall, instead of the usual abridgment of the experiments, give this at full length.

	Fire. Therm. D.	Talc. Therm. C.	
0′	65	65	
1	72	67 7	: 2 = ,289
2	77	$68\frac{3}{4}$ ... 12	: $3\frac{3}{8}$ = ,281
3	$80\frac{1}{2}$	$69\frac{1}{2}$ ... $15\frac{1}{2}$	: $4\frac{1}{2}$ = ,290
4	83	70 18	: 5 = ,278
5	85	$70\frac{3}{4}$ ... 20	: $5\frac{3}{4}$ = ,287

This substance stops 713 rays of fire-heat.

I am now to point out the singularity of this experiment; which consists, as we may see by the above register of it, in the apparently regular continuance of its power of transmitting heat, while its capacity of transmitting light was totally destroyed. For, when I placed this piece of talc over the hole in the screen, it was extremely transparent, as this substance is generally known to be; and yet, when the experiment was over, it appeared of a beautiful white colour; and its power of transmitting light was so totally destroyed, that even the sun in the meridian could not be perceived through it. Now, had the power of transmitting heat through this substance been really uniform during all the five minutes, it would have been quite a new phænomenon; as all my experiments are attended with a regular increase of it; but since, by calcination, the talc lost much of its transmitting power, we may easily account for this unexpected regularity.

123*d Experiment.*

	Fire.	Very dark red glass.
	66	66
	$89\frac{1}{4}$	$75 \ldots 23\frac{1}{4} : 9 = ,387$

This glass stops 613 rays of fire-heat.

124*th Experiment.*

	Fire.	Dark-red glass.
0′	67	67
5	$92\frac{3}{4}$	$78 \ldots 25\frac{3}{4} : 11 = ,427$

This glass, which stops 999,8 rays of candle-light, stops only 573 rays of fire-heat; whereas my piece of thick flint glass, which stops no more than 91 rays of that light, stops no less than 750 of fire-heat. It does not appear, by looking through these glasses, that there is a difference in their disposition to transmit candle-light or fire-light.

125*th Experiment.*

	Fire.	Orange glass.
0′	66	66
5	80	$71 \ldots 14 : 5 = ,357$

It stops 643 rays of fire-heat.

126*th Experiment.*

	Fire.	Yellow glass.
0′	$61\frac{1}{4}$	$61\frac{1}{4}$
5	83	$68\frac{7}{8} \ldots 21 : 7\frac{6}{8}$. cor. — $1\frac{1}{8}^{\circ}$. $20\frac{5}{8} : 6\frac{1}{2} = ,315$

This experiment being made early in the morning, before the temperature of the room was come to its usual height, the assistant thermometers shewed a gradual rising of $1\frac{1}{8}$ degree in the 5 minutes: they are in general very steady. The glass stops 685 rays of fire-heat.

127*th Experiment.*

	Fire.	Pale-green glass.
0′	$65\frac{3}{4}$	$65\frac{3}{4}$
5	85	$71\frac{3}{4} \ldots 19\frac{1}{4} : 6 = ,312$

It stops 688 rays of fire-heat.

128*th Experiment.*

	Fire.	Dark-green glass.
0′	68	68
5	$88\frac{3}{4}$	$73\frac{3}{8} \ldots 20\frac{3}{8} : 5\frac{3}{4}$ cor. $-\frac{1}{4}^{\circ} = ,255$

It stops 745 rays of fire-heat.

129*th Experiment.*

	Fire.	Bluish-green glass.
0′	$68\frac{1}{2}$	$68\frac{1}{2}$
5	87	$74\frac{1}{8} \ldots 18\frac{1}{2} : 5\frac{5}{8} = ,304$

It stops 696 rays of fire-heat.

130*th Experiment.*

	Fire.	Pale-blue glass.
0′	$68\frac{1}{2}$	68
5	$86\frac{1}{4}$	$73\frac{3}{4} \ldots 17\frac{3}{4} : 5\frac{3}{4} = ,324$

It stops 676 rays of fire-heat.

131st *Experiment.*

	Fire.	Dark-blue glass.
0′	67	67
5	$84\frac{7}{8}$	$73 \ldots 17\frac{7}{8} : 6$. cor. $- 1^\circ = ,296$

It stops 704 rays of fire-heat.

132d *Experiment.*

	Fire.	Indigo glass.
0′	$69\frac{1}{4}$	$69\frac{1}{4}$
5	$85\frac{3}{8}$	$73\frac{3}{4} \ldots 16\frac{1}{8} : 4\frac{1}{2} = ,279$

It stops 721 rays of fire-heat.

133d *Experiment.*

	Fire.	Pale indigo glass.
0′	$67\frac{1}{2}$	$67\frac{1}{2}$
5	$85\frac{7}{8}$	$74 \ldots 18\frac{3}{8} : 6\frac{1}{2}$. cor. $- \frac{1}{4}^\circ = ,345$

It stops 655 rays of fire-heat.

134th *Experiment.*

	Fire.	Purple glass.
0′	69	69
5	83	$73\frac{1}{2} \ldots 14 : 4\frac{1}{2} = ,321$

It stops 679 rays of fire-heat.

135th *Experiment.*

	Fire.	Violet glass.
0′	$66\frac{1}{2}$	$66\frac{1}{2}$
5	$86\frac{1}{2}$	$74\frac{1}{4} \ldots 20 : 7\frac{3}{4} = ,385$

It stops 615 rays of fire-heat,

136*th Experiment.*

	Fire.	Crown glass; one side rubbed on emery.
0′	$67\frac{5}{8}$	$67\frac{5}{8}$
5	$89\frac{3}{4}$	$73\frac{3}{4} \ldots 22\frac{1}{8} : 6\frac{1}{8} = ,277$

This glass, so prepared, stops 723 scattered rays of fire-heat.

137*th Experiment*

	Fire.	Coach glass; one side rubbed on emery.
0′	68	$67\frac{1}{2}$
5	$87\frac{1}{8}$	$72\frac{1}{8} \ldots 19\frac{1}{8} : 4\frac{5}{8} = ,242$

It stops 758 scattered rays of fire-heat.

138*th Experiment.*

	Fire.	Crown glass; both sides rubbed on emery.
0′	$68\frac{1}{2}$	68
5	$92\frac{3}{8}$	$73 \ldots 23\frac{7}{8} : 5 = ,209$

It stops 791 scattered rays of fire-heat.

139*th Experiment.*

	Fire.	Coach glass; both sides rubbed on emery.
0′	67	67
5	88	$70\frac{1}{2} \ldots 21 : 3\frac{1}{2}$. cor. — $\frac{1}{2}^{\circ} = ,146$

It stops 854 scattered rays of fire-heat.

140*th Experiment.*

	Fire.	{ Crown glass. Coach glass. } One side of each rubbed on emery.
0′	66	66
5	86	$69\frac{7}{8} \ldots 20 : 3\frac{7}{8}$. cor. — $1^{\circ} = ,151$

These glasses stop 849 scattered rays of fire-heat.

141*st Experiment.*

	Fire.	Crown glass. Coach glass. — Both sides of each rubbed on emery.
0′	$66\frac{3}{4}$	$66\frac{3}{4}$
5	$83\frac{3}{4}$	$68\frac{1}{2}$ . . . 17 : $1\frac{3}{4}$ = ,103

These glasses stop 897 scattered rays of fire-heat.

142*d Experiment.*

	Fire.	The four glasses of the two preceding experiments put together.
0′	66	66
5	80	$67\frac{3}{8}$ . . . 14 : $1\frac{3}{8}$ = ,098

These four glasses stop 902 scattered rays of fire-heat.

143*d Experiment.*

	Fire.	Olive colour, burnt into glass.
0′	$63\frac{3}{4}$	$63\frac{3}{4}$
5	$85\frac{3}{4}$	$67\frac{1}{2}$ . . . 22 : $3\frac{3}{4}$. cor. — $\frac{1}{2}^{\circ}$ = ,151

This glass stops 849 scattered rays of fire-heat.

144*th Experiment.*

	Fire.	Paper.
0′	$66\frac{1}{2}$	$66\frac{1}{2}$
5	$83\frac{1}{2}$	68 . . . 17 : $1\frac{1}{2}$ = ,0882

This substance stops 912 scattered rays of fire-heat; it was turned a little yellow by the exposure.

145*th Experiment.*

	Fire.	Linen.
0′	$63\frac{3}{4}$	$63\frac{3}{4}$
5	$84\frac{3}{4}$	67 . . . 21 : $3\frac{1}{4}$. cor. — $1\frac{1}{2}^{\circ}$ = ,0897

This substance stops 910 scattered rays of fire-heat.

146th Experiment.

	Fire.	White persian.
0′	$65\frac{3}{4}$	$65\frac{3}{4}$
5	$81\frac{1}{8}$	$68\frac{3}{8} \ldots 15\frac{3}{8} : 2\frac{5}{8} = ,171$

This substance stops 829 scattered rays of fire-heat.

147th Experiment.

	Fire.	Black muslin.
0′	66	66
5	$82\frac{1}{2}$	$70\frac{1}{2} \ldots 16\frac{1}{2} : 4\frac{1}{2}$. cor. $+ \frac{1}{2}^{\circ} = ,294$

This substance stops 706 scattered rays of fire-heat.

Transmission of the invisible Rays of solar Heat.

The same apparatus which I have used for the transmission of coloured prismatic rays,* will also do for the invisible part of the heat spectrum: it is only required to add two or three more parallel lines, one-tenth of an inch from each other, below the two which inclose the transmitting holes, in order to use them for directing the invisible rays of heat, by the position of the visible rays of light, to fall on the place required for coming to the thermometers.

148th Experiment.

	Invisible rays.	Bluish-white glass.
0′	48	47
5	$49\frac{3}{4}$	$48\frac{5}{8} \ldots 1\frac{3}{4} : 1\frac{5}{8} = ,929$

This glass stops only 71 invisible rays of heat.

* See Plate XXII. Fig. 3.

149*th Experiment.*

	Invisible rays.	Flint glass.
0′	$50\frac{3}{4}$	$49\frac{7}{8}$
5	52	$51\frac{1}{8} \ldots 1\frac{1}{4} : 1\frac{1}{4} = 1{,}000$

This glass stops no invisible rays of heat.

150*th Experiment.*

	Invisible rays.	Crown glass.
0′	$50\frac{1}{2}$	$49\frac{3}{4}$
5	$51\frac{7}{8}$	$50\frac{7}{8} \ldots 1\frac{3}{8} : 1\frac{1}{8} = ,818$

It stops 182 invisible rays of heat.

151*st Experiment.*

Invisible rays.	Coach glass.
$54\frac{1}{2}$	$53\frac{7}{8}$
$55\frac{3}{8}$	$54\frac{5}{8} \ldots \frac{7}{8} : \frac{3}{4} = ,857$

It stops 143 invisible rays of heat.

152*d Experiment.*

	Invisible rays.	Calcinable talc.
0′	$51\frac{3}{8}$	$50\frac{3}{4}$
5	$52\frac{7}{8}$	$51\frac{7}{8} \ldots 1\frac{1}{2} : 1\frac{1}{8} = ,750$

This substance stops 250 invisible rays of heat.

153*d Experiment.*

	Invisible rays.	Dark-red glass.
0′	$47\frac{5}{8}$	$46\frac{3}{4}$
5	$48\frac{5}{8}$	$47\frac{3}{4} \ldots 1 : 1 = 1{,}000$

This glass stops no invisible rays of heat. This accounts for the strong sensation of heat felt by the eye, in looking at the sun through a telescope, when red darkening glasses are used.

154*th Experiment.*

	Invisible rays.	Orange glass.
0′	$51\frac{5}{8}$	51
5	53	52 . . . $1\frac{3}{8} : 1 = ,727$

It stops 273 invisible rays of heat.

155*th Experiment.*

	Invisible rays.	Yellow glass.
0′	$51\frac{3}{4}$	51
5	53	52 . . . $1\frac{1}{4} : 1 = ,800$

It stops 200 invisible rays of heat.

156*th Experiment.*

	Invisible rays.	Pale-green glass.
0′	$51\frac{7}{8}$	$51\frac{1}{4}$
5	$52\frac{7}{8}$	$51\frac{7}{8}$ . . . $1 : \frac{5}{8} = ,625$

It stops 375 invisible rays of heat.

157*th Experiment.*

	Invisible rays.	Dark-green glass.
0′	$51\frac{7}{8}$	$51\frac{1}{2}$
5	$52\frac{7}{8}$	52 . . . $1 : \frac{1}{2} = ,500$

It stops 500 invisible rays of heat.

158*th Experiment.*

	Invisible rays.	Bluish-green glass.
0′	53	$52\frac{1}{4}$
5	$54\frac{1}{4}$	$52\frac{1}{2}$ . . . $1\frac{1}{4} : \frac{1}{4} = ,200$

It stops 800 invisible rays of heat.

159*th Experiment.*

	Invisible rays.	Pale-blue glass.
0'	$51\frac{7}{8}$	$51\frac{1}{4}$
5	$53\frac{3}{8}$	$51\frac{7}{8} \ldots 1\frac{1}{2} : \frac{5}{8} = ,417$

It stops 583 invisible rays of heat.

160*th Experiment.*

	Invisible rays.	Dark-blue glass.
0'	$52\frac{7}{8}$	$51\frac{5}{8}$
5	$52\frac{7}{8}$	$52\frac{1}{4} \ldots \frac{3}{4} : \frac{5}{8} = ,833$

It stops 167 invisible rays of heat.

161*st Experiment.*

	Invisible rays.	Indigo glass.
0'	$52\frac{7}{8}$	$52\frac{1}{4}$
5	$54\frac{3}{8}$	$53 \ldots 1\frac{1}{2} : \frac{3}{4} = ,500$

It stops 500 invisible rays of heat.

162*d Experiment.*

	Invisible rays.	Pale-indigo glass.
0'	$52\frac{3}{4}$	$52\frac{1}{8}$
5	$53\frac{3}{4}$	$52\frac{7}{8} \ldots 1 : \frac{3}{4} = ,750$

It stops 250 invisible rays of heat.

163*d Experiment.*

	Invisible rays.	Purple glass.
0'	$51\frac{1}{4}$	$50\frac{3}{8}$
5	$52\frac{5}{8}$	$51\frac{3}{8} \ldots 1\frac{3}{8} : 1 = ,727$

It stops 273 invisible rays of heat.

164*th Experiment.*

	Invisible rays.	Violet glass.
0′	$53\frac{1}{4}$	$52\frac{3}{8}$
5	$54\frac{1}{4}$	$53\frac{1}{8} \ldots 1 : \frac{3}{4} = ,750$

It stops 250 invisible rays of heat.

165*th Experiment.*

	Invisible rays.	Crown glass; one side rubbed on emery, rough side exposed.
0′	$49\frac{1}{2}$	$48\frac{3}{4}$
5	$50\frac{3}{4}$	$49\frac{1}{4} \ldots 1\frac{1}{4} : \frac{1}{2} = ,400$

This glass, so prepared, stops 600 scattered invisible rays of heat.

166*th Experiment.*

	Invisible rays.	Coach glass; one side rubbed on emery, rough side exposed.
0′	54	$53\frac{3}{8}$
5	$55\frac{1}{4}$	$54 \ldots 1\frac{1}{4} : \frac{5}{8} = ,500$

It stops 500 scattered invisible rays of heat.

167*th Experiment.*

	Invisible rays.	Crown glass; both sides rubbed on emery.
0′	50	$49\frac{1}{8}$
5	$51\frac{1}{4}$	$49\frac{5}{8} \ldots 1\frac{1}{4} : \frac{1}{2} = ,400$

It stops 600 scattered invisible rays of heat.

168*th Experiment.*

	Invisible rays.	Coach glass; both sides rubbed on emery.
0′	$54\frac{3}{4}$	$54\frac{1}{8}$
5	$55\frac{5}{8}$	$54\frac{3}{8} \ldots \frac{7}{8} : \frac{1}{4} = ,286$

It stops 714 scattered invisible rays of heat.

169*th Experiment.*

	Invisible rays.	Calcined talc.
0'	$51\frac{7}{8}$	$50\frac{7}{8}$
5	53	$51 \ldots 1\frac{1}{8} : \frac{1}{8} = ,111$

This substance stops 889 scattered invisible rays of heat.

Transmission of invisible terrestrial Heat.

This is perhaps the most extensive and most interesting of all the articles we have to investigate. Dark heat is with us the most common of all; and its passage from one body into another, is what it highly concerns us to trace out. The slightest change of temperature denotes the motion of invisible heat; and if we could be fully informed about the method of its transmission, much light would be thrown on what now still remains a mysterious subject. It must be remembered, that in the following experiments, I only mean to point out the transmission of such dark heat as I have before proved to consist of rays, without inquiring whether there be any other than such existing.

My apparatus for these experiments is as follows.* A box 12 inches long, $5\frac{1}{2}$ broad, and 3 deep, has a partition throughout its whole length, which divides it into two parts. At one end of each division is a hole $\frac{3}{4}$ inch in diameter; and each division contains a thermometer, with its ball exposed to the hole, and at one inch distance from the outside of the box. Four inches of the box, next to the holes, are covered; the rest is open. In the front of it is a narrow slip of wood, on which may rest any glass to be tried; and it is held close to the wood at the top, by a small spring applied against it. Two screws are planted upon the front, one on each side, which may be

* See Plate XXV. Fig. 1.

drawn out or screwed in, by way of accurately adjusting the distance of the thermometer from the line of action.

In order to procure invisible terrestrial heat, I have tried many different ways, but a stove is the most commodious of them. Iron is a substance that transmits invisible heat very readily; while, at the same time, it will most effectually intercept every visible ray of the fire by which it is heated, provided that be not carried to any great excess. I therefore made use of an iron stove,* having four flat sides, and being constructed so as to exclude all appearance of light. I had it placed close to a wall, that the pipe which conveys away smoke might not scatter heat into the room.

The thermometer box, when experiments are to be made, is to be put into an arrangement of twelve bricks, placed on a stand, with casters: † these bricks, when the stand is rolled close to the stove, which must not be done till an experiment is to begin, form an inclosure, just fitting round the sides, bottom, and covered part of the top of the thermometer box, and completely guard it against the heat of the stove. The box is then shoved into the brick opening, close to the iron side of the stove, where the two front screws, coming into contact with the iron plate, give the thermometers their proper distance; which, in the following experiments, has been such as to bring the most advanced part of the balls to one inch and four-tenths from the hot iron.

It will be necessary to remark, that on calculating the transmissions for the fifth minute, I found that it would not be doing justice to the stopping power of the glasses, to take so long a time; for, notwithstanding the use of brickwork, and the

* See Plate XXV. Fig. 2. † See Fig. 3.

precaution I had taken, of having two sets of it, that one might be cooling while the other was employed, and though neither of them was ever very hot, yet I found that so much heat came to the box, that when it was taken out of the bricks, in order to be cooled, the thermometers continued still to rise, at an average, about two degrees higher than they were. I have therefore now taken the third minute, as a much safer way to come at the truth.

170*th Experiment.*

	Stove.	Bluish-white glass.
0′	56	$55\frac{3}{4}$
3	$59\frac{3}{4}$	$56\frac{7}{8} \ldots 3\frac{3}{4} : 1\frac{1}{8} = ,300$

This glass stops 700 invisible rays of heat.

171*st Experiment.*

	Stove.	Flint glass.
0′	$53\frac{3}{4}$	$53\frac{1}{2}$
3	$55\frac{5}{8}$	$54\frac{3}{8} \ldots 1\frac{7}{8} : \frac{7}{8} = ,467$

It stops 533 invisible rays of heat.

172*d Experiment.*

	Stove.	Crown glass.
0′	$50\frac{1}{2}$	$50\frac{1}{2}$
3	$53\frac{3}{8}$	$51\frac{1}{8} \ldots 2\frac{7}{8} : \frac{5}{8} = ,217$

It stops 783 invisible rays of heat.

173*d Experiment.*

	Stove.	Coach glass.
0′	$50\frac{1}{2}$	$50\frac{1}{2}$
3	$52\frac{1}{2}$	$51\frac{1}{4} \ldots 2 : \frac{3}{4} = ,375$

It stops 625 invisible rays of heat.

174th Experiment.

	Stove.	Iceland crystal.
0′	47	$46\frac{1}{2}$
3	$54\frac{3}{4}$	$48\frac{5}{8} \ldots 7\frac{3}{4} : 2\frac{1}{8} = ,274$

This substance stops 726 invisible rays of heat.

175th Experiment.

	Stove.	Calcinable talc.
0′	51	$51\frac{5}{8}$
3	$57\frac{1}{2}$	$54\frac{1}{4} \ldots 6\frac{1}{2} : 2\frac{5}{8} = ,404$

At the end of five minutes, when the box was taken out of the bricks, the talc was perfectly turned into a scattering substance: as such, it stops 596 scattered invisible rays of heat. The sun cannot be seen through it; but this I find is chiefly owing to its scattering disposition. It stops however 997 scattered rays of light.

176th Experiment.

	Stove.	Dark red glass.
0′	58	58
3	$64\frac{3}{4}$	$60\frac{1}{2} \ldots 6\frac{3}{4} : 2\frac{1}{2} = ,370$

This glass stops 630 invisible rays of heat.

177th Experiment.

	Stove.	Orange glass.
0′	$55\frac{1}{2}$	$55\frac{1}{4}$
3	$60\frac{3}{4}$	$57\frac{3}{4} \ldots 5\frac{1}{4} : 2\frac{1}{2} = ,476$

It stops 524 invisible rays of heat.

178*th Experiment.*

	Stove.	Yellow glass.
0′	$57\frac{3}{4}$	$57\frac{1}{4}$
3	$61\frac{3}{4}$	$59\frac{3}{8} \ldots 4 : 2\frac{1}{8} = ,531$

It stops 469 invisible rays of heat.

179*th Experiment.*

	Stove.	Pale-green glass.
0′	$51\frac{1}{2}$	$51\frac{1}{2}$
3	$56\frac{1}{4}$	$53\frac{1}{4} \ldots 4\frac{3}{4} : 1\frac{3}{4} = ,368$

It stops 632 invisible rays of heat.

180*th Experiment.*

	Stove.	Dark-green glass.
0′	50	$49\frac{1}{2}$
3	$53\frac{3}{4}$	$50\frac{5}{8} \ldots 3\frac{3}{4} : 1\frac{1}{8} = ,300$

It stops 700 invisible rays of heat.

181*st Experiment.*

	Stove.	Bluish-green glass.
0′	51	51
3	$55\frac{1}{2}$	$53 \ldots 4\frac{1}{2} : 2 = ,444$

It stops 556 invisible rays of heat.

182*d Experiment.*

	Stove.	Pale-blue glass.
	$53\frac{3}{4}$	$53\frac{5}{8}$
	$57\frac{5}{8}$	$55\frac{3}{8} \ldots 3\frac{7}{8} : 1\frac{3}{4} = ,452$

It stops 548 invisible rays of heat.

183*d Experiment.*

	Stove.	Dark-blue glass.
0′	$53\frac{1}{2}$	53
5	$55\frac{7}{8}$	$53\frac{7}{8} \ldots 2\frac{3}{8} : \frac{7}{8} = ,368$

It stops 632 invisible rays of heat.

184*th Experiment.*

	Stove.	Indigo glass.
0′	$54\frac{1}{8}$	54
3	$59\frac{5}{8}$	$55\frac{7}{8} \ldots 5\frac{1}{2} : 1\frac{7}{8} = ,341$

It stops 659 invisible rays of heat.

185*th Experiment.*

	Stove.	Pale indigo glass.
0′	$53\frac{1}{2}$	$53\frac{1}{2}$
3	$59\frac{3}{4}$	$55\frac{3}{8} \ldots 6\frac{1}{4} : 1\frac{7}{8} = ,300$

It stops 700 invisible rays of heat.

186*th Experiment.*

	Stove.	Purple glass.
0′	$51\frac{3}{4}$	$51\frac{1}{8}$
3	$56\frac{3}{8}$	$52\frac{3}{8} \ldots 4\frac{5}{8} : 1\frac{1}{4} = ,270$

It stops 730 invisible rays of heat.

187*th Experiment.*

	Stove.	Violet glass.
0′	51	$51\frac{1}{2}$
3	$55\frac{3}{4}$	$53 \ldots 4\frac{3}{4} : 1\frac{1}{2} = ,316$

It stops 684 invisible rays of heat.

188*th Experiment.*

	Stove.	Crown glass; one side rubbed on emery.
0′	$49\frac{1}{4}$	$49\frac{1}{4}$
3	$54\frac{1}{4}$	$50\frac{3}{8} \ldots 5 : 1\frac{1}{8} = ,225$

This glass, so prepared, stops 775 invisible rays of scattered heat.

189*th Experiment.*

	Stove.	Coach glass; one side rubbed on emery,
0′	50	50
3	$57\frac{1}{4}$	$51\frac{7}{8} \ldots 7\frac{1}{4} : 1\frac{7}{8} = ,259$

It stops 741 invisible rays of scattered heat.

190*th Experiment.*

	Stove.	Crown glass; both sides rubbed on emery.
0′	52	52
3	58	$53 \ldots 6 : 1 = ,167$

It stops 833 invisible rays of scattered heat.

191*st Experiment.*

	Stove.	Coach glass; both sides rubbed on emery.
0′	52	52
3	$55\frac{1}{4}$	$52\frac{3}{4} \ldots 3\frac{1}{4} : \frac{3}{4} = ,231$

It stops 769 invisible rays of scattered heat.

192*d Experiment.*

	Stove.	Olive colour, burnt in glass.
0′	$51\frac{1}{2}$	$51\frac{1}{2}$
3	57	$53\frac{1}{2} \ldots 5\frac{1}{2} : 2 = ,364$

It stops 636 invisible rays of scattered heat.

193d Experiment.

	Stove.	White paper.
0′	52	52
3	$57\frac{3}{8}$	$54\frac{1}{2} \ldots 5\frac{3}{8} : 2\frac{1}{2} = ,465$

This substance stops only 535 invisible rays of scattered heat.

194th Experiment.

	Stove.	Linen.
0′	$53\frac{3}{8}$	$53\frac{3}{8}$
3	$57\frac{3}{4}$	$55\frac{3}{4} \ldots 4\frac{3}{8} : 2\frac{3}{8} = ,543$

It stops 457 invisible rays of scattered heat.

Article vi.—*Scattering of Solar Heat.*

We are now come to a branch of our inquiry which, from its novelty, would deserve a fuller investigation than we can at present enter into. The scattering of heat, is a reflection of it on the rough surfaces of bodies: it is therefore a principle of general influence, since all bodies, even the most polished, are sufficiently rough to scatter heat in all directions. In order, therefore, to compare the effect of rough surfaces on heat with their effect on light, I have made a number of experiments, from which the following are selected, for the purpose of our intended comparative view.

The apparatus I have used for scattering solar heat, is like that which served for transmissions;* but here the holes through which the sun's rays enter,† are very exactly $1\frac{1}{2}$ inch in diameter each; and are chamferred away on the under side,

* See Plate XXI. Fig. 1. † See Plate XXII. Fig. 4.

that no re-scattering may take place in the thickness of the covering board: the distance of the centre of the holes is 4 inches. A little more than an inch below, and under the centre of the holes, are the balls of the small thermometers A and B, well shaded from the direct rays of the sun, by small slips of wood, of the shape of the ball, and of that part of the stem which is exposed.

Under each thermometer is a small tablet,* on which the objects intended for scattering the sun's rays are to be placed. The tablets are contrived so as to bring the objects perpendicularly under the openings, and under the centre of the balls of the thermometers, at the distance of exactly one inch from them. Every thing being thus alike on both sides of the box, it is evident, from the equality of the holes, that an equal number of solar rays will fall on each object, and will by them be scattered back on the thermometers, at equal angles, and equal distances.

The first five experiments that follow, were made with an apparatus somewhat different from the one here described; and, though the result of them may not be so accurate as if they had been made with the present one, I must give them as they are, since time will not allow of a repetition.

195th Experiment.

	Sun.	Message card scattering.
0′	64	64
5	$69\frac{3}{4}$	$66\frac{3}{8}$ . . . $5\frac{3}{4} : 2\frac{3}{8} = ,413$

Here an object of a white colour, 3,6 inches long, and 2,6 broad, scattered, in 5 minutes, 413 rays of heat back upon one

* See Plate XXII. Fig. 5.

thermometer, while the other received a thousand, directly from the sun. Now, in order the better to compare the proportion of light and heat scattered by different objects, we shall put these 413 rays equal to 1000; or, which is nearly the same, multiply them by 2,421. Then, since the message card also scatters 1000 rays of light, as will be found in a table at the end of the transmission table, our present object may be made a standard for a comparison with the four following ones.

196*th Experiment.*

	Sun.	Pink-coloured paper scattering.
0′	64	64
5	70	$66\frac{5}{8} \ldots 6 : 2\frac{5}{8} =$,438

Here a piece of pink-coloured paper, of the same dimensions with the card of the last experiment, and placed in the same situation, scattered, as we find by the same mode of multiplication, 1060 rays of heat; and, by our table, it scatters 513 of light.

197*th Experiment.*

	Sun.	Pale-green paper scattering.
0′	$64\frac{1}{8}$	$64\frac{1}{8}$
5	$69\frac{7}{8}$	$66\frac{1}{4} \ldots 5\frac{3}{4} : 2\frac{1}{8} =$,370

This piece of paper scatters 896 rays of heat, and 549 of light.

198*th Experiment.*

	Sun.	Dark-green paper scattering.
0′	$64\frac{5}{8}$	$65\frac{1}{4}$
5	$69\frac{1}{2}$	$67\frac{3}{4} \ldots 4\frac{7}{8} : 2\frac{1}{2} =$,513

This paper scatters 1242 rays of heat, and only 308 of light.

199*th Experiment.*

Sun.	Black paper scattering.
$65\frac{1}{2}$	66
$70\frac{3}{8}$	68 . . . $4\frac{7}{8} : 2 = ,410$

This paper scatters 993 rays of heat, and 420 of light.

From these experiments it seems to be evident, that in scattering heat, the colour of the object is out of the question; or, at least, that it is no otherwise concerned than as far as it may influence the texture of the surface of bodies. For here we find that pale-green, which is brighter, or scatters more light, than dark-green, yet scatters less heat. Even black, so generally known to scatter but little light, scatters much heat. But, in order to put this surmise to a fairer trial, I made the following experiments with my new machine.

200*th Experiment.*

I covered one of the tablets with white paper, and the other with black. The quantity of sunshine admitted through the two openings, of $1\frac{1}{2}$ inch in diameter each, being equal, I found the heat scattered on both thermometers to be as follows.

	White paper.	Black paper scattering.
0′	$71\frac{3}{4}$	72
5	$75\frac{5}{8}$	75 . . . $3\frac{7}{8} : 3 = ,774$

I turned now the tablets, and had,

	Black paper.	White paper scattering.
0′	$73\frac{1}{4}$	$72\frac{3}{4}$
5	$75\frac{5}{8}$	$75\frac{7}{8}$ . . . $2\frac{3}{8} : 3\frac{1}{8} = ,760$

These results, agreeing sufficiently well together, shew that if we make white paper our standard, and suppose it to scatter

1000 rays of heat, and 1000 of light, then will black paper scatter 767 rays of heat, and 420 of light.

201*st Experiment.*

	White paper.	Black muslin scattering.
0′	$73\frac{3}{4}$	$73\frac{3}{4}$
5	$77\frac{3}{4}$	$77 \cdots 4 : 3\frac{1}{4} = ,813$

This scatters 813 rays of heat; and, when it is suspended so that the rays which pass through it may not be reflected, it scatters only 64 rays of light.

202*d Experiment.*

As my intention at present was to find a black substance that should scatter more heat than a white one, I thought it would be the readiest way to examine the white and black objects separately, that of all the white ones I might afterwards take that which scattered least, and compare it with the black one which scattered most.

	White paper.	White linen scattering.
0′	$74\frac{7}{8}$	75
5	79	$79\frac{1}{8} \cdots 4\frac{1}{8} : 4\frac{1}{8} = 1,000$

These objects scatter heat equally, and very nearly also light; for our table gives for linen 1008.

203*d Experiment.*

	White paper.	White cotton scattering.
0′	$74\frac{1}{2}$	$74\frac{5}{8}$
5	$78\frac{3}{8}$	$78\frac{1}{2} \cdots 3\frac{7}{8} : 3\frac{7}{8} = 1,000$

These objects scatter heat equally. White cotton scatters 1054 rays of light.

204*th Experiment.*

	White paper.	White muslin scattering.
0′	$73\frac{3}{8}$	$73\frac{3}{8}$
5	$77\frac{3}{8}$	$76\frac{7}{8} \ldots 4 : 3\frac{1}{2} = ,875$

White muslin scatters 875 rays of heat, and 827 of light.

205*th Experiment.*

	White paper.	White persian scattering.
0′	$74\frac{1}{2}$	$74\frac{5}{8}$
5	$77\frac{7}{8}$	$78\frac{1}{4} \ldots 3\frac{3}{8} : 3\frac{5}{8} = 1,074$

White persian scatters 1074 rays of heat; and, when suspended like the black muslin in the 201st experiment, it scatters 671 rays of light.

206*th Experiment.*

	White paper.	White knit worsted; rough side outwards.
0′	51	$51\frac{3}{4}$
5	$52\frac{5}{8}$	$53\frac{3}{4} \ldots 1\frac{5}{8} : 2 = 1,231$

White worsted scatters 1231 rays of heat, and 620 of light.

207*th Experiment.*

White paper.	White chamois leather; the smooth side exposed.
$74\frac{5}{8}$	$74\frac{5}{8}$
$78\frac{3}{8}$	$79 \ldots 3\frac{3}{4} : 4\frac{3}{8} = 1,167$

White chamois leather scatters 1167 rays of heat, and 1228 of light.

208*th Experiment.*

Black paper.	Black velvet scattering.
$75\frac{3}{4}$	$75\frac{7}{8}$
$79\frac{1}{4}$	$80 \ldots 3\frac{1}{2} : 4\frac{1}{8} = 1,179$

Making now black paper the standard, and supposing it to scatter 1000 rays of heat, and the same of light, then black velvet scatters 1179 rays of heat, and only 17 of light. This last number we obtain, by dividing the tabular number 7, for black velvet, by ,42, which is the proportion of black paper to white.

209*th Experiment.*

	Black paper.	Black muslin scattering.
0′	$75\frac{1}{8}$	$75\frac{1}{4}$
5	$78\frac{3}{8}$	$79\frac{1}{8} \ldots 3\frac{1}{4} : 3\frac{7}{8} = 1,192$

Black muslin scatters 1192 rays of heat, and 43 of light.

210*th Experiment.*

	Black paper.	Black satin scattering.
0′	$76\frac{1}{4}$	$76\frac{1}{4}$
5	79	$80\frac{1}{8} \ldots 2\frac{3}{4} : 3\frac{7}{8} = 1,409$

Black satin scatters 1409 rays of heat, and 243 of light.

211*th Experiment.*

Having now ascertained, that of all the white and black substances I had tried, white muslin scatters the least, and black satin the most heat, I placed the former on one tablet, while the latter was put on the other.

	White muslin.	Black satin scattering.
0′	$76\frac{3}{8}$	$76\frac{3}{8}$
5	80	$80\frac{1}{4} \ldots 3\frac{5}{8} : 3\frac{7}{8} = 1,069$

Here the black object scattered more heat than the white one; but, in order to try again the equality of the tablets and apparatus, I placed the objects under the opposite thermometers, and had as follows.

	Black satin.	White muslin scattering.
0′	78	78
5	$80\frac{5}{8}$	$80\frac{1}{2} \ldots 2\frac{5}{8} : 2\frac{1}{2} = 1,050$

So that, notwithstanding some little difference in the apparatus, or other unavoidable circumstances, the black object gave again the greatest scattering of heat; and consequently, as no colour can be more opposite than black and white, colour can have no concern in the laws that relate to the scattering of heat.

212*th Experiment.*

I wished now to try some experiments of the scattering power of metals, and had some plates of iron, brass, and copper, two inches square, set flat, and smooth-filed, by round strokes.

	Iron.	Copper scattering.
0′	74	$73\frac{3}{4}$
5	$78\frac{1}{2}$	$77\frac{7}{8} \ldots 4\frac{1}{2} : 4\frac{1}{8} = ,917$

213*th Experiment.*

	Tin foil.	Gold-leaf paper scattering.
0′	74	74
5	$77\frac{3}{4}$	$79\frac{5}{8} \ldots 3\frac{3}{4} : 5\frac{5}{8} = 1,500$

But the tin foil was considerably tarnished.

214*th Experiment.*

Finding the form of the last experiments inconvenient, for want of a standard, I had recourse again to white paper.

	White paper.	Tin foil scattering.
0′	$50\frac{1}{8}$	52
5	$53\frac{3}{8}$	$54\frac{7}{8} \ldots 3\frac{1}{4} : 2\frac{7}{8} = ,885$

This substance scatters 885 rays of heat, and 8483 of light.

215th Experiment.

	White paper.	Iron.
0′	$51\frac{5}{8}$	$53\frac{1}{2}$
5	$54\frac{5}{8}$	$55\frac{3}{4} \ldots 3 : 2\frac{1}{4} = ,750$

Some time having elapsed between the former observation and the present one, this plate of iron was not now so bright as before, and seems to have suffered more than brass or copper from having been laid by: it scatters now only 750 rays of heat, and 10014 of light.

216th Experiment.

	White paper.	Brass.
0′	50	$51\frac{1}{4}$
5	$53\frac{1}{8}$	$55\frac{3}{8} \ldots 3\frac{1}{8} : 4\frac{1}{8} = 1,320$

It scatters 1320 rays of heat, and no less than 43858 of light.

217th Experiment.

White paper.	Copper.
$49\frac{7}{8}$	$51\frac{7}{8}$
53	$55\frac{7}{8} \ldots 3\frac{1}{8} : 4 = 1,280$

It scatters 1280 rays of heat, and 13128 of light.

218th Experiment.

White paper.	Gold-leaf paper.
$54\frac{3}{4}$	$55\frac{3}{8}$
$56\frac{1}{2}$	$56 \ldots 1\frac{3}{4} : \frac{5}{8} = ,357$

I changed the tablets to see what difference there might be.

Gold paper.	White paper.
$55\frac{3}{8}$	$55\frac{7}{8}$
$56\frac{1}{8}$	$57\frac{3}{8} \ldots \frac{3}{4} : 1\frac{1}{2} = ,500$

A mean between the two gives ,429. Gold paper, therefore, scatters only 429 rays of heat, and no less than 124371 rays of light.

219th Experiment.

	Black velvet.	Gold paper scattering.
0′	52	$51\frac{7}{8}$
5	$53\frac{1}{8}$	$52\frac{1}{2} \ldots 1\frac{1}{8} : \frac{5}{8} =$,556

I turned the tablets, in order to ascertain the difference.

	Gold paper.	Black velvet.
0′	51	$51\frac{3}{4}$
5	$51\frac{3}{4}$	$53 \ldots \frac{3}{4} : 1\frac{1}{4} =$,600

From a mean of both it appears, that when black velvet scatters 1000 rays of heat, and only 7 rays of light, gold paper, on the contrary, scatters no more than 578 rays of heat, but 124371 of light.

ART. VII.—*Whether Light and Heat be occasioned by the same, or by different Rays.*

Before we enter into a discussion of this question, it appears to me that we are authorised, by the experiments which have been delivered in this Paper, to make certain conclusions, that will entirely alter the form of our inquiry. Thus, from the 18th experiment it appears, that 21 degrees of solar heat were given in one minute to a thermometer, by rays which had no power of illuminating objects, and which could not be rendered visible, notwithstanding they were brought together in the focus of a burning lens. The same has also been proved of terrestrial heat, in the 9th experiment; where, in one minute, 39 degrees of it were given to a thermometer, by rays totally invisible, even when condensed by a concave mirror. Hence it is established, by incontrovertible facts, that there are rays of heat, both solar and terrestrial, not endowed with a power of rendering objects visible.

It has also been proved, by the whole tenour of our prismatic experiments, that this invisible heat is continued, from the beginning of the least refrangible rays towards the most refrangible ones, in a series of uninterrupted gradation, from a gentle beginning to a certain maximum; and that it afterwards declines, as uniformly, to a vanishing state. These phenomena have been ascertained by an instrument, which, figuratively speaking, we may call blind, and which, therefore, could give us no information about light; yet, by its faithful report, the thermometer, which is the instrument alluded to, can leave no doubt about the existence of the different degrees of heat in the prismatic spectrum.

This consideration, as has been observed, must alter the form of our proposed inquiry; for the question being thus at least partly decided, since it is ascertained that we have rays of heat which give no light, it can only become a subject of inquiry, whether some of these heat-making rays may not have a power of rendering objects visible, superadded to their now already established power of heating bodies.

This being the case, it is evident that the *onus probandi* ought to lie with those who are willing to establish such an hypothesis; for it does not appear that nature is in the habit of using one and the same mechanism with any two of our senses; witness the vibrations of air that make sound; the effluvia that occasion smells; the particles that produce taste; the resistance or repulsive powers that affect the touch: all these are evidently suited to their respective organs of sense. Are we then here, on the contrary, to suppose that the same mechanism should be the cause of such different sensations, as the delicate perceptions of vision, and the very grossest of all affections, which are common to the coarsest parts of our bodies, when exposed to heat?

But, let us see what light may now be obtained from the several articles that have been discussed in this Paper. It has been shewn, that the effect of heat and of illumination may be represented by the two united spectra, which we have given.* Now, when these are compared, it appears that those who would have the rays of heat also to do the office of light, must be obliged to maintain the following arbitrary and revolting positions; namely, that a set of rays conveying heat, should all at once, in a certain part of the spectrum, begin to give a small degree of light; that this newly acquired power of illumination should increase, while the power of heating is on the decline; that when the illuminating principle is come to a maximum, it should, in its turn, also decline very rapidly, and vanish at the same time with the power of heating. How can effects that are so opposite be ascribed to the same cause? first of all, heat without light; next to this, decreasing heat, but increasing light; then again, decreasing heat and decreasing light. What modification can we suppose to be superadded to the heat-making power, that will produce such inconsistent results?

We must not omit to mention another difference between light and heat, which may be gathered from the same article of the refrangibility of heat-making rays. It is, that though light and heat are both refrangible, the ratio of the sines of

* See page 439, and Plate XX.

incidence and refraction of the mean rays is not the same in both. Heat is evidently less refrangible than light; whether we take a mean refrangible ray of each, or, which I believe to be the better way of proceeding, whether we take the maximum of heat and light separately. This appears, not only from the view we have taken of the two spectra already mentioned, but more evidently from the 23d experiment, by which we find, that heat cannot be collected by a lens, to the same focus where light is gathered together.

Our fifth article, in which an account has been given of the proportions of heat and light stopped by glasses and other substances, will afford us now an ample field for pointing out a striking difference between these two principles. From the 24th to the 30th experiment, we have the quantities intercepted by colourless substances as follows.

TABLE I.

Bluish-white glass stops	250	rays of heat, and	86	of light.
White flint glass - -	91	- - -	34	- -
Greenish crown glass -	259	- - -	203	- -
Coach glass - -	214	- - -	168	- -
Iceland crystal - -	244	- - -	150	- -
Talc - - -	139	- -	90	- -
Calcinable talc - -	184	- - -	288	- -

Now, by casting an eye on the above table, it will be seen immediately, that no kind of regularity takes place among the proportions of rays of one sort and of another, which are stopped in their passage. Heat and light seem to be entirely unconnected. The bluish-white and flint glasses, for instance, stop nearly three times as much heat as light; whereas, the greenish crown glass stops only about one-fourth more of the former than of the latter; but, as coloured glasses take in a much greater range, I will now also give a tabular result of the experiments that have been given relating to them.

TABLE II.

Very dark red glass stops	800	rays of heat, and	$999\frac{9}{10}$	of light.
Dark-red	606	- - -	$999\frac{8}{10}$	- -
Orange	604	- -	779	- -
Yellow	333	- - -	819	- -
Pale-green	633	- -	535	- -
Dark-green	849	- - - -	949	- -
Bluish-green	768	- - -	769	- -
Pale-blue	812	- - -	684	- -
Dark-blue	362	- -	801	- -
Indigo	633	- - -	$999\frac{7}{10}$	- -
Pale-indigo	532	- - -	978	- -
Purple	583	- -	993	- -
Violet	489	- - -	955	- -

From this table, I shall also point out a few of the most remarkable results. A yellow glass, for instance, stops only 333 rays of heat, but stops 819 of light: on the contrary, a pale blue stops 812 rays of heat, and but 684 of light. Again, a dark blue glass stops only 362 rays of heat, but intercepts 801 of light; and a dark red glass stops no more than 606 rays of heat, and yet intercepts nearly all the light; scarcely one ray out of 5000 being able to make its way through it.

Before I proceed to a more critical examination of these results, it will be necessary to add also a table of the same kind, collected from the experiments with liquids.

TABLE III.

Empty tube and 2 glasses stop	542 rays of heat, and	204 of light.
Spring water - - - -	558 - - -	211 - -
Sea water - - - -	682 - -	288 - -
Spirit of wine - - -	612 - - -	224 - -
Gin - - - -	739 - -	626 - -
Brandy - - -	794 - - -	996 - -

To which may be joined, a table containing the stoppages occasioned by scattering substances.

TABLE IV.

Rough crown glass stops	464 rays of heat, and	854 of light.
Rough coach glass -	571 - - -	879 - -
The 1st doubly rough -	667 - - -	932 - -
The 2d doubly rough -	735 - - -	946 - -
The 2 first together -	698 - - -	969 - -
The 2 next together -	800 - - -	979 - -
The 4 first together -	854 - - -	995 - -
Olive colour, burnt in -	839 - - -	984 - -
Calcined talc - -	867 - - -	996 - -
White paper - -	850 - - -	994 - -
White linen - -	916 - - -	952 - -
White persian - -	760 - - -	916 - -
Black muslin - -	714 - - -	737 - -

We shall now enter more particularly into the subject of these four tables, that we may, if possible, find a criterion by which to judge whether heat and light can be occasioned by the same rays or not. Now this I think will be obtained, if we can make it appear that stopping one sort of rays does not necessarily bring on a stoppage of the other sort; for, if it can be shewn that heat and light are in this respect independent of each other, it will follow that they must be occasioned by different rays; and I shall make all possible objections to the arguments I mean to draw from these tables, in order to shew that no hypothesis will evade the force of our conclusions.

It has been noticed, that bluish-white and flint glasses stop nearly three times as much heat as light; whereas, crown glass stops only about one-fourth more of the former than of the latter. Now, in answer to this, it may be alleged, "that the "ingredients of which the former glasses are made, dispose "them probably to stop the invisible rays of heat, and that "consequently a great interception of it may take place, with-"out bringing on a necessity of stopping much light; and that, "on the other hand, the different texture of crown glass may "stop one sort of heat as well as the other, so that nearly an "equality in this respect may be produced."

When a hypothesis is made in order to explain any phænomenon of nature, we ought to examine how it will agree with other facts; and, in this case, we are already furnished with experiments, which are decidedly against the supposition that has been brought forward. For, the 148th and 149th experiments shew that the bluish-white and flint glasses transmit all, or nearly all, the invisible rays of solar heat; whereas crown glass, by the 150th experiment, stops a considerable number of them. But, to assist the objecting argument, let it be alleged, as has been proved by the 94th experiment, that our bluish-white glass stops a considerable portion of the heat that goes with the red rays; then, if the 86 rays of light which this glass stops, are supposed to be all of that sort, the heat which will be stopped in consequence, will, according to the experiment we have mentioned, amount to 86 multiplied by ,375, that is, 32 rays of heat; but, since 250 have been stopped, there will remain 218 to be accounted for.

In this calculation, a manifest concession has been made, which ought to be explained. When I mention 86 red-coloured or red-making rays, I mean so many of them as will make up 86-thousandths of the whole effect of light; for the quantity of heat and light transmitted, or stopped, in all the experiments that have been given, has been reduced to what proportion it bears to unity; and, having afterwards represented the joint effect of every ray of heat and light by 1000, each mean ray of heat must be the thousandth part of that effect; but, a mean ray of light, although it be likewise the thousandth part of the whole effect of light, will not be so of heat, because the whole effect of the latter is partly owing to rays that have been proved to be invisible. On this account, the 86 mean rays of red light, stopped by our bluish-white glass, cannot even amount to a stoppage of 32 rays of heat, which we have allowed.

As I have made the concession on one hand, I must explain an advantage that may be claimed on the other; which is, that mean rays and promiscuous ones have already, in a former Paper, been proved to differ considerably, and that it remains therefore unknown how many red-making rays we may suppose to be stopped, in order to make up 86 mean rays of light. In answer to this, however, I must observe, that the number of promiscuous rays of light and of heat must always be inversely as their power of occasioning those sensations; so that if, for instance, a red ray is supposed to be twice as heating as a green one, there will only go half the number of them to make up a certain effect of heat; and, on the other hand, if a green ray should have a double power of illuminating, there will be no more than half the number of them necessary to occasion a certain effect of light. But, by my former experiments,* a red ray, though much inferior to a green one, is probably fully equal in illumination to a mean ray of all the colours united together. Now, as red rays have also been proved to be accompanied by the greatest heat, and as our bluish-white glass stops hardly any invisible heat rays, we have certainly gone the full length of fair concessions, by allowing all the light stopped by this glass to be of that sort; and thus it seems to be evident, that the heat which lies under the colours, if I may use this expression, may be stopped, without stopping the colours themselves.

It will not be necessary to lay much stress on this single experiment; our second table affords us sufficient ground on which to rest more forcible arguments. A dark-red glass, for instance, was found to stop 606 rays of heat, and 999,8 of light. This, even at the very first view, seems to amount to a total separation of the two principles; but let us discuss the phænomenon with precision.

As only one ray in 5000 can make its way through this glass, it is evident, that if the rays of light be also those of heat, there can hardly come any heat through it but what must be occasioned by rays that are invisible. It will therefore become a question to be examined, how many of this sort we can admit, if we proceed on a supposition that heat consists of light, as far as that will go. Now this, we find, has already been

* See page 270, 10th experiment.

ascertained, in a great measure, by our 13th, 17th, and 18th experiments. In the 13th, one hundred and twenty degrees of heat were given to a thermometer, in one minute, by the rays which accompany the coloured part of the spectrum. In the 17th experiment, on the contrary, we find only 45 degrees of heat communicated to the same thermometer, in the same time, by the invisible rays of the same spectrum. If we would be more scrupulous, the 18th experiment limits the heat from rays totally invisible even to 21 degrees; but, in order to make every possible allowance, let the proportion be the most favourable one of 120 to 45, which, reduced to mean rays of heat, will give 727 of them visible, and 273 invisible, to make up our thousand.

To return to the experiment: if the total number of rays of heat ascribed to light should accordingly be rated at 727, it is evident, from the stoppage of light of this glass, that 726 rays of heat at least must also be intercepted; and, in consequence of the 153d experiment, which shews that our glass opposes no obstruction to any of the invisible rays, we shall require no more. But, by our present experiment, this glass stops only 606 rays of heat; so that 120 of them will remain unaccounted for. Now, the moment we give up the hypothesis that heat is occasioned by the rays of light, the difficulty becomes fully resolved by our 100th experiment, which shews that full three-tenths of the rays that have the refrangibility of the red are actually transmitted.

In order, however, to make a second attempt to overcome this difficulty, without giving up the hypothesis, it may be supposed, "that perhaps the lens which has been used in the 13th, 17th, and "18th experiments might stop a greater number of invisible "than visible rays, and that its report therefore ought not to be "depended upon." Now, although it does not appear from the 148th experiment that such a supposition can have much foundation, yet, since those experiments were not made with a view to ascertain the proportion of heat contained in each part of the prismatic spectrum, we cannot lay so much stress upon them as the accuracy which is required in this case renders necessary. Let it therefore, contrary to our 100th experiment, be admitted, in order to explain the phænomenon of the red glass, which stops so much light and so little heat, that all the heat which it intercepts consists entirely of the rays which are visible, and that every one of the invisible rays of heat is transmitted. Then will 999,8 intercepted rays of light be equal to 606 rays of heat; and the remaining 394 will be the number of rays we are now to place to the account of the invisible heat which is transmitted.

Having thus also got rid of this difficulty, we are next to examine how other facts, collected in the same table, will agree with our new concession. A violet-coloured glass, for instance, stops 955 rays of light; these, at the rate of 999,8, or say 1000, to 606, must occasion a deficiency of 579 rays of heat. But, by our table, this glass stops only 489 of them; and there will thus be 90 rays of heat left unaccounted for. To enhance the difficulty, this glass, by our 164th experiment, stops also $\frac{1}{4}$ of the supposed 394 invisible rays, which will amount to an additional sum of 98. And our 111th experiment shews, that actually a great number of these rays, that otherwise cannot be accounted for, come from the store of heat, the rays of which are of the refrangibility of red light.

A dark-blue glass stops 801 rays of light; these, if light and heat were occasioned by the same rays, would produce a stoppage of 485 rays of heat; but we find that our glass stops no more than 362, so that 123 rays cannot be accounted for by this hypothesis. To this we should add 66 invisible rays, (that is, 394 × ,167,) which, according to our 160th experiment, this glass also intercepts. But the 107th experiment, if we reject the hypothesis, immediately explains the difficulty; for here we plainly see, that only 71 rays of heat of the refrangibility of red light are stopped, whatever may be the stoppage of that light itself.

A yellow glass stops 819 rays of light: these will occasion a stoppage of 496 rays of heat; but this glass intercepts only 333, and therefore 163 rays of heat must also remain unaccounted for. And, turning to the 155th experiment, we find that 79 rays, or $\frac{1}{5}$ of the 394 allowed to be invisible ones, are also to be added to that number.

If in the results of our second table we have had an excess of heat, which the last hypothesis would not account for, we shall, on the contrary, meet with a considerable deficiency, when we come to consider those of the third table.

For instance, our tube filled with well-water, including the glasses at the end, intercepted 211 rays of light. These, at the rate of 606 to the thousand, would produce only a stoppage of 128 rays of heat; but here we find no less than 558 of them intercepted. To evade the pressure of these consequences, it may be said, "that as before every invisible ray was supposed to "have been transmitted through glasses, so they may now be all "intercepted by liquids." And, granting this also to be possible, though by no means probable, for the great extent of these researches has not allowed sufficient time for many experiments to be made that have been planned for execution; yet, even then, 128 visible and 394 invisible rays to be intercepted, will only make up 522; so that a deficiency of 36 must still remain.

In sea-water, the balance will stand thus: 288 rays of light give 175 rays of heat; these and 394 invisible rays make up 569; but the rays actually intercepted were 682, which argues a deficiency of no less than 113 rays.

But if I have for a moment admitted the entire stoppage of the invisible rays of heat in liquids, the same indulgence cannot be granted for the empty tube, as we know it does neither take place in glasses, nor in air. Therefore we must calculate thus: this compound of glass and air stops 204 rays of light; these can amount only to 124 rays of heat; but it is found to stop 542 of them, so that 418 remain to be accounted for. Now, we certainly can not suppose more than 100 of them to owe their deficiency to the store of invisible heat; so that 318 will still remain unaccounted for.

And thus, from the second table, we have given instances where the assumed hypothesis of visible and invisible heat, in certain proportions, would require a greater stoppage than our experiments will admit; and now, on the contrary, it appears, that interceptions calculated according to the same hypothesis, should be less than the results in the third table give them. From which we conclude, that every other proportion fixed upon, would always be erroneous, either in excess or in defect.

Equal contradictions may be shewn to attend all endeavours to account for the results contained in our fourth table, by admitting any visible heat at all, let the quantity be what it will. To make the proof of this general, let 1000 be the total heat, and assume x for that part of it which we would suppose to be occasioned by visible rays; then will 1000 — x be the remainder, which must be ascribed to rays that cannot be seen. Now, by our table, we find that crown glass, of which one side has been rubbed on emery, stops 854 rays of light. These alone, if not a particle of invisible heat were stopped, would be equal to ,854 x visible rays of heat, that must be intercepted by the glass. When the other side of this glass has also been rubbed on emery, it will stop 932 rays of light, which will give ,932 x, for the quantity of heat to be intercepted, on the same supposition, that all invisible rays of heat are transmitted. But, by our fourth table, we have the actual stoppage of heat of these glasses; which will therefore give us the two following equations; $,854\, x = 464$, and $,932\, x = 667$. Then, taking the first from the last, and reducing the remaining equation, we obtain $x = \frac{203}{,078}$, for the visible part of the total heat. But $\frac{203}{,078}$, or 2602, being only a part, comes out greater than 1000, which is the whole; and this being absurd, it follows that visible rays of heat cannot be admitted, in any proportion whatsoever. This will equally hold good with any additional stoppage of invisible heat, provided it be equal in both glasses; and, of this equality, the 165th and 167th experiments can leave us no room to doubt.

But it is high time that we should now take into consideration a more direct proof, which may be drawn from our prismatic experiments. The results of them are here brought into a table, as follows.

TABLE V.

Stoppage of prismatic Heat of the Refrangibility of the Red Rays, and of the Invisible Rays.

	Red rays.	Invisible rays.
Bluish-white glass stops	375	71
Flint glass	143	000
Crown glass	294	182
Coach glass	200	143
Iceland crystal	200	——
Calcinable talc	133	250
Dark-red glass	692	000
Orange	500	273
Yellow	417	200
Pale-green	588	375
Dark-green	786	500
Bluish-green	462	800
Pale-blue	700	750
Dark-blue	71	167
Indigo	367	222
Pale-indigo	313	250
Purple	444	273
Violet	400	250
Crown glass, one side rough	389	600
Coach glass, ditto	500	500
Crown glass, both sides rough	471	600
Coach glass, ditto	833	714
Calcined talc	737	889

As a necessary introduction to the decisive experiment I am going to analyse, I must remark, that it has been shewn in a former Paper, that the prism separates invisible heat from the coloured spectrum, by throwing that which is less refrangible than light to one side. But it has also been proved, that heat of the same variety in refrangibility as the different colours, is likewise contained in every part of the coloured spectrum. The question which we are discussing at present, may therefore at once be reduced to this single point. Is the heat which has the refrangibility of the red rays occasioned by the light of these rays? For, should that be the case, as there will then be only one set of rays, one fate only can attend them, in being either transmitted or stopped, according to the power of the glass applied to them. We are now to appeal to our prismatic experiment upon the subject, which is to decide the question. First, with regard to light, I must anticipate a series of highly interesting observations I have made, but which, though they certainly claim, cannot find room in this Paper. These have given me the means of acting separately upon either of the extremes, or on the middle of the prismatic spectrum; and by them I am assured that red glass does not stop red rays. Indeed the appearance of objects seen through such coloured glasses, till I can give those observations, will be a sufficient proof to every one that they transmit red light in abundance. Next, with regard to the rays of heat, the case is just the reverse; for, by our preceding table, the red glass stops no less than 692, out of a thousand, of such rays as are of the refrangibility of red light. The incipient stoppage, moreover, or that in two minutes, of which something will be said hereafter, amounts even to 750 rays.

Now, if it should be suspected, "that on account of the great "breadth of prism, some invisible heat may be thrown upon the "spot where the red colour falls," I do not only agree to it, but am certain it cannot be otherwise: but this again, will give additional weight to our present argument; for, by the 153d experiment, as our last table shews, it has already been ascertained, that all such heat will be transmitted through a red glass; so that, were it not for some of this admixture, the stoppage might be still greater.

Here then we have a direct and simple proof, in the case of the red glass, that the rays of light are transmitted, while those of heat are stopped, and that thus they have nothing in common but a certain equal degree of refrangibility, which, by the power of the glass, must occasion them to be thrown together into the place which is pointed out to us by the visibility of the rays of light.

The manifest use of the union of these rays, arising from their equal refrangibility, will be explained at a future opportunity, when I may perhaps throw out several hints that have already occurred to me, where the contents of this Paper may be applied to the useful purposes of life.

There still remains a general argument, that heat and light are occasioned by different rays, which ought not to be omitted. This, on account of the contracted state in which the experiments have been given, cannot appear from my Paper; but, by an inspection of them at full length, it is proved, that the stoppage of solar heat, setting aside little irregularities, to which all observations are liable, has constantly been greater in the first, second, or third minute, than in the fourth or fifth; or, more accurately, nearer the beginning of the five minutes, than about the end of them. Now this does not happen in the transmission of light, which, as far as we know, is instantaneous; at least a failure in the brightness of an object, when first we look at it through a glass, amounting to one, two, or even three minutes, could not possibly have escaped our observation. This seems to suggest to us, that the law by which heat is transmitted, is different from that which directs the passage of light; and, in that case, it must become an irrefragable argument of the difference of the rays which occasion them.

The surmise of a difference in the law of the transmission of heat and of light, is considerably supported by an argument drawn from circumstances of a very different nature. In the scattered transmissions arising from rough surfaces, we find, that when crown glass, for instance, has one of its sides rubbed on emery, it will stop 205 rays of heat more than while that surface remained polished; but the effect of the roughness produced by emery scratches, is far more considerable on the rays of light; the additional stoppage of them amounting to no less than 651.

A confirmation of the same effect we have in coach glass; which, having also one side rubbed on emery, stops only 357 rays of heat more than it did before, while there is an additional stoppage of rays of light, amounting to no less than 717. Now, since the interior construction of these glasses, before and after having been rubbed on emery, remains the same, these remarkable effects can only be ascribed to the roughness of their surfaces. Hence, we may conclude, that as the same cause, when it acts upon the rays of heat and light, produces effects so very different, it can only be accounted for by admitting the rays themselves to be of a different nature, and therefore subject to a different law in being scattered. It has already been shewn, that the rays of heat are, upon an average, less *refrangible* than those of light; and now it appears that they are also, if I may introduce a convenient term, less *scatterable*.

We ought now also to take a short review of the phænomena attending the transmission of terrestrial heat. The results of the experiments which have been given, are drawn into one view in the following table.

TABLE VI.

	Rays of flame.	Fire.	Invisible heat.
Bluish-white glass stops	625	750	700
Flint glass	591	750	533
Crown glass	636	722	783
Coach glass	458	714	625
Iceland crystal	516	756	726
Talc	375	713	615
Very dark red glass	636	613	——
Dark-red	526	573	630
Orange	560	643	524
Yellow	583	685	531
Pale-green	500	688	632
Dark-green	739	745	700
Bluish-green	652	696	556
Pale-blue	609	676	548
Dark-blue	619	704	632
Indigo	679	721	659
Pale-indigo	571	655	700
Purple	520	679	730
Violet	500	615	684
Crown glass, one side rough	741	723	775
Coach glass, ditto	667	758	741
Crown glass, both sides rough	615	791	833
Coach glass, both	680	854	769
The two last but two, together	720	849	——
The two last together	667	897	——
The four last together	870	902	——
Olive-colour, burnt in glass	792	849	636
White paper	792	912	535
White linen	690	910	457
White persian	593	829	——
Black muslin	565	706	——

Let us now examine what information we may draw from the facts which are recorded in this table. The first that must occur is, that a candle which emits light, is also a copious source of invisible heat. If this should seem to require a proof, I give it as follows.

That the candle emits heat along with light, the thermometer has ascertained; and, that a considerable share of this at least must be invisible, follows from comparing together the quantity of light and heat which are stopped by different glasses. The bluish-white one, for instance, stops 86 rays of light, and 625 of heat. Hence, if only visible rays of heat came from the candle, a glass stopping more light, as for instance the dark-red glass, which stops 999,8, ought to stop all heat whatsoever; but the fact is, that it even stops one hundred rays less than the former.

This instance alone shews plainly, that the existence of invisible terrestrial heat in the flame of a candle, is proved; while, on the contrary, heat derived from rays that are visible, remains yet to be established, by those who would maintain that there are any such. But, for the sake of argument, let us endeavour to explain how visible rays of heat may be reconciled with the contents of our 6th table.

" Now although we must allow," it may be said, " that there " is a certain quantity of candle-heat which cannot be seen, we " are however at liberty to assign any ratio that this may bear to " its visible heat-rays. Let us therefore begin with the bluish- " white glass, and make the most favourable supposition we can, " in order to explain its phænomena. Visible or invisible, it stops " 625 rays of heat, and also 86 of light. Now, as in the last " column of the table we have likewise the proportional quantity " of invisible heat it intercepts, which is 700 out of a thousand, "we may surmise that the 914 rays of light, together with the "300 of the invisible rays which are transmitted, make up the 375 "rays of heat which pass through the glass. Hence, by algebra, "we have the number of invisible heat-rays 878, and the number "of the visible ones 122. Then, to try how this will answer, if "1000 rays of light give 122 of heat, 86 will give 10; and, if "out of a thousand invisible rays 700 be stopped, 878 will give "615 to be intercepted. The sum of these will be 625, which is "exactly the number pointed out by our table." Now this being a fair solution of one instance, let us see how it will agree with some others.

Before I proceed, however, I cannot help remarking, that the supporters of visible heat-rays must feel themselves already considerably confined, as our present argument will not allow them more than 122 of such rays out of a thousand.

Now, if the assumption that terrestrial heat is owing to a mixture of visible and invisible rays, in the proportion of 122 of the former to 878 of the latter, be well founded, it ought to explain every other phænomenon collected in our table.

The purple-coloured glass stops 993 rays of light, which, according to our present hypothesis, should stop 121 rays of heat: it also stops 730 invisible rays, which will give 641 rays of intercepted heat; therefore this glass should stop 762 rays of heat, out of every thousand that come from a candle; but, from our table, we find that it stops no more than 520, so that 242 rays cannot be accounted for.

The glass with an olive colour burnt into it, stops 984 rays of light, or 120 of heat, and 637 invisible rays, or 559 of heat. The sum is 679 which that glass should stop; but it stops actually 792; so that, as in the foregoing instance we had a deficiency of 242 rays, we now have an excess of 113; which plainly shews, that no hypothesis of any other proportion between the visible and invisible rays of heat can answer to both cases; and that consequently, not only the present, but every other assumption of this kind, must be given up as erroneous.

I shall not enlarge on these arguments, as I take them to be sufficiently clear to decide the question we have had under consideration. I also forbear going into an examination of what our sixth article, which treats of scattered heat, might afford, in addition to the former arguments. It may just be remarked, that the 211th experiment points out a black object, which scatters more heat than a white one; while the case, as to light, is well known to be the reverse. The 219th experiment also shews, that the scattering of heat of gold paper is considerably inferior to that of black velvet; whereas a contrary difference, of a very great extent, is pointed out between these two substances; for black velvet scatters only 7 rays of light, while the scattering of gold paper amounts to more than 124000. I am well aware that this difference will perhaps admit of a solution on other principles than those which relate merely to the laws of scattering, and confess that many experiments are still wanting to complete this article, which cannot now be given; but, as this Paper is already of an unusual length, I ought rather to apologize for having given so much, than for not giving more.

Table of the transmission of terrestrial scattered Light through various Substances; with a short Account of the Method by which the Results contained in this Table have been obtained.

The transmissions here delivered are called terrestrial and scattered, to distinguish them from others, which are direct and solar; and, in the use I have made of them in the foregoing Paper, it has been supposed that light-making rays, whether direct and solar, or scattered and terrestrial, are transmitted in the same manner; or that the difference, if there be any, may not be considerable enough to affect my arguments materially. In this I have only followed the example of an eminent optical writer, who does not so much as hint at a possibility that there may be a difference. Before I describe my apparatus, I ought to mention that it is intirely founded on the principles of the author now alluded to,* and that no other difficulty occurs in the execution of his plan, than how to guard properly against the scatterings of the lamp: for the light which this will throw on every object, must not be permitted to come to the vanes; since these scatterings cannot remain equal on both vanes, when one of them is moveable. In the following construction, the greatest difficulties have been removed; and a desirable consistency in the results of the experiments, when often repeated, has now been obtained.

A board about fourteen feet long, and six inches broad,† has two slips of deal, an inch square, fastened upon the two sides: these make a groove, for two short pieces to slide in, backwards and forwards. The two sliding pieces‡ carry each a small

* See *Traité d'Optique*, page 16, Fig. 5; *Ouvrage posthume de* M. BOUGUER.

† See Plate XXVI. Fig. 1. ‡ See Fig. 2 and 3.

board or vane; one towards the right, the other towards the left; but so as to meet in the middle, and apparently to make but one when placed side by side. The vanes are covered with a piece of fair white paper, which is to reflect, or rather to scatter light in every direction. To one end of the board is fixed a circular piece of wood, with an opening in it, which is afterwards to be shut up by a small moveable piece,* intended for placing the transmitting objects upon. This moveable piece contains two holes, at the distance of $1\frac{1}{2}$ inch from centre to centre, and $\frac{3}{4}$ inch in diameter each. Against the circular wooden screen, and close over the opening in it, is placed a lantern containing a lamp.† Its construction is such as to admit a current of air to feed the flame from below, by means of a false bottom, and to let it out by a covered roof; and the whole of the light, by the usual contrivance of dark lanterns, is thus kept within, so as to leave the room in perfect darkness. In the front, that is towards the vanes, the lantern has a sliding door of tin-plate, in which there is a parallelogrammic hole, covered with a spout five inches long, of the same shape. Two or three such doors, with different spouts and openings, will be required to be put in, according to the experiments to be made; but the first will do for most of them.

A narrow arm is fastened to the long board, which advances about three feet beyond the screen, and carries a circular piece of pasteboard, that has an adjustable hole in the centre, through which the observer is to look when the experiments are to be made. At the farther end of the long board is a pulley, over which a string, fastened to the back of the slider that carries one of the vanes, is made to pass. This string returns under the

* See Plate XXVI. Fig. 4. † See Fig. 5.

bottom of the long board, towards the other end, where, close to the observer, another pulley is fixed; and, after going also over this pulley, it returns at the top of the board, to the front of the same vane, to which the other end of it is fastened at the back. By pulling the string either way, the observer may bring forward the moveable vane, or draw it back, at pleasure.

At the side of the long board is a scale of tens of inches, numbered from the place of the flame of the lamp, 0, 10, 20, 30, 40, and so on to 160. A pair of compasses being applied from the last ten towards the vane, ascertains its distance from the flame, to as great an accuracy as may be required.

When the transmitting power of a glass is to be tried, it must be placed over one of the holes of the small moveable piece, which then is fastened with a button, upon the opening left for it in the circular wooden screen. Then, looking through the hole of the pasteboard at the two vanes, and bringing that which is seen through the glass near enough to give an image equally bright with that which is seen through the open hole, the observation will be completed. Having measured the odd inches by a pair of compasses, or immediately by a scale, we deduce, as usual, the transmitting power, by taking double the logarithm of the distance of the farthest vane from the lamp, from double the logarithm of the distance of the nearest vane. The remaining logarithm is that of the transmitting power, as compared to the light coming directly to the eye from the other vane.

I have now only to remark, that the use of this instrument requires some practice, especially when coloured glasses are to be examined; it will, however, be found, that the difference of the colour of the two objects, when their light is brought to an equality, may be overcome by a little abstraction, which is required for the purpose; for, by attending only to brightness, it has often happened to me, that both objects appeared at last of the same colour; which proved to be some mean between the two appearances considered separately.

Some glasses stop so much light, that it will be advisable to take them by the assistance of an intermediate one. Thus, instead of comparing the open vane directly to a red glass, I settle first the ratio of the violet one to that vane; then, taking the ratio of the red to the violet, and compounding these two ratios, the result will be more accurate. The reason for this will be easily comprehended, when the construction of the apparatus is considered. For a red glass, immediately compared to the open vane, would require its object to be brought extremely near the lamp, while the other must remain at a very great distance. This would occasion a considerable difference in the angles, both of incidence and of reflection, between the rays falling on one vane, and on the other. But, by dividing the observation into two operations, we avoid the errors that might be occasioned by the former arrangement.

In the following table, the first column contains the names of the different substances through which light has been transmitted. The second column shews the transmission of light, expressed in decimal fractions; or the proportion which it bears to the whole incident light considered as unity. An arithmetical complement to this fraction, or what it wants to unity, will therefore give us the proportion of light which is stopped by each of the substances contained in the first column; and that quantity multiplied by 1000 is placed in the third column.

TABLE VII.

Substances without colour.	Transmission.	Stoppage.
Bluish-white glass - -	,914 -	86
Flint glass - - -	,966 -	34
Crown glass - - -	,797 -	203
Coach glass - - -	,832 -	168
Iceland crystal - - -	,850 -	150
Talc - - - -	,910 -	90
Easily calcinable talc - -	,712 -	288
Glasses of the prismatic colours.		
Very dark red glass - -	,0001335 -	999,9
Dark-red glass - - -	,000188 -	999,8
Orange glass - - -	,221 -	779
Yellow glass - - -	,681 -	319
Pale-green glass - - -	,465 -	535
Dark-green glass - -	,0511 -	949
Bluish-green glass - - -	,231 -	769
Pale-blue glass - - -	,316 -	684
Dark-blue glass - -	,199 -	801
Indigo glass - - -	,000281 -	999,7
Pale-indigo glass - -	,0218 -	978
Purple glass - - -	,00675 -	993
Violet glass - - -	,0452 -	955
Liquids.		
Empty tube and two glasses -	,796 -	204
Well-water and ditto - -	,789 -	211
Sea-water - - -	,712 -	288

Liquids.	Transmission.	Stoppage.
Spirit of wine and two glasses	,776	224
Gin	,374	626
Brandy	,00381	996

Scattering Transmissions.

Crown glass, one side rubbed on emery	,146	854
Coach glass, ditto	,115	885
Crown glass, both sides rubbed on emery	,0685	932
Coach glass, ditto	,0542	946
The two first, together	,03158	969
The two next, together	,0208	979
The four first, together	,00456	995
Olive colour, burnt in glass	,0160	984
Calcined talc	,00345	997
White paper	,00556	994
Linen	,0483	952
White Persian	,0841	916
Black muslin	,263	737

Table of the proportional terrestrial Light scattered by various Substances.

The same apparatus which has been used to gain the results of the preceding table, has also been employed for the following one, with no other difference than that while the vane with the white paper remained on one side, the other vane was successively covered by the objects whose power of scattering light was to be ascertained, and both vanes were viewed directly through the two open holes in the screen; the eye being stationed in the same place as before.

It will be found, that this table contains the scattering of more objects than have been referred to in the preceding paper; but, as I made these experiments in a certain order, I thought it would be acceptable to give the table at full length.

The first column gives the names of the objects; and the second contains the number of rays of light scattered by them, when compared to a standard of white paper, which is supposed to scatter one thousand.

TABLE VIII.

White paper scatters - - -	1000 rays of light.
Message card - - -	1000 - -
White linen - - - -	1008 - -
White cotton - - -	1054 - -
White chamois leather, smooth side -	1228 - -
White worsted - - -	620 - -
White Persian, suspended - -	671 - -
White Persian, on whitish-brown paper -	719 - -
White Persian, on white Persian -	818 - -
White muslin - - -	827 - -
Red paper - - - -	158 - -
Deep pink-coloured paper - -	513 - -
Pale pink-coloured-paper - -	621 - -
Orange paper - - - -	619 - -
Yellow paper - - -	824 - -
Pale-green paper - - -	549 - -
Dark-green paper - - -	308 - -
Pale-blue paper - - -	665 - -
Dark-blue paper - - -	149 - -
Indigo paper, with a strong gloss -	144 - -

Dark-violet paper scatters - -	75	rays of light.
Brown paper - - -	101	- -
Black paper, with a strong gloss -	420	- -
Black satin - - -	102	- -
Black muslin, suspended - -	64	- -
Black muslin, upon black muslin -	18	- -
Black worsted - - -	16	- -
Black velvet - - -	7	- -
Tin-foil - - - -	8483	- -
Iron - - - -	10014	- -
Copper - - - -	13128	- -
Brass - - - -	43858	- -
Gold-leaf paper - - -	124371	- -

I cannot help remarking, that in making these last experiments, I found that black paper could not be distinguished from white; and that, on bringing it a little nearer to the light than it should be to make them perfectly equal, any of my friends who happened to be present, would mistake the black for the white.

EXPLANATION OF THE PLATES.

Plate XX, represents the spectrum of heat A, S, Q, A; and of light G, R, Q, G. If a prism be placed in a window, so as to throw the colours of light upon a table, and Plate XX be laid under the colours, so that they may respectively fall upon the places where their names are inserted, then may these colours be made to fit into their proper spaces, by lowering or raising the prism, at pleasure. When the colours occupy their proper situations, the line A Q will express the space over which the prism, by their different refrangibility, scatters the rays of heat; and the ordinates to A Q will nearly express the proportional elevations, which a set of equi-changeable thermometers would experience, when placed in the different situations of these ordinates.

Plate XXI. Fig. 1. A, B, is the box which holds the two thermometers, No. 1 and No. 5. C is the board which contains the transmitting holes, the slip of wood for supporting the glasses, and the perpendicular pin for adjusting the angle. D, E, are the boards joined together by hinges. F is a slip of mahogany screwed to E. G is the spring to confine the slip F; which will keep the board D up to any angle less than 90 degrees.

Fig. 2, is the cover for shutting the transmitting holes.

Plate XXII. Fig. 1, is the screen, which may be elevated, by the usual contrivance of springs at the back, to any required height, so as to permit the rays of the sun to pass through the opening in the middle, and to fall upon the transmitting holes of the box A, B, in Plate XXI.

Fig. 2, is a second upper part of the box A, B, in Plate XXI. The first upper part being screwed off, this is to be put on instead of it, when experiments with liquids are to be made. It contains, as before, the two transmitting holes, the slip of wood, and the pin; and it has moreover a small bracket fastened under one of the holes, on which the tube containing the liquid to be tried may be laid.

Fig. 3, is a third upper part to the box A, B, of Plate XXI. It contains two small holes, for transmitting prismatic rays to the two thermometers A and B, which must now be put into the box, instead of No. 1 and No. 5. The parallel lines *a*, *b*, inclosing the holes, will direct any coloured rays to the thermometers; and, by drawing the red rays down to the lower parallels *c* or *d*, invisible rays may be brought to enter the transmitting holes.

Fig. 4, is a fourth upper part to the box A, B, Plate XXI. It contains two large holes, for admitting the rays of the sun to fall upon the objects on Fig. 5.

Fig. 5, represents two tablets, *a*, *b*, united; they may be covered with any objects that are to be examined; for instance, *a* with white paper, and *b* with black velvet. These tablets, by a proper contrivance, are brought under the holes of figure 4, where a button fastens them at the required distance.

Plate XXIII. Fig. 1. A, B, is the box which holds the thermometers. C, D, are the screens, with the transmitting holes in them, opposite the flame of E, the candle. F, is a small weight, stretching a string across the glass, or other object, placed upright against the transmitting hole of the screen D. It may be carried round the screen C, if required, and hold a glass against the hole in it.

Fig. 2, is the double cover: in putting it on, it must be passed over the candle downwards, against the two transmitting holes.

Plate XXIV, represents a large screen, with the shelf A, B, carrying four thermometers, No. 1 and No. 5 opposite the transmitting holes, and the other two as represented. When the fire is properly prepared, lift the screen, by taking hold a little above A and B, and set it close to the fire, so that C, D, may touch the bottom of the grate; then take hold of the ring E, and pull the string far enough out to hang that ring on the hook F: this will open the transmission holes, when the experiment is to begin.

Plate XXV. Fig. 1, is the box containing the thermometers.

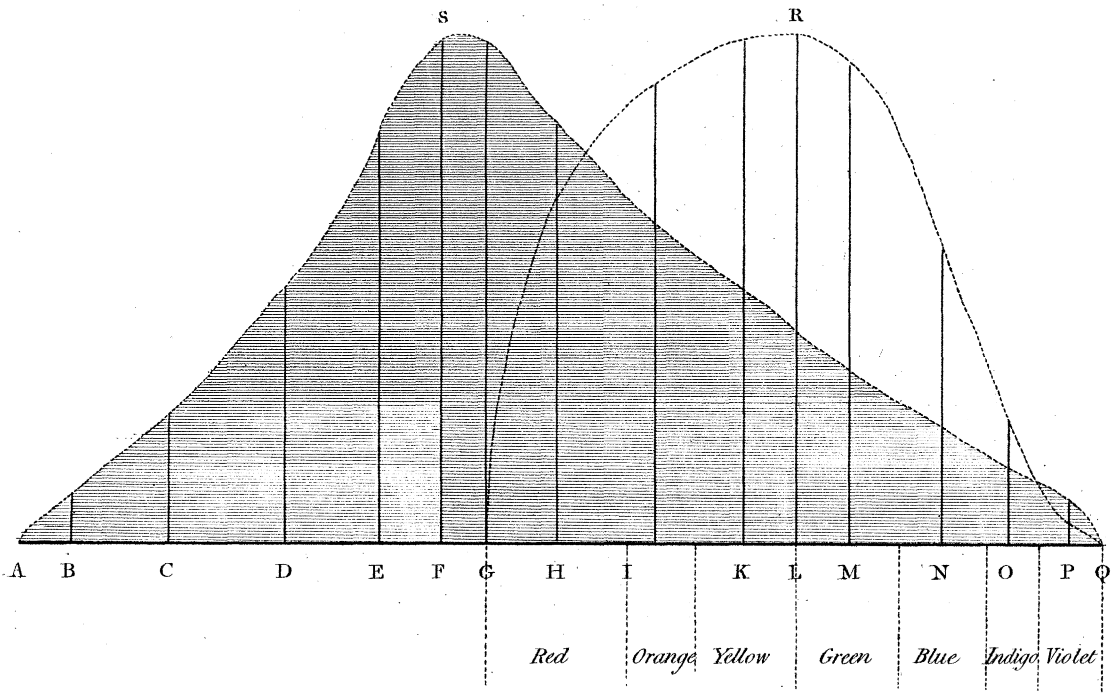
The bricks are piled up, as represented in Fig. 3. The stove, Fig. 2, being prepared, bring the stand, and brick-work, Fig. 3, close to it; and set also the two spare bricks, which lie on the stand, upon the front of the stove, that no heat may pass from the top of it to the brick inclosure; then put the box, Fig. 1, into the brick-work, close up to the stove, and begin the experiment. The ash-hole should also be covered with a brick.

Plate XXVI. Fig. 1, represents the Photometer. The hole at A, is for the observer to look through, that he may have a fixed station. The vanes F and G are moveable. By pulling the string at H, G will be brought nearer the lamp placed at K; and, by drawing the same string at I, it will be removed towards the vane F; which latter may be fixed at any distance most convenient for the experiment.

Fig. 2 and 3, shew the mechanism of the adjustable vane 2, and moveable one 3. There are, however, hooks on fig. 2, which will occasionally receive the strings from the hooks on fig. 3, when a motion of the left vane, instead of the right, is required.

Fig. 4, contains two limiting holes B, C; over one of which, C, a glass may be laid. This piece is to be buttoned on the rabbet of the screen, at D E, fig. 1. When liquids are to be tried, the second piece of fig. 4, which contains a bracket for supporting the transmitting tube, is to be fastened on D E, fig. 1, instead of the former plate.

Fig. 5, gives a view of the lamp and its sliding door, with the spout L, which, when the lamp is placed at K, fig. 1, conveys the light to the vanes F and G, without permitting it to be scattered on the long board.


S
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B
C
D
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Green
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Indigo
Violet

Basire sc.

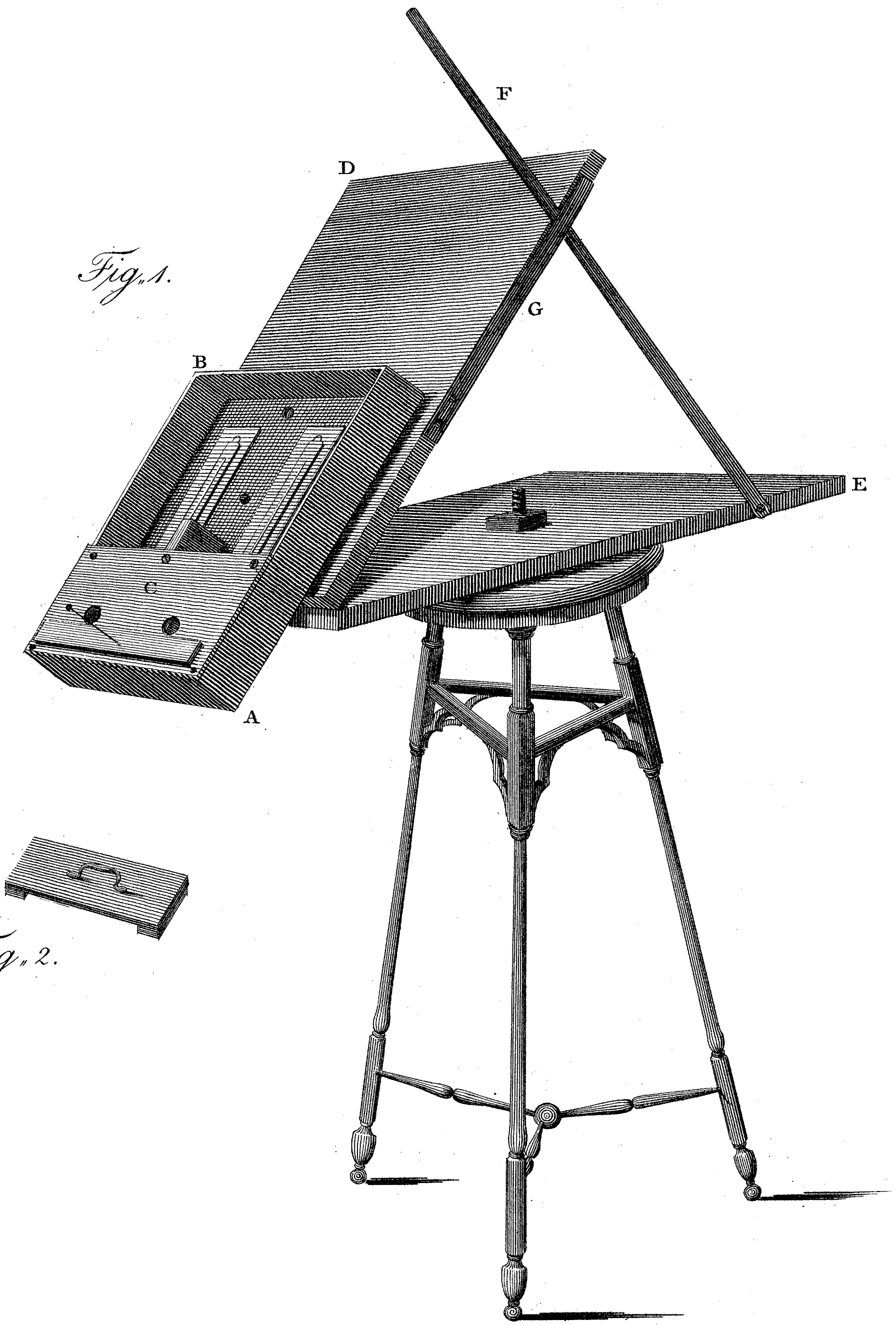


Fig. 1.

Fig. 2.

Basire sc.

Fig. 1.

Fig. 5.

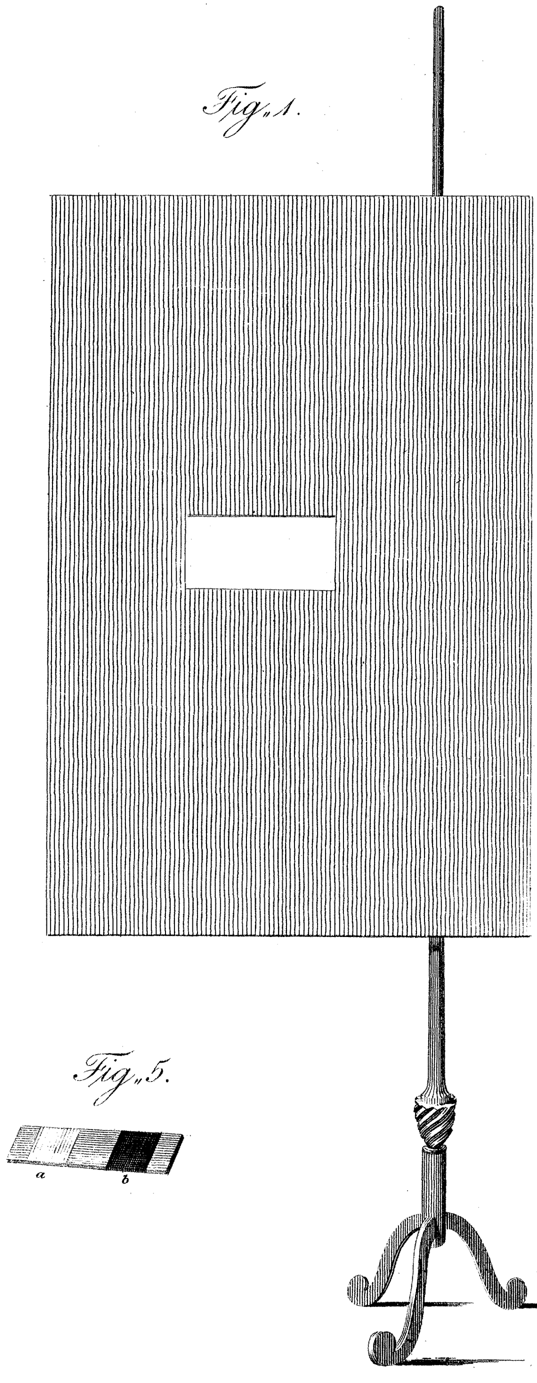


Fig. 2.

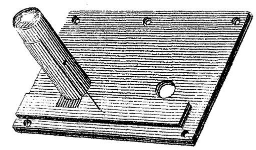


Fig. 3.

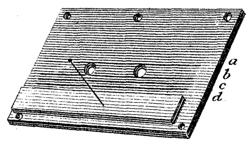
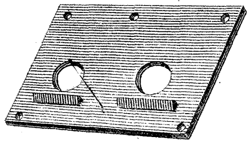


Fig. 4.



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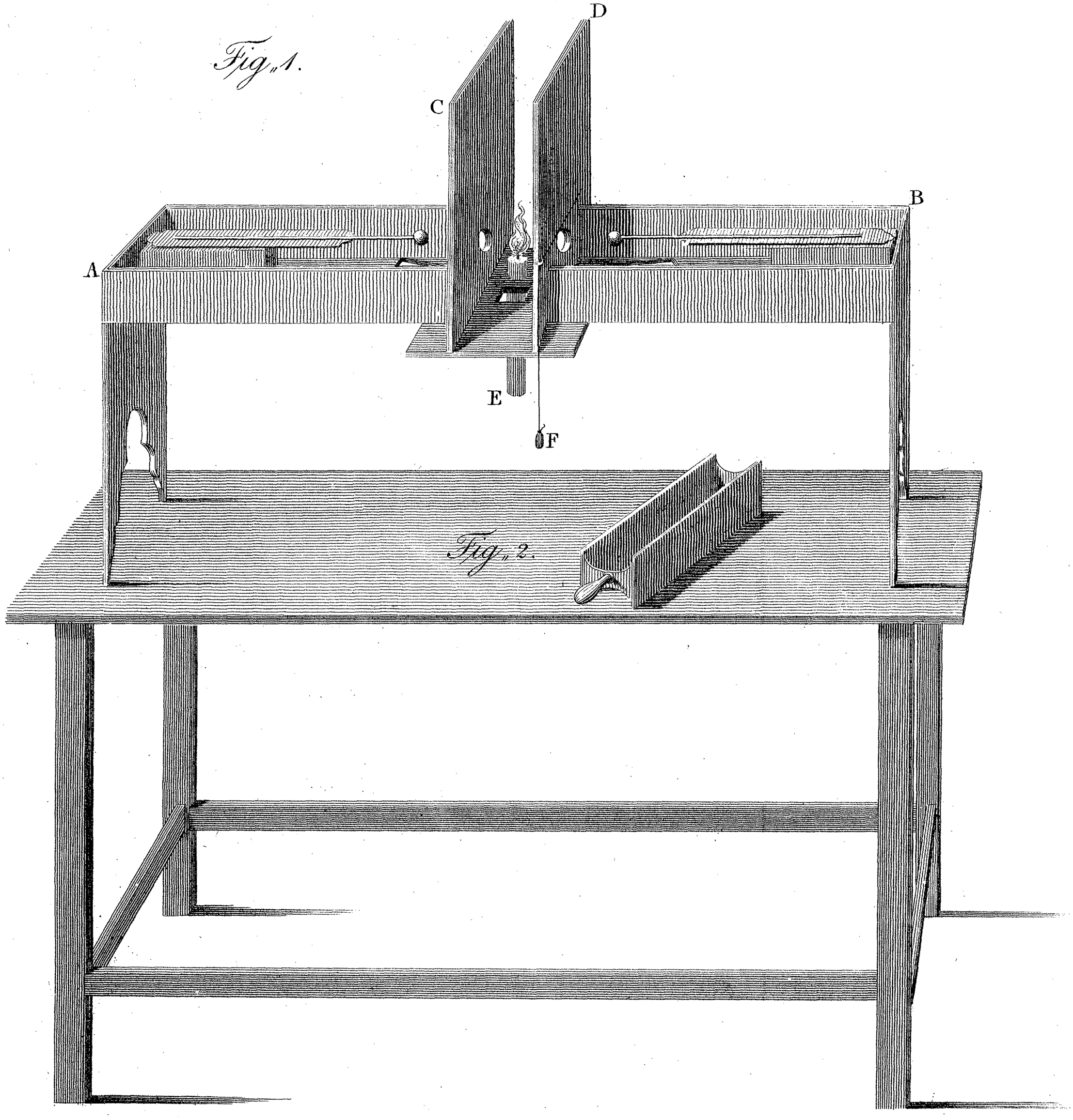

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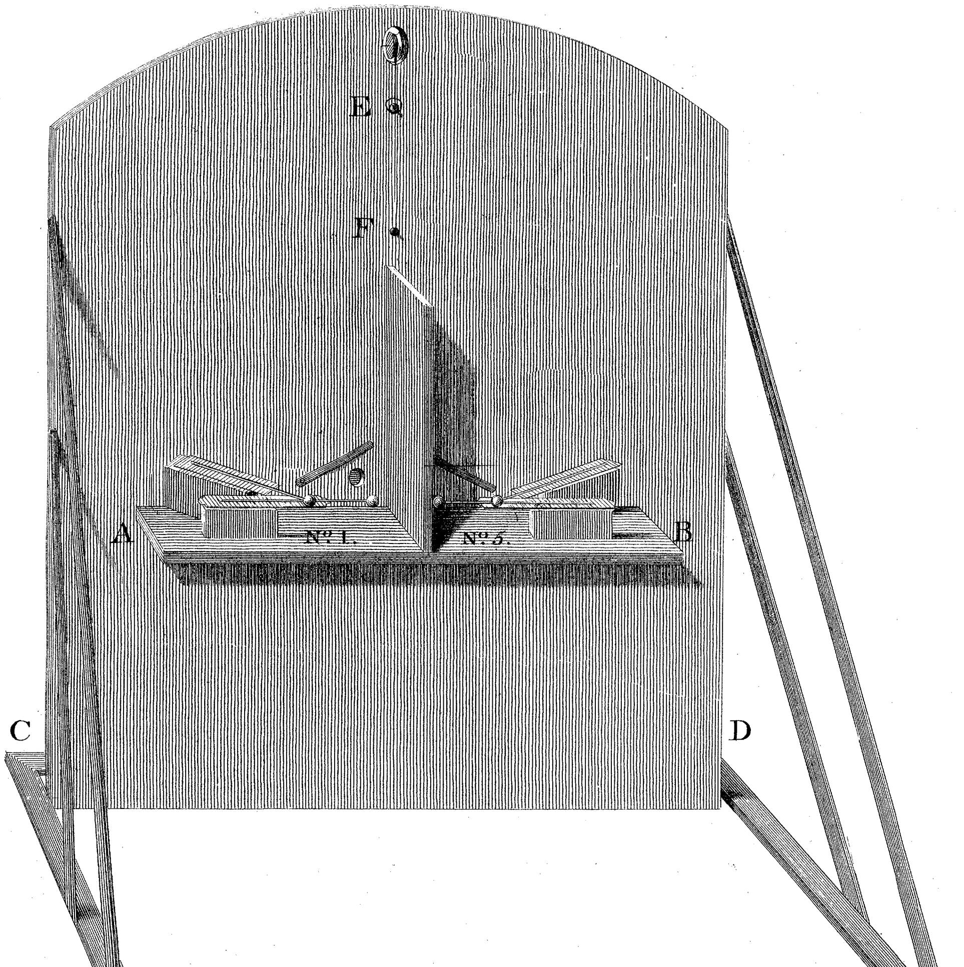

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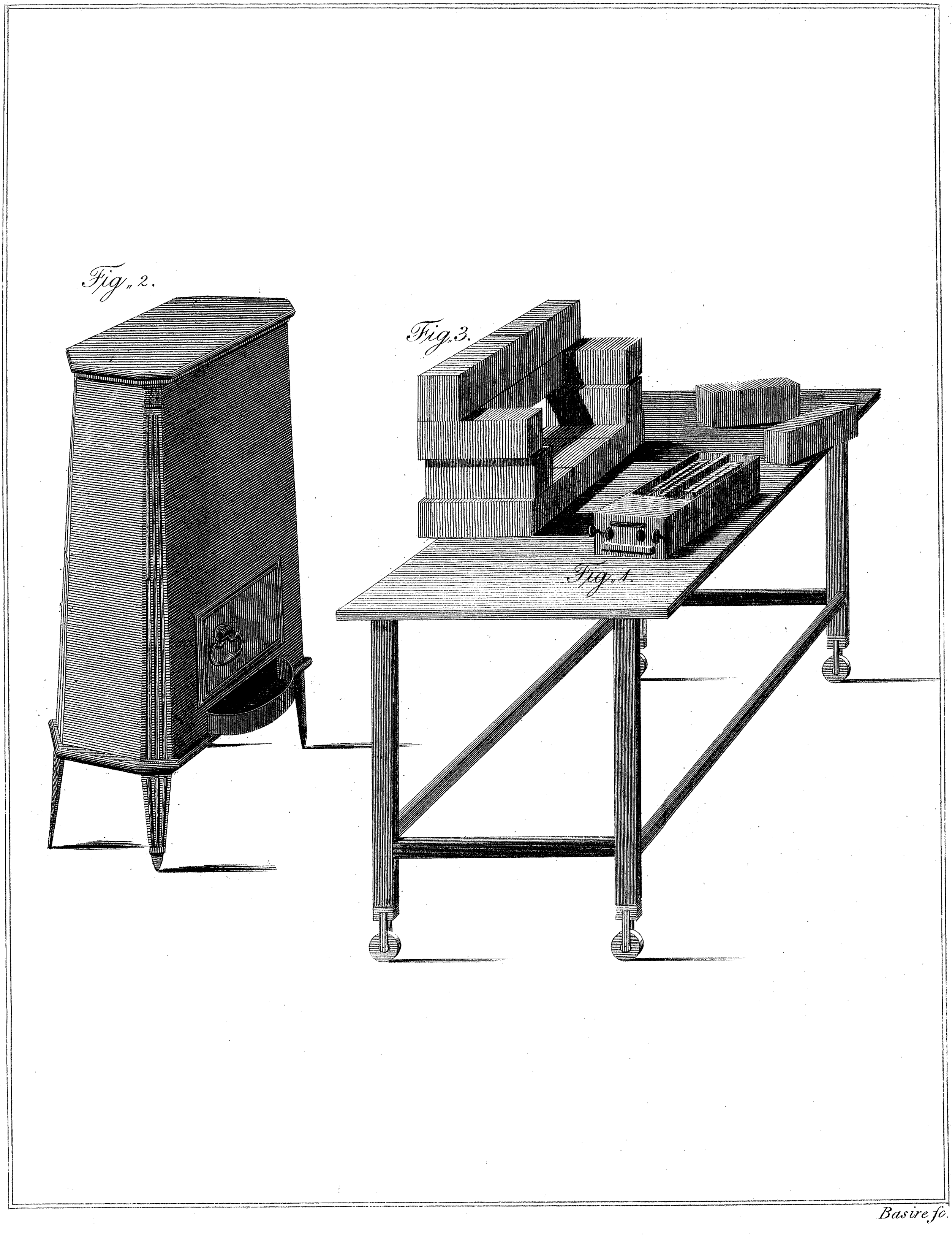

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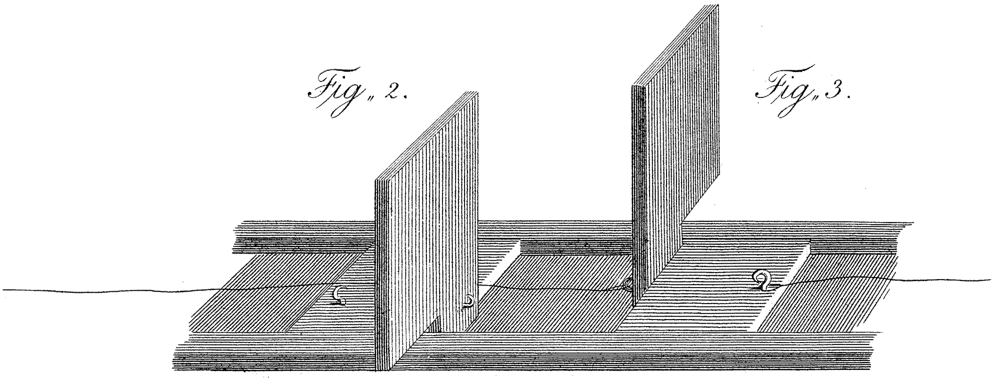
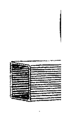
Fig. 2.

Fig. 3.





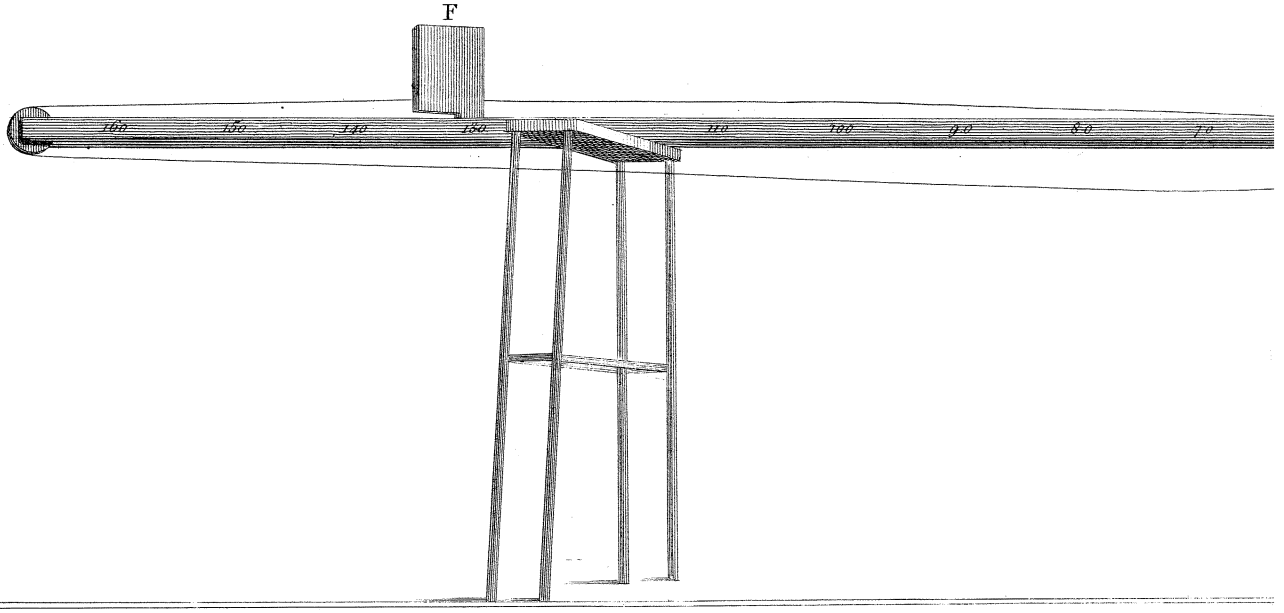


Fig. 5.

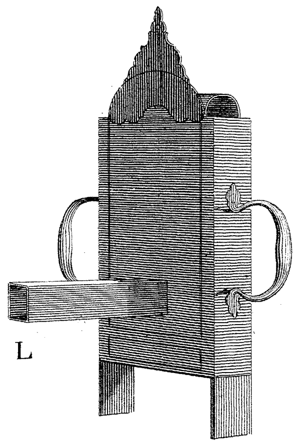


Fig. 4.

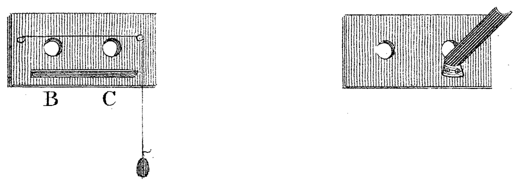
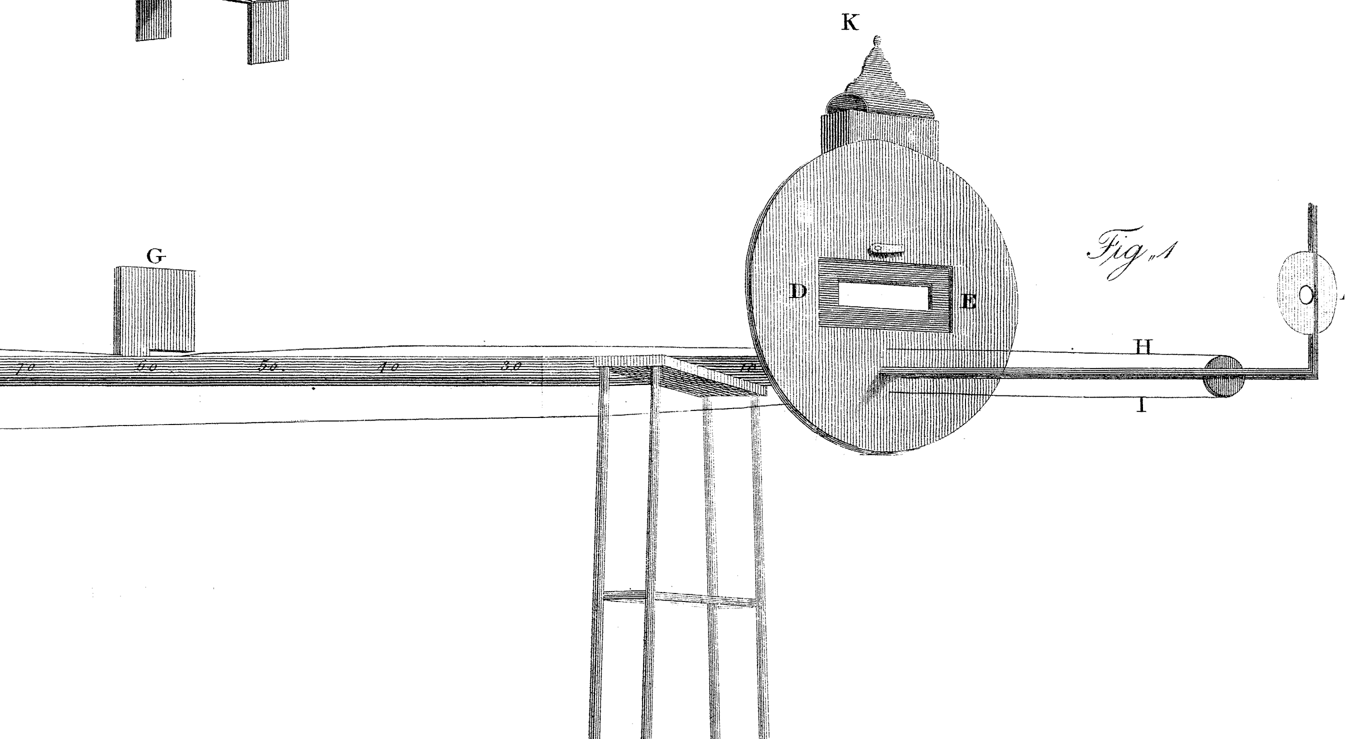


Fig. 1



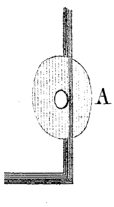


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Fig. 2. Fig. 3.

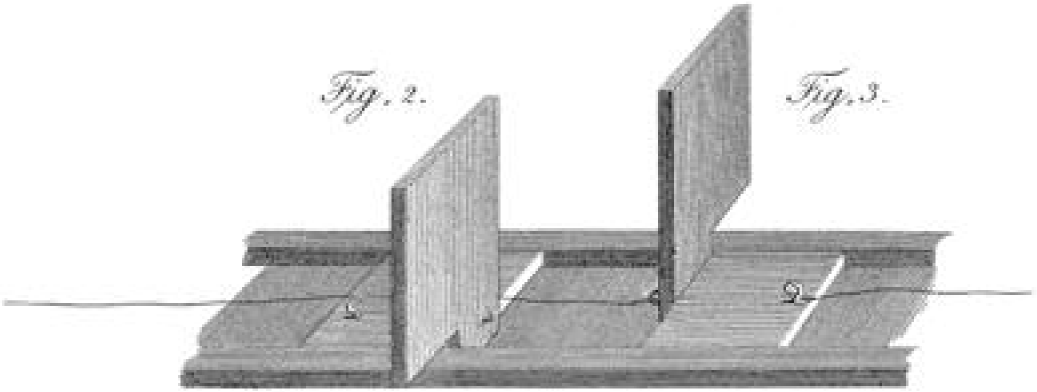

Fig. 5.

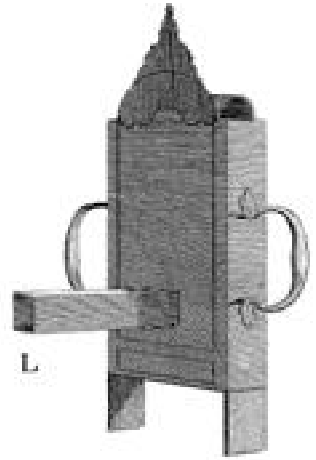

Fig. 4.

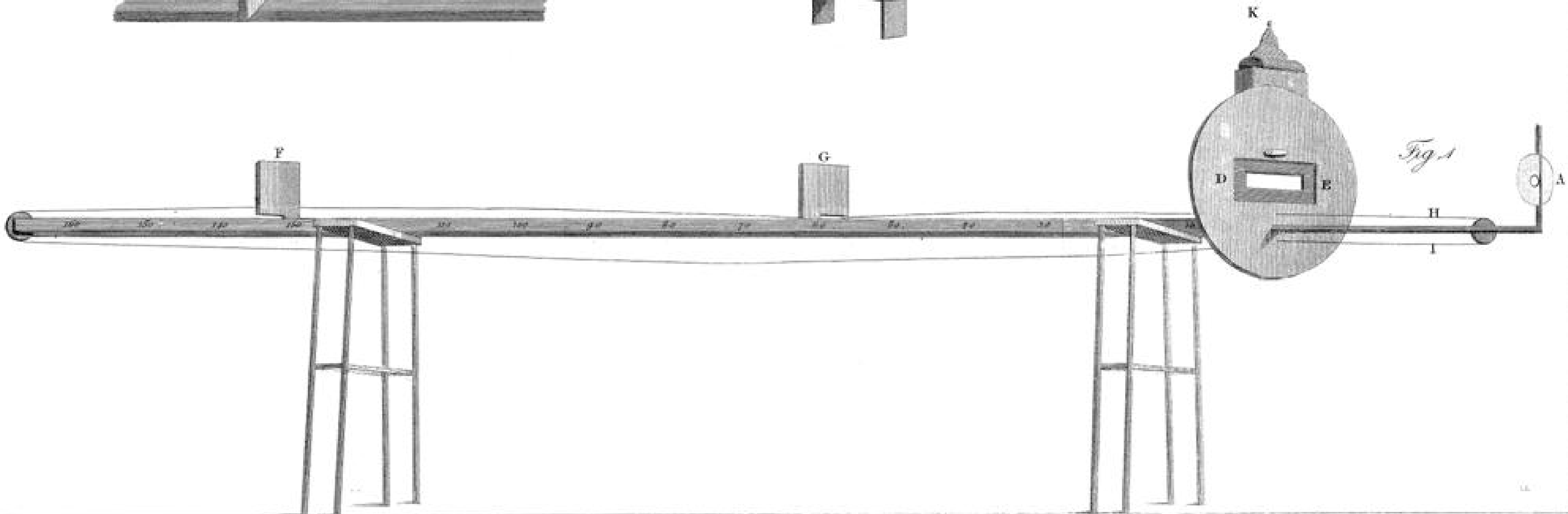

Fig. 1

Basire fc.