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.
To Measure the Velocity of Light.

1st Mode.

Place before the revolving mirror a long jet of air, and let the jet be placed so as not to disturb the mirror. The mirror is perpendicular to a line in a circle the centre of which is placed at a considerable distance from it, the jet being at the circumference of the circle. The jet impinges on the mirror in a line perpendicular to it. The jet is in motion, and when it has passed the jet it enters the sight of its observer. The mirror moves in the direction of the jet, and hence the jet is deflected by a distance equal to the difference of the velocities of light and the jet. The observer then measures the distance of the jet from the mirror, and hence the velocity of light.

If the jet is placed at $A$, the eye is placed at $B$. When the jet impinges on the jet the jet is deflected by a distance equal to the difference of the velocities of light and the jet. The degree of separation will indicate the velocity of light.

$$\text{jet}$$

$A$ $S$ $B$

The jet being placed at $A$, and the eye at $B$, the jet is deflected by a distance equal to the difference of the velocities of light and the jet. The observer then measures the distance of the jet from the mirror, and hence the velocity of light.

Instead of a refractive mirror, the jet may be placed in the centre of a large room, and the observer may be placed in the room; in this case the idea of a refractive mirror must be dispensed with.
In the course of an investigation of the phenomena of the electric sparks on which I have recently been engaged, the following experiment certainly seemed to me, though prejudging no higher interest to them than to belonging to popular classes of science, more from their novelty still be worthy a place in the Philosophical Magazine.

The electric sparks, whether obtained from the prime conductor of a machine, or from the discharge of a jar or battery, is so instantaneous in its duration as not to demand of comparison with any interval of time measurable by the most delicate instrument we possess to use. The following experiment is a consequence and a proof of this instantaneousness.

Let a sheet of card be made to rotate on the edge of a table, and the edge of the card be covered with a fine, smooth, and uncoloured ribbon (Fig. 1), of which the rotation continues the aid to be instantaneous. As soon as the ribbon is removed, the figure on the surface while while wing in the card to stationary and as distributed as it ever was on the table. The effect is the death of any explanation, the removal of the edges being seemingly known to it otherwise, and every conceivable fault with the motion of the body, which therefore be with the speed of the body, and eliminate the figures cannot remain in the lighted or on the paper, figure.
Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 2.
Draft paper by Wheatstone, 'New Optico-Electrical Experiments', in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 3.
Draft paper by Wheatstone, ‘New Optico-Electrical Experiments’, in which he describes experiments for measuring the velocity of electricity, [1834-1840], page 4.
Draft notes on experiments to measure the velocity of electricity and light, [1834-1840], page 1.
A. This is really analogous to the following well-known experiments, in which a whole detector on a card is placed on a mirror, when seen though a perforated regular distance round the circumference, which the detector, in reality, is not of anything. The whole mirror before the eye allows the reflected picture to be seen only as a circle, and the image remains on the disk. The image is only in the same number of similar positions; the same image appears continuous.

B. This again is analogous to the above suggested by the experiment of three days even. The mind that if the number of appearing exceeded the number of objects in the disk by unity, the reflected disk appeared on the paper in the same manner.

From what has passed, the following experiment will not be of difficult apprehension; and among others the electrical boy named for the new purpose of showing the effect when it was really made. To one of the in electricity and theory, the man of the same type of electric from the principle must be to correct the mind, and so on the form which may be joined to the elephant's moving figures.

Take a circular plate of glass, divide it into any number of sectors, and in the same number, draw the corresponding portion of the moving object of any object, on the lines those drawn with the same size of the form. To equal distances from each other. Let the line in the circumference be diminished by as little sections in a little hole covered with a plate of glass, and let the line near the centre of the plate. In the circle in contact with a metallic plate.
Draft notes on experiments to measure the velocity of electricity and light, [1834-1840], page 3.
The mind cannot estimate an interval of time much shorter than the eight of a second; nor can such small intervals be compared with any of the common methods usually employed to estimate time, such as the revolutions of a pendulum, &c.

All visual appearances of light may be such that above a half appear to the eye as equal durations and cannot be compared by any comparison with the usual subdivisions of time. No difference can be perceived by the eye between two flashes an hundredth of a second, the other a hundredth of a second.

If a luminous point change its place, travelling some given line, as it will be seen fairly in all parts of the line, and in the same cannot be determined which is the earliest of the appearances, when these appearances are less than a minute fraction of a second, the whole line will appear to the senses simultaneous. This necessarily follows from the appearance in both of the lights, that there is any peculiar property in the vibrations by which the impression remains longer, if the vibrations pertain any such property. It must be inferred from the phenomena, not from this.

K/PP107/4/1/5
Notes on experiments to measure an interval of time less than 8th of a second, [1834-1840], page 1.
If a luminous point of limited duration describe with an equal motion a given line, the duration of this light will be directly as the space described and inversely as the velocity. Therefore, though the duration be very small, it may be increased if velocity of the moving point, and the magnitude of the space required be given. The space being in this velocity, the problem is limited to a knowledge of the velocity, and shorter intervals will be maericaned in proportion as higher velocities are obtained. If we wish to ascertain the interval between two such points or paths the same mode of reasoning can be employed. (Be my first electric experiments.) The undetermined space then to perform experiments on these cases will be required.

If a luminous impulsion lasts but one the notion for a

With this time, a luminous point moving along a line should present the appearance of a moving lines, the length of the lines being determined by the duration of the impulsion, and the velocity of the motion. The real appearances have more in accordance with the supposition that the apparent duration arise from the inequality of the mind.

So in the duration or impulsion is extremely small intervals of time, there is no confusion, are uncertainty in the length of the line, which is similar to other cases when the perception is disturbed. The mind is not called up. This being the case these can be altered.
double cut that the apparent duration of light may be smaller as the same is more cut with in the same person.

The admissibility of this explanation will remove a great difficulty in the theory of vision. According to the ordinary notion the excited into an after action of the same kind, not also into one of a contrary description, which seems very difficult to conceive. I think 'tis more probable that the phenomena of colour spectra arise from a real duration of a physiological effect, while what is called the duration of luminous images is an illusion arising solely from the impressions of our percepts.
The Papers of Charles Wheatstone
K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

K/PP107/4/1/6
Notes on the use of revolving mirrors for experiments to measure the velocity of light, [1834-1840].
Let a luminous point be made to describe a circle; the point may be either an aperture in a metal plate, or a reflecting rod. 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 color will describe an equal circle having a different center, but all the centers 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 colors will not be concentric, but each will describe a perfect circle.

If the length of the spectrum be equal to the radius (fig. 2) it will be seen. One of the objects is here shown the division of the circle many posterior appearances will be observed; the resulting spectrum will be limited on the right and left by concentric circles, one over the other with and of the circle being equal. The supplementary green circle corresponding with the red A, the neutralizing points will fall elsewhere, and have the color probably from a curve cut by examined by prisms of different dimensions.
Notes and rough diagrams on the use of revolving mirrors to measure the velocity of light and electricity, [1834-1840].
Reflection and Refracting Surfaces in Motion.

An superficial cause may be produced by the continued motion of linear curves, and as the image of light is permanent to the perception for some time after the object is removed, it is preferable to construct mirrors by employing, instead of plane and curved surfaces, the generating lines of theses surfaces in motion. Thus

If two moving lines or paths or geodesies will generate a plane surface.

A segment of a sphere moving and a centre axis generates a spherical surface either convex or concave.

A semicircle moving and a line axis generates a cylindrical surface either convex or concave.

Many curves reflect the light. Some of the produce, for instance, two, more places of a different distance from the eye would generate two surfaces of reflection, and an object would be doubly reflected in the same direction. Multiple of these might on an extension of this principle might be produced.

The motions of reflecting and refracting surfaces may give rise to some very extraordinary phenomena by the colliding the rays in different directions which could not be obtained by the ordinary means.
Notes describing ‘Reflecting and Refracting Surfaces in Motion,’ [1834-1840], page 1.
Notes on single refraction and coloured polarisation, [1834-1875], page 1.
The Papers of Charles Wheatstone
K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

Coloured Polarisation.

Instead of employing a converging lens and placing the eye at
the centre of the cone, and not the circular range of a
converging plate, the equally small eye, using a diverging lenses,
and causing rays to be focused on a pair of ground glass plates,
put in the converging plate. If this experiment should succeed
instead of one diverging lens, several comparatively weak may be
employed, and figures resembling the real to exceed the figures might
be produced. The appearance would be precisely similar to Wheat's
electric elements ranging. A very strong light must be employed.
Modes of measuring minute intervals.

§1

If the two arms of an hour be unequally long, the shadow will rise as the measure, and the long arm as the magnifying index.

§2

Figs wheels of different wire are so placed on the same axis that give the same result. In this the axis is nearly a commutator of motion to the smaller wheel.

§3

The preceding mode will only work their angular magnitude, the metronomic measurement of strong & small must be affected by other means. A combination of a rod acting with a circular motion as in the sense will effect this. A rod is sure in cases of indefinite accuracy.

§4
Notes and diagrams on 'Modes of measuring minute intervals', [1834-1840], page 2.
The Papers of Charles Wheatstone
K/PP107/4/1 - Papers concerning reflecting and refracting surfaces in motion

Draft paper on 'Visual Duration of the Impressions of Light' or 'Luminous rays' - experiments to measure the velocity of light, [1834-1840], page 1.
Draft paper on 'Visual Duration of the Impressions of Light' or 'Luminous rays' - experiments to measure the velocity of light, [1834-1840], page 2.
Notes on William Hyde Wollaston’s (1766-1826), chemist and physicist, opinion on muscular contractions, [1834-1875], page 1.
May not the meteors called "falling stars" be small clouds or other congregations of matter charged with the electric fluid and by their rapid motion the time of their discharge visible? The difficulty in this case may be accounted for by the motion of the charged point, it may be rapidly attacked 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 have been explained by the greater energy of the discharge.
Notes describing a ‘Method of determining the duration of the appearance of shooting stars, and also whether their apparent velocity be equable or variable on reverse of ‘Methods of determining the duration of the motion of a projectile’, [1834-1875], page 1.
Methods of determining the duration of the motion of a projectile.

Two independent events, one shot from the other long, and a charged body fired at both, are conducted as such. The body in the free events to be thrown down to earth, after the same episode lead, and as pointed to continue before them, so as to arrive at the same point at the moment the distant was discharged. The interval is the same, and the other left the body when it arrives at its destination.

The motion of nature might be made to assume the purpose of overflying the duration of the motion of projectiles when the range is good, so that its arrival at its destination cannot be concordantly found.
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 path of a luminous point in a luminous line, when the motion of the point is sufficiently rapid to describe any sensible space in the eighth part of a second, has the same direction as if it were a point in motion, for by reasoning in the manner of the suppositions, the length of a given straight line indicates the space passed over in the eighth part of a second. But these can indicate only the rectilinear motion of a point at rest. The direction is also the same, but it may be determined by comparing with the rectilinear motion of the point with a moving plane. Denote $A$, $B$, $C$, and $D$ in the same plane; thus suppose a luminous point $P$ is moved from $A$ to $B$, and at the same time the plane on which $P$ moves to be carried from $C$ to $D$. The diagonal $AC$ of the plane moves from $A$ to $B$ when the plane is carried from $C$ to $D$. The diagonal $BD$ is divided in $E$, and when the point $P$ moves in the direction $A$ to $C$, the distance $AE$ is $2$, the point $E$ is then in the direction $B$ to $D$. The composition of motions will not only enable us to move from the direction of a moving luminous point, but also to velocity of the plane, which it will indicate the case where a part only of the path is visible, for the velocity of the plane being known it is known that when the velocity of the plane is the same as that of the point, then the angle of $AC$ is $90^o$, 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 certain 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 an celestial body, and also part of the celestial space.
The duration of luminous impulsion modifies the appearance of a number of electrical phenomena. When I drew a spring from the prism contact of a machine, I observed an intensely brilliant bright light. This is called an electrical spark, but it is impossible from their appearance to know what it is a real continuous line of light, or the effect of the incident bombardment of a particle luminous point in rapid motion. If one has the power to determine this point, we may make the spark, and this is the appearance I have employed for the purpose. If consists of a plate which I can move in the coordinate rapidly on a schlieren table, from the center of the plate runs an undulating gliding rod. The plate is attached at right angles to the beam having a hole at its end. The plate is immediately hence this is a similar plate. If I move the beam which is the gap in the primary plate. I draw with a black spot and move the plate, which is surrounded by a black spot. Now if I place the beam on the whole plate and put it in rapid motion, we may see the rapid motion with the spark between the two bodies.
Consider the revolution of the luminous point to be made in some the exact range necessary to complete the point in a circle, and then let it move in any oblique path of the same in the same space. If the angular motion 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 point must occur at every other 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 points where the revolution of the point is from each other, and these points, therefore, the place before a point is eclipsed in the same position. If the angular motion of the hand be one for the there are three points where the occurrence of every other revolution of the point, is revolution of the point, is revolution of the point, or one of these points as before it occurs at the same point. It happens from this that the three points are not produced by a continued absence of light, for in the last case there are these three luminous impressions to one intermittent action. Should the luminous impression last longer than the revolution the phenomenon will probably be modified, the number and positions of the bright spots will be the same, and their relative intensities will be varied.

In all the cases where 1 and 2 have been abled to the two motions are supposed to proceed in the same direction, or in opposite direction. Then the angular motion of...
The point and hand are the same. They will meet at every half revolution and consequently the points will be found.

When the angular motion of the hand is one half that of the point, they will meet at every third point of a revolution of either point or hand. Thus, the same experiment as in an earlier paper. The angular motion of the hand is one third. They will meet at every three fourths of a revolution, four such cycles therefore be found. In these cases the dark spots are not in any degree obliterated by points on luminous impressions as in the former cases.

We have now to consider the circumstance occurring when the angular velocity of the hand is greater than that of the point; and first, the case when the motion is turned around. That is, when the velocities are equal. They will always be seen as two such. Either the velocity of the hand is double the velocity of the pen, or one of the point; and when the velocity of the hand is double.
Observation on Dr Roget's experiment.

Dr Roget states that "the direction of curvature is precisely the same, whether the wheel be moving to the right or to the left of the observer". When a wheel moved and the bars were stationary, this would be the case, for the bars have only to the eyes as relative ingrades motion to the wheel; but when the axis of the wheel is stationary and the bars move, the phenomenon observed by Dr Roget 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 sphere is turned upwards.

Dr Roget has correctly laid down the law according to which the curved lines are generated; but he is not inclined in the physical explanation. The same causes may be produced by the combined motions of an opaque line and a wheel; but they are not thus produced in the same way here.

The rapid motion of the sphere of the wheel generates a 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 similar surface; also, the surface generated by the radius being the most luminous, whenever they intersect each other in a straight line is observed and is continued of the dark points generate the curved line.
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 4.
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.
amount from that calculated from the eclipses; and even this difference
will no doubt be destroyed by new and more rigorous analysis.

Such is the reason. In which these (observations on the annual
parallax of the stars) have been made, the diurnal parallax is
put into one single second; i.e. the radius of the earth
less a little to the mean to find from that the annual angle. It
cannot possibly have escaped detection and universal recognition.

However, have been one thousand, which amount for more than a
thousand times, in three centuries, in the effect of the smallest
motion times more, may be ascribed to the appearance of one a thousand
millions times more.
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

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.
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.
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.
Notes describing an ‘optical phenomenon in a revolving cube’, [1834-1875].
Universal delineator of curves, cyphers, figures etc.

Prepare two bars exactly similar each having a slant near by through their centre lengths place them at right angles to each other and in the aperture through both, place a pin leaving a small lead, it is evident that by varying the inclined motions of these two bars the lead may be brought to any direction within the square. To regulate the inclined motions each must be connected with a frame & equally in grooves.

It will be easy to set the wheel to any figure in the following manner; subdivide a point for the bread and 1st to follow a upper drawing of the figures required, set the wheel in motion and let a point on each describe the requisite lines and curves which will serve as guides for cutting the wheel.

The two wheels must communicate by pinions to the same toothed wheel, and the mechanism must be so contrived as to allow the complete figure or work to be described in the 1 horse of a second, and the wheel continuing to be wound will remain the point to go over the same path. If the figure covers a space, the wheel may be continuously turned the same way.

If the lead placed on a pin should be found to move yearly, 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.
Any figure containing a space may be produced in this manner. At the top of a revolving arm let there be placed a bar moving perpendicular to angular motion, but having a sliding motion of its own, and let this bar be fixed at the right end of the arm carrying the fixed, the other end of which has a hole through which the arm passes; the left end of the bar must move along a surface of the form A B D E to be described, and the point at the right end.

A continuous line curve in any manner may be obtained by a similar apparatus in which one end of the arm revolves in its fixed end as a straight line, and there must be no perpendicular lines.
Notes on ‘universal delineator of luminous images’ possibly Wheatstone’s photometer, [1834-1865].
Notes and rough diagrams listing experiments including a phantascope (optical apparatus) and an electrical chandelier, [1834-1875].
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.
Do not know whether the equation of the alkaled metal have yet been obtained by Dr. Faraday. There is one equation of the form of the electric spark. If the equation of the electric spark is a magnetic one, to obtain the other it may be necessary to take the spark in constant and by degree or nitrogen; they shall be taken in some one experiment to determine the general equation.

The highest degree of heat from flour rice not augment the number of lines of the induction spark doe. The degree of load and the intensity of an inductive spark to produce the same number of lines may be compared.

In the spectrum of alkaled do the lines preserve the respective intensities of the constituents.

It may be that the electric spark according to some different degree of concentration from one grain quartz line into another, but that it gives a very new line into existence in some cases brighter than those which have commenced at a lower intensity. I think that I have found an observing the same spectrum at different times. The what was the brightest line in one can was not in another. Even the color of the spark with the quartz line and the magneto-electric machine, [1860-1875], page 2.
Notes describing the 'prismatic decomposition of films and bands,' a type of spectrum analysis, [1834-1875], page 2.
Notes describing a method of spectrum analysis, [1834-1875], page 1.
In No. 2. Pieces of iron and platinum were juxtaposed, while the curtain was in one or the other direction. The same spectrum was exhibited.

When any body is very bright, the "c" of the spectrum may be made very narrow, but for want of time, we have not been able to study the effect produced. This may be observed in the double green line of the mercury spectrum.

Fig. 2.

A mirror placed on the mirror shown in addition to the line of the tellurium, the above-described line of iron.

When the line was opened by the No. 1, something more spectrums appeared, this forming an uniform spectrum coinciding with the line of the iron. Neither had did not so far.

Two sparks of different metals placed one after the other, as regarded by a spectroscope, show the line of the metal. The light of the hydrogen is then not absorbed by passing through the furnace.
Polarizing Spectroscope.

The thicker the plate, the more conspicuous are the bands.

The dark bands are less broad than the luminous spaces.

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

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

The spectrum, being horizontal and the dark bands consequently vertical, if a similar spectroscope be placed before the eyeglass having the slit horizontal (i.e. parallel to the spectrum), a new spectrum will appear having its central and dark bands put right ways to the original spectrum. Hence each central ray is again reflected and refracted; from the red end every other colour of the spectrum is refracted, and from every other ray are the rays of higher refrangibility or refracted, but none of lower refrangibility.

(A ray of light passed through red polychromat is not dispersed into its other rays, only the red is different.)

The luminous dark bands are the same in number as the resultant bands of the part of the longitute spectrum experiment upon.
Assuming the light to be produced by
the vibration of the elementary particles of
the metal (or other simple body) we must shew that in the electric spark, although there must be
some order arrangement as it seems part of the
electric circuit, the particles whatever it may be
directly since the light emitted by them shows
no signs of polarisation. To it possible by some
electric or electro-magnetic action to engage some
order arrangement on these particles so that they
themselves may be coped in a single plane or become
equivalent or equalised.

The following methods may be tried:
1. Place a wire conveying a strong current
passing by one of Wheatstone’s plates, in the direction of a
sparks from one 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 median part of a Wheatstone’s plate
with a spark conveying a strong current, leaving an
opening for the sparks to be seen.
3. Place the spark or Wheatstone’s plate between the
poles of a powerful magnet. Then, by this
experiment without any result employing an
equally powerful permanent magnet.
4. Bring a surface strongly charged in the positive
or negative electricity in the vicinity of the spark.
K/PP107/4/1/70
Wrapper for 'Spectra of Metals, photographed by Mr Crookes', [1860-1875].
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.
Photographs taken by William Crookes (1832-1919), chemist and physicist, showing the spectra of metals, [1860-1875].