# Extracts from the papers of Sir Charles Wheatstone

## WHEATSTONE 4: Working papers and experimental observations relating to optics including polarisation, photometry, spectra and the characteristics of light, [1834-1875]

## K/PP107/4/1

[1834-1875]

Experimental notes by Charles Wheatstone, principally concerning the practical implications of reflecting and refracting surfaces in motion, comprising proposals to measure the velocity of light; experiments designed to investigate the phenomenon of the electric spark and electrical light; proposals to measure small intervals of time and human perception of rapidly moving points of light; the duration of luminous discharges including meteors; optical phenomena associated with a revolving cube; brief descriptions of experiments involving light houses performed in Ireland, with diagrams and sketches.

# The Papers of Charles Wheatstone

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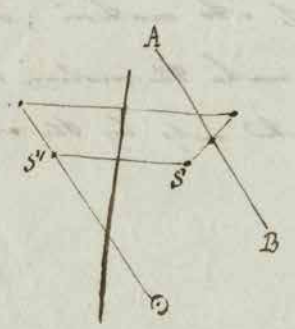
## To Measure the Velocity of Light.

### 1st Mode.

Place before the revolving mirror a charged jar and let it be discharged at the moment the mirror is perpendicular; at a considerable distance before it place a vertical, stationary, plane mirror. In the revolving mirror will be seen the reflection of the spark, and also the second reflection from the stationary mirror; the angular distance of the two sparks when the mirror is stationary, and when it is in motion, will indicate by their difference the ~~velocity of~~ angle in which light travels through double the distance from the spark to the mirror. One of the great difficulties in this apparatus will be to discharge the jar at the precise instant the mirror is vertical.

If the stationary be thus placed A.B the eye placed before the revolving mirror when stationary will see one image superpose the eye, and the degree of separation will indicate the velocity.




The spark being placed at S' and the eye at O let a line O S' be drawn to the image of S'; that the two reflections may superpose the mirror A.B must be parallel to this line.

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Instead of a reflecting surface, two sparks at the extremities of a long wire placed vertical to the mirror may be taken; in this case the time of electricity passing must be deducted.

K/PP107/4/1/2

Draft paper describing two methods of measuring the velocity of light using a rotating mirror, [quoted on page 67, Brian Bowers, *Sir Charles Wheatstone FRS 1802-1875*, HMSO Science Museum 1975, revised edition 2001], [1834-1840], page 1.

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2d Method

The method by the revolving mirror seem favorable from the facility of multiplying the apparent velocity by taking more first reflection in the revolving mirror; but the difficulty of estimating the angular deviation induced me to look for another method

For either of the preceding experiments substitute for the revolving mirror a small circular disk with a white surface and a fixed black radius. ~~The~~ If there is any difference of time between the two sparks, in the one case, or the spark and its reflected image in the other, when the disk is in motion two radii will be seen, and their angular distance will indicate the time. The sensibility is not so great as the mirror because the angular deviation cannot be observed so accurately, and in one revolution of the disk only one mark is made. The following arrangements may however in some measure overcome this imperfection

Instead of a disk cause to revolve only a single radius, but instead of regarding the radius itself look at its lengthened shadow cast on a card placed at right angles to the plane of its motion; or observe the radius itself by a telescope with a micrometer. Or make the revolving radius an object in a solar omnioscope, but illuminate only by the electric light.

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Draft paper describing two methods of measuring the velocity of light using a rotating mirror, [quoted on page 67, Brian Bowers, *Sir Charles Wheatstone FRS 1802-1875*, HMSO Science Museum 1975, revised edition 2001], [1834-1840], page 2.

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New Optico-Electrical Experiments.

by

C. Wheatstone.

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In the course of an investigation of the phenomena of the electric spark in which I have recently been engaged, the following experiments incidently occurred ~~to me~~; these, though possessing no higher interest than that belonging to popular illustrations of science, may, from their novelty, still be deemed worthy a place in the Philosophical Magazine.

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The electric spark, whether obtained from the prime conductor of a machine, or from the discharge of a jar or battery, is so momentaneous in its duration as not to admit of comparison with any interval of time measurable by the most delicate ~~instrument~~ instruments in present use. The following experiment is a consequence and a proof of this instantaneousness.

Let a disk of card be made to rotate with considerable velocity by means of ~~the~~ any instrument with a multiplying wheel (Fig 1); if, while the rotation continues the disk be illuminated by ~~an electric spark~~ the discharge of a jar, the figure on ~~the~~ its surface will be seen perfectly stationary and as distinct as if it were at rest. This effect ~~results~~ admits of easy explanation; the duration of the spark being exceedingly transient is not at all comparable ~~that~~ with the motion of the disk, which therefore while ~~it~~ the spark lasts, ~~or~~ and illuminates the object, cannot advance in the slightest perceptible degree;

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Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 1.

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the apparent dwelling of the picture on the eye is owing to the well known physiological fact of the duration of luminous impressions on the visual organ. The vividness of the picture is increased by making the room as dark as possible; but the experiment is more effective when there is just sufficient light ~~in the room~~ to see the uniform surface of the revolving disk instantaneously succeeded by the fixed figure, which appears in this case to start into existence as by the touch of a magic wand.

It has been remarked, but I cannot call to mind my authority, that a flash of lightning during a sea storm at night renders all the surrounding objects visible in a state of unnatural tranquillity; and the flash ~~of lightning~~ which is nothing more than an enormous electric spark, has no sensible duration, must obviously be true; the motions of the masts, of the rolling ships, of the human beings who hurry along the deck or ascend the shrouds are slow and measurable in the comparison, and while the flash endures no motion of theirs can be perceptible to the eye. The apparent permanency of the picture is owing, ~~but~~ as in the preceding case, to the duration of the impression, which transforms as it were a stormy sea with its tumultuous objects into a picture of still life.

The rapidity with which two trains of carriages impelled by steam power, pass each other in opposite direction on a rail way, ~~is~~ renders the carriages of one train and the passengers which travel in them perfectly undistinguishable by a passenger in the other ~~train~~; but should the transit happen in a dark night at the instant a flash of lightning occurs, all the objects would be seen by him perfectly still, and should his eye chance to be directly towards him (?) he might even distinguish the features of an acquaintance. In a similar manner, a discharge of a jar or battery may be employed to ascertain the instantaneous position of a machine however rapidly and variously its parts may be moving. ~~I have made many experiments of this kind & important~~ This means of investigating the temporary positions ~~[illegible]~~ of rapid

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Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 2.

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motion has suggested to me several experiments of philosophical importance which it does not come within the scope of this paper to detail.

But to return from this digression to the second experiment of the series. Fig 2 represents a disk of wood to be screwed on the axis of the rotating machine; round the circumference of this disk are placed at equal distances small brass balls, in the figure, their number is sixteen; these balls are each connected by wire ~~on~~ which pass on the under side of the disk to a small metal ~~disk plate~~ ~~through it~~ connected with the axis. On placing the circumference of the disk within a proper distance of the prime conductor of a machine in action, or the knob of a charged jar, as many successive sparks will be drawn during the rotation of the disk as there are balls round its circumference. Care must be taken ~~in all~~ in the ensuing experiments (that no balls in passing shall omit drawing a spark otherwise they will not perfectly succeed.

Screw on this disk a card (Fig 3) ~~on the circum~~ on the surface of which is depicted a single figure not subtending a greater angle than ~~that~~ included between two radii joining the center and two successive knobs. On turning the disk and drawing the sparks, the object will be seen multiplied as many times as there have been sparks taken during one revolution of the disk. If there are 16 knobs ~~If~~ the object is a radial line a what with 16 spokes ~~star~~ will be the result, if a piece of money ~~it~~ 16 images of it will be visible arranged at equal distances in a circle &c. To understand this effect it must be recollected that when the card rotates illuminated by continuous light, images are sent to the eye from each place the object successively occupies, ~~and~~ and from the infinity of their superpositions the component picture at any place is entirely obliterated. A single instantaneous flash of light, if properly timed, shows the object in the place in which it conveniently exists, after this no image is ~~to~~ presented to the eye, because no

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Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 3.

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light is reflected from the object, until another flash succeeds; during this time the object has travelled ~~from~~ the angular distance between two knobs, it then appears again, and so on till all the knobs have discharged their sparks; if the motion be continued the ~~objects~~ multiplied images are rendered permanent.

If, instead of a single object, as many similar objects be regularly placed as there are knobs round the circumference, the appearance will be precisely the same as ~~in the previous instance~~ if there were only one object. As the multiplied images of each object must, if the sparks are regular, actually superpose each other. A wheel with 15 radii will therefore appear stationary.

A If the number of knobs and objects do not correspond each successive image of the disk will occupy a different position and the objects will appear multiplied. If these successive positions have an regular difference very little from each other and if the ~~[illegible]~~ be sufficiently slow ~~to~~ to allow time for the image on the retina upon to be effaced, the wheel will appear to have a slow progressive motion. This may be effected by ~~making the~~ increasing either the number of knobs or objects by unity.

The visual perception of motion is nothing more than that of the succession of images made to the eye by an object while its position changes. If therefore ~~instead~~ for the of similar objects, successive phases of the same object supposed in motion be substituted; their regular recurrence in the same place will give an exact representation of ~~the~~ an object in motion. ~~To illustrate by applying this principle~~ It is to the ingenuity of Prof. Plateau of Brussels that we owe the suggestion of ~~the~~ the means of thus representing natural & artificial motions by the succession of fixed pictures; for the purpose of obtaining intermittences of light recurring regularly as the pictures succeed each other in the same place he employed the means invented by Mr Faraday and which is above noticed. The amusing toy "the Phenakiscope", now so well known to need description.

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Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 4.

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In the optical means of exhibiting these phenomena there is always an certain indistinctness arising from the breadth of the slits for the figures to be perfectly unconfused these slits should be mathematical lines, and this is quite impossible, but it is necessary to have them of some breadth to admit a sufficient quantity of light to render them visible. These defects are entirely obviated in exhibiting these experiments by the electric light, the figures are then as sharp and distinct as when revolving at rest.

Now ~~all these~~ the Phantasmagoric figures may be exhibited to numerous spectators at once by ~~substituting for the slits the same number of balls~~ placing the card on the disk fig: when the balls move as substitutes for the slits corresponding in number and angular distance to them. The successive electric sparks drawn during the revolution of the disk, answer the same purpose as the intermittent glares through the successive slits at the reflected pictures.

A single electric spark ~~is only of~~ (sufficient intensity) to momentarily illuminate the entire disk, but a great accession of illuminating power may be obtained by the following variation in the experiment. Instead of allowing the electricity ~~spark~~ drawn by each ball to be immediately conducted to the earth, let all the balls be insulated, and a silk thread ~~being with the balls~~ (upon which are strung at short and equal distances a succession of metal beads) be connected with them all so as to complete the circle and draw the spark on the opposite side of the circumference by a ball held in the hand. Each ball when it passes the point conductor will as before draw a spark, but instead of afterwards passing invisibly to the earth, the ~~orbit~~ circle will be momentarily illuminated by all the sparks between the beads, as they pass

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Draft notes on experiments to measure the velocity of electricity and light, [1834-1840], page 1.

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A This is exactly analogous to Dr Faraday's well known experiment, in which a wheel delineated on a card disk appears stationary in a mirror, when seen through slits perforated at regular distances round the circumference of the disk, which ~~the card~~ itself is rapidly rotating. The slits moving before the eye allow the reflected picture to be seen only at intervals; and the image moving uniformly with the disk, the image is ~~seen~~ only at the moments of recurrence of similar positions; ~~therefore~~ the image consequently appears stationary.

B This again is analogous to, and was suggested by an experiment of Dr Faraday's. He found that if the number of apertures exceeded the number of objects on the disk by unity, the reflected disk appeared in the opposite motion.

From what has preceded, the following experiment will not be of difficult apprehension; ~~and~~ among all the electrical toys devised for the mere purpose of ~~pleasing the eye~~ there is certainly none that can vie with it in brilliancy and beauty; ~~the~~ and is remarkable for its mechanical variety, ~~of which it is~~ which ~~the principle on which they depend being understood, will suggest themselves to~~ in the forms which may be given to the illuminated moving figure.

Take a circular plate of glass, divide it into any number of sectors, and in the successive sectors, draw the concentric positions of the running motion of any object; on the lines thus drawn stick small dots of tin foil at equal distances from each other. Let the line at the circumference be terminated by a hollow metal ball or a pith ball covered with gold leaf and let the line near the centre of the plate be nearly in contact with a metal plate. ~~Now this~~ Attach this

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Draft notes on experiments to measure the velocity of electricity and light, [1834-1840], page 2.

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glass plate to the whirling machine, and ~~—~~ place it so as to rotate near the positive conductor of a machine. The balls at the circumference will draw sparks in succession, and each spark will in its passage to the centre of the plate, pass through and illuminate one of the sectors. The sectors representing successive positions of an ~~[illegible]~~ object supposed in motion, appearing after each other in the same place to the eye, the figures appear stationary as regards the ~~sectors~~ place they occupy, ~~[illegible]~~

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Draft notes on experiments to measure the velocity of electricity and light, [1834-1840], page 3.

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The mind cannot estimate an interval of time much shorter than the eighth of a second; nor can such small intervals be compared with any of the recurring motions usually employed to estimate time, such as the vibrations of a pendulum &c.

All visual appearances of less duration than that above stated appear to the eye of equal duration, and cannot be measured by any comparison with the usual instruments of time. No difference can be perceived by the eye between two flashes, one lasting the hundredth of a second, the other the millionth of a second.

If a luminous point change its place, with rapidity travelling over a given line; as it will be successively in all points of the line, and as the sense cannot determine which is the earliest of its appearances when the ~~appearances are~~ interval between them is less, or, than an certain small fraction of a second, the whole line will necessarily appear to the sense simultaneous. It is unnecessary therefore to infer, nor need it, from the apparent duration of the light, that there is ~~in~~ any peculiar property in the retina by which the impression remains ~~upon~~ it; if the retina possess any such property it must be inferred from other phenomena, not from this.

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Notes on experiments to measure an interval of time less than 8th of a second, [1834-1840], page 1.

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If a luminous point of limited duration describe, with an equable motion, a given line, the duration of the light will be directly as the space described and inversely as the velocity. Therefore, though the duration be very small, it may be ascertained if the velocity of the moving point and the magnitude of the space described be given. The space being as the velocity, the problem is limited to a knowledge of the velocity, and shorter durations will be capable of measurement in proportion as higher velocities are obtained. — If we wish to ascertain the interval between two successive sparks the same mode of estimation can be employed. (Ex. my first electric experiment.) The unilluminate space between the successive appearance of the sparks in this case will be measured.

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If a luminous impression lasted on the retina for a ~~[illegible]~~ definite time, a luminous point moving along a line should present the appearance of a moving line, the length of the line being determined by the duration of the impression, and ~~[illegible]~~ the velocity of the motion. The real appearances however are more in accordance with the supposition that the apparent duration arises from the incapacity of the mind to estimate duration or succession in extremely small intervals of time; there is a confusion, an uncertainty in the length of the line, which is similar to that case when the perceptions are disturbed, the mind is in fact puzzled. This being the case there can be little

doubt but that the apparent duration of light may be smaller as the sense is more cultivated in the same person.

The admission of this explanation will remove a great difficulty in the theory of vision. According to the ordinary notion the retina is excited into an after action of the same kind, and also into one of a contrary description; which seems very difficult to conceive. I think it more probable that the phenomena of ocular spectra arise from a real duration of a physiological effect, while what is called the duration of luminous impression is an illusion arising solely from the limitations imperfections of our perceptions.

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It is easy to make a mirror revolve as rapid as one hundred times in a second, but it is a matter of considerable difficulty by any means in use to regulate this motion to a constant velocity without any fluctuation. The means now employed are 1st by attaching to the machine a registering apparatus to be compared with a pendulum or chronometer & 2dly Mr Dunlin's tachometer. 3dly the governor with a graduated scale attached. None of these means are sufficiently convenient or accurate for the purpose required; but the following leaves nothing to be desired either in simplicity of application, or precision in its indications. This regulator & proper is the sense of touch guided by that of hearing.

On the same axis as the mirror is to be attached the plate of a small syren having two apertures; when the mirror moves at the rate of a hundred revolutions in a second the sound corresponding with 1000 simple vibrations will be heard; and the hand turning the first wheel of the multiplying train must regulate the motion so as to keep the sound at a constant pitch. As the motion increases or decreases in velocity the sound will become sharper or flatter. Now the ear can easily distinguish the difference between 1000 and 1010 vibrations per second corresponding to the difference of ten revolutions of the mirror; and that the touch can be regulated the motion with equal accuracy when guided by the sense of hearing cannot be doubted by those who know the exactness with which an organist performs can keep in time.

If the manual application be dispensed with, and any other moving power be employed, still the acoustic means is indispensable to enable us to regulate the velocity.

To assist the determination of the ear, a free tongue or other sonorous body may continue to vibrate while the motion lasts; any deviation from perfect unisonance will be immediately sensible by the beats of the non-isochronous vibrations.

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Notes on the use of revolving mirrors for experiments to measure the velocity of light, [1834-1840].

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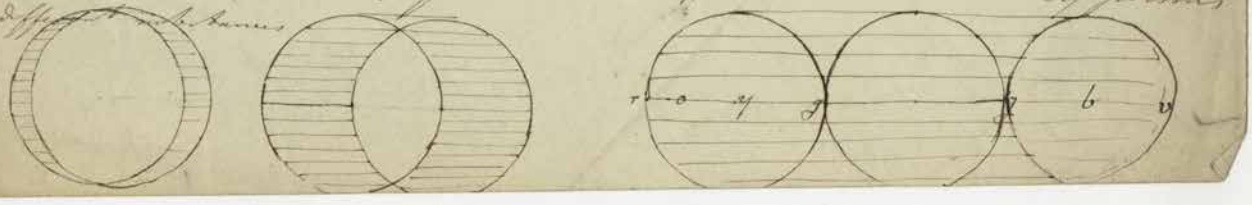
Let a luminous point be made to describe a circle; the point may be either an aperture in a metal plate, or a reflecting bead. Examine this circle with a prism; the luminous object at each point of its path will be converted into a prismatic spectrum, and consequently each definite colour will describe an equal circle having a different center, but all the centers will be in the same straight line. If the radius of the circle which the luminous point describes be much greater than the length of the spectrum, something like a circle with a prismatic circumference will be seen (fig 1) the colours will not be concentric, but each will describe a perfect circle. If the length of the spectrum be equal to the radius, (fig 2) will be seen. But if the ~~spectrum~~ ~~circle~~ be ~~greater than~~ ~~equal to~~ the ~~diameter~~ diameter of the circle many instructive appearances will be observed; the resulting spectrum will be bounded on the right and left by convergent, one red the other violet; and if the circle be so regulated that the complementary green shall ~~corresponding~~ with the red at x, the neutralizing points will fall elsewhere, and together will probably form a curve which will vary when examined by prisms of different substances

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Notes and diagrams on an experiment to use a luminous point to describe a circle, [1834-1840].

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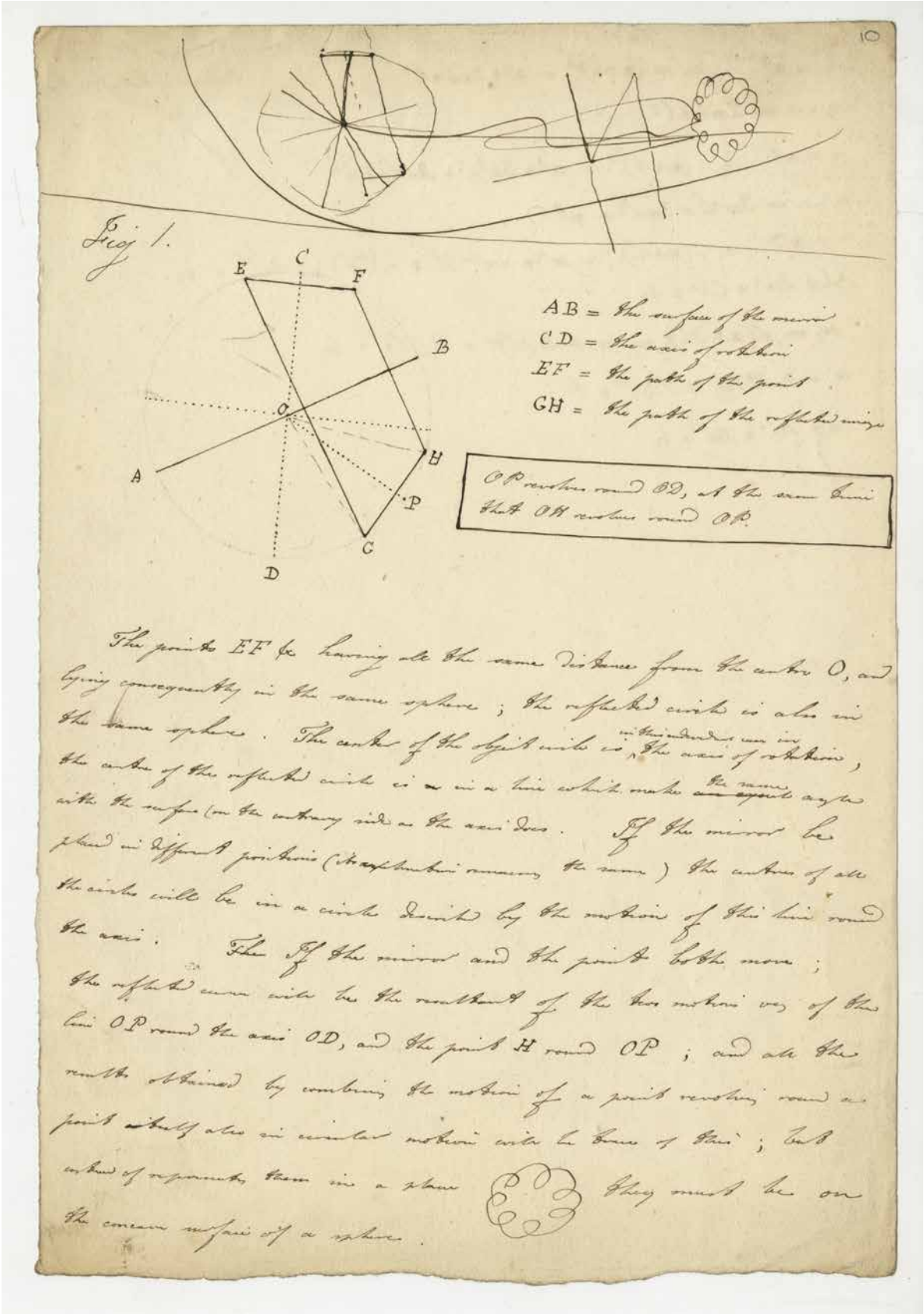

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Fig 1.

E C F B O A H P G D

AB = the surface of the mirror
CD = the axis of rotation
EF = the path of the point
GH = the path of the reflected image

OP revolves round OD, at the same time that OH revolves round OP.

The points EF be having all the same distance from the centre O, and lying consequently in the same sphere; the reflected circle is also in the same sphere. The centre of the digit circle is in the indefinite line in the axis of rotation, the centre of the reflected circle is in a line which makes the same angle with the surface on the contrary side as the axis does. If the mirror be placed in different positions (the rotation remaining the same) the centres of all the circles will be in a circle described by the motion of this line round the axis. ~~The~~ If the mirror and the point both move; the reflected curve will be the resultant of the two motions viz of the line OP round the axis OD, and the point H round OP; and all the results obtained by combining the motion of a point revolving round a point itself also in circular motion will be those of this; but instead of representing them in a plane they must be on the concave surface of a sphere.

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Notes and rough diagrams on the use of revolving mirrors to measure the velocity of light and electricity, [1834-1840].

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## Reflecting and Refracting Surfaces in Motion.

As superficial curves may be produced by the combined motion of linear curves, and as the impression of light is permanent to the perception for some time after the object is removed, it is possible to construct mirrors by employing, instead of plane and curved surfaces, the generating lines of these surfaces in motion. Thus

A line moving on a centre or progressing rectilinearly will generate a plane surface.

A segment of a sphere, moving round a centre will generate a spherical surface either convex or concave.

A semi-annulus progressing rectilinearly will generate a cylindrical surface either convex or concave.

Many curious effects might by this means be produced, for instance, two moving radii placed at different distances from the eye would generate two surfaces of reflection one behind the other, and an object would be doubly reflected in the same direction. Multiple reflections might on an extension of this principle might be produced

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The motions of reflecting and refracting surfaces would give rise to some very extraordinary phenomena by distributing the rays in different directions which could not be obtained by the ordinary means. ~~Thus~~

~~[illegible] the rays in [illegible] direction only, but [illegible] the person could~~

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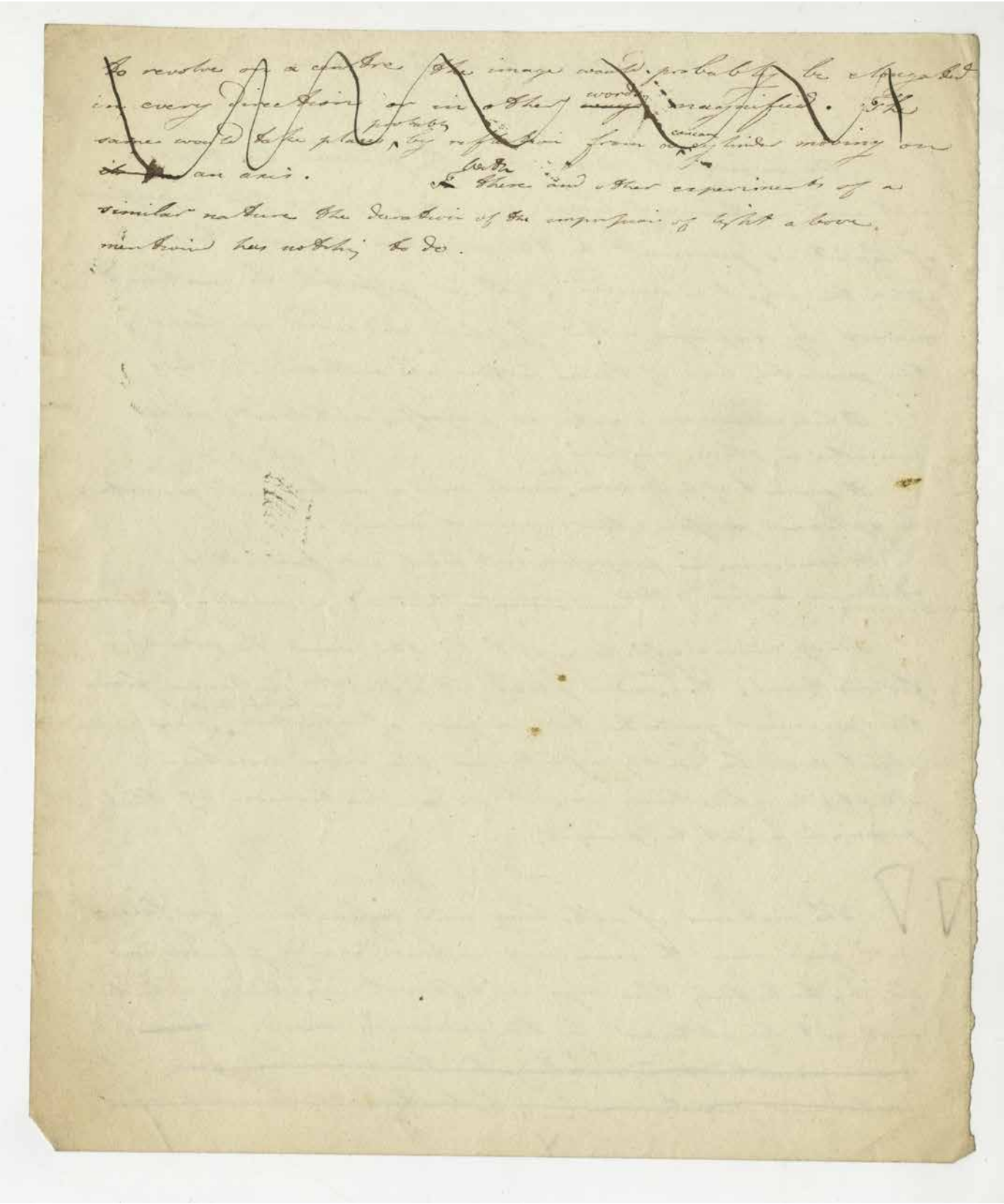

To revolve on a centre the image would probably be expanded in every direction or in other words magnified. The same would take place probably by reflection from a cylinder moving on an axis.

In these and other experiments of a similar nature the duration of the impression of light above mentioned has nothing to do.

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Notes describing 'Reflecting and Refracting Surfaces in Motion', [1834-1840], page 1.

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## Single Refraction.

1. A refracting plane placed between an object and the eye so refracts the rays of light, that their apparent convergence is to a point nearer to the eye than to the object

2 If the object and refracting surface remain fixed, the image does not change with the position of the eye; because the diverging beam from the apparent image is as regular as, the diverging beam from the real place when the refracting surface is not interposed.

3. The ~~pos~~ refracting plane being moved parallel to itself to or from the eye does not alter the apparent place of the object.

4 The apparent image is always in a perpendicular to the refracting surface drawn to the real place of the object. Therefore the apparent image changes with every alteration in the position of the refracting surface.

5 The image advances towards the eye as the ~~distance~~ thickness of the refracting body increases.

6. Had the law of refraction been different from what it is, the emerging rays would not converge to a point, and objects would not be seen distinctly through refracting surfaces.

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Notes on single refraction and coloured polarisation, [1834-1875], page 1.

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Coloured Polarization.

Instead of employing a converging beam and placing the eye at the vertex of the cone, would not the circular rings of a crystallized plate be equally seen by using a diverging beam, and causing the rings to be formed on a piece of ground glass placed parallel to the crystallized plate. If this experiment should succeed instead of one diverging beam, several symmetrically placed may be employed, and figures resembling the resultant acoustic figures might be produced. The appearances would be precisely similar to Nobili's electrochemical rings. A very strong light must be employed.

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Notes on single refraction and coloured polarisation, [1834-1875], page 2.

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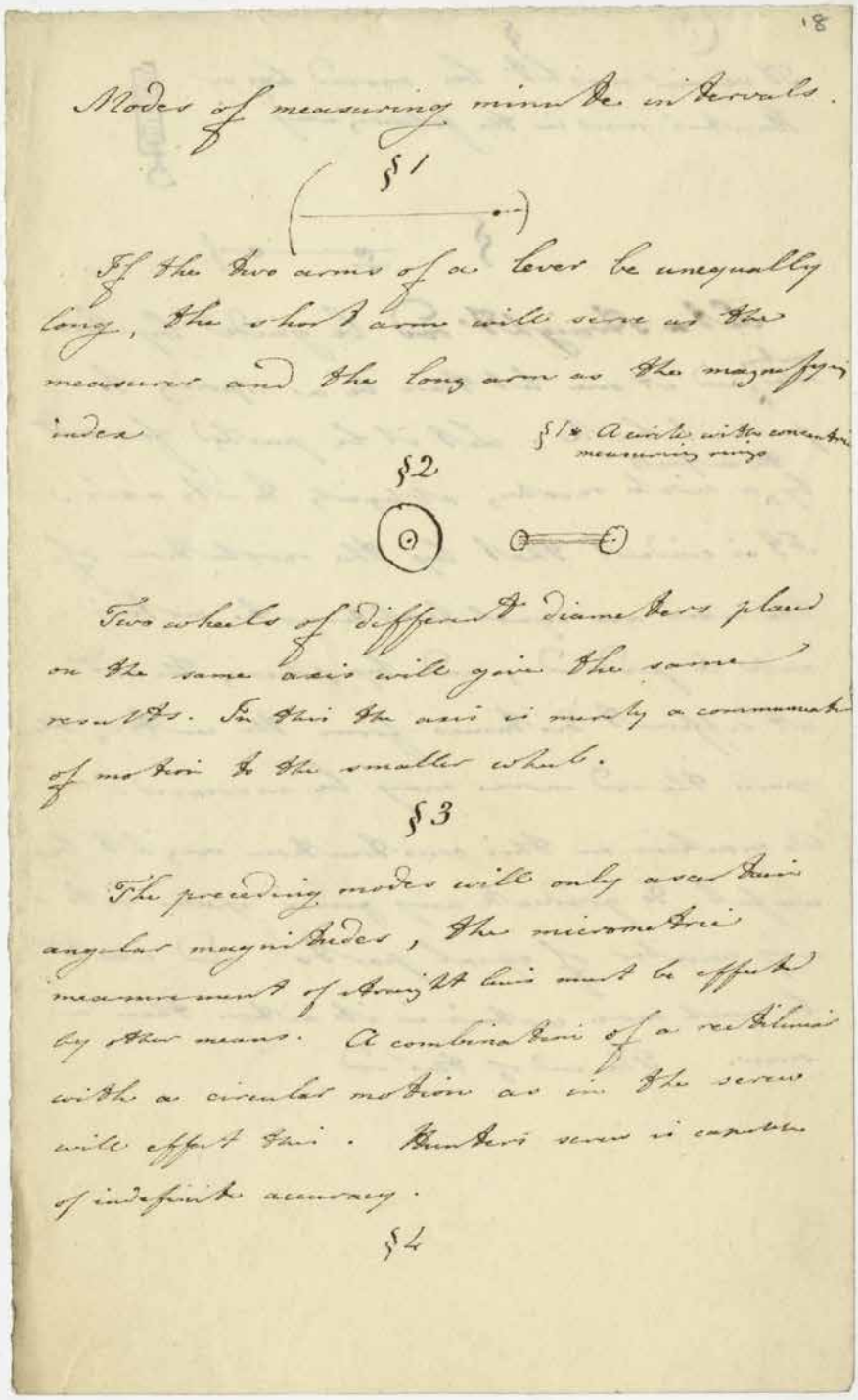

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Modes of measuring minute intervals.

§1



If the two arms of a lever be unequally long, the short arm will serve as the measurer and the long arm as the magnifying index

§1* A circle with concentric measuring rings

§2



Two wheels of different diameters placed on the same axis will give the same results. In this the axis is merely a communicator of motion to the smaller wheel.

§3

The preceding modes will only ascertain angular magnitudes, the micrometric measurement of straight lines must be effected by other means. A combination of a rectilinear with a circular motion as in the screw will effect this. Hunter's screw is capable of indefinite accuracy.

§4

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Notes and diagrams on 'Modes of measuring minute intervals', [1834-1840], page 1.

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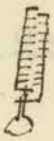
A vernier might be moved by a Beaufort screw in the following way.



Let a straight rod be guided by two guides, and at one end there be a spring to push it back. Let it be pushed forward by the surface of a circle revolving obliquely to its axis. It is evident that by the revolution of the axis an equal & alternate motion will be produced, and by placing the rod at different distances from the centre, the space the rod moves may be increased. A machine on this construction may be useful to graduate any given space into any number of equal parts, and would be much more certain in its action than a screw. The end of this rod

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Notes and diagrams on 'Modes of measuring minute intervals', [1834-1840], page 2.

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Luminous rays.

Visual Duration of the Impressions of Light.

—

The luminous lines seen on the plate of an electrical machine are occasioned in this manner; the particles of amalgam which adhere to the glass become charged, and as they discharge themselves while the plate is in motion the luminous spark occupying successively all the points of a line ~~must~~ it appears as a luminous line. The duration of discharge might be determined by ascertaining the length of the luminous line and the time of the revolution of the plate, and experiments might be instituted to determine the duration of the discharges of different surfaces by attaching pieces of tinfoil to the plate; the relative discharging power of different metals might be observed by placing upon the same radius of the revolving plate pieces of foil of the same size but of different substances. Were the rubber to revolve instead of the plate no luminous lines would be observed.

It is possible by the means I have indicated to reduce to actual measurement some of the most transient phenomena even those which occupy but the most evanescent portions of time; and it is not improbable that future improvements in the apparatus

# The Papers of Charles Wheatstone

K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

for producing rapid, equable and calculable motions, may assist the progress of physical philosophy in as great a degree as the Microscope and the Telescope have already. The former instrument ~~magnifies~~ shows us spaces, and the latter distances invisible to the unassisted eye; while the Chronoscope will render the evanescent portions of duration visible. ~~[illegible]~~

In the case of the visual duration of a moving luminous point each point of the line is not less visibly bright than the originating point when stationary but it is even apparently more bright; for it is a known fact that the continuance of a luminous point on the same point of the retina renders the sensation feebler, therefore each point of the line presents to the eye the same brilliancy as its first impulsion.

K/PP107/4/1/21

Draft paper on 'Visual Duration of the Impressions of Light' or 'Luminous rays' - experiments to measure the velocity of light, [1834-1840], page 2.

# The Papers of Charles Wheatstone

K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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Dr Wollaston has emitted the opinion that in all cases of muscular contraction the motion is effected by a series of periodical jerks; whether this be case or not we can prove ~~that~~ no jerks are made whose periodical intervals are less than (say) (1000) in a second; for if so they would be rendered resistible by the compound motion of a moving body with the eye, the line of an equably moving point instead of being a dizzying point would present this appearance

K/PP107/4/1/23

Notes on William Hyde Wollaston's (1766-1826), chemist and physicist, opinion on muscular contractions, [1834-1875], page 1.

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May not the meteors called falling stars be small clouds or other congregation of matter charged with the electric fluid and by their rapid motion rendering the time of their discharge visible. The difficulty will in this case be to account for the motion of the charged point; it may be rapidly attracted by the earth or by certain parts of the atmosphere. The paths of these meteors appear to be more luminous at their commencement, this may hardly be explained by the greater energy of the discharge.

K/PP107/4/1/23

Notes on William Hyde Wollaston's (1766-1826), chemist and physicist, opinion on muscular contractions, [1834-1875], page 2.

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Method of determining the duration of the appearance of shooting stars, and also whether their apparent velocity be equable or variable.

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The rectilineal path of a shooting star seen through a revolving prism or in a revolving mirror (inclined to the axis of rotation) will, if the duration of a revolution be less than the duration of the appearance, show itself as a curve the length and shape of which will indicate the duration and law of motion of the appearance. If the duration of the revolution be made shorter a ~~series~~ series of curves with numerous loops will be seen, each loop meaning a revolution of the mirror or prism. It is obvious that the direction of the motion of the star is also easily determined by this means.

Ascertain the law of the curve formed by the refracted images of a fixed luminous point seen in a revolving prism, the refringent angle and refractive density of which is known.

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## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

Method of determining the duration of the motion of a projectile.

~~1st Two other circuits~~

Two independent circuits, one short the other long, and a charged leyden jar or battery interposed in each. The breaks in the two circuits to be brought close to each other on the same spark board, and a pendulum to revolve before them or a mirror behind them. One circuit to be discharged ~~the moment~~ by the ball at the moment it leaves the gun, and the other by the ball when it arrives at its destination.

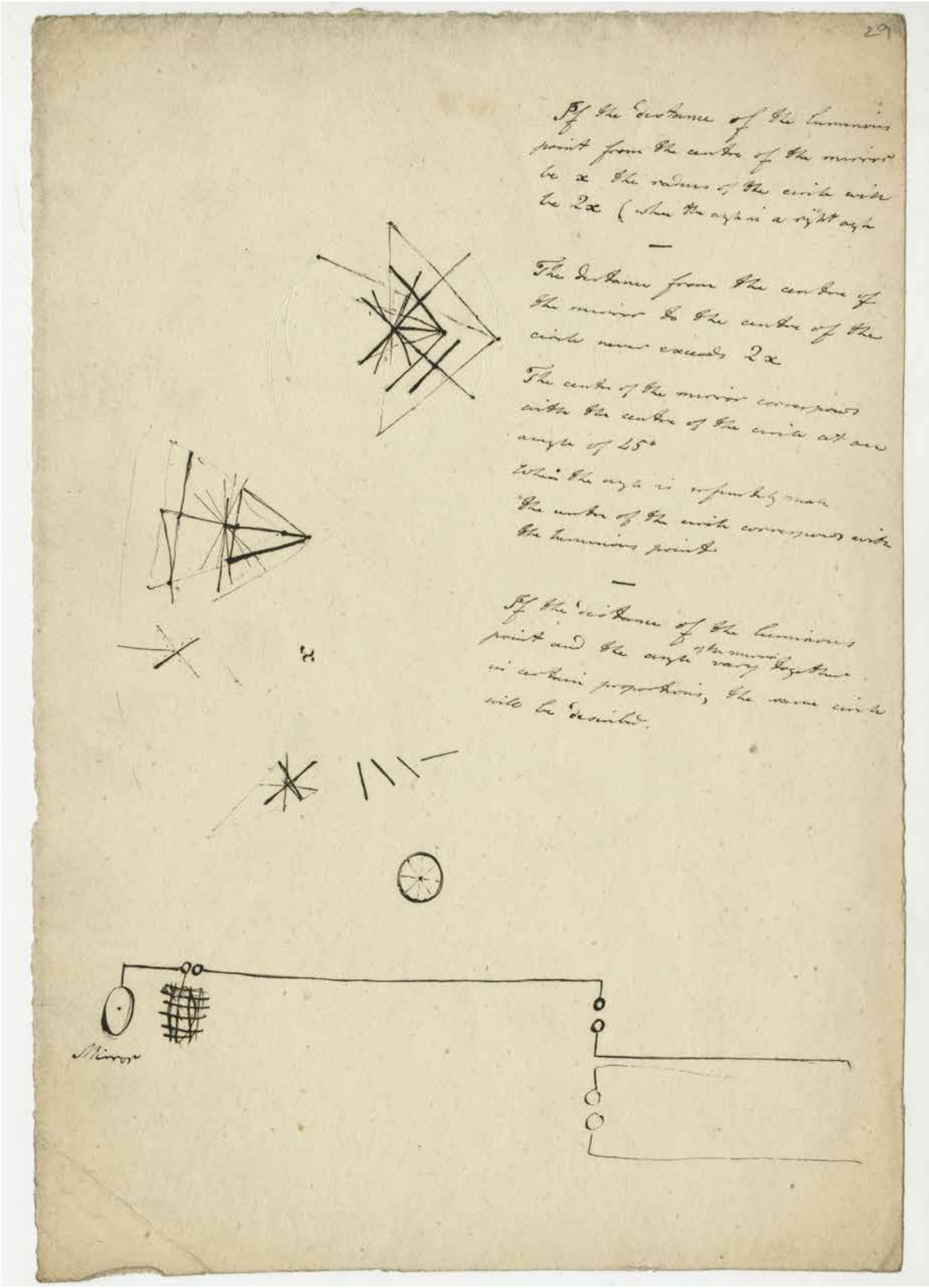
The motion of needles might be made to answer the purpose of ascertaining the duration of the motion of projectiles when the range is great and so that its arrival at its destination cannot be immediately observed.

K/PP107/4/1/24

Notes describing a 'Method of determining the duration of the motion of a projectile' on reverse of 'Methods of determining the duration of the appearance of shooting stars, and also whether their apparent velocity be equable or variable, [1834-1875], page 2.

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion




K/PP107/4/1/29

Rough notes and diagrams calculating the distance, angle and radius of circle between a luminous point, the centre of a mirror and reflection, [1834-1875].

# The Papers of Charles Wheatstone

K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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The path ~~of~~ in which a luminous point moves appears as a luminous line when the motion of the point is sufficiently rapid to describe any sensible space in the eighth part of a second. From the experiments of D'Arcy it would appear that variations in intensity, distance and colour, produce no sensible modifications in the duration of the impression; ~~therefore~~ if this be true the length of a generated line indicates the space passed over in the eighth part of a second. But this can indicate only the velocity of a point's motion, its direction is still unknown, but it may be ascertained by compounding ~~with~~ the rectilineal motion of the point with a motion perpendicular to it and in the same plane; thus suppose a luminous point to move in a right line from A to B, and at the same time the plane on which it moves to be carried forward in the direction ~~AC~~ CD; if the point moves from A to B when the plane is at rest it will move in the diagonal direction AC when it is in motion, and when the point moves in the contrary direction from B to A the diagonal BD will be described. The composition of motion will not only enable us to ascertain the direction of a moving luminous point, but also its velocity which it will indicate even when a part only of the path is visible; for the velocity of the plane being known it is obvious that when its velocity is the same as that of the point the angle of ~~the~~ the direction of the path will be 45°, and every other angular direction will be the diagonal of the parallelogram indicating the two velocities; one being known the other is easily found; if either of the velocities are variable curved lines will be exhibited instead of straight ones.

I shall now endeavour to apply these principles experimentally to ascertaining the direction and velocity of the motion of any point of a vibrating body, and also that of the electrical spark.

K/PP107/4/1/32

Notes describing the path of a luminous point in relation to experiments conducted by Patrick D'Arcy (1725-1779), soldier and mathematician, [1834-1875], page 1.

# The Papers of Charles Wheatstone

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which

~~The~~ The duration of luminous impressions modifies the appearance of a number of electrical phenomena. When I draw a spark from the prime conductor of a machine I observe an intensely ~~bullant~~ bright line of light, this is called an electrical spark, but it is impossible from this appearance to know whether it is a real continuous line of light, or the effect of the visual duration of a single luminous point in rapid motion. It is in our power to determine this point, ~~for if we make the spark~~ and this is the apparatus I have employed for the purpose, it consists of a plate which I can cause to revolve with considerable rapidity on a whirling table; from the centre of this plate rises an insulating glass rod to which is attached at right angles a brass beam bearing a ball at its end, on the plate immediately beneath is a similar ball. If I hold the brass arm which ~~I surround~~ surrounds the glass rod to the prime conductor I draw a spark which afterwards passes between these two balls. Now if I place this on the whirling table and set it in rapid rotation, and when in this rapid motion ~~that~~ pass the spark between the two balls

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26 50

# The Papers of Charles Wheatstone

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1 35

We will suppose the revolution of the luminous point to be made in ~~one~~ the exact time necessary to complete the visual circle, and the hand to move over any aliquot portion of the space in the same time. If the angular motions of the point and the hand be the same it is evident that the hand must either always or never eclipse the point. If the angular motion of the hand be one half, a transit must occur at every second revolution of the point, or which is the same thing at every complete revolution of the hand. If the angular motion of the hand be one third there are two transits occurring 1/2 revolution of the point from each other, three revolutions of the point or 1 of the hand therefore take place before a point is eclipsed in the same position. If the angular motion of the hand be one fourth there are three transits occurring at every 1/3 revolution of the point; 4 revolutions of the point or one of the hand therefore elapses before a transit occurs at the same point. It appears from this that the black points are not produced by a continued absence of light for in the last case there are three reiterate luminous impressions to one intermittent action. Should the luminous impression lasts longer than the revolution the phenomena will probably be modified, the number and positions of the black spots will be the same but their relative intensities will be varied.

In all that has been above stated the two motions are supposed to proceed in the same direction; we will now examine the consequences which ensue where these two motions are made in opposite directions. When the angular motions of

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the point and hand are the same they will meet at every half revolution and consequently two points will be formed. When the angular motion of the hand is one half that of the point they will meet at every two thirds of a revolution of either point or hand, there will consequently be three dark spots. When the angular motion of the hand is one third, they will meet at every three-fourths of a revolution, four spots will therefore be formed. &c. In these cases the dark spots are not in any degree obliterated by newly acting luminous impressions as in the former cases.

We have now to consider the circumstances occurring where the angular velocity of the hand is greater than that of the point; and first the case when the motions proceed in the same direction. When the velocities are equal they either always or never eclipse each other. When the velocity of the hand is double, the transit occurs at every two revolutions of the ~~hand~~ point or one of the ~~point~~ hand. When the velocity of the hand is triple.

Condon Lady

# The Papers of Charles Wheatstone

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Observations on Dr Roget's experiment.

Dr R. observes that "the direction of curvature is precisely the same, whether the wheel be moving to the right or to the left of the spectator". When a wheel moves and the bars are stationary this must be the case, for the bars have in both cases a relative retrograde motion to the wheel; but when the axis of the wheel is stationary and the bars move, the phenomenon observed by Dr R is observed only when the bars move in a contrary direction to the motion of the wheel; when the bars move in the same direction as the wheel the convexity of the curved images of the spokes is turned upwards.

Dr R. has correctly laid down the law according to which the curved lines are generated; but he is mistaken in the physical explanation, the same curves may be produced by the combined motions of an aperture and radius, but they are not thus produced in the case in question

The rapid motion of the spoke of the wheel generates a ~~bar~~ visible surface, and the eye being fixed to the axis of the wheel, the apparent retrograde motion of the bars causes them to generate a visible surface also; the surface generated by the radius being the most luminous, wherever they intersect each other a ~~black~~ dark point is observed and a continuch of the dark points generate the curved line.

K/PP107/4/1/35

Notes describing experiments to measure rotations of a luminous point and experiments conducted by Peter Mark Roget (1779-1869), physician and philologist, [1934-1875], page 3.

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I must leave for a future communication the description of an instrument for delineating the luminous track of any cyphers, ~~curves~~ figures &c, whatever, and to an instrument for describing a variety of mathematical curves from their equations, and the proposed construction of a telegraph for communicating intelligence by the ordinary characters and in writing.

P  E  S  H

# The Papers of Charles Wheatstone

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Data

These instruments (chronometers) are now brought to such perfection, that an irregularity in the rate of going, to the extent of a single second in twenty-four hours in two consecutive days, is not deemed in one of good character; so that any interval of time less than twenty-four hours may be certainly ascertained within a few tenths of a second by their use.

In good transit observatories, an error of two or three tenths of a second in the moment of a star's culmination is the utmost which need be apprehended, exclusive of the error of the clock: in other words, a clock may be compared with the earth's diurnal motion by a single observation, without risk of greater error. By multiplying observations, of course, a yet greater degree of precision may be obtained.

Astronomical levels are furnished with a divided scale, by which the place of the end of a bubble can be nicely marked; and it is said that they can be divided with such delicacy, as to indicate a single second of angular deviation from exact horizontality.

The velocity required (in Roemer's explanation of the phenomena of the eclipses of Jupiter's satellites) 192000 miles per second, was so great as to startle many, and, at all events, to require confirmation. This has been afforded since, and of the most unequivocal kind, by Bradley's discovery of the aberration of light. The velocity of light deduced from this last phenomenon differs by less than one eighthieth of its

K/PP107/4/1/36

Paper on 'data' and the importance of accurate chronometers in transit observations, astronomical levels and measuring velocity, possibly made from the work of John Frederick William Herschel (1792-1871) astronomer and physicist, [1834-1875], page 1.

# The Papers of Charles Wheatstone

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amount from that calculated from the eclipses, and even this difference will no doubt be destroyed by nice and more rigorously defined observations.

Such is the accuracy to which these (observations on the annual parallax of the stars) have been carried, that if the quantity in question amount to a single second, i.e. if the radius of the earth's orbit subtend at the nearest fixed star that minute angle) it could not possibly have escaped detection and universal recognition.

Microscopes have been constructed which magnify more than a thousand times in linear dimensions, so that the smallest visible grain of sand may be enlarged to the appearance of one a thousand million times more bulky.

Herschel

K/PP107/4/1/36

Paper on 'data' and the importance of accurate chronometers in transit observations, astronomical levels and measuring velocity, possibly made from the work of John Frederick William Herschel (1792-1871) astronomer and physicist, [1834-1875], page 2.

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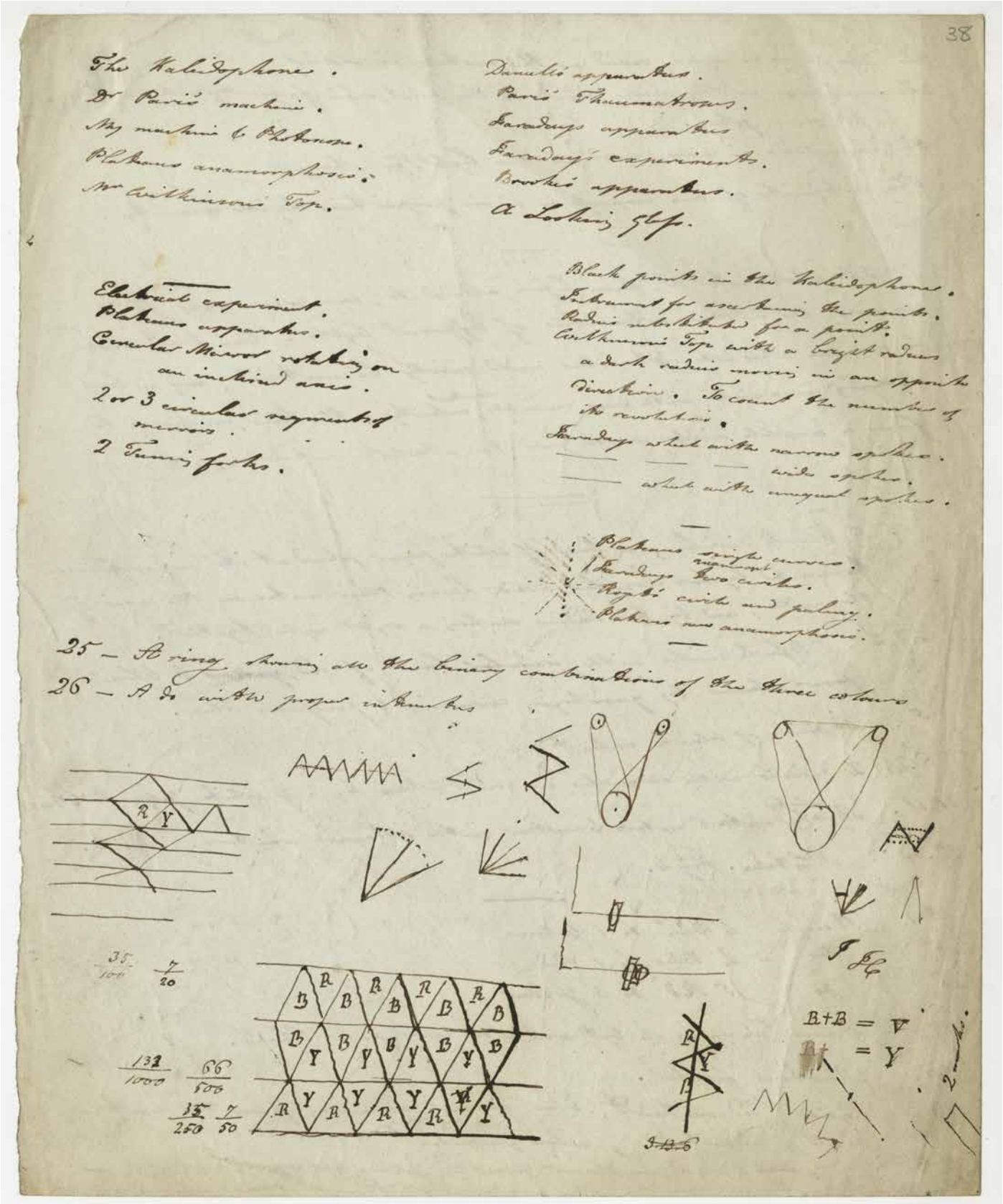
## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion




K/PP107/4/1/38

List of apparatus and experiments by various scientists including John Ayrton Paris ([1785]-1845), physician and author, John Frederic Daniell (1790-1845), chemist and Professor at King's College London, Michael Faraday (1791-1867), natural philosopher, kaleidophone, tuning forks, and rotating circular mirror used in the development of Wheatstone's photometer, [1834-1865], page 1.

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

The impression is more vivid as the motion is slower.
The impression is the more vivid as the point more frequently returns to the same place.
The impression is more vivid as the light is stronger.
The continuity of an impression is in proportion to its vividity.

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The photometer I have before alluded to, can serve only for comparing the relative intensities of different lights. One that shd be measure absolute intensities could easily be contrived, viz a band revolving in a circle with any variable centre velocity; the time necessary to form a complete circle would give the absolute intensity.

---

1. A black circle, a band of white paper placed at its circumference bounded by two circular arcs having their centre on the axis of the needle, and by two radii making a right angle together.
2, 3, 4. Black circles with similar bands of red, yellow & blue paper coloured by gamboge, carmine & prussian blue.
5. A circle of black velvet.
6, 7, 8, 9 X white circle 12 spokes as in Plateau Fig 2 - white, yellow, Red & Blue
10, 11. A white circle 6 sectors & another circle 18 equal sectors. Fig 3.
12. 13. Plateau. Fig 4.

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14. A circle 4 Blue to 1 yellow
15. do - 4 Blue to 1 Red
16. do 5 Red to 3 Yellow
17. A circle same as 14 but with a very pale blue.
18. Newton's circle.
19. Circle, red centre, blue gradually to sky blue increasing from the centre
20. Circle, red centre, yellow graduate
21, 22, 23, 24 . ~~Blue~~ Blue c, red o — Blue cent. Yellow o — Yellow c, blue o — Yellow c red o —

K/PP107/4/1/38
List of apparatus and experiments by various scientists including John Ayrton Paris ([1785]-1845), physician and author, John Frederic Daniell (1790-1845), chemist and Professor at King's College London, Michael Faraday (1791-1867), natural philosopher, kaleidophone, tuning forks, and rotating circular mirror used in the development of Wheatstone's photometer, [1834-1865], page 2.

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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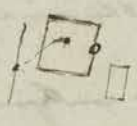
Experiments

1st part

Red hot coal or stick placed on the whirling table.
Small spherical mirror – do
A fixture for Plateau's circles.
Apparatus for the electric spark.
A plane mirror in the form of a circular meter
Another do. to be placed over the above.
Circular plate with a slit, and a glass painting.
× Instrument for showing mechanical curves. (Photometric scale)
Dr Young's experiment – a lap. P.P. strings fixed on a board, – a lens.
× The Kaleidophone.

2d part.



A wire on a board.
Coal on the Kaleidophone wire.
Tuning fork with a needle, placed on the axis of a revolving circle.
Glass plate with a bead.
The Thaumatrope.

Double the number of the others to be taken.

3d part.

My instrument
Plateau's instrument for showing the intersection of lines producing curves.
Dr Roget's & Mr Faraday's experiments – Mr Brooke's apparatus.
Plateau's anamorphosis.
A string on a board with transverse lines – a guitar.
A single wheel with teeth perpendicular to the plane.

4th part.

Newton, plateau and my own circles
Concave lens.

K/PP107/4/1/39

List of experiments and apparatus by various scientists including Thomas Young (1773-1829), physician and natural philosopher, Peter Mark Roget (1779-1869), physician and philologist, kaleidophone, spark gap, and rotating circular mirror used in the development of Wheatstone's photometer, [1834-1865], page 1.

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

To put beads at different parts of the radius of the wheel of the white, &c.

The energy of an impression – the duration of do.

1 The energy of an impression decreases as the motion is more rapid
2 The

1. The intensity of the spectral line decreases as the motion of the point becomes more rapid
2. — ——— — — ——— — increases with the frequency of the impression.
3. Therefore the intensity is equal when the rapidity of motion and frequency of the impression are to each other in the same ratio.

1 A white vector on a black ground appears equally intense at every distance from the centre of rotation.
2 Therefore the ~~an~~ intensity of the spectra is in proportion to the continuity of the impression.

If the continuity of the impression is inversely as its intensity, the intensity of the spectra is constant.

K/PP107/4/1/39

List of experiments and apparatus by various scientists including Thomas Young (1773-1829), physician and natural philosopher, Peter Mark Roget (1779-1869), physician and philologist, kaleidophone, spark gap, and rotating circular mirror used in the development of Wheatstone's photometer, [1834-1865], page 2.

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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Optical phenomenon in a revolving cube.

If a skeleton cube be caused to revolve on one of its axes, it will describe two right angled cones joined together at their bases by a hollow band; the section of this figure is ⟨◊⟩. The surface of the cones is uniform being formed by the continued motion of the three adjacent sides following in each other track, the curved part, formed by the four sides which do not touch the axis, is not so, but as the middle points of these four lines follow in the same track they will describe a circle which is very obvious on looking down on the figure, it is darker than any other line because it is formed of six superpositions, while the cone is only formed of three.

But the remarkable phenomenon which it is my chief object to describe is that while this figure is produced by the rapid motion of the cube, a variety of symmetrical field lines are observed in any one bright in the cone inclosed within the figure; they are bright if the edges of the cube are black and the back ground be white, they are on the contrary black if the edges be bright and the back ground be black. These lines observed at those places where two lines of the revolving cube ~~in its motion~~ intersect each other, and therefore differ in form with every position of the eye. ~~This the implies that the superposition of two dark lines should give rise to a bright line and vice versa~~. To explain the appearance of these lines let us examine one of the simplest cases, that of a rectangle rotating on an axis parallel to two of its sides, the right line appears to be bright and placed before a dark ground. The moment of a single side produces, from the persistency impression on the retina, a line of light over the dark ground, the other side ~~following it~~ passing over the same space produces a similar track, and the impressions of each line in such cases made successively the retina is affected by their joint action, but where one passes over the other it is evident that but a single effect can be produced and the place of intersection either points or lines must appear less luminous than the other parts.

Impressions produced by intermittent impulses produced the same luminous effect on the eye whether the second each other regularly or irregularly provided there be the same number in a given time

. . . . . .

. . . . . .

otherwise two sides moving in opposite directions would produce an side of unequal intensity in different parts.

K/PP107/4/1/41

Notes describing an 'optical phenomenon in a revolving cube', [1834-1875].

# The Papers of Charles Wheatstone

K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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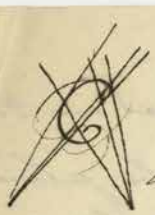
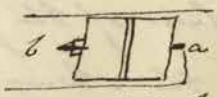
Universal delineator of curves, ~~cyphers~~, cyphers, figures &c &c



Prepare two bars exactly similar each having a slit nearly through their entire lengths, place them at right angles to each other and in the aperture through both, place a pin bearing a steel bead; it is evident that by varying the rectilinear motions of these two bars the bead may be brought to any situation within the square. To regulate these two motions each bar must be connected with a frame




against one end of this frame a a spring must press, and against the other b a wheel with different elevations and depressions must act; and the frame must work easily in grooves.

It will be easy to set the wheels to any figure in the following manner; substitute a point for the bead and let it follow a ~~copy~~ drawing of the figure required, set the wheels in motion and let a point on each describe the requisite lines and curves which will serve as guides for cutting the wheels.

The two wheels must communicate by pinions to ~~the~~ the same toothed wheel, and the mechanism must be so contrived as to allow the complete figure or word to be described in the 8th of a second; and the wheels continuing to be turned, without ever stopping, will occasion the point to go over the same path. If the figure encloses a space the wheels may be continually turned the same way

If the bead placed on a pin should be found not to move quickly enough, it may be placed at the end of a long spring

K/PP107/4/1/43

Notes describing the 'universal delineator of curves, cyphers, figures etc' possibly Wheatstone's photometer, [1834-1865], page 1.

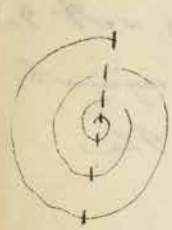
# The Papers of Charles Wheatstone

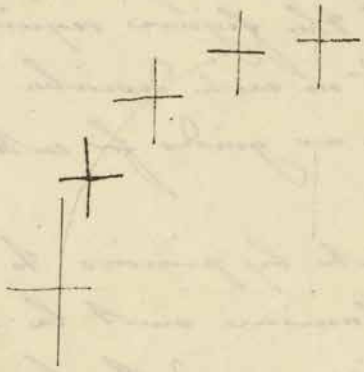
## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

Any figure circumscribing a space may be produced in this manner. At the top of a revolving arbor let there be placed a bar ~~moving~~ participating its angular motion but having a sliding motion of its own, and let this bar be thus bent

to the straight end of the bar let a expanding spring be fixed, the other end of which having a hole through which the arbor axis passes; the bent end of the bar must move along a surface of the form intended to be described, keep the point at the straight end.

A continuous line curved in any manner of any length may be obtained by a similar apparatus in which instead of the arbor revolving it moves along a straight line, but there must be no perpendicular lines





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Notes describing the 'universal delineator of curves, cyphers, figures etc' possibly Wheatstone's photometer, [1834-1865], page 2.

# The Papers of Charles Wheatstone

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Universal Delineator of Luminous images. —

Fix a rigid rod to a stand by means of a flexible spring and let it be inclined to the base by a certain angle say 45°; on the top of the rod fasten a steel bead. Prepare two planes sliding in frames capable of being pushed forwards and receding by means of springs, let these be so placed that the direction in which they slide may be 45° distant from each other; and place one as little below the other as possible and so that the rod may lay in the angle formed by their intersection. Perpendicular to each of these planes place a wheel cut upon their circumferences with various depressions so as to act upon the moveable planes.

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Notes on ‘universal delineator of luminous images’ possibly Wheatstone’s photometer, [1834-1865].

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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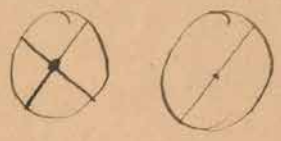
Instead of the points on the spark-taker place a uniform smooth wheel with radii of copper wire. One with two wires, another with four.



If the above succeeds in producing sparks without splashing, make a phantascope and the revolving discs with 8 or 12 sparks.

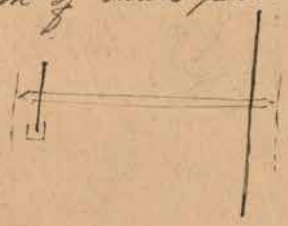
Exp 1. A Gunnion multiplied.

2. Phantascope.

3. A moving wheel apparently stationary.

4. A wheel apparently moving softly.

A disk of thick pasteboard



Electrical Chandelier made of metal beads strung on silk

Spangles sewn on narrow silk ribbon – say half a mile. for illuminating the lecture room.

K/PP107/4/1/50

Notes and rough diagrams listing experiments including a phantascope (optical apparatus) and an electrical chandelier, [1834-1875].

# The Papers of Charles Wheatstone

## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

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Spectrum Analysis.

Apps Inductorium, the primary coil in circuit with two of Grove's cells without a condenser gives a spark which exhibits only a few lines in a metallic spectrum. As the surface of the condenser is increased the lines become more numerous and when it has about 20 inches surface the lines are very bright and numerous. By constructing a condenser of variable dimensions say of 50 inches varying by an inch at a time we might be able to measure, or at least to make a comparative table of the intensities of the lines forming any spectrum, and of the same lines in different spectra.

The same purpose might be effected by employing the direct spark of a powerful battery with resistant coils and a rheostat to vary the intensity of the current; but the above would be preferable as requiring less battery power.

My tension magneto-electric machine would perhaps answer the purpose, and would have the advantage of being almost constant

Conversely the intensity of electric sparks might be measured by the number of lines of a mercury spark brought into action.

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Notes describing a method of spectrum analysis using an 'inductorium' or induction coil by Alfred Apps (1839-1913), instrument maker, battery cells by William Robert Grove (1811-1896), natural philosopher and judge, and Wheatstone's 'tension magneto-electric machine', [1860-1875], page 1.

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I do not know whether the spectra of the alkalied metals have yet been obtained by the electric spark. The sodium spectrum is a magnificent one. To obtain the others it may be necessary to take the sparks in carbonic acid, hydrogen or nitrogen; they should be taken in several different gases to eliminate the gaseous spectra.

The highest degree of heat from flames will not augment the number of lines, like an induction spark does. The degree of heat and the intensity of an inductric spark to produce the same number of lines may be compared.

In the spectra of alloys do the lines preserve the respective intensities of their constituents.

It may be that the electric spark according to its different degree of concentration does not change faint lines into stronger, but that it actually brings new lines into existence in some cases brighter than those which have commenced at a lower intensity. I think that I have perceived on observing the same spectrum at different times that what was the brightest line in one case was not in another. Even the colour of the spark to the naked eye with the apparatus I and the appd was very different in the first much more strongly violet than in the second, showing that the relations of the intensity of the lines was not observed.

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Notes describing a method of spectrum analysis using an 'inductorium' or induction coil by Alfred Apps (1839-1913), instrument maker, battery cells by William Robert Grove (1811-1896), natural philosopher and judge, and Wheatstone's 'tension magneto-electric machine', [1860-1875], page 2.

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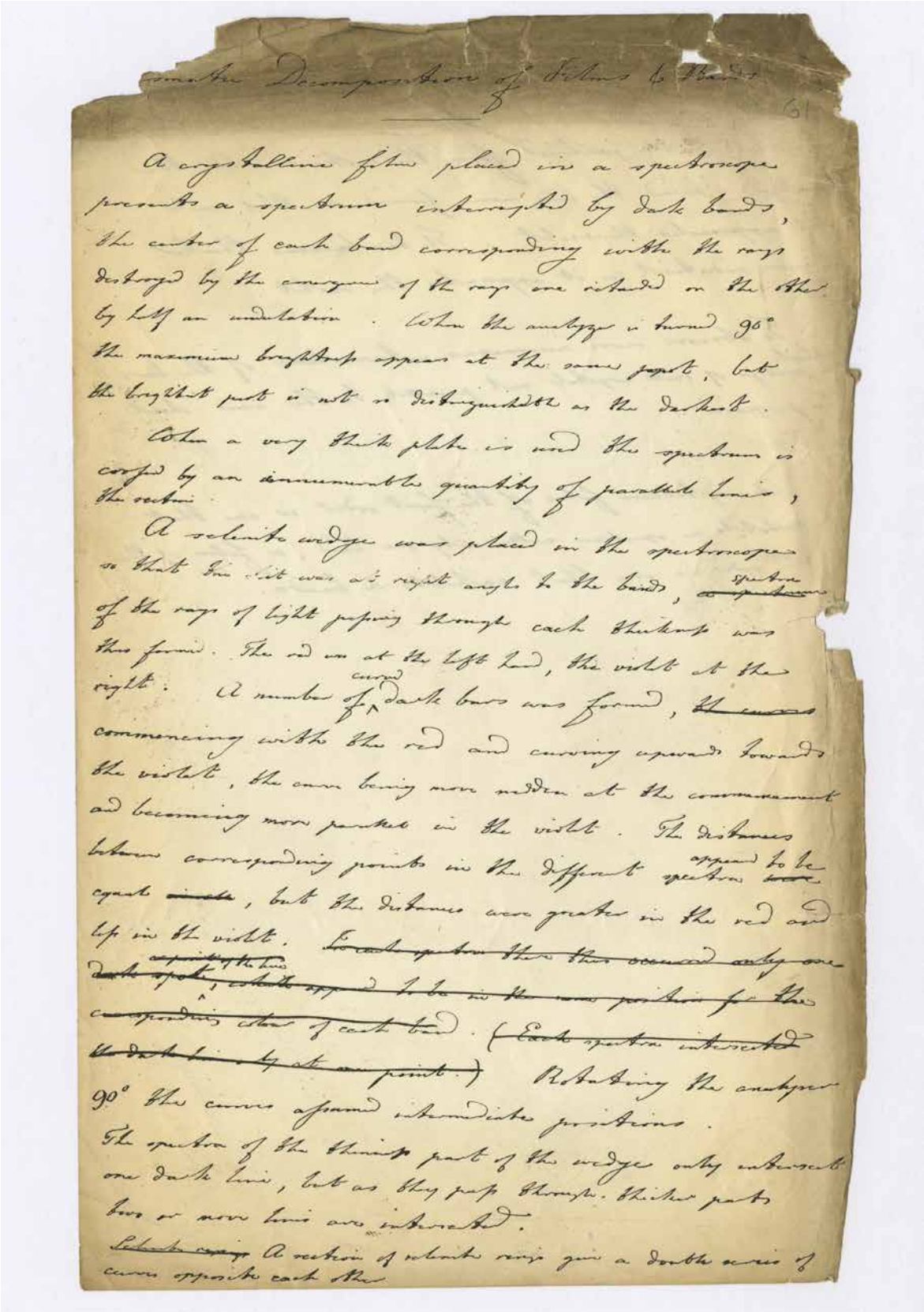

Prismatic Decomposition of Films & Bands

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A crystalline film placed in a spectroscope presents a spectrum interrupted by dark bands, the centre of each band corresponding with the rays destroyed by the emergence of the rays one retarded on the other by half an undulation. When the analyzer is turned 90° the maximum brightness appears at the same point, but the brightest part is not so distinguishable as the darkest.

When a very thick plate is used the spectrum is crossed by an innumerable quantity of parallel lines, the centre

A solenite wedge was placed in the spectroscope so that the slit was at right angles to the bands, ~~a spectrum~~ spectra of the rays of light passing through each thickness was thus formed. The red on at the left hand, the violet at the right. A number of curved dark bars was formed, ~~the curves~~ commencing with the red and curving upwards towards the violet, the curve being more sudden at the commencement and becoming more parallel in the violet. The distances between corresponding points in the different spectra appeared to be equal ~~inside~~, but the distances were greater in the red and less in the violet. ~~In each spectrum there was only one dark spot, which appeared to be in the same position for the corresponding color of each band. (Each spectra intersected the dark line only at one point.)~~ Rotating the analyzer 90° the curves assumed intermediate positions.

The spectra of the thinnest part of the wedge only intersected one dark line, but as they passed through thicker parts two or more lines were intersected.

~~Selenite crystal~~ A section of selenite rings gave a double series of curves opposite each other

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A wedge of rock crystal placed so that the rays of transmit rays from every thickness shows only a single line not greatly inclined from the vertical. As the analyzer is turned the line moves forward so that each point approaches the violet. The bar becomes thicker and more indistinct as it approaches the violet.

To observe more numerous intersections of the bars, a thick wedge of rock crystal cut parallel to the axis should be prepared.

A crystalline filter of the first order is one that exhibits a spectrum with only one band; a filter of the $n^{th}$ order is one that exhibits $n$ bands.

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Notes describing the 'prismatic decomposition of films and bands', a type of spectrum analysis, [1834-1875], page 2.

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## Spectrum Analysis.

Two different spark producers were employed. 1 Three of Grove's cells were placed in circuit with a short coarse coil, and the circuit made and broken by an independent electromagnetic apparatus worked by a single cell. 2 Two of Grove's cells were placed in circuit with the primary coil of Ruhmkorff's machine, and the spark was obtained from the secondary coil and by a condenser of 40 jars, by the juxtaposition of two wires, or small fragments of metal.

With the first the mercury spectrum presented only five lines (but the first yellow was distinctly double); with the second a great number of lines. It seemed however (but this may not be correct) that the lines of the first were not always the brightest in the second, for instance the brilliant single violet line of the first did not appear more brilliant than any of the numerous violet lines of the second, and a green line appeared particularly brilliant in the second.

With No 2. Metallic sodium presented a most brilliant spectrum with numerous bright lines. With No 1 only the single bright yellow line of Sodium appeared. Sodium is easily experimented with by the electric spark as it does not deflagrate with it.

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In No 2. Wires of iron and platinum were juxtaposed; while the current was in one or the other direction the same spectrum was exhibited.

When any light is very bright, the slit of the spectroscope may be made very narrow; but for weak lights, in order that they shall be visible the slit must be broad. This may be observed in the double green line of the mercury spectrum.

Note No 1
Sodium deflagrated in mercury shows, in addition to the lines of the latter metal, the characteristic line of Soda.

When metal lines were opened upon with No 1, numerous red sparks appeared, then produced an uniform spectrum coinciding with the lines of the iron. Metal lines did not do so.

Two sparks of different metals placed one before the other and regarded by a spectroscope shows the lines of both metals. The light of the hindmost is therefore not absorbed by passing through the foremost.

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Polarizing Spectroscope.

The thicker the plate is the more numerous are the bands.

The dark bands are less broad than the luminous spaces.

The dark bands and luminous spaces increase in breadth towards the violet portion of the spectrum.

Commencing from the thin edge of the wedge each dark band curves from the violet towards the red end of the spectrum.

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The spectrum being horizontal and the dark bands consequently vertical, if a small spectroscope be placed before the eye, slits having its slit horizontal (i.e. parallel to the spectrum) a new spectrum with upper having its coloured and dark bands at right angles to the original spectrum. Hence each coloured ray is again refracted and separated; from the red ray every other colour of the spectrum is refracted, and from every other ray all the rays of higher refrangibility are refracted, but none of lower refrangibilities.

(A ray of light passed through red gelatine is not decomposed with all the other rays, only the red is diffused)

The horizontal dark bands are the same in number as the vertical bands of the part of the horizontal spectrum experimented upon.

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Notes describing a 'Polarizing Spectroscope', [1834-1875].

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Electric Spark.

Assuming the light to be produced by the vibrations of the elementary particles of the metal (or other simple body) we must admit that in the electric spark, although there must be some polar arrangement as it forms part of the electric circuit, the particles vibrate in every direction since the light emitted by them shows no signs of polarization. Is it possible by some electric or electro-magnetic action to impress some polar arrangement on these particles so that their vibrations may be confined to a single plane, or become circular or elliptical.

The following methods may be tried.

1 Place a wire conveying a strong current parallel to one of Plücker's tubes, or to the direction of a spark from iron or any other metal. Observe whether there is any difference of effect when the current is in one direction or the other.

2 Surround the narrow part of a Plücker's tube with a spiral conveying a strong current, leaving an opening for the spark to be observed.

3 Place the spark or Plücker's tube between the poles of a powerful magnet. Then trial this experiment without any result employing a comparatively small magnet.

4 Bring a surface strongly charged either with positive or negative electricity in the vicinity of the spark.

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Notes describing the use of an 'electric spark' in polarisation, [1834-1875].

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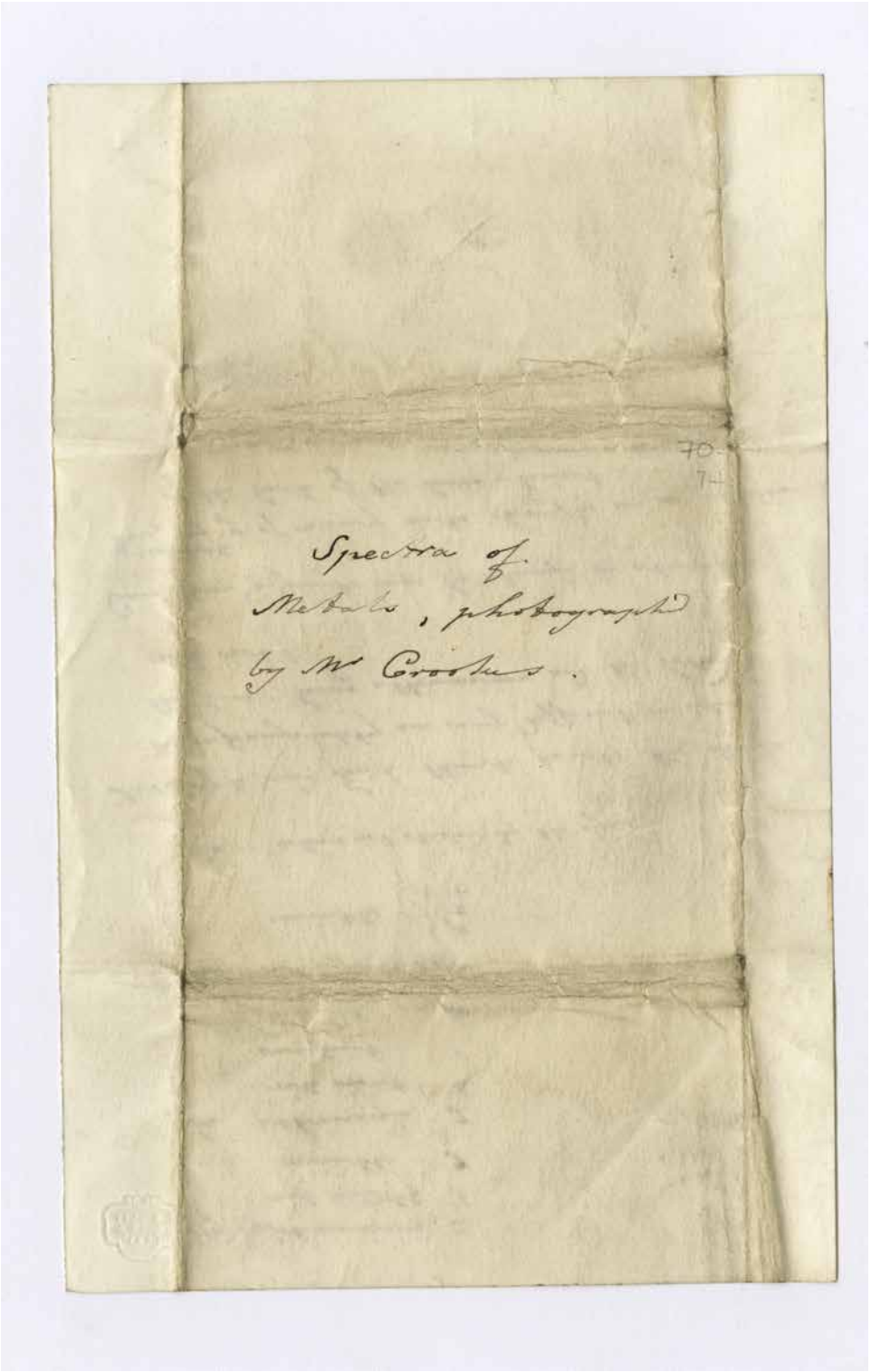
## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion




K/PP107/4/1/70
Wrapper for 'Spectra of Metals, photographed by Mr Crookes', [1860-1875].

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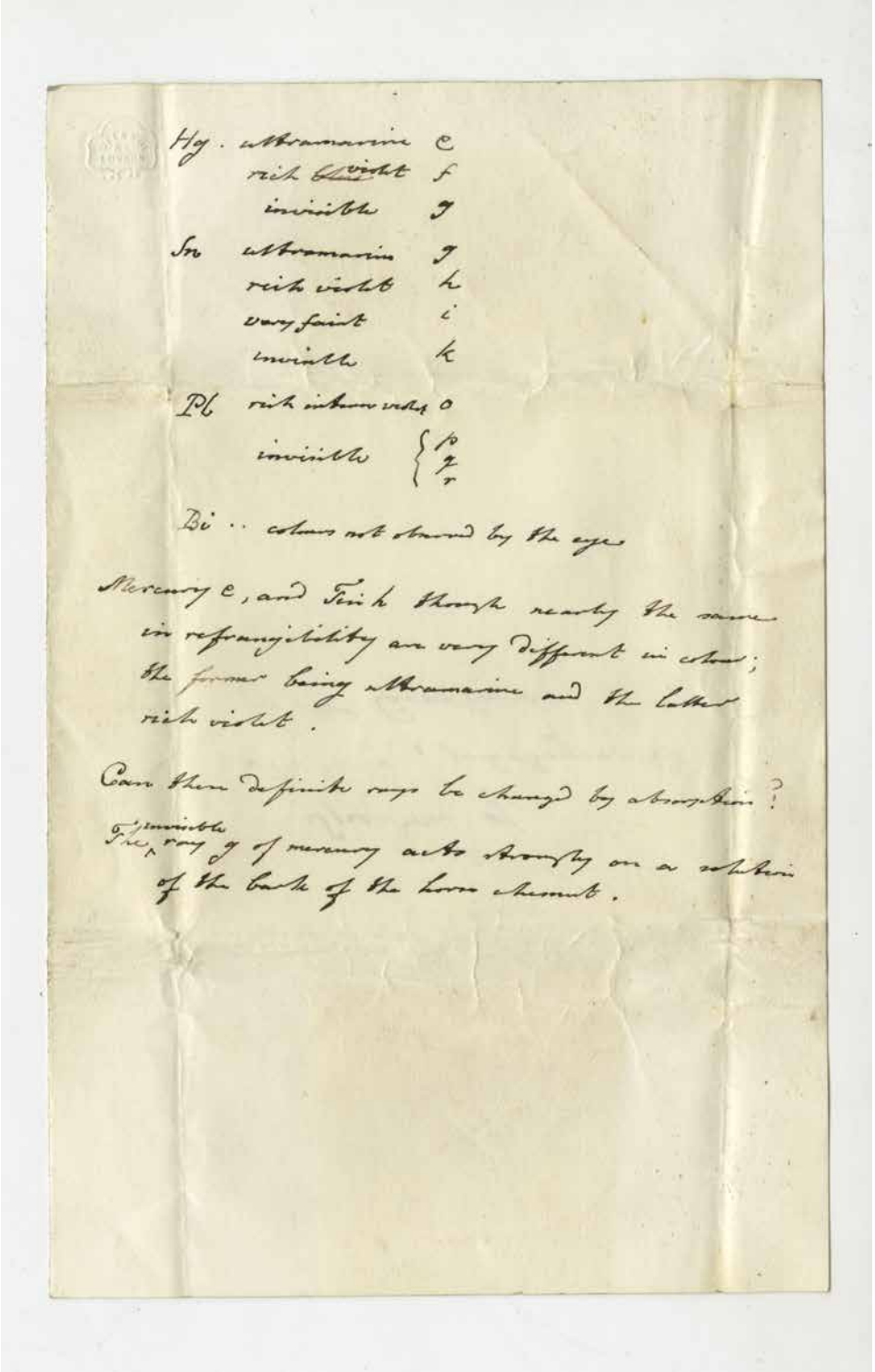
## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion



Hg. ultramarine e
rich ~~blue~~ violet f
invisible g

Sn ultramarine g
rich violet h
very faint i
invisible k

Pb rich intense violet o
invisible { p q r

Bi .. colours not observed by the eye

Mercury e, and Tin h though nearly the same in refrangibility are very different in colour; the former being ultramarine and the latter rich violet.

Can these definite rays be changed by absorption?

The invisible ray g of mercury acts strongly on a solution of the bark of the horse chestnut.

K/PP107/4/1/70
List and questions relating to the spectra of metals photographed by William Crookes (1832-1919), chemist and physicist, [1860-1875], see K/PP107/4/1/71-74.

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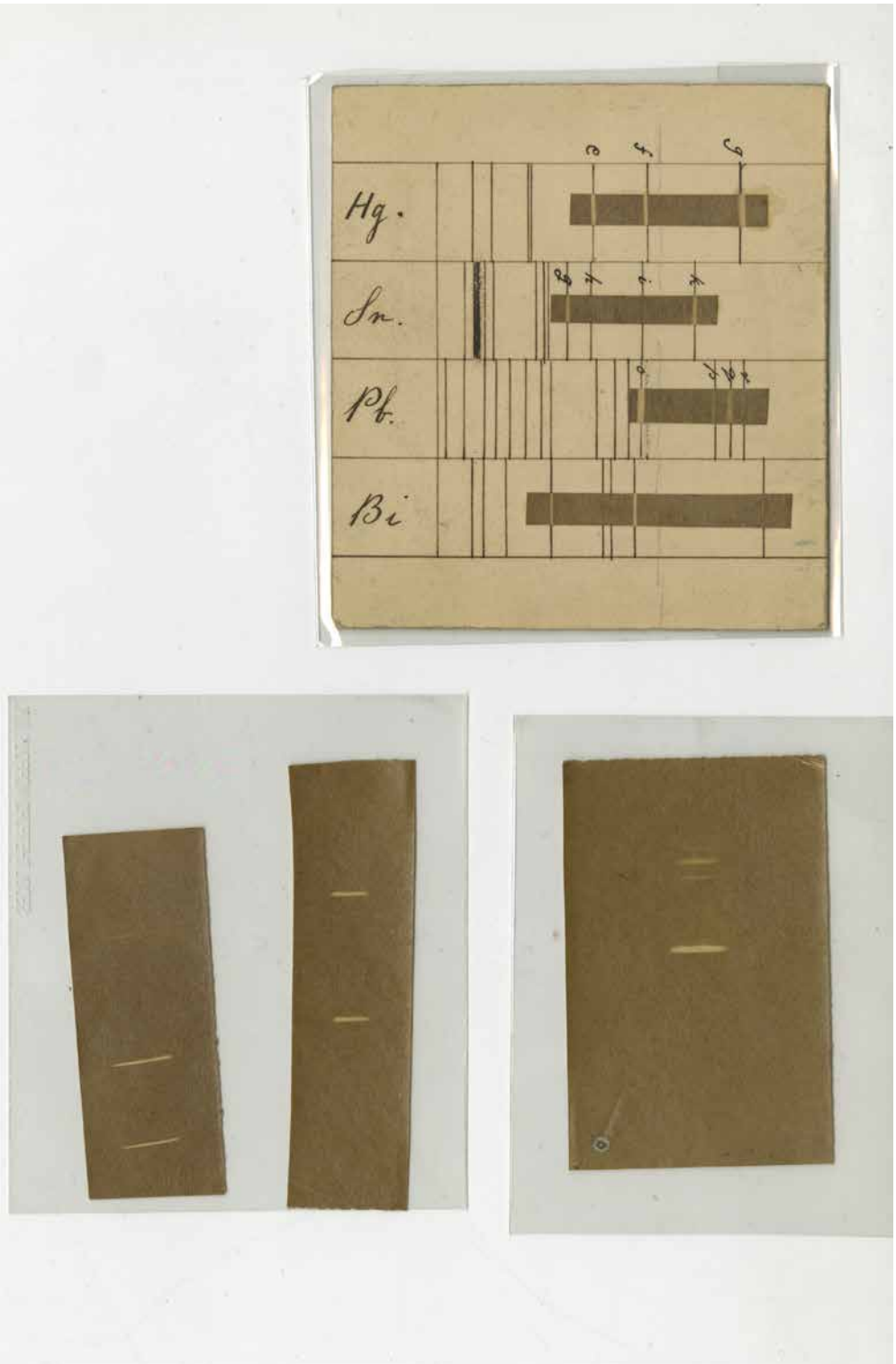
## K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion




K/PP107/4/1/71-74
Photographs taken by William Crookes (1832-1919), chemist and physicist, showing the spectra of metals, [1860-1875].