XVII. *On the reflection and decomposition of light at the separating surfaces of media of the same and of different refractive powers**. *By* David Brewster, *L.L.D. F.R.S. L. & E.*

Read February 12, 1829.

It is a necessary result of the Newtonian theory of light, and one which Newton himself deduced, that when white light is incident on the separating surfaces of different media, it preserves its whiteness after reflection, excepting in those cases where the thickness of one of the media is beneath the 80 millionth part of an inch.

When the discovery of the different dispersive powers of bodies was made, it should have been obvious that reflected light never could be perfectly white under any circumstances, though such a modification was not likely to be detected in the usual routine of optical experiments. The only philosopher indeed who, in as far as I know, has made any experiments on the subject is Mr. Herschel; and as his opinions may be considered as representing those of the present period, I shall make no apology for quoting them.

"The phenomena which take place when light is reflected at the common surface of two media are such as from the above theory we might be led to expect, with the addition however of some circumstances, which lead us to limit the generality of our assumptions, and tend to establish a relation between the attractive and repulsive forces to which the refraction and reflection of light are supposed to be owing. For it is found that when two media are placed in perfect contact, (such as that of a fluid with a solid, or of two fluids

* The principal experiments contained in this paper were made in 1816, and were signed by the president of the Physical Class of the Royal Society of Edinburgh. A brief notice of them was published in the Quarterly Journal for July—October, 1816, and a more extended paper was read at the Royal Society of Edinburgh on the 4th of January 1819. The difficulties of the subject, however, prevented me from pursuing it but at distant intervals; and the more fertile topic of polarisation afterwards required all the time I could devote to such inquiries.

with one another,) the intensity of reflection at their common surface is always less the nearer the refractive indices of the media approach to equality; and when they are exactly equal, reflection ceases altogether, and the ray pursues its course in the second medium, unchanged either in direction, velocity, or intensity. It is evident from this fact, which is general, that the reflective or refractive forces, in all media of equal refractive densities follow exactly the same laws, and are similarly related to one another; and that in media unequally refractive, the relation between the reflecting and refracting forces is not arbitrary, but that the one is dependent on the other, and increases and diminishes with it. This remarkable circumstance renders the supposition of the identity of form of the function expressing the law of action of the molecules of all bodies on light indifferently, less improbable.

"To show experimentally the phenomena in question, take a glass prism or thin wedge of a very small refracting angle (half a degree for instance: almost any fragment of plate glass indeed will do, as it is seldom the two sides are parallel), and placing it conveniently with the eye close to it, view the image of a candle reflected from the exterior of the face next the eye. This will be seen accompanied at a little distance by another image reflected internally from the other face, and the two images will be nearly of equal brightness, if the incidence be not very great. Now apply a little water, or a wet finger, or still better, any black substance wetted, to the posterior face, at the spot where the internal reflection takes place, and the second image will immediately lose great part of its brightness. If olive oil be applied instead of water, the defalcation of light will be much greater; and if the substance applied be pitch, softened by heat so as to make it adhere, the second image will be totally obliterated. On the other hand, if we apply substances of a higher refractive power than glass, the second image again appears. Thus with oil of cassia it is considerably bright. With sulphur it cannot be distinguished from that reflected at the first surface; and if we apply mercury or amalgam (as in a silvered looking-glass), the reflection at the common surface of the glass and metal is much more vivid than that reflected from the glass alone. The destruction of reflection at the common surface of two media of equal refractive powers explains many curious phenomena, &c."*

* Treatise on Light, § 547, 548.

In the year 1814, when I was investigating the law of polarisation for light reflected at the separating surface of different media*, I had occasion to inclose oil of cassia between two flint glass prisms. The blue colour of the reflected light at first surprised me; but though the fact was new, and the experiment itself interesting, the decomposition of the light was obviously explicable upon known principles. Although the refractive density of oil of cassia exceeds greatly that of flint glass for the mean rays, yet the action of the two bodies on the less refrangible rays is nearly the same; and hence the red rays must be in a great measure transmitted, while there will be reflected a small portion of the orange, a greater portion of the yellow, a still greater proportion of the green, and a very great proportion of the blue: and consequently the colour of the pencil formed by reflection must necessarily be principally blue.

By using different kinds of glass and different oils I obtained various analogous results, in which different rays of the spectrum were extinguished by effecting (as far as possible) an equilibrium between the two opposite actions exerted upon them by the solid and the fluid media. When the blue light is extinguished, the colour of the reflected pencil has a yellow tinge; and it is obvious that the resulting pencil can never have a decided colour, but must always be bluish or yellowish.

As the indices of refraction remain the same for all obliquities of incidence, the tint of the reflected pencil, though it varies in intensity, can never vary in its colour; so that we cannot obtain any succession of tints or coloured rings from this partial decomposition of the incident rays.

These observations establish it as a general fact, that in all cases of reflection from transparent surfaces, the reflected pencil must necessarily have a different tint from the incident pencil, excepting in the extreme case where the two bodies in contact have mathematically the same refractive and dispersive powers.

I was now anxious to observe the effect of an approximation to this last condition, or to a perfect equilibrium of all the forces which affect the incident rays; as it is often in extreme cases, and at a limit such as this, that nature delights in the development of new phænomena. This experiment, however, was attended with more difficulty than I expected; but amid the numerous

* Phil. Trans. 1825, p. 137.

disappointments which it occasioned, I was led to the results which I shall now proceed to describe.

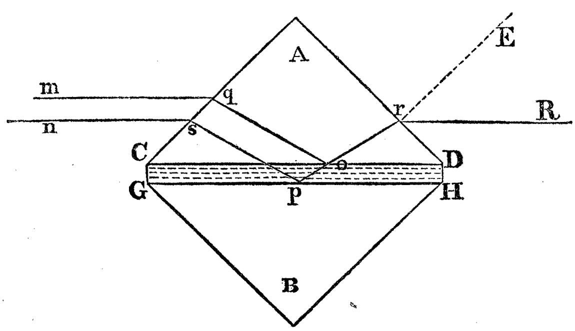
The solids which I employed were two prisms of plate glass, which I shall call A and B. The prism A, whose section was an isosceles right-angled triangle, had its base polished at the plate glass manufactory where it was made. The prism B was executed for me by Dollond, and very finely polished, having also its section a right-angled isosceles triangle. The refractive indices were

In A ... $m = 1{,}508$
In B ... $m = 1.510$

The fluids which I employed were castor oil and balsam of capivi, the latter having a greater and the former a less refractive power than the glass prisms. The refractive indices were

In castor oil .... $m = 1.490$
In balsam of capivi ... $m = 1.528$

Fig. 1.



The prisms A, B were now fixed together as in fig. 1, and a film C D of castor oil interposed between them. A ray of light R *r* will after refraction at *r* be reflected in the direction *o q m* from the surface C *o* D which separates the prism A and the oil; and another portion of it will be reflected in the direction *p s m* from the surface G *p* H which separates the prism B and the oil. In order that the two rays *q m*, *s n* may be sufficiently separated, the common sections of the faces which contain the right angle are slightly inclined to each other.

When the angle of incidence R *r* E is very great, the light suffers total reflection at the surface C *o* D. Within the limit of total reflection the light *o q m* is yellow; and by diminishing the angle of incidence gradually, the pencil *o q m* passes through all the tints of nearly three orders of colours, as shown in the following Table.

	Colours.	Angles of Incidence R r E.	Angles of Incidence on Surface C o D*.
		°	° ′
1st Order.	Yellow	70	83 33
	Orange	63	81 13
	Red	61	80 27
	Pink	59½	79 51
	Limit of pink and blue	58	79 14
2nd Order.	Bluish pink	57	78 46
	Full blue	55	77 54
	Greenish blue	52	76 30
	Yellowish blue	48	74 32
	Yellow	41	70 46
	Reddish yellow	34	66 46
	Redder still	26	61 54
	Red	21	59 4
	Pink red	17	56 11
	Limit of pink and blue	14	54 14
3rd Order.	Blue	+ 9	50 57
	Bluish green	0	45 0
	Yellowish	−15	35 46
	Full yellow	−22	30 37
	Reddish yellow	−31	25 21
	Pink	−52	13 30

The colour of the pencil *p s n* produced by the other separating surface G *p* H is at all incidences a faint yellowish gray, (which is best seen by turning the system of prisms upside down; and receiving the ray R *r* upon the prism B, so that the reflected ray *p s n* may not pass through the oil;) and its intensity suffers very little change. This fact is a very remarkable one, and arises (as will be presently seen) from some specific property of the glass itself. When the lower prism is of the same glass as A, and produces the colours in the preceding table at different angles of incidence from those of A, the play of colours

* This column is calculated from the formula $A = 45° \pm \frac{\sin. I}{m}$, I being the angles of incidence in the 1st column, A the angles in the 2nd, and $m = 1.508$ the refractive index of the glass.

is particularly fine, and the whole phænomenon is one of the most beautiful in physical optics.

When the incident light is homogeneous, no colours of course are seen; but the reflected pencils have their maxima and minima of intensity, like the rings of thin plates or the fringes of inflected light when formed by homogeneous rays.

The following are the periods for red and for blue light.

	Red Light.	Blue Light.
1st minimum	77° 54′	80° 27′
2nd minimum	50 57	59 4

If we substitute for the prism A a square prism, the tints are thrown more closely together; and if the luminous object is a long stripe of bright light, we may see most of the colours at one view.

If we now apply heat to the oil so as to diminish its refractive power, the brightness of the colours is greatly diminished, and the first period is completed at a less angle of incidence.

Such are the phænomena which take place when the refractive power of the glass exceeds that of the fluid. We shall now see what happens when the fluid has a greater refractive energy than the solid; a case of peculiar interest, because we are able to reduce the two refractive powers to a perfect equality for any given ray of the spectrum.

The same prisms being employed, let the film C D H G be now balsam of capivi. Before total reflection takes place, the reflected pencil is perfectly white: it then becomes yellow, and passes through the same orders of colours as in castor oil. All the colours, however, are produced at less angles of incidence, the 1st order terminating at an angle of 64° 58′, as appears from the following Table, in which I have given only the leading tints.

	Colours.	Angles of Incidence R *r* E.	Angles of Incidence on the Surface C *o* D.
1st Order.	Yellowish	47°	74° 10′
	Yellow	41	70 47
	Pink red	36	67 57
	Pink	33	66 10
	Limit of pink and blue	31	64 58

	Colours.	Angles of Incidence R r E.	Angles of Incidence on the Surface C o D.
2nd Order.	Bluish pink	28°	63° 8′
	Full blue	26	61 54
	Bluish green	22	59 23
	Bluish yellow	18	56 50
	Yellow	10	51 37
	Reddish yellow	1	45 40
	Red	−8	39 42
	Pink red	−13	36 25
	Limit of pink and blue	−16	34 28
3rd Order.	Blue	−22	30 37
	Bluish green	−26	28 56
	Green	−30	25 29
	Yellowish green	−41	19 13

Having ascertained that at a temperature of about 94° the mean refractive index of the balsam was nearly equal to that of the glass prisms, I proceeded to examine the influence which a varying temperature from 50° to above 94° exercised over the intensity and the colour of the reflected pencil.

The prisms were therefore fixed so as to exhibit the full blue of the second order, and the heat was gradually applied. The colour of the tint was obviously improved by heat, though the intensity of its light was diminished. No particular change marked the instant when the refractive density of the glass and the balsam was equal. Beyond 94° the intensity of the tints increased in consequence of the diminution in the refractive power of the balsam; but when the temperature was considerably augmented, the tints completely disappeared.

Let us now attend to a very remarkable phænomenon exhibited in the relative intensities of the pencils *o q m* and *p s n*. At an angle of incidence of 61° 54′ on the surface C *o* D, and at a temperature of about 50°, the pencil *o q m* is a full blue, while *p s n* is a grayish white of rather less intensity than the blue pencil. By increasing the angle of incidence, the pencil *o q m* increases rapidly in intensity, while the gray pencil diminishes slowly: so that at an incidence of 74°

o q m is ten or twelve times more luminous than *p s n*; whereas at smaller incidences than 61° 54′, the pencil *p s n* surpasses *o q m* in the intensity of its light. By the application of heat *p s n* becomes yellowish-white, and increases greatly in intensity. It now approaches at oblique incidences to the brightness of *o p m*, but is still inferior to it, while at small incidences it surpasses it in intensity.

In the preceding experiments the solid had nearly the same refractive density as the balsam. We shall now take a solid, namely obsidian, which has nearly the same refractive power as the oil.

When the lower prism B is obsidian, and the film C D, H G balsam of capivi, the ray *p s n* passes through three orders of colours; namely,

1st Order. { White, Yellow, Red, Limit of red and blue at 73°.

2nd Order. { Blue, Bluish-green, Yellowish white, Reddish white, Pink, faint.

3rd Order. { Bluish, Bluish-white.

These colours are by no means good, nor are they much improved by heat, which approximates the refractive power of the fluid to that of the solid. The heat reduces the orders to two, each colour being now developed at a much smaller angle of incidence. The first order, for example, which ended at an incidence of 73°, now ends at an incidence of 52°. When the heat is so great that we cannot touch the prisms with the hand, all the colours are effaced.

If we now substitute the castor oil in place of the balsam, no colours are visible; but the reflected pencil *p s n* is white and bright, notwithstanding the coincidence between the refractive energies of the solid and the fluid. Heat increases the intensity of the pencil, but produces no colour.

Hitherto we have considered the action of the two surfaces of the film as exhibited separately in the two images displaced laterally by the prismatic shape of the fluid. We shall now briefly notice the phænomena which are presented by the superposed images when the film of fluid has its surfaces parallel. If the two prisms A, B give separately the same periods of colours, but at different angles of incidence, then the resulting tints are very irregular and indistinct; but if the maxima of the periods produced by one prism coincide with the minima of the periods produced by the other, the colours will be almost wholly obliterated, though it is not easy to ensure the condition on which this compensation depends. When the separate prisms give exactly the same periods at the same angles of incidence, then the minima of the one will correspond with the minima of the other, and the maxima with the maxima; so that the combination produces the same periods of colours that were produced by each prism separately; but the intensity of the tints is doubled. This duplication of the tints is easily observed by bisecting a prism which produces distinct periods, and separating the two halves by a fluid film.

Although the preceding experiments are sufficient to establish the existence, and explain the nature of this class of phænomena, yet, as they will probably lead to very important consequences in the theory of light, I shall make no apology for giving an account of another series, of a very instructive kind, and performed with fluids particularly fitted for the investigation. I continued to use the same prisms of plate glass; but as the oil and balsam formerly employed differed considerably in refractive power from the glass, I sought for two oils with nearly the same mean refraction as the prisms; and those which I selected were oil of cummin and distilled wood oil*, which were fortunately capable of being mixed together with great facility. Their refractive powers for the mean yellow rays were nearly as follows:

	Indices of Refraction.
Oil of cummin	1.512
Plate glass, prism B	1.510
Oil of cummin and wood oil mixed	1.5085
Plate glass, prism A	1.508
Wood oil	1.506

As nothing depends on the numerical accuracy of these indices, I did not measure them with any peculiar attention; but by immersing a right angle

* This oil was sent to me from the East Indies by GEORGE SWINTON, Esq., Secretary to the Government at Calcutta.

of each prism in a vessel containing each of the three oils, I carefully determined that, at a temperature of 50°, they acted on the homogeneous yellow light of a monochromatic lamp, in the order in which they are above placed.

I now combined each of the oils in succession with the two prisms, as shown in Fig. 1, and in all the combinations the separating surface of the prism A and the oils produced from a white flame, nearly three orders of colours of the same intensity, and nearly at the same angles of incidence, as in balsam of capivi; while the separating surface of the prism B and the oils reflected only a faint gray image of very little intensity, and generally growing fainter as the angle of incidence increased.

When the homogeneous yellow light of a monochromatic lamp was used, the separating surface of the prism A and all the oils produced the first minimum at nearly the same angle of incidence; and though I applied heat gradually to the least refractive oil, and cold to the most refractive one, so as to produce a perfect compensation of opposite refractions for the yellow rays, yet no perceptible change appeared either in the place of the first minimum or in the intensity of the reflected light. In the case of the mixed oil the compensation was effected without any other change of temperature but what was occasioned by a change of position in the apartment.

In the expectation of discovering some solid or fluid medium which would produce with plate glass a greater number of orders of colours, I made the experiments contained in the following Tables.

TABLE, Showing the periods of colours produced at the separating surfaces of plate glass and oils and other fluids.

Names of Oils.	Image at the Surface of Prism A.	Image at the Surface of Prism B.
Oil of Cassia	Pale red tints at 65° of incidence; then at less incidences pale blue, and then pale red. Heat strengthens the tints a little.	White and bright.
Balsam of Peru ..	Slight tinges of red; blue as above. Two faint orders of colours brought out by heat.	Yellowish white.
Oil of Anise-seeds	The tinges of two orders of colours. Heat of 200° brings out two good orders of colours. Limit of pink and blue of the first order at an incidence less than 65°.	Grayish or bluish white.
Balsam of Styrax..	Tinges of two orders of colours. Improved by heat.	Bright white.

Names of Oils.	Image at the Surface of Prism A.	Image at the Surface of Prism B.
Canada Balsam ..	Above two orders of colours; pink of second the best. Improved by heat.	Grayish or bluish white.
Oil of Tobacco ..	Two faint orders of colours. Heat brings out nearly three.	Grayish white.
Oil of Cloves	Two faint orders. Heat brings out part of a third. First limit of pink and blue about 65° of incidence.	Yellowish white; but bluish gray with heat.
Oil of Sassafras ..	Two orders. First red pale. First blue good.	Grayish white.
Balsam of Capivi ..	See page 191.	
Muriate of Antimony	Two tolerably distinct orders of colours.	Grayish white.
Oil of Cummin....	Two beautiful orders. A fine yellow in the second order. Heat spoils them all.	Faint grayish, becoming more intense and yellow by heat.
Nut Oil	Two faint orders, the second red and second blue being tolerably good. Heat brings out two fine orders, the first limit of pink and blue ending at about 76° of incidence.	Yellowish white.
Oil of Pimento....	Three good orders of colours. First limit of pink and blue at 65° of incidence.	Pale blue, very faint at great incidences.
Oil of Sweet Fennel-seeds..........	Two orders; pink good.	Bluish gray.
Wood Oil........	Three good orders of colours. First pink and blue fine. First limit of pink and blue ends at 65°.	Bluish gray, weaker at great incidences.
Oil of Amber	Two excellent orders of colours. First limit of pink and blue at 65°. Improved by heat.	Pale blue, very faint at great incidences.
Oil of Rhodium ..	Two and a half good periods. First limit at 65°. Heat injures them.	Yellowish white.
Treacle..........	At temp. 50° three orders, which are not good, especially the pink of first and blue of second order. Heat brings out three splendid orders with periods, as in castor oil*.	Yellowish white.
Balsam of Sulphur .	Three fine orders. First limit of pink and blue at about 67°.	Faint gray, getting fainter and bluer at great incidences.
Honey	Two pretty good orders. First limit at about 65°.	Slightly yellowish white.
Oil of Angelica ..	Two and a half orders. First pink and first blue fine; second red good.	Whitish yellow.
Oil of Nutmeg....	Three not very bright orders. First limit at 73°.	Whitish yellow.

* The treacle used in this experiment is much inferior in refractive power to the prism A.

Names of Oils.	Image at the Surface of Prism A.	Image at the Surface of Prism B.
Oil of Marjoram ..	At a low temperature the orders are scarcely perceptible, the second limit only being visible. Heat brings out the second limit at a less incidence, and creates the first limit at 79°.	Whitish yellow.
Castor Oil	See page 193.	
Oil of Hyssop	Colours very faint. Heat brings out three good orders. First limit at 77°.	Whitish yellow.
Oil of Fenugreek..	Colours rather better than the preceding. Heat brings out three good orders. First limit at 75°.	Whitish yellow.
Oil of Caraway-seeds	Two orders, not good.	Whitish yellow.
Oil of Thyme	Slight tinges of colour. Heat brings out two good orders.	Yellowish white.
Oil of Turpentine .	Two tolerably good orders. First limit at 74°.	Whitish yellow.
Cajeput Oil	Two tolerably good orders. First red bad, second red good.	Yellowish white.
Linseed Oil	Two extremely faint orders. Three good orders brought out by heat. First limit at 73°.	Yellowish white.
Train Oil	Three very good orders. First red and first blue excellent. First limit at 73°. Heat spoils the first order.	Yellowish white.
Oil of Savine	Almost no colours, both images being yellowish, and that of B brightest. Heat brings out three orders. First limit at 80°, which a greater heat brings to 75°.	Yellowish white.
Oil of Pennyroyal .	Almost no colours. A sort of bluish gray when cold. Heat brings out two good orders when temp. only 90°, but greater heat injures them.	Yellowish white.
Oil of Almonds ..	Three tolerable orders. First red bad, second red good.	Yellowish white.
Oil of Mace	Gives three and a quarter orders when cold. First limit at about 80°. When the film of the oil begins to crystallize, it displays red, blue, and greenish tints, at the same incidence, in different places.	Pretty bright.
Oil of Spearmint ..	Very faint colours. Heat brings out three good orders. First limit at about 77°.	Yellowish at great incidences.
Oil of Lemons	Three fine orders. First limit at 74°. Heat destroys the first order.	Yellowish white.
Oil of Dill Seed ..	Two poor orders of colours. First limit at 73°. Heat improves them.	Yellowish white.
Oil of Peppermint .	Two good orders. First limit 73°. Heat destroys the first order.	Yellowish white.
Oil of Rapeseed ..	Two very faint orders. First limit at 65° when improved by heat.	Bluish gray.
Naphtha from Persia	Three very good orders.	White.

Names of Oils.	Image at the Surface of Prism A.	Image at the Surface of Prism B.
Oil of Bergamot ..	Three very fine orders. First limit at 73°. Heat spoils first order.	Yellowish white.
Oil of Beech Nut	Three excellent orders, and well defined. First limit at 73°. Heat spoils first order.	Yellowish white.
Spermaceti Oil....	Two tolerable orders. First red and blue bad, second red and blue good. First limit at 73°.	Yellowish white.
Oil of Olives	Three good orders. First limit at 73°.	Whitish yellow.
Grass Oil........	Three good orders. First limit at 73°.	Grayish white.
Oil of Rosemary ..	Two good orders and more. First limit at 73°.	Whitish yellow.
Oil of Poppy	Three excellent orders. First limit at 73°. Heat injures the colours.	Yellowish white.
Oil of Lavender ..	Three good orders. First red and first blue very fine. First limit at 74°.	Yellowish white.
Oil of Camomile ..	Two good periods. First limit about 60°.	Bright yellowish white.
Oil of Wormwood .	Three good periods. First limit at 71°, but not well defined.	Yellowish white.
Bhela Juice	Three faint orders at low temperatures, but finely brought out by heat. First limit at 73°.	Yellowish white.
Muriatic Acid	Traces of tints.	Yellowish white.
Sulphuric Acid....	Two pretty good orders.	Yellowish white.
Vitreous Humour of the Haddock	Traces of colours.	Bright.
Oil of Rhue	No colours.	Bright.
Oil of Boxwood ..	No colours.	Bright.
Alcohol	Traces of reddish, bluish, and greenish yellow tints.	Bright.
Water...........	Traces of tints.	Bright.

The experiments * recorded in the preceding pages may be divided into two classes.

I. Those which establish the existence of reflecting forces at the confines of media of the same refractive power; and,

* These experiments have been extended to a great number of mixed oils and to soft solids, gums and resins, combined with the prisms A and B. I have also substituted for these prisms others of different kinds of glass, which give similar results; and I have examined the phænomena at the confines of different fluids and a great number of minerals of various refractive powers between chromate of lead and fluor spar.

II. Those in which periodical colours are produced at the confines of particular kinds of glass, and various fluids and soft solids.

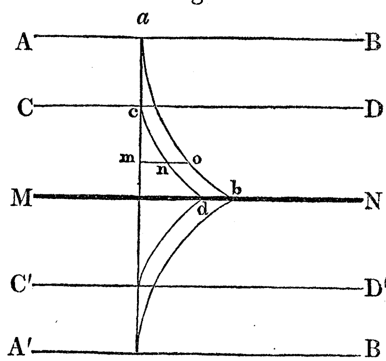
From the first of these classes of facts the following conclusions may be drawn.

1. The reflective and refractive forces in media of the same refractive power do not follow the same law. This result is clearly established by the experiments with the prism B, which produced no orders of colours. Not only was there a strong reflected pencil when a perfect equilibrium was effected between the opposite refracting forces, but there was not even an approximation to evanescence as the forces advanced to their point of compensation. The same result was obtained with a prism newly ground and polished.

2. The force which produces reflection varies according to a different law in different bodies. If the curve which represents the law of the reflective force were exactly the same in the prism B and the fluids combined with it, then the ordinates which represent the intensity of the force at any given point would be exactly equal, and consequently there would be a perfect equilibrium of opposite actions, and no reflection of the passing light. But as a copious reflection takes place even when the opposite forces are balanced, we are entitled to infer that the law of the two forces is different.

The reflective forces in the solid and fluid may be conceived to decrease in various ways.

Fig. 2.



1. They may extend to different distances from the reflecting surface, and decrease according to the same law. This relation is shown in Fig. 2, where M N is the reflecting surface, A B the limit of the sphere of reflecting activity in the solid, and C D that in the fluid,—*a o b* the curve which represents the reflecting force of the solid, and *c n d* that of the fluid. In this case there can be no compensation of opposite reflections, and an unbalanced reflecting force will exist at almost every point of the sphere of reflecting activity. From *a* to *c* the light will be acted upon by the undiminished force of the solid. At *c* the force of the fluid begins to oppose that of the solid, and the unbalanced force at any other line *m o* is equal to *n o*, the difference of the two forces *m n*, *m o*. In this case there will be a sphere of reflecting activity extending from A B to A′ B′, and such a combination must reflect light without refracting it.

2. The reflecting forces may extend to different distances, and vary according to a different law. Two cases of this kind are shown in Fig. 3 and 4.

Fig. 3.

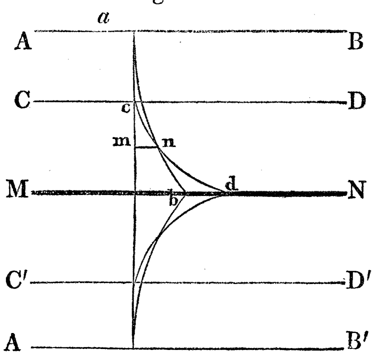
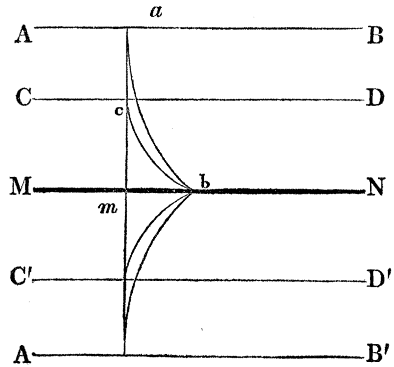


Fig. 4.



In the case of Fig. 3. the curves expressing the law of the forces have a common ordinate *m n* where the reflections are compensated; but from *a* to *n* the reflecting force of the solid will predominate over that of the fluid, and from *n* to *d* the force of the fluid will predominate over that of the solid; so that in such a combination there will be two spheres of reflecting activity, one of which begins where the other ends.

In the case of Fig. 4, where the curves have the same maximum ordinate *m b*, we shall have a sphere of reflecting activity commencing at *a*, reaching its maximum at *c*, and its minimum at *b*.

3. The reflecting forces may be conceived to extend to the same distance, and to vary according to different laws. Two cases of this kind may occur; one, as in Fig. 5, where the maximum of unbalanced force is distant from the surface, and another, as in fig. 6. where the maximum takes place at the reflecting surface.

Fig. 5.

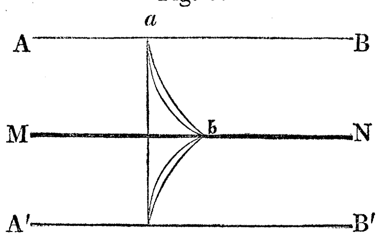
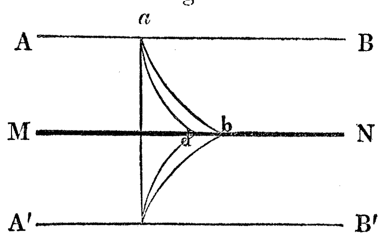


Fig. 6.



In the conclusions which we have drawn respecting the independence of the reflecting and refracting forces, it was supposed that the latter follow the same law in solids and fluids. There seems to be no method of determining whether or not this is the case; for experiment indicates only the total effect, or the sum of all the ordinates, and these may be compensated, though they vary according to different laws.

There is one hypothesis, however, on which the preceding experiments may be reconciled with the supposition of the mutual dependence of the reflecting and refracting forces. If we suppose, for example, as in Fig. 3, that the refracting forces of the solid and fluid are regulated by the same curves as their reflecting forces, and that the absolute effect of each is the same; then, though the refractive forces are perfectly balanced, and though the total effect of each reflecting force taken separately is the same in the solid as in the fluid, yet light will still be reflected in the manner formerly described. It seems highly probable that the law of the refracting force varies in different bodies; and if we take for granted the mutual dependence of the refracting and reflecting forces, the preceding experiments will establish a variation in the law of the refracting forces of different media.

In the undulatory system, the preceding facts may be explained by supposing that the density or elasticity of the ether varies near the surface of different bodies; a supposition in itself highly probable, and which has been already adopted to explain the loss of part of an undulation in several of the phænomena of interference. In such a case the reflection of the light will commence at a line where the density or elasticity of the ether in the first medium begins to change, and will continue till the ray has penetrated to that part of the second medium where the density or elasticity of the ether is uniform. In this theory, therefore, the preceding facts may be regarded as proving the variable condition of the ether near the surfaces of bodies, and of establishing the beautiful and sagacious deduction of Dr. YOUNG, that the part of an undulation lost is a variable fraction depending on the nature of the contiguous media.

II. We come now to consider the second class of phænomena, or the existence of periodical colours at the confines of certain media of the same and of different refractive powers.

That the periods of colour arise, as in all similar phænomena, from the interference of two portions of light cannot be questioned; though it does not appear how these interfering pencils are generated. If we adopt the hypothesis of the reflecting forces shown in Fig. 4, we may conceive the light reflected about C D to be interfered with by the light reflected about C′ D′, so that the same effect nearly might be produced as if C D, C′ D′ were the limits of a thin plate. If this supposition is not admissible, we may hazard the conjecture, countenanced by some facts which will presently be stated, that an invisible film differing in refractive power from the plate glass, has been formed upon its surface.

There is one phænomenon which has been more than once mentioned, and which requires some further notice; namely, the decrease in the intensity of the pencil as the incidence becomes more oblique. In re-examining this very perplexing fact, which takes place in the prism B though it does not produce periodical colours, I have observed at a great incidence a distinct change of colour, from a bluish gray to a blue; so that I have no doubt that in this case the tints are those of a long period approaching slowly to its minimum. This consideration led me to suppose that in the case of balsam of capivi and other fluids, where the first order ends at and below 65°, there might be another minimum between that angle and 90°, which was prevented from showing itself by the intensity of the reflected light. This conjecture was confirmed by a careful repetition of the experiment with cubes of glass, and also by another prism in which the only tint was a pink red at an incidence of about 85°, and a blue shading off into a greenish gray at less angles of incidence. In this case, then, there was only one minimum at about 85°. A slight diminution of temperature shifted this minimum towards 90°, while an increase of temperature brought it to a lesser incidence than 85°.

Although there can be little doubt that periodical tints are more or less developed in every combination of solids and fluids of the same refractive power, yet their production in combinations where there is much uncompensated refraction, is influenced by certain changes on the surface of the solid, the nature and origin of which I have in vain attempted to discover.

Having observed that the colours occasionally became less bright after the media had remained some time in contact, and that different parts of the same surface produced the same tint at inclinations sensibly different, I took a prism which gave with castor oil three fine periods; and having brought it to a white heat, I then ground and repolished its faces. It now ceased to give the same periods as before; but it still decomposed the white light reflected from its confines with balsam of capivi, and reflected a strong pencil of a blue colour, even when the opposite refractions were perfectly compensated. I now ground and repolished one of the faces of the obsidian already mentioned. It also ceased to give the colours with balsam of capivi formerly described; but it now produced, when combined with castor oil, with which it previously gave no colours, a beautiful yellow pencil, the reflected light being white at great incidences, and becoming yellower as the ray approached the perpendicular. In order to ascertain what changes might be owing to the processes of grinding and polishing, I sought out an old face of fracture in a plate of glass, whose wrought surfaces gave fine periodical colours; and I formed a new face of fracture. The old face which had been exposed for ten years gave the usual orders of colours; but the new face gave only one colour, which was a bright blue, but which, from the nature of the surface, I could not trace to high or low incidences.

As these results seemed to indicate that the glass had received from exposure to the air some incrustation, or had absorbed to a small depth some transparent matter in a minute state of division, or had suffered some change in its mechanical condition, I made various fruitless attempts to ascertain the nature of the change. No superficial tarnish could be rendered visible, either by the microscope or by any other means. I boiled the prisms in muriatic acid, and in strong alkaline solutions: I steeped them in alcohol, and applied a strong pressure along their surfaces; but I could not in the slightest degree change their action upon light.

If a superficial film had been formed upon the glass of such a thickness as to give the periodical colours, then its refractive power must be different from that of the glass. I therefore took a prism which gave the periodical colours, and another of the same glass which had been deprived of this property; and I found that they polarised light at exactly the same angle. I then placed them upon the base of a flint glass prism with oil of cassia interposed, and I determined that the angle at which they reflected light totally was the same*. Hence it was manifest that the supposed film did not differ in refractive power

* The prism which produced the periodical colours, did not give so distinct a boundary between partial and total reflection as the other.

from the glass; and even if it did, some one of the oils with which it was in contact in the foregoing experiments must have had the same refractive energy, and must thus have deprived it of its power to develope the periodical tints. In the hope of unravelling this mystery, I took two prisms of glass cut out of the same plate, and which gave fine periodical colours with castor oil. By the aid of screws I pressed the bases of the prisms into optical contact: at great incidences the light was yellow; and by diminishing the inclination of the ray it became gradually orange and deep red when it vanished, no light being visible at smaller angles of incidence. In this experiment the surfaces of the two films, if they do exist, were brought into optical contact, so that we ought to have had orders of colours corresponding to a film of twice the thickness.

But even if such a film could be supposed to exist invisibly on the glass, it could not afford any explanation of the splendid colours which are exhibited when the solid is a crystallized mineral, and where its tint is related to its axis of double refraction. That some unrecognised physical principle is the cause of all these phænomena, will appear still more probable when I submit to the Society a paper on the very same periods of colour produced at similar angles of incidence, by the surfaces of metals and transparent solids when acting singly upon light.

The action of the surfaces of crystallized bodies presents many remarkable phænomena, in the investigation of which I have been long occupied. The results to which I have been led will form the subject of two communications. The first will treat of the action of the surfaces of bodies as an universal mineralogical character, with the description of a lithoscope for discriminating minerals. The second will contain an inquiry into the influence of the doubly refracting forces upon the ordinary forces which reflect and polarise light at the surfaces of bodies. My early experiments on this subject are recorded in the Phil. Trans. for 1819, but I have resumed the inquiry, and have obtained results of considerable interest.

Allerly, February 2nd, 1829.