f. 1

$$\frac{1}{f} = (\mu - 1) \cdot \frac{2}{R} \qquad R = 0.474$$

$$= (\mu - 1)\frac{2}{\rho} + \frac{(\mu-1)^2}{\mu} \cdot \frac{t}{\rho^2}$$

t = 0.25
ρ of thick lens

μ = 1.60

$$\frac{2}{R} = \frac{2}{\rho} + \frac{(\mu-1)}{\mu} \cdot \frac{t}{\rho^2}$$

× ... $R\rho^2$

$$2\rho^2 = 2R\rho + \frac{(\mu-1)}{\mu} \cdot Rt$$

divide by 2

$$\rho^2 - R\rho = \frac{(\mu-1)}{2\mu} Rt$$

$$= \frac{0.60}{3.20} \times 0.474 \times 0.25$$

(A)

$$= \frac{9}{8} \times 0.118$$

$$\begin{array}{r} 118 \\ 9 \\ \hline \end{array}$$

$$= \frac{1.062}{8} = 0.133$$

$$\rho^2 - R\rho + \frac{1}{4} \cdot R^2 = 0.13 + \frac{1}{4} R^2$$

$$= 0.28$$

$$\rho = R + \sqrt[2]{0.18}$$

.42

by 1.255
0.628

$\frac{1}{2}R = 0.23$

$$\begin{array}{r} 0.23 \\ 23 \\ \hline 69 \\ 46 \\ \hline \end{array}$$

$\frac{1}{4}R^2 = 0.0529$

$$\begin{array}{r} 0.13 \\ \hline 0.18 \end{array}$$

5/...

Continued from (A)

$$= \frac{60}{32} \times 0.118$$

$$= \frac{15}{8} \times 0.118 \qquad = 15 \times 0.014$$

15
70
14
0.210

$$= 0.21$$

$$\rho^2 - R\rho + \frac{R^2}{4} = 0.21 + \frac{R^2}{4}$$

$$= \begin{array}{r} 0.21 \\ +0.18 \\ \hline \end{array}$$

$$= 0.39$$

$$\rho - \frac{R}{2} = 0.61$$

2)15670
7835

$$\rho = \begin{array}{r} 0.61 \\ +0.23 \\ \hline 0.84 \end{array}$$

1 : 2
1 : $\frac{\mu}{r}$

$\frac{r}{x}$ - $\frac{R}{2}$ ~~[illegible]~~ directly after firing

1 : 2

m
1.20 : 1.34 :: ~~31 : x~~ r : R
instead

$$x = \frac{134 \times 31}{120}$$

134
31
134
402
120)4154(34.6
360
554
480
74

69.2

1.34 : 120 :: r : x :: 31 : x

120
31
120
360
134)3720(27.7
268
1040
1020

55.4

f. 3

Index of refraction of water (m) = 1.34
" " of Flint glass (μ) = 1.60

Radius of curvature of cornea (ρ) = 0.31
" " of double convex lens of Flint glass = r

f = focal distance (in air)

Then $\Sigma \frac{1}{f} \left\{ = \Sigma \left(\frac{M-1}{R} \right) \right\} = 0$

or $\frac{m-1}{\rho} + 2 \frac{m-1}{r} - 2 \frac{\mu-1}{r} = 0$

$\frac{0.34}{0.31} + 2 \frac{0.34}{r} - 2 \frac{0.60}{r} = 0$

$r \times 34 = 31 \times 2 \{0.60 - 0.34\}$

$= 62 \times 0.26$ ~~= 0.47~~

By $r = 0.47$ of an inch

$r \overline{m-1} + 2\rho \overline{m-\mu} = 0$

$r = 2\rho \frac{\mu-m}{m-1}$

$=$ ~~0.62~~

$= 2 \times 0.31 \cdot \frac{0.60 - 0.34}{0.34}$

$= 0.62 \frac{0.26}{0.34}$

$= 0.47$ of an inch

$f = \frac{R}{2(m-1)} = \frac{0.47}{1.20} = .39$ of an inch

or otherwise ~~(2) what comes to the same thing~~

$\Sigma \frac{1}{f} = 0$

$\frac{m-1}{m\rho} = 2 \frac{\frac{\mu}{m} - 1}{r} = \frac{2(\mu - m)}{mr}$

$r(m-1) = 2(\mu - m)\rho = 0$

&c as before.

```
  0.62
    26
   372
  124
34 ) 16.12 ( .47
     136
      252
      238
```

F. 4

To find focal length in water
of spectacle double convex flint
rad: of curvature both surfaces = 0.47

μ flint = 1.60
m water = 1.34

$\frac{\mu}{m}$ = 1.20

$$F = \frac{r}{2\left(\frac{\mu}{m}-1\right)} = \frac{0.47}{0.40}$$

40/47 (1.17
40
70
40
300

= 1.17 inch in water

rad: of spectacle 0.95
" combination 1.25

$t = 0.40$

$r = 0.50$

$\frac{\mu}{m} = 1.20$

$$\frac{1}{f} = (0.20)\frac{2}{0.50} + \frac{(0.20)^2}{1.20}\frac{0.40}{(0.50)^2}$$

$$= \frac{0.4}{0.5} + \frac{0.4}{1.2} \times \frac{0.4}{0.25}$$

$$= \frac{4}{5} + \frac{0.16}{0.30}$$

$$= \frac{4}{5} + \frac{8}{15}$$

$$\frac{1}{f} = \frac{12+8}{15} = \frac{20}{15} = 1.33$$

15/20 (1.33 15 50 45 50

$$f = \frac{15}{20} = \frac{3}{4} = 0.75$$ which it is in my spectacles (1st lens)

$$\frac{m\,r}{m-[\text{blot}]} = \frac{R}{2\left(\frac{\mu}{m}-1\right)} = \frac{Rm}{2(\mu-m)}$$

$$2\,\overline{\mu-m}\,r = R\,\overline{m-1}$$

$$R = 2\cdot\frac{\mu-m}{m-1}\,r$$

$$= 2\cdot\frac{0.24}{0.34}\times 0.31 = \frac{24}{17}\times 0.31 = 0.474$$

1.60 μ
1.34 m
0.24

24
0.31
26
78
$17 \overline{)\,8.06}$ (0.474
68
126
119
70

or $\Sigma \frac{1}{F} = 0$ refr supposed to take place through intermediate layers of air

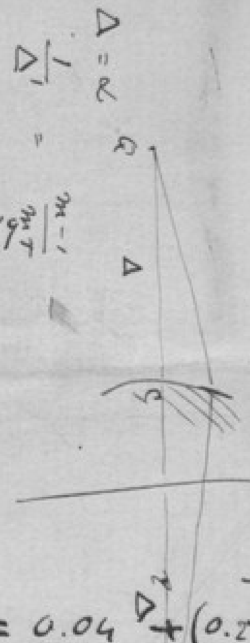
$$\frac{m-1}{r} + \frac{2\,\overline{m-1}}{R} - \frac{2\,\overline{\mu-1}}{R} = 0$$

$$\overline{m-1}\,R + 2\,\overline{m-\mu}\cdot r = 0$$

$$R = 2\,\frac{\mu-m}{m-1}\,r = 2\,\frac{0.26}{0.34}\times 0.31 \text{ as before } = 0.474$$

Considering thickness of lens formula is $\frac{1}{F} = \overline{\mu-1}\cdot\frac{2}{R} + \frac{\overline{\mu-1}^2}{\mu}\cdot\frac{t}{R^2}$

$$\frac{1}{0.474} = \frac{\overline{\mu-1}\cdot 2}{R_1} + \frac{\overline{\mu-1}^2\cdot t}{\mu R_1^2}$$



$$\frac{0.60\times 0.25}{1.60}\cdot\frac{1}{R^2}$$

$$= \frac{0.15}{1.60} \qquad 160\overline{)\,1500}(0.09\tfrac{3}{8} \quad 1440$$

$$= 0.09$$

$$\overline{\mu-1}\times 2 = 1.20$$

$$\therefore \frac{1}{0.474} = \frac{1.20}{R} + \frac{0.09}{R^2}$$

0.474
1.20
9480
474
56880 = 0.57

0.474
0.09
0.04266 = 0.04

$$R^2 - R\,0.57 + (0.28)^2 = 0.04 + (0.28)^2$$

$$R - 0.28 = \sqrt[2]{0.12}$$

1.0791
.346 · 5395

2488

0.28
0.28
224
56
0.0784
0.04
0.12

$$R = \begin{array}{r}0.346\\ 0.28\\ \hline 0.626\end{array}$$

$$\frac{1}{f} = (\mu - 1)\cdot\frac{2}{R}$$ $R = 0.474$ (not considering thickness t

$$= (\mu-1)\frac{2}{\rho} + \frac{(\mu-1)^2}{\mu}\frac{t}{\rho^2}$$ (considering do.

$$\frac{2}{R} = \frac{2}{\rho} + \left(\frac{\mu-1}{\mu}\right)\cdot\frac{t}{\rho^2}$$

$\mu = 1.60$

$R = 0.474$

×ly by $\frac{\mu}{(\mu-1)\cdot t}$

$$\frac{2\mu}{(\mu-1)\cdot t}\cdot\frac{1}{R} = \frac{2\mu}{(\mu-1)\cdot t}\frac{1}{\rho} + \frac{1}{\rho^2}$$

15/320(21

30

20

15

50

$$\frac{2\mu}{(\mu-1)t} = \frac{3.20}{(0.60)\times 0.25} = \frac{3.20}{0.15} = 21$$

$$\frac{21}{R} = 21\frac{1}{\rho} + \frac{1}{\rho^2}$$

×ly by $R\rho^2$

$$21\rho^2 = 21.R\rho + R$$

$$\rho^2 - \rho . R = \frac{R}{21}$$

We observe that this very subject has been the topic of a paper read by Mr Francis Galton at the British Association this year, in which he investigates the causes of this indistinctness as well as the correcting lenses that may be used to obviate it. The theory is simple. When the smugglers looked through the flat glass bottom of their cask, they saw every thing in the water with the same sharpness of outline as if they had been in the air. Now suppose they had taken out the flat glass bottom and put a curved one like a huge watch glass, into its place. What would be the result? They would see through it in air with the same facility as through the flat glass, as we may look without inconvenience through the curved front window of a brougham; but they

f. 1v

they would ~~have~~ see nothing in the water. The ~~curved~~ convex outer surface of the glass, would have indented a corresponding concavity in the water, & ~~the smuggler instead of looking simple would find~~ that a concave water lens, may would be placed between ~~him~~ the smuggler & the sea bottom. This is precisely the nature of the action of the cornea of the Eye, & the ~~and the effect of structure is very considerable. It whose~~ radius is so small, being only ~~moreover~~ 0.31 of an inch that it indents a concave water lens of very considerable power. What then is the ~~foc~~ power of the double convex lens which, (when plunged into the water) shall neutralise this ~~result imp~~ disturbing influence. The calculation is perfectly simple — we may conceive

f. 25

the lenses to form part of a separate apparatus ~~convex through which~~ so well compensated in its parts that the eye can see just as well, whether it be ~~the water may be viewed just~~ in air [illegible] in front of it, or not, ~~as distinctly as if it were removed~~.

The conditions of this apparatus are: that ~~there~~ it shall be ~~a concavity~~ made of water, ~~with a [illegible] ice if it be difficult to think of a~~ hollowed above, into a concave lens, ~~about~~ the radius of whose curvature shall be 0.31 of an inch

2. that it shall be flat below, &,

3. that a ~~con~~ double convex flint glass lens shall be imbedded in it. It is now required to find the ~~power particular~~ curvatures of the surfaces of the lens.

~~It will be observed that we have nothing to do with the~~ Calculation ~~shows~~ from the above considerations, that the radius of curvature of the lens should be only 0.47 of an inch, its focal ~~and its focal~~ distance being consequently only 0.39 of an inch. ~~[illegible]~~ [illegible] such glasses they must be specially ground [illegible] [illegible] [illegible] It appears this is high power & involves a very bulging glass ~~[illegible]~~ [illegible] a spectacle [illegible] [illegible] do not combination glasses for this spectacle that Mr. Galton has ... lenses under water, with great success, ~~& that~~ & that he is still engaged with the subject. ~~These~~ The glasses ~~would~~ would be of great use to divers for pearl & sponges, for sailors who had to examine the bottom of their ships. They might also be a great amusement to bathers generally, & especially to my cousins. They would give the bathers who wore glasses in their pupils the privilege of intelligent entrance into a new element. Persons in diving bells or in diving helmets do not require them. Water, for their eyes never come into contact with the water. Their case is that of the smuggler and his cask. It follows from this theory that extremely short sighted persons, whose imperfection of sight is due, as it commonly is the case, to malformation of the crystalline lens, & not to prominence of the cornea, ought to see much better in water than ~~other~~ ordinary people. On land they use concave spectacles; they take them off when they bathe; in the water they are _minus_ their concave glasses, which is the same thing as being _plus_ convex ones. —

 2/1/3/2 (1) f. 3r

Bathers who have overcome the natural repugnance felt by beginners, to opening their eyes when they dive, find when they look about them under water that it is to be seen with distinctness. They perceive little else than a haze diffused of light. When focussed in the water, when they look at their hand held 8 inches from their face the indeterminateness of vision is found to be so extreme, that they cannot even discover the spaces between their fingers when they have them as widely as possibly separated. At that distance the hand's appearance of the spread-out fingers is that of a mere blurr of white.

Now what is the precise cause of their indistinctness of vision? By what optical arrangements can it be compensated? & how do amphibious animals accomodate their vision to the requirements both of air & of water?

Perhaps the most popularly intelligible way of explaining the cause of indistinctness of vision, is to take a tube with a flat bottom of glass, & fill it with water. When we have done so we find we can see objects lying in the water as well as objects in air, below the bottom glass of the tube, without the slightest confusion of these

Now raise the apparatus (2) f. 3v

outlines. let us [approach] to the

We observe that as soon as

Eye the moment, the

is touched by the eyeball that

the water, distinctness of vision (absolutely)

instantaneously ceases to exist. The convex surface of the

has

Eye ball indented the plane surface of

and thereby into a concavo-plane

the water,

causes to look through a stratum of water bounded by two plane surfaces

Concave water-lens

Now the convexity of the (protect cornea) that of ordinary

It is much greater than

Cornea is very great. It forms

part of a sphere having only .3 inch radius

& therefore the power of the plano-concave

which the water proportionately large

water lens is its power is

equal & opposite to that of a doubly convex lens of flint glass (bounded)

by surfaces each having a radius of . . inch, the

focal distance of the lens being consequently

.. inch. If we hold a lens of

this description before our apparatus,

distinctness of vision is at once restored.

(3) f. 45

~~But~~ This arrangement does not ~~however~~ meets the requirements of a diver. His spectacles wd be necessary if immersed in water. The ~~parallel~~ experiment ~~to represent~~ to answer his needs ~~would~~ consists in taking a second tube similar to the first, with a glass bottom as before & dropping a lens ~~of~~ into it of ~~power~~ adequate power under those conditions to counteract the divergence of the plano concave water lens. A double convex lens of flint glass bounded by surfaces each having a radius of .45 inches. ~~possesses~~ that power. according to calculation

The calculation is perfectly simple

0.3 inch = radius of cornea of eye 1.60 = refraction power of flint glass 1.34 equal that of water. r = radius of surfaces of flint glass lens then $\Sigma \frac{\mu - 1}{r} = 0$
if F = the focal distance of a lens $\Sigma \frac{1}{F}$ or

that is $\frac{0.34}{0.30} + \frac{0.34}{r} \times 2 = \frac{0.60}{r} \cdot 2 = 0$ whence r = 0. & F =

Furnished with a pair of spectacles, containing lenses of this high power, the vision of a diver under water is just as clear as that of a man in air. Its range is limited by the cloudiness of the water. It does not suffer from indistinctness of outline.

It must clearly be understood that men in diving machines or in diving head gear do not require lenses. Their eyeballs do not touch the water, & evidently it is not concave lenses that they want. All that their machines need is to have ordinary windows of thick plate glass through which they may see into the water, just as we can see into an aquarium on shore.

My enthusiasm refers to divers in pearl fisheries, to sailors who have to examine the bottom of their ship, to men who have dropped something in the water which they desire to recover, & to bathers generally. I can promise that the use of these eye lenses will add materially to their enjoyment. It is no slight pleasure to live the life of a merman, keeping below water from ½ a minute to a minute at a time & seeing everything around one as clearly as a man can see, who bends over the gunwale of his boat & looks down into the water, on the rare occasion of a perfectly still day when there are no ripples. It gives him the sensation of a new power

5

f. 5r

power & in ~~some~~ substantial sense the privilege of entrance to a new element. It is only a very short time since this matter occurred to me & as I was then abroad & could get neither the measurements of the curvature of the cornea I wanted, nor proper lenses I had to employ the combinations of such as I had in hand. I combined the object glasses of my opera glass a stanhope lens & other lenses until I formed a triplet through which I obtained distinct vision, but which was not very manageable to use. I now lay on the table lenses that I have had especially made for me according to the calculated measurements as given above that I have ~~had~~ only once had an opportunity of testing them ~~&~~ disporting myself with them under water ~~on occasion~~. — Their performance is quite satisfactory.

Lastly as regards the very amphibia. There are many animals that see under water very perfectly. Among these are seals, hippopotami & otters, water rats, & diving birds of many descriptions. Now

(6) f. 5v

of their size both were comparatively flat in front, they would of all these creatures indent concave boxes of ~~compensat~~ ~~the~~ moderate power, and the compensating arrangement for clear sight under water need be proportionately small. Now the cornea of the seal appears to be remarkably flat & therefore in respect to the seal there is not much difficulty. But it is far otherwise ~~in the case~~ with the very ~~Other animals I have ... ...~~ eyes so far as I can judge from looking at them carefully in menageries are by no means flat ~~Their~~ power of accomodating their ~~sight~~ & therefore to amphibious conditions is wholly inexplicable on any facts or theory that so far as I can discover physiologists have as yet propounded. I have consulted all the principal works of reference & have made myself ~~applied~~ for acquainted with what our best collections,

f. 6r

collection that of the Royal College of Surgeons has to shew. It is simply the eye of a seal, with a paragraph from Blumenbach quite incommensurate with the difficulties of the problem. It never seems to have occurred to physiology that the accomodating power of the eye in amphibious animals must be enormous; or that if the refraction power of the component fluids or solids of the eye are so nearly that of water as they are in the human being, that no alteration of their shape within credible limits would suffice to give distinct vision in water. The eye of man is not greatly different in its refracting efficacy, to that of a bag of water of the same size & shape, and that if dipped

f. 6v

into water would have no effect whatever, beyond upon the course of the subaqueous rays of light. The ~~chief~~ only effect an eye could have, whose refractive power differed from that of the medium in which it was used would be due to its pupil. The pupil would act as a small hole in the shutters of a darkened chamber, on whose walls a faint image of the surrounding landscape is thrown.

It is quite clear that the theory of vision of amphibious animals requires yet to be ~~thought for~~ examined into. I have no facts of my own to offer but I simply direct attention to it. our ignorance, comparing the curvature of the 1 & that of the 2 surfaces still

The eye of a water rat ~~confined~~ ~~in which water could be forced & drawn off at will,~~ ~~in an aquarium~~ could be easily ~~examined~~ measured as that of any other animal. ~~by an~~ The rat being confined in an aquarium into which water was forced & withdrawn alternately.

f. 7c

A determination of the refractive powers of the humours of the ~~cattle~~ extent of the ratio Eye and its ~~direction~~ anatomy, might determine the rest.

The subject is a very interesting one, for the theory of the accomodating power of the human Eye to different focal distances is not yet wholly fixed. Therefore ~~the~~ examination of Eyes of other animals which possess this power in an enormously greater degree than man, must certainly be instructive.

Eye Glasses for the use of divers, to ensure clear sight ~~vision~~ under water, with remarks on the ~~vision~~ ~~accomodating~~ Eyes power of the Eyes of amphibiae.

...con
...still
...lens
...ll,
...ed
...d
...
...

f. 7v

Stanmore Hall,
Stanmore. N.W.

f.1

Diving Spectacles

1866

Theory – measurement of cornea = 0.307 in

water $m = 1.34$
flint glass – 1.40

$$\frac{m-1}{0.31} = \frac{\mu-\mu_1}{r}$$ (water)

$$\frac{0.34}{0.31} = \frac{0.26}{r}$$

$$100r = \frac{26 \times 31}{34} = 24$$

$$\begin{array}{r} 26 \\ 31 \\ \hline 26 \\ 78 \\ \hline 806 \end{array}$$

34) 806 (24
68
126

$$r = 0.24$$

$$F = \frac{r}{\mu-1} \text{ (in air)} = \frac{0.24}{0.40}$$

$$F = 0.40$$

40) 240 (0.40
240

	r plano convex	F in air.
Experiment	0.30	0.50
Theory	0.24 say ¼ inch.	0.40
2nd Experiment –	0.264	0.44

Stanhope opera & toy combination

$$\frac{1}{F} = \overline{m-1}\,\frac{1}{R} = \overline{m-1}\,\sum \frac{1}{r} \quad \text{(in air)}$$

$$= 0.60 \left\{ \frac{1}{0.54} + \frac{1}{1.41} + \frac{1}{2.00} \right\}$$

$$= 0.60 \{ 3 \} \text{ very nearly}$$

$$= 1.80$$

$$F = \frac{100}{180} = 0.55$$

add the other Stanhope tube $= \frac{1}{3}$ then

$$\frac{1}{F} = 0.60 \{ 3 + \tfrac{1}{3})$$

$$= .2$$

$F = 0.50$

$R = 0.60 \times 0.50$

$= 0.30$ of an inch

or as

$$\frac{1}{F} = \overline{m-1}\,\frac{1}{R}$$

$$\therefore R = \overline{m-1} \times F$$

$$= 0.60 \times 0.55$$

$$\begin{array}{r} 0.55 \\ 0.60 \\ \hline 0.3300 \end{array}$$

$R = 0.33$ of an inch plano convex

$= 0.66$ — double convex.

f. 3

Gand 10 Octobre 1866

Monsieur

J'ai l'honneur de vous adresser un exemplaire d'un mémoire que je viens de publier _Sur la vision des poissons et des amphibies_. Ainsi que vous le verrez par la lecture de ce travail mes recherches anatomiques et mes expériences m'ont conduit à une opinion qui ne s'accorde pas avec celles que vous avez exposées dans une communication faite en 1865 à l'Association Britannique.

J'ai donc cru convenable, Monsieur, de vous mettre à même de juger mes objections et la valeur des faits sur lesquels je les appuie. Je dois dire du reste que je n'ai eu connaissance de votre mémoire que par un résumé publié dans le journal _The Reader_ (1865 vol VI No 149, page 520)

Veuillez agréer, Monsieur, l'assurance de ma haute considération

F. Plateau

Gand. Place du Casino. No 15.